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SIMULATION OF SOLAR- WIND HYBRID MICRO-GRID SYSTEM WITH VOLTAGE CONTROL USING STATCOM DEVICE

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Abstract : Renewable energy sources play an important role in electricity generation. Various renewable energy sources like wind, solar, geothermal, ocean thermal and biomass can be used for generation of electricity. Energy from the sun is the best option for electricity generation as it is available everywhere and is free to harness. Electricity from the sun can be generated through the solar photovoltaic modules (PV). Electricity generation from the wind and solar photovoltaic (PV) systems are highly dependent upon weather conditions. Their intermittent nature leads to fluctuations in their output. Therefore, the need for rapid compensation for energy transmission and distribution systems is increasingly important. Static Synchronous Compensator (STATCOM) can be adopted for reactive power compensation and for decreasing the voltage fluctuation caused by the system and renewable energy sources. This study presents modelling of a Solar PV-Wind Hybrid Micro-grid and the increase of the stable operating limit of the system in case of the incorporation of STATCOM is examined. The major contribution of this paper is the optimization of gain parameters of four PI controllers in STATCOM based on genetic algorithms (GA) and therefore obtaining better responses and voltage stability in terms of nonlinear nature of solar-wind hybrid micro-grid.

Keywords-STATCOM, PV, RER, PI, GA,etc.

I. INTRODUCTION

Rapid depletion of fossil fuel resources on a worldwide basis has necessitated an urgent search for alternative energy sources to cater to the present days' demand. . Therefore, it is imperative to find alternative energy sources to cover the continuously increasing demand of energy while minimize the negative environmental impacts Recent research and development of alternative energy sources have shown excellent potential as a form of contribution to conventional power generation systems. There is a huge potential for utilizing renewable energy sources, for example solar energy, wind energy, or micro-hydropower to provide a quality power supply to remote areas. The abundant energy available in nature can be harnessed and converted to electricity in a sustainable way to supply the necessary power demand and thus to elevate the living standards of the people without access to the electricity grid. The advantages of using renewable energy sources for generating power in remote islands are obvious such as the cost of transported fuel are often prohibitive fossil fuel and that there is increasing concern on the issues of climate change and global warming. The electric power generation system, which consists of renewable energy and fossil fuel generators together with an energy storage system and power conditioning system, is known as a hybrid power system. A hybrid power system has the ability to provide 24 hour grid quality electricity to the load. This system offers a better efficiency, flexibility of planning and environmental benefits compared to the diesel generator stand-alone system.

The maintenance costs of the diesel generator can be decreased as a consequence of improving the efficiency of operation and reducing the operational time which also means less fuel usage. The system also gives the opportunity for expanding its capacity in order to cope with the increasing demand in the future. This can be done by increasing either the rated power of diesel generator, renewable generator or both of them. The disadvantage of standalone power systems using renewable energy is that the availability of renewable energy sources has daily and seasonal patterns which results in difficulties of regulating the output power to cope with the load demand. Also, a very high initial capital investment cost is required. Combining the renewable energy generation with conventional diesel power generation will enable the power generated from a renewable energy sources to be more reliable, affordable and used more efficiently. Solar and wind energy systems are being considered as promising power generating sources due to their availability and topological advantages for local power generations in remote areas.

Utilization of solar and wind energy has become increasingly significant, attractive and cost-effective, since the oil crises of early 1970s. This Paper focuses on the combination of solar wind systems for sustainable power generation. The solar energy also varies with the hourly, daily and seasonal variation of solar irradiation. The wind turbine output power varies with the wind speed at different conditions. However, a drawback, common to solar irradiation and wind speed options, is their unpredictable nature and dependence on weather and climatic changes, and the variations of solar and wind energy may not match with the time distribution of load demand. This shortcoming not only affects the system's energy performance, but also results in batteries being discarded too early. Generally, the independent use of both energy resources may result in considerable over-sizing, which in turn makes the design costly. It is prudent that neither a stand-alone solar energy system nor a wind energy system can provide a continuous power supply due to seasonal and periodical variations for stand-alone systems. Thus wind system is hybridized with solar system to maximize use of renewable energy generation system while minimizing the total system cost.

II. SOLAR PV SYSTEM

In solar photovoltaic effect of converting lighting process into electricity (voltage). Photovoltaic cells are semi conducting material that charge between top & bottom layer. Exposed to dry light, electron in the absorb the photons & become highly energized. Generates electrons a current as a direct current & fed to inverter circuit for converting direct current to alternating current at home application.

SOLAR PV SYSTEM WITH MPPT

Photovoltaic system with MPPT (Grid connected)

Grid connected in two stage

Stage-1: - Grid connection PV systems connected to DC-DC boost converter & then fed to a DC-AC converter.

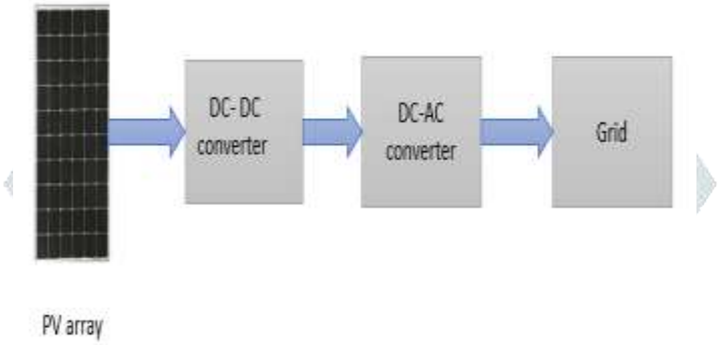

Figure 1 Grid integrated Solar PV system with DC-DC converter and DC-AC converter

In this system have Boost converter and inverter circuit use and connected at grid side. Parallel operation with PV system is grid connected for conventional electricity distribution system. Electricity feed into grid system or power loads which can also fed from the grid.

Stage-2: - Directly connected to DC-AC converter & the grid connection to PV system.

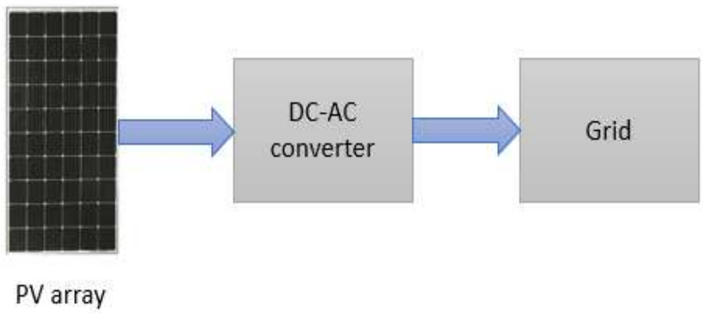

Figure 2 Grid integration PV system with DC-AC converter

But the Grid integrated PV system with DC-DC converter & inverter is preferred DC-AC converter are useful noise isolation & power bus regulation.

Standalone solar PV system (Off grid)

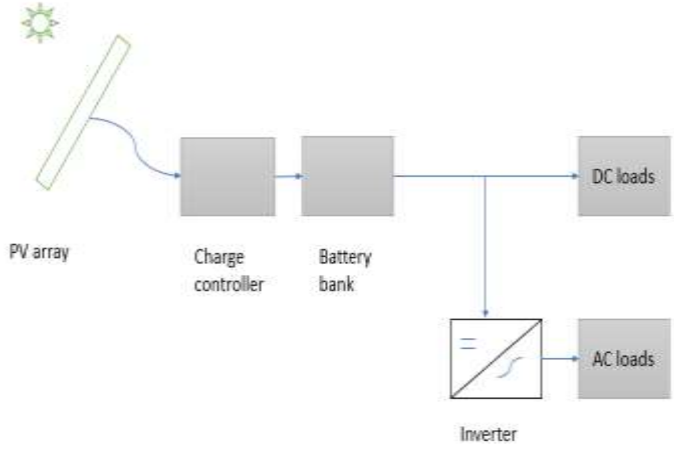

Figure 3 PV system is stand-alone (off grid)

Stand-alone operates independently PV system of other power supplies any supplies electricity to dedicate loads storage facility like battery bank to supplies electricity provide during night & sunlight level down. Standalone system also often uses autonomous system since independent operation of other power source.

WIND POWER

Wind power generation capacity in India has significantly increased in recent years. As of 31 December 2019, the total installed wind power capacity was 37.505, bringing the global total to nearly 487 GW. China again led for new installations, despite a significant decline in the country's annual market. Asia represented about half of added capacity, with Europe and North America accounting for most of the rest, but new markets continued to open around the world. By year's end, more than 90 countries had seen commercial activity. At least 24 countries met 5% or more of their annual electricity demand. For the constant output generation to meet the load demand of the consumer solar-wind hybrid system must be require with the grid integration. For the energy back up the BESS is used with the solar-wind hybrid system. The block diagram of the proposed system is shown in Figure4 below.

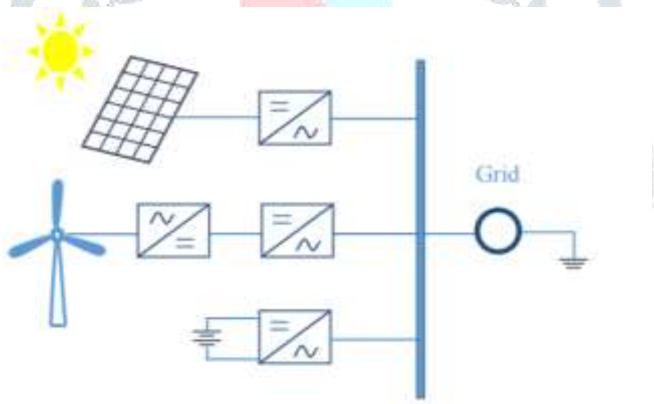

Figure 4 Solar PV-Wind Hybrid system

III. POWER QUALITY ISSUES

The power quality problem is a problem as imbalance in voltage, current, frequency, due to that equipment failure or malfunctioning of the equipment occurred. The latest electronics equipment consumes power and electricity different compare to other conventional appliances. The power quality problems and resulting consequences are occurred due to the increase of use of switching devices, nonlinear loads, sensitive loads, maximum use and increase in demand of power electronics switching devices, etc.

Harmonics

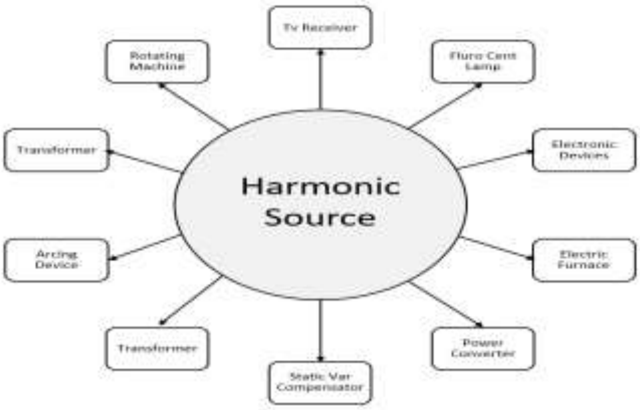

Figure 5- Harmonics source

Effects of Harmonics

- Problem caused by harmonics
- over loading of neutral
- Overheating of neutral
- nuisance tripping of circuit barker
- skin effect
- Overheating of induction motor

Therefore a pure voltage or current sine wave has no distortion and no harmonics and a non-sinusoidal wave has distortion and harmonics. In order to quantify the distortion, the term of Total Harmonics Distortion (THD) is used.

Total Harmonic Distortion

The THD is a measure of the effective value of the harmonic components of a distorted waveform. That is, it is the potential heating value of the harmonics relative to the fundamental. This index can be calculated for either voltage or current:

$$THD = \frac{\sqrt{\sum_{h>1}^{h\,max} M^2 h}}{M_1} \quad (1)$$

Where M_h is the rms value of harmonic component h of the quantity M. The rms value of a distorted waveform is the square root of the sum of the squares as shown in Eq. (1) and (2). The THD is related to the rms value of the waveform as follows:

$$RMS=\sqrt{\sum_{h=1}^{h\,max} M^2\, h}=M_1\sqrt{1+THD^2} \quad (2)$$

The THD is a very useful quantity for many applications, but its limitations must be realized. It can provide a good idea of how much extra heat will be realized when a distorted voltage is applied across a resistive load. Likewise, it can give an indication of the additional losses caused by the current flowing through a conductor.

Voltage Sags: Voltage sags are the most common power problems encountered in power system. Sags are a short-term reduction in voltage (that is 10-90% of normal voltage) and can cause interruptions to sensitive equipment such as adjustable speed drives, relays, robots etc. Sags are most often caused by fuse or breaker operation, starting of high rating motors, capacitors switching etc. Voltage sags typically are non-repetitive or repeat only a few times due to recloser operation. Sags can occur on multiple phases or a single phase and can be accompanied by voltage swells on other phase.

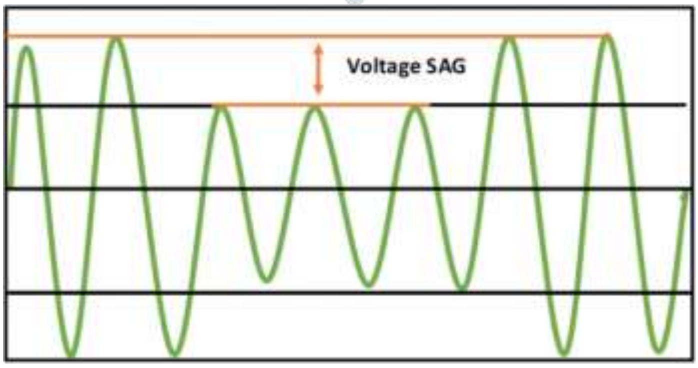

Figure 6: Voltage sag waveform

Voltage Swells: Swell is an rms increase in the AC voltage, at the power frequency, for durations from a half-cycle to a few seconds, which occurs on the healthy phases of a three-phase system during a single line-to-ground fault. The magnitude of swell is related to system grounding. Voltage swells are almost always caused by an abrupt reduction in load on a circuit with a poor or damaged voltage regulator, although they can also be caused by a damaged or loose neutral connection and also due to over reactive power compensation.

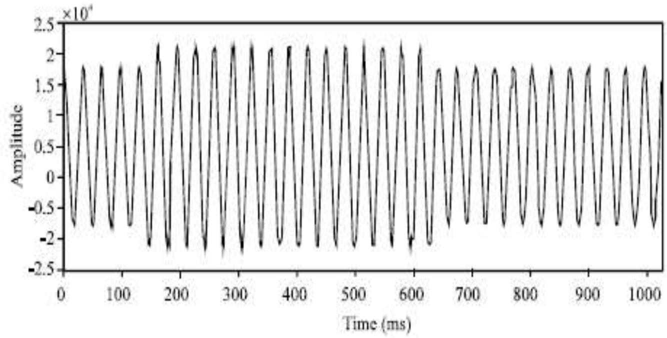

Figure 7: Voltage Swell waveform

Power Interruption (Momentary): Power interruptions are zero-voltage events that can be caused by equipment malfunctions, recloser operation or transmission outages. Interruptions can occur on one or more phases and are typically short duration events. Vast majority of power interruptions are of duration less than 30 second.

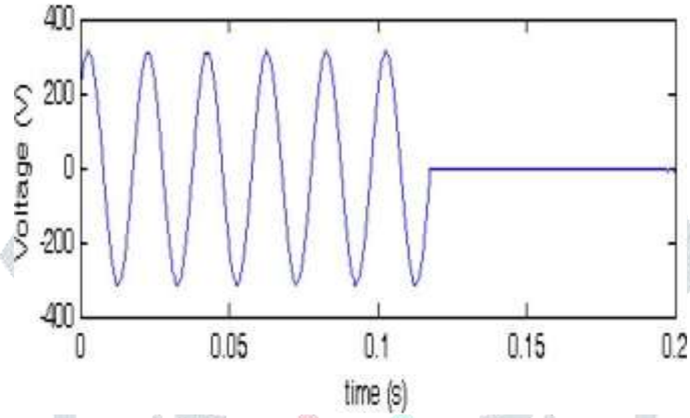

Figure 8: Power interruption waveform

IV. PROPOSED TOPOLOGY

Electricity generation from the wind and solar photovoltaic (PV) systems are highly dependent upon weather conditions. Their intermittent nature leads to fluctuations in their output. Therefore, the need for rapid compensation for energy transmission and distribution systems is increasingly important. Static Synchronous Compensator (STATCOM) can be adopted for reactive power compensation and for decreasing the voltage fluctuation caused by the system and renewable energy sources.

This study presents modelling of a Solar PV-Wind Hybrid Micro-grid and the increase of the stable operating limit of the system in case of the incorporation of STATCOM is examined. The major contribution of this paper is the optimization of gain parameters of four PI controllers in STATCOM based on genetic algorithms (GA) and therefore obtaining better responses and voltage stability in terms of nonlinear nature of solar-wind hybrid micro-grid.

The proposed hybrid system architecture modeled in Simulink is shown in Figure 9. A wind turbine based doubly fed induction generator was modeled and rotor side and grid side controls were performed. An indirect MPPT method was used according to wind speed and optimal torque production. The STATCOM was added to the Point of Common Coupling (PCC) for reducing the voltage fluctuation at the end of the busbar, and reactive power compensation. The current, voltage, reactive power values at the end of busbar are firstly measured for the system without STATCOM.

In this study, the time domain criterion is used to evaluate the PI controller in the STATCOM's control circuit for voltage stability. In the control system, if the controller tuning constants get improper value, the system's characteristics may deteriorate and the system may become unstable. For this reason, optimal adjustment of controller parameters and proper selection of tuning constants have an important role in the proper performance of this control.

V. SIMULATION AND RESULT DISCUSSION

Simulation and Results of Solar PV-Wind and Battery Hybrid System

In this section Matlab simulation of Solar PV. Wind hybrid system is done with battery backup. The solar PV system is developed with MPPT algorithm for maximum power tracking. The hybrid of Solar PV and wind system relate to D.C bus through D.C to D.C boost converter. The output of Solar PV, wind and battery is converted D.C into A.C using inverter as shown in the simulation with inverter control topology. The output A.C is given to the A.C load.

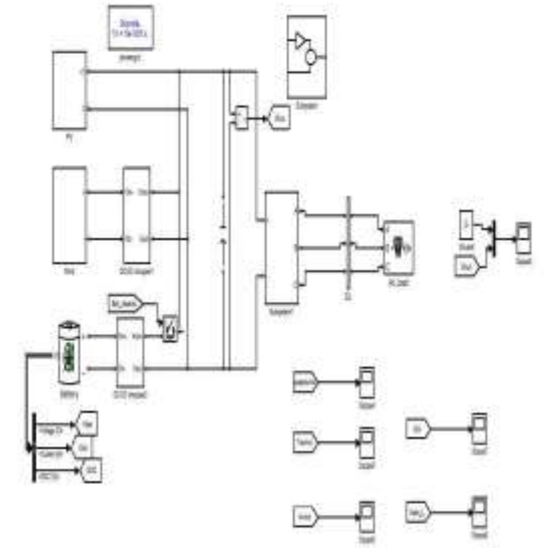

Fig 10- Solar PV-Wind and Battery Hybrid system

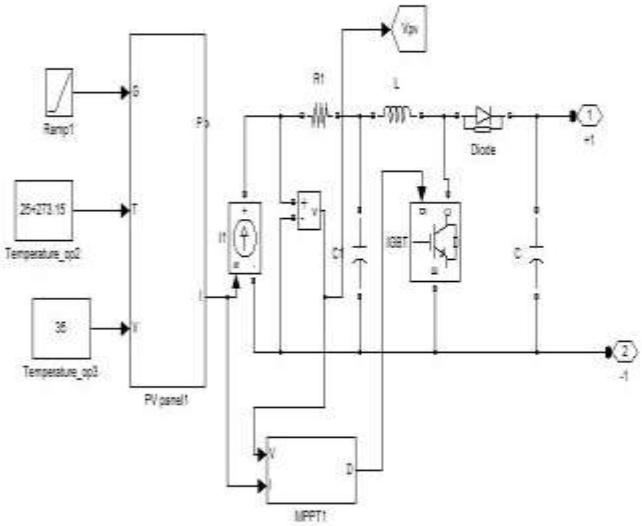

Fig 11- Solar PV system with MPPT

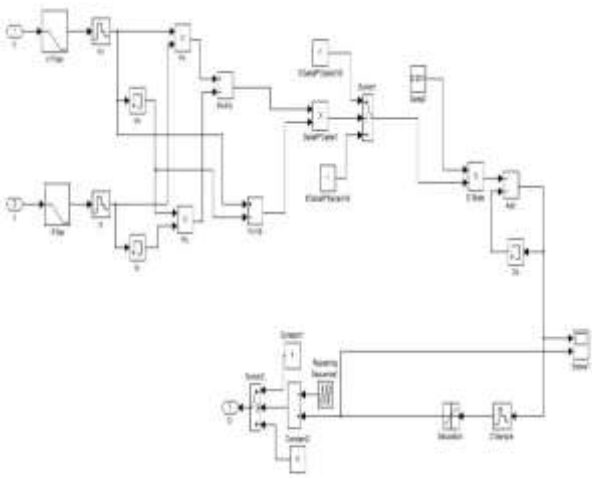

Fig 12- Solar PV MPPT P&O Algorithm System

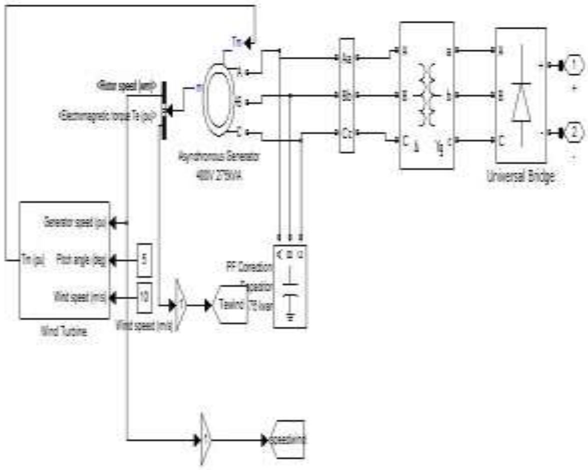

Fig 13- Wind power plant subsystem with Rectifier for D.C Conversion

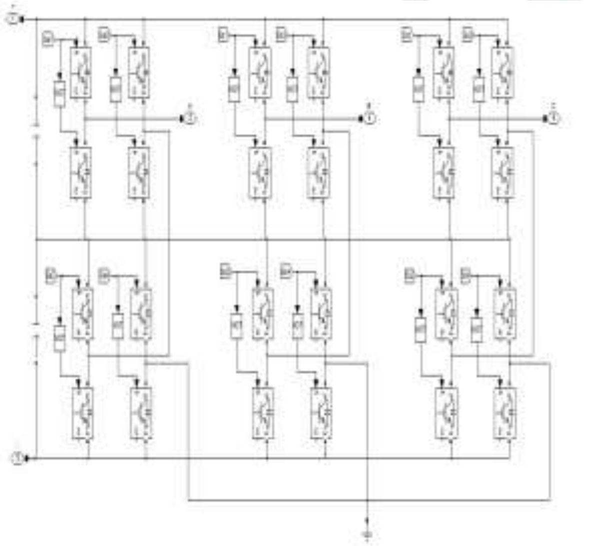

Fig 14- Inverter simulation for D.C to A.C Conversion

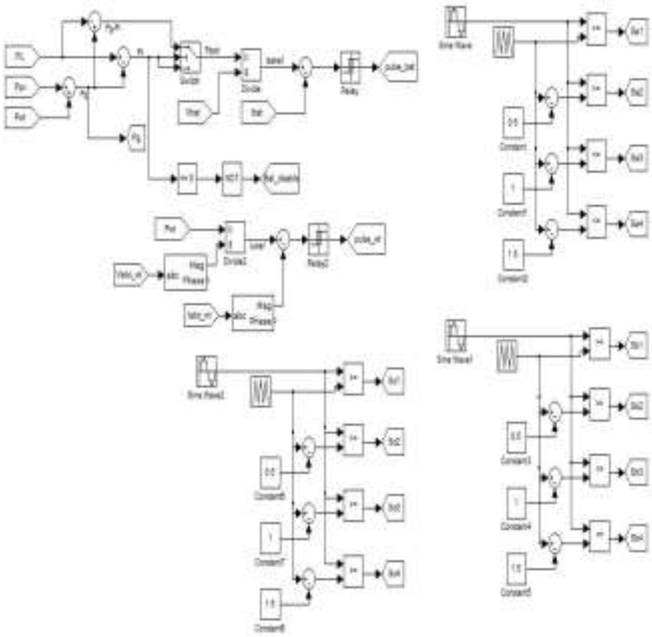

Fig 15- Inverter Control system

Simulation Results

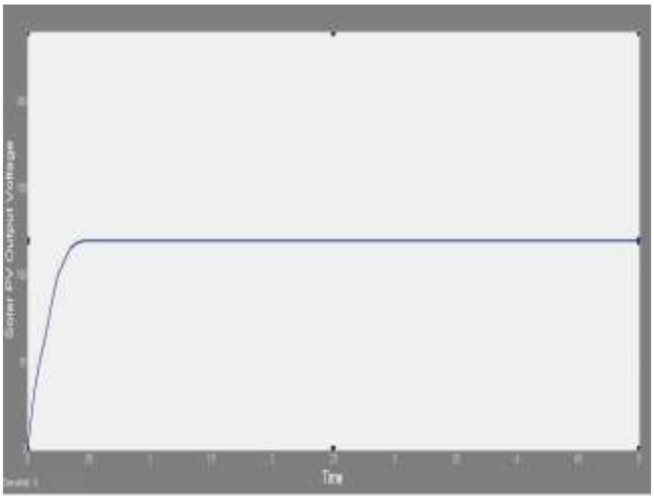

Fig 16- Solar PV Output D.C Voltage

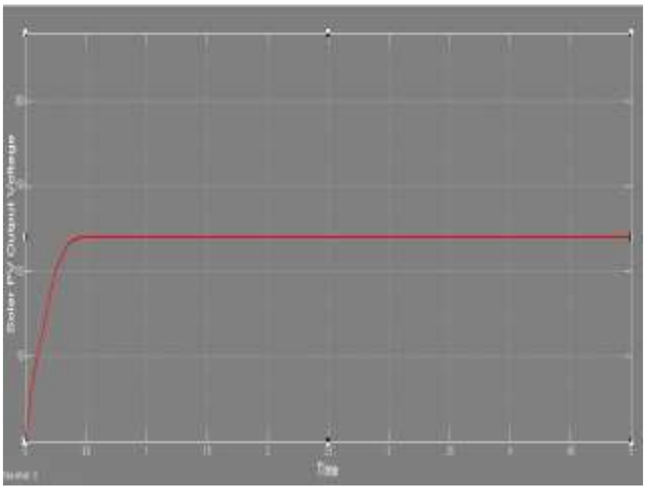

Fig 17- Solar PV Output D.C Voltage

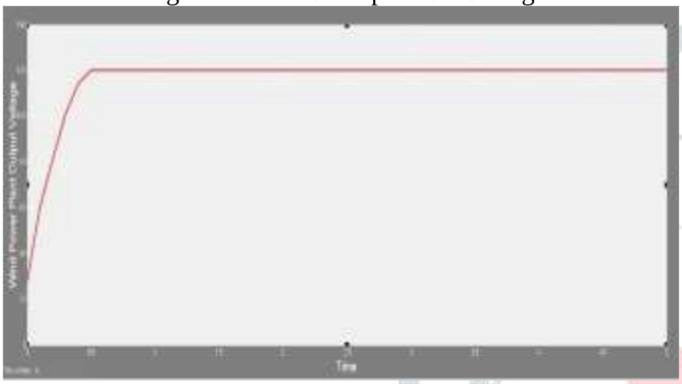

Fig 18- Wind power plant output D.C Voltage

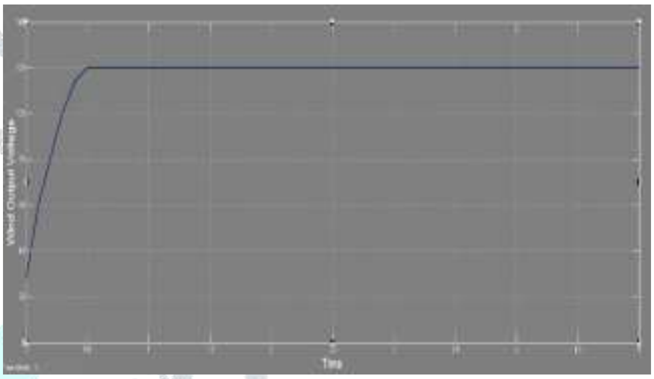

Fig 19- Wind D.C Output Voltage

Fig 20-D.C bus voltage constant 120V

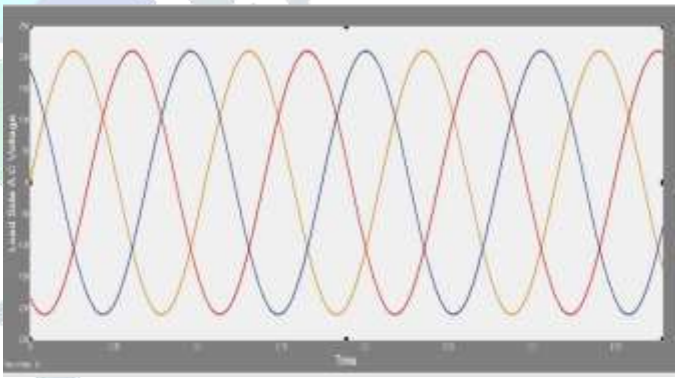

Fig 21- Load Side A.C Voltage

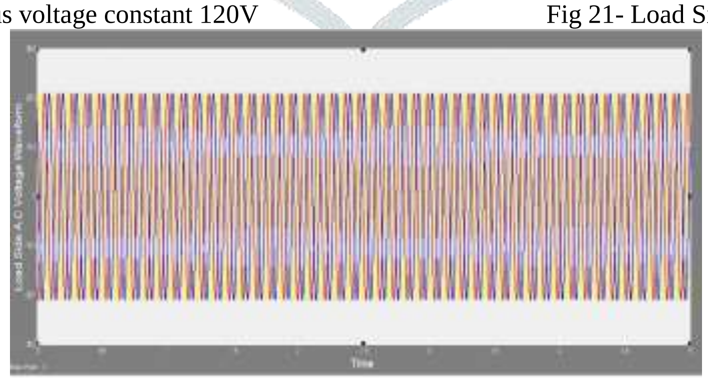

Fig 22- Load Side A.C Output Voltage

V. CONCLUSION

In this paper a micro grid model with solar PV, wind and battery is investigated. To actively achieve power demand using DG units, an enhanced DG unit control scheme proposed that uses the concept of Power demand control. In the proposed microgrid coordination strategy, the overall economic benefits are optimized with the day-ahead 24-hour power supply and the hourly micro-turbine operation, and the customer bills, demand energy quantity and voltage regulation are considered to guarantee the customer benefits. To ensure the optimization results are robust against the uncertain wind turbine outputs, PV outputs and load demands. The Matlab simulation of solar PV, wind and battery hybrid system is successfully developed. The grid integration of STATCOM device for Power Quality enhancement is required for the use of Non-Linear Load and grid unbalancing.

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