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Make in Tanzania Program Depicting the G2(B&C) Interface: A Forward Outlook and Long-Term Approach

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Abstract: In the rapidly changing economy of Tanzania, the network and contribution of investors in the respective ministries has grown into a vast ecosystem that requires cooperation among stakeholders. The Make in Tanzania initiative will create a conducive environment for investments. It will foster innovation, building best in class infrastructure, and making Tanzania a hub for manufacturing, design, and innovation. It will be the first 'Vocal for Local' initiative that will showcase Tanzania's manufacturing prowess to the world. Make in Tanzania will focus on the initial phase sectors under Make in Tanzania umbrella with its apex interface of Government to Business and Citizens Model, G2(B&C). The Department for Promotion of Industry and Internal Trade (DPIIT) will coordinate Action Plans for manufacturing sectors, while the Department of Commerce will coordinate Action Plans for service sectors. DPIIT will work closely with sub- sectors keeping in mind the Tanzania industries strength and competitive edge, need for import substitution, potential for export and increased employability. Efforts are on to boost the growth of the sub-sectors in a holistic and coordinated manner. In a short space of time, the obsolete and obstructive frameworks of the past will be dismantled and replaced with a transparent and user-friendly system. This will help to drive investment, foster innovation, develop skills, protect Intellectual Property (IP) and build best-in-class manufacturing infrastructure. The most striking indicator of progress is the unprecedented opening of key sectors including railways, renewable energy, roads and highways, agriculture and food processing, thermal power, tourism and hospitality, construction, defence manufacturing, biotechnology, pharmaceuticals, Chemicals, automobile and components, aviation, oil and gas, mining, electrical machinery, electronic systems, Information and Technology, media and entertainment, leather, ports and shipping, space, textile and garments, wellness and fitness – to substantially higher levels of Foreign Direct Investment and Private Sector engagement that will act as a catalyst to social-economic development of Tanzania.

Keywords: Make in Tanzania, Department for Promotion of Industry and Internal Trade (DPIIT), Intellectual Property (IP), key sectors, frameworks, best-in-class manufacturing infrastructure.

1. Introduction

With an average real GDP growth rate of 6.3% over the past decade (2010-2019), Tanzania is among the fastest-growing economies in Africa and in the world. However, the GDP growth rate has been slowing down in recent years, from a peak of 7.9% in 2011. The IMF estimates a GDP growth for Tanzania of +5.1% in 2022, and 6.0% in 2026. According to the Bank of Tanzania (BOT) and the International Monetary Fund (IMF), the real GDP of Tanzania grew by 4.9% in 2021 reaching USD 70.28 billion.

The real GDP of Tanzania was USD 64.4 billion in 2020 and USD 60.8 billion in 2019. In its Africa's Macroeconomic Performance and Outlook – January 2023, the African Development Bank (AfDB) estimates that the GDP of Tanzania will have grown by +4.6% in 2022, and projects it will grow by +5.1% in 2023, and by +6.1% in 2024. Similarly, the World Bank (WB) forecasts in its Global Economic Prospects Report – January

2023 that the GDP of Tanzania will expand by +5.6% in 2023, and by +6.1% in 2024. In April 2021, Tanzania's new president Samia Suluhu Hassan gave her first speech to the parliament, mentioning the priorities of the Sixth Phase Government in the next five years to reach a GDP growth rate of at least 8% yearly.

Tanzania's GNI per capita rose by 6.1% during the ten-year period 2010–2019, from USD 720 to USD 1,080. In 2019, Tanzania became a middle-income country with a GNI per capita of USD 1,080, against an average of USD 1,550 in Sub-Saharan Africa. According to the economic data included in the National Data of Tanzania Mainland of 2013-2019 by the National Bureau of Statistics, at current market prices, Services made the highest shares of GDP (40.0%) followed by Industry and Construction (31.1%) and Agriculture, Forestry and Fishing (28.9%)

Notable sectors of the Tanzanian economy are tourism, mining, construction, agriculture, and manufacturing. In November 2020, President Magufuli announced that in the next five years its government will put great emphasis on key economic sectors, especially agriculture, livestock, fisheries, industry, mining, trade, and tourism. In 2022 (January to December) the average annual headline inflation in Tanzania was 4.3%. In 2021 it was 3.7% and 3.3% in 2020. It remained well within the range set in the 3rd Tanzania Five-Year Development Plan (FYDP III) between 3.0% and 5.0% over the medium term. On 18th January 2022, the average market exchange rates (source bot.go.tz) for the Tanzanian shilling (TZS) against major currencies provided were: USD/TZS 2,297.9, GBP/TZS 3136.7, EUR/TZS 2621.5007, RMB/TZS 361.9. A year earlier, on 26th January 2021, the average market exchange rates (source xe.com) for the Tanzanian shilling (TZS) against major currencies provided were: USD/TZS 2,319.1, GBP/TZS 3,168.9, EUR/TZS 2,814.8, RMB/TZS 358.3.

Tanzania is a net importer with a negative balance of trade of USD -3,095.9 million in the year ended November 2019 (latest BOT data). The value of exports of goods and services amounted to USD 8,839.9 million in the year ended November 2020, lower than USD 9,460.8 million in the year ended November 2019, due to a decline in services receipts (mainly tourism affected by Covid-19). In 2018, Tanzania's top exports were gold (USD 892 m), tobacco (USD 333 m), raw copper (USD 231 m), refined copper (USD 150 m), and other furniture (USD 147 m), exporting mostly to Rwanda, Kenya, the DRC, Zambia, and Uganda. The top imports of Tanzania were refined petroleum (USD 1.77 b), palm oil (USD 280 m), packaged medicaments (USD 220), cars (USD 191 m), and wheat (USD 182 m), imported mostly from China, India, UAE, Saudi Arabia, and South Africa.

As of December 2019, Tanzania's total national debt amounts to USD 28.6 billion with external debt accounting for 78% of the total and domestic debt with 22%. Tanzania's external debt amounted to USD 22.4 billion (40% of GDP) in December 2019 representing a 6% YoY increase (2018: USD 21.06 billion). Tanzania's domestic debt amounted to USD 6.3 billion (11% of GDP) in December 2019 representing a 1% YoY decrease (2017: USD 6.2 billion). The Tanzanian Central Government is the largest borrower holding 78% of the country's external debt, followed by the private sector (21%), and public corporations (0.4%). The funds were allocated mostly to the transport and telecommunications sectors (27%), followed by social welfare and education (17%), and energy and mining (15%).

Foreign Direct Investment (FDI) inflows to Tanzania reached USD 4.144 billion in the period March-November 2021. This is 300% more than the USD 1.013 billion in FDIs in 2020. Investments were drawn mostly to the mining sector, the oil and gas industry, and the primary agricultural products sector (coffee, cashew nuts, and tobacco). The top five providers of FDI in Tanzania are South Africa, the UK, Kenya, Canada, and China. In the WB Doing Business Report of 2020, Tanzania ranked 141st among 190 countries and ranked 4th in the East African Community (EAC) for the ease of doing business. The country is currently implementing the "Blueprint for Regulatory Reforms to Improve the Business Environment in Tanzania" and aims to raise its score to at least 100. Sources: *African Development Bank (AfDB), Bank of Tanzania (BoT), Foreign Service Institute of the US Department of State, International Monetary Fund (IMF), United Nations Conference on Trade and Development (UNCTAD), Tanzania National Bureau of Statistics, World Bank (WB).*

Make in Tanzania initiative Program will be a part of a wider set of Tanzania-building initiatives, it is by devise a chance to transform Tanzania into a global design and manufacturing hub, Make in Tanzania will be a timely response to a critical situation. Between 2007 and 2018, the much-hyped emerging markets bubble had burst, and Tanzania's growth rate had fallen to it's lowest level in a decade. The promise of the Innovated Tanzania had faded, and Tanzania was tagged as one of the so-called 'Poverty African Countries'. Global investors debated whether the democractic nation was a risk or an opportunity. Tanzania's 45 million citizens by 2012 questioned whether Tanzania was too big to succeed or too big to fail. Tanzania was on the brink of severe economic failure, desperately in need of a big push.

Make in Tanzania Process will prevail against the backdrop of crisis and quickly become a rallying cry for Tanzania's innumerable stakeholders and partners. It will be a powerful, galvanising call to action to Tanzania's citizens and business leaders, and an invitation to potential partners and investors around the world. Make in Tanznaia as an inspiring slogan, it will represent a comprehensive and unprecedented overhaul of outdated processes and policies. Most importantly, it will represent a complete change of the government's mindset – a shift from issuing authority to business partner, in keeping with Hon. President Samia's tenet of 'Minimum Government, Maximum Governance'.

Make in Tanzania Plan is to start a movement that needs a strategy that inspires, empowers and enables in equal measure. Make in Tanzania will need a different kind of campaign: instead of the typical statistics-laden newspaper advertisements, this exercise will require messaging that is informative, well-packaged and most importantly, credible. It will (a) inspire confidence in Tanzania's capabilities amongst potential partners abroad, the Tanzanian business community and citizens at large; (b) provide a framework for a vast amount of technical information on the industry sectors; and (c) reach out to a vast local and global audience via social media and constantly keep them updated about opportunities, reforms, etc.

Make in Tanzania Partnership initiative will be built on layers of a collaborative effort. DPIIT will initiate this process by inviting participation from other Ministers, Secretaries to the Government of Tanzania, Regional and Local governments, industry leaders, and various knowledge partners. Next, a Tanzania Workshop on sector specific industries will bring Secretaries to the Government of Tanzania and industry leaders together to debate and formulate an action plan for the next four to five years, which aim to raise the contribution of the manufacturing sector to 25% of the GDP by 2025-30. This plan will be presented to the Hon. President, Ministers, industry associations and industry leaders.

2. Role and Functions

2.1. Allocation of Business to the Department

According to the Allocation of Business (AOB) Rules, the Department will be responsible for determining the Industrial Policy at the Government level, including the following matters: Administration of the Industries and grant of Industrial Licenses; Acknowledgment of the Industrial Entrepreneur Memorandum (IEM); Industrial management and Productivity in industry; Matters related to e-Commerce, Promotion of Internal Trade, including Retail Trade; Welfare of Traders and their Employees; Matters relating to facilitating "Ease of Doing Business" and Matters relating to Start-Ups; Integrated development of Logistics Sector.

The Department will handle matters related to Protection of Intellectual Property Rights (IPR) and administer acts related to IPRs. The Department will also handle matters related to Foreign Direct Investment (FDI) and undertake promotion of direct foreign and non-resident investment. It will looks after promotion of investment by Overseas Tanzanian in Tanzania, including innovative investments and policy initiatives consistent with the overall Government policies, particularly in areas such as Special Economic Zones for Overseas Tanzanians.

The Department will be responsible for promotion and development of industries related to Cables, Light Engineering products (eg. Sewing machines, typewriters, weighing machines, bicycles, etc.), Light Industries (e.g. Polywood, stationery, matches, cigarettes etc.), Light Electrical Engineering products, Raw Films, Hard Board, Paper and Newsprint, Tyres and Tubes, Salt, Cement, Ceramics, Tiles and Glass, Leather and Leather Goods Industry, Soaps and Detergents, Footwear Design & Development and any other Industry not covered by other Ministries/Departments.

2.2.Organization of the Ministry of Investment, Industry and Trade (MIIT)

The Ministry of Investment, Industry and Trade has eight (8) Departments, six (6) Divisions and 17 Institutions. These institutions have a unique importance in developing and connecting the Industry and Trade Sector with other sectors in the country. The Ministry has Investment Development Departments; Empowerment and Development of the Private Sector; Industrial Development; Small Industries and Small Businesses; Business Integration; Business Development; Policies and Programs; and Human Resource Management and Development. The Ministry's units are Finance and Accounting; Internal Audit; Legal Services; Procurement Management; Communications in Government; and IT.

Institutions under the Ministry include five Organizations which are; National Development Corporation (NDC), Small Industries Development Organization (SIDO), Tanzania Industrial Research Development Organization (TIRDO), Engineering and Design Organization of Machinery (Tanzania Engineering and Manufacturing Design Organization - TEMDO) and Tanzania Bureau of Standards - TBS. In addition, there are two (2) Agencies which are the Weights and Measures Agency - WMA and the Business Registration and Licensing Agency - BRELA. There are also two (2) Authorities which are the Export Processing Zones Authority (EPZA) and the Tanzania Trade Development Authority (TANTRADE).

In addition, the Ministry has three (3) councils which are the Fair Competition Tribunal (FCT), the National Consumer Advocacy Council (NCAC) and the National Economic Empowerment Council – NEEC).

The Ministry also has two (2) Centers to develop technology and business which are the Center for Agricultural Mechanization of Rural Technology (CAMARTEC) and the Tanzania Investment Center (TIC). The Ministry manages one (1) College of Business Education (CBE), one (1) Fair Competition Commission (FCC) and one (1) Warehouse Receipt Regulatory Board -WRRB.

2.3.Foreign Direct Investment

The Department for Promotion of Industry and Internal Trade, the Nodal Department for formulation of policy of the Government on Foreign Direct Investment (FDI). It will be responsible for maintenance and management of data on inward FDI, based upon the remittances reported by the Bank of Tanzania. With a view to attract higher levels of FDI, Government has to put in place a liberal policy on FDI, under which, FDI up to 100%, should be permitted, under the automatic route, in most sectors/activities.

Significant changes should be made in the FDI policy regime in the recent times to ensure that Tanzania remains an increasingly attractive investment destination. The Department will play an active role in the liberalization and rationalization of the FDI policy. Towards this start, it will be constructively engaged in the extensive stakeholder consultations on various aspects of the FDI Policy.

2.4.Make in Tanzania

The Make in Tanzania initiative will create a conducive environment for investments aimed at fostering innovation, building world class infrastructure, and making Tanzania a hub for manufacturing, design, and innovation. It will be one of the first 'Vocal for Local' initiatives that will showcase Tanzania's manufacturing prowess to the world. After its launch, Make in Tanzania will have significant achievements and will focus on the sectors under the Action Plans.

Department for Promotion of Industry and Internal Trade (DPIIT) will coordinate Action Plans for manufacturing sectors and service sectors. DPIIT will work closely with sub- sectors keeping in mind the Tanzanian industries strengths and competitive edge, need for import substitution, potential for export and increased employability. Efforts are on to boost the growth of the sub-sectors in a holistic manner.

Steering Committee for Advancing Local Value-add and Employability (SCALE) will be initiated to identify the sub-sectors, in which Tanzania can truly become self-reliant by strengthening its domestic manufacturing, which will translate into more employability, greater potential for exports and a sound manufacturing domestic base within the country to meet its own demand.

2.4.1. Investment Promotion and International Cooperation

The Department will play an active role in investment promotion and facilitation through dissemination of information, on opportunities in Tanzania by advising prospective investors about investment policies, procedures and opportunities. International Cooperation for industrial partnerships will be solicited through both bilateral and multilateral arrangements. It will also coordinate with apex industry associations like Federation of Tanzania Chambers of Commerce and Industry (FTCCI), Confederation of Tanzania Industry (CTI), the Associated Chambers of Commerce and Industry (ASSOCHAM), etc in their activities relating to promotion of industrial cooperation, both through bilateral and multilateral initiatives intended to stimulate the investments in Tanzania.

2.4.2. One District One Product

Government of Tanzania has to work on a transformational initiative to foster balanced regional development across all districts of the country. This is called the One District One Product (ODOP) initiative, with the objective of identifying and promoting the production of unique products in each district in Tanzania that can be globally marketed. This will help realize the true potential of a district, fueling economic growth, generating employment and rural entrepreneurship. ODOP initiative will operationally be merged with the 'Districts as Export Hub' initiative being implemented by Directorate General of Foreign Trade, DGFT. Department of Commerce with DPIIT as a major stakeholder to synergize the work undertaken by DGFT.

2.4.3. Tanzania Single Window System

While presenting Budget 2022-23, The Minister for Finance and Planning announced plans with the theme on Accelerating Economic Recovery and Enhancing Productive Sectors for Improved Livelihoods, to set up an

Investment Clearance Cell (ICC) to provide "end to end" facilitation and support to investors, including pre-investment advisory, provide information related to land banks and facilitate clearances at National and Regional level. The cell will operate through an online digital portal envisioned as a one-stop shop for taking all the regulatory approvals and services in the country, TSWS

2.4.4. Invest Tanzania

Invest Tanzania will be set as a Joint Venture (Not for Profit) Company between Department for Promotion of Industry and Internal trade under MIIT, Federation of Tanzania Chambers of Commerce & Industry (FTCCI), Cil and various Government Bodies. Invest Tanzania will be the National Investment Promotion and Facilitation Agency of Tanzania and will act as the first point of reference for investors in Tanzania.

Invest Tanzania will transform the country's investment climate by simplifying the business environment for investors. Its experts, specializing across different countries, Tanzania regions and sectors, handhold investors through their investment lifecycle - from pre-investment to after-care. Invest Tanzania will provide multiple forms of support such as market entry strategies, deep dive industry analysis, partner search and location assessment policy advocacy with decision makers.

2.4.5. Tanzania Industrial Land Bank

The Group of Secretaries on Commerce and Industry will be formed by the Government and will recommend NITT to coordinate and develop a comprehensive National Plan for Manufacturing Clusters in collaboration with the respective Ministries and Regions. The objective of the National Plan is to bring about convergence in the multiple models of development of industrial clusters by the Regional Government and Local Government so as to affect better cost efficiency and optimal utilization of resources.

2.4.6. Industrial Park Rating System

Industrial Park Rating System (IPRS), an exercise which recognizes best performing parks, identifying interventions and serving as a decision support system for investors and policy makers. This exercise will be undertaken by DPIIT and Invest Tanzania. DPIIT will released a pilot phase report a year after it’s launch on Industrial Park Rating System aimed at enhancing Industrial competitiveness.

DPIIT will develope 'Industrial Park Rating System 2.0' that will widen its coverage and bring in qualitative assessment further to the pilot phase. Under IPRS 2.0, the assessment of Industrial Parks will include private industrial parks and SEZs with introduction of qualitative indicators for assessing these parks/ zones will be undertaken across parameters identified under the 4 pillar i.e. internal infrastructure &utilities, External infrastructure & Connectivity, Business Support Systems and Environmental & Safety Management. IPRS 2.0 wil include the introduction of feedback mechanism which will help in assessment of the developer's responses and also engage directly with the ultimate beneficiaries of this exercise.

2.5.Tanzania Intellectual Property Rights (IPR) Policy

The National IPR Policy will lay the roadmap for intellectual property in Tanzania. The Policy will recognize the abundance of creative and innovative energies that flow in Tanzania, and the need to tap into and channelize these energies towards a better and brighter future for all. The National IPR Policy is a vision document that will aim to create and exploit synergies between all forms of concerned statutes and agencies.

It will set in place an institutional mechanism for implementation, monitoring and review. It will aim to incorporate and adapt global best practices to the Tanzanian scenario. This policy shall weave in the strengths of the Government, research and development organizations, educational institutions, corporate entities including MSMEs, start-ups and other stakeholders in creation of an innovation-conducive environment, which stimulates creativity and innovation across sectors, as also facilitates a stable, transparent and service-oriented IPR administration in the country.

The policy will recognize that Tanzania has a well-established Trade-Related Aspects of Intellectual Property Rights, TRIPS - compliant legislative administrative and judicial framework to safeguard IPRs, which meets its international obligations while utilizing the flexibilities provided in the international regime to address its developmental concerns. It will reiterate Tanzania’s commitment to the Doha Development Agenda and the TRIPS agreement.

The Policy will lay down the following objectives: IPR Awareness: Outreach and Promotion - To create public awareness about the economic, social and cultural benefits of IPRs among all sections of society;

Generation of IPRs: To stimulate the generation of IPRs; Legal and Legislative Framework: To have strong and effective IPR laws, which balance the interests of rights owners with larger public interest.

The Policy will lay down additional objectives: Administration and Management: To modernize and strengthen service- oriented IPR administration; Commercialization of IPRs: Get value for IPRs through commercialization; Enforcement and Adjudication: To strengthen the adjudicatory mechanisms for combating IPR infringements; Human Capital Development: To strengthen and expand human resources, institutions and capacities for teaching, training, research and skill building in IPRs.

These objectives are sought to be achieved through detailed action points. The action by different Ministries/Departments shall be monitored by DPIIT, which shall be the nodal Department to coordinate, guide and oversee implementation and future development of IPRs in Tanzania.

2.5.1. Cell for IPR Promotion and Management (CIPAM)

In pursuance of the National IPR Policy, a specialized professional body/Cell for IPR Promotion and Management (CIPAM), should be created under the aegis of DPIIT under MIIT, which will be instrumental in taking forward the objectives and visions of the Policy.

2.5.2. Intellectual Property Rights Administration

Department for Promotion of Industry and Internal Trade (DPIIT) as the nodal department for administration of various laws related to Intellectual Property Rights in the country such as Patents, Trade Marks, Industrial Designs, Geographical Indications of Goods, Copyrights, and Semiconductor Integrated Circuits Layout Designs. Being nodal Department for IPR related matters, DPIIT will vett number of MoUs/MoCs/MoAs/ Cabinet Notes/NDAs etc. entered into by various Ministries/ Departments of Government of Tanzania from IPR angle.

The negotiations on IPR Chapter under various International Trade Agreements will also be done by DPIIT. Besides, DPIIT as the nodal department for matters related to World Intellectual Property Organization (WIPO), the Office of the Controller General of Patents, Designs and Trade Marks (CGPDTM), a subordinate Office under DPIIT, will carry out statutory functions related to Patents, Trade Marks, Designs, Copyrights, Geographical Indications and Semiconductor Integrated Circuits Layout Designs.

2.6.Tanzania Design Policy

The Tanzania Design Policy inter-alia, will include: Promotion of Tanzania design through a well-defined and managed regulatory, promotional and institutional framework; Setting up of specialized Design Centres of “Innovation Hubs” for sectors such as automobiles and transportation, jewellery, leather, soft goods, digital products, toys and games, which will provide common facilities and enabling tools like rapid product development, high performance visualization, etc. along with enterprise incubation as well as financial support through mechanisms like venture funding, loans and market development assistance forstart-updesign-ledventuresandyoung designers’ design firms/houses; Formulation of schemes for setting up Design Centres/Innovation Hubs in selected locations/industrial clusters/ backward regions;

Laying special focus on up gradation of existing design institutes and faculty resources to international standards, particularly the National Institute of Design (NID) – New and its new campuses/centres with a view to spreading quality education in design to all regions of Tanzania; Encouraging establishment of Departments of design in all the Tanzania Institutes of Technology (TIT) and all the National Institutes of Technologies (NITs) as well as in prestigious private sector colleges of Engineering and Architectures; Preparation of a mechanism for recognizing and awarding industry achievers in creating a brand image for Tanzania design through award of Tanzania Design Mark on designs which satisfy key design criteria like originality, innovation, ergonomic features, safety and Eco-friendliness;

Facilitating the establishment of a Chartered Society for designers (on the lines of institutions of engineers, the institution of Architects., the Medical Council, the Bar Council, etc.), to govern the registration of Design Professionals and various matters relating to standards setting in the profession; Setting up a Tanzanian Design Council (TDC) with eminent personalities drawn from different walks of life; The Design Clinic Scheme project will be implemented by NID across the country which intends to improve the manufacturing competency of the MSMEs through design intervention to products and services and provide them design edge in the global market and will support the Make in Tanzania program of the Government of Tanzania.

2.7.Easy of Doing Business

Department for Promotion of Industry and Internal Trade (DPIIT) will spearhead the exercise for improving overall business regulatory environment in the country by streamlining the existing regulations and processes and eliminating unnecessary requirements and procedures. DPIIT, in consultation with the State Ministries, will start a comprehensive reform exercise in Regions and Districts under Business Reforms Action Plan (BRAP), all Regions in the country will be ranked on the basis of reforms implemented by them on designated parameters. This exercise will help in improving business environment across Regions. The BRAP Portal will be launched to track implementation of reforms on a real–time basis.

A 169 point Tanzania Districts' Reforms Plan will be prepared and shared with Regions for implementation of reforms by all the districts. It will spread across 8 areas: Starting a Business, Urban Local Body Services, Land Reform Enabler, Land Administration and Property Registration Enablers, Obtaining Approval for Construction, Paying Taxes, Miscellaneous and Grievance Redressal/ Paperless Courts and Law & Order. DPIIT as the Nodal Department for coordination with Ministries/Departments and Regions to reduce compliance burden on citizens and business activities, it's objective in this exercise is to improve Ease of Doing Business and Ease of Living by Simplifying, Rationalizing, Digitizing and Decriminalizing Government to Business and Citizen Interfaces across Ministries/Departments and Regions.

The key focus areas of the exercise will be: Rationalization/Auto-renewal of licenses/ certificates/ permissions; Risk-based/Third-party Inspections and Audits; Standardized and simplified return filing; Rationalized maintenance of registers; Minimize/eliminate display requirements; Digitization and simplification of manual forms and records. In order to monitor large database of compliances across Ministries/ Departments and Regions, DPIIT will launch the Regulatory Compliance. Ministries/ Departments and Regions will upload the details of compliances which have been reduced by them under this exercise.

2.8.Start-up Tanzania

Startup Tanzania as a flagship initiative of the Government of Tanzania, will intend to catalyze startup culture and build a strong and inclusive ecosystem for innovation and entrepreneurship in Tanzania. The Startup Tanzania Action Plan will outline objectives of supporting entrepreneurs, building up a robust startup ecosystem and transforming Tanzania into a country of job creators instead of job seekers. Department for Promotion of Industry & Internal Trade (DPIIT) will act as the nodal Department for coordinating the efforts of all the Government Departments and State Ministries for carrying this plan forward.

2.9.Division of Public Procurement

Public Procurement will create an assured domestic market for manufacturers, who are genuinely 'Make in Tanzania', thereby encouraging utilization of Tanzanian material resources for the provision of goods required for public procurements.

Various activities will be performed by the Division as under: Oversee the implementation of PPP-MIT Order, including issuance of amendments, based upon feedback/response received from stakeholders; Advise various Nodal Ministries/ Departments and procuring agencies on matters related to PPP-MIT Order; Scrutiny of high value tenders published on State Public Procurement and GeM Portal for its compliance with PPP-MIT Order and follow up with concerned procuring agency and controlling Ministry for corrective action.

Analyze the grievances, received from stakeholders for alleged violation of PPP-MII Order, and advise concerned procuring agency and controlling Ministry/ Department for resolution; Convene Industry specific grievance review meetings for speedy resolution of industry grievances; Process applications received for registration of bidders, having beneficial ownership in land borders; Process requests seeking permission for floating global tender enquiry; Convene Standing Committee meetings for resolution of outstanding issues related to implementation of PPP-MIT Order as also for resolution for grievances, received from stakeholders for alleged violation of PPP-MIT.

2.10. Development of Logistics Sector

The Logistics Divsion in the Department of Commerce will have amendments in the Allocation of Business Rules with the mandate for integrated development of logistics sector in the country and bring about reduction in the logistics cost. For the said mandate, the Division will be engaged in identification of regulatory, infrastructure or services bottlenecks in freight logistics and easing them through industry engagement and inter-ministerial coordination, monitoring performance and efficiency of logistics infrastructure and services, creation of an integrated system of infrastructure and policy/ regulatory interventions to promote inter-modality and identification of skill gaps across modes. The Division will also promote and encourage adoption of digitization across logistics value chains.

2.11. Project Monitoring Group

Project Monitoring Group (PMG) will be set in Cabinet Secretariat and be merged with DPIIT, with Invest in Tanzania tied up to provide implementation support in its functioning. PMG as an institutional mechanism for resolving issues and bottlenecks and fast tracking the setting up and commissioning of large infrastructure projects in Public and Private sectors, any investor facing delays or bottlenecks in the execution of a project with an estimated value of TShs. 100 billion and above can raise it on the PMG portal, which in turn takes them up with concerned authorities in the State Government until the issues are resolved.

Furthermore, the PMG portal a year after its launch will be upgraded from an issue-based resolution mechanism to a Milestone-based monitoring system. The new system will ensure proactive monitoring of projects and will help in initiating course correction measures in time. This will put the Project Monitoring Group at the forefront of driving transformational change in the infrastructure space. PMG portal will be developed with an agile and user-friendly interface to strengthen the project monitoring framework. All the relevant stakeholders including project proponents, concerned ministries and regional departments will be on board on the portal for regular updation of the project milestones and issue statuses.

2.12. Industrial Corridors

Government of Tanzania will develop various Industrial Corridor Projects as part of Tanzania Industrial Corridor Programme – TICP which will develop futuristic industrial cities in Tanzania which can compete with the best manufacturing and investment destinations in the world. The program will provide multi modal connectivity with complete "plug and play" infrastructure till the plot level along with building resilient and sustainable future ready cities / Green Cities.

2.13. Tanzania Industrial Infrastructure Upgradation System (TIIUS)

Tanzania Industrial Infrastructure Upgradation Scheme (TIIUS) will be launched with the objective of enhancing industrial competitiveness of domestic industry by providing quality infrastructure through public private partnership in selected functional clusters/locations, which have the potential to become globally competitive. Several projects can be approved in Five Year Plan under TIIUS.

2.14. Productivity and Quality

DPIIT as the nodal department for the promotion of productivity and quality in the industrial sector, Tanzania Productivity Council (TPC) will undertake productivity augmentation through domain specific consultancy, training, workshops, seminars and conferences for Government, Public and Private sectors, Productivity related research, Monitoring & Evaluation of various government schemes & projects and information dissemination through collaboration with International Trade Organizations.

QCI will operate its quality assurance activities in areas related to industry, education environment, health care, sports etc. Through its constituent boards formed [namely: Tanzania Accreditation Boards for Testing & Calibration Laboratories (TABL); Tanzania Accreditation Board for Hospitals & Healthcare Providers (TABH); Tanzania Accreditation Board for Education & Training (TABET); Tanzania Accreditation Board for and Division [namely: Zero Defect Zero Effect (ZED), Project Analysis and Documentation Division (PADD) & Project Planning and Implementation Division (PPID)]. Every Board is functionally independent and works within its area of expertise.

2.15. United Nations Industrial Development Organization (UNIDO) Activities

DPIIT under MIIT, the nodal Department for all matters related to UNIDO operations in Tanzania. UNIDO is a specialized agency of the United Nations for industrial activities within the United Nation's system. Tanzania has been an active member of the organization since its inception. UNIDO has established its presence in Tanzania by means of following centres/offices with different mandates viz. UNIDO Regional Office (URO) headed by UNIDO Representative (UR) to Tanzania and Africa regions Facility for International Cooperation for Inclusive and Sustainable Industrial Development (FIC-ISID)

2.16. Specific Industries Administered by MIIT

The Department will monitor industrial growth and production in general and in select industrial sectors such as leather, cement, paper and pulp, tyre and rubber, light electrical industries, consumer goods, consumer durables, light machine tools, light industrial machinery, light engineering industries etc. as indicated in the allocation of Business Rules.

2.17. Monitoring of Industrial Activity, Production and Prices

DPIIT will monitor the performance of the industrial sector by collating information from IEM, Industrial License, Letter of Intent, Foreign Investment data and Industrial production returns. The Department will also compile and prepare Index of production of TShs. 2.3 Billion infrastructure industries on monthly basis. Besides, the Department will publish the monthly Wholesale Price Index (WPI) which forms the basis for official information on inflation.

2.18. Internal Trade and E-Commerce

The Department will involve the formulation and negotiation of Tanzania's stance on ecommerce, for discussions in bilateral and multilateral fora, such as WTO and Free Trade Agreements (FTAs). The Department will pioneer the initiative of Open Network for Digital Commerce (ONDC) to promote open networks for all aspects of exchange of goods and services over digital or electronic networks based on open- sourced methodology, using open specifications and open network protocols independent of any specific platform. ONDC will make e-Commerce more inclusive and accessible for consumers, standardize operations, promote inclusion of local suppliers, drive efficiencies in logistics and lead to enhancement of value for consumers.

2.19. Technical Regulations

In order to provide safe reliable quality goods, minimizing health hazards to consumers, promoting exports and substituting imports, Technical regulations/Quality Control Orders (QCOs) will be issued by DPIIT for industries falling under its domain viz. Light Engineering Industry (LEI), Consumer Industry (CI), Cement, Paper, Rubber & Linoleum, Leather & Footwear, and Explosives. DPIIT as per its mandate will issue QCOs. QCI for several products under Tanzania Bureau of Standards, TBS Act, 2009 (No. 2 of 2009) as well as other products under Tanzania Explosives Act, 2002 (Gas Cylinders, Valves and Regulators) will be issued. DPIIT will continuously engage with TBS and relevant stakeholders for notification and implementation of QCOs.

2.20. Tanzania Medical Devices Promotion Council

The Medical Devices Industry (MDI) will play a critical role in the health care ecosystem and it will be indispensable to achieve the goal of health for all citizens of the country. A Tanzania Medical Devices Promotion Council will be setup. Tanzanian manufacturing companies and startups will move towards creating innovative products, the setting-up of the Council will spur domestic manufacturing in this sector.

2.21. Strengthening Data System of Schemes and Non-schematic Interventions

The Department in collaboration with NITT will take key steps to ensure data preparedness. An institutional mechanism in the form of a Data & Strategy Unit will be set up to lay down Data Strategy. An Action Plan will prepare eight major schemes and three non- schematic interventions for improving various features of Data System viz. data generation; data quality; data analysis; use & dissemination; use of technology; data security & HR capacity; and data management during 2022-23, 2023-24, 2024-25. The plan will be implemented to promote synergistic data, inter-agency collaboration and prescriptive analytics to drive better data-based outcomes.

3. Industrial Promotion

3.1 Empowered Group of Secretaries

In order to provide support and facilitation to investors for investing in Tanzania and to boost growth in key sectors of the economy, an Empowered Group of Secretaries (EGoS) has to be created, which will look into hindrances being faced by investors, and also take up cross cutting policy issues with the following objectives: To bring synergies and ensure timely clearances from different Departments and Ministries; To attract increased investments into Tanzania and provide investment support, facilitation to global investors; To facilitate investments of top investors in a targeted manner and to usher policy stability & consistency in the overall investment environment.

3.2 Project Development Cells (PDCs)

PDC will facilitate and provide investor friendly ecosystem to investors investing in Tanzania, the Government has to approve the constitution of Project Development Cells (PDCs) in all Ministries to fast- track investments in coordination between the Regional Government and Local Government and thereby grow the pipeline of investible projects in Tanzania to increase domestic investments and FDI inflow. PDCs have the following main objectives:- To create projects with all approvals, land available for allocation and with the complete detailed project reports for adoption/ investments by investors; To identify issues that need to be resolved in order to attract and finalize the investments and put forth these before the Empowered Group.

3.3 Investment Clearance Cell (ICC)

It will provide “end to end” facilitation and support to investors, including pre-investment advisory, provide information related to land banks and facilitate clearances at National and Regional level. The cell will operate through an online digital portal. DPIIT along with Invest Tanzania will initiate the process of developing the portal as a Tanzania Single Window System (TSWS) envisioned as a one-stop for taking all the regulatory approvals and services in the country.

3.4 Industrial Licensing

The list of items covered under Compulsory Licensing is reviewed on an ongoing basis. Presently, there are no items reserved for exclusive manufacture by Small Scale Sector. Presently, few industries are reserved exclusively for the public sector. The following measures should be considered for easing the process of Industrial Licensing: Period of validity of Industrial License in general it has to be from 2 to 3 years. As a measure of further ease of doing business, two extensions of two years each in the initial validity of three years of the Industrial Licence should be allowed up to seven years; Guidelines should be issued to streamline the processing of applications for grant of extension of validity of Industrial License.

Partial commencement of production should be treated as commencement of production of all the items included in the license; The ‘Security Manual for Licensed Defense Industry’ should be issued. With the issue of the Security Manual, the requirement of affidavit from the applicants should be done away with; Restriction of annual capacity in the Industrial License for Defense Sector should be removed under Industries (Development & Regulation) Act; Licensee should be allowed to sell the defense items to the government entities under the control of PSUs.

3.5 Industrial Performance

The Index of Industrial Production (IIP), one of the core economic indicators, is a short-term indicator for measuring growth of industrial production in the country. Based on the production data sourced from various Ministries/Departments including DPIIT, present series of IIP with base year 2022-23 should be released by the Tanzania Statistical Office every month under the Ministry of Investment, Industry and Trade, Government of Tanzania.

4. Tanzania Master Plan for MultiModel Connectivity

4.1 Background

It is estimated that Tanzania, to realize the vision of a $100 billion economy by 2030, creation of new and upgrading existing infrastructure will be the key to raising Tanzania's competitiveness and achieving this target. lmproved infrastructure (National road map infrastructure projects) capacities create efficiency gains through improved logistics and networks, which would improve the competitiveness of the economy. This can help in boosting a virtuous cycle of higher investments, growth and employment generation in the Tanzanian economy.

With this vision, the Tanzania Master Plan coordinated by Hon. President Samia Suluhu Hassan will accordingly depict the economic zones and the infrastructure linkages required to support them with an objective to holistically integrate all the multimodal connectivity projects and remove missing gaps for seamless movement of people, goods & services. The GDP in Tanzania was worth 60.8 billion USD in 2019, 64.4 billion USD in 2020 and 67.8 billion USD in 2021, according to Trading Economics global macro model and analysts expectations.

GDP in Tanzania is expected to reach 100 billion USD by 2030 upon accomplishment of national road map infrastructure projects, prioritizing Foreign Direct Investments, rapid inflation, stimulating the economy with deregulation, tax cuts and rebates.

4.2 The Tanzania Master Plan (TMP)

The Tanzania Master Plan (TMP) as an integrated plan depicting all the existing and proposed development initiatives of various Ministries for better synergy, it is a response in this direction. The objectives are to ensure that various economic zones are interconnected with a network of multimodal connectivity infrastructure up to the last mile, remove missing gaps for seamless movement of people, goods & services, ensure quick completion of works with cost efficiency, minimize disruptions and improve logistics efficiency.

In the TMP for multimodel connectivity, all the existing and proposed economic zones will be mapped along with the multimodel connectivity infrastructure in a single platform ranging in three time periods, i.e., status as on 2022-25, achievements made by 2025-28 and planned interventions up to 2028-30 for movement of people, goods & services. The comprehensive map will provide a bird's eye view of infrastructure development with key layers based on completion timelines of various Economic Zones, infrastructure & Utilities across the country.

The digital TMP portal will be developed by Tanzania Informatics Centre of Excellence, TICE using dynamic Geographic Information System (GlS) platform wherein data on specific action plan of all the Ministries will be mapped on to the portal. The TMP portal will also provide analytical tools for planning, permissions and project management, etc. As envisaged this plan will provide the necessary boost to economic and overall development of the regions. The same will provide physical linkages to promote comprehensive and integrated multimodal Tanzania network of transportation and logistics thereby enabling smooth transportation of goods, people and services to create efficiency gains and avenues for further developments, value addition and creating employment opportunities.

The Government or Private Sector, before planning any investment in any economic activity like textile park, fishing cluster, agro- processing centers etc., will know beforehand the status of current multimodal connectivity like proximity to highways, airports, rail, ports, etc. for making informed decisions. On the other hand, infrastructure connectivity Ministries will be able to priorities connectivity enhancement for ensuring last mile connectivity in a certain defined time frame.

4.3 Institutional Structure

TMP will establish an institutional framework to bring into action the whole of government approach for implementing its vision. Accordingly, the apex body - an Empowered Group of Secretaries (EGoS) under the Chairmanship of Cabinet Secretary has to be constituted to approve any changes in the Master Plan for meeting any emerging requirements. An integrated Multimodal Network Planning Group (NPG) will be be operational with representation from various connectivity infrastructure Ministries/Departments involving their heads of Network Planning Division for unified planning and integration of the proposals and assist the EGoS.

5. Reforms for Easy of Doing Business

5.1 Introduction EoDB

Regulatory burden on a business has a significant impact on its performance. Regulations impose both time and cost for compliance and, thus, affect competitiveness of business. Regulations, however, are an important tool for ensuring that markets work effectively and do not meet failure due to trust deficit in products or among various players. Regulations bring in the minimum threshold of acceptability and thereby make markets work.

In view of these conflicting aspects, there is a requirement to ensure that, while necessary regulations are put in place, their implementation remains efficient and effective. The time and costs imposed by the regulations should be minimum. Low regulatory burden means that entrepreneurs can devote their time on productive activities. It also leads to lower costs as the requirement of engaging regulatory experts is reduced. There are several ways in which delivery of government services can be improved.

Citizens are paramount to all initiatives of the Government of Tanzania. It is also felt that reduction in compliance burden on citizens will lead to the overall objective of Ease of Living in the country. Government of Tanzania will spearhead the exercise to improve overall business regulatory environment and reduce compliance burden for businesses and citizens in the country by streamlining the existing regulations and processes and eliminating unnecessary requirements and procedures. This is evident from three major initiatives being pursued by the Government focusing on – the efforts for World Bank’s Doing Business Report, Region & District Reform Action Plans and systematic approach to reduce compliance burden on businesses and citizens.

5.2 Efforts for Improving Tanzania’s Rank in World Bank’s Doing Business Report

MIIT will coordinate on regular basis with nodal Ministries/Departments/Regions concerned and monitor the exercise for improving Tanzania’s ranking in World Bank’s Doing Business Report (DBR). Some of the major indicator wise reforms to be considered by the Government towards easing the business environment are as under: Starting a Business: Introduction of a software platform, BRELA by MIIT for Company Incorporation saves time and efforts required in Company Incorporation. This form combines various services like NIDA/TIN/Activities etc. In most of the cases, company incorporation is being completed on the same day of filing the details in Brela and other services like obtaining Certificate of Incorporation etc. take 2 to 3 days.

Obtaining Construction Permits: Online Building Permission System (OBPS) to be introduced by Ministry of Lands, Housing and Human Settlements Development, a Single Window for obtaining building permissions. All agencies involved in granting clearance for construction will be integrated on the portal and the applicant is no longer required to visit each agency individually; Trading Across Borders and Resolving Insolvency promote reorganization proceedings in practice : Reduced import border compliance time by improving infrastructure at the Ports. Export and import border compliance cost to be reduced by eliminating merchant overtime fees and through the increased use of electronic and mobile platforms. Implementation of electronic self-sealing of containers for exporters at their own facilities. Adoption of the Advance Bill of Entry for importers to start custom clearance before the arrival of the vessel; Getting Electricity: Rationalization of Service Line Cum Development Charges to bring connections under Low Tension category, will make it simpler to obtain electricity connection.

5.3 Regions and Districts – Level Easy of Doing Business Reforms

Under the reform action plan, all regions in the country will be ranked on the basis of reforms undertaken by them on designated parameters. In order to handhold regions in implementation of reforms, Capacity Building Webinars, video conferences and regional workshops will be conducted.

5.4 Exercise for Reducing Compliance Burden on Businesses and Citizens

DPIIT under MIIT will be responsible to reduce compliance burden on citizen and business activities. The objective of this exercise is to improve Ease of Doing Business and Ease of Living by Simplifying, Rationalizing, Digitizing and Decriminalizing Government to Business and Citizen Interfaces across Ministries. This will ensure hassle-free service delivery seamlessly till the last mile to the ultimate beneficiary.

6. Startup Tanzania

6.1 Startup Tanzania Action Plan

The Startup Tanzania Action Plan will be launched with the objective of supporting entrepreneurs, building a robust startup ecosystem, and transforming Tanzania into a country of job creators instead of job seekers. DPIIT will coordinate the efforts of the government in carrying this plan forward and spread across regions in Tanzania.

6.2 Fund of Funds for Startups (FFS)

For providing fund support for Startups, the Government will create a 'Fund of Funds for Startups' (FFS). The FFS shall contribute to the corpus of Alternate Investment Funds (AIFs) for investing in equity and equity linked instruments of various Startups. The FFS will be managed by the Bank of Tanzania for which operational guidelines will be issued.

6.3 Relaxed Norms in Public Procurement for Startups

The requirement of submission of bid security/ earnest money deposit and prior turnover & experience will be at ease to encourage startups to participate in public sector procurement. 'GeM Startup Runway' will be launched as a dedicated corner for startups to sell products and services to the Government buyers.

6.4 Startup Tanzania Seed Fund Scheme (STSFS)

Department for Promotion of Industry and Internal Trade (DPIIT) will create Startup Tanzania Seed Fund Scheme (STSFS) to provide financial assistance to startups for Proof of Concept, prototype development, product trials, market entry and commercialization. This will enable early-stage startups to graduate to a level where they will be able to raise investments from angel investors or venture capitalists or seek loans from commercial banks or financial institutions.

6.5 Tax Incentives

Tax Exemption to Startups for 3 Years and Tax Exemption on Investments above Fair Market Value.

6.6 Legal Support and Fast-tracking Patent Examination at Lower Costs

Startups will be eligible for 80% rebate in patent filing fees, 50% rebate in trademark filing fees. Additionally, Startups will also provide the facility of expedited examination of patent applications to reduce time taken in granting patents.

6.7 Self-Certification based Compliance Regime

Compliance norms which relate to Environmental and Labour laws will be at ease in order to reduce the regulatory burden on Startups thereby allowing them to focus on their core business and keep compliance costs low.

6.8 Setting up of Incubators and Tinkering Labs

Samia Innovation Mission (SIM) will select incubators and tinkering labs across the country to provide financial support through grants in aid and disburse grants to the incubators and tinkering labs.

6.9 Regulatory Reforms

Redressal of regulatory issues will require continuous and deep engagement between the Government, Startups and stakeholders of the ecosystem. DPIIT will engage with stakeholders on regular basis to invite consultations on regulatory issues raised by Startups, investors and others in the ecosystem.

7. United Nations Industrial Development Organization

7.1 Introduction and Overview

The United Nations Industrial Development Organization (UNIDO) is the specialized agency of the United Nations that promotes industrial development for poverty reduction, inclusive globalization and environmental sustainability. UNIDO's mission is to promote and accelerate inclusive and sustainable industrial development (ISID) in its 170 Member States. Tanzania has been an active member of UNIDO since its inception. Tanzania is both a recipient and as well as a contributor to the programmes of UNIDO. MIIT (DPIIT) is the nodal government ministry for all matters related to the operations of UNIDO in Tanzania.

UNIDO's activities in Tanzania qare guided by a Country Program (CP), which serves as the framework for its interventions, aligned with national priorities. The country evaluation confirmed the relevance and strong alignment between UNIDO projects and government policies, existence of strong partnerships with national institutions, and revealed across-the-board satisfactory progress towards outputs and outcomes. The CP focuses on 4 key result areas, namely (i) productive and resilient MSMEs; (ii) solutions for climate, resources and environment; (iii) inclusive and responsible value chains and businesses; and (iv) strategic policy for industrial transformation. The objectives of the CP are fully aligned with the United Nations Sustainable Development Framework (UNSDF).

7.2 About UNIDO

DPIIT under MIIT will be the nodal department in the Government of Tanzania for all matters related to UNIDO's operations in Tanzania. UNIDO, headquartered in Vienna (Austria), was established in 1966 and became a specialized agency of the United Nations in 1985 to promote industrial development and cooperation at the global, regional, national and sectoral levels. India has been an active member of the organization since its inception.

7.3 Aims and Objectives

UNIDO's mission, as described in the Lima Declaration adopted at the fifteenth session of the UNIDO General Conference in 2013, is to promote and accelerate inclusive and sustainable industrial development (ISID) in developing countries and economies in transition. In line with this mandate, the organization's programmatic focus is structured in four strategic priorities: Creating shared prosperity, Advancing economic competitiveness; Safeguarding the environment, Strengthening knowledge and institutions

Each of these programmatic fields of activity contains a number of individual programs, which are implemented in a holistic manner to achieve effective outcomes and impacts through UNIDO's four enabling functions: (i) technical cooperation; (ii) analytical and research functions and policy advisory services; (iii) normative functions and standards and quality-related activities; and (iv) convening and partnerships for knowledge transfer, networking and industrial cooperation.

7.4 Organization and its Policymaking Organs

The Organization is headed by a Director-General. The main policymaking organs of UNIDO are (i) General Conference; (ii) Industrial Development Board; and (iii) Programme and Budget Committee: General Conference (GC): It is UNIDO's supreme policymaking organ where all Member States meet once every two years. The GC determines the guiding principles and policies of the Organization, approves the budget and work programme of UNIDO. Every four years, the GC appoints the Director-General. The GC also elects the members of the Industrial Development Board and the Programme and Budget Committee.

Industrial Development Board (IDB): It comprises (53 members), elected for a four- year term on a rotational basis from all Member States. It reviews the implementation of the work programme, the regular and operational budgets, makes recommendations to the General Conference on policy matters, including the appointment of the Director-General; Program and Budget Committee (PBC): The PBC (27 members) meets once a year to assist the Board in the preparation and examination of the work programme, the budget and other financial matters.

7.5 Collaboration and Other UN Agencies

At the national level, UNIDO is part of the UN system, through the United Nations Country Team (UNCT), which comprises the Heads of Agencies residing in the country and convened by the UN Resident Coordinator (UNRC). Through the UNCT, UNIDO actively participates in government and business outreach, advocacy, coordination meetings and annual strategic meetings, aimed to facilitate joint programming and implementation with other UN agencies.

With the implementation of the reform agenda for the UN development system from January 2019, UNIDO has been strengthening its collaboration with sister UN agencies, including in Tanzania. For example, UNIDO jointly implements project on sustainable city development with UN Habitat and on alternatives to DDT with UN Environment, whereas UNIDO also contributed to joint UN missions to support the International Solar Alliance (ISA) and the implementation of the National Clean Air Program (NCAP).

7.6 Tanzania's Contribution

Tanzania is a founding member of UNIDO. It is both a recipient as well as a contributor to UNIDO's programs. Tanzania contributes to the regular budget of UNIDO (assessed contribution). The assessed contribution of Tanzania towards UNIDO makes an annual voluntary contribution to the Industrial Development Fund (IDF) of UNIDO.

7.7 Facility for International Cooperation for Inclusive and Sustainable Industrial Development

FIC-ISID aims to contribute to initiating, directing and supporting the inclusive and sustainable transformation of policy and practice for industrial development in Tanzania particularly for the manufacturing and allied productive sectors through knowledge, learning, projects development and partnerships facilitation. FIC-ISID is therefore structured in following two parallel and mutually reinforcing components, respectively: Knowledge & Learning Facility: aimed at improving awareness, understanding and knowledge on ISID in support of projects, policies and programs of government, business sector and/or civil society; and Projects and Partnerships Facility: aimed at initiating, developing and supporting projects and partnerships for ISID focused on sectors, topics, regions etc.

FIC-ISID furthermore serves as a platform for advocacy on aspects of inclusive and sustainable industrial development in Tanzania. The advocacy works carried out under FIC-ISID are as under:
Policy dialogue with the Ministry of Agriculture in Manufacturing excellence; Resurgence of MSMEs-Inclusive and Sustainable Recovery in Tanzania: UN agencies (such as UNIDO, UNDP, ILO and UN Women) organized a consultation with MSME (micro and small enterprises) and shared the strategy for resurgence of MSME from the negative impact of COVID-19 and developing a vibrant sector; Remanufacturing in Tanzania: On the occasion of the Global Remanufacturing Day 2021, Re:CREATe and UN Industrial Development Organization (UNIDO), in collaboration with UN Tanzania Business Forum (UNTBF), organized a deliberation, where policy makers, global leaders participated. The dialogue provided an impetus for initiatives related to remanufacturing, circular economy transition, resource efficiency and sustainable consumption and production, building on efforts being deployed internationally.

7.8 Firm-Level Demonstration of Technologies and Productivity Enhancement for Projects

The project envisages to demonstrate (on a pilot scale at mill level, at multiple locations across the country) two technologies (membrane filtration and liquor heat treatment), along with the development of the requisite capacity and process improvement interventions. The project aims to facilitate technology uptake and firm level innovation leading to increased productivity and competitiveness.

This project has been designed as a follow- up to the completed project 'Development and adoption of appropriate technologies for enhancing the productivity of the paper and pulp sector', which focused on strengthening the capability and capacity of the nodal technical institution and paper industry associations. Building on this strengthened meso-level capacity, the ongoing project aims to facilitate key interventions from the Phase-1 project, at the firm level.

8. Attachment and Subordinate Report of Jambo Food Products

8.1 Executive Summary of Jambo Food Products

A Standing Committee comprising experts in the field of design, operation of EHV Switchyard, various power utilities and research/academic institutes was constituted to investigate the power fluctuations and above voltage class substation / switchyard equipment such as Power/Generator Transformer, Circuit Breaker (CB), Instrument Transformer [i.e. Current Transformer (CT), Potential Transformer (PT) & Capacitor Voltage Transformer (CVT)], Surge Arrester (SA), Isolator etc. and recommend measures to avert recurrence of such fluctuations in future. As a part of such activity, **Jambo Group of Companies** has been receiving reports of leakages of various switchyard equipment from power utilities.

The prime objective of Standing Committee is to visit site of fluctuations, investigate the cause of leakage, discuss the cause of power flicker of various switchyard equipment of Power utilities in the meeting, recommend remedial measures to prevent recurrence of such power flickers in future and prepare a compendium of all perturbations. In the process, the participating utilities are mutually benefitted so as to adopt best practices.

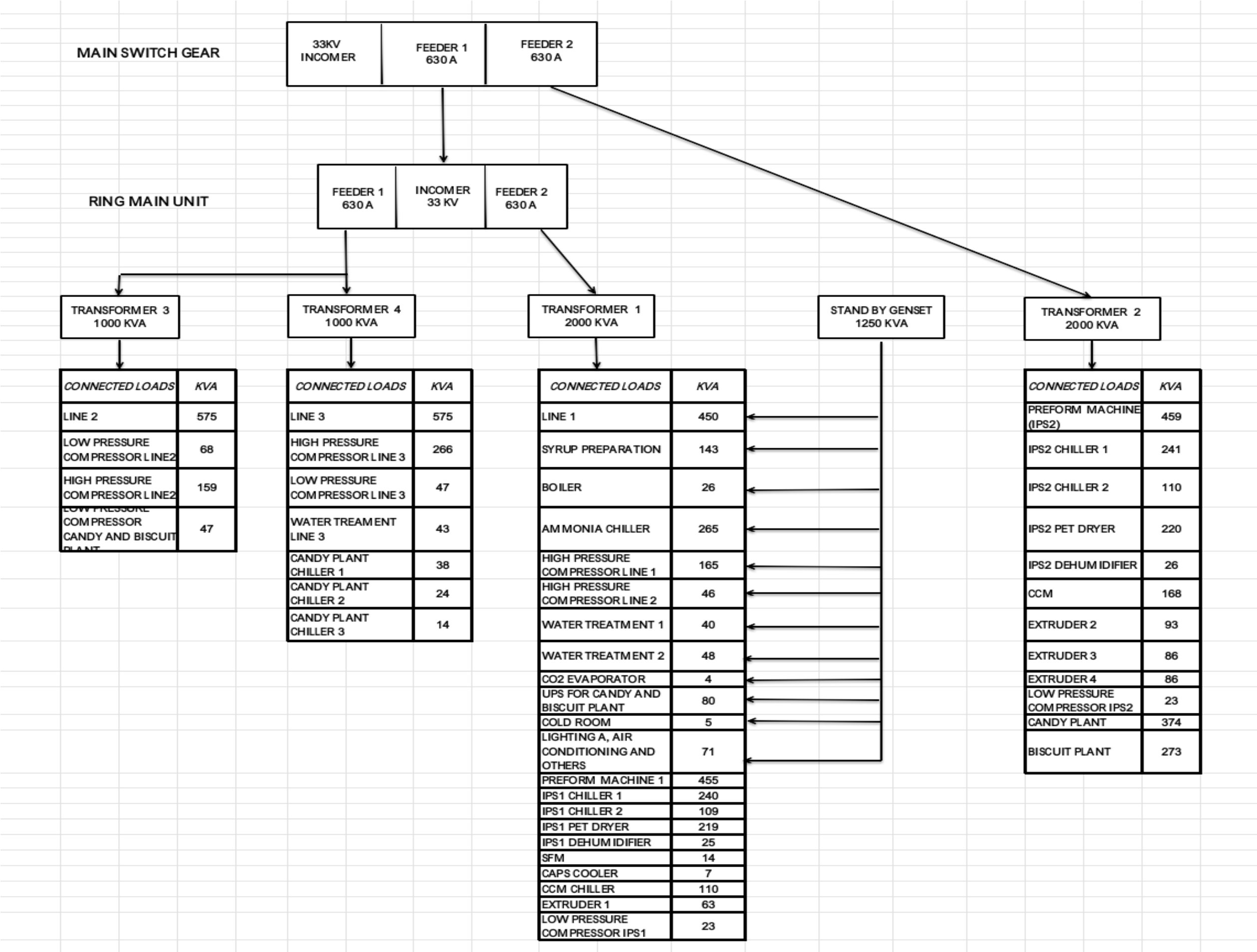
As per the requirement of the Standing Committee, all utilities are supposed to report the fluctuations of substation/ switchyard equipment & above voltage class to **Jambo Group of Companies** (**Department of Technical and Research Design**). In fact, number of power flicker cases remain unreported as many of power utilities [State Transmission Utilities, Private Utilities/Licensees, Central Transmission Utilities, Public Sector Power Utilities] in the country neither report the failure of substation / switchyard equipment nor participate in such National level meeting.

Hence, the basic purpose of formation of above standing committee gets defeated. This fact has been brought to the notice of Jambo Group of Companies Administration and all State Regulatory Commissions. In most of the cases, due to delay in reporting of event, the visit to site of power fluctuations do not materialize and analysis of cause of failure is done based on information provided by utilities. The information furnished by utilities is generally found to be inadequate for analysis of cause of failure. Either many vital information is found to be missing or not available with O&M section because the O&M history of equipment / transformer, records of all test results including tests carried out before & after failure incidences (factory tests, pre-commissioning tests, tests carried out during O&M etc.) are not properly maintained.

For the information and use of the utilities, the format for furnishing of information of failure of substation equipment is provided at Appendix - I. The utilities should provide adequate information in the format and submit it to the **Department of Technical and Research Design** along with supporting test reports, O&M history, disturbance recorder data, photographs etc. as early as possible after the occurrence of power fluctuations. A meeting of the Standing Committee of experts was held via ZOOM Meeting on 17th November 2021 to discuss cause of power fluctuations of switchyard equipment for which the information/failure report was received by **Jambo Group of Companies** between 20th November and 30th November 2021. Minutes of the meeting are enclosed at Appendix.- II.

A work reviewed by CEA in India depicts the same case that might have occurred in **Jambo Group of Companies**, During discussion in the meeting on the failure of Surge Arresters of KPTCL, it emerged that some of the arresters were reported failed in view of leakage current in these arresters found to be more than acceptable values during leakage current measurement. The committee decided that such cases should not be treated as failures and hence has been left out from the report.

8.2 Brief Details of Jambo Electrical Power Distribution



8.3 Observations on Jambo Power Fluctuations

It is observed that reported failures are primarily due to following reasons: Normal Ageing; Failure of Insulation system for CB/CT/PT/CVT/SA; Failure of Insulation system & Bushing for Transformers & Reactors; Lack of prudent maintenance practices; Frequent System Faults and transient over voltages generated by the system; Improper installation (Cross Linked Polyethylene, XLPE cable); In most of the failure cases of CT/PT/CVT/SA, equipment blast or get completely damaged making it impossible to carry out any test after failure. Without tests, internal condition of the failed equipment cannot be assessed and cause of failure cannot be determined. However, in most of the cases it is assumed that degradation of insulation due to ingress of moisture and transient system voltages might be the reason of failure of these equipment.

Condition Based Maintenance (CBM) Practices using modern diagnostic tools is not being followed by most of the **Jambo** utilities and in general, Time Based Maintenance is still being practiced; Adequate modern Diagnostic tools are not available with most of the **Jambo Utilities**; Most of the utilities are facing problem due to shortage of technical staff for operation & maintenance of switch gear equipment.

Sometimes interpretation of test results becomes difficult in absence of experts / experienced O&M staff in **Jambo Group of Companies**; Sometimes due to unavailability of shut down, maintenance of equipment is deferred which affects the efficient functioning of the equipment and further deteriorate the health of equipment.

In most of the cases of failures, utilities do not furnish factory test reports, pre-commissioning test reports, history of O&M & repairs, relay settings, environmental & system conditions at the time of failure etc. which makes it very difficult to analyze the cause of failure; In case of failure of transformers and reactors, report of detailed internal inspection carried out by OEM at site or at its works are not provided; In some cases, even though, there are indications of abnormalities after carrying out diagnostic tests, no corrective actions are taken; It is observed that sometimes same tests are carried out using different test methods with different kind/rating of test apparatus under different environment conditions which results in inconsistent and erroneous results.

It's analysed that all current flow causes losses both in the supply and distribution system. A load with a power factor of 1.0 results in the most efficient loading of the supply. A load with a power factor of, say, 0.8, results in much higher losses in the supply system and a higher bill for **Jambo**; In the interest of reducing the losses in the **Jambo Electrical distribution system**, power factor correction is added to neutralise a portion of the magnetising current of the motor. Power factor correction is achieved by the addition of capacitors in parallel with the connected motor circuits and can be applied at the starter, or applied at the switchboard or distribution panel.

As it is observed in certain cases that the type of capacitor was selected without considering future expansion of machineries in the plant**.** Some time these **Jambo** machines are found to be generating harmonic affecting the life of capacitor. Check the date of installation of capacitor and type of additional load being connected after installation of capacitors**;** The harmonics in the **Jambo plants** can be easily found If the plant has loads using power electronic components such as UPS, drives and furnace. Loads such as are welding, cfl tubes and electronic controlled machines also generate harmonics. Note that neighbouring **Jambo plants** connected to the grid may also affect the capacitors by importing the harmonic. (Harmonic voltage easily travels through the grid from one installation to another, the effect leads to failure of capacitor).

Effects of unbalanced electrical loads is observed which leads to harmonics in the system by UPS, decrease life cycle of the equipment, relay malfunction, inaccurate measurements, decrease capacity of transformers, cable and lines, increase distribution losses, increase energy bills in **Jambo Group of Companies** by increasing maximum demand (For energy consumption TANESCO does not charge on kVA but on kW for Residential customers. This means that they are charged for the "actual" energy used and not charged for the "total" energy supplied. Thus the power factor and Maximum Demand do not impact residential customers. But Commercial, Industrial and H.T Connection charged by its maximum demand . We have to specify the maximum "demand"(in kVA) at the time of connection. During the month if you exceed your maximum "demand" you have to pay penalty (or extra price) for the same. That is the MDI penalty that appears on electricity bills)

8.4 Recommendations to improve Plants' Performance

Recommended measures suggested by the Committee for the Utilities to improve the performance of **JAMBO GROUP OF COMPANIES' PLANTS** equipment are listed below. Some of the recommendations are being repeated from the previous report with the objective to remind the actions required to be taken by utilities to improve performance of equipment and to use modern diagnostic tools for condition assessment so as to keep Jambo Plants' equipment healthy for long trouble-free and reliable operation.

General Recommendations: The utilities should report to the Original Equipment Manufacturer (OEM) about the failure of equipment, even if warranty has expired, which may help the manufacturers to take corrective action for improving the product design; The practice of Condition Based Monitoring using modern diagnostic tools should be followed instead of Time Based Maintenance. Some of the important diagnostic tools have also been suggested based on the Technical Standards for Construction of Electrical Plants and Electric Lines.

The frequency/periodicity of measurement should be changed depending on condition/healthiness of equipment in operation. The trend of the test results should be monitored rather than absolute values of test result; Utilities should follow best practices for maintenance of each equipment. All the equipment which have reached/approaching end of service life need to be monitored closely and utility should plan and take action in advance for replacement of such equipment in a phased manner.

The utilities should make it a practice to carry out various tests on major electrical equipment at sites one or two months prior to expiry of warranty period of respective equipment so that any abnormality observed in test results can be discussed with OEM for taking up further necessary action within warranty period; The utilities must be careful while storing the equipment as spare or keeping transformer in the yard for long time before putting in to service. The manufacturer's recommendation for storage should be followed strictly.

TRANSFORMER	RATED KVA	RATED CURRENT (AMPERES)	CONNECTED LOADS	CONNNECTED LOADS RATING (AMPERES) FULL LOAD	CONNECTED LOAD RATING (KVA)
TRANSFORMER 1 (LINE1)	2000	2886.8	LINE 1	630	453
			SYRUP PREPARATION	200	144
			BOILER	8	6
			AMMONIA CHILLER	370	266
			HIGH PRESSURE COMPRESSOR LINE 1	230	165
			LOW PRESSURE COMPRESSOR LINE 1	65	47
			WATER TREATMENT 1	56	40
			WATER TREATMENT 2	68	49
			CO2 EVAPORATOR	6	4
			UPS FOR CANDY AND BISCUIT PLANT	120	86
			COLD ROOM	8	6
			LIGHTING A, AIR CONDITIONING AND OTHERS	100	72
			PREFORM MACHINE 1 (IPS 1)	633	455
			IPS1 CHILLER 1	335	241
			IPS1 CHILLER 2	153	110
			IPS1 PET DRYER	306	220
			IPS1 DEHUMIDIFIER	36	26
			SFM	20	14
			CAPS COOLER	10	7
			CCM CHILLER	154	111
			EXTRUDER 1	130	93
			LOW PRESSURE COMPRESSOR IPS1	32	23
	2000	2886.8		3670	2638
TRANSFORMER 1 (LINE 1) FULLY UTILISED					
TRANSFORMER 2 (PREFORM PLANT)	2000	2666.74	PREFORM MACHINE (IPS2)	638	459
			IPS2 CHILLER 1	335	241
			IPS2 CHILLER 2	153	110
			IPS2 PET DRYER	306	220
			IPS2 DEHUMIDIFIER	36	26
			CCM	234	168
			EXTRUDER 2	130	93
			EXTRUDER 3	120	86
			EXTRUDER 4	120	86
			LOW PRESSURE COMPRESSOR IPS2	32	23
			CANDY PLANT	520	374
			BISCUIT PLANT	380	273
	2000	2666.74		3004	2159
TRANSFORMER 2 (PREFORM PLANT)FULLY UTILISED					
TRANSFORMER 3 (LINE2)	1000	1391.2	LINE 2	800	575
			LOW PRESSURE COMPRESSOR LINE2	95	68
			HIGH PRESSURE COMPRESSOR LINE2	221	159
			LOW PRESSURE COMPRESSOR CANDY AND BISCUIT PLANT	65	47
	1000	1391.2		1181	849
TRANSFORMER 3 (LINE2) ROOM FOR ADDITIONAL LOAD OF 150 KVA=210A					
TRANSFORMER 4 (LINE 3)	1000	1391.2	LINE 3	800	575
			HIGH PRESSURE COMPRESSOR LINE 3	370	266
			LOW PRESSURE COMPRESSOR LINE 3	65	47
			WATER TREAMENT LINE 3	60	43
			CANDY PLANT ROOM COOLING CHILLER 1	54	39
			CANDY PLANT CHILLER 1	53	38
			CANDY PLANT CHILLER 2	33	24
			CANDY PLANT CHILLER 3	20	14
	1000	1391.2		1455	1046
TRANSFORMER 4 (LINE 3) FULLY UTILISED					

Utilities should take appropriate actions for repair/replacement of concerned equipment as soon as some abnormality is observed through visual inspection or diagnostic tests; Frequent failures of equipment of any particular make should be thoroughly investigated in consultation with OEM and necessary action including design modification, if required, should be carried out by OEM; Most of the utilities are facing problem due to shortage of supporting staff for operation & maintenance of sub-station equipment. The manpower should be strengthened for efficient O&M.

The regular cleaning of dust deposited on the housings of major equipment and bushings of transformer are essential to avoid flash over across the insulators, as such frequent flashover across the bushing / housing of equipment (due to operation in such dusty environment) may lead to failure of equipment. Wherever feasible, the porcelain housings of major equipment (CB/LA/CT/CVT) and bushings of transformer may be protected by providing Room Temperature Vulcanization (RTV) coating. RTV coating over porcelain housing of equipment (CB/LA/CT/CVT) / bushings of transformer & reactors may also be considered by utilities for substation equipment installed in pollution prone areas.

Utilities should create and maintain complete data base of equipment/transformers including previous test reports (reports of factory tests/pre-commissioning tests/tests during O&M etc.), operation & maintenance history of equipment with make, model & year of commissioning etc. for proper evaluation, interpretation of test results and for taking Run-Refurbish-Replacement decision.

However, merely maintaining the history of O&M is not sufficient. Test results are not useful if correct method of testing is not followed. All tests and maintenance should be carried out as per best practices. The method of testing as well as the conditions while conducting the tests should be consistent / identical to previous testing condition as far as possible. For example, test voltage, tap position at which test is conducted etc. should be maintained while measuring IR or Turns Ratio, or conducting SFRA and other similar tests. Details of test kits, should be maintained so that the test results can be compared with subsequent test results. For variation in temperature, required correction factors could be incorporated. Calibration of the testing instruments should be ensured for reliability of the assessment.

Lowering the facility's peak demand is the primary step to improving load factor and will ***reduce the amount paid monthly for electricity***. To determine the potential for improving load factor, analyze billing records to identify the seasons during which the peak demand is the greatest. In general, the greatest demand for electricity in **Jambo Group of Companies** occurs on hot days in the summer. While this implies that a large electric load is dedicated to space cooling, it is not necessarily true for every facility. It is always best to observe operations at the facility to determine what equipment may be causing the peak demand. Once the contributing equipment loads have been identified, determine what can be done to sequence or schedule events or processes in order to minimize the simultaneous operation of high wattage equipment.

Note: The demand rate structure automatically rewards customers for improving their load factor. Since load factor is an expression of how much energy was actually used compared to the peak demand, **Jambo Group of Companies** can use the same amount of electricity from one month to the next and still cause their average cost per kilowatt-hour to drop as much as 40% simply by reducing the peak demand. For instance, a 25% load factor in the summer would yield an average cost per kWh of 13.5 cents, while an 80% load factor would yield an average cost per kWh of 8.5 cents. Remember, this is comparing two months in which the customer used the same amount of electricity (kWh) with different peak demands.

To use electrical power efficiently your system should draw mostly real power, measured in kilowatts (kW), from our system. If your equipment draws too much reactive power, measured in kilovolt-amperes-reactive (kVAR), it can't perform work as efficiently and limits the capacity of our lines to deliver real power and quality voltage to your facility. The total power your facility draws, also called apparent power, is the square root of the sum of the squares of real and reactive powers. The ratio of real power to total power is called power factor, and your equipment is performing best when that ratio is between 90% and 100%.

Note: Poor power factor at your site can cause voltage fluctuations and power quality issues for other **Jambo Plants** (neighbouring facilities), which negatively affects their equipment. It also limits the capacity of lines to deliver energy to **Jambo Group of Companies** and to other Jambo Plants. To counteract these effects we need to install capacitors on **Jambo Integrated Machines** to use lines efficiently and to maintain power quality for the whole **Jambo Plants** on the line.

To reduce the kva required for any given load, you must shorten the line that represents the kvar. This is precisely what capacitors do. By supplying kvar right at the load, the capacitors relieve the utility of the burden of carrying the extra kvar. This makes the utility transmission/distribution system more efficient, reducing cost for the utility and their customers. The ratio of actual power to apparent power is usually expressed in percentage and is called power factor.

Recommendations for Transformers (ICT and GT) and Instrument Transformers (CT/PT/CVT): The proper handling, loading, transportation, unloading, and storage at site before assembling play important role in satisfactory operation of equipment / transformer; The erection of major equipment including transformers should always be carried out by experienced technical team under the close supervision of manufacturer; Inordinate delay in commissioning of equipment after reaching at site should be avoided; When there is a wide gap between the year of manufacturing and year of commissioning of the transformers, proper care must be taken to ensure satisfactory operation of transformer. Storage of transformer should be done as per manufacturer's recommendations.

Transformer should not be kept for more than three (3) months with dry air/inert gas (Nitrogen) filling and all throughout the period, required pressure needs to be maintained in order to avoid the exposure of active part to atmosphere. After three (3) months, transformer should be filled with oil under vacuum and transformer should be provided with oil conservator including oil level indicator and breather. The oil parameters need to be monitored regularly; As far possible the transformer should be transported filled with dry air. Nitrogen should be avoided; Whenever there is movement of transformer either from manufacturing works or from one station to other, SFRA should be carried out before movement and after shifting to new location. SFRA signature would provide valuable information about deformation in core during transportation

OLTC is one of the contributors to the failure of transformer. Possibility of eliminating OLTC from 400kV & 765kV class transformer should be considered (based on system studies) in consultation with **Jambo Power Committee** (JPC) and **Jambo Load Dispatch Centre** (JLDC) / POSOCO and CEA. The reduction in number of taps/steps can also be considered in case of OLTC of 220kV and below voltage class transformers. The removal of OLTC will simplify the design and manufacturing of transformers; Tertiary winding should be avoided, wherever feasible, as it increases the probability of failure of the transformer. Tertiary terminals of transformer prone to short circuiting by external elements.

An internal inspection of the failed transformer on-site is warranted at times to locate fault inside the transformer and to assess the extent of damage. As far as possible, internal inspection should be carried out in association with OEM / in presence of representative of OEM. All safety precautions must be observed at all times. Internal inspection must be performed by experienced staff with proper training. The internal inspection should not cause any further damage to the transformer and precaution should be taken to prevent ingress of moisture and any foreign material into the transformer and hence internal inspection should be meticulously planned.

The capacitance and tan delta measurement of transformer bushing at variable frequency and DGA of bushing oil should be carried out for health assessment of bushings as this has been proved to be very effective in assessing the condition of in-service bushings; Periodic oil testing including DGA (wherever feasible) in case of instrument transformers are recommended. Health of gaskets and bellows needs to be checked periodically for CTs. Thermo vision scanning of CTs, CVTs and PTs should also be carried out regularly as a good maintenance; While measuring tan delta of transformer bushing/CT/PT/CVT, apart from absolute value, rate of rise of tan delta should also be monitored and it should not be more than 0.1% per year. Frequency of measurement should be increased in case tan delta value is approaching 0.7%. Following table can be referred while measuring tan δ and capacitance of CVTs:

Change in Tanδ	Monitoring Frequency
Up to +0.002	Three Yearly
+0.002 to +0.003	Yearly
Above +0.003	Alarming
Change in Capacitance	**Monitoring Frequency**
Up to ±2%	Three Yearly
±2% to ±3%	Yearly
Above ±6%	Alarming

(Source: - CBIP Manual on EHV Substation Equipment Maintenance)

The change in secondary voltage of CVTs is a very good indicator of the condition/health of CVTs. Following table may be referred for monitoring of secondary voltage:

Drift in secondary Voltage	Condition	Monitoring Frequency
Up to ± 0.5 volts	Healthy	Six monthly
± 0.5 to ±0.8 volts	To be monitored	Three monthly
+0.8 to +1.2 volts	Close monitoring	Monthly
+1.2 to +2.0 volts	Close monitoring	15 days
above +2.0 volts	Alarming	Replacement
-0.8 to -4.0 volts	Close monitoring	15 days
less than -4.0 volts	Alarming	Replacement

(Drift in secondary Voltage (to be measured by 0.2 / 0.5 class multimeter))

Following table can be referred while measuring tan δ of CTs:

Value of Tanδ	Monitoring Frequency
Up to 0.007	Yearly
0.007 to 0.011	Half Yearly
Above 0.011	Replace the CT

(Source: - CBIP Manual on EHV Substation Equipment Maintenance)

Oil level should be checked before charging. For CTs with metallic bellows, the oil should be present up to the top of the bellow for proper functioning. The oil leakage needs to be checked periodically. Bellow level should be closely watched. The level of bellows of all CTs in one bay should be same at any time. Different bellow level may be an indicator of oil leakage, gassing or fault. Similarly, Capacitor units & EMU of CVTs in one bay should have same oil level indication at any time.

Varistors protect the CVT from over voltage due to Ferro-resonance (FR) oscillations. They may fail in service if FR is sustained or the energy to be discharged is beyond its designed capacity. Simple visual check will ensure the healthiness. A varistor should be replaced by the varistor of the same voltage rating, as secondary voltage is tuned to a varistor.

Recommendations for Surge Arrester: Measurement of the 3rd harmonic resistive component of leakage current is a very good method for assessing healthiness of SA. If 3rd harmonic component of resistive current is more than 150 μA, then Insulation Resistance (IR) value test should also be conducted and if current exceeds 350 μA, then SA should be removed from service and replaced. The measurement of leakage current before and after the monsoon should be carried out so as to ascertain the effect of moisture; Before erection, the condition of the Arrester unit should be checked and it should be ensured that there is no damage during erection. If SA is kept on an uneven surface, it is likely to damage the pressure relief diaphragm. Any damage to this thin & sensitive material while handling & erecting will result into moisture entry into Surge Arrester, which will lead to its failure.

Thermal scanning is another simple on-line check often used on SAs to locate hot spot due to improper/defective terminations/excessive watt loss; The specification of SA should include Sealing Test which can be carried out at manufacturer's works to ensure proper sealing against ingress of moisture; Digital surge counter's employment in substations could be explored.

Recommendations for Circuit Breaker: Dynamic Contact Resistance Measurement (DCRM) test kit is a very important tool to assess the healthiness of circuit breaker. This test may be carried out once in two years; Moreover, while formulating the specification for procurement of CB for new switch gear, provision for procurement of Operational Analyzer along with Dynamic Contact Resistance Measurement (DCRM) test kit should be included for one substation or a group of nearby substations depending upon the requirement.

Recommendations for Cross Linked PolyEthylene (XLPE) Cable: The cable should be laid in the configuration as approved during design stage as per manufacturer's recommendations. If cable is repaired, it should be restored to its original laying condition; The monitoring of healthiness of Sheath Voltage Limiter (SVL) and monitoring of Partial Discharge (PD) of all straight-through joints & terminations in addition to hot spot monitoring using Distributed Temperature Sensor (DTS) is essential.

Recommendations for Capacitor Banks: Supply voltage to capacitor should be checked for any over voltage. This can be verified of voltage stabilisers are connected in the installation, light fitting are regularly replaced, this indicates the over voltage; It is generally found that IC based APFC relays are big in size as compared to microprocessor relays. These IC based relays are found to be malfunctioning. The capacitors are switched "OFF" & "ON" very fast without discharge of capacitor, leading to high current drawn by capacitors. Such operation leads to failure of capacitor.

Check the time set in APFC relays connected for the operation, as various make of relays are preset for 15-20 sec. This setting of time should be verified in presence of customer at panel with operation of relay. The switching of capacitor from one step to another should have min time gap of 60 second. This should be physically watched. No replacement shall be considered in such cases where in the time is set below 60sec; The chattering of contactor can also lead to failure of capacitor. This chattering may happen due to low voltage or loose connection to contactor coils etc. If the capacitors are operated in manual mode using push button, check whether the on delay timer is provided in the individual steps. Verify whether the time set of 60sec or not. No replacement should be considered in such cases where in the timer is set below 60sec. or it is not provided.

Check whether capacitor duty contactor is provided or if the inrush limiting inductor coils are used. This becomes important in case the capacitors are switched 'ON' with the other capacitor connected in the same bus. Parallel switching of capacitor is generally found in capacitor panels having APFC and push buttons for switching "on" & "off"; Check whether the harmonic is present. For this take a fresh capacitor, charge the capacitor and then calculate whether the current drawn by capacitor is within the limit. If the current is more, then it may be due to over voltage. If not then it is clear that the capacitor is drawing high current due to presence of harmonics.

In case the installation is having MD-XL capacitors with connected loads generating harmonics then the capacitor may be drawing additional 30% current. In such conditions the fuses may blow out cable will heat up and Temperature of capacitor will be also increased. Ensure that the fuse rating should not be increased. The switchgear and cable size should be suitably increased. The capacitor will continue to work but the life of capacitor may not be longer. This clearly indicates that the capacitor is over loaded and if required the reactor Should be provided for controlling the over current; Check the short circuit protection device. Please note that you may come across the customer using fuses almost double the current rating of capacitors. This is generally found in the plants having harmonic problems and the installations having hired local electricians for maintenance.

Check the date of installation of capacitor and type of additional load being connected after installation of capacitors. As it is observed in certain cases that the type of capacitor was selected without considering future expansion of machineries in the plant**.** Some time these machines are found to be generating harmonic affecting the life of capacitor; In the Automatic Power Factor Correction (APFC) Panel, Please check if required kVAr of capacitors are installed, Check the type of capacitor installed is suitable for application or the capacitors are de rated, Check if the capacitors are permanently 'ON' (The Capacitor are not switched off), when the load is not working, under such condition the average power factor is found to be lower side, Check whether all the capacitors are operated in APFC depending upon the load operation, Check whether the APFC installed in the installation is working or not. Check the CT connection is taken from the main incomer side of transformer, after the fix compensation of transformer, Check if the load demand in the system is increased and finally Check if power transformer compensation is provided.

Before charging capacitor banks, make sure that Capacitor voltage rating is equal to the max voltage recorded in the installation, Capacitor is mounted vertically, Earthing at two different points is done, Proper lugs are used for termination, Proper size of cable is used, Ph- ph gap is 25mm and ph-earth is 19mm, The bus bar used for banking is 1.8 x rated current of the bank, Cross ventilation provision is provided in the installation area / in the panel, The plant has the facility to trip the capacitor under over voltage conditions (10%), Capacitor is provided with suitable size of HRC fuse / MCCB rating for protection, Suitable inrush current device is connected in series with contactor to limit the inrush current or capacitor duty contactor is used, Capacitor is provided with suitable on delay timer to ensure that the capacitor is not switched on within 60sec after it is switched off, Capacitor is provided with insulating cover to ensure the safety, Capacitor is installed in the area free from entry of dust, chemical fume and rain water, APFC relay provided in the panel is set for 60 second. 'On delay' provided are also set for 60 second, The filter banks are provided with MCCB for protection apart from above points and the MCCB should be set for 1.3 x rated current of filter bank.

During installation before commissioning harmonic filters verify and note that Capacitor banks without reactor should not be permitted on the secondary size of transformer circuit which is having filter banks connected. Please remove capacitors without reactors from the same network (as IEC- 61642), Filter rated voltage is equal to the max voltage recorded in the installation, Capacitor used with reactors is always of special voltage recorded in the installation, Earthing should be done at capacitors and reactors separately, Proper lugs are used for termination, Proper size of cable is used, Ph- ph gap is 25mm and ph-earth is 19mm, The bus bar used for banking is 1.8 x rated bank current, Forced cross ventilation should be provided in the installation area, The plant has the facility to trip the filter banks under over voltage conditions. Set for 10% over voltage, Filter banks are provided with suitable size of MCCB rating for protection, The MCCB is set for 1.3 x rated current of filter bank. MCCB are recommended, Filter is provided with suitable 'on delay' timer to ensure that the capacitor is not switched on within 60sec. After it is switched off, Filter is installed in the area free from entry of dust, chemical fumes and rain water, APFC relay provided in the panel for switching filters is set for 60 second.

Recommendations to prevent unbalanced loads: All the single phase loads should be distributed on the three phase system such that they put equal load on three phases; Replacing the disturbing equipments i.e. with unbalanced three phase reactance; Reducing the harmonics also reduces the unbalance, which can be done by installing reactive or active filters. These filters reduce the negative phase sequence currents by injecting a compensating current wave; In case the disturbing loads cannot be replaced or repaired, connect them with high voltage side this reduces the effects in terms of percentage and even controlled disturbance in low voltage side; Motors with unbalanced phase reactance should be replaced and re-winded; Distribution of single-phase loads equally to all phases.

Single-phase regulators have been installed that can be used to correct the unbalance but care must be exercised to ensure that they are controlled carefully not to introduce further unbalance; Passive network systems and active power electronic systems such as static var compensators and line conditioners also have been suggested for unbalance correction; Load balancing; Use of passive networks and static VAR compensators; Equipment that is sensitive to voltage unbalance should not be connected to systems which supply single-phase loads; Effect of voltage unbalance on ac variable speed drives can be reduced by properly sizing ac side and dc link reactors.

Tight all Neutral Connections of the System; Install Proper size of Capacitor Bank to the System; Load Scheduling, where the loads in an electrical network are scheduled in a way to turn on and off at precise times to prevent the overloading of any one phase; Manual Load Shifting, where an electrician opens a breaker panel and physically removes the loads from one phase and inserts them onto another phase; Load Shedding, where the loads in an electrical network are immediately turned off in order to instantly "rebalance" the phases. This is usually done by ranking the loads in a network by how long they can be turned off before it affects operations.

Note: Effects of Unbalanced Loads include: Increase of Electricity Bill by increase of Maximum Demand**;** Harmonics in system by Uninterruptible Power Supply, UPS**;** Decrease life cycle of equipments; Relay Malfunctions, Increase distribution losses and Loose connection of neutral wire**;** Inaccurate Measurement, Failure of transformer; Unsuitable capacitor bank installation, Decrease capacity of transformers, cables and lines.

8.5 Load Generation Balance Report

The Load Generation Balance Report (LGBR) 2020-21 brings out the likely month-wise Power Supply Position in terms of Requirement and Availability while simultaneously identifying the plants with surplus power, which could be procured/ contracted by **Jambo Plants** facing deficit. The LGBR 2020-21 also presents a review of the Actual Power Supply Position in **Jambo Group of Companies** during the previous year i.e. 2019-20. Most importantly, it makes an assessment of the power requirement of all Plants during the year 2020-21, as well as an estimation of expected power availability from generating stations either owned or through their shares in the common projects or, based on long term and medium term contracts.

8.5.1 Actual Power Supply Position

During the year 2019-20, total ex-bus Energy Supplied increased by 1.3% over the previous year and the Peak Met increased by 4.0%. The Energy Requirement and Peak Demand registered a growth of 1.3% and 3.8% respectively during the year 2019-20 as compared to 2018-19. The relevant statistics are seen below:

Energy in Watts	2018-19	2019-20	Actual Growth (%)
Energy Requirement (Units, U)	1,406,339	1,539,629	8.66
Energy Supplied (Units, U)	1,027,121	1,143,808	10.20
Peak Demand (MW)	2,940	2,970	1.01
Peak Met (MW)	2,500	2,572	2.80

Plants	ENERGY				PEAK			
	Requirement	Supplied	Not Supplied		Demand	Met	Not Met	
	(U)	(U)	(U)	%	(MW)	(MW)	(MW)	%
CSD	461,888.70	343,142.40	118,746.30	7.7130	891.00	771.60	119.40	4.02
Plastics	384,907.25	285,952.00	98,955.25	6.4275	742.50	643.00	99.50	3.35
Bakery	246,340.64	183,009.28	63,331.36	4.1136	475.20	411.52	63.68	2.14
Biscuits	184,755.48	137,256.96	47,498.52	3.0852	356.40	308.64	47.76	1.61
Candy,Ice	184,755.48	137,256.96	47,498.52	3.0852	356.40	308.64	47.76	1.61
Office	76,981.45	57,190.40	19,791.05	1.2855	148.50	128.60	19.90	0.67
Total	**1,539,629**	1,143,808	395,821	25.71	2,970	2,572	398	13.40

It may thus, be seen that the growth in supply of electricity has been commensurate to the growth in demand during the year 2019-20.The above figures indicates that the country witnessed a marginal demand-supply gap both in terms of Energy and Peak. However, this demand-supply gap was generally due to factors other than inadequacy of power availability in **Jambo Group of Companies**.

The month-wise Actual Power Supply Position in **Jambo Plants** during the year 2019-20 is elaborated:

Month-wise Actual Power Supply Position of Jambo during the year 2019-20								
Month/Year	ENERGY				PEAK			
	Requirement	Supplied	Not Supplied		Demand	Met	Not Met	
	(U)	(U)	(U)	%	(MW)	(MW)	(MW)	%
April - 19	1,027,121	923,872	103,249	10.05	2,944	2445	499	16.95
May - 19	1,027,121	1,021,199	5,922	0.58	2,945	2643	302	10.25
June - 19	1,027,121	1,005,017	22,104	2.15	2,942	2685	257	8.74
July - 19	1,027,121	971,542	55,579	5.41	2,941	2724	217	7.38
Aug - 19	1,406,339	1,245,790	160,549	11.42	2,947	2856	91	3.09
Sep - 19	1,406,339	1,076,626	329,713	23.44	2,948	2739	209	7.09
Oct - 19	1,406,339	1,191,446	214,893	15.28	2,944	2898	46	1.56
Nov - 19	1,500,303	1,406,339	93,964	6.26	2,945	2937	8	0.27
Dec - 19	1,406,339	1,094,501	311,838	22.17	2,972	2940	32	1.08
Jan - 20	1,143,808	802,247	341,561	29.86	2,971	2319	652	21.95
Feb - 20	1,406,339	1,164,310	242,029	17.21	2,974	2715	259	8.71
Mar - 20	1,143,808	885,321	258,487	22.60	2,978	2238	740	24.85

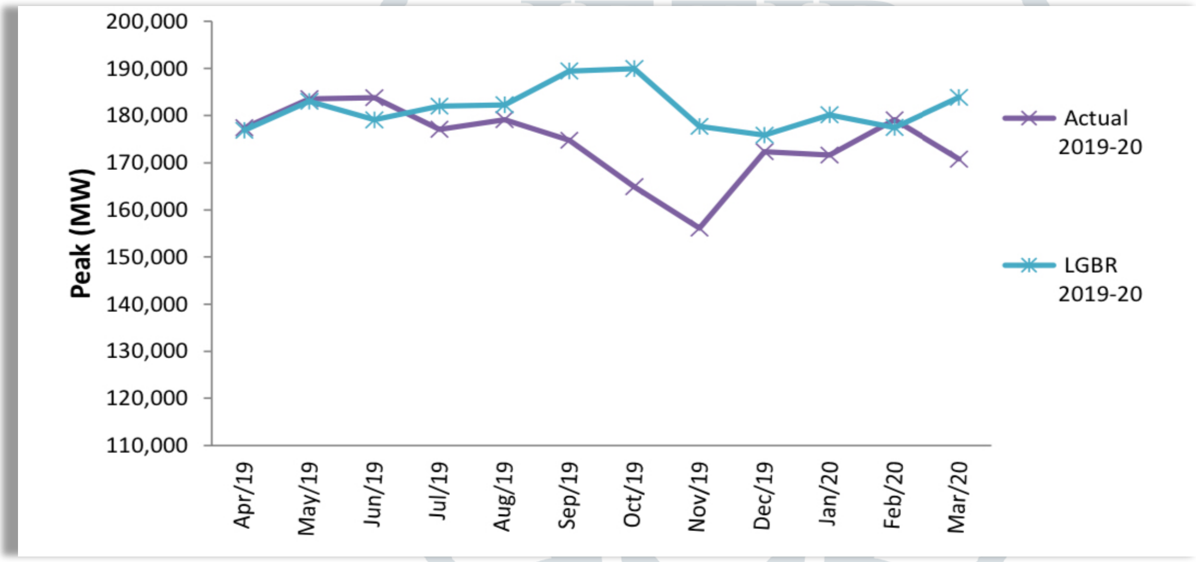
8.5.2 Review of Load Generation Balance - The Year 2019-20

The forecast of All **Jambo Energy Requirements** and Peak Demand as per the LGBR of 2019-20 were higher than the actual figures of 2019-20 by 8.66 % and 1.01 % respectively. The comparison of Forecast as per LGBR vis-à-vis Actual Power Supply Position of the **Jambo Plants** for the year 2019-20, is given below:

Jambo Plants	As per LGBR of 2019-20	Actual figures of 2019-20	Deviation from LGBR (%)
Energy Requirements (U)	1,539,629	1,406,339	-8.66
Energy Met (U)	1,143,808	1,027,121	-10.20
Peak Demand (MW)	2,970	2940	-1.01
Peak Met (MW)	2,572	2,500	-2.80

It may be mentioned that in actual operation the Energy Availability and Peak Met were commensurate to the Energy Requirement and Peak Demand respectively for the year 2019-20. The month-wise pattern of All **Jambo Plants** Peak Demand as per LGBR of 2019-20 Vs Actual Peak Demand of 2019-20 is graphically depicted below:

All Jambo Plants Pattern of Peak Demand for 2019 -20



All Jambo Plants Pattern of Energy Requirement for 2019 -20

8.5.3 Overview Of Load Generation Balance - Year 2020-21

The exercise for formulating the anticipated power supply position in **Jambo Plants** for the year 2020-21 involves: Assessment of month-wise power requirement in each plant in terms of Unrestricted Energy Requirement and Peak Demand; Realistic estimate of electricity availability both in terms of MU and MW capacity from various sources.

The Peak Demand and Energy Requirement in **Jambo Plants** have been worked out on the basis of the trend analysis considering the actual data for the preceding years as also the specific load requirements, if any, as per the established methodology. The availability of electricity has been worked out on the basis of generation programme firmed up by Lovely Professional University, L.P.U and University of Toronto, UoT, after detailed consultations with the generating companies/ Utilities and finally approved by Electrical Installation Units Department in **Krones**. **Jambo** Power Committees (JPCs) prepared the estimates of month-wise power requirement and availability (both in terms of MU and MW) for each of the **Jambo Plants** and finalized the same in consultation with them.

Jambo plant-wise anticipated power supply position has been comprehensively analyzed by Electricity Authority Boards from L.P.U and UoT to bring out the Load Generation Balance Report, LGBR for the year 2020-21. Based on the approved generation programme, the anticipated power supply position in the LGBR for the year 2020-21, indicates an overall energy surplus of 2.7% and peak surplus of 9.1% in **Jambo Plants**.

8.5.3.1 Assessment of Anticipated Power Scenario For 2020-21

The assessment of gross energy generation in **Jambo Group of Companies** during the year 2020-21 has been carried out taking into consideration the past performance of the Jambo plants, their vintage, maintenance schedule of the generating units during the year, likely partial and forced outages and availability of fuel etc in observation to Tanzania Electric Supply Co. Ltd, TANESCO.

Estimation of Energy Availability/Met - The Net Energy Availability (Ex-bus) corresponding to Gross Generation Scheme is computed for all generating plants taking into consideration the normative auxiliary consumption. The Energy Availability for each **Jambo Plant** is worked out by respective **Jambo Plant Committee**, JPC forum as under:

Generation from generating plants owned by TANESCO; Share of power from the Common Projects; Allocation of firm power from Central Generating Stations (CGSs); Allocation from unallocated quota of power from Central Generating Stations; Energy import/ export under long term bilateral agreements; Generation from Non-conventional and Renewable Energy Sources, support from **Jambo's Captive Power Plants** i.e Combined Solar and Biomass Power Plants, Combined Solar and Wind Plants.

The short-term sale/purchase under bilateral contracts and through power exchanges is generally not taken into consideration as the same is decided by TANESCO during the course of actual operation on evolution of the power supply scenario. Depending upon the actual exchanges of power and over-drawls/ under-drawls of energy The short-term sale/purchase under bilateral contracts and through power exchanges is generally not taken into consideration as the same is decided by TANESCO during the course of actual operation on evolution of the power supply scenario. Depending upon the actual exchanges of power and over-drawls/ under-drawls of energy.

Estimation of Peak Availability/Met - The Estimated Peak Availability (Ex-bus) is calculated based on the capacity available to TANESCO from the committed generating units in various months after considering the scheduled maintenance (finalized in the **Jambo Power Committee, JPC**) and auxiliary consumption.

Assessment of Energy Requirement and Peak Demand - The Unrestricted Energy Requirement and Peak Demand of each **Jambo Plant** is assessed utilizing the past data and trend analysis in consultation with the concerned Plant Personnel and finalized after detailed discussions at the respective JPC forum.

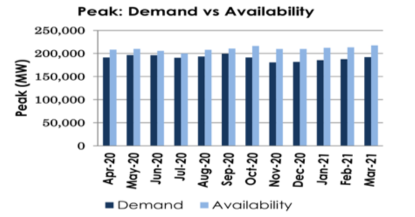
Assessment of Surplus (+) / Deficit (-) - The anticipated surplus or deficit in terms of Energy and Peak, is calculated as the difference between the assessed Energy Requirement/Peak Demand and the estimated Energy Availability/Peak Availability.

8.5.3.2 Anticipated Power Supply Position For 2020 – 21

As per the LGBR for the year 2020-21, an Energy surplus of 25.19% (Units) and Peak surplus of 29.71% (kVA) is anticipated with the Generation Programme approved by **Jambo Power Committee, JPC**. The anticipated Energy Requirement Versus Energy Availability and Peak Demand Versus Peak Availability in **Jambo Group of Companies** as anticipated for the year 2020-21 are given in the Table below:

Year – Wise Anticipated Power Supply Position of Jambo Group of Companies		
PARTICULARS	**ENERGY**	**PEAK**
Requirement/Demand	1,439,013	3,513
Availability	1,923,510	4,998
Surplus (+) / Deficit (-)	484,497	1,485
Surplus (+) / Deficit (-)	25.19%	29.71%

Month – Wise Anticipated Power Supply Position of Jambo Group of Companies								
Month	**PEAK**				**ENERGY**			
	Dmn	**Avl**	**Sur+/Dem-**		**Rqt**	**Avl**	**Sur+/Dem-**	
	kVA	**kVA**	**kVA**	**%**	**MU**	**MU**	**MU**	**%**
Apr/20	2572	2084	488	18.97	0.91	0.93	0.02	2.15
May/20	3513	2562	951	27.07	0.93	1.09	0.16	14.68
Jun/20	2572	1995	577	22.43	0.90	0.91	0.01	1.10
Jul/20	3513	2538	975	27.75	0.95	1.20	0.25	20.83
Aug/20	3513	2841	672	19.13	0.99	1.38	0.39	28.26
Sep/20	3513	2880	633	18.02	1.02	1.54	0.52	33.77
Oct/20	3513	2916	597	16.99	0.98	1.35	0.37	27.41
Nov/20	3513	2970	543	15.46	1.01	1.48	0.47	31.76
Dec/20	3513	2817	696	19.81	0.92	0.99	0.07	7.07
Jan/21	3513	3231	282	8.03	0.96	1.22	0.26	21.31
Feb/21	3513	3003	510	14.52	0.97	1.32	0.35	26.52
Mar/21	5200	4998	202	3.88	0.94	1.17	0.23	19.66
Annual	3497	2903	557	29.71	1.00	1.44	0.44	25.19



The Electricity Monthly Bill for Jambo Meter No. 21130991 at Peak Demand for 2019-20-21 is given below.

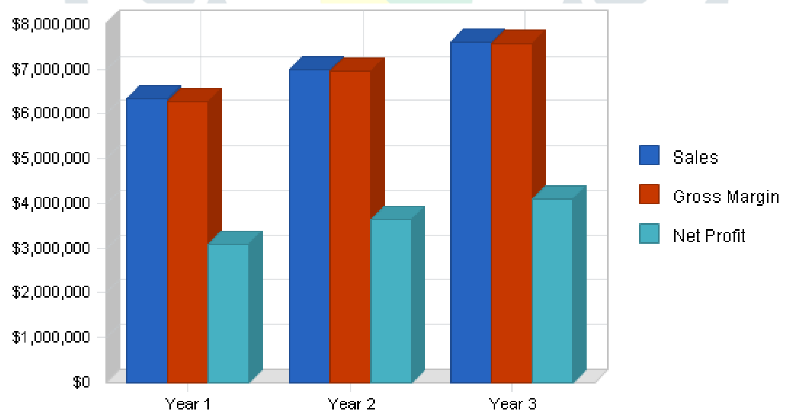
Electricity Monthly Bill For Jambo Meter No. 21130991				
Date	**Present Reading**	**Previous Reading**	**Units Consumed**	**KVA Reading**
07/11/2021	58,632,561	56,709,051	1,923,510	3,681
13/10/2021	56,709,051	54,990,230	1,718,821	3,279
07/09/2021	54,990,230	53,262,160	1,728,070	3,123
03/08/2021	53,262,160	51,572,876	1,689,284	3,111
08/07/2021	51,572,876	50,021,032	1,551,844	2,979
08/06/2021	50,021,032	48,927,089	1,093,943	3,749
09/05/2021	48,927,089	47,819,132	1,107,957	3,749
06/04/2021	47,819,132	46,515,175	1,303,957	3,749
07/03/2021	46,515,175	45,342,324	1,172,851	4,998
01/02/2021	45,342,324	44,023,240	1,319,084	3,003
05/01/2021	44,023,240	42,803,409	1,219,831	3,231
01/12/2021	42,803,409	41,818,104	985,305	2,817
05/11/2020	41,818,104	40,334,627	1,483,477	2,970
01/10/2020	40,334,627	38,984,544	1,350,083	2,916
08/09/2020	38,984,544	37,444,915	1,539,629	2,880
11/08/2020	37,444,915	36,067,946	1,376,969	2,841
04/07/2020	36,067,946	34,863,427	1,204,519	2,538
01/06/2020	34,863,427	33,950,760	912,667	1,995
06/05/2020	33,950,760	32,855,613	1,095,147	2,562
01/04/2020	32,855,613	31,929,592	926,021	2,084
08/03/2020	31,929,592	31,044,271	885,321	2,238
05/02/2020	31,044,271	29,879,961	1,164,310	2,715
07/01/2020	29,879,961	29,077,714	802,247	2,319

9. Executive Summary of Demha Recycles Investment B2B model

We are committed to working for a sustainable development of the Energy Production from Renewable Sources, through the use of an innovative and efficient technology that delivers small size plants and extremely low environmental impacts. Innovation is our passion, and our mean. We collaborate with universities and research centres, nation-wide and inter- nationally, to evaluate and transfer to our plants state-of-the- art technologies, materials and processes. We work with suppliers/partners with the highest expertise on the market in their respective fields. In this way, we aspire to enable the development of new models of economic growth based on the exploitation of available biomass. The high efficiency of the process and the small-scale of the plant allow to attain the production of electrical and thermal energy in self-production units of small size located in several points of the territory, where the biomass is present and available. The unique characteristics of the gasification process allow a wide range of applications, ranging from Agro-Energy chains to Bio waste to Energy. Our industrial project aims to develop a small-scale, distributed power generation technology based on the gasification process.

Afro-Energy Chains, the gasification of virgin biomass from dedicated energy crops can produce renewable energy more efficiently and therefore with higher profitability than alternative technologies based on combustion. Other than from energy crops, biomass can be derived from agricultural residues or industrial byproducts such as PE, PETs, LDPE, forest service residues or saw mill shaving chips, and nonetheless represent a valuable resource to be exploited through the gasification technology. Our system has been designed focusing on the concept of flexibility with respect to the biomass fed, which may vary significantly in order to its physical and chemical characteristics though continuing to fuel the process effectively. Through our plants different businesses like farming, forest servicing, etc. can provide a stable and additional source of income to their business.

Bio waste to Energy, beyond being able to use a wide variety of organic materials to produce power and heat, the gasification process has another important characteristic: it performs a strong volume shrinkage of the mass input (the only residue of the thermo- chemical process is the ash contained in the biomass). This suggests the application of the process to waste feedstocks generated by agricultural or industrial activities, that will be transformed into energy rather than disposed to landfill, making such a transformation not only economically viable but also environmentally sustainable. Our plant's design is suited to gasifying virgin biomass (i.e. wood chips) as well as organic waste fractions like anaerobic digestive, poultry litter, sewage sludge from civil and industrial water treatment processes (i.e. wastewater sludge or paper mill sludge) and still meet all the applicable emissions regulations.



Highlights of **Jambo** Biomass Plant's Plant

9.1 Demha Recycles' Services

9.1.1 Turnkey Solution

We assist the client in every phase of the project, from feasibility study to after-sales service, taking advantage of qualified partners when necessary, to ensure the conditions required for the successful completion of the project: Feasibility study (technical/financial); Assessment of available biomass; Implementation of a tailor-made solution; Assistance for authorizations and permitting procedures; Supply of "turnkey" plants; Training of customer's personnel for plant management; Ordinary and extraordinary maintenance; After sales support.

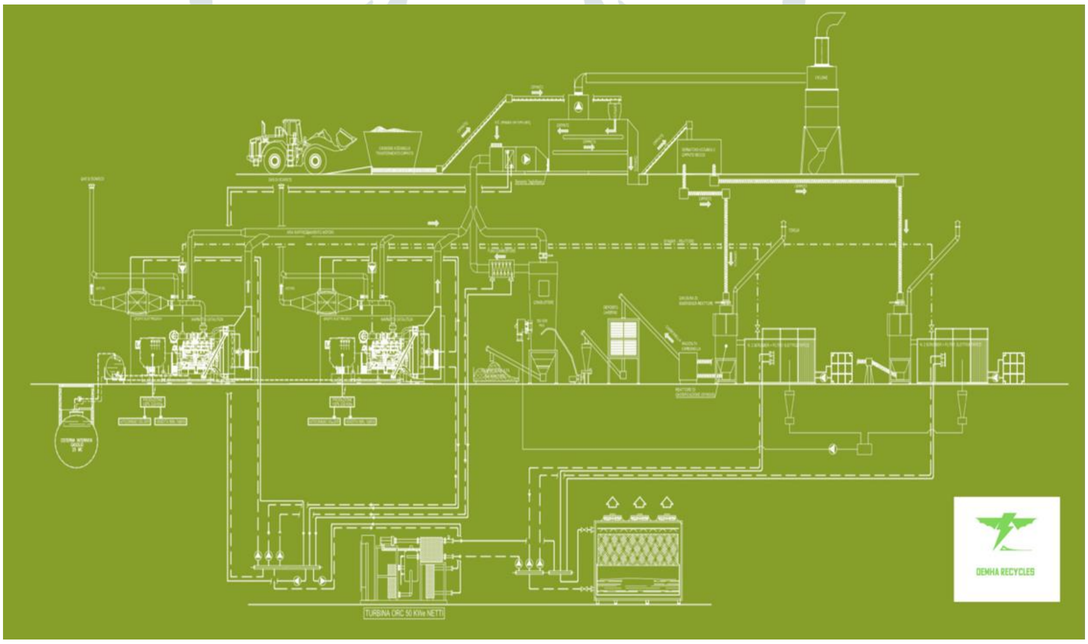
9.1.2 Gasification Plant

Our solution offers a number of alternative technologies of biomass-to-energy conversion:

Small scale (the installed capacity of the single module is of 300kWe or less), *high efficiency plant* linked to combined heat and power production, allowing decentralized energy generation; **Superior electrical efficiency** (50% higher than a conventional conversion process of the same size based on biomass combustion) and, as a consequence, higher return on investment in the plant; **Extremely compact design**, allowing the plant to be conveniently located in any agricultural or industrial environment (higher plant efficiency implies reduced logistic requirements in terms of biomass storage, number of transports etc., and the characteristics of the thermochemical conversion process consent to reduce the footprint both in terms of plant height and surface area occupied)

Scalability through modular approach (by installing multiple modules you get the desired electrical capacity, commensurate with the availability of local biomass); **Broad range of applicable fuels** (virtually any organic material having C-H-O composition can be used in gasification through appropriate pretreatments); **Very low emissions level** (the gasification process itself does not produce any emissions) and substantial amount of CO_2 avoided; Virtually *no waste products* (the only by-product of the process is the ash originally contained in the biomass fed to the plant), all the energy potential of the biomass is exploited.

Large variety of possible applications (the process allows the transformation of the energy carrier from solid to gas, increasing ease and ability to use: the syngas can be used to fuel internal combustion engines for power production or fired directly for the production of heat in existing plants such as kilns, boilers or industrial dryers); **Complete automation** through the use of a PLC based control system. The control system is designed with the purpose of ensuring the necessary availability and reliability along with the maximum safety of the entire system.



Demha Recycles Plant Layout

9.1.3 Biomass Power Plant Layout

Drying is required when the humidity content of the available biomass is higher than 10%. Dryer: temperature controlled device where the biomass humidity decreases due to evaporation, until it reaches the value required by the next phase of gasification process. Biomass is dried using the heat cogenerate by the plant. The choice of the drying technology is made on the basis of environmental conditions and customer needs (amongst the applicable: rotary drum dryers, belt/conveyor dryers, bed/grate etc.)

Gasification reactor: inside the reactor the biomass is converted into a combustible gas (syngas, from synthesis gas) through a succession of thermo-chemical reactions which take place at high temperature, without combustion, with a controlled amount of oxygen. The carbonaceous solid co-product (char) is extracted from the bottom of the reactor and continuously fed to the oxidizer. The syngas is directed to the next phase of gas conditioning.

The syngas leaves the reactor at elevated temperature with a certain heating value and pollutant load, and must be conditioned (cooled and cleaned) prior to being fed to the engine. The main components of the conditioning chain are: Cyclone separator: hot syngas leaving the reactor is first de-dusted by removing particulate through vortex separation Wet scrubber: syngas is then sprayed with water for further cleaning and cooling (cooling increases the energy density of the gas).

Demha Recycles Gasification Plant

Electrostatic precipitator: condensable and solid particles that may have passed the first two cleaning systems are finally removed from the flowing syngas using the force of an induced electrostatic charge. An extremely clean syngas is now ready to feed the engine. The liquid fuel which may be produced by condensed vapours is directly fed to the oxidizer.

Internal combustion engine fuelled with syngas generated from biomass. Cogeneration: electrical power is produced by an alternator linked to the engine and sent to the grid; heat from engine's cooling circuits and exhaust gases is recovered for thermal needs.

Oxidizer: a secondary reactor specifically designed in which the liquid and solid components generated simultaneously to the gas inside the gasification reactor are converted to clean flue gas. The recovered heat is conveyed for thermal needs or converted to power through an ORC system.

9.2 Deployment of Science and Technology

9.2.1 Demha Chemical Reactions

Gasification can be defined as the thermochemical conversion of biomass in to fuel gas. The industrial process involves two key sets of thermochemical reactions carried over at high temperature and with a controlled amount of oxygen: pyrolysis and gasification.

During pyro gasification, biomass long chain chemical bonds are broken down into simpler molecules. As a result, the generic molecule of solid biomass is converted into three co-products:

$$C_nH_mO_p(biomass) \Rightarrow \sum_{gas} C_aH_bO_c + \sum_{liquid} C_xH_yO_z + C(char) + H_2O$$

The gaseous fraction (syngas) composed of lighter, non-condensable molecules. It consists mainly of hydrogen, carbon monoxide, methane, carbon dioxide and nitrogen.

The condensable vapours produced by the sudden depolymerization of cellulosic components (cellulose and hemicellulose). Once condensed, the mix of these hydrocarbon complexes with high heating value is generically referred to as tar or pyrolysis oil.

The part of I reacted charcoal (char), carbon of carbon plus the ash initially contained in the biomass. The relative amounts of these three co-products depend on multiple factors, including the Heating Rate (Speed at which the biomass is heated), the Equivalent Ratio (amount of oxygen used in the process), the process temperature and others.

In our reactor these parameters are optimised for the production of syngas. Due to the high efficiency of the process, over 90% of the energy content of the biomass is converted into pyro gasification co-products.

9.2.2 Reactor Design and Main Process Phases

Demha Recycles gasification reactor (proprietary design) can be defined as “stratified downdraft twin fire” fixed bed gasifier. Referring to the scheme, the main steps of the process inside the reactor are:

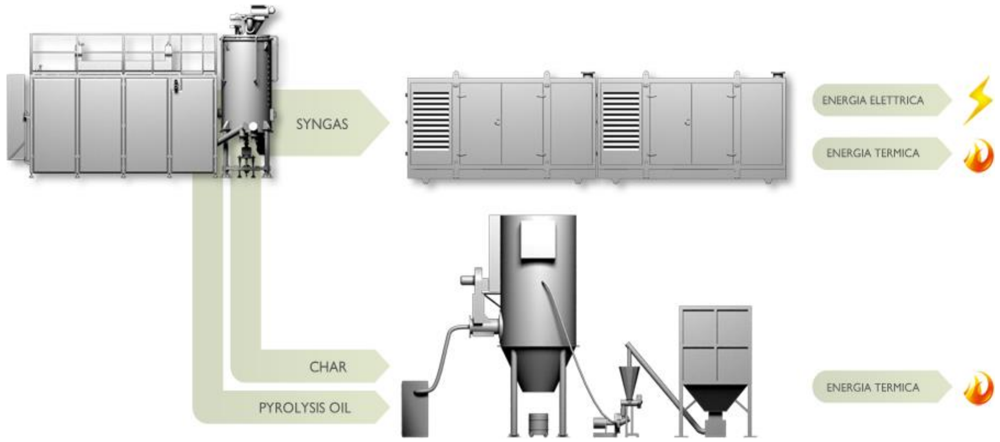
A. Pyrolysis (200ºC < T < 600ºC): The volatile components of biomass (cellulose, hemicellulose) vaporize generating the so-called pyrolysis gas, rich in hydrocarbons, whilst non-volatile components (lignin) remain in the solid phase forming charcoal
B. Oxidation (T 800 to 1,000ºC): Part of the biomass is oxidized under non-stoichiometric conditions, producing the heat necessary for the gasification re- actions. The pyrolysis gas passes through the high temperature combustion zone where it undergoes a thermal cracking: complex hydrocarbons are decomposed into elementary molecules like CH4
C. Reduction (T lowers to 600 – 700ºC): The charcoal then reacts with the combustion gases absorb- ing heat and producing CO and H_2

Demha Recycles Reactor Design Phases

9.2.3 Energy Conversion

Gasification process converts the biomass, a renewable fuel, into co-products which are themselves fuels. The power derived from gasification and combustion of the resultant products is considered to be a source of renewable energy if the gasified compounds were obtained from biomass. Energy conversion of gasification products is achieved through the use of technological solutions that are best suited to the characteristics of each fuel stream: Syngas, the most relevant stream, is converted into power and heat through a high-yield co generator (internal combustion engine); Char and pyrolysis oil are converted into thermal energy through a secondary oxidation reactor (oxidizer)

The typical configuration of a Demha Recycles gasification system, in which all streams are converted to produce power and heat, is illustrated. Gross overall yield of the system in this configuration is around 75 to 80 percent; The power produced converting biomass can be used on site or poured into the national grid to get the incentives granted for the generation of electricity from renewable sources; The heat can be transferred to thermal loads (e.g. district heating, biomass drying, industrial drying processes) or converted into additional power through an ORC system.



Typical Configuration of Demha Recycles Gasification System

9.2.4 Emissions Control

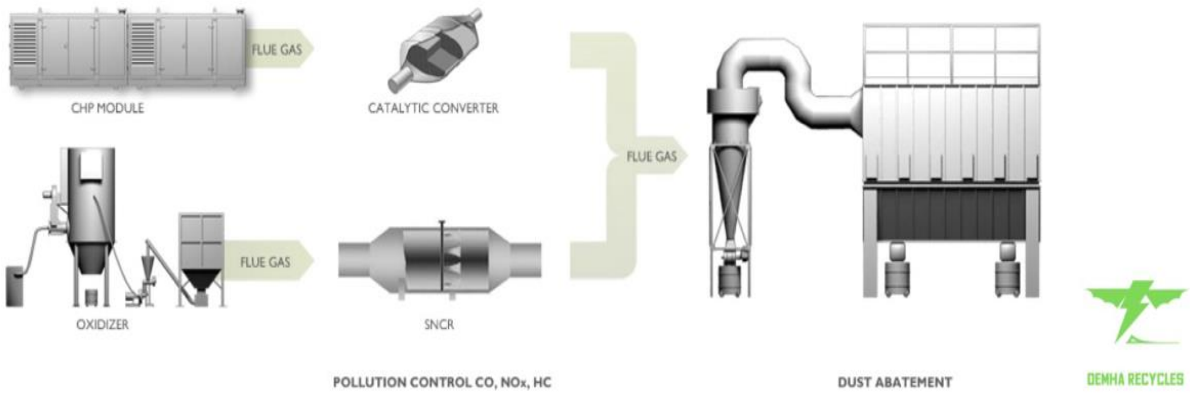
In the field of energy production from RES, the strict control of emissions from power generation systems is particularly important, also because of the "environmental value" of this type of installations.

Greenhouse effect: The environmental impact of converting a renewable source such as wood chips into energy is null, because it returns to the atmosphere the same amount of carbon dioxide absorbed by plants through the photosynthesis during their growth.

Air emissions: Demha Recycles gasification plant adopts the state of the art of available technology (BAT - Best Available Techniques) in order to control emissions. In particular:

Gaseous effluents**:** Gasification process produces no emissions, transforming solid biomass into a gas which is entirely channeled to the CHP module**;** The CHP module, depending on size and technological characteristics of the internal combustion engine, is equipped with a catalytic converter or a SCR system for the abatement of pollutants**;** The oxidizer is equipped with an SNCR system (with use of a reagent) for NO_2 control; Dust or Powder**:** Exhaust gases, before discharged to the atmosphere, undergo a further treatment aimed at controlling particulate material through the use of a de-dusting cyclone and a bag-house filter.

Plant waste: The only effluent produced by the plant is the ash initially contained in the biomass. This bio-ash is rich in nutrients (such as potassium and phosphorus) and could be effectively utilized by the farming industry.



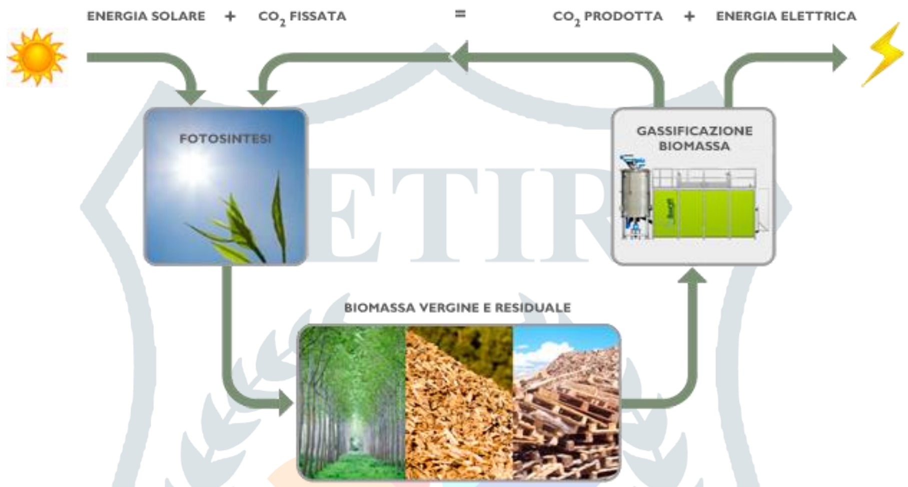
Configuration of Organic Rankine Cycle, ORC System

9.3 Demha Recycles Energy from Biomass

9.3.1 Biomass as a Renewable Energy Source

From energy point of view, biomass is organic matter (based on carbon, hydrogen and oxygen) of non-fossil origin that has an intrinsic chemical energy content. It includes all terrestrial and aquatic vegetation, better known as virgin biomass and all the biodegradable organic waste, such as municipal solid waste, animal waste, agricultural and forestry residues and certain types of industrial waste.

From a regulatory point of view, biomass used for energy production can be defined on the promotion of electricity from renewable energy sources in the internal electricity market. The chemical energy contained in the biomass derives directly or indirectly from photosynthesis. Through this process, CO_2 and water from the environment are used, due to the light energy captured from the sun, to nurture the growth of organic matter. In a nutshell, the energy contained in the biomass is nothing but stored solar energy which is converted into power with null CO_2 balance.



Biomass as renewable energy source

9.3.2 Types of Usable Biomass

Any biomass composed of carbon, hydrogen and oxygen (CHO) can be converted into syngas. Naturally, the performances of the pyro gasification process depend on the chemical – physical characteristics of the biomass fed. The parameters that most influence the process are the following:

- **Water content**: The moisture present in the biomass as it is, must be reduced to a very low value (<10%) before the process can be fed.
- **Ash content**: The ashes are inorganic compounds that do not bring calorific value and affect the performance in the plant if present in significant quantities or with a particularly low melting point (low – melting ash).
- **Calorific value**: It is the measure of the energy power of the fuel and determines the specific consumption of the plant with the same output.
- **Composition**: The relative content of Carbon and Hydrogen and the chemical species prevalent in biomass ((lignin, cellulose, resins) affect the relative quantity of gas, liquid and solid produced by the process and their qualitative characteristics.
- **Size**: Excessively fine or dusty material does not allow the reaction bed to 'breathe' properly, hindering the correct flow of the combiner and them of the syngas through the biomass. In the event that the available biomass has these characteristics, a correct granule entry of the material can be restored through the production of pellets or briquettes.

The Demha Recycles pyro gasification plant can use a wide variety of biomass, individually or in a co-gasification regime mixed with a 'structuring' (typically wood chips)

9.3.3 Incentives for the Production of Renewable Energy

The use of biomass for the production of renewable electrical and thermal energy is of great environmental interest and the plants that use them have access to the incentive mechanisms defined in the Renewable Energy Source.

Then incentive recognized for the production of electricity (all-inclusive tariff) is a function of: **Installed power** (favoured small plants with **P < 300kWe**); **Type of biomass used and their possible mix** (favoured the use of by-products); **Use of high-efficiency** Combined Heat and Power (CHP premium, district heating premium); **Low emissions into the atmosphere** (Emissions award)

Assumptions of tariffs 0 to 300 kWe in the most favourable hypothesis

A. Dedicated crops: 229 + 40 (CHP) + 30 (emissions) = 805,000Tshs./MWh
B. By-products: 257 + 10 (CHP) + 30 (district heating) + 30 (emissions) = 880,000Tshs./MWh

Assumptions of tariffs 300 to 10000 kWe in the most favourable hypothesis

A. Dedicated crops: 180 + 40 (CHP) + 30 (emissions) = 673,000Tshs./MWh
B. By-products: 209 + 10 (CHP) + 30 (district heating) + 30 (emissions) = 751,000Tshs./MWh

Demha Recycles Pyro gasification Plant in a co-gasification regime

The following table summarizes the structure of the all-inclusive tariff which remunerated the energy sold into the grid by a biomass-fuelled RES plant:

Table 1: Energy sales into the grid by a biomass-fuelled RES plant

RES	Type	Capacity (kW)	Plant lifetime in Years	Base tariff Tshs./MWh	CHP prize Tshs./MWh	District heating prize Tshs./MWh	Low emission prize (Tshs./MWh)
Bio-mass	Products of biological origin	1<P<=300	20	610,000/=	106,600/=	-	80,000/=
		300<P<=1000	20	480,000/=	106,600/=	-	80,000/=
		1000<P<=5000	20	355,000/=	106,600	-	80,000/=
		P>5000	20	325,000/=	106,600	-	80,000/=
	Animal by-products	1<P<=300	20	685,000/=	26,600/=	80,000/=	80,000/=
		300<P<=1000	20	560,000/=	26,600/=	80,000/=	80,000/=
	Separate collection	1000<P<=5000	20	430,000/=	26,600/=	80,000/=	80,000/=
		P>5000	20	390,000/=	26,600/=	80,000/=	80,000/=
	Biodegradable waste	1<P<=5000	20	463,000/=	26,600/=	-	80,000/=
		P>5000	20	333,000/=	26,600/=	-	80,000/=

9.3.4 Performance and Milestone of the Biomass Power Plant Module

PLANT PERFORMANCE

The following table shows the main performance parameters of our gasification module:

Table 2: Fuel Consumption Performance

Fuel Consumption	
Reference Biomass	Wood chips (LHV ≈ 4 to 5 kWh/kg DM)
Syngas Production	2, 2 to 2, 5 Nm^3/kg DM
Syngas max flow rate	720 Nm^3/h
LHV Syngas	1, 3 to 1, 5 kWh/Nm^3
Biomass specific consumption rate	0, 8 to 1, 2 kg DM/kWhe

Table 3: Nominal Capacity Parameters

Nominal Capacity	
Single module installed capacity(1)	200 to 300 kWe
Annual operation hours	+7.000 h/y
Gross electricity generation	1, 4 to 2, 1 GWh/y

Table 4: Gross Thermal Power Parameters

Gross thermal power (2)	
CHP exhaust gas (@400°C)	170 to 250 kWth
Hot air from engine cooling system (@65°C)	170 to 250 kWth
Oxidizer flue gas (@900°C)	250 to 350 kWth

(1)Depending on the size of the installed CHP module.
(2)Depending on the installed capacity.

Higher installed capacity can be obtained by scaling-up the system through a modular approach (two or more gasification modules in parallel.

The available thermal power can be used for: Drying biomass and supplying heat; Producing additional electricity (e.g. through an ORC system).

ENVIRONMENTAL PERFORMANCE

The two most important environmental parameters qualifying energy production from renewable sources are the amount of CO_2 avoided and the Primary Energy Savings (PES). In the table below the values of the parameters have been estimated for a single gasification module (based on 7,000 hours of operation per year) under the hypothesis of exploiting all the power and heat available:

Table 5: Cogeneration from RES Parameters

Cogeneration from RES	
CO_2 avoided	ca 2,500 ton/y
Primary energy saving	ca 1,100 tep/y

For systems with installed capacity ranging from 0.15 MW and 3 MW and fed with solid fuels, the emission limits are set as follows (with 11% oxygen content in effluent gases):

Table 6: Emission Limits Values

Emissions	
Dust	100 mg/Nm^3
Carbon Monoxide (CO)	350 mg/Nm^3
Nitrogen oxides (as NO_2)	500 mg/Nm^3
Sulphur Oxides (as $S0_2$)	200 mg/Nm^3

The plant consumes a small amount of water necessary for the operation of the cooling tower. No process residues are produced, with the exception of mineral ashes originally contained in the biomass fed to the plant. The system does not generate significant noise emissions, which are largely kept within the limits prescribed by law.

Table 7: Water Consumption Performance

Other	
Water consumption	600 to 700 m^3/y
Biomass ashes	40 to 50 ton/y
Noise emissions	within the limits prescribed by law

MILESTONE

The following table lists important program milestones, with dates and managers in charge, and budgets for each. The milestone schedule indicates our emphasis on planning for implementation.

Table 8: Milestone Budgets

MILESTONES			
Milestone	**Start date**	**End date**	**Budget**
Business plan	18/11/2023	20/11/2023	$0
Funding	01/12/2023	11/12/2023	$0
Site Preparation	12/12/2023	24/12/2023	$0
Form LLC	20/12/2023	24/12/2023	$500
Industrial set up	01/01/2024	14/01/2024	$0
Order Machineries	15/01/2024	25/02/2024	$180,000
Hire staff	28/02/2024	01/03/2024	$16,680
Begin production	03/03/2024	31/12/2024	$0
Total			$196,680

9.4 Management Summary

9.4.1 Management Team

The management team of DEMHA Recycles will be comprised of the following executive positions:

- ✓ Business Owner: JAMBO GROUP OF COMPANIES – Power Plant Entity
- ✓ Advisory Board Members: H. H. Mansoor, founder H. H. Mansoor Transporter Co. Ltd., Said Pamui, Former CRDB Zonal Manager., Salum Khamis Salum, CEO, Founder and Director Jambo Group of Companies., Sleman Khamis Salum, Salaam Khamis Salum and Khamis S. Khamis, Directors Jambo Group of Companies and Ahmed H. H. Mansoor, founder of Demha Recycles Investment Co. Ltd.
- ✓ Operation Manager: One who has operated a solid recycling firm for 7 years and biomass recycling facility for 2 years and is intimately familiar with the uses of raw materials and markets.
- ✓ Controller: One who has a background in business and management and will handle administrative details such as taxes, check writing and bookkeeping.

9.4.2 Management Team Gaps

To assist in sales and marketing, Demha Recycles Investment Co. Ltd utilizes the services of a Consulting, LLC, a management consultant firm based in Tanzania. The Consulting firm specializes in business planning, marketing planning, training, website design and marketing to the federal government. Marketing and sales will play an important role in convincing consumers to switch from their old products to our products.

The consulting firm will help create the need for our products and services while at the same time capturing the attention of the consumers' targeted. Some of Consultation duties will include writing press releases, coordinating print and radio press, monitoring the competition, making presentations to potential clients, and studying the markets to identify customers' needs and determine how to best appeal to those needs.

9.4.3 Personnel Plan

The Personnel Plan reflects the staffing levels required to manage and achieve the anticipated levels of production, and establish the customer base needed to achieve the revenues projected and reach profitability. We have projected a staff of 22 employees in early 2022. This includes the owner, 2 managers, 3 truck drivers, 4 equipment operators, 2 laborers, 2 metal workers, and 1 secretary; this staff of fifteen will operate the biomass recycling facility.

In addition, a staff of seven, including one supervisor and 6 laborers, will provide sawdust, wood chip, and bark removal on a full time basis; the contract for this work has been won. The raw materials collected will be used in the baling and byproduct process.

On top of that, Demha Recycles plans to hire a local trucking firm to deliver raw materials to customers. This is expected to result in the creation of two additional jobs. Therefore, the total employment impact of this venture is expected to be the creation of 24 jobs in the first year of operation.

9.4.4 Web Plan Summary

Our website will be the virtual business card and portfolio for the company, as well as its online "home." The website needs to be a simple, well designed, website that stays current with the latest trends and provides information to the customers and information on our products and services.

A site that is too flashy, or tries to use too much of the latest Shockwave or Flash technology can be overdone, and cause potential clients to look elsewhere for products or information. Our website will be an important means by which we can educate potential customers about feasibility, potential uses of our products and services.

9.5 Financial Plan

Our financial plan is based on receiving several loans to purchase/fabricate the production equipment, provide initial operating capital, and establish the customer base. We will achieve profitability early in the first year and due to the expected high growth rate, we will realize strong profits on sales by year three.

9.5.1 Start-up Funding

The start-up funding will be provided as follows: **Jambo Group of Companies**' equity investment in the form of equity or loan from CRDB, Cooperative and Rural Development Bank or NMB, National Microfinance Bank; this loan is secured by **Jambo**'s real estate assets. The Regional Revolving Loan Fund is an economic development fund sponsored by the respective county in Dar Es Salaam and Mwanza. The balance of funding will be provided through an SBA guaranteed loan. Details of funding are shown in the table below.

Table 9. Funding Details

STARTUP FUNDING	
Startup Expenses to Fund	$186,180
Startup Assets to Fund	$1,013,820
Total Funding Required	$1,200,000

ASSETS	
Non cash assets from startup	$832,920
Cash requirements from startup	$180,900
Additional cash raised	$0
Cash balance on starting date	$180,900
Total Assets	$1,013,820

LIABILITIES AND CAPITAL	
LIABILITIES	
Current Borrowing	$0
Long term Liabilities	$850,000
Accounts Payable (Outstanding Bills)	$0
Other Current Liabilities (Interests free)	$0
Total Liabilities	$850,000
CAPITAL	
Planned Investment	$0
Owner	$150,000
Others	$0
Additional Investment Requirements	$0
Total Capital	$150,000

Total Funding Required = Startup requirements Startup requirements = Assets + Expenses

9.5.2 Planned Investment

Table 10. Planned Investment

LOSS AT STARTUPS (STARTUP EXPENSES)	
Total Capital	$57,820
Total Capital and Liabilities	$1,013,820
Total Funding	$1,200,000

USE OF FUNDS	
USE	AMOUNT
Processing Plants 2 * $190,460	$380,920
Processing Plants built in-house 2 * $40,000	$80,000

Sheds 48[1] * 72[1] 4 * $18,500	$74,000
Skid Truck 2 * $73,000 (average price)	$146,000
Backhoe	$40,000
Front-end Loader 2 * $50,000	$100,000
Tandem Dump Trailer 2 * $6,000	$12,000
TOTAL	$832,920

9.5.3 Important Assumptions

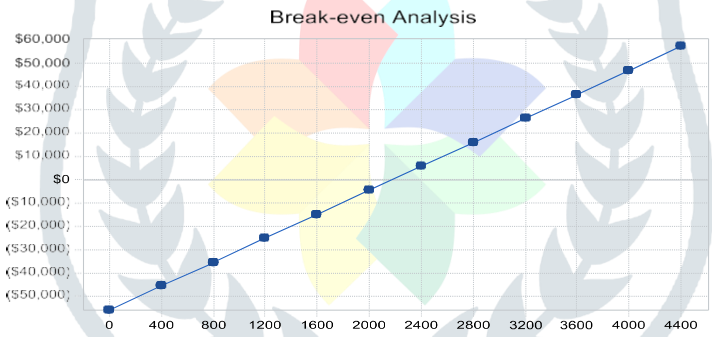
The table below presents some assumptions used in the financial calculations of this business plan. Table

11. General Financial Assumptions

FINANCIAL ASSUMPTIONS			
Assumptions	Year 1	Year 2	Year 3
Plan Month	1	2	3
Current Interest Rate	7.00%	7.00%	7.00%
Long term interest rate	7.00%	7.00%	7.00%
Tax rate	25.00%	25.00%	25.00%
Others	0	0	0

9.5.4 Break-even Analysis

The chart and table below contain the break-even analysis for the Biomass Power Plant.



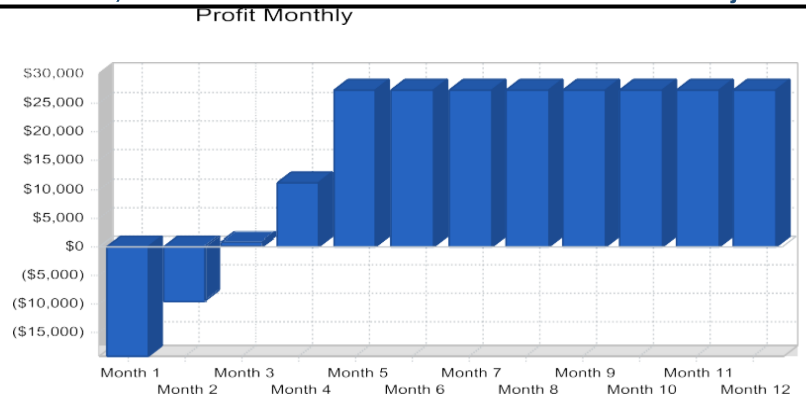
Break-even Analysis

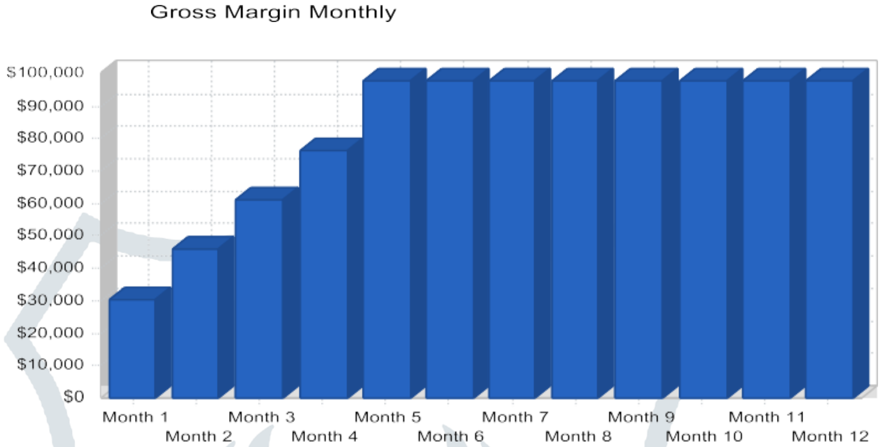
Table 12. Break-even Analysis

BREAK-EVEN ANALYSIS	
Monthly Units Break-even	2,180
Monthly Revenue Break-even	$62,905
Assumptions	
Average Per unit Revenue	$28.85
Average Per unit Variable Cost	$3.15
Estimated Monthly Fixed Cost	$56,029

9.5.5 Projected Profit and Loss

The following table summarizes our anticipated profit and loss for the first three years. A monthly profit and loss projection for the first year of operations is included in the appendices.





Plots of Monthly Profit and Gross Margin

Table 13. Pro Forma Income Statement

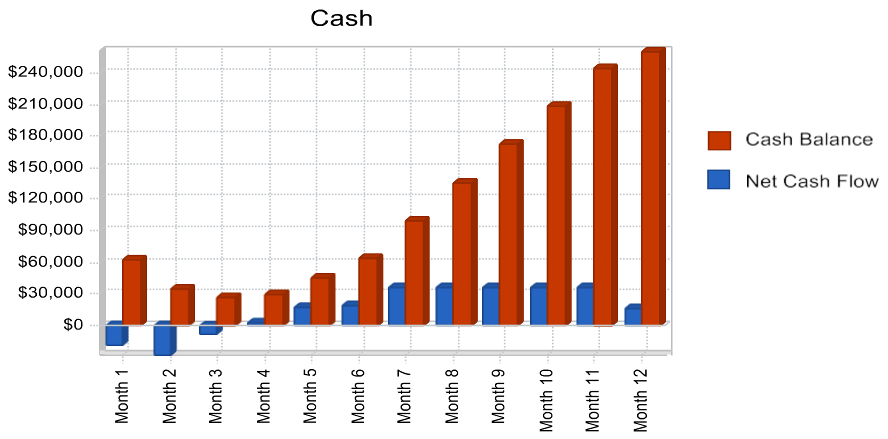
PRO FORMA PROFIT AND LOSS			
Parameters	Year 1	Year 2	Year 3
Sales	$1,121,168	$2,555,069	$5,108,918
Direct cost of sales	$122,550	$297,853	$612,688
Other cost of goods	$0	$0	$0
Total cost of sales	$122,550	$297,853	$612,688
Gross margin	$998,618	$2,257,215	$4,496,230
Gross margin (%)	89.07%	88.34%	88.01%
Expenses			
Payroll	$374,053	$766,326	$1,422,040
Sales, market , expense	$12,000	$24,000	$48,000
Depreciation	$165,384	$325,384	$645,384
Rent	$0	$40,000	$100,000
Utilities	$18,000	$36,000	$72,000
Insurance	$18,000	$36,000	$72,000
Payroll taxes	$56,108	$114,949	$213,306
Maintenance & repair	$4,800	$9,600	$20,000
Other	$24,000	$48,000	$96,000
Total operate expenses	$672,345	$1,400,259	$2,688,730
Profit before tax	$326,273	$856,956	$1,807,500
EBITDA	$491,657	$1,182,340	$2,452,884
Interest Expenses	$57,217	$52,956	$48,223
Tax incurred	$67,264	$201,000	$439,819
Net Profit	$201,792	$603,000	$1,319,458
Net Profit/Sales	18%	23.6%	25.83%

9.5.6 Projected Cash Flow

The chart and table below project increasing cash flow throughout the first three years of plan implementation. The second and third years of operation reflect large long-term asset purchases whichreflects our intent to expand the business by opening additional facilities in those years. This expansionwill be funded by business revenue with no anticipated need for outside financing. The row labelled "Long-term Liabilities Principal Repayment" reflects repayment of the SBA guaranteed 504 Debenture Program loan.

Table 14. Pro Forma Cash Flow Statement

PRO FORMA CASH FLOW			
Cash received	Year 1	Year 2	Year 3
Cash from operations			
Cash sales	$448,467	$1,022,028	$2,043,567
Cash from receivables	$542,495	$1,366,516	$2,768,762
Subtotal cash op'n	$990,962	$2,388,544	$4,812,329
Additional cash received			
Sales Tax, VAT, GST	$0	$0	$0
New Current Borrows	$0	$0	$0
New other liabilities	$0	$0	$0
Long term liabilities	$0	$0	$0
Sales of current asset	$0	$0	$0
Sales long term assets	$0	$0	$0
New Investment	$0	$0	$0
Subtotal cash receive	$990,962	$2,388,544	$4,812,329
Expenditures			
Expenditures from operations			
Cash spending	$374,053	$766,326	$1,422,040
Bill payments	$357,477	$843,317	$1,684,617
Subtotal spent op'n	$731,530	$1,609,643	$3,106,657
Additional cash spent			
Sales Tax, VAT, GST	$0	$0	$0
P Current Borrowing	$0	$0	$0
Liabilities P Repay	$0	$0	$0
Long term liabilities	$60,859	$65,258	$69,976
Purchase CurrentAsset	$0	$0	$0
Purchase L.T Assets	$0	$800,000	$1,600,000
Dividends	$20,000	$30,000	$40,000
Subtotal Cash Spent	$812,388	$2,504,901	$4,816,633
Net cash flow	$178,574	$116,357	$4,303
Cash balance	$259,474	$143,117	$138,814



Projected Cashflow

9.6 Projected Balance Sheet

The following table projects healthy growth in sales and net worth. Table 15.

Pro Forma Balance Sheet

PRO FORMA BALANCE SHEET			
Assets	Year 1	Year 2	Year 3
Current Assets			
Cash	$259,474	$143,117	$138,814
Accounts receivable	$130,206	$296,731	$593,320
Inventory	$13,494	$32,796	$67,463
Other Current Assets	$0	$0	$0
Total Current Assets	$403,174	$472,644	$799,597
Long term Assets			
Long term Assets	$826,920	$1,626,920	$3,226,920
Accum'd depreciation	$165,384	$490,768	$1,136,152
Total long term assets	$661,536	$1,136,152	$2,090,768
Total assets	$1,064,710	$1,608,796	$2,890,365
Liabilities and Capital			
Current Liabilities			
Accounts payable	$35,957	$72,301	$144,387
Current borrowing	$0	$0	$0
Current liabilities	$0	$0	$0
Subtotal current liab'	$35,957	$72,301	$144,387
Long term liabilities	$789,141	$723,883	$653,908
Total liabilities	$825,098	$796,184	$798,294
Paid-in capital	$150,000	$150,000	$150,000
Retained earnings	$112,180	$59,612	$622,612
Earnings	$201,792	$603,000	$1,319,458
Total capital	$239,612	$812,612	$2,092,070
Liabilities + Capital	$1,064,710	$1,608,796	$2,890,365
Net worth	$239,612	$812,612	$2,092,070

9.7 Business Ratios

The following table outlines some of the more important ratios from the Biomass Recycling, waste materials industry. The final column, Industry Profile, details specific ratios based on the industry as it is classified by the Standard Industry Classification (SIC) code, 4953.9905.

Table 16. Ratio Analysis

Duration	Year 1	Year 2	Year 3	Ind' profile
Sales Growth	n.a	127.89%	99.95%	7.24%
% of total assets, A				
A/Cs Receivable	12.3%	18.41%	20.52%	4.89%
Inventory	1.27%	4.12%	4.00%	0.35%
Other Current A	0.00%	0.00%	0.00%	31.71%
Total Current A	37.87%	29.50%	27.69%	36.95%
Long term Assets	62.13%	70.50%	72.31%	63.05%
Total Assets	100%	100%	100%	100%
Current Liability	3.38%	4.66%	50.3%	18.58%
Long term Liability	74.12%	44.92%	22.61%	26.10%
Total Liabilities	77.50%	49.58%	27.65%	44.68%
Net worth	22.50%	50.42%	72.35%	55.32%
% of Sales	100%	100%	100%	100%
Gross margin	89.07%	88.34%	88.01%	34.70%
Selling, Gen Expense	72.77%	64.88%	61.97%	14.39%
Advertise Exp	0.00%	0.00%	0.00%	0.25%
Profit before tax	29.10%	33.54%	35.38%	1.59%
Main Ratios				
Current	11.21	6.33	5.50	1.10
Quick	10.84	5.45	4.71	0.89
Total debt to A	77.5%	49.58%	27.65%	63.47%
Pre tax return NW	112.29%	98.94%	84.09%	1.16%
Pre tax return A	25.27%	49.89%	60.84%	3.16%
Additional ratios				
Net profit margin	18%	23.6%	25.83%	n.a
Return on equity	84.22%	74.21%	63.07%	n.a
Activity ratios				
A/Cs receive TO	5.17	5.17	5.17	n.a
Collection days	57	51	53	n.a
Inventory TO	10.91	7.46	6.74	n.a
A/Cs payable TO	10.94	12.17	12.17	n.a
Payment days	27	22	23	n.a
Total Asset TO	1.05	1.59	1.77	n.a
Debt ratios				
Debt to NW	3.44	0.98	0.38	n.a
Current lia to lia	0.04	0.09	0.18	n.a
Liquidity ratios				
Net work capital	$367,217	$400,344	$655,210	n.a
Interest coverage	5.70	16.18	37.48	n.a
Additional ratios				

Assets to sales	0.95	0.63	0.57	n.a
Curr debt/total A	3%	5%	5%	n.a
Acid Test	7.22	1.50	0.63	n.a
Sales/NW	4.68	3.14	2.44	n.a
Dividend payout	0.10	0.05	0.03	n.a

10. Metaheuristic Cost Effective Method for an Integrated Design of a Controller

One of the primary objectives of electric utility industry is to maintain a satisfactory power supply to its electrical loads at all the time. This can be achieved by a well coordinate planning and operation of the power system. While planning is done for the future, operation has to deal with the current situation. Due to various reasons such as addition of generators to network, change in the pattern of load growth and unexpected component outages causes the change in system state from any anticipated condition.

However, under such circumstances it is necessary to operate the system so as to ensure its stability. The significant points for stability of the power system control as shown in fig. 1.1 are voltage and frequency studies. Considering the stability point of view the frequency studies plays key role in balancing and controlling of the power system network, where as deviation of nominal frequency results in, imbalance between the load and generation.

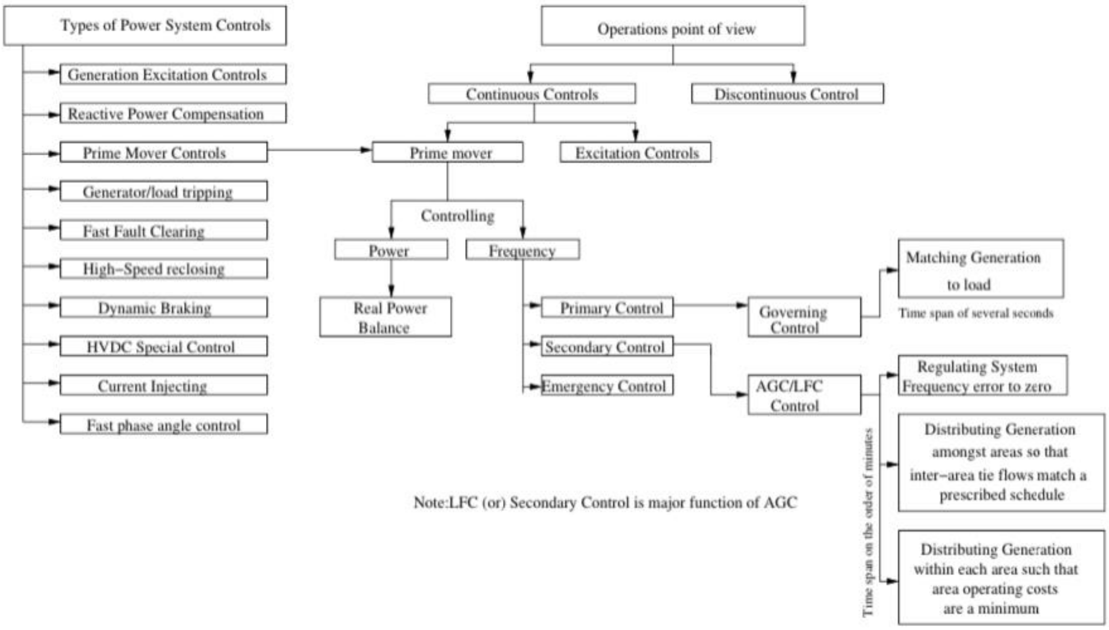


Figure 1.1: Power System Control Layout

Frequency is directly relative to speed of the prime mover. Any deviation in frequency of the power system occurs then the governor mechanism initially comes into the operation to regulate input steam of the turbine via steam valve by open- ing or closing the valve which depends upon current position of the power system. Depending on the frequency deviation ranges in additive with governor response classified into three types of operating controls, i.e primary control (normal operation), secondary control or automatic generation control (large frequency operation) and emergency or tertiary control (Emergency operation) as depicted in fig.1.2.

The load frequency control (LFC) has been one of the important control scheme in electric power system design and operation. Initial LFC is performed by governor of the plant which uses proportional feedback technique to control steam valve. But it suffers from the steady state frequency error, when plants are interconnected. To address this problem secondary controller like proportional integral (PI) controller is introduced as automatic generation control (AGC) or automatic load frequency control(ALFC). The PI controller is latter replaced with a proportional integral derivative (PID) controller for a better transient response.

The primary objective of the AGC is to regulate frequency at specified nominal value and to maintain the power exchange between the control areas at the scheduled values by adjusting the generated power of specific generators. The combined effects of both the tie line power and the system frequency deviation is generally treated as controlled output of AGC known as Area Control Error(ACE). As the ACE is adjusted to zero by the AGC, both frequency and tie-line power errors becomes zero. This can be achieved by tuning of controller parameters for optimal control action and is performed through various techniques.

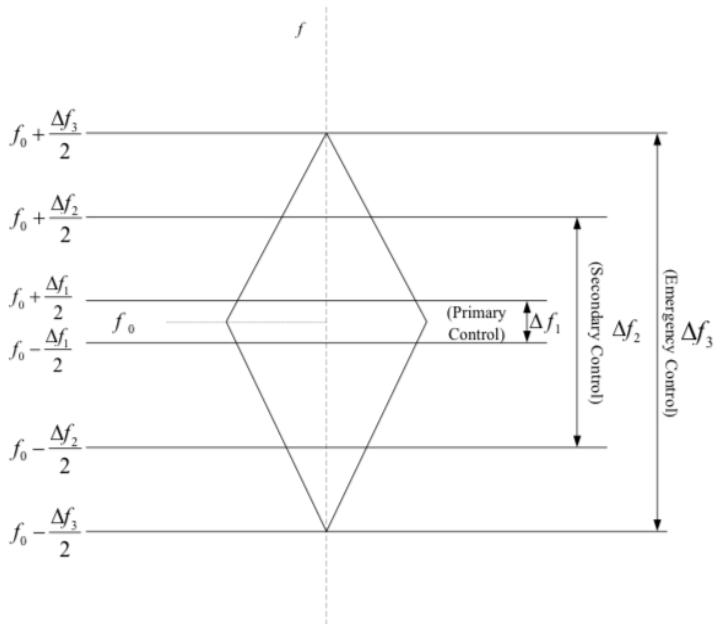


Figure 1.2: Hierarchical frequency controls and operating ranges

10.1 Literature Survey

Power system is one of the largest networks with several interconnected systems which aims to supply undisturbed power to all consumers. To make the system stable and reduce the losses, generation equals to demand through a control mechanism and the frequency of the system should be close to the preference value at all instances. To achieve the stability of an electrical power system, there are two control variables to be maintained. The frequency variable maintains the real power balance and tie-line power or reactive power exchange maintains the voltage profile [1-3]. The combined effects of the two variables are weighted together to form one variable which is the Area Control Error (ACE).

In addition, the total ACE can be used to improve the stability of an isolated power system with a single control area. Thus, the input to the Automatic Load Frequency Control (ALFC) or Automatic Generation Control (AGC) is the ACE, as the ACE is adjusted to zero by the AGC, both the tie-line power and frequency errors become zero. Therefore, Generation Control simultaneously maintain the power exchange between control areas at the scheduled values by adjusting the power of specific generating units and it is required to regulate frequency at specified nominal values [4, 5]. The AGC of an interconnected power system limited to the optimal selection of controllers by observing the effect of physical constraints, impact of Flexible AC transmission systems (FACTS) devices [6, 7] and Energy Storage Systems [8-10].

The standard and non-standard definitions for ALFC on electric power systems were approved by the IEEE standards committee in 1968 [11]. The operating problems of system regulation and factors influencing interconnected systems were summoned [12]. To meet the standards for AGC, there is a need to have a model with issues to improve the performance of AGC. These parameter variations, uncertainties, time delay [13, 14], generator rate constraints (GRC) [15, 16], governor dead band nonlinearity, impacts of deregulation and load characteristics were portrayed in literature. In context to the issues, control techniques such as modern control, classical control and intelligent control methods have been utilised to the ALFC problem [17-18].

A proportional-integral (PI) controller is proposed for ALFC with its gains optimised using genetic algorithm (GA) [19] for a proper AGC evaluation and performance. A concept proposed by Ahamed et al. based on reinforcement learning approach in ALFC [20]. The discussion on the design of PID controller for two-area non-reheat interconnected system using bacteria foraging optimisation algorithm (BFOA) based on LFC has been portrayed in [21]. The concept of utilising Flexible AC transmission System (FACTS) devices improve power operation and control during dynamic and steady state condition, the FACTS devices have improved the controllability of both real and reactive power. An effort was made to enhance the dynamic stability of the power system by introducing a damping controller based on the thyristor-controlled phase shifter (TCPS), Kazem et al [22].

A particle swarm optimisation based non-linear time-varying acceleration coefficients (NTVAC-PSO) is presented for solving optimisation problems and modelling of unified power flow controller (UPFC) for damping of power oscillation [23]. Balancing of power supply and demand is always a challenge particularly at peak loads. As an outcome, serious observations about reliable operations may likely to occur. So, it is convenient to include battery energy storage (BES) systems to improve the AGC problem. [24-26]. Accomplishment with Interline Power Flow Controller (IPFC) to tie- line and Redox Flow Batteries (RFB) for enhanced system performance was portrayed [27]

10.1.1 Research Motivation

India is a developing economy which requires large amount of electricity consumption. With growing demand, Indian electricity production is also increasing day by day, which requires to maintenance the frequency level strictly at the nominal value. If it is not achieved properly, a serious problems like blackouts may occur. For this purpose secondary controller like AGC should be advanced to overcome the problems.

Due to the increase in production and consumption of electricity the transmission system might get overloaded which requires the FACTS to control the real and reactive power flow. The effect of such devices on the frequency controller should be analysed and necessarily be compensated. Along with this numerous renewable energy resources are supplemented to the electrical network, which do not contains inertia required to supply the kinetic energy with addition of load. So all these ideas has motivated & inspired to work on the presented area of research.

10.1.2 Objectives of the Proposed Work

Effect of Decentralised controller design methods for Automatic Generation Control; Modelling of Automatic Generation Control with physical constraints and their effects on the design of controller, particularly PID controller; Comparison of response of change in tie line power obtained by using objective functions, FFA and BSA algorithms at 5% and 25% load disturbances; SBA and FPA integration design of a controller using cost functions, RFB and UPFC.

10.1.3 Organisation of the Report

The proposed work is divided into five chapters and short descriptions of each chapter have been stated: Chapter 10.1 includes a brief introduction of AGC. Based on previous work, a corresponding literature survey is included here. The literature survey provided some important research gap insights which motivated us to work on the objectives postulated in this chapter. Chapter 10.2 deals with models of power system components of an interconnected power system. The interconnected thermal power system, contains speed-governing, turbine, generator, and other power plant parts.

In various engineering problems for a small percentage improvement in the output will result in lager scale saving. For this purpose optimisation techniques are required which are cost effective and useful. Generally optimisation algorithms are categorised into deterministic & meta-heuristic algorithms. Most of meta-heuristic algorithms are inspire through nature phenomenon and are applicable to large section of engineering problems. Chapter 10.3 deals with various meta-heuristic algorithms proposed.

Some power systems are simple in modelling as the nonlinear & time delaying elements like GRC, dead band & time delay are eliminated. Chapter 10.4 deals with model where all these nonlinearities are included and analysed for tuning a controller. This chapter also provides an interesting analysis of various kinds of meta-heuristic algorithms utilised in designing a PID controller. It includes a rigorous statistical outputs for various meta-heuristic algorithms efforts to design a better AGC.

Modern power systems are complex and demand intensive, but the infrastructure to satisfy such demand will be difficult to build in a clustered cities. So devices like FACTS & BES are used to enhance the capabilities of the laid infrastructure of transmission system. But these devices also influence the frequency and real power exchange of the system. Hence a system model with devices like FACTS & BES is developed and the parameters of the AGC is obtained by novel strawberry algorithm (SBA) and is discussed in detail in Chapter10. 5.

Chapter 10.6 deals with model where all these nonlinearities are included and analysed for tuning a controller. This chapter also provides an interesting analysis of various kinds of meta-heuristic algorithms utilised in designing a PID controller. It includes a rigorous statistical outputs for various meta-heuristic algorithms efforts to design a better AGC. Conclusion and future scope are discussed in Chapter 10.7.

10.2 Dynamic Models of Power System

10.2.1 Introduction

The Automatic generation control of an interconnected power system has two principal aspects i.e maintenance of frequency and exchange of power over inter-area tie lines on their respective scheduled values. To understand the dynamics of an interconnected power system associated with load disturbance and to propose a re- liable system, detailed modelling approaches are required. Accordingly system can be modelled in different complexity levels. This chapter presents modelling of speed governing system, turbine, power system and tie line.

10.2.2 Modelling of speed governing system and turbine

The real power in the power system network is directly related to the torque of the turbine shaft and is proportional to the amount of steam release via control valve. At steady state condition there is no deviation in real power, whereas when the system attains with some perturbation a control mechanism comes into picture known as speed governing system. The system is initially in a constant steady state, characterised by a constant nominal speed or frequency f^0, a constant prime mover valve setting X^0_E, and a constant generator output power $P_G{}^0$. By means of the speed changer, we command a power increase ΔP_C. As a result of this command, the linkage point A moves downward a small distance ΔX_A proportional to ΔP_C. The movement of linkage point A causes small position changes ΔX_C and ΔX_D of the linkage points *C* and *D*. As oil flows into the hydraulic motor, the steam valve will move the small distance ΔX_E, resulting in increased turbine and, consequently, a power increase ΔP_G.

The increased power output causes a momentary surplus or accelerating power in the system. If the system is very large ("infinite"), the increased generator power will not noticeably affect the speed or frequency. However, if the system is of finite size, the speed and frequency will experience a slight increase Δf that will cause the linkage point *B* to move downward, a small distance ΔX_B proportional to Δf. The speed governor being fast, we neglect any time delay in it. Consequently, we say ΔX_B proportional to Δf. All incremental movements $\Delta X_A,...,\Delta X_E$ are assumed to be positive indicated directions. Since all linkage movements are small, we have the linear relationships.

$$\Delta Xc = k1\Delta f - k2\Delta Pc. \qquad \text{Equation 2.1}$$

$$\Delta XD = k3\Delta Xc + k4\Delta XE \qquad \text{Equation 2.2}$$

The positive constants k_1 and k_2 depend upon the lengths of the linkage arms 1 and 2 upon the proportional constants of the speed changer and the speed governor. The positive constants k_3 and k_4 depend upon the lengths of the linkage arms 3 and 4. If we assume that the oil flow into the hydraulic motor is proportional to position ΔX_D of the pilot valve, we obtain the following relationship for the position of the main piston.

$$\Delta XE = k5\ Int(-\Delta XD)dt \qquad \text{Equation 2.3}$$

The positive constant K_5 depends upon orifice and cylinder geometries and fluid pressure. By taking the Laplace transform of equations. (2.1) & (2.3), and eliminating the variables ΔX_C and ΔX_D, we obtain the following equation:

$$\Delta XE\ (s) = (k2k3\Delta Pc(s) - k1k3\Delta F\ (s))/\ (k4 + s/k5) \qquad \text{Equation 2.4}$$

For modelling a turbine the primary interest is vested with the resulting generator power increase ΔP_G rather than the turbine valve position per second as the entire system is related with power control. The change in valve position, ΔX_E, cause an incremental increase in turbine power, ΔP_T , which, via the electromechanical interactions within the generator, will result in an increased generator power ΔP_G. This overall mechanism is relatively complicated, particularly if the generator voltage simultaneously undergoes wild swings due to major network disturbances.

In the present case, if we assume that the voltage level is constant and the torque variations are of small size, then an incremental analysis of the type we performed for the speed governor, above, will give a relatively simple dynamic relationship between ΔX_E and ΔP_G. Such an analysis reveals considerable differences, not only between steam turbines and hydro turbines, but also between various types (reheat and non reheat) of steam turbines. In the crudest model representation, characterise a non-reheat turbine generator with a single gain factor K_T and a single time constant T_T in the range *0.2* to *2s.*

$G_T(s) == \Delta P_G(s) / \Delta X_E(s) = K_T/(1+sT_T)$ Equation 2.5

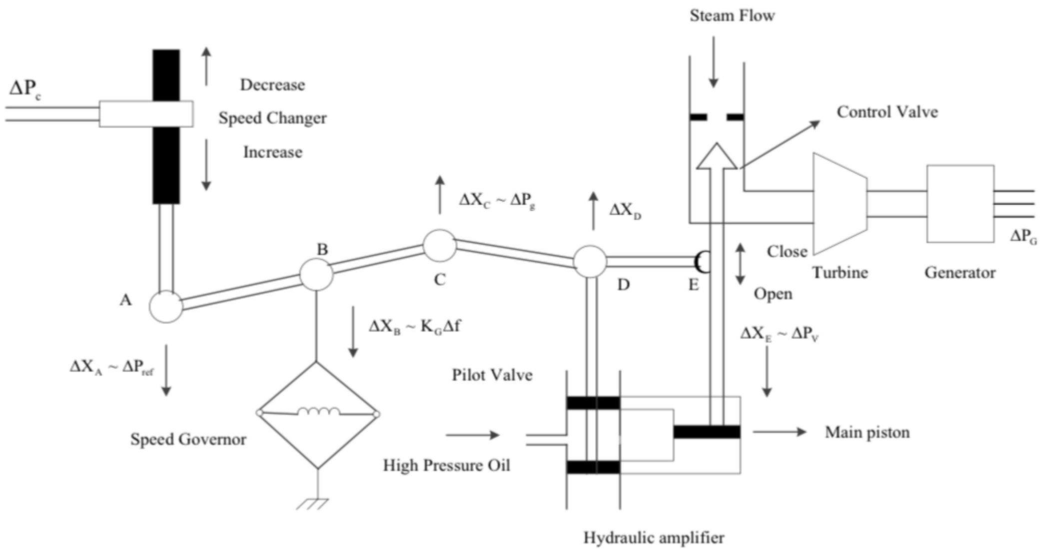


Figure 2.1: Typical turbine arrangement

10.2.3 Modelling of Power System and Tie line

The net surplus power in the area following a disturbance ΔP_D equal to $\Delta P_G - \Delta P_D$ *MW,* and this power will be absorbed by the system in three ways; by increasing the area kinetic energy W_{kin} at the rate, by an increased load consumption, by increasing the export of power, via tie lines with the total amount *|DeltaP*$_{tie}$*MW* defined positive out from the area. In summary, the following power equilibrium equation applies to area i:

$\Delta P_{Gi} - \Delta P_{Di} = (2W_{kin}/f^*)\ i^*\ d(\Delta f)/dt + D_i\Delta f_i + \Delta P_{tie\ I}$ Equation 2.6

$[\Delta P_{Gi} - \Delta P_{Di} - \Delta P_{tie}\ i]\ K_{pi}/1+sT_{pi} = \Delta F_i(s).$ Equation 2.7

Upon defining the area transfer function the control area can be represented by the block diagram in fig 2.2.

$G_{pi}(s) == k_{pi} / (1+sT_{pi}).$ Equation 2.8

The total real power exported from area i, $P_{tie\ i}$ equals the sum of all out flowing line powers, $P_{tie\ iv}$ in the lines connecting area i with neighbouring areas, i.e. fig. 2.3. The summation shall be extended over all lines v that terminate in area i. If the line losses are neglected, the individual line powers can be written in the form

$P_{tie\ iv} = |Vi||Vv|\sin(\delta i - \delta v) / X_{iv} P_{ri}.$ Equation 2.9

The total increment in exported power from area i,

$\Delta P_{tie\ i}(s) = 1/s\ SUM\ T_{iv} * [\Delta F_i(s) - \Delta F_v(s)].$ Equation 2.10

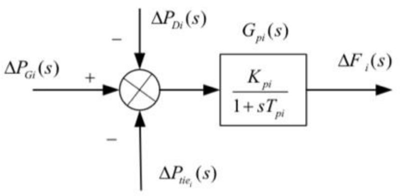


Figure 2.2: Control area block diagram

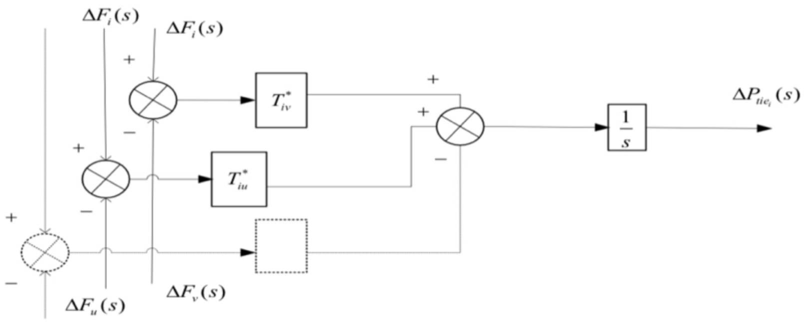


Figure 2.3: Incremental tie-line power out of area i

10.2.4 Modelling of UPFC and RFB

Finally the investigation on AGC systems incorporating Flexible AC Transmission Systems (FACTS) for improvement of system operation and controlled effectively. The Unified Power Flow Controller (UPFC) is one of the versatile FACTS controller that has been employed with transmission line to control the power flow through it . In [73, 74] UPFC installed in series with a tie-line and provides damping of oscillations of the tie-line power . Two area interconnected power system with UPFC is shown in fig. 2.4, where V_{se} is the series voltage magnitude and φ_{se} is the phase angle of series voltage. The shunt converter injects controllable shunt voltage such that the real component of the current in the shunt branch balances the real power demanded by the series converter. It is clear from fig. 2.4 that, the complex power at the receiving-end of the line is as follows:

$$P_{real} - jQ_{reactive} = V_r * I_{line} = V_r * \{(V_s + V_{se} - V_r)/j(x)\} \qquad \text{Equation 2.11}$$

Where; $V_{se} = |V_{se}| < (\delta_s - \varphi_{se})$ Equation 2.12

Solving Eq. (2.11), the real part as given below:

$$P_{real} = (|V_s||V_r|\sin(\delta))/(X) + ((|V_s||V_{se}|)/X)\sin(\delta - \varphi_{se}) \qquad \text{Equation 2.13}$$

$$= P_o(\delta) + P_{se}(\delta, \varphi_{se}) \qquad \text{Equation 2.14}$$

From the above equation, if $V_{se} = 0$, it represents that the real power is uncompensated system, whereas the UPFC series voltage magnitude can be controlled between 0 and V_{se} max, and its phase angle (φ_{se}) can be controlled between 0o and 360o at any power angle. The UPFC based controller can be represented in LFC as follows [75]:

$$\Delta P_{UPFC}(s) = \{ 1/(1+sT_{UPFC})\}\Delta F(s) \qquad \text{Equation 2.15}$$

where T_{UPFC} is the time constant of UPFC

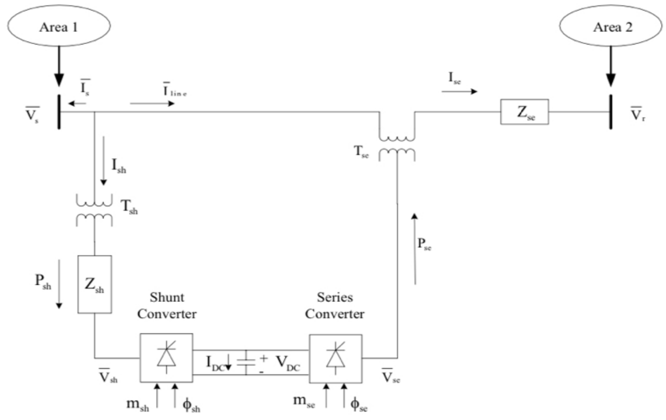


Figure 2.4: Two area interconnected power system with UPFC

Beginning in the mid-seventies, several investigations were performed to find out the possible contributions of storage technologies to solving the issues in the power system. An interconnected power system achieve small load disturbance, and which deviation of nominal frequency and tie line power values. Due to outstanding controllability energy storage devices seems to be extremely well suitable for AGC purposes. Therefore, in order to reduce the frequency deviations and change in tie-line power, an active power source with quick response such as RFB can be expected to the most effective one [76, 77] .

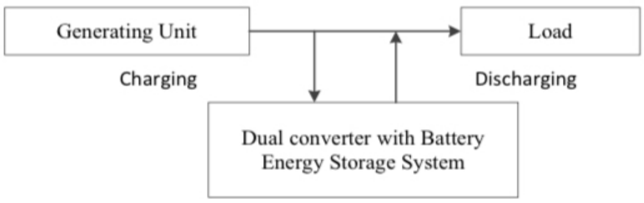


Figure 2.5: General block diagram of RFB

The RFB is found to be superior over the other energy storage devices like SMES because of its easy operation at normal temperature, very small losses during operating conditions and has long service life [78] . How- ever, it will be difficult to place RFB in each and every area in the interconnected power system due to the economical reasons. Since, RFB is capable of ensuring a very quick response , $\Delta F1$ is being used directly as the input command value for load frequency control. The general block diagram of the RFB used for LFC in the interconnected power system is shown in fig. 2.5 [79]. where during very small load duration battery charges and delivers the energy to the system during sudden load changes. The dual converter performs both rectifier and inverter action. For sudden step load perturbation the change of output of a RFB is given as:

$$\Delta P_{RFB} = K_{RFB}/(1 + sT_{RFB})\Delta F_1 \quad \text{Equation 2.16}$$

where K_{RFB} is gain and T_{RFB} is time constant of RFB in sec. RFB – Redox Flow Batteries

10.3 Methodologies

10.3.1 Introduction

Design of automatic generation control for an interconnected power system is a challenging task. There are numerous methods to design these controllers in the literature. Among them meta heuristic algorithms are used in this work because they can handle complex objective function and provide outputs with higher accuracy. Some of these meta heuristic algorithms are discussed in this chapter.

10.3.2 Overview of Strawberry Algorithm

Plants are the part of life of the climate which does not able to move for various climatically condition for reproduction because they do not have muscles and brain like animals. Some plants (as strawberry) and grass are propagate through stolon (or runner) which are going to generate daughter plants and the process continues. Each daughter plant initially produce some roots and runners after accomplished with sufficient roots and growth, the daughter pant separate from mother plant and it act as a new mother plant. Merrikh [49] proposed strawberry algorithm (SBA) which is like a plant movement, where runner as global search and roots of daughter plants as local search in the mathematic point of view and also they act like agents to perform a optimisation. By these agents the objective function is going to evaluate at various point in the domain problem. For a brief description a flow chart is depicted in fig. (3.1)

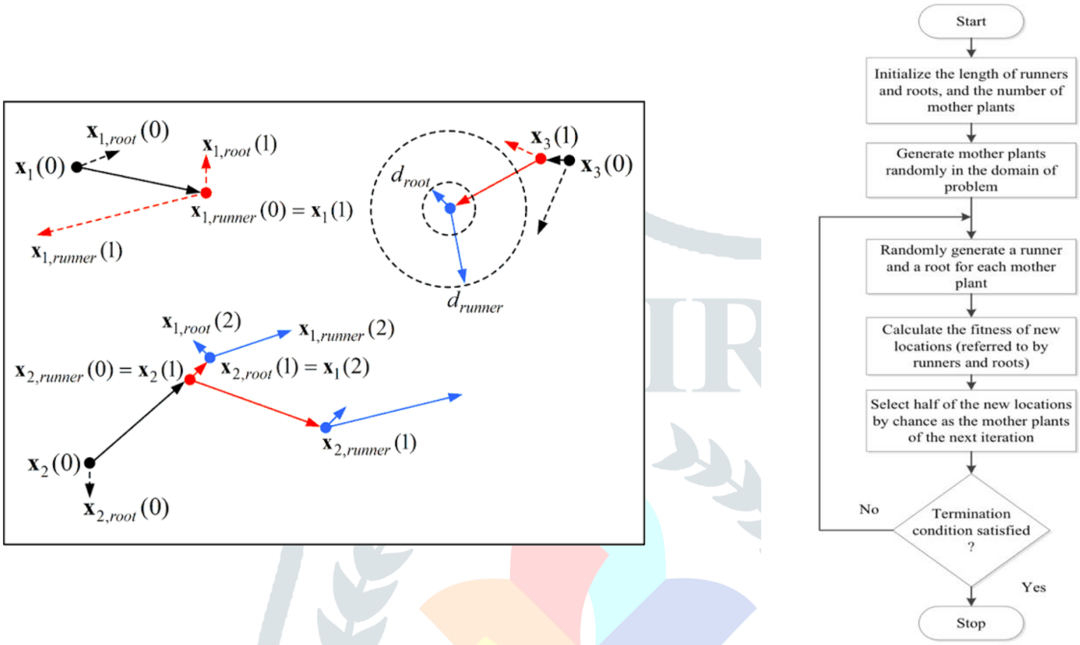


Figure 3.1: SBA Flow Chart

The propagation of the strawberry plant being modelled by three facts: Strawberry plant propagate through runner randomly in problem domain (global search); Strawberry mother plant develop through roots and hairs randomly in problem domain (local); The daughter plants of respective mother plants approach resources for healthy propagation of roots and runners, if not they dies.

10.3.3 Initialisation

For an optimisation problem:

$$min\ f(x),\ x_l \leq x \leq x_u \qquad \text{Equation 3.1}$$

where $f : R^m \rightarrow R$ is the m-variable objective function, $x \,\varepsilon\, R^m$ is the solution vector to be calculated and x_l , $x_u \,\varepsilon\, R^m$ are bounds of variables.

Initialisation of mother plants N and distances of roots d_{root} and runners d_{runner} randomly in problem domain. For each variable of x with lower boundary xl and upper boundary x_u, initial values of variables are randomly selected in the interval of $[x_1, x_u]$.

10.3.4 Duplication

Assuming $x_j(i) \,\varepsilon\, R^m$ stands j^{th} mother plant at i^{th} iteration and the matrix which contains the location of corresponding runners and roots at this iteration, $x_{prop}(i)$ computed below and each of the resulted vectors as a column in it.

$$x_{prop}\ (i) = [x_{root}\ (i) x_{runner}\ (i)] = [x(i)x(i)] + [d_{root}r_1\ d_{runner}r_2] \qquad \text{Equation 3.2}$$

where: $x(i) = [x_1(i)\ x_2(i) \ldots x_N(i)]$, $x_{prop}(i) = [x_{1,prop}(i)\ x_{2,prop}(i) \ldots x_{2N,prop}(i)]$, $x_{root}(i)\ \varepsilon R^{m*n}$ and $X_{runner}(i)\ \varepsilon R^{m*n}$ are matrices containing the locations of roots and runners which follows

$$x_{root}(i) = [x_{1,root}(i), x_{2,root}(i) \ldots x_{N,root}(i)] \quad \text{Equation 3.3}$$

$$x_{runner}(i) = [x_{1,runner}(i), x_{2,runner}(i) \ldots x_{N,runner}(i)] \quad \text{Equation 3.4}$$

$r_1, r_2\ \varepsilon R^{m*n}$ are random matrices, distances of roots as d_{root} and runners as d_{runner}

10.3.5 Elimination

Computing the fitness of runners and roots in the first duplication by using following equation

$$fit(x_{j,prop}(i)) = 1/(a+f(x_{j,prop}(i)), f(x_{j,prop}(i)) > 0, j=1,\ldots,N \quad \text{Equation 3.5}$$

$$fit(x_{j,prop}(i)) = (a+f(x_{j,prop}(i)), f(x_{j,prop}(i)) <= 0, j=1,\ldots,N \quad \text{Equation 3.6}$$

10.3.6 Overview of Flower Pollination Algorithm

Flower Pollination Algorithm (FPA) was developed by Xin-She Yang in 2012 [50, 51], inspired by pollination of flowering plants. FPA with multi-objective optimisation function is utilised for controller design [52, 53]. In [54–57] it has been illustrated that FPA has the better quality solution, robustness than other published methods and also shown consider domination over GA. It has only one key parameter p (switch probability) which makes the algorithm easier to implement and faster to reach optimum solution [58]. FPA has special capabilities such as extensive domain search with quality and consistency solution. So, it is utilised along with DE for multi-objective optimal dispatch problem [59]. FPA is compared with numerous algorithms [60] and its performance encourages to implement.

Flower pollination is an activity that involves the transfer of pollen among the flowers. This takes place typically in two ways. First one is through self pollination (or local pollination) is a biotic form, which contributes 10% of pollination where no pollinators are required. The second one is through cross pollination (or global pollination) is an abiotic form which involves pollinators such as insects, birds, bats and other animals, contributes 90% of pollination.This phenomenon involves agents like pollinators that move from one flower to other flowers exhibiting a foraging behaviour with a pollinator moving more frequently to certain flowers that others. The frequency of visit to a flower is indicated by term flower constancy. The proposed flower pollination algorithm depicted through flow chart is shown in fig.3.2.

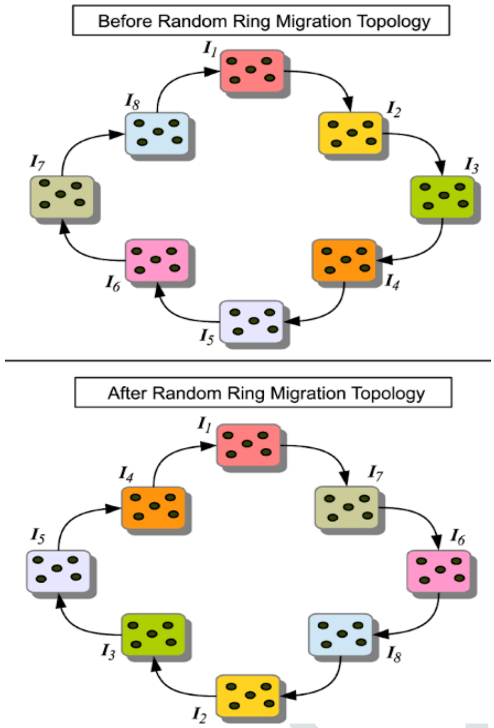
From the flow chart, it is evident that initial step of this algorithm deals with the selection of population size *(N)* and a parameter *(p)* which help to decide the amount of self pollination & cross pollination to take place.The algorithm continues by initialising specified number of population *(N)*, where each one containing a group of variables which are optimised using the objective function. This algorithm contains an indexing term called flower constancy for each population which determines how well their variables minimises the objective function. Based on the flower constancy, population are queued.

FPA proceeds through generation of new population based on the parameter p, which decides whether this population is generated through self pollination (or) cross pollination. This is carried out by generating a random variable between [0, 1] & comparing with p i.e., if the random variable is less than p, global pollination takes place (or) else local pollination occurs. For global pollination, agents would move with a different step size of length from one flower to another, which is mimicked by levy distribution of flight [61,62] and mathematically represented below,

$$L = ((\lambda\Gamma(\lambda)\sin(\pi\lambda/2))/\lambda)*1/(S \text{ power } 1+\lambda), (s>>s_0>0) \quad \text{Equation 3.7}$$

The new population generated through global pollination is given by the below equation,

$$X^{t+1}_i = x^t_i + \gamma L(\lambda)(g_* - x^t_i) \quad \text{Equation 3.8}$$



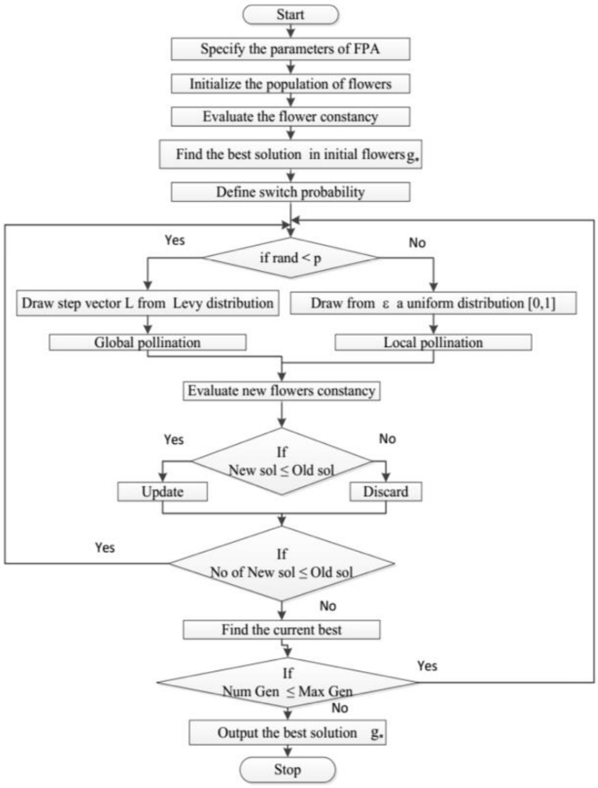


Figure 3.2: FPA Flow Chart

Were x^t_i is the pollen i or solution vector x_i at iteration t and g_* is the current best solution found among all population at the current iteration. Here γ is a scaling factor to control the step size, L(λ) is a step-size parameter that corresponds to the strength of the pollination and a standard gamma function. The local pollination occurs within a small neighbourhood of the current population. So its step size 'ε' is taken from a uniform distribution. The mathematical expression for such an operation is denoted as,

$$X^{t+1}_i = x^t_i + \varepsilon(x^t_j - x^t_k) \qquad \text{Equation 3.9}$$

where x^t_j and x^t_k are pollen from different flowers of the same plant species.

Flower constancy for the new population is found in a similar manner as stated before. If new population flower constancy is better than the previous population, they are updated in the position of the previous one(or) else discarded.This process of generation and comparison will continue until the count reaches N. The best among the current population is found and declared as current global best. This process repeats for a maximum number of iterations as specified. The current global best is declared as best solution.

10.4 Overview of the revised Backtracking Search Algorithm

The meta heuristic algorithms are enormously used due to increasing in a number of algorithms that can handle non-linear objective functions. Keen observation and study of nature inspired phenomenon helped to give an insight of computational steps for finding the optimal solution, which made them better than their predecessor algorithms. One such algorithm is backtracking search optimisation algorithm (BSA) [31], where it is shown that BSA is better than genetic algorithm (GA) [32, 33] for optimal design of type-I and multi-objective type-II fuzzy controllers and Differential Evolution algorithm (DE) used along with a dynamic adaptation of parameters [34]. BSA is not sensitive to initial conditions contrary to most of the meta heuristic algorithms [35], where as BSA is suitable to solve the problem with complicated and non smooth objective function [36]. In [37] controllers are tuned effectively by BSA to be applied in practical nonlinear system. In load shed- ding problems BSA shows better performance as compared with GA [38]. In [39] BSA employed to produce solutions to ascertain distributed generation because of its efficacy and robustness. BSA is also able to solve non-convex economic dispatch problem [40]. As mention above BSA is superior to the previous algorithms, hence there is a scope for utilised of BSA.

The BSA is categorised as evolutionary algorithm because its computation of optimal solution is through the generation of trial individuals. The trial individual from the search space providing best fitness would be the solution to the current design problem. The generation of such trial individual are accomplished through the processes like selections, mutation & crossover of the previous population. These operations are basic traits of algorithms like Genetic Algorithm (GA), Differential Evolution Algorithm (DEA), Bacterial Foraging Optimisation Algorithm (BFOA) etc.. These algorithms differ from each other through variation in computational steps of operations like mutation crossovers & selections. A flow chart of BSA portrait in fig. 3.2

10.4.2 Initialisation

Initialisation of population P in BSA is done through Eq.(4.0):

$P_{i,j} \sim U(low_j, up_j).$ Equation 3.10

for $i = 1,2,3...N$ and $j = 1,2,3...D$, where N and D are the population size and the problem dimension, respectively, U is the uniform distribution and each P_i *is* a target individual in the population P.

10.4.3 Selection-I

For calculating the search direction old population *oldP* is required which are deter- mine during BSA's selection-I stage. The initial old population is determined using Eq.(4.1):

$OldP_{i,j} \sim U(low_j, up_j).$ Equation 3.11

At the beginning of each iteration BSA has the choice of redefining oldP through
the 'if-then' rule in Eq.(4.2):

$if a < b\ then\ OldP := P|a,b = U(0,1),b.$ Equation 3.12

where := is the update operation. It ensures that BSA designates a population belonging to a randomly selected previous generation as the old population and remembers this historical population until it is changed. Thus, BSA has a memory. After oldP is determined, Eq.(4.3) is used to randomly change the order of the individuals in oldP:

$oldP := permuting(oldP).$ Equation 3.13

The permuting function used in Eq.(3.4) is a random shuffling function.

10.4.4 Mutation

BSA's mutation method generates the initial style of the trial population Mutant by using Eq.(4.4).

$Mutant = P + F.(oldP - P).$ Equation 3.14

In Eq.(3.14), F controls the amplitude of the search-direction matrix ($oldP - P$) . As a result the historical population is used to obtain the calculation of the search-direction matrix, BSA generates an endeavour population, taking partial advantage of its experiences from previous generations. During this work uses the value $F = Three\ rndn$, where $rndn = N(0,1)$ and (N is the standard normal distribution).

10.4.5 Crossover

Trial population T generation is completed with BSA's crossover method that utilises the mutant population generated through mutation method. This trial population can facilitate the analysis of main population P. This involves the following three steps;

- First step is to develop a binary number value matrix referred to as map of dimension $N.D$ for this map matrix is initialised with an initial value 1. Later by employing a ceiling function outlined as $rnd = U(0,1)$, we tend to generate random parameter a,b for every path population.If $a < b$ then the chosen trial population connected map matrix is modified reckoning on *mixrate.rndD* i.e $map_{i,u(1:[mixrate\ rnd\ D])} = 0$ else each population individual is replaced without below equation 3.15

$$Map_{i,rani(D)} = 0 \qquad \text{Equation 3.15}$$

- we get binary integer-valued matrix(map) by recursion of above steps for each population . Second step is the stage wherever crossover happens. For the crossover operation, map matrix elements are investigated and several path population T is changed i.e if $map_{i,j} = 1$, by replace $T_{i,j}$ with $P_{i,j}$.

- Third step is to see the obtained path population for any individual elements which are out of bound from given search area, for such element we tend to replace them as $T_{i,j}$ *and.*$(up_j - low_j) + low_j$

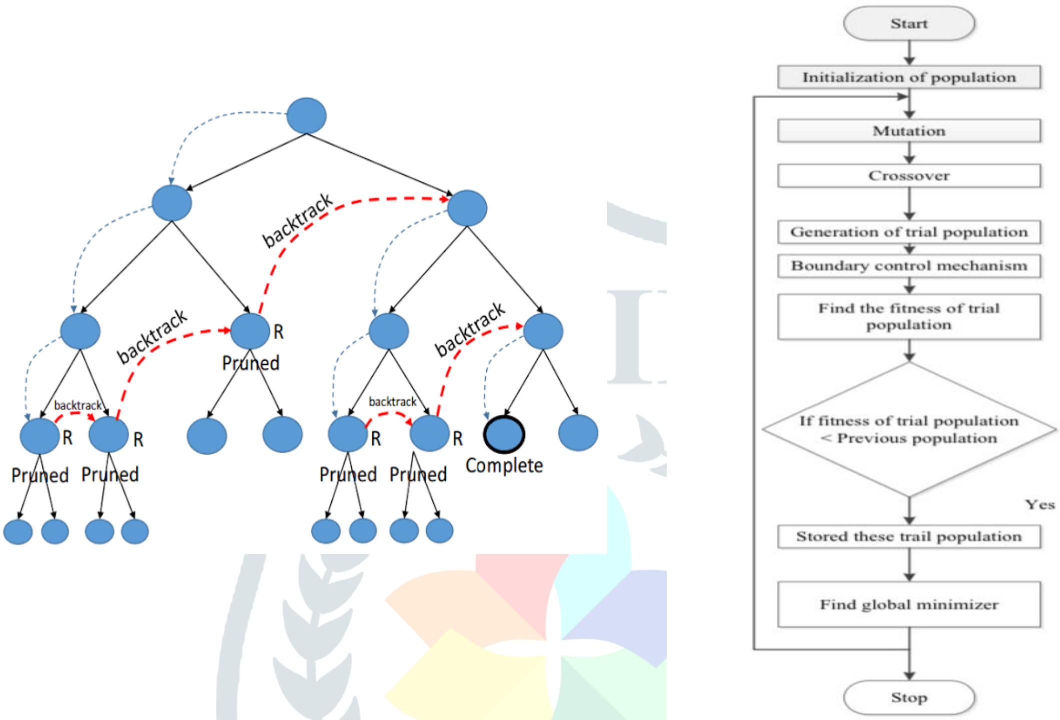


Figure 3.3: BSA Flow Chart

10.4.6 Selection-II

In Selection-II stage of BSA, the P_i*s* are replaced with higher fitness T_i*s* which could be a greedy choice. Among the P_i*s is* the simplest individual $P(P_{best})$ has better fitness with global minimum value gmv and this P is updated as P_{best}.

10.5 Overview of the revised Fruit Fly Optimisation Algorithm

Fruit Fly Optimisation algorithm (FFA) which is analogous to swarm intelligence technique [41], follows its predecessors like ant colony optimisation used for optimisation of fuzzy controllers [42, 43]. In [44] states that FFA easily and quickly solve the searching and tuning problems of PID controller parameters as compared with GA. The authors of [45] implemented FFA to solve the multidimensional knapsack problem. FFA being their descendant algorithm proved to be very useful in tuning various controllers for AGC under deregulated environment [46]. FFA is used for tuning optimal PID controller as secondary control of frequency in an interconnected system. This algorithm is a kind of swarm intelligent technique like Particle Swarm Optimisation (PSO), Ant Colony Optimisation (ACO), Artificial Bee Colony Algorithm (ABC) etc., whose agents search for food. FFA agents search for food which is their optimal solution available at a particular location of space.

To mimic this phenomenon of the search for an optimal solution a space of search is constructed for a given problem whose optimal solution is to be found. For this purpose each parameter involving in the solution requires construction of a 2-dimensional space containing positive quadrants in the form of co-ordinates. As this is a swarm type of technique the agents mimics as fruit flys which detects the food through smell and later via vision to find the optimal solution. FFA flow chart as shown in fig. (3.3) and FFA is composed of following steps.

- At start consider the search location of food in 2-D space of positive quadrant *InitX_axis and then InitY_axis*
- *Select* the random direction and distance for food search using property osphresis of an individual fruit fly. X_i *equals to X_axis + RandomValue* and Y_i *equals to Y_axis + RandomValue*
- As the food location is not known so its distance from the initial point is evaluated and smell concentration judgment value(S) is measured using distance(Dist)

$Dist_i = (sqrt\ X_i^2 + Y_i^2)\ S_i = 1/Dist_i$ Equation 3.16

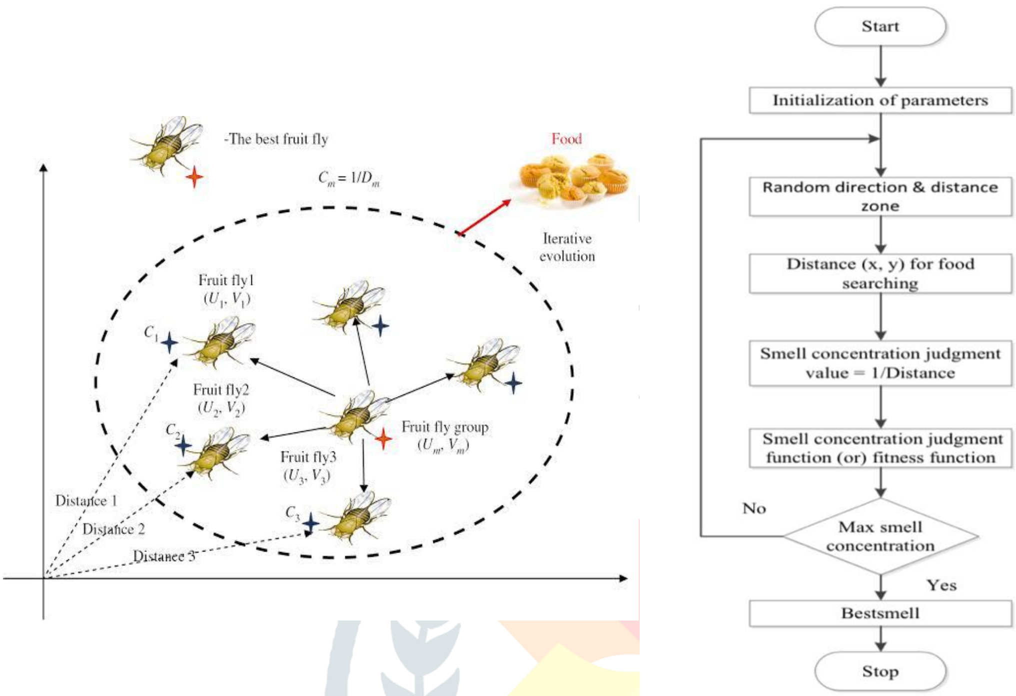


Figure 3.4: FFA Flow Chart

- The known smell concentration estimated value(S) is inserted in the desired objective function to find smell concentration ($Smell_i$) of the common location of the fruit fly. Smell, $Smell_i = Function(S_i)$
- Find out the fruit fly with overall smell concentration (finding the maximal overall value) among the fruit fly swarm. Best smell best index *[bestSmellbestIndex] equals to max(Smell)*
- Keep the best smell concentration value and x, y coordinate, and at this point, the fruit fly swarm will use sight to fly towards that location.
- Enter iterative optimisation to re cut the implementation of steps 2–5, then estimate and judge if the smell concentration is advanced or superior to the previous iterative smell concentration, if so, re do the sixth step.

11. Revised BSA|FFA Analysis of Cost Functions and Values Sensitivity Towards a Controller

This chapter concentrates on the validation of meta heuristic algorithms like back- tracking search optimisation algorithm (BSA) and fruit fly optimisation algorithm (FFA) for tuning of optimal PID controller for automatic generation control. For this purpose, a two area reheat interconnected thermal system with nonlinearities like generator rate constant (GRC), dead-band and time delay are considered. The proposed work is implemented using MATLAB for various load conditions with objective functions for meta heuristic algorithms capturing signals from various positions of proposed model. The results obtained using two algorithms are compared and discussed.

11.1 Proposed model under study

For the verification of advanced methodologies; FFA and BSA, a model of a two area reheat interconnected thermal power system with non-linearities like dead-band, generate rate constraint (GRC) and time delay are considered. The considered work is simulated using MATLAB for various load conditions with cost functions or objective functions for meta-heuristic algorithms seizing signals from numerous positions of the considered model.

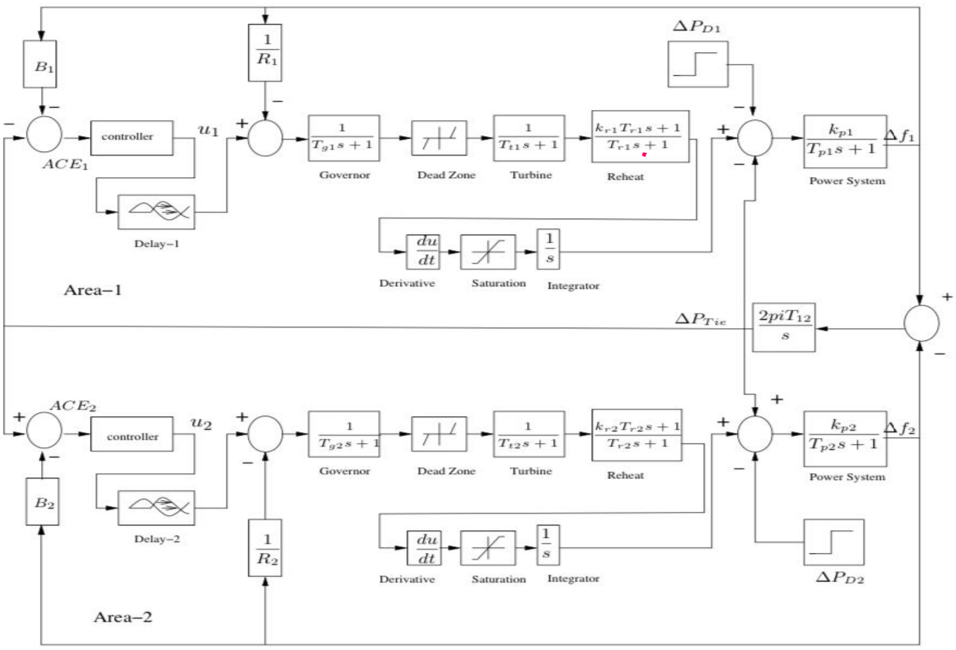


Figure 4.1: Two Area Interconnected Reheat Thermal Power System

The results obtained using two algorithms are evaluated and then compared with the nature algorithms. The model depicted is a two area thermal reheat system with non linearities or physical constraints to obtain optimal control of power system, analysis of cost/objective functions and parameters sensitivity towards controller.

11.2 The Proposed Approach

The present work considers a two area interconnected thermal reheat system model with physical constrains like generation rate constraints, time delay and governor dead band [28, 29]. As represented in fig. 1, B_1, B_2 are frequency bias parametric values; ACE_1, ACE_2 represent the area control error values; u_1 and u_2 depict the control outputs from the designed controller; R_1, R_2 show the governor speed regulation parametric values in p.u. Hz; T_{g1}, T_{g2} are speed governor time constants in seconds; T_{t1}, T_{t2} are turbine time constants in seconds; ΔP_{D1}, ΔP_{D2} are the load demand values; ΔP_{Tie} is a change in an increment of the tie line power (p.u.); K_{p1}, K_{p2} are power system gains; K_{r1}, K_{r2} are Reheat gains; T_{p1s}, T_{p2s} are power system time constants in seconds; T_{12} is the synchronizing coefficient and Δf_1, Δf_2 are system frequency deviations in Hz. The relevant parameters are given in the Appendix, A.2.

From literature these algorithms to have better performance than their predecessor when implemented in various fields of engineering. So the performance comparison of these two algorithms for tuning an AGC controller is needed. The AGC controller tuned for optimal action requires to mitigate the changes in frequencies of each area and to limit the tie line power. So the error signals from these quantities should guide the tuning for optimal controllers. The objective functions of the meta-heuristic algorithms are composed of these error signals. The performance of proposed controller is evaluated based on indices such as Integrated Absolute Error (IAE), Integrated Squared Error (ISE), Integrated Time Multiplied Absolute Error (ITAE), Integrated Time Multiplied Squared Error (ITSE) etc., are used as in [30]. Among them Integrated Time Multiplied Absolute Error, ITAE is frequently used in literature. To test and compare algorithms, three objective functions J_1, J_2 *and* J_3 are constructed using the error signals obtained at various locations of proposed model which is based on ITAE function.

$$J1 = ITAE = Int\ (0\ to\ tsim)[|\Delta f1| + |\Delta f2| + |\Delta PTie|].t.dt \quad \text{Equation 4.1}$$

The tested algorithms use this function J_1 and tunes controllers for the model at load disturbances of 5% and 25%. B_1, B_2, R_1, R_2, T_{g1}, T_{g2}, T_{t1}, T_{t2}, T_{r1}, T_{r2}, K_{r1}, K_{r2} are various system parameters that could effect the performance of the controller. For studying each parameter sensitivity in the design of controller by the proposed algorithms, a sequence of performance is seen by considering variations in the system parameters. This is observed for −25%,+25% change in each parametric value by keeping other parameters as constant as per the proposed system

$$ACE1 = B1\Delta f1 + \Delta PTie. \quad \text{Equation 4.2}$$

$$ACE2 = B2\Delta f2 + \Delta PTie. \quad \text{Equation 4.3}$$

These signals (1.2),(1.3) can be used to guide the algorithm for design of the optimal controller. So ACE_1 & ACE_2 signals are utilized along with ITAE to create an objective function J_2 .

$$J2 = ITAE = Int\ (0\ to\ tsim)[|\Delta ACE1| + |\Delta ACE2|].t.dt \quad \text{Equation 4.4}$$

AGC controllers are designed for 5%, 25% load disturbances in proposed model using these algorithms and their performances are compared. It can be observed from fig. 1 that u_1 and u_2 are the output signals of controller (PID) which are given as;

$$u1 = KP1ACE1 + KI1ACE1. \quad \text{Equation 4.5}$$

$$u2 = KP2ACE2 + KI2ACE2. \quad \text{Equation 4.6}$$

substituting (1.2) & (1.3) in (1.5) & (1.6) respectively we have;

$$u1 = \left(Kp1B1 + KI1Int\ B1 + KD1\frac{dB1}{dt}\right)\Delta f1 + \left(KP1 + KI1Int + \frac{KD1d}{dt}\right)\Delta PTie \quad \text{Equation 4.7}$$

$$u2 = \left(Kp2B2 + KI2Int\ B2 + KD2\frac{dB2}{dt}\right)\Delta f2 - \left(KP2 + KI2Int + \frac{KD2d}{dt}\right)\Delta PTie \quad \text{Equation 4.8}$$

From equations (1.7),(1.8) it is seen that u_1 and u_2 also depends on Δf_1, Δf_2, ΔP_{Tie}. So these signals are used along with ITAE to form objective function J3 for algorithms for optimum design of controller

$$J3 = ITAE = Int\ (0\ to\ tsim)[|\Delta u1| + |\Delta u2| + |\Delta ACE2 - \Delta ACE1|].t.dt \quad \text{Equation 4.9}$$

From equations (4.7),(4.8) we can observe that u_1 and u_2 also depends on Δf_1, Δf_2, ΔP_{Tie}. So these signals are used along with ITAE to form objective function J_3 for algorithms to design a optimal controller using objective function J_3 above model is simulated for 5%, 25% load perturbation and found optimal values.

Quick Note:- The ISE and ITSE functions are appropriate to use for measuring the performance when error value is greater than one and vice versa with IAE and ITAE. The ITAE and ITSE are good measures when error signal persists for a long time and helps to improve steady state error. While IAE and ISE are useful to mitigate the initial transients.

11.3 Simulation and Results

From section-4.3 postulated cost function j_1 is used to tune the optimal controller for proposed model with the help of BSA and FFA algorithms. The above system is simulated using MATLAB 2020b version for a load perturbation of 5%, 10%, 15% and 25% in Area-1 of proposed model. The rate of convergence of FFA & BSA for the proposed model is given in figs. 4.2&.3

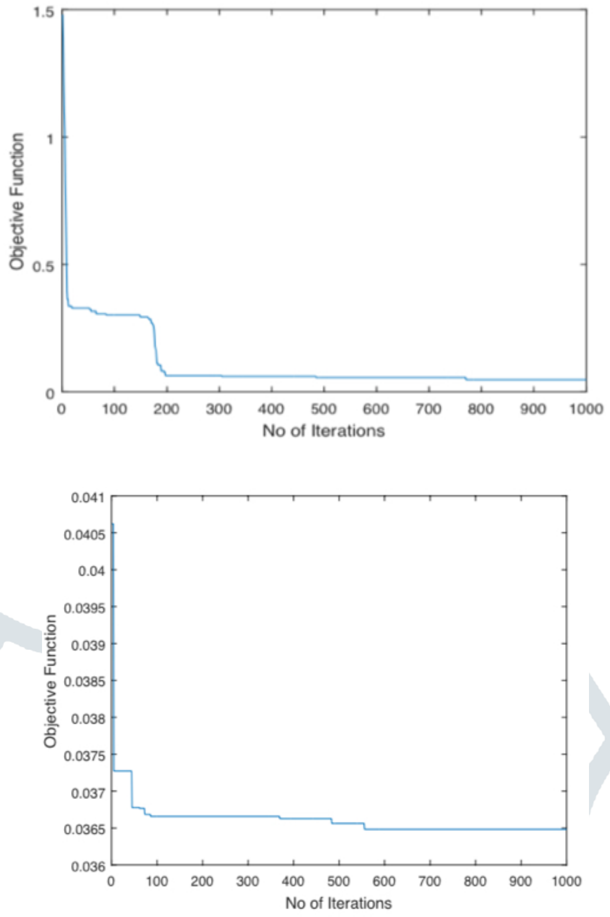


Figure 4.2: Rate of Convergence of FFA, BSA

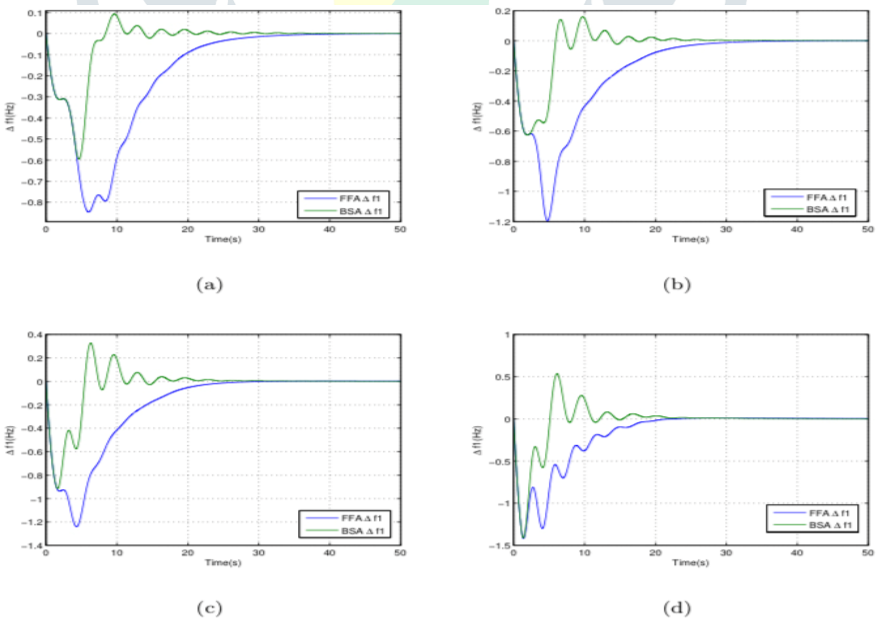


Figure 4.3: Comparison of frequency response from area-1 of proposed model using BSA & FFA tuned controllers at various load perturbation (a) 5% load. (b) 10% load. (c) 15% load. (d) 25% load

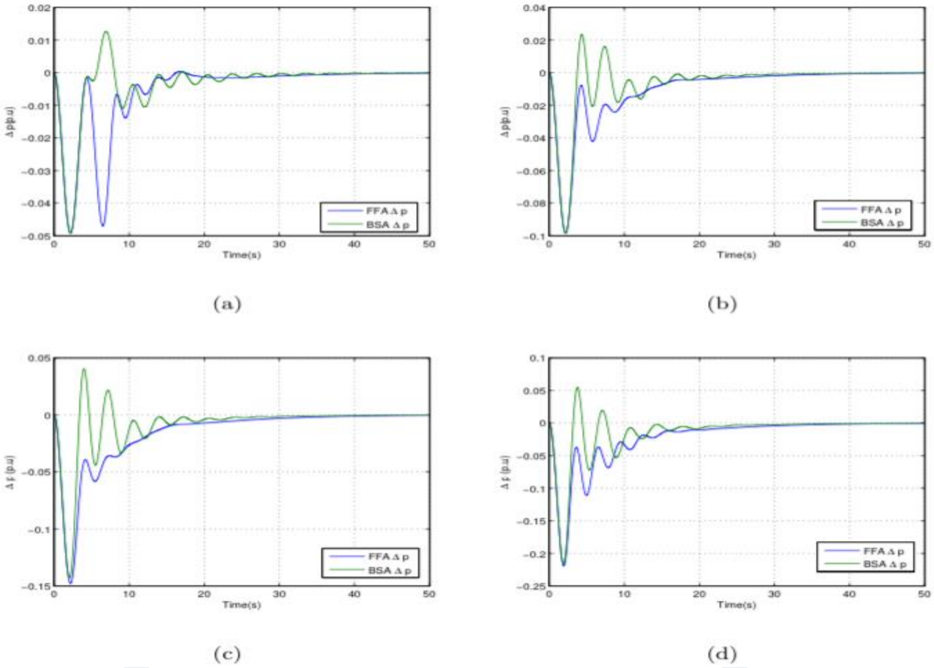


Figure 4.4: Comparison of frequency response from area-2 of proposed model using BSA & FFA tuned controllers at various load perturbation (a)5% load. (b) 10% load. (c) 15% load. (d) 25% load

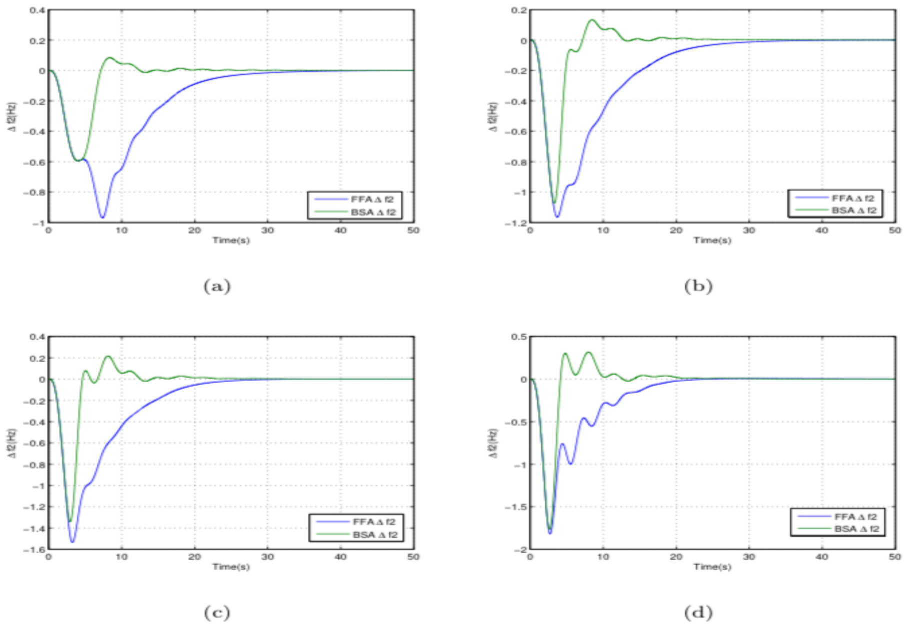


Figure 4.5: Comparison of change in tie line power of proposed model using BSA & FFA tuned controllers at various load perturbation (a) 5% load. (b) 10% load. (c) 15% load. (d) 25% load

Each parameter of proposed system is varied for a change of −25%, +25% of nominal values presented in appendix-A, by keeping other system parameters as constant. Using these modified model of the proposed system, optimal controller are tuned by BSA and FFA algorithms using J1 objective function at load perturbation of 25%.

Table 4.1: At Initial Condition of FFA and BSA

	FFA-Area-1			BSA-Area-1			
	u_{sh}	o_{sh}	t_s	u_{sh}	o_{sh}	t_s	
	-2.4470	0.1343	27.56	-2.4390	1.4840	16.41	
	-2.6460	0.1254	25.63	-2.5140	1.0370	18.52	
	-0.3756	0.0000	30.88	-0.3667	0.0584	17.08	
	FFA-Area-2			**BSA-Area-2**			
	u_{sh}	o_{sh}	t_s	u_{sh}	o_{sh}	t_s	
	-2.5590	0.0852	26.43	-2.5260	0.9541	18.44	
	-2.4410	0.0973	28.28	-2.440	1.2180	18.99	
	0.0000	0.3688	30.97	-0.0670	0.3669	25.92	

Table 4.2: Performance characteristics of responses obtained with change in system parameters of Area-1 at 25% load perturbation using FFA and BSA

	Value	*Change*	Δf_1			Δf_2			Δp		
			u_{sh}	o_{sh}	t_s	u_{sh}	o_{sh}	t_s	u_{sh}	o_{sh}	t_s
FFA	T_g	+25%	-2.47	0.15	25.89	-2.65	0.14	25.20	-0.38	0.00	29.60
		-25%	-2.42	0.00	22.47	-2.54	0.00	16.07	-0.37	0.00	30.16
	T_t	+25%	-2.48	0.00	26.82	-2.60	0.00	27.69	-0.38	0.00	34.20
		-25%	-2.40	0.34	23.56	-2.58	0.39	15.76	-0.37	0.00	27.86
	T_r	+25%	-2.45	0.00	31.66	-2.64	0.00	18.19	-0.38	0.00	33.59
		-25%	-2.44	0.56	21.59	-2.60	0.55	20.95	-0.37	0.00	25.28
FFA	K_r	+25%	-2.38	0.00	21.28	-2.51	0.00	21.62	-0.36	0.00	35.13
		-25%	-2.52	0.00	28.17	-2.72	0.00	26.04	-0.39	0.00	32.37
	B	+25%	-2.45	0.16	22.23	-2.61	0.16	20.61	-0.37	0.00	27.83
		-25%	-2.45	0.15	32.27	-2.63	0.14	30.52	-0.37	0.00	32.50
	R	+25%	-2.61	0.28	24.11	-2.75	0.26	22.71	-0.40	0.00	30.58
		-25%	-2.19	0.00	28.30	-2.29	0.00	25.66	-0.32	0.00	31.71
BSA	T_g	+25%	-2.46	0.84	20.93	-2.57	0.59	19.38	-0.37	0.04	24.22
		-25%	-2.42	1.29	19.29	-2.50	0.99	18.16	-0.36	0.06	20.51
	T_t	+25%	-2.49	0.84	21.72	-2.63	0.66	18.54	-0.38	0.05	24.87
		-25%	-2.39	1.43	16.09	-2.47	1.02	15.67	-0.36	0.05	16.03
	T_r	+25%	-2.44	1.34	18.69	-2.52	0.86	17.81	-0.37	0.04	18.83

		-25%	-2.44	0.94	19.95	-2.53	0.57	18.66	-0.37	0.04	23.46
BSA	**K$_r$**	+25%	-2.38	0.63	17.88	-2.49	0.56	16.31	-0.36	0.06	23.91
		-25%	-2.51	1.03	23.40	-2.59	0.75	22.23	-0.38	0.07	26.28
	B	+25%	-2.44	1.00	17.91	-2.53	0.58	18.56	-0.37	0.06	22.64
		-25%	-2.44	1.30	13.41	-2.53	0.93	11.84	-0.37	0.03	20.33
	R	+25%	-2.62	0.82	22.37	-2.76	0.70	21.28	-0.40	0.02	25.47
		-25%	-2.19	1.16	17.67	-2.26	0.88	16.91	-0.32	0.06	21.22

Each parameter of proposed system is varied for a change of −25%, +25% of nominal values presented in appendix-A, by keeping other system parameters as constant. Using these modified model of the proposed system, optimal controller are tuned by BSA and FFA algorithms using J1 objective function at load perturbation of 25%.

Table 4.3: Performance characteristics of responses obtained with change in system parameters of Area-2 at 25% load perturbation using FFA and BSA

	Value	*Change*	Δf_1			Δf_2			Δp		
			u_{sh}	o_{sh}	t_s	u_{sh}	o_{sh}	t_s	u_{sh}	o_{sh}	t_s
FFA	**T$_g$**	+25%	-2.44	0.12	28.53	-2.63	0.11	26.59	-0.37	0.00	31.67
		-25%	-2.45	0.14	25.91	-2.61	0.13	24.11	-0.37	0.00	29.58
	T$_t$	+25%	-2.45	0.00	18.23	-2.71	0.00	18.46	-0.38	0.00	33.73
		-25%	-2.45	0.00	18.09	-2.59	0.00	18.32	-0.38	0.00	33.30
	T$_r$	+25%	-2.45	0.00	27.18	-2.66	0.00	18.02	-0.38	0.00	38.02
		-25%	-2.45	0.00	28.52	-2.64	0.00	28.85	-0.38	0.00	30.52
FFA	**K$_r$**	+25%	-2.45	0.00	27.83	-2.53	0.00	28.20	-0.38	0.00	33.13
		-25%	-2.45	0.00	18.62	-2.72	0.00	19.70	-0.37	0.00	34.52
	B	+25%	-2.45	0.00	18.67	-2.60	0.00	22.13	-0.37	0.00	38.22
		-25%	-2.44	0.00	19.99	-2.61	0.00	20.30	-0.37	0.00	31.45
	R	+25%	-2.45	0.00	19.54	-2.93	0.00	20.60	-0.38	0.00	34.02
		-25%	-2.45	0.22	23.93	-2.25	0.18	22.61	-0.37	0.00	27.23
BSA	**T$_g$**	+25%	-2.44	1.00	20.30	-2.56	0.72	19.09	-0.37	0.05	23.74
		-25%	-2.44	0.97	21.56	-2.50	0.57	20.36	-0.37	0.05	24.58
	T$_t$	+25%	-2.44	1.34	19.55	-2.57	0.98	18.45	-0.37	0.06	24.47
		-25%	-2.44	1.19	19.01	-2.46	0.78	19.48	-0.37	0.04	23.02
	T$_r$	+25%	-2.44	1.29	17.61	-2.53	1.12	19.94	-0.37	0.08	19.71
		-25%	-2.45	0.08	20.96	-2.62	0.00	18.83	-0.37	0.00	24.06
BSA	**K$_r$**	+25%	-2.44	0.87	17.86	-2.46	0.65	18.57	-0.37	0.03	20.68
		-25%	-2.44	1.52	16.55	-2.61	1.10	19.11	-0.37	0.10	25.71

	B	+25%	-2.44	1.09	21.23	-2.47	0.71	20.40	-0.37	0.02	25.89
		-25%	-2.45	0.76	21.24	-2.62	0.52	19.73	-0.37	0.09	21.75
	R	+25%	-2.44	1.07	20.57	-2.76	0.74	19.19	-0.37	0.08	24.02
		-25%	-2.44	0.89	19.82	-2.21	0.75	19.43	-0.37	0.04	21.62

Similar case study responses of controller tuned by FFA are presented in same tables. Following observations about BSA are portrayed; For each case of test results, undershoot & overshoot of system response lies inside the stable region with a minute variation for a ±25% change in parameters. Settling time of these responses does not show satisfactory results as its variation is in the range of ±25% of nominal value. While there is a satisfactory response at 25% load disturbance in Area-2.

Table 4.4: Controller gains obtained while testing sensitivity of system parameters when tuned for optimal controller using BSA and FFA

PID CONTROLLER GAINS OF BSA AND FFA													
		BSA						FFA					
		Area-1-f_1.			Area-2-f_2.			Area-1-f_1.			Area-2-f_2.		
	Val.Change.	K_{P1}	K_{I1}	K_{D1}	K_{P2}	K_{I2}	K_{D2}	K_{P1}	K_{I1}	K_{D1}	K_{P2}	K_{I2}	K_{D2}
T_g	+25%	0.355	0.498	0.148	0.372	0.564	0.201	0.125	0.213	0.082	0.078	0.172	0.135
	-25%	0.458	0.702	0.299	0.395	0.557	0.301	0.382	0.180	0.130	0.143	0.214	0.093
T_t	+25%	0.339	0.472	0.098	0.415	0.643	0.283	0.305	0.113	0.145	0.093	0.128	0.078
	-25%	0.496	0.790	0.374	0.407	0.702	0.362	0.093	0.341	0.107	0.115	0.131	0.074
T_r	+25%	0.408	0.729	0.342	0.437	0.724	0.265	0.148	0.135	0.089	0.115	0.13	0.074
	-25%	0.386	0.526	0.221	0.370	0.218	0.044	0.183	0.414	0.094	0.138	0.099	0.082
K_r	+25%	0.320	0.475	0.091	0.371	0.618	0.207	0.089	0.120	0.164	0.138	0.099	0.082
	-25%	0.440	0.515	0.357	0.437	0.686	0.310	0.145	0.147	0.137	0.292	0.139	0.044
B	+25%	0.358	0.502	0.209	0.323	0.567	0.304	0.126	0.195	0.899	0.086	0.116	0.111
	-25%	0.442	0.794	0.343	0.368	0.510	0.099	0.111	0.223	0.139	0.098	0.115	0.179
R	+25%	0.266	0.443	0.125	0.336	0.503	0.184	0.071	0.196	0.200	0.103	0.122	0.069
	-25%	0.453	0.820	0.339	0.356	0.685	0.332	0.149	0.196	0.245	0.401	0.326	0.086

The response characteristics like overshoot (O_{sh}),undershoot (U_{sh}), settling time (t_s) for change in frequencies and tie line power of these resulting controllers are postulated in tables 4.2 and 4.3 for BSA. Similar case study responses of controller tuned by FFA are presented in same tables. Following observations about BSA are portrayed; For each case of test results, undershoot & overshoot of system response lies inside the stable region with a minute variation for a ±25% change in parameters. Settling time of these responses does not show satisfactory results as its variation is in the range of ±25% of nominal value. While there is a satisfactory response at 25% load disturbance in Area-2 of the model.

Further observation for FFA responses provide following inferences; The response from the FFA tuned controller are always critically damped. The undershoot of response for FFA based controller behaves similar to the BSA tuned controller. FFA tuned controller is sensitive to regulator constant R1 & R2, so the resultant controller response settling time varies beyond the acceptable limit. From control system theory characteristics of transient response are calculated using parameters like maximum overshoot (O_{sh}) maximum undershoot (U_{sh}), settling time (t_s) in the time domain analysis of a power system. For tuning PID controllers to a given system the signals considered are; change in frequency and exchange of tie line power. The transient response characteristics recovered from these considered signals are minimum if the controller is tuned well otherwise it is referred as poorly tuned controller. To verify tuning capabilities of both algorithms the corresponding response characteristics are needed to be executed for respective tuned controllers.

As proposed algorithms are typically heuristic in nature and produce a near optimal solution, the statistical calculation of these response characteristics is needed. So proposed system with J1 objective function is simulated for 30 times and at every instant each controller parameters are acquired and reserved. This method is prolonged for FFA algorithm, later to PSO & GA algorithms for comparison and validation purpose. For every runtime of simulation, the considered signal response characteristics like peak overshoot *(O_{sh})* undershoot*(U_{sh})*, settling time *(t_s)* are executed. The standard deviation and mean are obtained for these executed response characteristics.

The controller parameters obtained for each simulation case to test the system parameter sensitivity towards tuning of optimal controller by BSA and FFA algorithms are tabulated in table 4.4. This table shows the variation of gains of PID controller w.r.t the change in the system parameters of the schematic model. The objective function J2 has signals ACE_1, ACE_2, that are linear combinations of Δf_1, Δf_2, ΔP_{Tie} whose minimal response is the desired criteria. Here objective functions J2, J3 provided to algorithms does not give the direct calculation of these desired signals rather a linear combination of (Δf_1,Δf_2 & ΔP_{Tie}) that would effect the algorithms efficiency.

To find their effectiveness for tuning the optimal solution, these objective function are utilized at a 25% & 5% of load perturbation. The found optimal controllers has produced the responses for desired signals Δf_1,Δf_2,ΔP_{Tie} that are compared with J1 algorithm optimal responses at same loading conditions. The comparison of results are postulated in figs. 4.6 to 4.8. The statistical measurements of these algorithms are shown in Table 4.5. Similar analysis is carried out for J2 & J3 objective functions and are seen in Tables 4.6 & 4.7 respectively.

From above comparison of results in Fig 4.6 to 4.8, following observations about the algorithms for tuning controllers are proposed; FFA & BSA tuned controllers using J2 objective function gave a stable and stored response. Utilizing J2 objective function, controller response is degraded in performance as compared with J1 at both 5% & 25% load perturbation. J3 objective function is not capable to produce optimal controller using BSA algorithm for 5% load disturbance. While there is a satisfactory controller designed for 25% load disturbance. FFA proves to be good in tuning controller parameters at both percentage of load disturbance. The scope analysis gives insight about BSA abnormality to sense error signal when there is a large distortion of in-feed desire signals produced with small load disturbance.

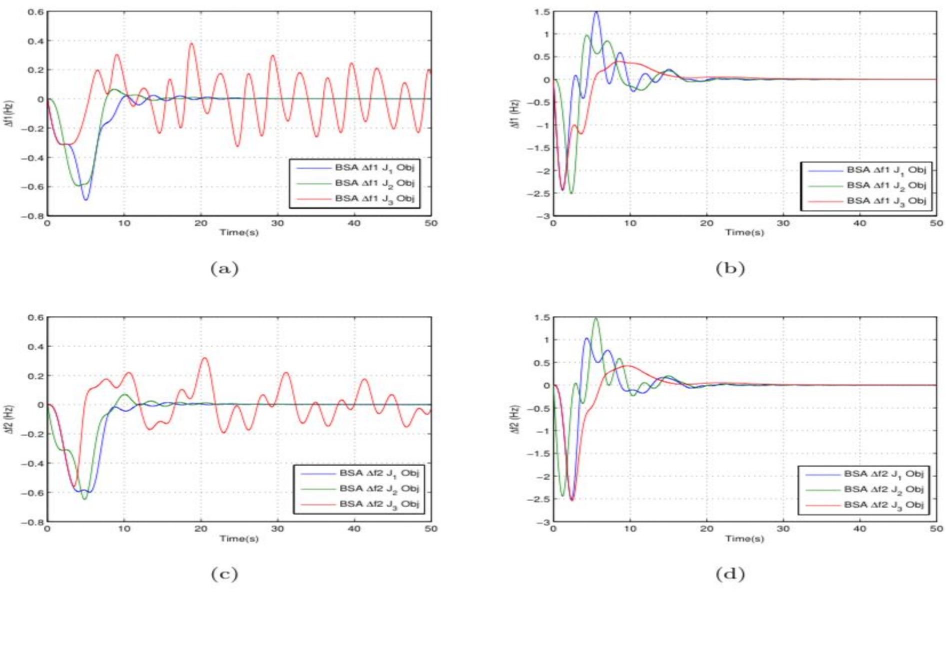


Figure 4.6: Comparison of change in frequency response obtained from area-1 and area-2 by using objective functions , BSA at 5% and 25% load disturbance (a) BSA−Model−5%−Δf1. (b) BSA−Model−25%−Δf1. (c) BSA− Model−5%−Δf2. (d) BSA−Model−25%−Δf2.

From tables 4.5, 4.6 and 4.7 the following observations are made. BSA has least standard deviation for all response characteristics which shows good convergence compared to the other algorithms. The best scope response among the 30 runs of PSO has superiority over the other algorithms. While utilizing J2 objective function PSO performance seems poor compared to other algorithms and it completely distort to tune controllers for J3 objective function.

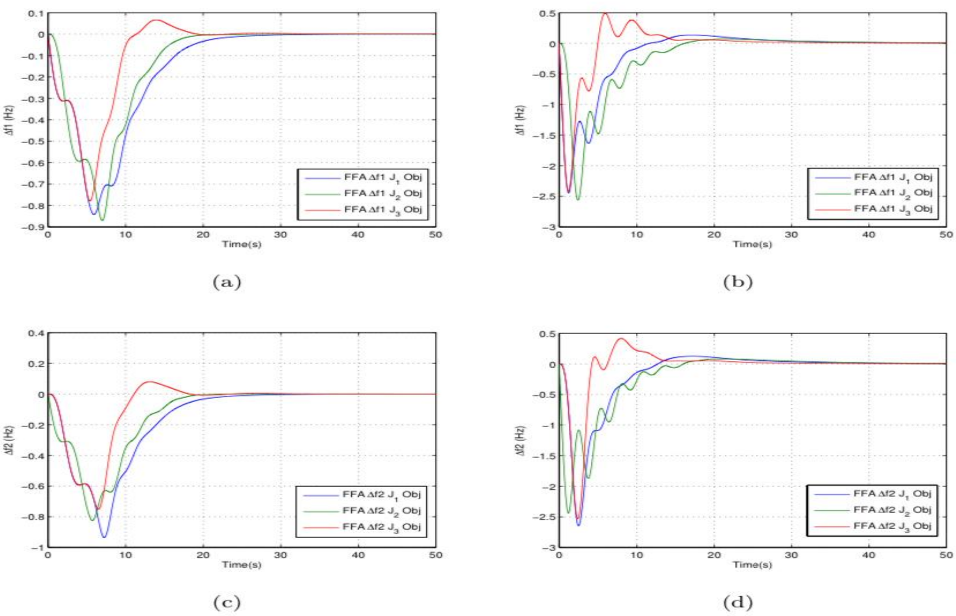


Figure 4.7: Comparison of change in frequency response obtained from area-1 and area-2 by using objective functions , FFA at 5% and 25% load disturbance (a) FFA−Model−5%−Δf1. (b) FFA−Model−25%−Δf1. (c) FFA− Model−5%−Δf2. (d) FFA−Model−25%−Δf2.

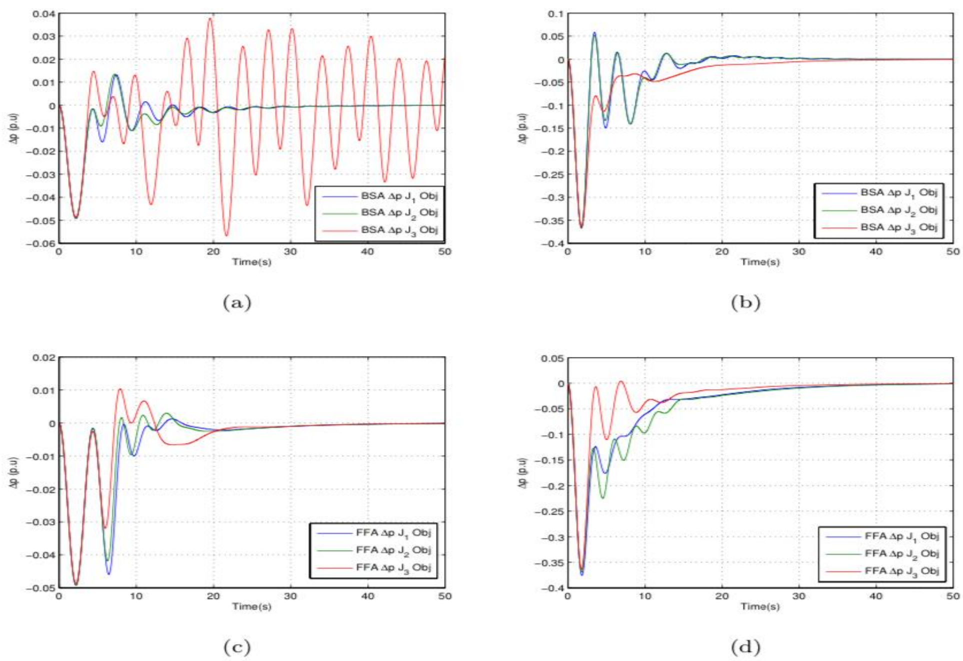


Figure 4.8: Comparison of response of change in tie line power obtained by using objective functions, FFA and BSA algorithms at 5% and 25% load disturbance (a) BSA−Model−5%−Δp. (b) BSA−Model−25%−Δp. (c) FFA−Model−5%−Δp. (d) FFA−Model−25%−Δp.

GA algorithm provides consistent performance using all three objective functions, but it does not have better statistical results as compared to BSA. FFA almost has negligible overshoot (O_{sh}) as compared to all other algorithms, and also convergence to give optimal solution.

Table 4.5: Statistical results obtained by tuning PID controller through PSO, GA, FFA & BSA algorithms using J1 objective function for 30 run times at 25% step load disturbance

J FUNC	FREQ, PTIE	RESPONSES	STD, MEAN	PSO	GA	FFA	BSA
J_1	ΔF_1	O_{sh}	STD	+0.152	+0.176	+0.200	+0.018
			Mean	+1.234	+0.914	+0.136	+1.280
		u_{sh}	STD	+0.001	+0.002	+0.002	8*10^-5
			Mean	-2.440	-2.442	-2.443	-2.439
		t_s	STD	+1.292	+0.727	+4.082	+0.103
			Mean	+19.25	+20.70	+23.91	+19.42
J_1	ΔF_2	O_{sh}	STD	+0.150	+0.152	+0.164	+0.040
			Mean	+0.946	+0.658	+0.117	+0.923
		u_{sh}	STD	+0.015	+0.030	+0.032	+0.001
			Mean	-2.527	-2.553	-2.593	-2.521
		t_s	STD	+0.600	+0.597	+4.110	+0.073
			Mean	+18.77	+19.35	+22.18	+18.35
J_1	ΔP_{Tie}	O_{sh}	STD	+0.014	+0.013	+0.012	+0.005
			Mean	+0.063	+0.044	+0.003	+0.058
		u_{sh}	STD	7*10^-4	+0.002	+0.002	2.7*10^-5
			Mean	-0.367	-0.686	-0.371	-0.366
		t_s	STD	+2.502	+0.980	+3.443	+0.225
			Mean	+27.33	+24.21	+32.04	+22.21
STD: Standard deviation of 30 iterations, Mean: Mean of 30 iterations							

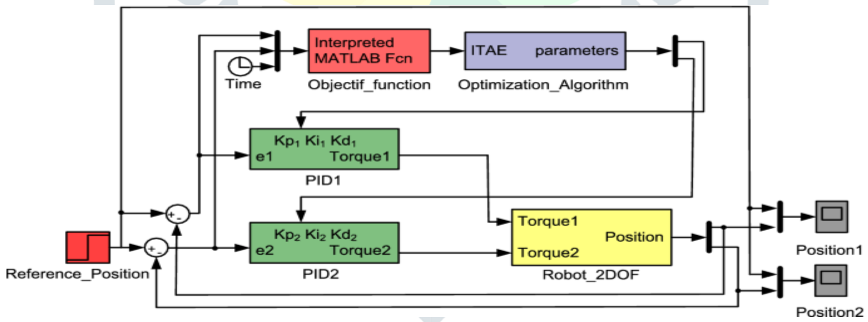
Table 4.6: Statistical results obtained by tuning PID controller through PSO, GA, FFA & BSA algorithms using J2 objective function for 30 run times at 25% step load disturbance

J FUNC	FREQ, PTIE	RESPONSES	STD, MEAN	PSO	GA	FFA	BSA
J_2	ΔF_1	O_{sh}	STD	+0.231	+0.303	+0.243	+0.146
			Mean	+1.156	+1.004	+0.191	+1.212
		u_{sh}	STD	+0.001	+0.200	+0.002	6.3*10^-5
			Mean	-2.440	-2.412	-2.443	-2.440
		t_s	STD	+1.452	+1.143	+3.080	+0.830
			Mean	+19.09	+19.94	+23.05	+17.24
J_2	ΔF_2	O_{sh}	STD	+0.203	+0.233	+0.198	+0.123
			Mean	+0.858	+0.729	+0.154	+0.883
		u_{sh}	STD	+0.017	+0.027	+0.036	+0.010
			Mean	-2.531	-2.543	-2.603	-2.521
		t_s	STD	+0.700	+0.635	+3.206	+0.429
			Mean	+19.08	+19.15	+2.465	+18.65
J_2	ΔP_{Tie}	O_{sh}	STD	+0.015	+0.020	+0.005	+0.107
			Mean	+0.053	+0.042	+0.001	+0.556
		u_{sh}	STD	8.7*10^-4	+0.001	+0.002	66*10^-4
			Mean	-0.367	-0.368	-0.372	-0.367
		t_s	STD	+2.839	+2.461	+4.176	+1.621
			Mean	+2.140	+24.42	+31.63	+21.73
STD: Standard deviation of 30 iterations, Mean: Mean of 30 iterations							

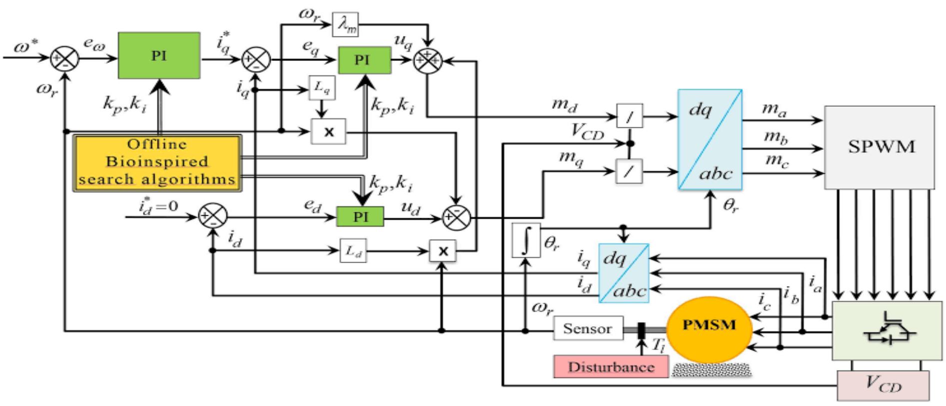
The evolution of meta heuristic algorithms has continuously developed in time. Advanced algorithms appear in each year, and it's not solely clear these algorithms add a new content for the research on the tidings computation. The demand to understand the characteristics of various algorithms has a panel of steps which include; Store a set list of solutions, to construct a mimic solution using the present data, to develop the provisional solution with a detailed local search or the next algorithm and update the set of present solution with the new solution. Most used meta heuristic algorithms are used to solve some power and energy system problems including Unit Commitment, Economic Dispatch, Optimal Load Flow and Maintenance Scheduling as seen in [47,48]

Table 4.7: Statistical results obtained by tuning PID controller through PSO, GA, FFA & BSA algorithms using J3 objective function for 30 run times at 25% step load disturbance

J FUNC	FREQ, PTIE	RESPONSES	STD, MEAN	PSO	GA	FFA	BSA
J_3	ΔF_1	O_{sh}	STD	+0.000	+0.155	+0.113	+0.064
			Mean	+0.000	+0.498	+0.122	+0.500
		u_{sh}	STD	9.1*10^-6	+0.043	+0.002	+0.003
			Mean	-2.436	-2.434	-2.417	-2.423
		t_s	STD	0.000	+1.824	+4.917	+0.328
			Mean	Unsettled	+22.54	+24.49	+21.51
J_3	ΔF_2	O_{sh}	STD	+0.000	+0.160	+0.087	+0.044
			Mean	+0.000	+0.408	+0.100	+0.342
		u_{sh}	STD	4.5*10^-16	+0.147	+0.063	+0.035
			Mean	-2.729	-2.606	-2.539	-2.561
		t_s	STD	+0.000	+2.670	+3.849	+1.163
			Mean	Unsettled	+19.04	+21.73	+18.37
J_3	ΔP_{Tie}	O_{sh}	STD	+0.000	+0.013	+0.000	+0.013
			Mean	+0.000	+0.014	+0.000	+0.013
		u_{sh}	STD	+0.000	+0.013	+0.002	+0.003
			Mean	-0.804	-0.370	-0.364	-0.366
		t_s	STD	Unsettled	+1.844	+2.333	+0.538
			Mean	Unsettled	+26.38	+31.85	+25.55
STD: Standard deviation of 30 iterations, Mean: Mean of 30 iterations							



Note: Whale Optimizer Algorithm and Offline Bio inspired Search Algorithms to tune PID controller



12. SBA Performance in the Design of a Controller integrated with Energy Storage and FACTs

A distinct strawberry algorithm (SBA) which is proposed for adjusting the parameters of PID controller in the two area multi source interconnected system which is an integration of hydro, gas and reheat thermal turbine power plants. The parameters of controller are optimized using SBA through minimization of ITAE. Using ancillary FACTS devices like Unified Power Flow Controller (UPFC) and energy storage device such as Redox Flow Batteries (RFB) are embedded in the proposed model to analyze its performance. Comparison of the simulated results of SBA with differential evaluation algorithm (DEA) at various loading condition indicates that the proposed genuine algorithm promptly performed in damping the tie line oscillation and stabilizing the frequency of the system.

12.1 Proposed model under Study

To study and analysis the proposed work, a transfer model of interconnected two area power system with the combination of multi sources thermal, hydro and gas [63, 64] along with UPFC & RFB [65] has been consider and is represented in figure. 1. Where U_T , U_G and U_H are the control outputs; K_T , K_G and K_H are the participation elements for thermal, hydro and gas units respectively; T_{SG} sec, T_t and T_r are the thermal speed governor time constant, steam turbine and reheat time constant in sec respectively; T_{GH}, T_{RH}, T_{RS} & T_W are the various time constant in penstock, speed governor reset time, speed governor transient droop and speed governor main servo in seconds respectively for hydro unit. Where as T_F is a gas unit the time constant; X_C is lead time constant and Y_C is lag time constant; c_g , b_g are the gas turbine valve position; T_{CR} and T_{CD} are the gas turbine combustion reaction time delay and discharge volume time constant in sec respectively; K_{PS} is power system gain in Hz/p.u. MW, T_{PS} is power system time constant in sec; ΔF is incremental change in frequency and ΔP_D is change in load. The vivid parameters of the system are in A.1.2

12.2 The Proposed Approach

In recent times, many control techniques and strategies have been simulated for AGC including Proportional and integral (PI), Proportional Integral Derivative (PID) and Optimal controllers [66] and variable structure control. In this reference, PID controllers are used to enhance the performance of AGC for a two area thermal system. In this work SBA is applied to tune the parameters of the PID controllers. There are three control parameters, i.e Proportional gain(K_P),Integral gain constant(K_I) and Derivative gain constant (K_D). The controllers in both the areas are considered to be identical so that $K_{P1}=K_{P2}=K_P$, $K_{I1}=K_{I2}=K_I$, and $K_{D1}=K_{D2}=K_D$. From the figure. 1 below, the error inputs to the optimal controllers are the respective area control errors (ACE) indicated by:

$$e1(t) = ACE1 = B1\Delta f1 + \Delta PTie \quad \text{Equation 5.1}$$

$$e2(t) = ACE2 = B2\Delta f2 + \Delta PTie \quad \text{Equation 5.2}$$

The controllers in both the control areas are considered to be similar i.e., $K_{P1}=K_{P2}$, $K_{D1}=K_{D2}$, $K_{I1}=K_{I2}$,. In this context, flower pollination algorithm (FPA) is used to adjust the PID controller for a two area Interconnected system. Proportional gain constant (K_{P1}), Integral gain constant (K_I), Derivative gain constant (K_D) are considered as variables describing a population defined in FPA. FPA needs a cost function which utilizes the design criteria to evaluate the flower constancy of the defined population.

An objective function is created which uses the variables of the population from FPA and passes through a model containing two area thermal system and obtains the error signals frequency, tie line power. The performance of these responses is measured using performance functions [41] like Integral of Time multiplied Absolute Error (ITAE), Integral of Time multiplied Squared Error (ITSE), Integral of Absolute Error (IAE), Integral of Squared Error (ISE), given by equations (5.5), (5.6), (5.7) and (5.8) respectively.

The control inputs of the power system u_1 and u_2 with PID structure are given by equations (5.3) and (5.4)

$$u1 = KP1ACE1 + KI1iACE1 + KD1\left(\frac{dACE1}{dt}\right) \quad \text{Equation 5.3}$$

$$u2 = KP2ACE2 + KI2iACE2 + KD2\left(\frac{dACE2}{dt}\right) \quad \text{Equation 5.4}$$

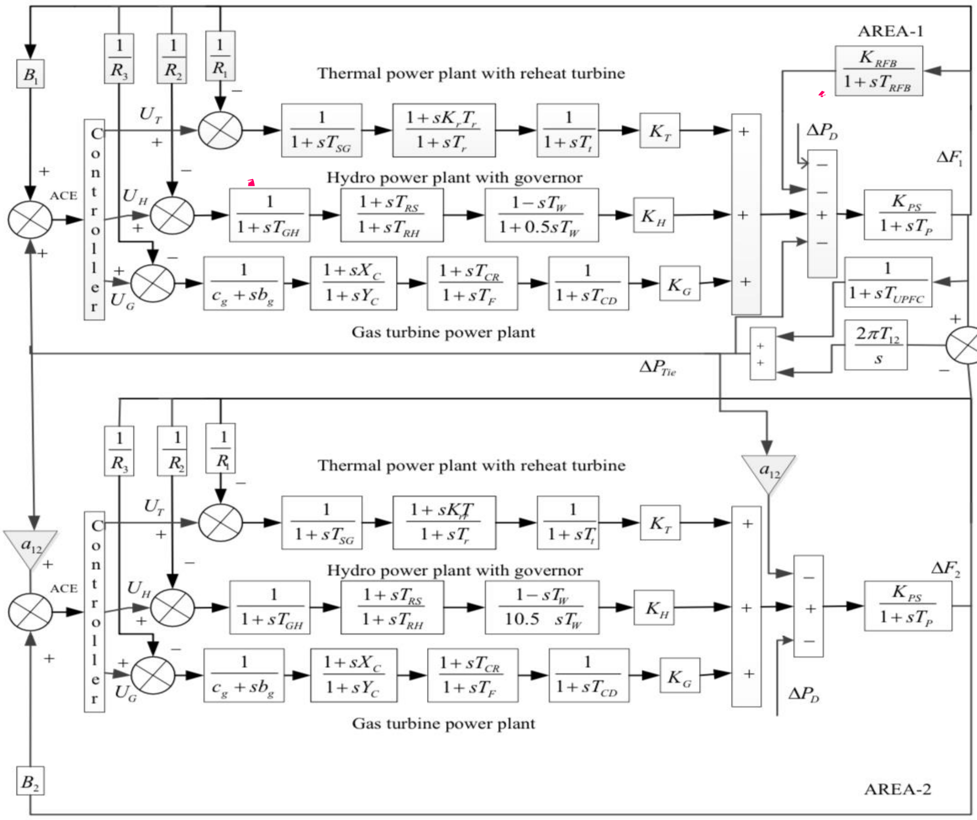


Fig. 5.1. Transfer function model of two area multi source interconnected thermal power system

$J1 = IAE = i\ 0\ to\ tsim\ [|\Delta f1| + |\Delta f2| + |\Delta PTie|].dt$ Equation 5.5

$J2 = ISE = i\ 0\ to\ tsim\ (\Delta f1)sqr + (\Delta f2)sqr + (\Delta PTie)2.dt$ Equation 5.6

$J3 = ITAE = i\ 0\ to\ tsim\ (|\Delta f1| + |\Delta f2| + |\Delta PTie|).t.dt$ Equation 5.7

$J4 = ITSE = i\ 0\ to\ tsim\ [(\Delta f1)sqr + (\Delta f2)sqr + (\Delta PT\ ie)2].t.dt$ Equation 5.8

The cost effective function is simulated to consider all the criteria through a weighted sum method and is reevaluated by equation (5.9)

$$J5 = \omega 1.IAE + \omega 2.ISE + \omega 3.ITAE + \omega 4.ITSE$$ Equation 5.9

In[67, 68], the proposed objective function was based on fixed step load perturbation and the obtained controller parameters were optimal at fixed step load. Where as in this work the objective function includes responses of various percentage step load changes, hence the designed controller parameters give optimal response under various load disturbances.

12.3 Simulation and Results

The presupposed cost function ITAE is utilized to adjust the optimal controller for postulated model with the help of SBA algorithm. The above assumed system is modeled and simulated using MATLAB 2020b version for 1% load disturbance for various loading conditions i.e 25%, 50%, 75% & 90% in Area-1 of proposed model with and without UPFC & RFB. The controlled responses Δf_1, Δf_2, ΔP_{tie} obtained for SBA tuned controllers at a particular loading conditions are shown in figs. 5.3(a), 5.3(b), 5.3(c), 5.4(a), 5.4(b) & 5.4(c).

To justify the obtained simulated responses and performance of SBA, a comparison made between SBA and DEA on the proposed model at 90% loading condition with 1% disturbance along with both UPFC & RFB were presented in figs. 5(a), 5(b)& 5(c). It is clearly observed from the simulated results that SBA performance is better as compared to DEA. The rate of convergence of SBA for the proposed model is given in figure 5.1.

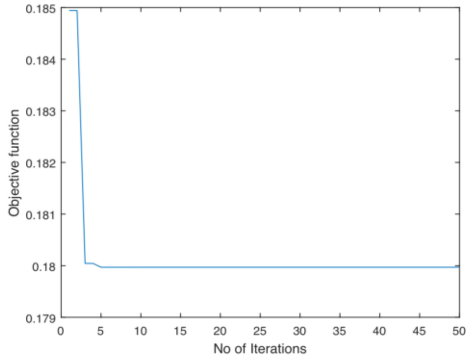


Figure 5.2: High Rate of Convergence

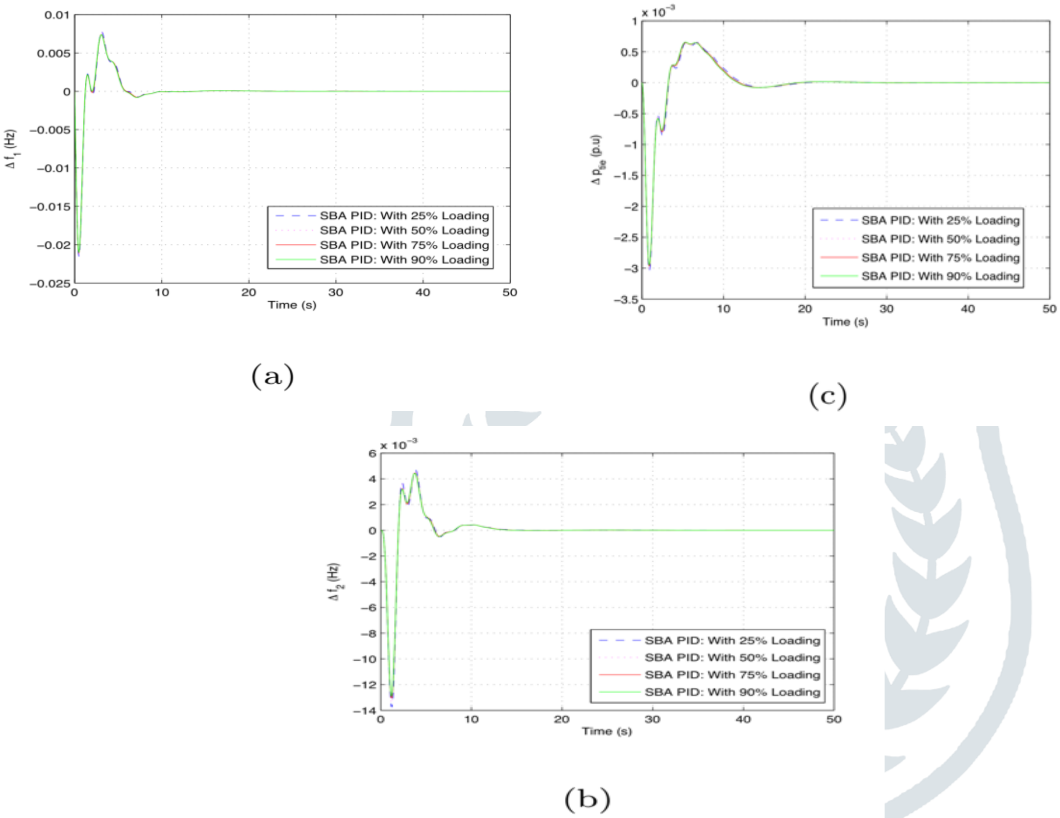
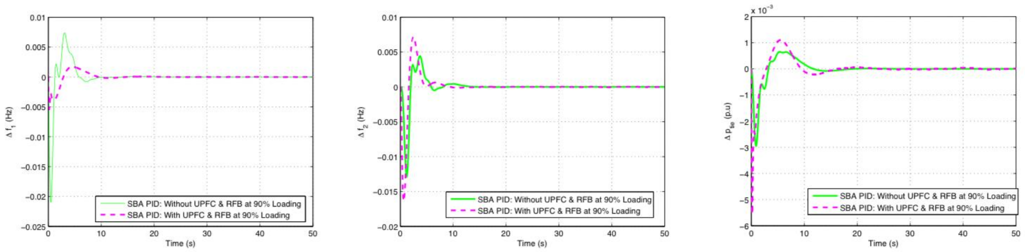


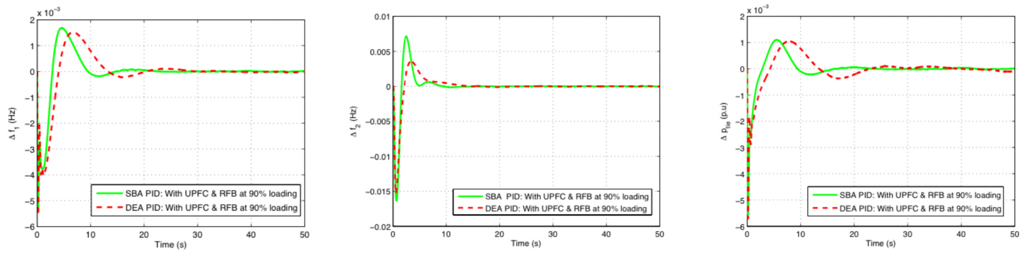
Figure 5.3: (a)Change in frequency of area-1 for various loading conditions. (b)Change in frequency of area-2 for various loading conditions. (c)Change in tie line power for various loading conditions.

The presupposed algorithm has three main differences with the trivial nature-inspired optimization methods: duplication elimination of the computational tails at all repetitions, subjecting all tails or agents to both small and large movements from the inception to end, and the lack of conveyance (information to exchange) between tails. Moreover, it has the merit of using only three parametric values to be adjusted by user. This presupposed algorithm is carried out to precisely test the functions and the scope analysis are compared with DEA, GA and PSO. The presupposed algorithm is also utilized to solve an open challenge in the field of robust control theory.



(a) (b) (c)

Figure 5.4: With & without UPFC & RFB (a)Change in frequency of area-. (b)Change in frequency of area-2. (c)Change in tie line power.



(a) (b) (c)

Figure 5.5: (a)Comparison of change in frequency of area-1. (b)frequency of area-2. (c)tie line power.

This part represents the presupposed model and performance reevaluation of FPA based Proportional Integral Derivative (PID) controllers for AGC of an interconnected electrical power system. A two-area thermal electrical power system with speed governor dead-band non-linearity is achieved for the design and scope analysis. A different technique is made to design a cost effective or multi-objective function which involves the weighted performance indexed functions such as ITSE, ITAE, ISE and IAE. These weights are the functions of the presupposed system response as modeled and simulated. It is analyzed that the dynamic indexed performance of new effective cost optimized PID controller is better than others pin pointed in the references. The cost function has performance response for different percentage of loads, so that the gain parametric values are optimal for dynamic load conditions.

13. FPA Integrated Design of a Controller using Cost Effective Function

This section depicts the design and performance analysis of FPA based Proportional Integral Derivative (PID) controllers for AGC of an interconnected power system. A two area thermal system with governor dead-band nonlinearity is considered for the design and analysis purpose. A different kind of approach is made to design a multi-objective function which contains weighted performance functions such as ISE, IAE, ISTE, ITAE. These weights are the functions of system response. It is noticed that the dynamic performance of new objective optimized PID con- troller is better than the others mentioned in the literature. The objective function also includes performance response for various percentage of loads, so that obtained gain parameters are optimal for dynamic load conditions.

13.1 Proposed model under Study

The primary objective of the Automatic generation control (AGC) is to take control of the power system frequency to the specified distinct nominal value for small disturbance in load. An interconnected thermal power system is referred in figure.6.1. Each area is gathered with the non-reheat turbine and a governor designed along with dead band non-linearity. These areas are connected through a tie line and the whole coverage system is under observation. In figure.6.1, B_1 and B_2 are the frequency (bias) parameters; ACE_1 and ACE_2 are the area control errors; U_1 and U_2 are the control outputs from the designed controller; R_1 and R_2 are the governors speed regulation values in p.u. Hz; T_{G1} and T_{G2} are the speed governor time constants denoted in seconds; ΔP_{G1} and ΔP_{G2} are the changes in governor valve positions given in (p.u.); T_{T1} and T_{T2} are the turbine time constants denoted in seconds; ΔP_{T1} and ΔP_{T2} are the changes in turbine output powers; ΔP_{D1} and ΔP_{D2} are the load demand changes; ΔP_{Tie} is the incremental change in tie line power denoted in (p.u.); K_{PS1} and K_{PS2} are the power system gains; T_{PS1} and T_{PS2} are the power system time constants noted in seconds; T_{12} is the synchronizing coefficient and Δf_1 and Δf_2 are the system frequency deviations denoted in Hz. The relevant parameters of the presupposed model are given in Appendix A.1.3. The transfer function of governor with nonlinearity is given by equation 4.1 [69]

13.2 The Proposed Approach

In recent times, many control methodologies and strategies have been proposed for AGC which include, Proportional and integral (PI), Proportional, Integral, Derivative (PID), etc [70]. In this context, PID controllers are used to improve the dynamic performance of AGC for a two area thermal power system. Where PI and PID control action depends on K_P, K_I, K_D gains which vary for different applications. The tuning of these variable depends on the desired responses of the system. The main function of AGC is to take control of load frequency and tie line power during load disturbances. So the error signals of frequency and tie line power are utilized design to tune the PID controller. The error inputs to the controllers are the respective area control errors (ACE) given by equations 6.1 and 6.2

$$e1(t) = ACE1 = B1\Delta f1 + \Delta PTie \quad \text{Equation 6.1}$$

$$e2(t) = ACE2 = B2\Delta f2 + \Delta PTie \quad \text{Equation 6.2}$$

The control inputs of the power system u_1 and u_2 with PID structure are given by equations 6.3 and 6.4

$$u1 = KP1ACE1 + KI1iACE1 + KD1\left(\frac{dACE1}{dt}\right) \quad \text{Equation 6.3}$$

$$u2 = KP2ACE2 + KI2iACE2 + KD2\left(\frac{dACE2}{dt}\right) \quad \text{Equation 6.4}$$

The controllers in both the control areas are considered to be similar i.e., K_{P1} =K_{P2}, K_{D1} = K_{D2}, K_{I1} = K_{I2},. In this context, flower pollination algorithm (FPA) is used to adjust the PID controller for a two area Interconnected system. Proportional gain constant (K_{P1}), Integral gain constant (K_I), Derivative gain constant (K_D) are considered as variables describing a population defined in FPA. FPA needs a cost function which utilizes the design criteria to evaluate the flower constancy of the defined population.

An objective function is created which uses the variables of the population from FPA and passes through a model containing two area thermal system and obtains the error signals frequency, tie line power. The performance of these responses is measured using performance functions [71]. Like Integral of Time multiplied Absolute Error (ITAE), Integral of Time multiplied Squared Error (ITSE), Integral of Absolute Error (IAE), Integral of Squared Error (ISE), given by equations (6.5), (6.6), (6.7) and (6.8) respectively.

$$J1 = IAE = i\ 0\ to\ tsim\ [|\Delta f1| + |\Delta f2| + |\Delta PTie|].dt \quad \text{Equation 6.5}$$

$$J2 = ISE = i\ 0\ to\ tsim\ (\Delta f1)sqr + (\Delta f2)sqr + (\Delta PTie)2.dt \quad \text{Equation 6.6}$$

$$J3 = ITAE = i\ 0\ to\ tsim\ (|\Delta f1| + |\Delta f2| + |\Delta PTie|).t.dt \quad \text{Equation 6.7}$$

$$J4 = ITSE = i\ 0\ to\ tsim\ [(\Delta f1)sqr + (\Delta f2)sqr + (\Delta PT\ ie)2].t.dt. \quad \text{Equation 6.8}$$

The cost effective function is simulated to consider all the criteria through a weighted sum method and is reevaluated by equation (6.9)

$$J5 = \omega1.IAE + \omega2.ISE + \omega3.ITAE + \omega4.ITSE. \quad \text{Equation 6.9}$$

where, ω1, ω2, ω3, ω4 are multiplied with IAE, ISE, ITAE, ITSE respectively. All these weights should satisfy the following equations as (6.10)

A summation of weights from i = 1 to N (Δωi) =1, ωi > 0 Equation 6.10

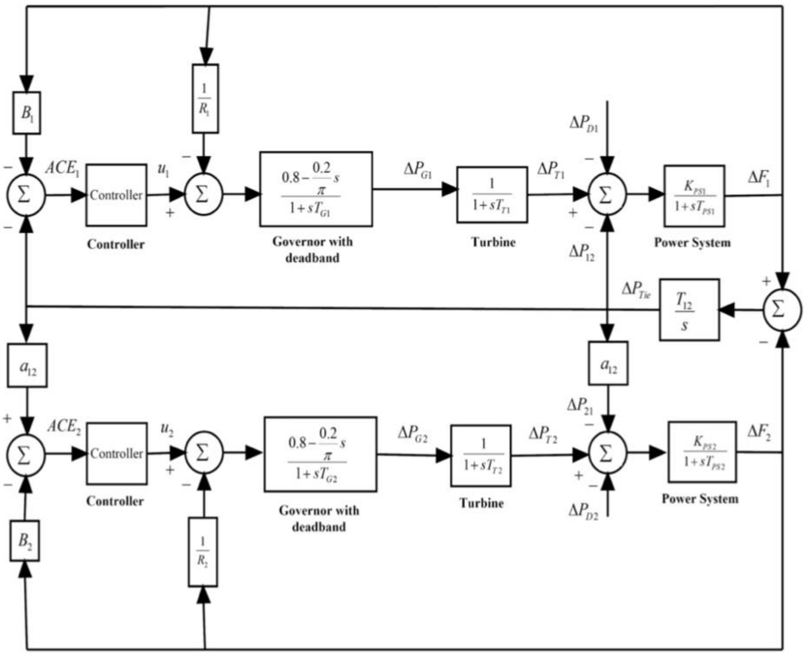


Figure 6.1: Transfer function model of two-area interconnected thermal power system

Pareto optimality is utilized for picking these weights. In this proposed model, following technique is analyzed to assign weights to the objective function. For this reason, the performance function behavior is revised from [72]. It presents the following conclusions.

- The ISE and ITSE functions are appropriate to utilize for measuring the performance index when error value is greater than one and vice versa with ITAE and IAE.
- The ITSE and ITAE are good measures when error signal holds for a long time and helps to improve the steady state error.
- While ISE and IAE are needful to mitigate the initial transients. So they are utilized when the transient time is less than one second.

The alternate responses that are investigated depicts all situations, highlighting the vivid fact, that which one of the above reevaluation criteria are better suited for steady time intervals, from a control point of reference. When a cost function gets a response from presupposed model for a population in FPA.

This response is segmented for a small range of step time. A condition is designed to utilize the conclusions of performance criteria. This condition assists to assign the highest parametric value to $\Delta\omega_{ji}$ when j^{th} performance criteria are suited for step time, while the others are assign with minimum values. Later the ωj are found from equations (6.11) and (6.12).

$$N = \text{Total simulation time/Definite time interval step} \qquad \text{Equation 6.11}$$

$$w_j = 1/N\ [\text{A summation of } j^{th} \text{ performance from } I = 1 \text{ to } N\ \Delta\omega_{ji}\ ] \qquad \text{Equation 6.12}$$

Using these weights and equation (6.9) flower constancy for FPA is found. This procedure is carried for a fixed number of iteration in FPA, then weights obtained for total best is chosen as fixed weights (or) optimal weights. The FPA restarts its procedure for finding the solution for PID controller parameters K_P, K_I, K_D using objective for which now has known weights. Thus, resolution for desired PID controller is determined. In [8, 30, 37, 38], the proposed cost function was based on fixed step load disturbance and the obtained controller parameters were optimal at fixed step load. But the presupposed system load is dynamic, so there is a requirement to make a controller that give optimal response for different load conditions. In this reference, the cost function includes responses of various percentage step load manipulations, so the designed controller parameters give optimal response for most load perturbations.

13.3 Simulation and Results

In this section a two area thermal system with governor dead band is used to hypothesize the proposed theory along with FPA. The simulation is performed by using MATLAB 2020b on a X86-64 processor base with 4GB ram. It is observed that FPA has parametric indexes p, N size of population and itermax, maximum number of iterations. The parameter p denotes the amount of global and local search for FPA. To choose this validated parameter, the per proposed method is modeled and simulated for various values of p values and this ranges from 0.1 to 1 with a step size of 0.01. The performance for parameter p and respective global minima shown in figure. 6.2 (a).

Figure: 6.2(a) shows that cost function is constantly minimized between 0.5 to 0.6. This is carried out for a number of times and in each case above condition is true, so p is chosen as 0.55. A Similar case study is done for a maximum number of iteration, which shows that after 40 iterations count value of global minima remains constant as shown in figure. 6.2(b). Similarly from the figure. 6.2(c) we have obtained the parameter population size as N = 30.

The cost function contains multiple performance criteria as mentioned in above section, with equation (6.12) a set of the combination for weights are created. These weights combined together will result in 65, 536 permutations. By using constraint equation (6.12), this number is reduced to 367. Each summation of the weights is passed through FPA and respective global minima are determined and restored. These summation of weights along with the restored vector of global minima are traced through pareto efficiency algorithm and following pareto optimal weights are determined [0.1420 0.3020 0.1290 0.4250]. These integration of weights are re-sorted according to ascending order of global minima. The first 10% of weight combinations that yields best global minima are analyzed by plotting their histogram as shown in figure. 6.2(d).

Proposed technique would divide the response like Δf_1 into definite time interval (0.01s) as shown in figure. 6.2(e). To illustrate the theory behind the proposed approach following example is made . As Δf_1 described in figure. 6.2(e) contains various points, among them a point at 1.02s is taken and it has the error value 0.1507. As per proposed theory because this point had magnitude less than one and evaluated at time greater than one, ITAE chosen to be best suited cost function for minimizing error at this point, so $\Delta \omega_{ji}$, ITAE is assigned with a higher value, while weights related to ITSE, IAE, ISE is assigned with the lowest value. Similarly this procedure is applied to Δf_2, ΔP_{tie} signals. The mean of step weights $\Delta \omega_{ji}$, three signals is found for objective function. It is followed by step weights of other performance functions.

This procedure is carried out for total simulation time (20s). Now equation (6.12) is used to find the weights ω1, ω2, ω3, ω4 from this step weight vectors. As mentioned in the proposed method, all this procedure is carried out for single population and using equation (6.9) flower constancy of the population is found. This is carried out for 20 iterations in FPA then weight obtained for total global minima is fixed and are given as [0.1255 0.1000 0.5796 0.1949]. The figure .8 shows the responses for both methods and it is observed that proposed method has slightly good response when compared to pareto method. Hence proposed method is easy to implement and is compared to pareto method.

The second aspect of proposed theory is to construct a cost function which includes a performance for various load percentages (1%, 9%, 29%, 54%, 64%, 79%, 89%) to obtain tuned parameters for a controller of considered system. This yielded gain parameters which is optimal for any load manipulation between (1 to 100%). These gain parameters were tested for 15.00%, 36.00%, 54.00%, 72.00% load disturbance. Again obtained gain parameters tuned for 15.00% fixed load and test for 36.00%, 54.00%, 72.00% load changes. The similarity of the above two performances is seen in the Figures. 9, 10 and 11 for $\Delta f1$, $\Delta f2$, ΔP_{tie} respectively. It is concluded that chosen parameters for presupposed method are optimal for most load manipulations, so these could give optimal performance for dynamic loads also.

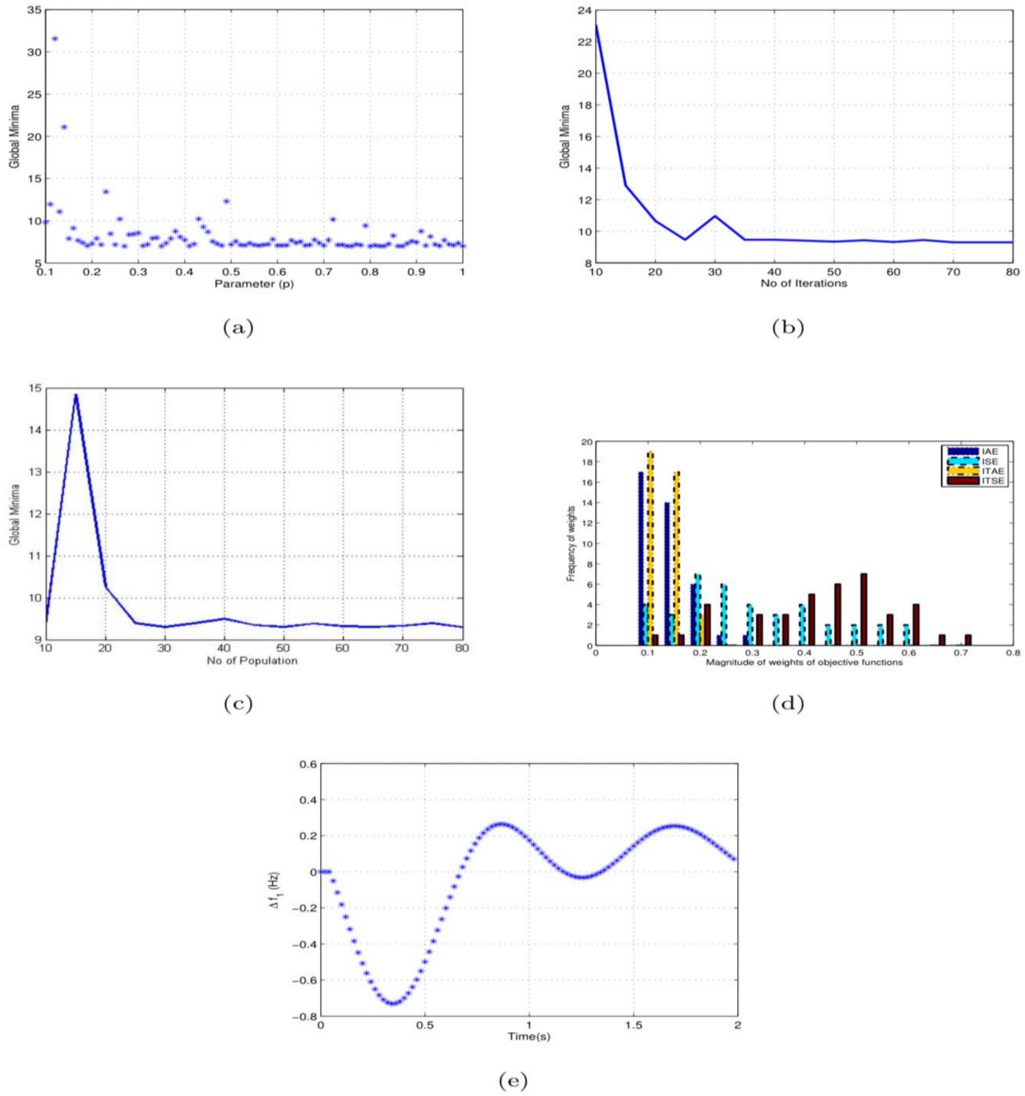


Figure 6.2: (a) Change in the global minima with respect to Parameter p of FPA. (b) Change in the global minima with respect to Number of Iteration of FPA. (c) Change in the global minima with respect to Population of FPA. (d) Magnitude of the weights of cost functions Vs Frequency of the weights. (e) Discrete response from presupposed model for Δf_1 Vs time.

A new kind of approach is made to design a multi-objective or cost function which contains weighted optimization functions. This technique takes less effort to obtain the weights for multi objective function. With a single run of the approached algorithm yields both optimal weights and global minimum. The performance of the results are comparable with pareto optimal solution.

Where the cost function also includes performance response for a various percentage of loads so that obtained gain parameters are optimal for different load conditions and this change could be observed in Δf_1, Δf_2, ΔP_{tie} responses. Cost effective design optimization problems need multi objective optimization methods to resolve the challenges, and it it is often very problematic to obtain high quality Pareto fronts precisely.

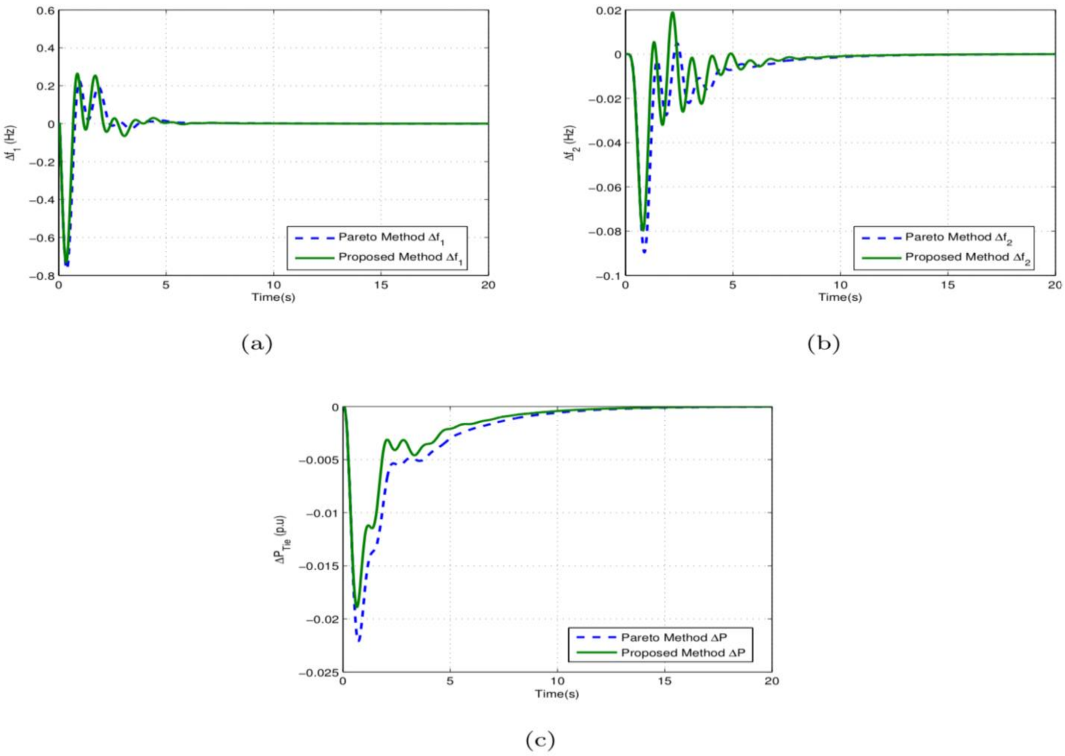


Figure 6.3: Comparison of proposed and pareto methods with variations in the frequency of Area 1, Frequency of Area 2 and Tie line power flow. (a)Δf_1 (b)Δf_2 (c)ΔP_{tie}

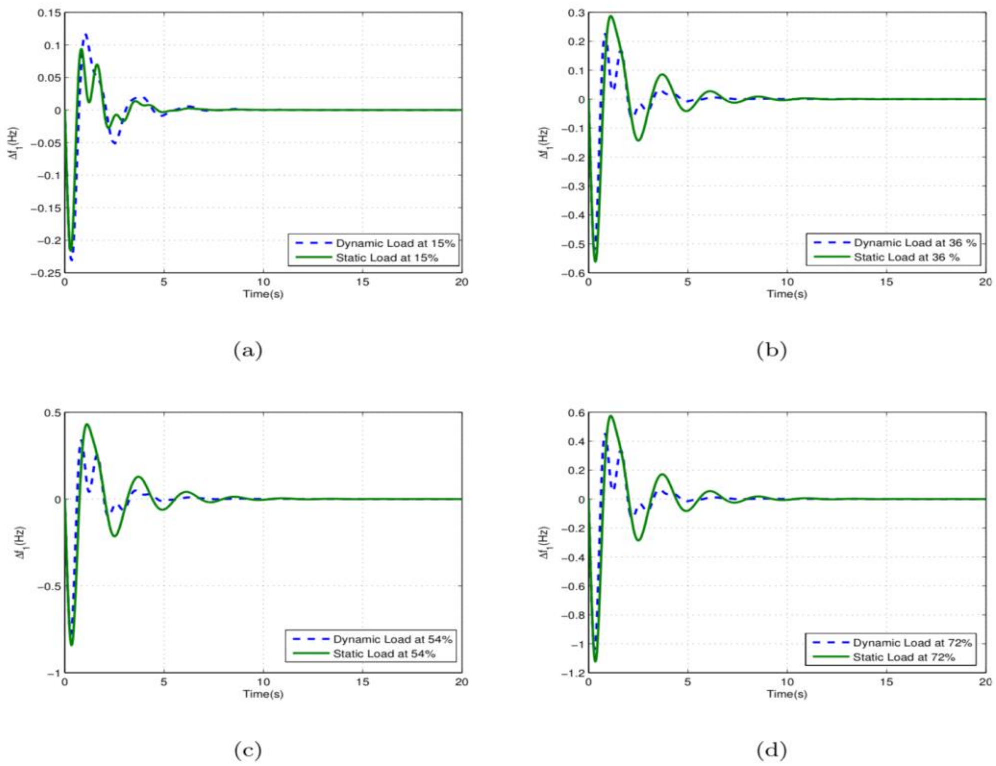


Figure 6.4: Change in the Frequency of Area 1 (a) At 15% load variation. (b) At 36% load variation. (c) At 54% load variation. (d) At 72% load variation.

FPA is extended to resolve cost effective optimization problems and the comparison of the presupposed algorithm has been observed which depicts that FPA is efficient with a better convergence rate.

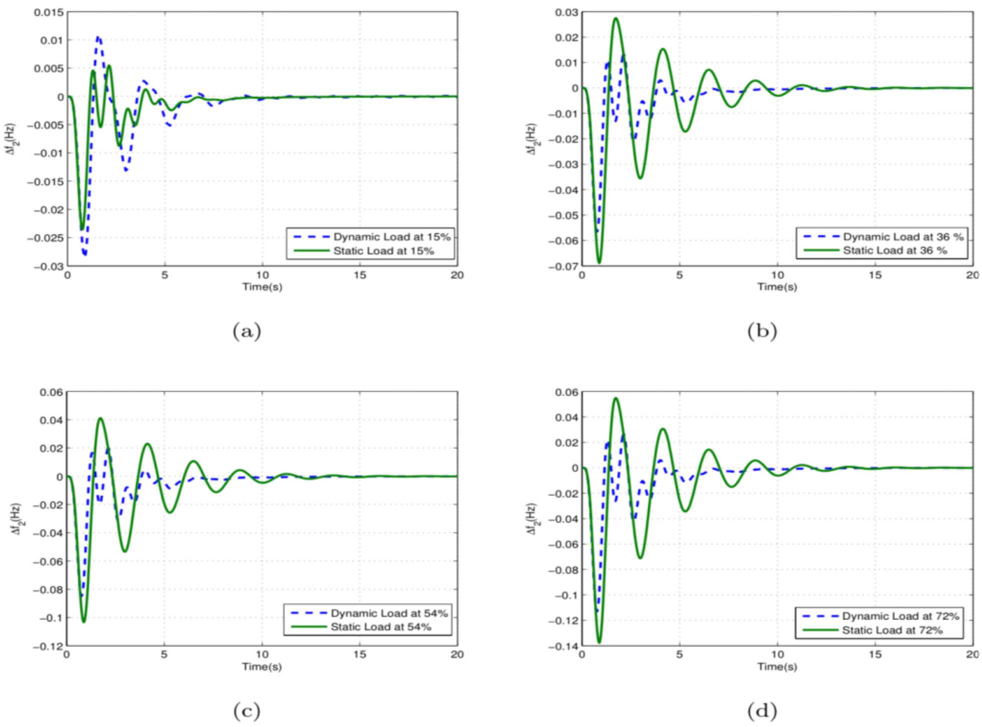


Figure 6.5: Change in the FREQUENCY of AREA-2 (a)At 15% load perturbation. (b)At 36% load perturbation. (c)At 54% load perturbation. (d)At 72% load perturbation.

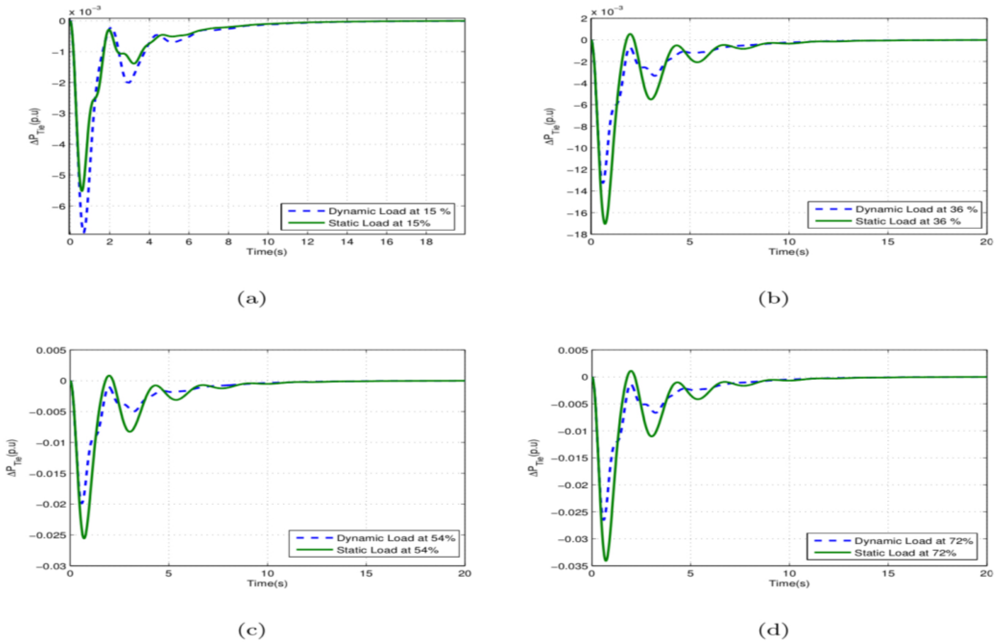


Figure 6.6: Change in the TIE LINE POWER (a)At 15% load perturbation . (b)At 36% load perturbation . (c)At 54% load perturbation. (d)At 72% load perturbation.

14. Conclusion and Scope for Future Applications

The optimal building of controllers does not only develop with the category of objective function and constraints used but also with the methodologies that will foster these objectives. New meta-heuristic algorithms like BSA & FFA were used for optimal design of controller in two area interconnected reheat thermal power system at numerous percentage load perturbations. At the instant comparison of time domain responses in terms of undershoot, overshoot & settling time were also sketched and depicts approximately outcomes. A sensitivity analysis of system parameters of the model under investigation were considered in the range of −25% to +25% change with respect to their nominal values.

It is observed that BSA has least standard deviation for all response characteristics which shows better concurrency as compared with the other algorithms . Statistical tidings to evaluate the meta-heuristic algorithms like FFA& BSA and their precursors like GA, GA-PSO, PSO were also obtained. Further analysis as disused on the literature point of view, Strawberry (SBA) Algorithm proved to obtain better results in the performance and design of controllers. Current study on the design of ALFC controller has ignited some solutions over the least areas of research which are broadly important for efficient and optimum operation of an electrical power system network as considered in the proposed model.

Scope for Future Applications: As ALFC control is through remote operation attained by an entity for instance Independent system operator (ISO) which is distant from generating units and stations. But the decentralized control unit is placed in each of these generation stations whose integral operation would yield good performance than the present ALFC. The advancement of decentralized control is in its theoretical level. Hence there is a further scope in this direction of research and analysis. The integration of more renewable energy to an electrical power system demands good controllers because they do not evolve natural inertia based kinetic energy to provide sudden deficiency of power. Modeling of these systems, evaluation and control performance w.r.t

ALFC is a problem and requires time and resources. Due to deregulation of power system there is large increase in private partnerships for production and transmission of power through the electrical power system network. They are done based on power purchase agreement (PPA) which involves power transfer from one control area to another area. The private partnerships participants do not regulate the system parameters but employee ISO to provide spinning reserves to attain frequency and other parameters.

Declaration

I hereby declare that the project embodied and entitled MAKE IN TANZANIA submitted to the Hon. President Samia Suluhu Hassan and to be coordinated by the Ministry of Investment, Industry and Trade and to be funded by the Ministry of Finance and Planning is an independent task carried out under the supervision and guidance of Hamad Hilal Mansoor, Business Owner and M.D. of H. H. Mansoor Transporters Co. Ltd., Shekha Ahmed Salum, Mother of Ahmed H. H. Mansoor.

Additional mentorship from Mufti Abubakar Zubeir Ally of Tanzania., Dr. Amit Kumar Singh, Assistant Professor, L.P.U, Dept. of Electrical and Electronics Engineering., , Dr. Kishor Bhanushali, Academic Researcher, Karnavati University, United World Business School., Ramla Said Ahmed, M.D. of Sara Day Care., Hon. Salaam Khamis Salum, M.D. of Jambo Group of Companies., Fatina Senzota Said, Business Owner and M.D. of Alfa Education Centre Limited (Alpha Schools), Jafra Investment Co. Ltd and FMJ Hardware., Hon. Said Pamui, Former CRDB Zonal Manager Shinyanga Region.

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Conflicts of Interest: The Authors declare no conflict of interest.

Appendix A

System Parameters and Pseudo Coding

A.1 Nominal Parameters of the proposed approach

Table A.1.1: Parameters of two area multi source interconnected thermal power system

Variables	Typical Values
B_1, B_2	0.4312p.u.MW/Hz, 0.4312p.u.MW/Hz
R_1, R_2	2.4Hz/p.u, 2.4Hz/p.u
T_{SG}	0.08s
T_t	0.3s
K_R	0.3
T_R	10s
K_{ps1}, K_{ps2}	68.9566Hz/p.u.MW, 68.9566Hz/p.u.MW
T_{ps1}, T_{ps2}	11.49s, 11.50s
T_{12}	0.0433
A_{12}	-1
T_w	1s
T_{RS}	5s
T_{RH}	28.75s
T_{GH}	0.2s
X_C	0.6s
Y_C	1s
C_g	1
B_g	0.05s
T_F	0.23s
T_{CR}	0.01s
T_{CD}	0.2s
K_T	0.543478
K_H	0.326084
K_G	0.130438
K_{DC}	1
K_{RFB}	0.67
T_{RFB}	0s
T_{UPFC}	0.01s

Table A.1.2: Parameters of two-area interconnected thermal power system

Variables	Typical Values
f	60HZ
B_1, B_2	0.045, 0.045
R_1, R_2	2.4Hz/p.u, 2.4Hz/p.u
T_{g1}, $-T_{g2}$	0.08s, 0.08s
T_{t1}, T_{t2}	0.3s, 0.3s
T_{r1}, T_{r2}	10s, 10s
T_{p1}, T_{p2}	20s, 20s
K_{r1}, K_{r2}	0.5, 0.5
K_{p1}, K_{p2}	120Hz/p.u.MW, 120Hz/p.u.MW

Table A.1.3 : Parameters of two area interconnected reheat thermal power system

Variables	Typical Values
f	60Hz
B_1, B_2	0.045, 0.044
R_1, R_2	2.39, 2.4O Hz/p.u.
$T_{g1}, -T_{g2}$	0.08s
T_{r1}, T_{r2} | T_{p1}, T_{p2}	10.00s | 20.00s
T_{t1}, T_{t2}	0.30s
K_{r1}, K_{r2}	0.50
K_{p1}, K_{p2}	120Hz/p.u.MW

Table A.1.4 : Abbreviations

S.No.	Acronym	Description
1	MIIT	Ministry of Investment, Industry and Trade
2	UNIDO	United Nations Industrial Development Organization
3	EODB	Easy of Doing Business
4	FDI	Foreign Direct Investment
5	LGBR	Load Generation Balance Report
6	IPR	Intellectual Property Rights
7	DPIIT	Department for Promotion of Industry and Internal Trade
8	CT	Current Transformer
9	CB	Circuit Breaker
10	PT	Power Transformer
11	CVT	Capacitive Voltage Transformer
12	SA	Surge Arresters
13	CBM	Condition Based Maintenance
14	XLPE	Cross Linked Polyethylene
15	O&M	Operation and Maintenance
16	OEM	Original Equipment Manufacturer
17	UPS	Uninterruptible Power Supply
18	IPS	Integrated Plastic Systems
19	MDI	Max Demand Incentive
20	RTV	Room Temperature Vulcanization
21	IR/TR	Power (I*R) / Turns Ratio
22	SFRA	Sweep Frequency Response Analysis
23	ICT	Inter Connecting Transformer
24	GT	Generator Transformer
25	OLTC	On Load Tap Changer
26	POSOCO	Power System Operation Corporation
27	CEA	Central Electricity Authority
28	DGA	Dissolved Gas Analysis
29	CBIP	Central Board of Irrigation and Power
30	EHV	Extra High Voltage
31	EMU	Electromagnetic Unit
32	FR	Ferro Resonance
33	IR	Insulation Resistance
34	DCRM	Dynamic Constant Resistance Measurement
35	PD	Potential Discharge
36	SVL	Stealth Voltage Limiter
37	DTS	Distributed Temperature Sensor
38	APFC	Auto Power Factor Correction
39	IC	Integrated Circuit
40	MD – XL	Ultra Heavy Duty – Low Voltage Capacitor

41	**HT**	High Tension
42	**MCCB**	Modded Case Circuit Breaker
43	**IEC**	International Electrotechnical Commission
44	**HRC Fuse**	High Rupturing Capacity Fuse
45	**LA**	Lead Acid batteries
46	**TANESCO**	Tanzania National Electric Supply Company
47	**kW**	Kilowatt
48	**kVAR**	KiloVoltAmpere Reactive
49	**kVA**	KiloVoltAmpere
50	**CSD**	Carbonated Soft Drinks
51	**MU**	Million Units
52	**MW**	Mega Watt
53	**IEM**	Industrial Entrepreneur Memorandum
54	**NDC**	National Development Corporation
55	**SIDO**	Small Industries Development Organization
56	**TIRDO**	Tanzania Industrial Research Development Organization
57	**TEMDO**	Tanzania Engineering and Manufacturing Design Organization
58	**TBS**	Tanzania Bureau of Standards
59	**WMA**	Weights and Measures Agency
60	**BRELA**	Business Registration and Licensing Agency
61	**EPZA**	Export Processing Zones Authority
62	**TANTRADE**	Tanzania Trade Development Authority
63	**FCT**	Fair Competition Tribunal
64	**NCAC**	National Consumer Advocacy Council
65	**NEEC**	National Economic Empowerment Council
66	**CAMARTEC**	Center for Agricultural Mechanisation of Rural Technology
67	**TIC**	Tanzania Investment Center
68	**CBE**	College of Business Education
69	**FCC**	Fair Competition Commission
70	**WRRB**	Warehouse Receipt Regulatory Board
71	**SCALE**	Steering Committee for Advancing Local Value-add Employability
72	**FTCCI**	Federation of Tanzania Chambers of Commerce and Industry
73	**CTI**	Confederation of Tanzania Industry
74	**ASSOCHAM**	Associated Chambers of Commerce and Industry
75	**DGFT**	Directorate General of Foreign Trade
76	**ODOP**	One District One Product
77	**TSWS**	Tanzania Single Window System
78	**IPRS**	Industrial Parking Rating System
79	**SEZs**	Special Economic Zones
80	**CIPAM**	Cell for IPR Promotion and Management
81	**TRIPS**	Trade-Related Aspects of IPRs
82	**MOU**	Memorandum of Understanding
83	**MOA**	Memorandum of Association
84	**MOC**	Memorandum of Cooperation
85	**NDA**	Non-Disclosure Agreement
86	**CGPDTM**	Controller General of Patents, Designs and TradeMark
87	**NID**	National Institute of Design
88	**TIT**	Tanzania Institutes of Technology
89	**NIT**	National Institutes of Technology
90	**TDC**	Tanzania Design Council
91	**BRAP**	Business Reforms Action Plan
92	**PPP-MIT**	Public Procurement (Preference to Make in Tanzania)

93	**GeM**	Government e-Market Portal
94	**PMG**	Project Monitoring Group
95	**TMP**	Tanzania Master Plan
96	**TICE**	Tanzania Informatics Centre of Excellence
97	**TICP**	Tanzania Industrial Corridor Programme
98	**TIIUS**	Tanzania Industrial Infrastructure Upgradation System
99	**TPC**	Tanzania Productivity Council
100	**QCT**	Quality Council of Tanzania
101	**QCO**	Quality Control Orders
102	**TABL**	Tanzania Accreditation Boards for Testing and Callibration Laboratories
103	**TABH**	Tanzania Accreditation Boards for Hospitals and Heatlcare Providers
104	**TABET**	Tanzania Accreditation Boards for Education and Training
105	**ZED**	Zero Defect Zero Effect
106	**PADD**	Project Analysis & Documentation Division
107	**PPID**	Project Planning & Implementation Division
108	**URO**	UNIDO Regional Office
109	**UR**	UNIDO Representative
110	**FIC**	Facility for International Cooperation
111	**ISID**	Inclusive and Sustainable Industrial Development
112	**LOI**	Letter of Intent
113	**WPI**	Wholesale Price Index
114	**ITeC**	Industrial Trade and e-Commerce
115	**WTO**	World Trade Organization
116	**FTA**	Free Trade Agreement
117	**ONDC**	Open Network for Digital Commerce
118	**TBS**	Tanzania Bureau of Standards
119	**MDI**	Medical Devices Industry
120	**PDC**	Project Development Cell
121	**ICC**	Investment Clearance Cell
122	**PSUs**	Public Sector Undertakings
123	**IIP**	Index of Industrial Production
124	**GDP**	Gross Domestic Product
125	**GIS**	Geographical Information System
126	**NPG**	Network Planning Group
127	**EGoS**	Empowered Group of Secretaries
128	**DBR**	Doing Business Report
129	**BRELA**	Business Registration and Licensing Agency
130	**OBPS**	Online Building Permission System
131	**FFS**	Fund of Funds for Startups
132	**AIFs**	Alternate Investment Funds
133	**STSFS**	Startup Tanzania Seed Fund Scheme
134	**IMB**	Inter-Ministerial Board
135	**SIM**	Samia Innovation Mission
136	**CP**	Country Program
137	**UNSDF**	United Nations Sustainable Development Framework
138	**UNCT**	United Nations Country Team
139	**UNRC**	United Nations Resident Coordinator
140	**ISA**	International Solar Alliance
141	**NCAP**	National Clean Air Program
142	**IDF**	Industrial Development Fund
143	**ACE**	Area Control Error
144	**AGC**	Automatic Generation Control
145	**LFC**	Load Frequency Control

146	**SBA**	Strawberry Algorith
147	**FPA**	Flower Pollination Search Algorithm
148	**DEA**	Differential Evolution Algorithm
149	**FACTS**	Flexible AC Transmission Systems
150	**FFA**	Fruit Fly Optimisation Algorithm
151	**BSA**	Backtracking Search Optimisation Algorithm
152	**GA**	Genetic Algorithm
153	**GRC**	Generation Rate Constraint
154	**IAE**	Integral of Absolute Error
155	**ISE**	Integral of Squared Error
156	**ITAE**	Integral of Time Multiplied Absolute Error
157	**ITSE**	Integral of Time Multiplied Squared Error
158	**LFC**	Load Frequency Control
159	**PI**	Proportional plus Integral
160	**PID**	Proportional Integral Derivative
161	**PSO**	Particle Swarm Optimisation
162	**GC**	Generation Control
163	**UPFC**	Unified Power Flow Controller
164	**RFB**	Redox Flow Battery

A.2 SBA and FPA Coding

STRAWBERRY ALGORITHM

Part:1 straw.m

clc; clear all

N = 50; %number of mother plants; N must be an even number
m = 3; %number of variables
ul = [-2 -2 -2]; %lower bound of variables
uh = [2 2 2]; %upper bound of variables
z=ones(1,N);
drunner = 50; %length of runners
droot = 5; %length of roots
a = 0; %used in the definition of fitness function
kmax = 50; %maximum number of iterations or repetitions at each run
r1 = ul'*z+(uh-ul)'*z.*rand(m,N); %each column of r1 represents the location
f_best = 100; %an arbitrary initial value for f_best. %f_best contains the best (minimum) value obtained for objective function so far.
f = zeros(1, 2*N); %the i-th column of f contains the value of objective function when the i-th column of r2 is substituted in it
x_best = ones(m,1); %x_best involves the best solution performed so far (at each iteration and run)
for k=1:kmax %each run (simulation) stops after kmax iterations
r2 = [r1+drunner*(rand(m,N)-.5) r1+droot*(rand(m,N)-.5)];
for i=1:m for j=1:N*2 if r2(i,j)>uh(i) r2(i,j) = uh(i); %if a solution (runner or root) lies at the margin of the legal area, it is put at the apex
end f = for end for end elseif r2(i,j)<ul(i) r2(i,j) = ul(i); end end
zeros(1, 2*N); j=1:2*N f(j) = objective_fun(r2(:,j)'); f_sorted = sort(f,'ascend ');
j =1:N/2 r1(:,j) = r2(:,find(f==f_sorted(j),1)); %fitness evaluation
for j=1:2*N if f(j)>0 weights(j) = 1/(a+f(j)); else weights(j) = a+abs(f(j)); end end
for j=N/2+1:N chosen_index = fortune_wheel(weights);

```
r1(:,j) = r2(:,chosen_index); end if min(f)<f_best f_best = min(f) x_best = r2(:,find(f==min(f),1)) end best_so_far
= f_best; X = f_best; end
x_best f_best kp1=x_best(1); ki1=x_best(2); kd1=x_best(3);
open('E:\Ahmed_11919183\Running\SBA\Three_Area_Thermal_Hydro_Gas_UPFC_RFB ');
opt=simset('srcworkspace ','current ');
sim('E:\Ahmed_11919183\Running\SBA\Three_Area_Thermal_Hydro_Gas_UPFC_RFB ',[0 50], opt );
```

Part:2 Objective Function

```
function H=objective_fun(x_best) kp1=x_best(1); ki1=x_best(2); kd1=x_best(3);
open('E:\Ahmed_11919183\Running\SBA\Three_Area_Thermal_Hydro_Gas_UPFC_RFB ');
opt=simset('srcworkspace ','current ');
sim('E:\Ahmed_11919183\Running\SBA\Three_Area_Thermal_Hydro_Gas_UPFC_RFB ',[0 50],
opt ); H=max(itae);
```

Part:3 Fortune_wheel

```
function choice = fortune_wheel(weights)
accumulation = cumsum(weights);
p = rand() * accumulation(end); chosen_index = -1;
for index = 1 : length(accumulation)
if (accumulation(index) > p) chosen_index = index; break; end end
choice = chosen_index;
```

FLOWER POLLINATION ALGORITHM

Part:1 new_fpa_opt.m

```
clear all; clc;
para =[40 0.7]; n=para(1); p=para(2); N_iter =30;
d=3; Lb =[0 0 0]; Ub =[10 10 10]; sol=ones(n,d); for i=1:n, sol(i,:)=Lb+(Ub-Lb).*rand(1,d); kp1=sol(i,1);
ki1=sol(i,2); kd1=sol(i,3); kp2=kp1; ki2=ki1; kd2=kd1;
fitness(i)=objective_fun_mod(kp1,ki1,kd1,kp2,ki2,kd2); end
[fmin,I]=min(fitness); best=sol(I,:);
s=sol; for t=1:N_iter; for i=1:n, if rand>p, L=Levy(d);
dS=L.*(sol(i,:)-best); s(i,:)=sol(i,:)+dS; s(i,:)=simplebounds(s(i,:),Lb,Ub); else epsilon=rand;
JK=randperm(n); s(i,:)=s(i,:)+epsilon*(sol(JK(1),:)-sol(JK(2),:)); s(i,:)=simplebounds(s(i,:),Lb,Ub); end
kp1=s(i,1); ki1=s(i,2); kd1=s(i,3); kp2=kp1; ki2=ki1; kd2=kd1;
fnew=objective_fun_mod(kp1,ki1,kd1,kp2,ki2,kd2);
if (fnew<=fitness(i)),
sol(i,:)=s(i,:); fitness(i)=fnew; [fmin,I]=min(fitness); best=sol(I,:); end end end
disp(['Total number of evaluations ',num2str(N_iter*n)]);
disp(['Best Solution =', num2str(best),'fmin=',num2str(fmin)]);
kp2=best(1); kp1=kp2; ki1=best(2); ki2=ki1; kd1=best(3); kd2=kd1; %lo=0.25;
open('E:\Ahmed_11919183\Revise\FPA\Matlab_Programming\Main_Program_Static\PID\One');
sim('E:\Ahmed_11919183\Revise\FPA\Matlab_Programming\Main_Program_Static\PID\One');
```

Part:2 Objective Function

```
function [J5]=objective_fun_mod(kp1,ki1,kd1,kp2,ki2,kd2)
J1 =0; J2 =0; J3 =0; J4 =0; [t,delf1,delf2,delP]=sim_data(kp1,ki1,kd1,kp2,ki2,kd2); for k=1:length(t),
T=t(k); F1=abs(delf1(k)); F2=abs(delf2(k)); P=abs(delP(k)); if (T <=1.25)
if(P<0.1&&(F1<1||F2<1)||P<0.01) w1 =0.6; w2 =0.2; w3 =0.1; w4 =0.1;
else w1 =0.2; w2 =0.6; w3 =0.1; w4 =0.1; end else
```

```
if(P<0.1&&(F1<1||F2<1)||P<0.01) w1 =0.1; w2 =0; w3 =0.8; w4 =0.1; else w1 =0.1; w2 =0.1; w3 =0.2; w4 =0.6;
end end
J1=J1+w1*(F1+F2+P*10); J2=J2+w2*(F1*F1+F2*F2+P*P); J3=J3+w3*T*(F1+F2+P*10);
J4=J4+w4*T*(F1*F1+F2*F2+P*P);
End
J5=J1+J2+J3+J4;
```

Part:3 Sim_data

```
function[t,freq1,freq2,Ptie]=sim_data(kp1,ki1,kd1,kp2,ki2,kd2)
open('E:\Ahmed_11919183\Revise\FPA\Matlab_Programming\Main_Program_Static\PID\One');
opt=simset('srcworkspace','current');
sim('E:\Ahmed_11919183\Revise\FPA\Matlab_Programming\Main_Program_Static\PID\One',[0 20],opt);
t=delta_f(:,1);
freq1=delta_f(:,2); freq2=delta_f1(:,2); Ptie=delta_p(:,2);
```

Part:4 simplebouns

```
function s =simplebounds(s,Lb,Ub)
ns_tmp=s; I=ns_tmp <Lb; ns_tmp(I)=Lb(I); J=ns_tmp >Ub; ns_tmp(J)=Ub(J); s=ns_tmp;
```

A.3 FFA and BSA Coding

FRUIT FLY ALGORITHM PSEUDO CODING

Part:1 FFA.m

```
clc; clear all; %function [del_f1,del_f2,del_p]=fruit_fly()
maxgen =100; parameters =3; popsize =30; %initialization of parameters
X=zeros(popsize, parameters); Y=zeros(popsize, parameters);
S=zeros(popsize, parameters);
D=S;% intialize the location of flies;
for j=1:parameters,
X_axis(j)=10*rand(); Y_axis(j)=10*rand();
End
for i=1:popsize, for j=1:parameters, %initialisation of population
X(i,j)=X_axis(j)+2*rand()-1; Y(i,j)=Y_axis(j)+2*rand()-1; D(i,j)=(X(i,j)^2+Y(i,j)^2)^0.5; S(i,j)=1/D(i,j);
end
kp=S(i,1); ki=S(i,2); kd=S(i,3);
smell(i)=objective_fun(kp,ki,kd);
end
[bestsmell bestindex]=min(smell);
for j=1:parameters, X_axis(j)=X(bestindex ,j); Y_axis(j)=Y(bestindex ,j); end
Smellbest= bestsmell;
for gen =1: maxgen, for i=1:popsize, for j=1:parameters ,
```

```
X(i,j)=X_axis(j)+2*rand()-1; Y(i,j)=Y_axis(j)+2*rand()-1; D(i,j)=(X(i,j)^2+Y(i,j)^2)^0.5; S(i,j)=1/D(i,j);
end
kp=S(i,1); ki=S(i,2); kd=S(i,3); smell(i)=objective_fun(kp,ki,kd); end
[bestsmell bestindex]=min(smell);
if bestsmell >Smellbest for j=1:parameters ,
X_axis(j)=X(bestindex ,j); Y_axis(j)=Y(bestindex ,j); Z_axis(j)=Z(bestindex ,j); end
Smellbest=bestsmell; end  end
kp1=S(bestindex ,1); ki1=S(bestindex ,2); kd1=S(bestindex ,3); kp2=kp1;ki2=ki1;kd2=kd1;
open('D:\ELE569_Ahmed(11919183)\Accepted\FFA_rev_2\FFA\FFA_pid\Two_Reheat_PID_Normal'); opt=simset('srcworkspace','current');
sim('D:\ELE569_Ahmed(11919183)\Accepted\FFA_rev_2\FFA\FFA_pid\Two_Reheat_PID_Normal ',[0 25], opt);
```

Part:2 FFA Cost/Objective function

```
function H=objective_fun(x,y,z)
kp1=x; ki1=y; kd1=z; kp2=x; ki2=y; kd2=z;
open('D:\ELE569_Ahmed(11919183)\Accepted\FFA_rev_2\FFA\FFA_pid\Two_Reheat_PID_Normal');
opt=simset('srcworkspace','current');
sim('D:\ELE569_Ahmed(11919183)\Accepted\FFA_rev_2\FFA\FFA_pid\Two_Reheat_PID_Normal ',[0 25], opt); H=max(itae);
```

BACKTRACK SEARCH ALGORITHM PSEUDO CODING

Part1: BSA.m

```
clc; clear all;
N=20; %pop size
D=3; %dimension of parameter
max_cycle =100; %max iteration
mixrate =0.5; %parameter to control rate  crossover
low=[-2,-2,-2]; %bound constraints of parameters
upper =[2 ,2 ,2]; globalminimum=inf;
for i=1:N, %intialize population
P(i,:)=low+(upper-low).*rand(1,D);  oldP(i,:)=low+(upper-low).*rand(1,D);
fitnessP(i)=objective_fun(P(i,:)); end
for g=1:max_cycle , a=rand; b=rand;
if(a<b) for i=1:N 1=randi(N); k=randi(N);
tp=oldP(1,:); oldP(l,:)=oldP(k,:); oldP(k,:)=tp;
```

```
end %permuting the arbitrary change in the old population
end
mutant=P+rand*3*(oldP-P); map=ones(N,D); c=rand; d=rand;
for i=1:N,if (c<d)
map(i,1:round(mixrate*rand*D))=0; else map(i,randi(D))=0; end  end
T=mutant;  for i=1:N for j=1:D if map(i,j)==1
T(i,j)=P(i,j);%crossover operation based on thhe map values end
if (T(i,j)<low(j)||T(i,j)>upper(j)) % if unbounded then we randomly initiate
T(i,j)=low(j)+rand*(upper(j)-low(j)); end end
fitnessT(i)=objective_fun(T(i,:)); end
for i=1:N, if(fitnessT(i)<fitnessP(i))  fitnessP(i)= fitnessT(i); P(i,:)=T(i,:); end end
[Pbest,I]=min(fitnessP); if(Pbest<globalminimum) globalminimum=Pbest globalminimizer=P(I,:) end end
kp1=globalminimizer(1);ki1=globalminimizer(2);kd1=globalminimizer(3); kp2=kp1; ki2=ki1; kd2=kd1;
open('E:\ELE569_Ahmed(11919183)\Running\BSA\Two_Area_Interconnected_Reheat_TPS');
opt=simset('srcworkspace','current');
sim('E:\ELE569_Ahmed(11919183)\Running\BSA\Two_Area_Interconnected_Reheat_TPS ',[0 25], opt)
```

Part:2 BSA Cost/Objective Function

```
function H=objective_fun(x) kp1=x(1); ki1=x(2); kd1=x(3); kp2=kp1;  ki2=ki1;  kd2=kd1;
open('E:\ELE569_Ahmed(11919183)\Running\BSA\Two_Area_Interconnected_Reheat_TPS');
opt=simset('srcworkspace','current');
sim('E:\ELE569_Ahmed(11919183)\Running\BSA\Two_Area_Interconnected_Reheat_TPS ',[0 25], opt);
H=max(itae);
```

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