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CONTROL OF MICRO GRID FED BY HYBRID ENERGY SOURCES

D. Manikanta, Ch. Rami Reddy

Dept. of Electrical and Electronics Engineering, Nalanda Institute of Engineering and Technology, Sattenapalli - 522438. AP, India. Email: manikanta12307@gmail.com

Abstract- Microgrids are turning to be one of the most important factors for future power systems. Microgrid concept integrates large amounts of micro sources without disrupting the operation of main utility grid. This hybrid Microgrid consists of PV/wind energy sources for DC and AC networks respectively. Energy storage systems may be connected to either AC or DC Microgrids. This project presents a control of a micro-grid at an isolated location fed from wind and solar based hybrid energy sources. The machine used for wind energy conversion is doubly fed induction generator (DFIG) and a battery bank is connected to a common DC bus of them. A solar photovoltaic (PV) array is used to convert solar power, which is evacuated at the common DC bus of DFIG using a DC-DC boost converter in a cost effective way. The voltage and frequency are controlled through an indirect vector control of the line side converter, which is incorporated with droop characteristics. It alters the frequency set point based on the energy level of the battery, which slows down over charging or discharging of the battery. The system is also able to work when wind power source is unavailable. Both wind and solar energy blocks, have maximum power point tracking (MPPT) in their control algorithm. The system is designed for complete automatic operation taking consideration of all the practical conditions. The system is also provided with a provision of external power support for the battery charging without any additional requirement. A simulation model of system is developed in Matlab environment and simulation results are presented for various conditions e.g. unviability of wind or solar energies, unbalanced and nonlinear loads, low state of charge of the battery.

I. INTRODUCTION

Essentially a Microgrid includes the joining of numerous appropriated energy accumulation sources; the power from these sources is assembled, prepared and disseminated to take care of the demand loads. At the point when control elements interfaces with miniaturized scale energy framing a solitary element, its operation requires a control network. Such a control network is required to give adaptability, and to save the particular energy system and the power quality. The advancement of Microgrid fills in as a method for picking up favorable position contrasted with different networks. As of natural concerns, a Microgrid chops down contamination since it utilizes microsource that deliver low or zero discharges. Microgrids work in parallel to the utility Grid; by dealing with specific burdens they bolster the utility network. The additional limit given by Microgrids can help avoiding over-burden circumstances and power outages of the national grid. Economically, there is diminishment in long transmission line establishment and the comparing transmission.

The minimal effort establishment of the Microgrid networks locally impressively spares foundation expenses and transmission misfortunes. Microgrids additionally help in decreasing the utilization of fossil energy. By working in both grid associated and islanded mode, it guarantees uninterruptable burdens. This makes it more solid and conveys superb energy to the basic loads. The Microgrid exploits heat energy sparing when utilizing combined heat and power. This is a simple procedure to accomplish with the micro source in a Microgrid. The microsource can be sent nearer to heat and electrical loads for amplifying energy proficiency. The Microgrid exploits heat energy sparing when utilizing combined heat and power. This is a simple procedure to accomplish with the microsource of a Microgrid. For boosting energy effectiveness, the microsource can be conveyed nearer to the heat and electrical loads. Each conveyance utility has a commitment to supply its clients power at a voltage inside a predetermined breaking point. This prerequisite frequently decides the plan and cost of the dissemination circuit so that throughout the years procedures have been created to make the greatest utilization of appropriation circuits to supply clients inside the required voltage.

Some circulation utilities utilize more advanced control of the on load tap changers of the dissemination transformer by controllers on the feeder and including the utilization of the present flag intensified with the voltage estimation at the exchanged capacitor on feeders. Two parts of energy quality are generally thought to be essential: (i) transient voltage varieties and (ii) consonant twisting of the system voltage. The Microgrid can bring about transient voltage minor departure from the system if generally vast current changes amid association and disengagement of the generator are permitted. In this manner, it is important to utmost voltage varieties to limit the light variety. Large stack vacillation can bring about voltage variety and additionally source change. Microgrid units can possibly bring about undesirable transient voltage varieties at the neighborhood control network. Step changes in the yields of the Microgrid units with regular vacillations and the communication between the Microgrid and voltage controlling gadgets in the feeder can bring about noteworthy voltage varieties. The independent operation of Microgrid units gives more potential for voltage varieties because of load unsettling influences, which make sudden current changes the DG inverter. In the event that the yield impedance of the inverter is sufficiently high, the adjustments in the present will bring about noteworthy changes in the voltage drop, and therefore, the AC yield voltage will vacillate. On the other hand, frail ties in the network mix mode give a possibility for transient voltage varieties to happen yet bring down degrees than in the independent mode.

II. MICROGRID

Every source of energy produces an alternate power signals, i.e. Photovoltaic cells produces DC and wind produces AC. Adaption is must be needed between them. This adaption is called as coupling. Coupling can be done in two different ways: AC or DC. They can be utilized as a part of both on-grid, off-grid and also in mixed design. In AC-coupling and DC- coupling the number of parts are almost same but the only difference is dump load is used in DC whereas WTG inverter in AC- coupling.. Important is the way that the WTG inverter frequently is made with a breaking chopper, essentially a DC-DC switching
hurtful current and voltages into a resistor creating heat, to protect the inverter rather than a dump load. Depending on connection, Micrgrids are divided into three types

1. DC Migrogrids
2. AC Microgrids
3. Hybrid DC and AC coupled Microgrids

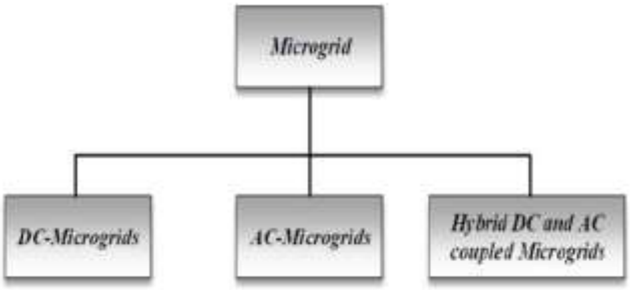

Fig:1. Three types of grids

In AC micro grid energy systems, every part of system connected to the standard AC voltage of the grid for example 50Hz, 230/400V, at a joint point before the local load. Expandability is the one of the main feature in this system. Recently these types of connecting systems have become greatly popular due to increased amounts of decentralized power grids. Main drawback with these systems is that they need inverter. The inverter is, as one with the PV-modules, a part which is basic for each grid- tied PV system. Its energy rating is relying upon the most extreme production from the PV-modules and is in this way a regularly changing quality specific for each system. Regularly most PV cell inverters have a combined DC-DC-converter and inverter, i.e. the MPPT system is coordinated in an same box as converts DC to AC. So as to connect an additional power source to these, the equipment must be adjusted electrically or must be altered with new programming. On the off chance that the network just has one MPPT for all input-ports applying new programming to the MPPT will bring about constrained power extraction from then modules and ought to in this manner just be done if the inverter has more than one MPPT. Based on connected case the search for the ideal inverter brought about guidelines which are listed in numerical order:

1. Inverter is WTG ready, i.e. it has at least one extra ports proposed for a WTG.
2. Inverter is blank completely, i.e. it has no tracking systems incorporated.
3. Inverter has separate MPPT for various association ports and where the MPPT programming is re programmable or removable.

It is additionally possible to connect a WTG to a present existing inverter that has a high power capacity, i.e. its ability to increase the aggregate power rating of both the WTG and PV modules, and if the MPPT is not connected. This kind of system has no requirement for a dump load.

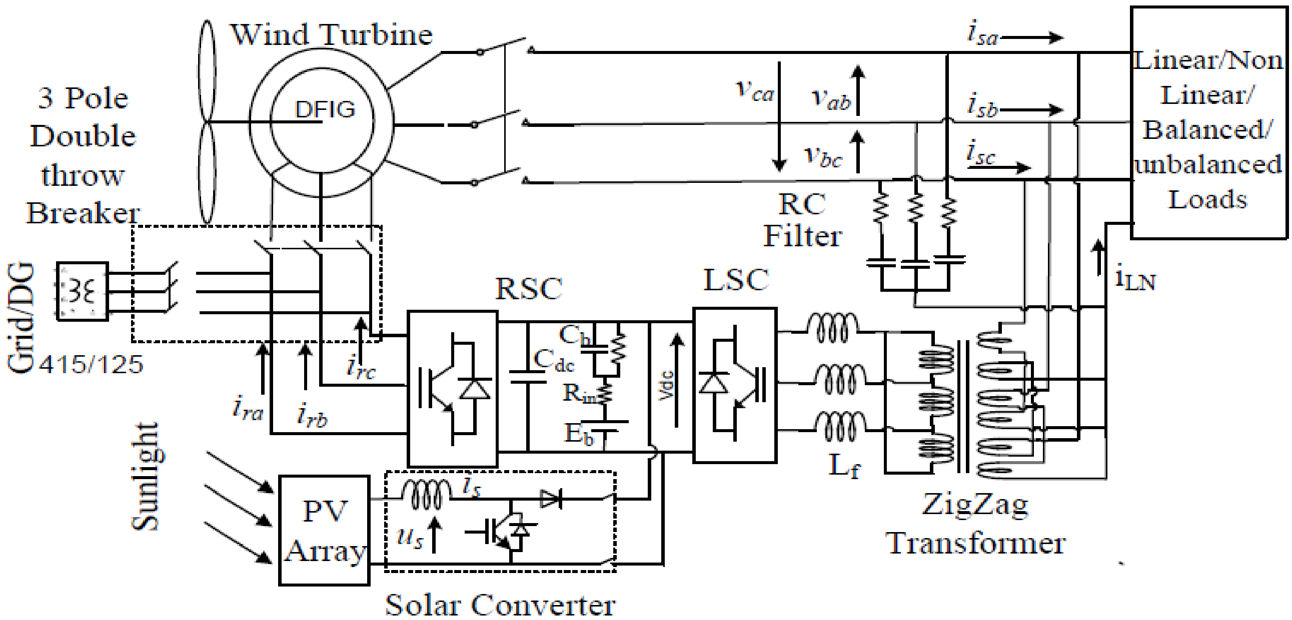

Fig:2. Schematic of isolated micro-grid network fed by renewable energy source using battery storage.

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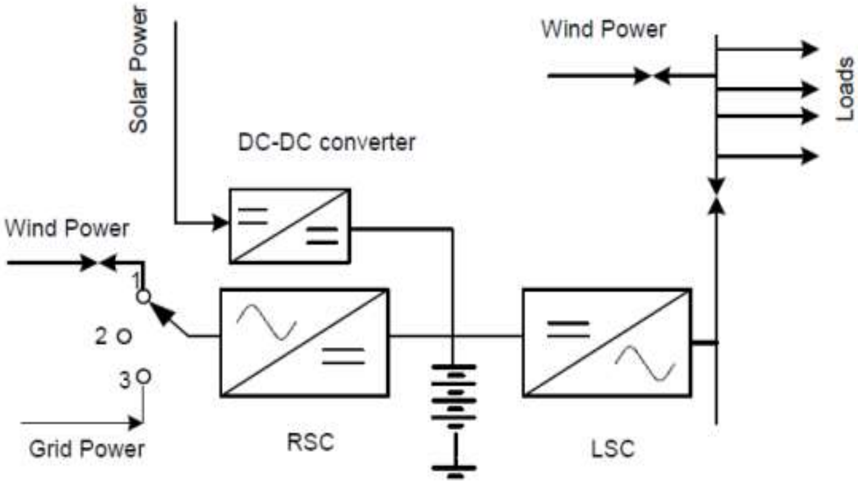

Fig:3. Energy flow diagram of isolated micro-grid network fed by renewable energy source using battery storage.

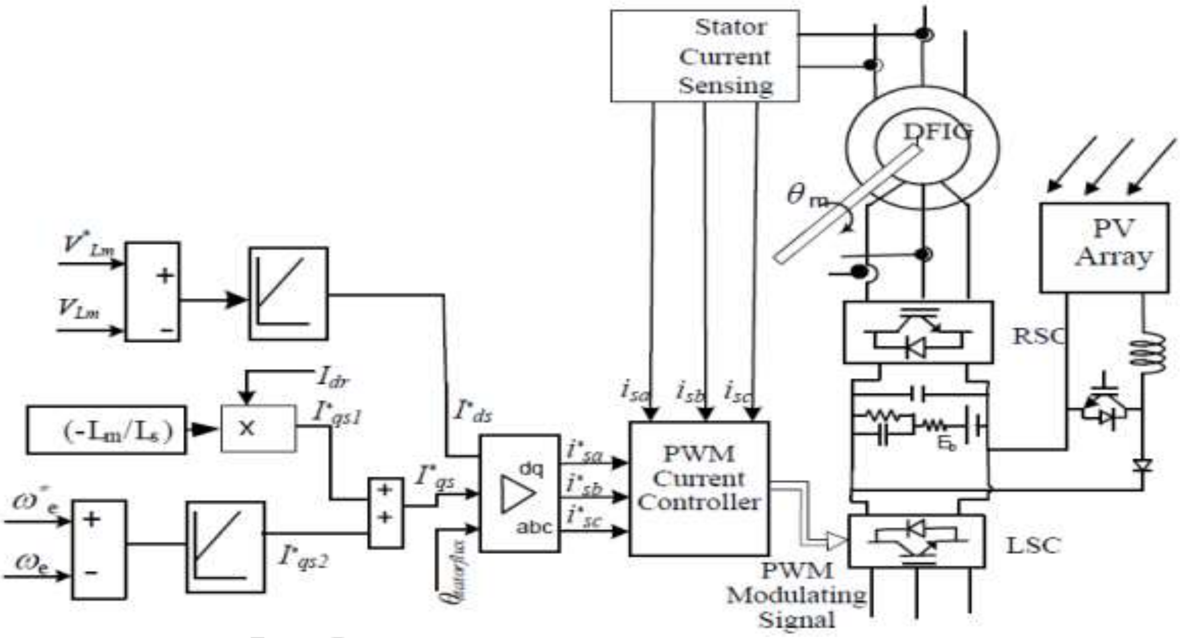

Fig:4. Control diagram of LSC for REGS energy fed micro-grid

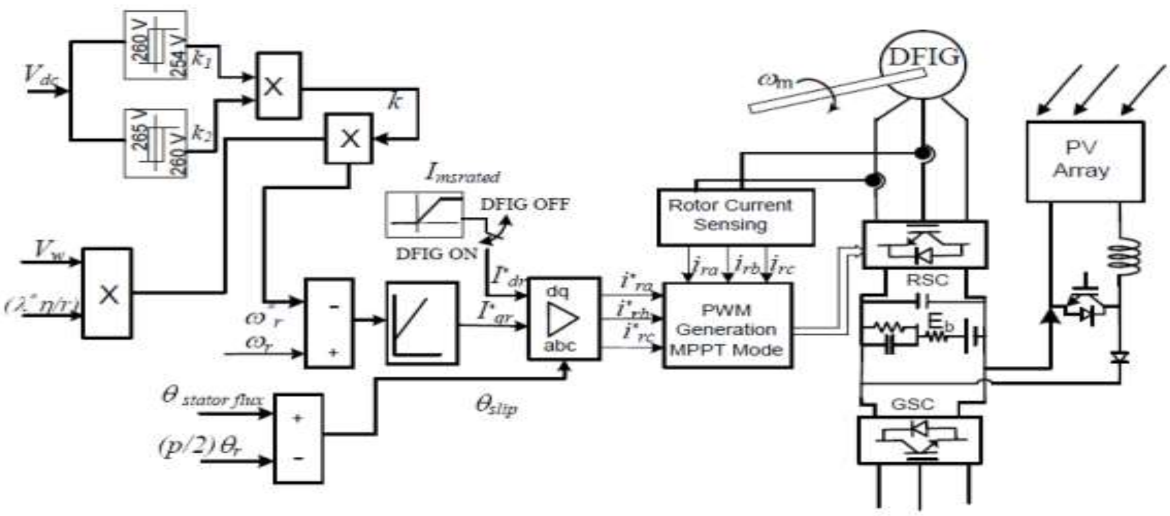

Fig:5. Control diagram of RSC for REGS fed micro-grid

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III. SYSTEM MODELING

A single line diagram of the proposed renewable energy generation system (REGS) fed micro-grid is shown in Fig.2. The same has been designed for location having maximum power demand and average power demand of 15 kW and 5 kW, respectively. The rated capacity of both wind and solar energy block in REGS, is taken as 15 kW. The capacity utilisation factor of 20% is considered for both energy blocks, which is enough to provide full day energy requirement of the hamlet.

As shown in a schematic diagram, the wind energy source is isolated using a 3-pole breaker from the network in case of insufficient wind speed. The DC side of both RSC and LSC along with HV side of solar converter, is connected at the battery bank. RSC helps the wind energy system to run at the optimum rotation speed as required by W-MPPT algorithm. The LSC controls the network voltage and frequency. The energy flow diagram of the system is shown in Fig.3.

The design methodology of major components of REGS, is shown in following sub-sections.

The wind turbine captures the kinetic energy of the wind and provides driving torque for DFIG. When the wind turbine is in service, the complete magnetising power requirement of machine is provided by RSC. Hence 11.83 kW capacity of DFIG is adequate to convert mechanical power from 15 kW wind energy system to electrical energy. The load and stator terminals are connected to the LSC through a zig-zag transformer, which also provides neutral for single phase loads at 415 V side. The maximum absolute value of rotor slip, is 0.3 and accordingly, the maximum rotor voltage *Vrmax* becomes 125 V(0.3×415 V). The voltage at the LV side of zig-zag transformer is also chosen to be equal to *Vrmax* Accordingly the transformer has a voltage ratio 415/125 V and its HV windings are connected to the stator and the load. The zig-zag transformer should meet the combined kVA requirement of load as well as connected filters. Accordingly, a 20 kVA transformer is chosen, which is sufficient to transfer rated power along with meeting reactive power requirement of the connected loads and filters at peak demand.

A solar converter, which is a boost type DC-DC converter used to evacuate solar power with embedded S-MPPT logic. It is based on incremental conductance method. The S-MPPT through intelligent switching regulates *us* so as the solar system operates at MPP. Since the onshore wind turbine generates power only for 60-70% of the time, the system should be designed to work when no wind power is available. As shown in the control diagram in Fig.4, *i*qs* consists of two components. The first component, *iqs1* corresponds to the power component of DFIG current, when wind turbine is in operation. The second components *iqs2* corresponds to the power component drawn when stator of DFIG is not connected to the load terminal. The direct component of current, *i*ds* corresponds to the reactive power requirement at the point of common interconnection of the generator and filter. The information of *i*qs* and *i*ds* provides the reference stator currents and help in maintaining the voltage and frequency through the indirect vector control.

The stator frequency is controlled by the LSC. Though the system has to generate rated frequency, a droop characteristic has been incorporated. Vdcmax is taken as 272.5 V, which is the bus voltage corresponding Vbmax during charging. Similarly, *Vdcmin* is being taken as 213.5 V, which bus voltage corresponds *Vbmin* and the battery being discharged. With these figures, the frequency varies from 49 Hz to 51 Hz. RSC regulates the speed of turbine so that the system operates at MPP irrespective of varying wind conditions. It also provides magnetizing power to the generator. The control philosophy as shown in Fig.5, includes control algorithm for determination of quadrature and direct components of rotor currents, *Iqr*, *Idr* and transformation angle, θ*slip*.

The value of *k* is determined from the two relays namely, *k1* and *k2* as shown in Fig.5. The output of relay falls to 0.85 if the DC bus voltage increases beyond threshold value. The threshold values of both relay, are kept 260 and 265, respectively. The *k* attains values of 0.85 and 0.72 as the *Vdc* exceeds 260 V and 265 V, respectively. The error signals of reference currents and sensed currents (*ira*, *irb* and *irc*) through hysteresis current regulator, generate control signals for RSC.

IV. SIMULATION RESULTS

The Simulink model of micro-grid fed by REGS is developed in Matlab. The solar panels and wind turbine are modeled using their functions.

CASE-A: Performance of System at Constant Load and Cut-in and Cut-out of Wind Power

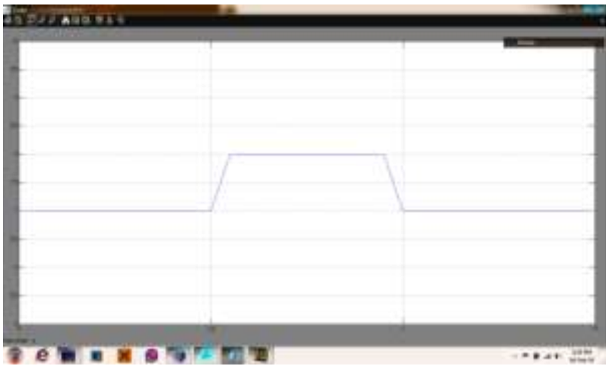
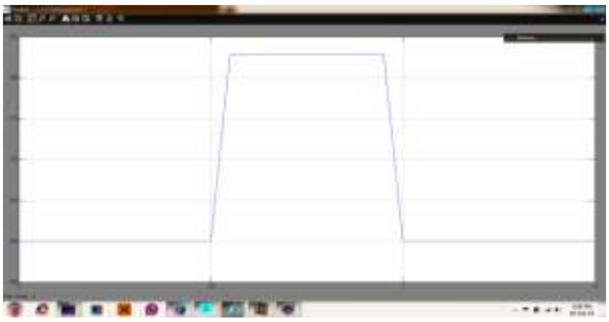


Fig:6(a)



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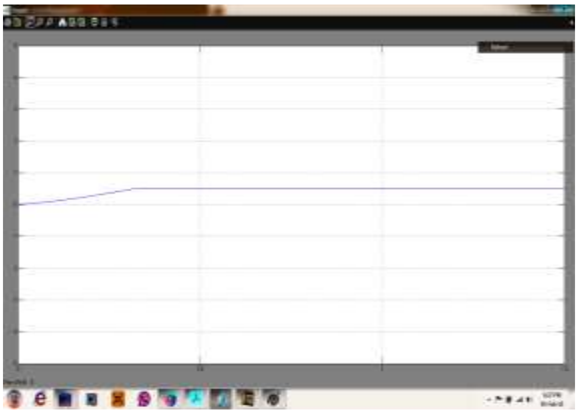
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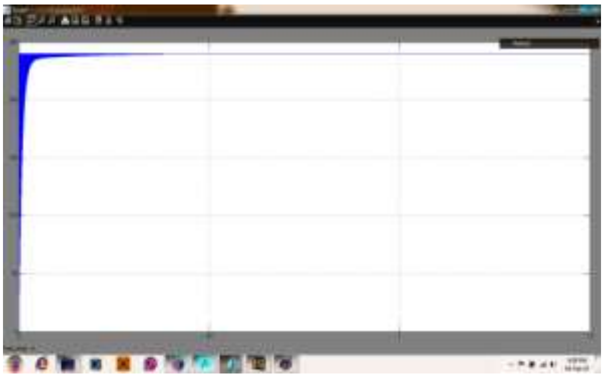
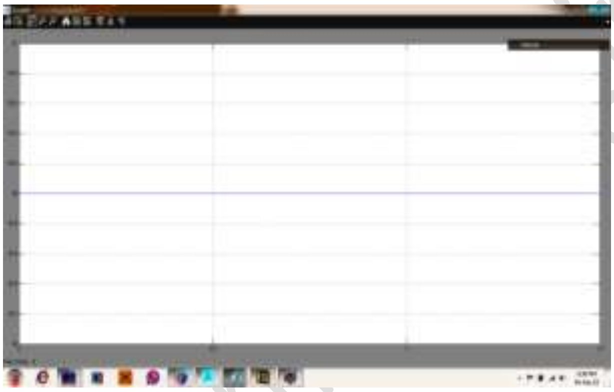


Fig:6(d)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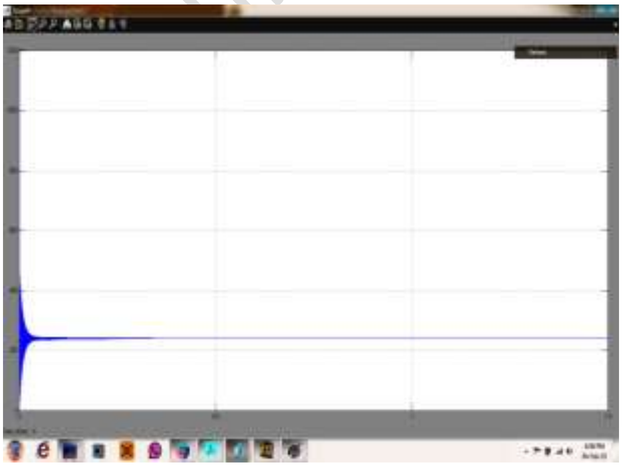
Fig:6(f)

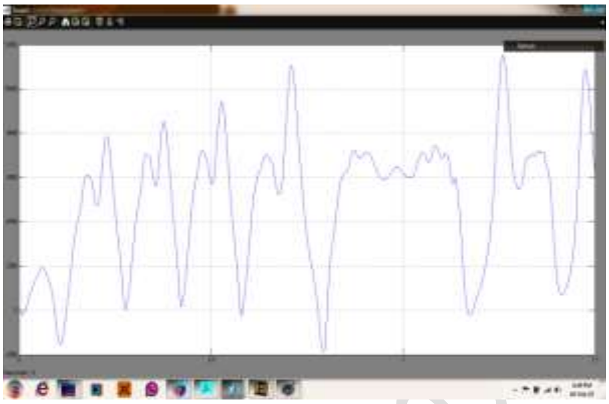
Fig:6(g)

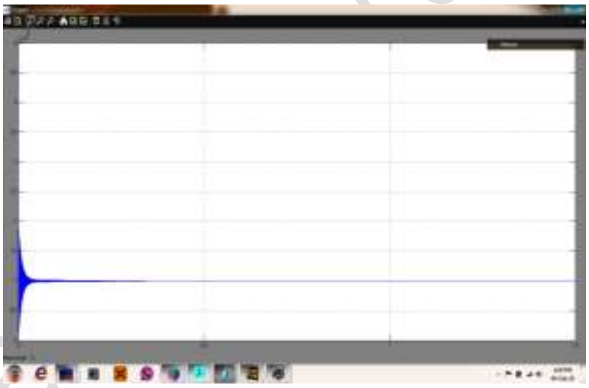
Fig:6(h)

Fig:6- Performance of REGS fed micro-grid with wind energy source.

As shown in Fig. 6, the system is started with 10 kW and 6 kVAR load without wind or solar energy sources. At t=0.25 s, the wind generator at wind speed of 7 m/s, is taken in service. As a result, a momentary fluctuation in the system voltage is observed. At t=0.6 s, the wind speed of turbine is increased from 7 m/s to 8 m/s followed by reduction of the wind speed to its original value at t=0.1 s. The rotor control action, maintains the desired rotational speed as per the W-MPPT algorithm. At t=0.14 s, the wind generator is taken out of service.

CASE-B: Performance of System at Constant Load and Cut-in and Cut-out of Solar Power

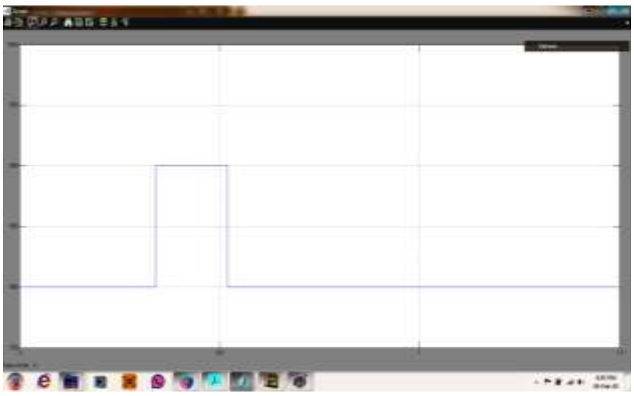
Fig:7(a)

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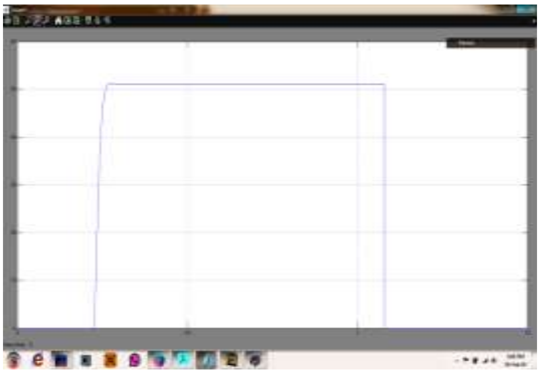

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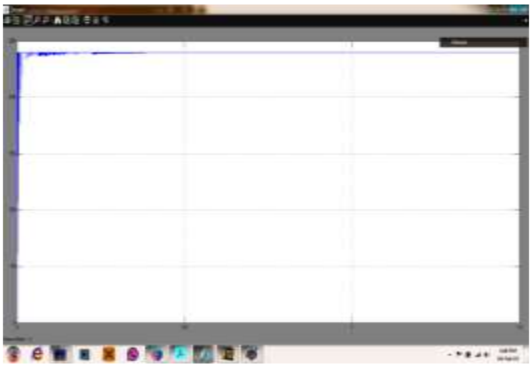

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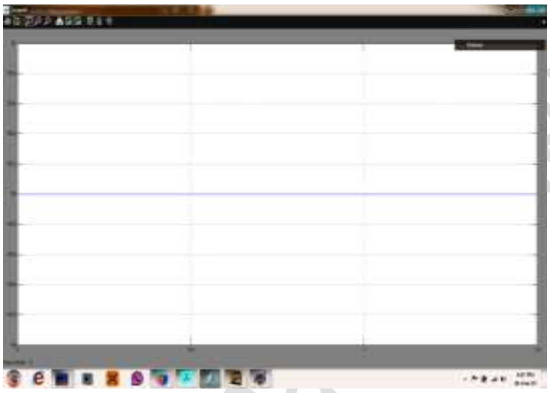

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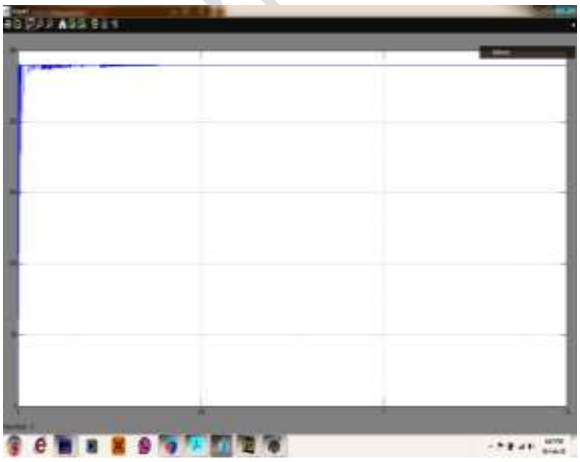

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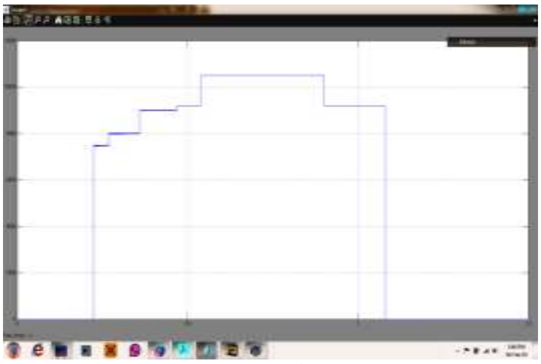

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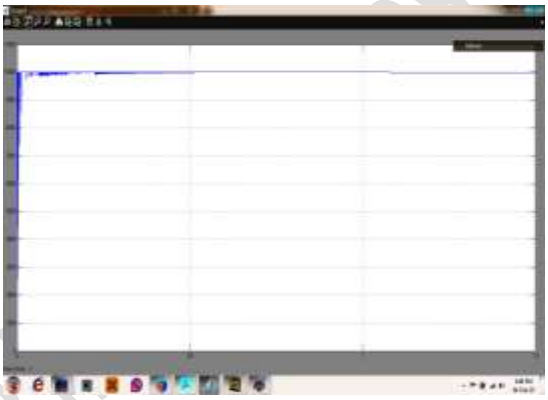

Fig:7(g)

Fig:7. Performance of the system without generating source and solar system is taken in the service.

The system is started with a 10 kW and 6 kVAR load without wind or solar energy. As shown in Fig.7, at t=0.25 s, solar system is taken into the service at radiation of 800 W/m2. At t=0.4 s, the solar radiation is raised to 900 W/m2 and again it is reduced to 800 W/m2 at t=0.6 s. The solar converter adjusts the solar PV voltage and operates at S-MPPT. At t=0.7 s, the solar system is taken out of service. No significant variation of system voltage is observed at any transition point.

CASE-C: Performance of System at Unbalanced Nonlinear Load

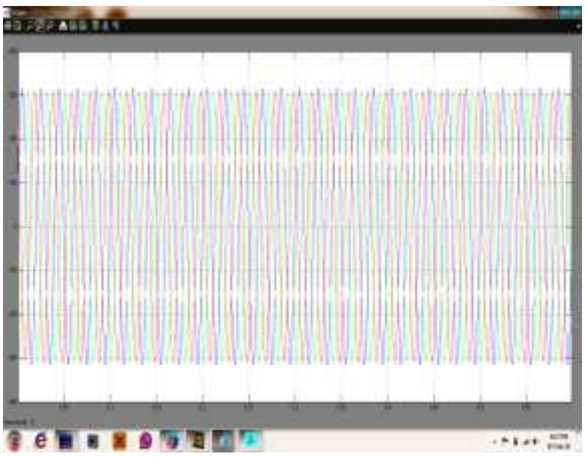

Fig:8(a)

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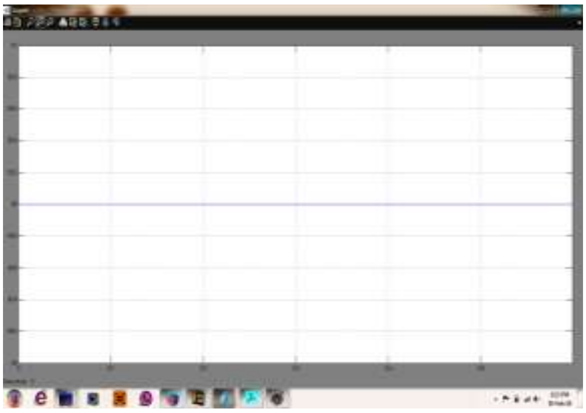
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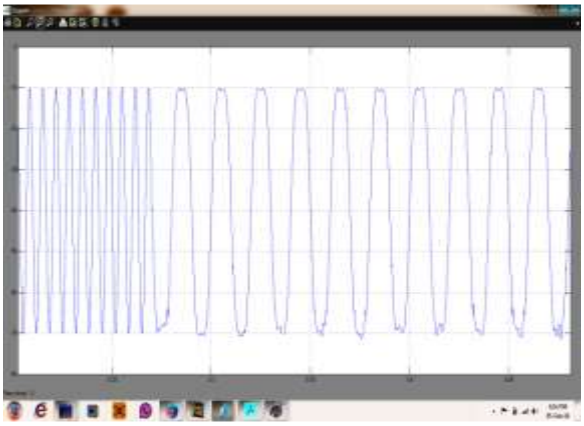
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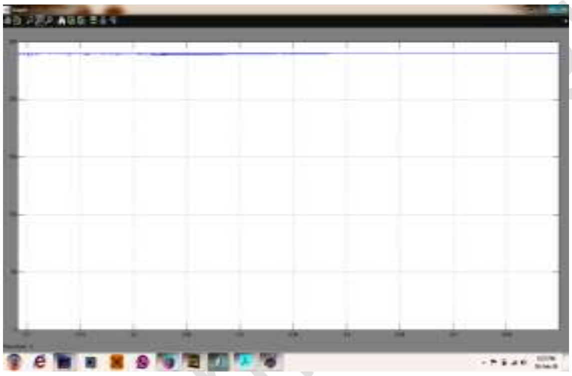
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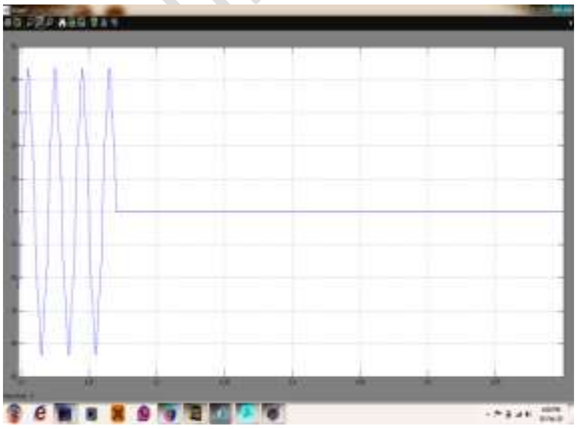
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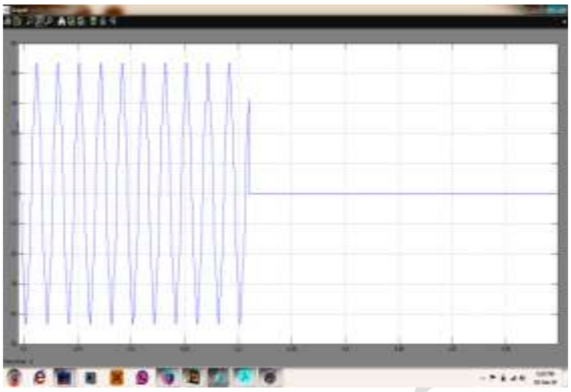
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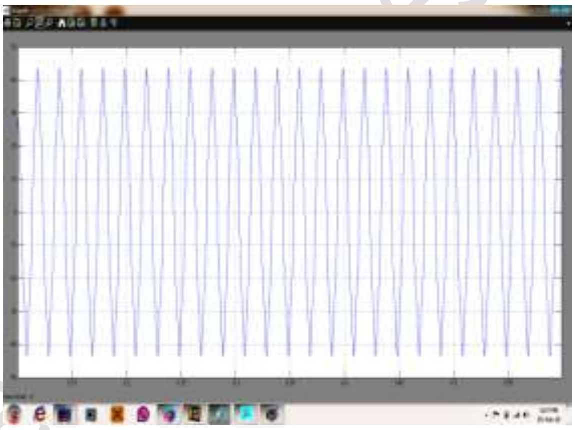
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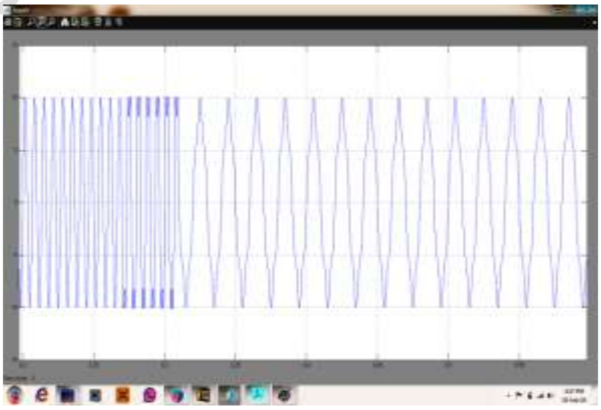
Fig:8(h)

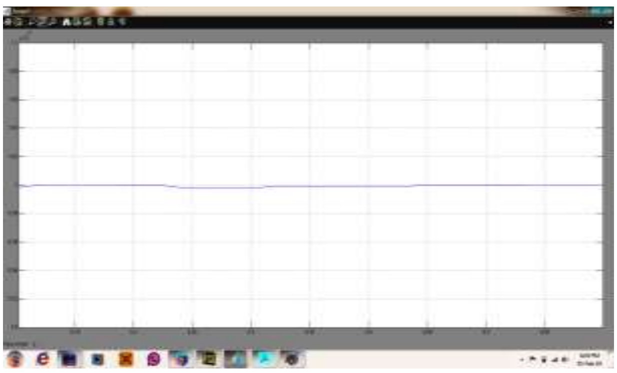
Fig:8(i)

Fig:8. Performance of the system at unbalanced and nonlinear load

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The performance of the system at unbalanced nonlinear is shown in Fig. 8. A micro-grid should be suitable to provide requirement of unbalanced nonlinear load. A worst case scenario is taken when there are no generating sources. The connected load consists of 2 kW linear load and 8 kW nonlinear load. At t=0.325 s, the load of a-phase is disconnected from the network followed by b-phase load at t=0.346 s. It is seen from the results that the system is able to provide quality power to its customer in case of unbalanced as well as nonlinear load.

CASE-D: Performance of System at Loss of Load

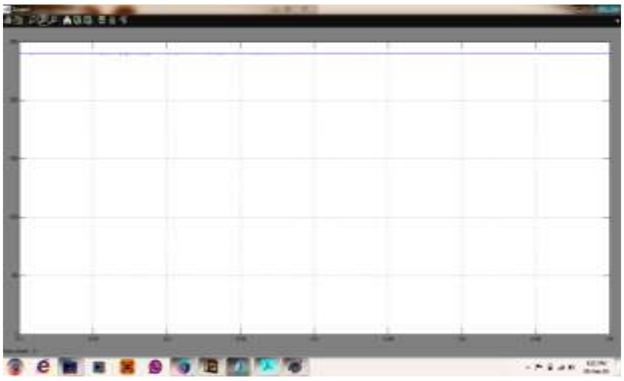
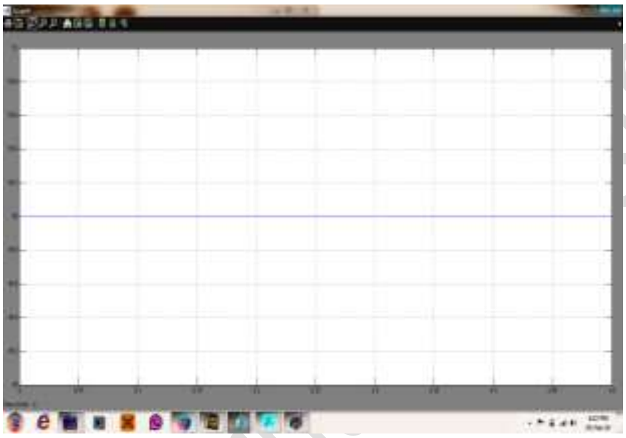


Fig:9(a)



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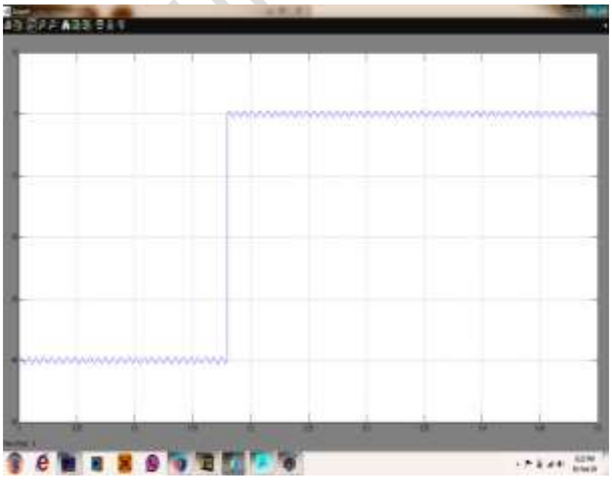
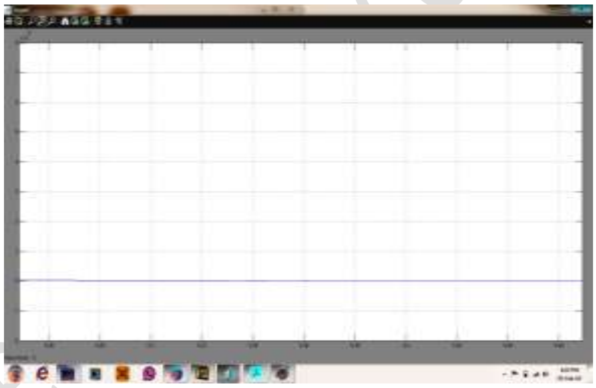


Fig:9(c)

Fig:9(d)



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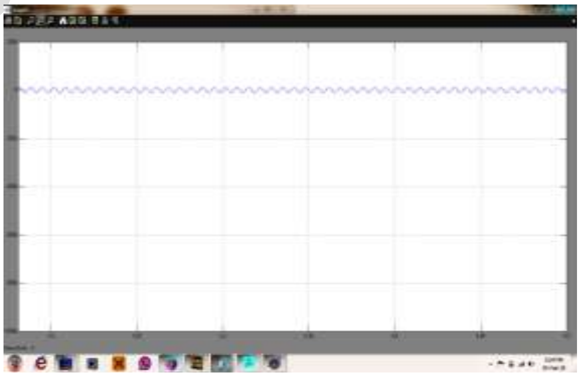

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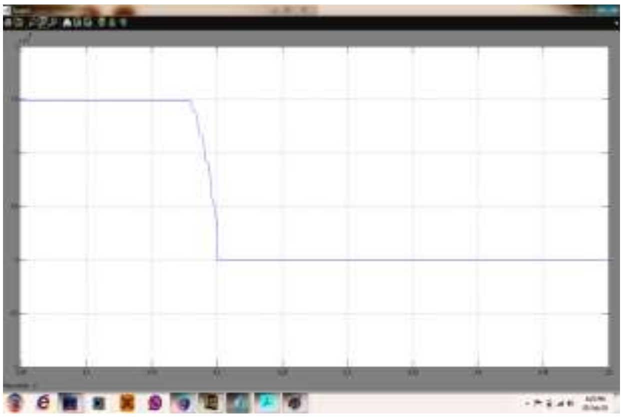

Fig:9(g)

Fig:9. Performance of the system under loss of load at battery power

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The performance of the micro-grid for loss of load, is shown in Fig. 9. A 10 kW and 6 kVAR load, is connected at the terminals prior to start of simulation. Neither wind nor solar power, is available and the load is fed by the battery. At t=0.2 s, the system load is disconnected. It is found that the system voltage and frequency remain constant of the network.

CASE-E: System Running without Generating Source and Battery Charged from the Grid

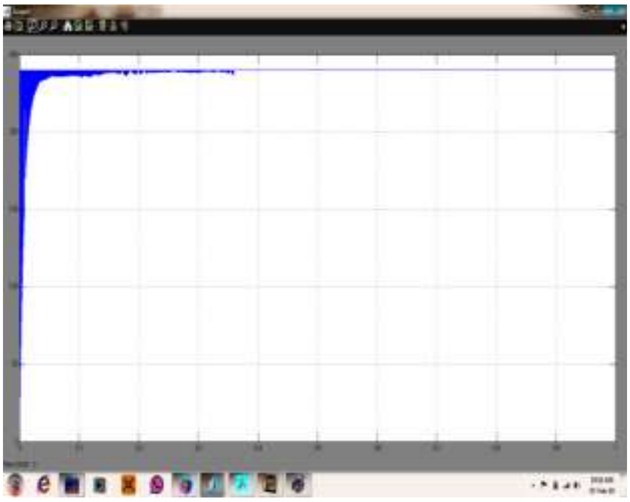
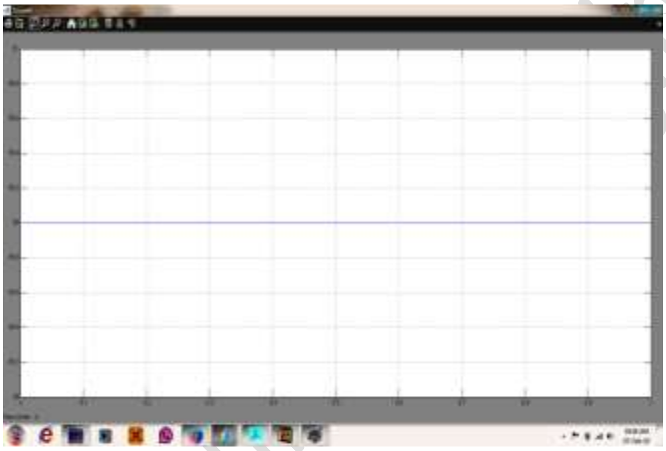


Fig:10(a)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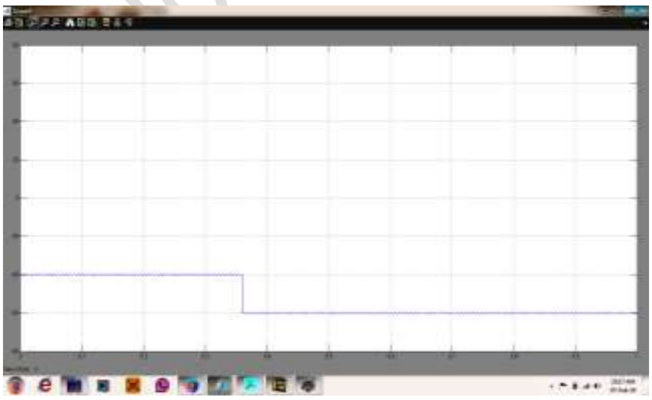
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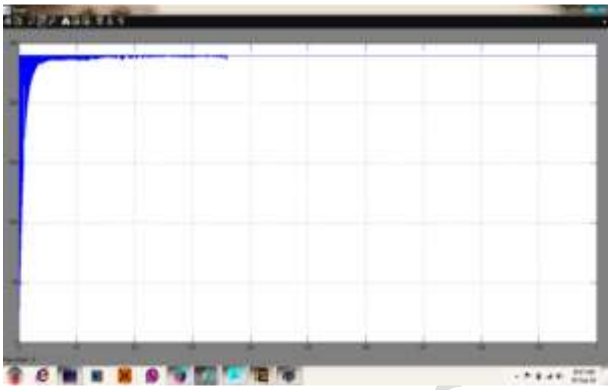
Fig:10(d)

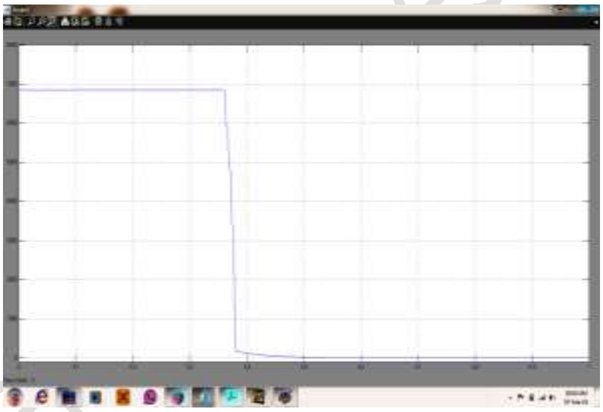
Fig:10(e)

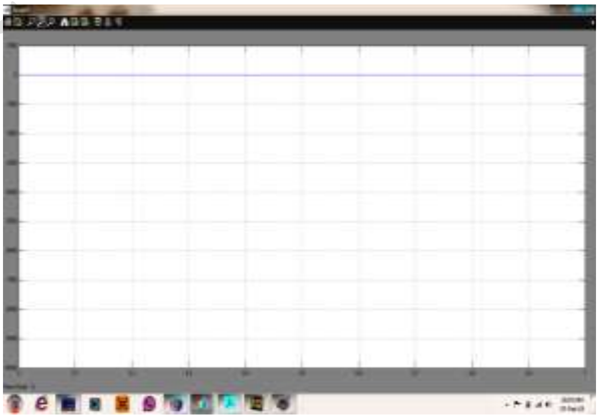
Fig:10(f)

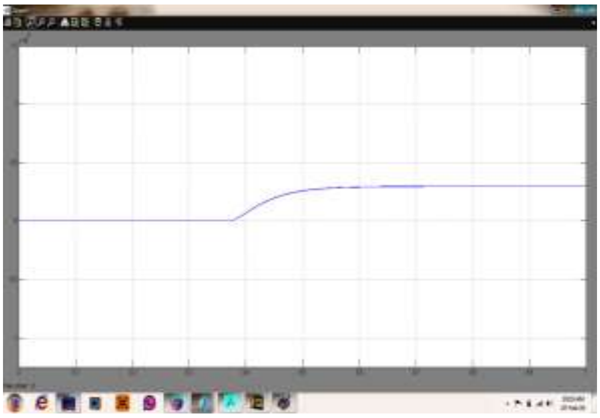
Fig:10(g)

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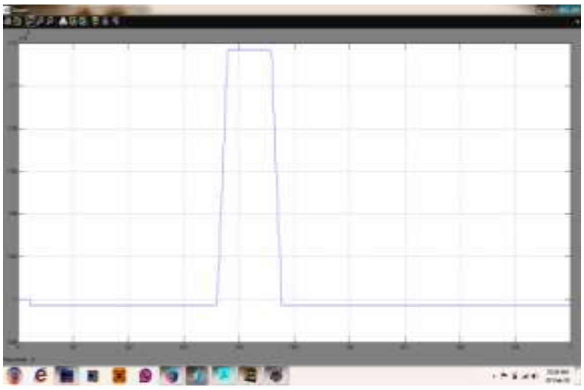


Fig:10(h)
Fig:10 Performance of system through external charging

Fig.10 shows the scenario when there are no generating sources feeding to the network combined with low battery. External charging is required to sustain the load requirement. Charging circuit is enabled as per the logic condition. At t=0.4 s, wind generation is taken out of service and because of lower battery voltage, the charging circuit is initiated. As a result external power is injected through the RSC to cater load requirement in addition to charging the batteries.

CASE-F. Performance of System during High Generation and Over-voltage Scenario of DC bus

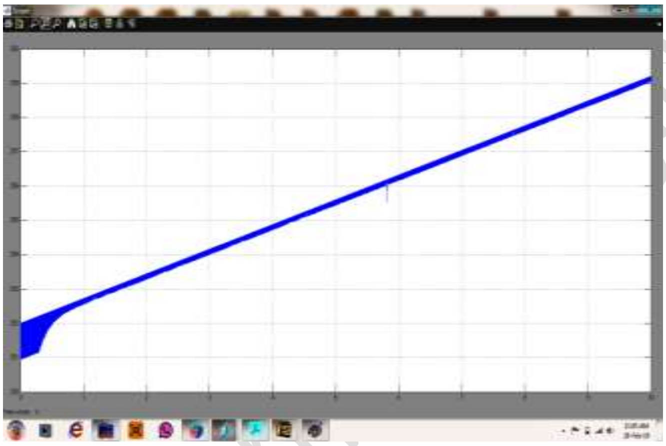


Fig.11(a)

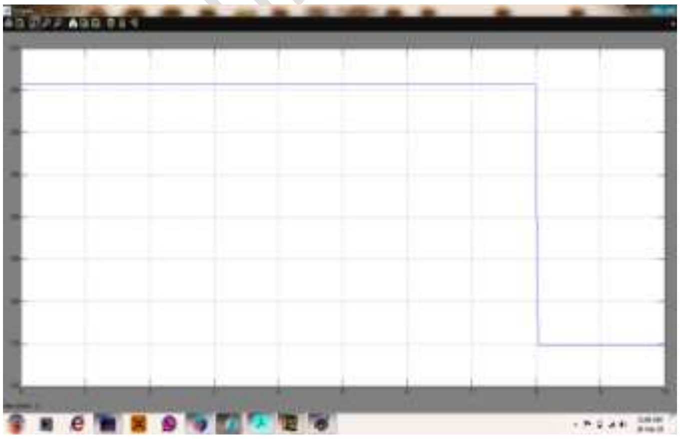


Fig.11(b)

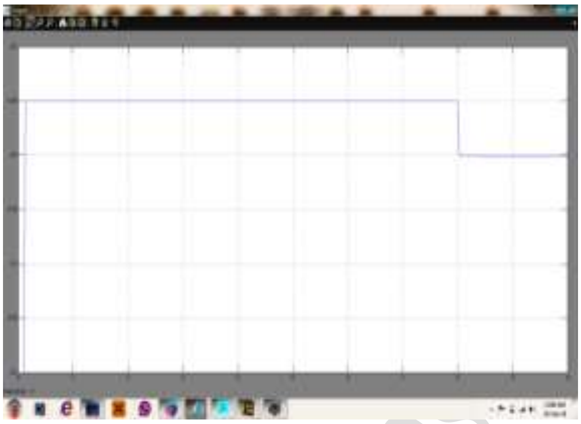


Fig.11(c)

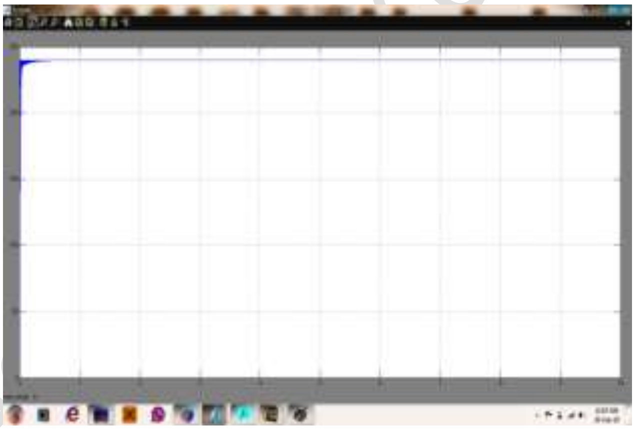


Fig.1(d)

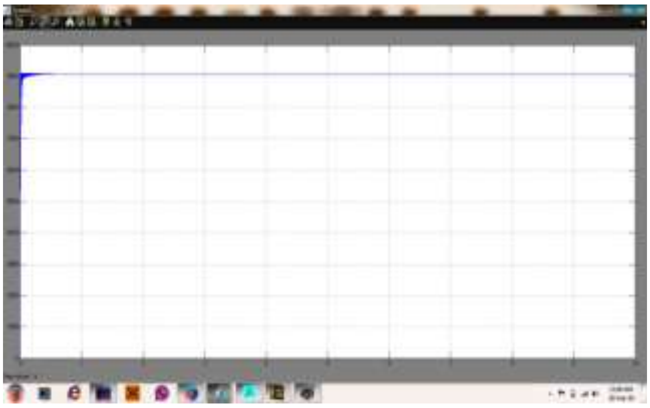
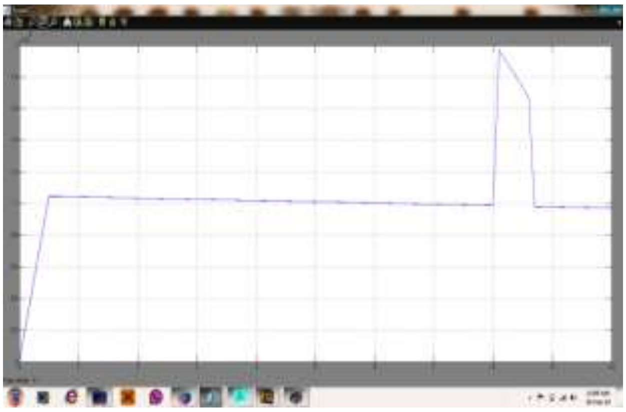


Fig.11(e)



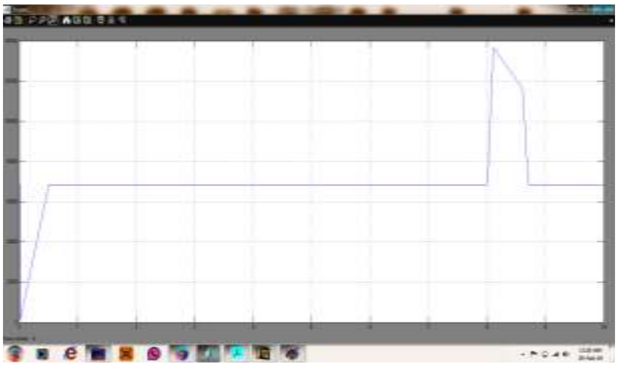


Fig:11- Performance of system during high generation and over-voltage scenario of DC bus

Performance of system at high net generation and over-voltage scenario of DC bus, is shown in Fig. 11. To make the effect visible, the AH of the battery is reduced by 1/200 times. The wind speed and solar irradiance, are kept 9 m/s and 700 W/m2 respectively. It is seen from the curve, that once the *Vdc* reaches 260 V, RSC control reduces the DFIG speed set point to 85% of the MPPT set point. It is seen from Fig. 5.12 that charging power, *Pc* is reduced and the voltage rise is reduced.

V. CONCLUTION

The proposed micro-grid system fed from REGS has been found suitable for meeting load requirement of a remote isolated location comprising few households. REGS comprises of wind and solar energy blocks, which are designed to extract the maximum power from the renewable energy sources and at the same time, it provides quality power to the consumers. The system has been designed for complete automated operation. This work also presents the sizing of the major components. The performance of the system has been presented for change in input conditions for different type of load profiles. Under all the conditions, the power quality at the load terminals, remains within acceptable limit. The effectiveness of the system is also presented with test results with prototype in the laboratory. The system has also envisaged the external battery charging by utilizing the rotor side converter and its sensors for achieving rectifier operation at unity power factor.

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