Fuzzy logic load frequency control of multi-area power system

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Abstract— Energy is the defining need of the 21st century & electrical energy has replaced most of the other conventional sources of the energy due to its cost, reliability & other advantages. The demand for electricity is rapidly increasing & thus integration of renewable energy generation plants in a multi area generation setup is required. This work aims at optimization of operational cost of power generation in a multi area power generation System comprised of various types of power generation setups such as non-renewable ones, Thermal & nuclear as the renewable ones such as solar or wind. The proposed work aims at development of fuzzy logic controller with corresponding embedded hardware to demonstrate multi area power generation with priority to renewable energy optimization of generation cost depending upon the varied load conditions. This work demonstrates on embedded 'C' controlled hardware controlled vid fuzzy logic implemented in Matlab over connection on RS232 port.

Keywords— Multi area power generation, Fuzzy logic, Matlab, Data Aequitsiton tool box, Dual converter.

I. Introduction

Power is the rate of doing work or transferring heat, the amount of energy transferred or converted per unit time. Having no direction, it is a scalar quantity. In the International System of Units, the unit of power is the joule per second (J/s), known as the watt in honour of James Watt, the eighteenth-century developer of the steam engine condenser. Another common and traditional measure is horsepower (comparing to the power of a horse). Being the rate of work, the equation for power can be written:

Power=Work/Time

As a physical concept, power requires both a change in the physical system and a specified time in which the change occurs. This is distinct from the concept of work, which is only measured in terms of a net change in the state of the physical system. The same amount of work is done when carrying a load up a flight of stairs whether the person carrying it walks or runs, but more power is needed for running because the work is done in a shorter amount of time.

The output power of an electric motor is the product of the torque that the motor generates and the angular velocity of its output shaft. The power involved in moving a vehicle is the product of the traction force of the wheels and the velocity of the vehicle. The rate at which a light bulb converts electrical energy into light and heat is measured in watts—the higher the wattage, the more power, or equivalently the more electrical energy is used per unit time.

An important aspect of any electrical or electronic circuit is the power associated with it. It is found that when a current flows through a resistor, electrical energy is converted into heat. This fact is used by electrical heaters which consist of a resistor through which current flows. Light bulbs use the same principle, heating the element up so that it glows white hot and produces light. At other times much smaller resistors and very much smaller currents are used. Here the amount of heat generated may be very small. However if some current flows then some heat is generated. In this instance the heat generated represents the amount of electrical power being dissipated.

II. LITERATURE REVIEW

In this paper a number of decentralised and centralised PI and Model Predictive Control (MPC) based algorithms were proposed for the purposes of Automatic Generation Control (AGC) in Multi-Terminal HVDC (MTDC) grids. The use of voltage offsets was also proposed as an additional control variable to improve performance. The paper discusses how this approach improves the sharing of secondary reserves and could assist in achieving EU energy targets for 2030 and beyond.[1]

In this paper the gravitational search algorithm is used to obtain optimum gains of the PIDF controller for problem of automatic generation control (AGC). First GSA is illustrated in detail and therefore investigated power system under study. The results of simulation emphasize the effectiveness of the GSA. The PIDF controller which is tuned by GSA has been strongly proposed for automatic generation control. [2]

A multi-level power system is considered in the paper with wind-energy generation in area-1. The contingency situations of sudden loss of generation and sudden loss of loads are simulated for a two-area system with one of the areas having Wind-turbine generator. The results show that the frequency deviation and the voltage profiles are within the limits in the two situations. Coordinated scheduling of power is necessary to maintain the system parameters under control. [3]

This paper applies the ACO based fuzzy controller to the SEDC Motor. The fuzzy rules are optimized off line, while the parameters of the fuzzy controller are tuned on line. By a comparison the Hybrid Fuzzy ACA Controller, ACA and Fuzzy logic controller, the Hybrid Fuzzy-ACA Controller is not only more robust, but can also achieve a better static and dynamic performance of the system. [4]

A simulation study of single area, two areas and three areas as a multi system with automatic generation and control is carried out with models developed in SIMULINK MATLAB. The system experiences frequency drift following a load disturbance and it is mainly due to the mismatch between the electrical load and the mechanical input to the turbine. [5]

In this work, a type 1 fuzzy controller is used for controlling the load frequency of the single area non-reheat thermal power plant. A 1% step load perturbation is applied in the load demand of the power plant and analysis the system responses in terms of settling time, peak overshoot and peak undershoot. So, it is necessary to maintain the system frequency is to be constant. [6]

This paper is ratified with a novel hybrid DECRPSO algorithm optimized FPID controller used in both the areas of a mutually connected hydro-thermal power system to minimize the ACE. To achieve better regulation over tie-line power and frequency deviation, the gains of the FPID controller are optimized by PSO, CRPSO and hybrid DECRPSO algorithms. [7]

In this paper, the optimal load frequency control (LFC) of interconnected power systems is investigated. The impact of LFC control method on the fluctuations caused by step load disturbance is examined; also the effect of LFC controller is analyzed. The Proportional-Integral Derivative (PID) controller parameters of the investigated LFC model are optimized by different techniques. An application of new approach based on hybrid Genetic Algorithm and Particle Swarm Optimization (HGA-PSO) to solve LFC problem is developed. The proposed hybrid GAPSO algorithm is first applied to the two-area interconnected power system and then extended to the large three-area 9-unit interconnected power system model. The comparative study demonstrates the validity and the potential of the proposed approach and shows its robustness to solve the optimal LFC problem.[8]

The present article developed a new approach for the LFC of a single-area power system as an extension of the TDF-IMC scheme. The inner and outer loop controllers were computed with the help of a predictive model, observed from the responses and performance indices that the proposed configuration generates better results with the nominal and perturbed parameters. Furthermore, it was observed that the proposed scheme gives better transient and steady state performances with the external load disturbance. [9]

Comparison of the settling times of MSMA power system using ADRC and PID as secondary controllers is shown in Table 1. From the Table, it is observed that the settling time using ADRC is less compared to PID Controller. Not only settling time but also overshoots/undershoots remain very low by using an ADRC Controller which is observed from Figs 8 - 25. Settling time remains same for both the ADRC and PID controllers for different load changes in the power system. [10]

This paper investigates the performance of automatic generation control of three area thermal power system. To demonstrate the effectiveness of proposed controller, evolutionary (Genetic Algorithm for tuning of Integer controller) controller. AGC with load following is treated as an ancillary service that is essential for maintaining the electrical system reliability at an adequate level recent years, major changes have been introduced into the structure of electric power utilities all around the world.[11]

In this paper, an electrical energy management system, that implements an overall electricity consumption prediction model, was proposed. This model was established using the Fuzzy Logic method. Several individual houses were instrumented to highlight the importance of the prediction model. Finally, the system proposed here provides safety guarantees, and particularly during AC-line disconnection.[12]

Green energy targets for coming decades advocate high penetration of wind energy in main energy matrix, which pose incendiary threat to stability and reliability of modern electric grid if their integration aspects are not assessed beforehand. Real-time balancing of demand and supply or Automatic generation control is a challenging task in modern electric grid when penetrated with unpredictable and variable wind power. [13]

In this study, fuzzy logic control approach is employed for load frequency control of an isolated system as well as on an inter-connected power system with non-reheat turbine system. The proposed fuzzy controller is reported as with better performance in comparison to PID controllers reported in literature. This mismatch has to be corrected by load frequency control (LFC), which is defined as the regulation of power output of generators within a tolerable limit.[14]

In this paper, the various optimization techniques for the Automatic Generation Control are introduced. From above discussion, it is clear that all techniques are having its distinct benefits like GA is a simple technique, suitable for less dimension problems. BF has global search ability. ANN is based on adaptive learning with no need of programming. Conventional controller is simple for implementation but takes more time and gives large frequency deviation.[15]

III. METHODOLOGY

System Block Diagram

In this block diagram we can see here is four power plants these are generates electrical energy. And here left sided power plats are power plant 1 and power plant 2. And right sided power plants are power plant 3 and power plant 4. Left sided power plants and right sided power plants are stable at short distance and connected together with dual converter. Power plant 1 is connected to step up transformer with bus B1 and power plant 2 is connected to step up transfrotmer with bus B2 these step up transformer is used for boost voltage of these power plants. Power plant 1 and power plant 2 powers is mixed together after bus B5 then this power go to bus B6 then go to bus b7. Then here is 20 MW load is connected that consume this power. Three phase fault detector is connected with Bus B7 that indicates when any fault is detected. Then this power goes to bus B8 then goes to bus B9. Bus B9 is connected with dual converter. Same work is done at the right hand side 1st plant 3 and plant 4 voltage is boost then mixed up at bus B12 then go to bus B10 via bus b11 and load is connected with bus B10. Dual converter is used for pass power from left power plants to right side. And right power plants to left side. If load at left side is high and left sided power plants not fulfill of power requirement of load then dual converter pass power from right side to left side. And if right side load is increases and right sided power plants are not full fill requirement of power then duel converter pass power from left side to right side.

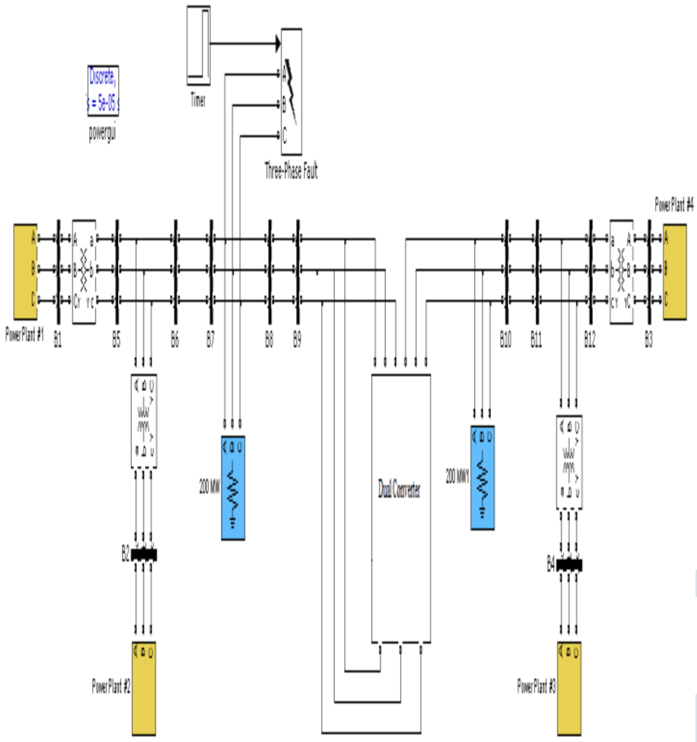

Fig: 3.1 System Block Diagram

PWM Invertor Flow Chart

In this flow chart we can see 1st code is start then portb is equal to zero. Then f0 to f7 of port b is equal to zero then after delay of 5 mille second f0, f2, f4, f6 of port b is equal to 1 and f1, f3, f5, f7 of port b is equal to zero. Then after delay of 5 milli second f0 to f7 of port b is equal to zero. Then after delay of 5 milli second f0, f2, f4, f6 of port b is equal to zero and f1, f3, f5, f7 of port b is equal to 1. Then after delay of 5 milli second algorithm will be stop and repeat again.

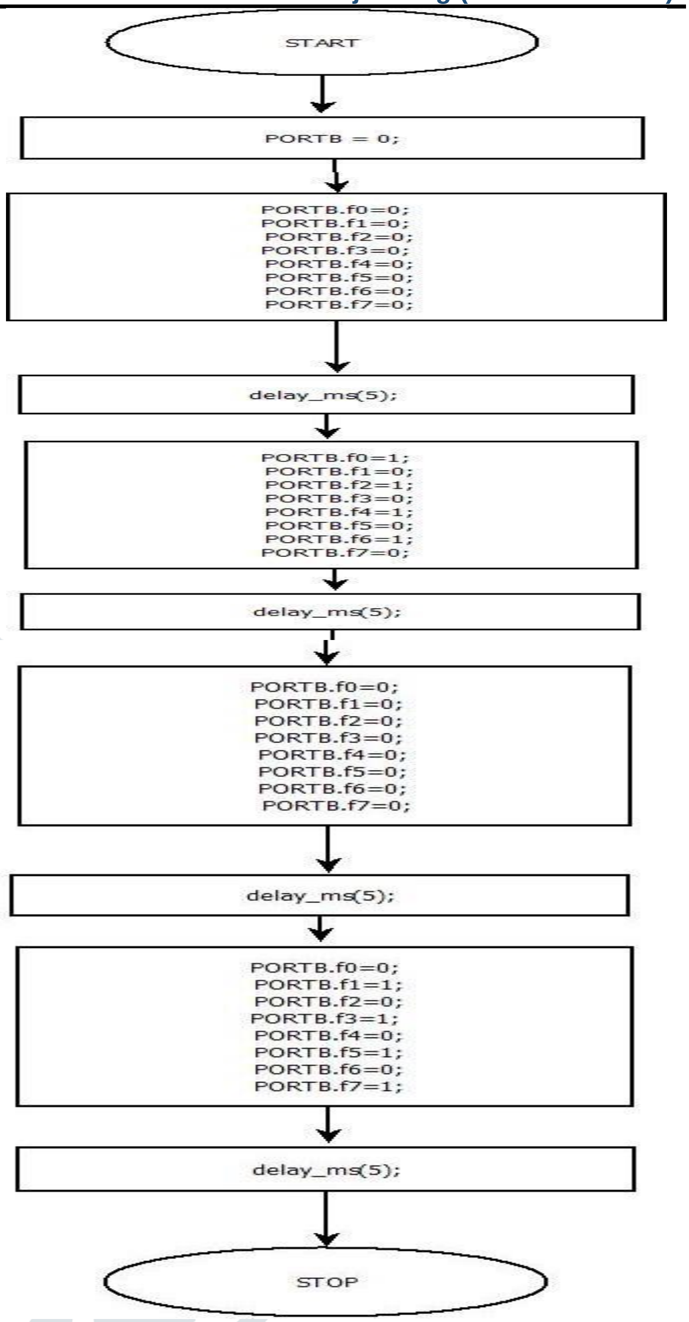

Fig: 3.2 PWM Invertor Flow

IV. RESULT

In this window we can see different voltage and current from the different power plants. When only solar power is on.

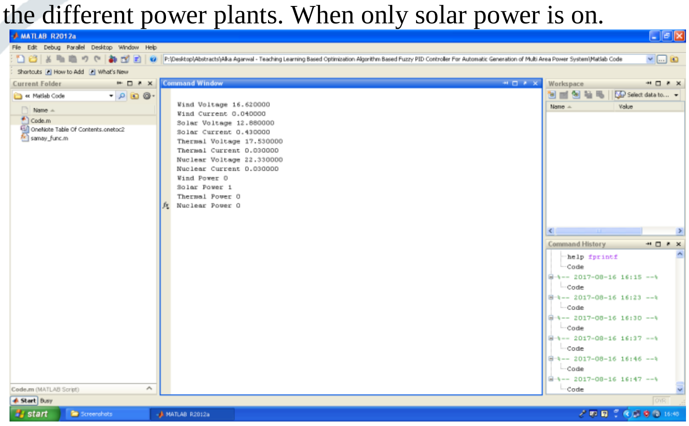

Fig 4.1 Voltage and current values from different power plant

In this window we can see different voltage and current from the different power plants. When only solar power is on. When solar power and wind power is on.

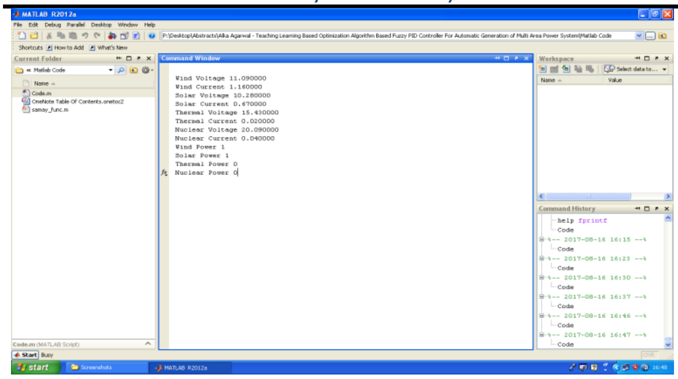

Fig 4.2 Voltage and current values from different power plant

In this window we can see different voltage and current from the different power plants. When only solar power is on. When solar power, wind power and thermal power is on and nuclear power is off.

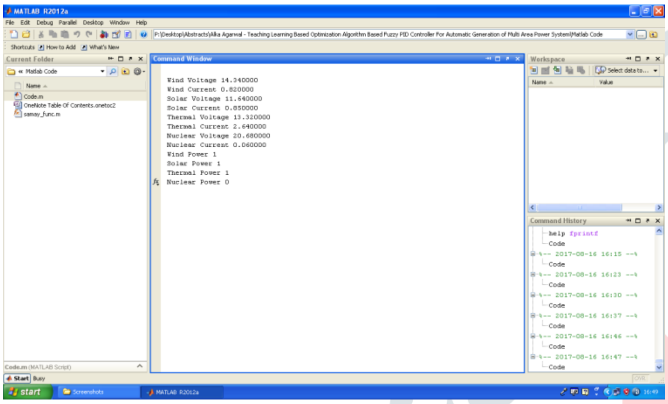

Fig 4.3 Voltage and current values from different power plant

In this window we can see different voltage and current from the different power plants.When solar power, wind power and thermal power is on and nuclear power is off. When wind power , solar power, thermal power and nuclear power is on.

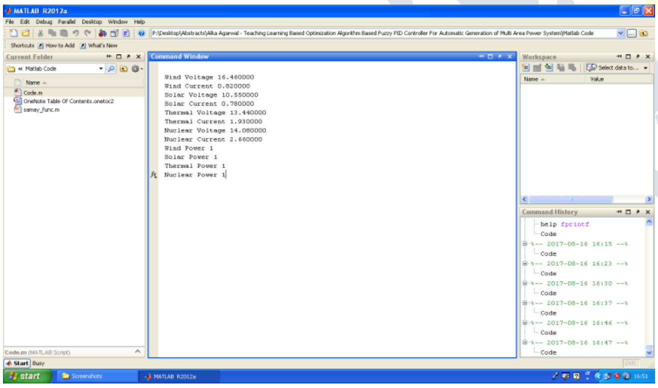

Fig 4.4 Voltage and current values from different power plant

In this window we can see different voltage and current from the different power plants. When wind power, solar power, and thermal power is on and nuclear power is off.

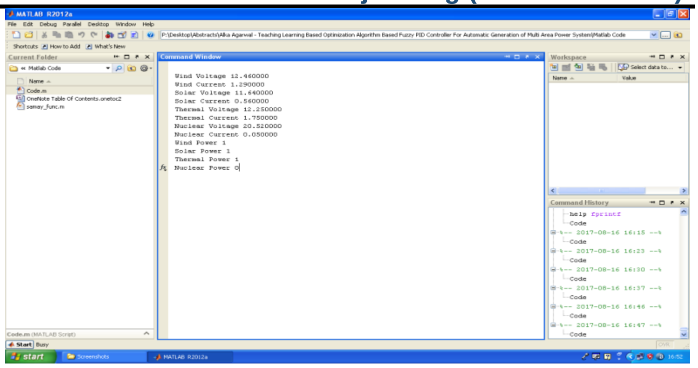

Fig 4.5 Voltage and current values from different power plant

In this window we can see different voltage and current from the different power plants. When wind power power, wind power and nuclear power is on and thermal power is off.

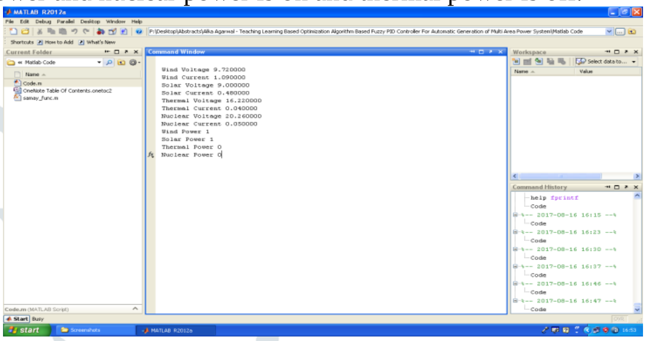

Fig 4.6 Voltage and current values from different power plant

S.NO	Wind Power	Solar Power	Thermal Power	Nuclear Power
1.	Off	On	Off	Off
2.	On	On	Off	Off
3.	On	On	On	Off
4.	On	On	On	On
5.	On	On	On	Off
6.	On	On	Off	Off

Table: 4.1 Switching Of Various Power Stations According To Load

S.No	Wind power	Solar Power	Thermal Power	Nuclear Power
1.	0.6408	5.1944	0.5259	0.6699
2.	12.8644	6.8876	0.3086	0.8836
3.	11.75	9.894	35.16	1.2408
4.	13.4972	8.229	25.9392	37.4528
5.	16.0734	9.3184	21.4375	1.0025
6.	10.5948	4.32	0.6488	1.013

Table: 4.2 Instantaneous powers of various power generations

S. No.	Wind Voltage	Wind Current	Solar Voltage	Solar Current	Thermal Voltage	Thermal Current	Nuclear Voltage	Nuclear Current
	16.62	0.04	12.08	0.43	17.53	0.03	22.33	0.03
	11.09	1.16	10.28	0.67	15.43	0.02	22.09	0.04
	14.34	0.82	11.64	0.85	13.32	2.64	20.68	0.06
	16.46	0.82	10.55	0.78	13.44	1.93	14.08	2.66
	12.46	1.29	11.64	0.56	12.25	1.75	20.52	0.05
	9.72	1.09	9.00	0.48	16.22	0.04	20.26	0.05

Table: 4.3 Observation of voltage & current of various power generation stations

V. CONCLUSIONS

The premise of this research is to optimize the cost of generation in multi area varied source power generation systems feeding combined load. As described above the system implements multiple (up to H) power generation setups by employing PWM inverters. More the over power generation setup connect to a load feeding bus or local AC bus. Also demonstrated is power sharing between various AC Buses (Local Buses) using dual converter.

The demonstration hardware setup is employs three 8 bit microcontroller from microchip for PWM generation, dual converter pulse generation & main controller acting as a slave serial unit to individually form on/off specific power generation setup according to the serial command. Successful implementation of embedded 'C' programming is demonstrated by PWM inverters & dual converter function & adherence of hardware to the predefined communication control process. Fuzzy logic controller for the proposed system has been developed in Matlab & is interfaced to the hardware over RS232 port using data equation toolbox methods. As demonstrate by the results the fuzzy controller automatically turns on or off requires power generation setups according to the load condition with prioritization of renewable energy & optimization of operational cost.

VI. FUTURE SCOPE

The autohor has proposed and demonstrate a multi area power generation algorithm with primary priority to reneuable energy sorces & also focused on cost optimization of generation station/sorces. As the technology is rapidly evolving & energy crisis day by day there ia continual demand in enhancements of systems cataing to multi area power generation especially micro power generation using reneuable energy sorces. A lot of enhancements can be introduced in the demonstreated work but the primilarily soughtones include inclusion of high speed data communication gateway over plcc & local RF repeaters to enable real time information & having between generation stations GSS, load despotch etc. to optimize generation reduce probability of faults & trips. Another important enhancement would be to include PWM control of dual converter to enable power flow quantity that control & prioritization to important load centers.

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