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COMPARATIVE ANALYSIS OF PHOTOVOLTAIC FED WIND DRIVEN INDUCTION GENERATOR WITH BATTERY AND GRID CONNECTED HYBRID WIND DRIVEN PMSG-PHOTOVOLTAIC SYSTEM

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ABSTRACT

Hybrid Wind-solar stand-alone renewable energy systems is consider as more economical and reliable one than the stand-alone system with the single sources of wind and solar.Two different requirements storage capacity systems has been calculated in Hybrid system. The first main requirement of the storage capacity for supplying the Real and Reactive Power when there is no availability of solar energy and wind Resources. The second Main Requirement of the storage capacity which is used to supplying Reactive power only to the induction Generator when there is no availability of solar power. The calculations of storage capacity under different condition could satisfying the constraint for maintaining the Zero Loss of power supply probability (LPSP) and for improving the life of the battery bank system.A renewable resource such as the solar wind etc. offers clean, abundant energy. However, if, the Demand of power increases the Power failures gets increased so the renewable energy can be used to provide the constant Loads. Maximum power point tracking (MPPT) controller is necessary for ensuring the output of PV power generating systems at the maximum output power as possible. Distributed Generators based on Wind and Solar Requires a New Power electronics interface and controlling strategy for improving the efficiency and quality of Power in Hybrid systems. Distributed Generator system based on Single Source has been considered unreliable due to the harmonizing nature of the resources.PMSGs is commonly employed in such Hybrid schemes where they might not require reactive power support. Where areas PMSGs to be directly driven with wind-turbine system which avoids a gear box arrangement and do not require any maintenance. Permanent magnet synchronous generator has been received much attention because of its self-excited property which might leads to high power factor and high efficiency.

Keywords: battery storage systems, state of charge, photovoltaic fed wind driven induction generator, grid connecting hybrid based systems, distributed generators hybrid systems (DGs), wind driven PMSG–Photovoltaic system.

1. INTRODUCTION

Hybrid system have its own advantage over conceding more flexible for designing the system in order to choose the rating of solar and wind-driven generators, based on the Load conditions and Resource availability. However, hybrid Systems are to be considered more reliable and inexpensively better than Stand-alone Wind and solar energy system which require a less storage when comparing to the single source [1]-[3].

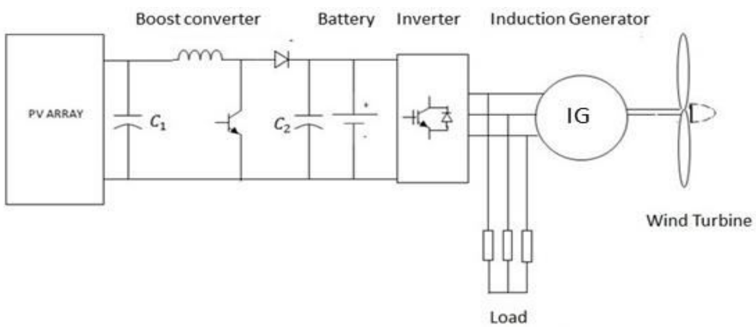

Figure-1. Schematic diagram of proposed Photovoltaic Fed Wind Driven Induction Generator.

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Hybrid Generation Systems based on Wind-PV system which offers high reliability for maintaining continuous output power compared to other individual power generating system [1]-[2]. In isolated areas stand-alone Wind-PV and Hybrid Generating system are particularly attractive and more valuable. However, Wind and Photovoltaic power systems is more harmonizing for an extent conditions since peak power for PV is achieved in sunny Days and strong wind power are achieved mostly during cloudy days and night time whereas weak winds are calm during the sunny days.Substantially,Energy storage systems plays a key role in Hybrid based system ,it cannot be completely eliminated, which requires for the supply of real and reactive powers when the solar and wind sources are not available and for storing the excessive energy efficiently generated by the discontinuous sources. Lead acid battery have been preferred for storage in Hybrid and stand-alone systems for its efficiency, less cost, maintenance easy characteristics and wide operated ranging system[4]-[5].Nowadays, Renewable Energy system based on wind energy and solar energy with distributed power generation systems (DPGSs), are making much more contribution for the total energy production all over the world for an efficiency, flexible, and reliable energy conversion power electronics interface and converters have found a wide variety of applications in Distributed Generators.Combined wind-Photovoltaic hybrid generation system utilizes the wind and PV resources for the electrical power generations. Individual wind and solar renewable sources have unpredictable random behaviour. Net Energy buildings, needs the cumulative energy consumption have been encountered by renewable energy source installing surrounded by its area, have become more and more popular. Distributed power Generators based on Wind and Solar Requires New Power electronics interfaces and controlling strategy for improving the efficiency and quality of Power in Hybrid systems.Distributed Generator systems based on Single Sources which is considered unreliable due to the harmonizing nature of the resources [8]-[10]. PMSG with direct-driven is used for wind generator model because PMSG with direct-driven which has drained over its attention for the residential and scale power levels due to its gear-less operation systems.In case of Induction Generator (IG), gear box is required for matching the speed of the turbine and the rotor. However, the gearbox systems suffers many times from faults and problems, it requires regular maintenance where the system which is unreliable under gearbox conditions.

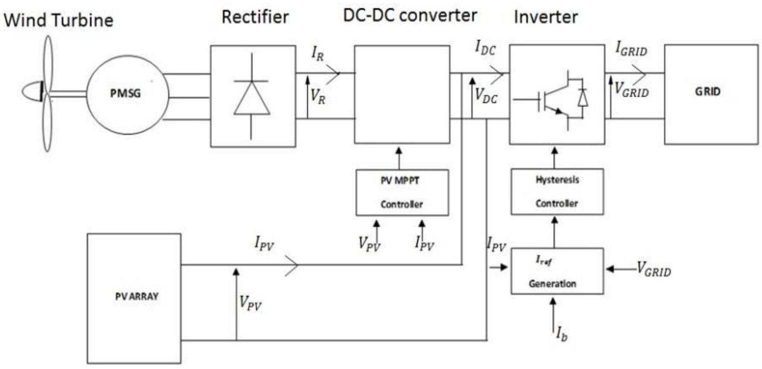

Figure-2. Schematic diagram of proposed Hybrid PMSG-Photovoltaic system.

2. SYSTEM DESCRIPTION

The schematic for Hybrid System as shown in Figure-1, the Photovoltaic array (PVA) feed to DC-to-DC boost converter. The basic Perturbed and Observe (P&O) method with the Maximum Power point Extraction (MPPT) algorithm employed for extracting maximum power from photovoltaic arrays. DC-to-DC output which is fed to a voltage source inverter with 180 mode of conduction with switching frequency (20 MHz) and frequency fixed to 50Hz .A Battery bank System used as storage capacity connecting in between DC to DC boost converter and IGBT based voltage source inverter. As a Dc-link Battery Maintains a Voltage constantly across the Load terminal. Three phase load which is connected to an output of IGBT based inverter. The Load demand sharing is done by wind driven induction generator and photovoltaic array (PV) depending on Wind speed gained and irradiation level. If power to be generated from the Photovoltaic and wind energy which is higher than load demand battery bank system gets charged simultaneously. Loads during extensive outages when sunlight is not available large battery bank supply storage capacity is needed which leads to more expensive one. The schematic diagram of distributed generator (DG) system is shown in Fig 2, where photovoltaic array and PMSG are acting as sources. The output of the PMSG is rectified using diode rectifier feeds by the DC-to-DC converter. The output of diode rectifier voltage gets varied respect to Wind turbine speed. The terminals of photovoltaic array connected to the DC-to-DC boost converter where, photovoltaic array acts as common DC link system. The input terminals of three phase inverter are coupled to Dc-link. The voltage of photovoltaic array is fixed to DC-to-DC boost converter output voltage where output terminals of photovoltaic array and DC-to-DC boost converter are coupled together. The DC-to-DC boost converter output voltage varies automatically using photovoltaic Maximum Power point Extraction controller, the controller 1 draws maximum power point voltage from photovoltaic array. The Hysteresis current controller of three phase inverter extracts Maximum current from Photovoltaic array at a given irradiation level. The hysteresis current controller output voltage is coupled with grid side frequency, voltage for the grid synchronization purpose.The inverter feds current to the grid system given as (I_{GRID}) and the voltage is given as (V_{GRID}) respectively.The reference current signal (i_{ref}) gets vary automatically by Hysteresis controller and extracts maximum current from the photovoltaic array and from PMSG system. The Hysteresis controller which varies according to the inverter output connected to grid.

A. PV Array

The photovoltaic arrays consist of series and paralleled connected solar cells. Each of Solar cells formed by a PN junction semiconductor material and produces current by photovoltaic effect. Power characteristics curve to be shown when maximum power point existed. In order, for utilizing maximum output power from the photovoltaic array (PVA), an appropriate controlling algorithm needed for implementation [9].Crystalline silicon based on semiconductor solar array cells are more dominating in today's marketing levels, whereas new technology based on organic material and plastics with different combination of semiconductor are increased achieving in markets [15].

B. MPPT Technique

Photovoltaic panels have a nonlinear voltage and current characteristics, with distinctive maximum power point (MPP), where it basically depends on environmental factors (i.e., Temperature and irradiation level).Tracking a Maximum point of power from Photovoltaic array is more essential one in a Photovoltaic system. The problem considered by Maximum power point tracker(MPPT) technique which automatically finds the voltage maximum power-point(VMPP) and maximum power-point current(IMPP) in which a photovoltaic (PV) array should operate for obtaining the maximum output power(PMPP) form a given temperature and irradiation[9].This algorithm perturbs the operating voltage for ensuring the maximum power.

C.MPPT Algorithm

Various maximum power-point tracking (MPPT) techniques have been developed. The perturb and observe MPPT algorithm is implemented because of its simplicity. Its output power changes depending upon controlled output current.The main objective of perturbed and observe (P and O) MPPT algorithm, to determine the changing direction of load current [14]-[15].While there are several advanced and more optimized variants of this algorithm, a basic P&O method with MPPT algorithm is shown below.

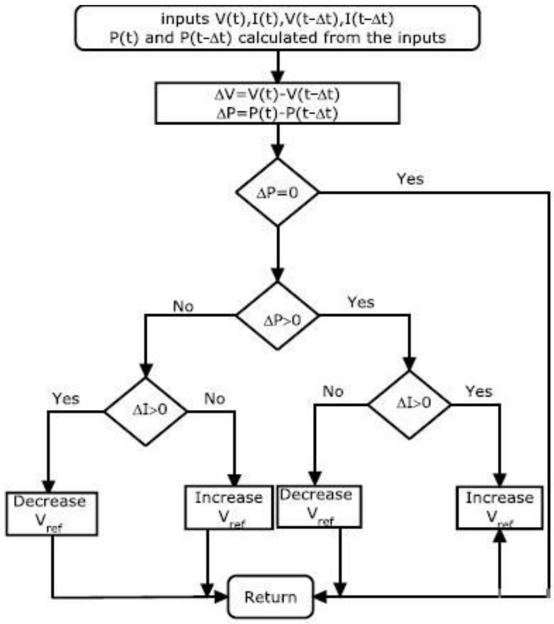

Figure-3. Flow chart for P and O method with maximum power point algorithm.

3. MODELLING OF HYBRID SCHEME

Modelling of the Distributed Generation system is implemented in order to investigate the DG system performance. The steady-state equivalent diagram of PMSG is given and shown as,

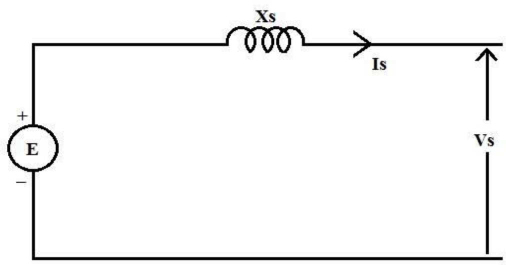

Figure-4. Per-phase steady state equivalent diagram of Permanent magnet synchronous generator.

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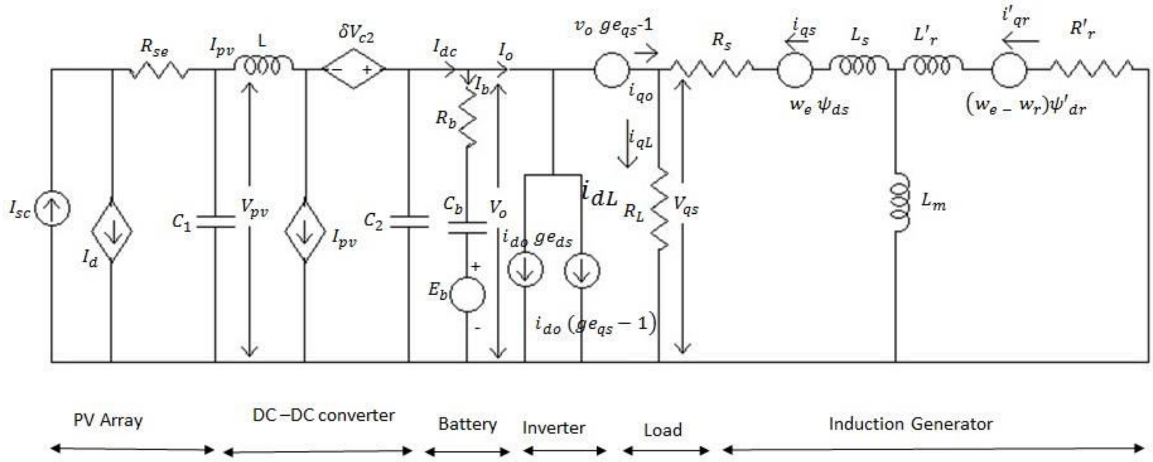

Figure-5. d Axis equivalent circuit scheme.

The d-q modelling of photovoltaic fed wind driven Induction Generator is shown. It extents the interposing of DC-to-DC boost converter with photovoltaic array and the three phase inverter respectively. The battery bank storage capacity also includes in-between DC to DC converter and the three phase inverter. The direct and quadrature axis(d-q axis) along with battery bank storage capacity is expressed and shown respectively. The equivalent scheme of storage capacity (i.e., Battery bank) represents voltage source connecting series to a resistance R_b and a capacitor C_b.

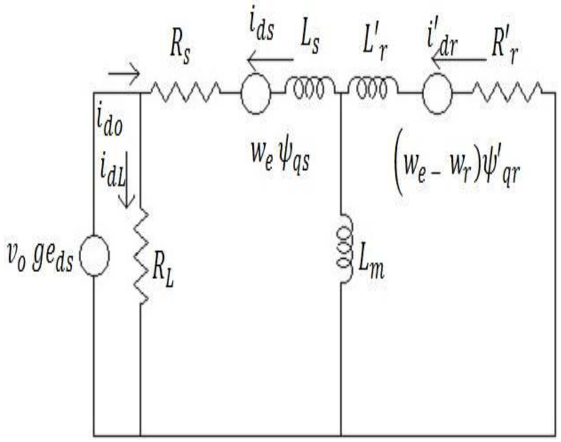

Figure-6. Q axis equivalent circuit scheme.

The equations are,

$$\frac{d[\omega r]}{dt} = \frac{1}{2H}(T_e - F_{\omega r} - T_m) \quad (1)$$

$$T_e = -\left(\frac{3}{2}\right)\left(\frac{p}{2}\right)L_m\left(i_{qs}i_{dr} - i_{ds}i_{qr}\right) \quad (2)$$

Where T_e is the electromechanical torque and T_m is the mechanical torque.

The machine voltage and the dc side voltage can be given as,

$$v_{qs} = \frac{2}{\pi}(v_o)\left(g_{qs}^e\right) \quad (3)$$

$$v_{ds} = \frac{2}{\pi}(v_o)(g_{ds}^e) \quad (4)$$

Where

$$g_{qs}^e = 1 + \frac{2}{35}\,cos6\omega_e t - \frac{2}{143}cos12\omega_e t + \cdots \quad (5)$$

$$g_{ds}^e = \frac{12}{35}\,cos6\omega_e t - \frac{24}{143}cos12\omega_e t + \cdots \quad (6)$$

The load current of direct axis,quadrature axis are given by,

$$i_{ql} = \frac{v_{qs}}{R_L} \quad (7)$$

$$i_{dl} = \frac{v_{ds}}{R_L} \quad (8)$$

As per the Equivalent diagram given as,

$$i_{q0} = i_{ql} - i_{qs} \quad (9)$$

$$i_{d0} = i_{dl} - i_{ds} \quad (10)$$

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4. INVESTIGATIONS ON SCHEME

Squirrel cage induction generator, the rating of machine which is expressed as 0.25P.U(kw) chosen as rated power consists of 4poles and speed is about 1500RPM.The sizing of battery bank and generator design done for maintaining constant peak load. The investigation of Battery bank, DC to DC boost converter, PV array and induction generator is investigated by different cases and sizing to be done based on the parameters chosen in the system. The induction generator parameters are chosen as (stator resistance Rs=9 ohm, Ls=0.02 H, L0r=0.02H, Lm=0.3 H, R0r=7.6X) and 100Ah battery capacity is chosen. PMSG ratings are chosen as base voltage about 100V (rms), Base current about 10A (rms), and rated power chosen as 0.75P.U (KW) with 12 poles. The PV array open- circuit voltage,(V_{oc}=0.22p.u), and the short-circuit current,(I_{sc}=0.47p.u) is chosen respectively.

Case 1: Stand-alone Photovoltaic system

In this case stand-alone photovoltaic system is considered. In case there is no real power deliver to three phase load by the Induction generator. Photovoltaic array and battery bank system which supplies the load. In case there is no irradiance the battery bank system state of charge gets decreased linearly where it supplies constant current to the load[8]-[9]. For ensuring zero loss of power supply probability proper choice of battery bank state of charge is chosen. If the battery bank system gets discharges below 50% for the similar irradiance and load which is maintained same for further days the life of battery gets affected.

Case 2: Wind alone system

In this case stand-alone wind energy system is considered, Wind driven induction generator generated power is higher than the demand of the load at that time battery bank system gets charged and supplies reactive power simultaneously [8]. When power produced from the induction generator is not enough for supplying load at that time battery bank system gets discharged deeply in order to met the load demand and simultaneously insufficiency of reactive power also occurred, where at this conditions the state of charge will not maintained within limits and the battery bank system life gets affected at these conditions.

Case 3: Hybrid system Photovoltaic and wind system

In this case Hybrid Renewable system is considered, photovoltaic array and induction generator with Battery bank system supplies the real power in order to met the load demand. The state of charge limits to be properly chosen where in the peak hours the irradiance level which is maintained nearly 85% and at end of day the state of charge discharge below 64% and maintains with in limit conditions. More over if the load is reduced to 50 % at night time at the end of the day the state of charge which is maintained at 74% and ranged within its proper limits. At the end the battery state of charge to be maintained at proper Minimum and maximum prescribed limits in hybrid system case where from this case clearly understood that battery bank life is not affected.

5. COMPARISON RESULTS AND DISCUSSIONS OF HYBRID SCHEMES

The paper represents the Hybrid based system and to analyse the different operating conditions [16]. In this scheme consists of DC-DC boost converter, photovoltaic array and induction generator to be considered which is to be extracted maximum power is simulated in MATLAB Simulink.

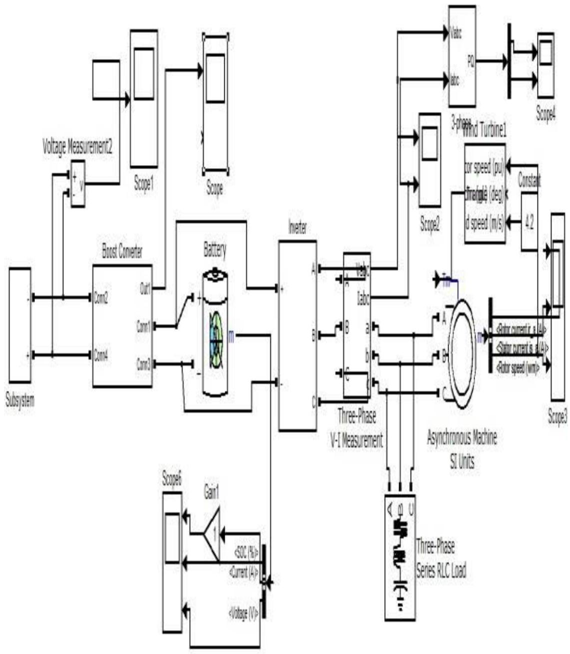

Figure-7. Simulation schematic of Photovoltaic fed Wind Driven Induction Generator.

The simulation response of inverter voltage has shown below in Figure-8.The output response is plotted for time in x-axis versus voltage in y axis at time 0 to 2seconds.Hence the resulting voltage observed from the waveform for phase A,B,C about 210 volts.

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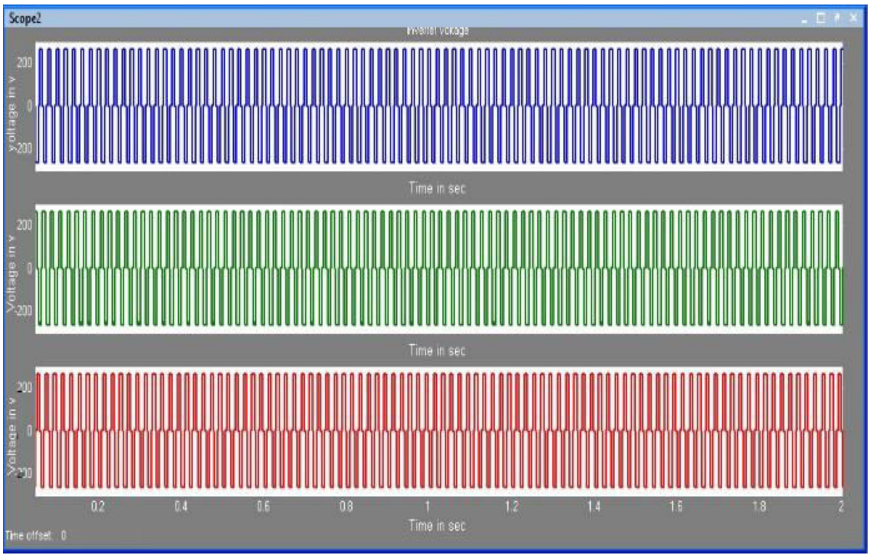

Figure-8. Output of inverter voltage.

The simulation response of inverter current has shown below in Figure-9.The output response is plotted for time in x-axis versus current in y axis at time 0 to 3secondshence the resulting current observed from the waveform for the phase A,B,C about 10amps.

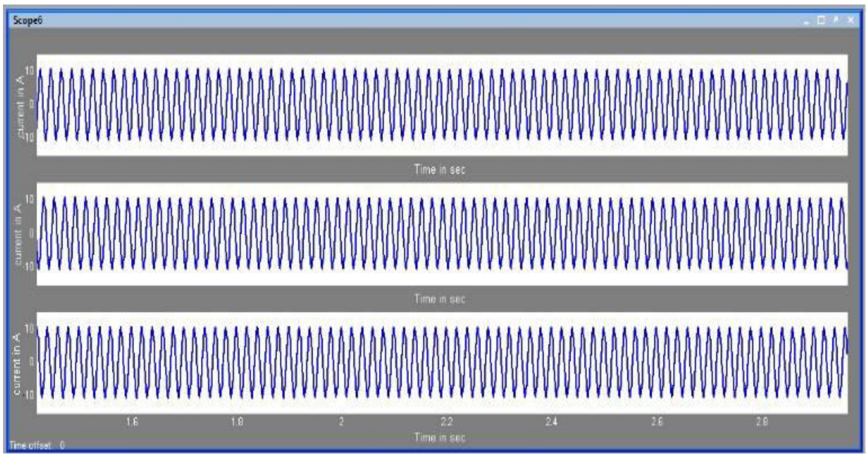

Figure-9. Output current of the inverter.

The simulation response of Battery SOC has shown below in Figure-10.The output response is plotted for time in x-axis versus Battery SOC in y axis at time 0 to 5seconds. Battery bank State of charge gets increase and decrease depends on irradiance and wind turbine speed which maintains nearly 80% to the starting State of charge of battery bank system.

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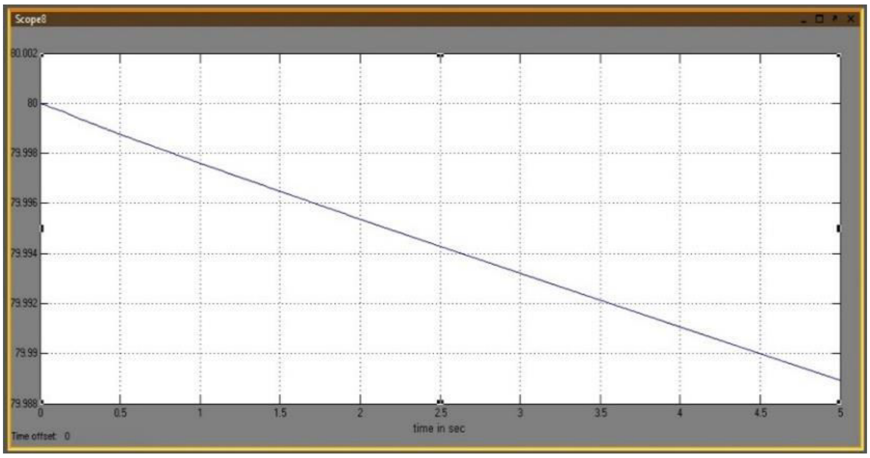

Figure-10. Output for battery state of charge.

The simulation response of Battery voltage has shown below in Figure-11.The output response is plotted for time in x-axis versus voltage in y axis at time 0 to 5seconds.Hence the battery maintains about 264 volt from the resulting waveform.

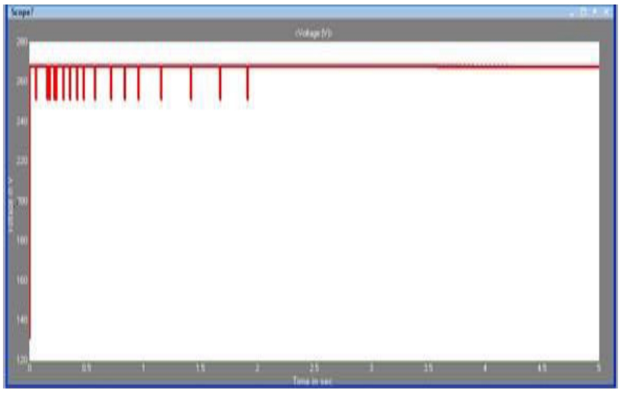

Figure-11. Output voltage of the lead acid battery.

Grid connected based system is considered, photovoltaic array and permanent magnet synchronous generator are acting as a sources in this hybrid scheme both sources are connected commonly to a DC link system. This hybrid system consists of multiple input DC to DC converters and multiple input three phase inverter. By using both the controllers' maximum power to be extracted from the sources experimentally the scheme is simulated in MATLAB Simulink.

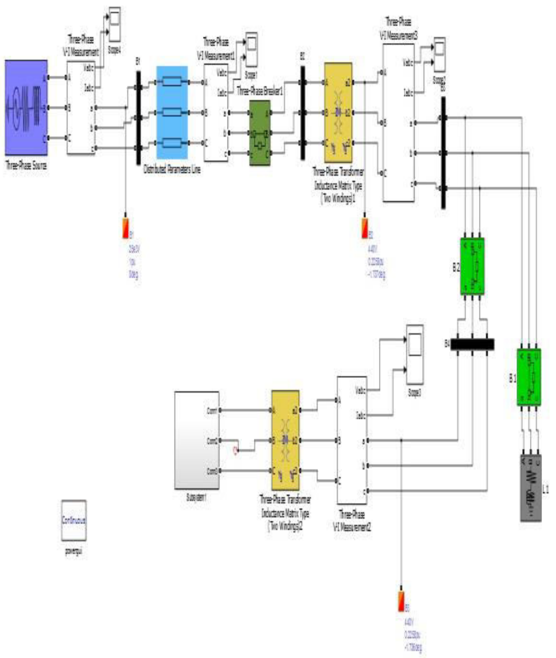

Figure-12. Simulation schematic of Grid connected PMSG-Photovoltaic system.

The simulation response for Grid side voltage and current has shown below in Figure-13.The output response is plotted for time in x-axis versus voltage in y axis at time 0 to 1.5seconds.Hence the resulting voltage about 20kv and current is about 4 A.

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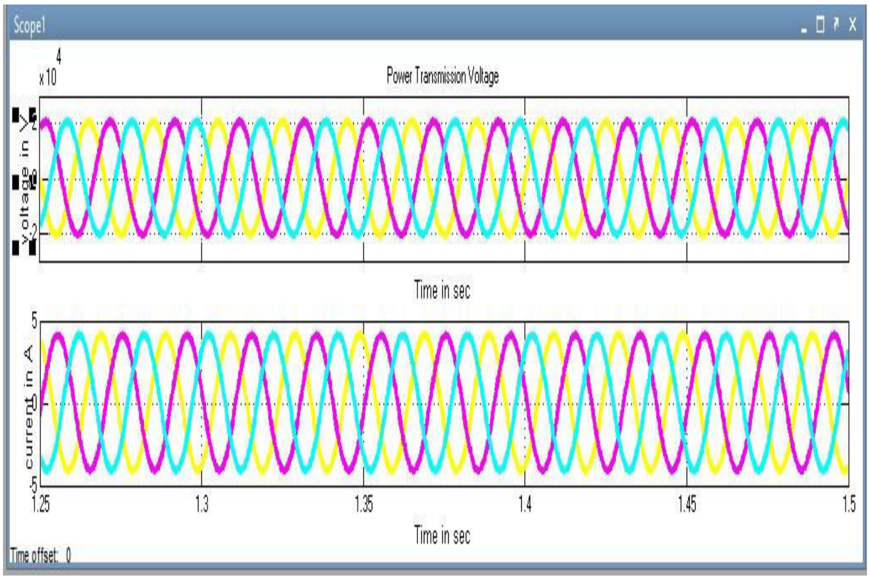

Figure-13. Grid side voltage and current.

The simulation response of Electrical and Mechanical Torque has shown below in Figure-14.The output response is plotted for time in x-axis versus T_e and T_m in y axis at time 0 to 3.5seconds.the electrical and mechanical torque meeting at same point shows that PMSG running at synchronous speed as per swing equation up to time t=0.5seconds.Where the torque maintains 40Nm after 0.5 seconds. Hence the rotor speed initially at about 200rad/s and maintains 150rad/s after time t=0.5seconds

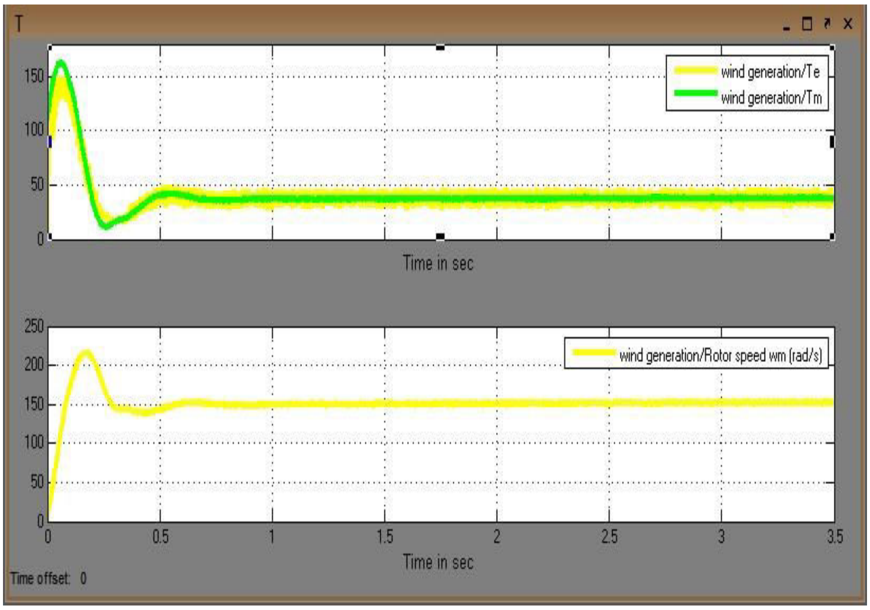

Figure-14. Electrical and mechanical torque for Grid connected PMSG.

The simulation responses of the real and reactive power have been shown below in Figure-15.The output response is plotted for time in x-axis versus real and reactive power in y axis at time 0 to 3.5seconds.After 0.5 seconds the real and reactive power maintains constant power.

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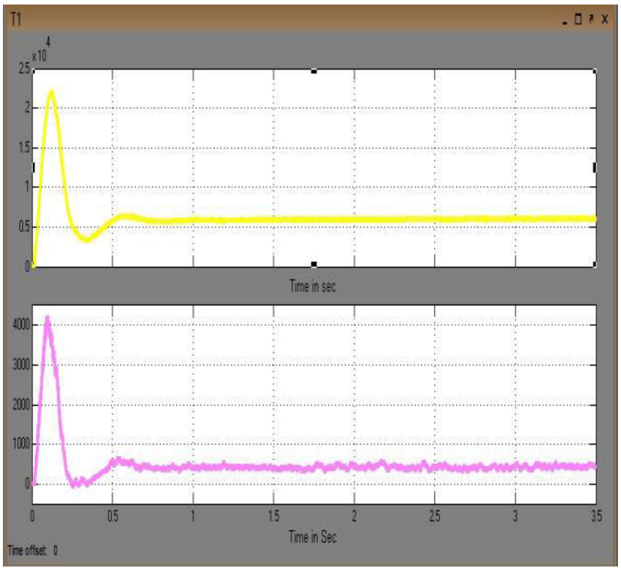

Figure-15. Real and reactive power for PMSG system.

The simulation response of real power has shown below in Figure-16.The output response is plotted for time in x-axis versus real power in y axis at time 0 to 5seconds.Hence the resulting Real power is consumed about 2400w initially after 0.04 seconds it maintains about 2200w.

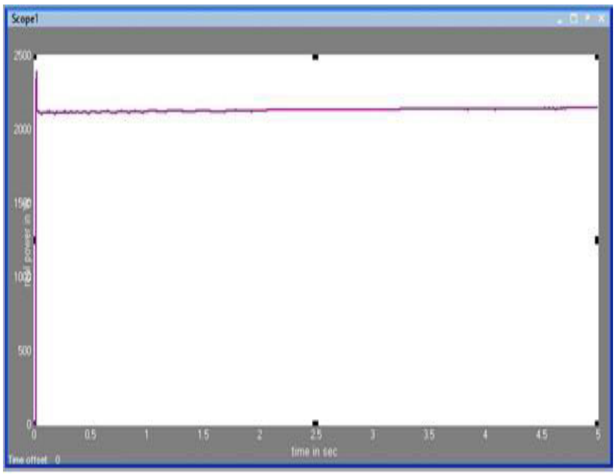

Figure-16. Real power for Photovoltaic Fed Wind- Drive Induction Generator.

Simulation response for reactive power has shown below in Figure-17.The output response is plotted for time in x-axis versus reactive power in y axis at time 0 to 5seconds.Hence the resulting Reactive power about 3900w is produced.

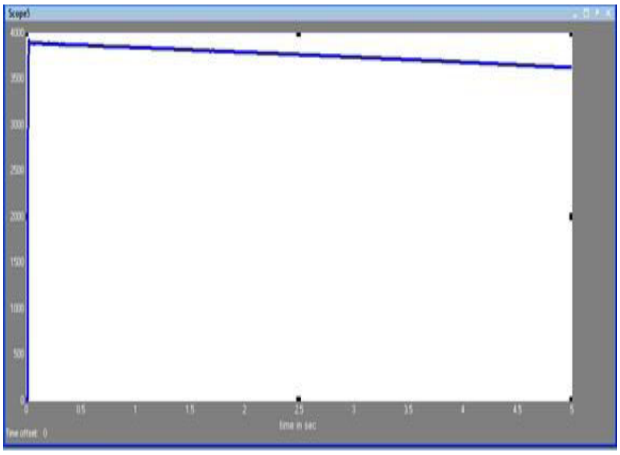

Figure-17. Real power for Photovoltaic Fed Wind -drive Induction Generator.

Simulation response of the turbine power characteristics has shown below in Figure-18.The output response is plotted for turbine speed in x-axis versus turbine power in y axis .Hence in this waveform for wind speed 12m/s power generated is about 0.7w in P.U

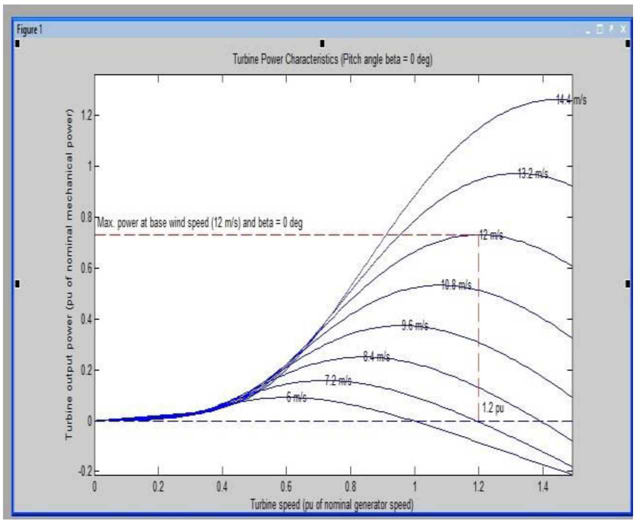

Figure-18. Turbine power characteristics for Induction Generator.

The simulation response of turbine power characteristics has shown below in Figure-19. The output response is plotted for turbine speed in x-axis versus turbine power in y axis .Hence in this waveform for wind speed 12m/s power generated is about 0.8w in P.U.

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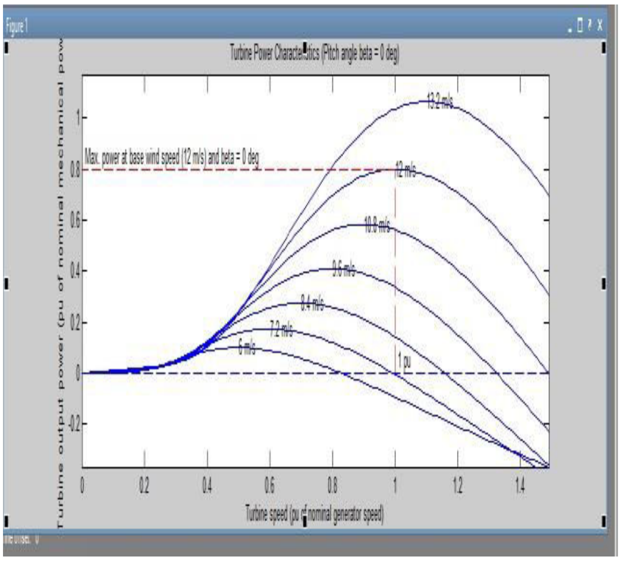

Figure-19. Turbine power characteristics for PMSG.

The simulation response of frequency has shown below in Figure-20.The output response is plotted for Time in x-axis versus Frequency (Hz) in y axis. Hence this Waveform shows that Grid side frequency after time t=0.8seconds the frequency which is maintaining 50Hz.

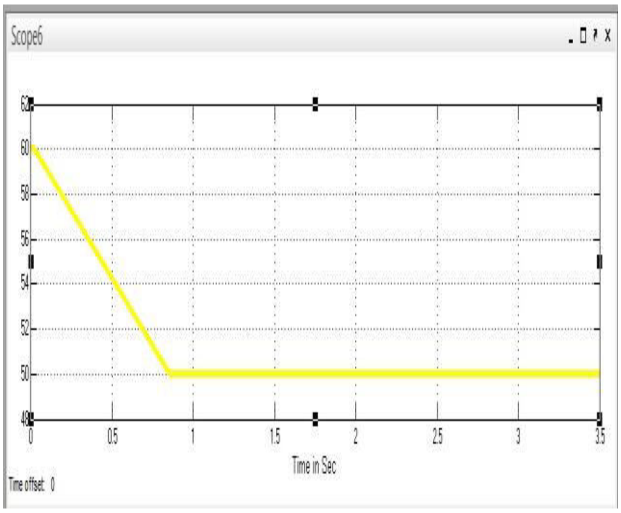

Figure-20. Frequency for Grid connected system.

The simulation response of frequency has shown below in Figure-21.The output response is plotted for Time in x-axis versus Frequency (Hz) in y axis. Hence this Waveform shows that Grid side frequency after time t=0.8seconds the frequency which is maintaining 50Hz.from the graph clearly shows that at time 0.8 seconds the frequency gets synchronising with grid side frequency.

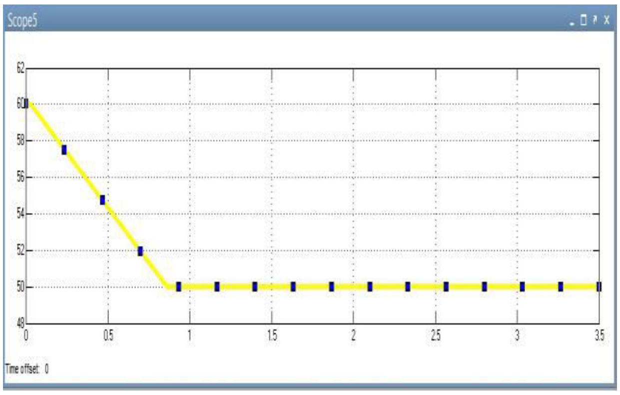

Figure-21. Frequency for PMSG-PV system.

CONCLUSIONS

Distributed Generation with hybrid system consisting of photovoltaic array and PMSG acting as a sources, which consists of one DC to DC converter, three phase inverter, maximum power point tracking (MPPT) controller is particularly designed in this system in a reliable manner. More reliable, no need of maintenance and less cost are the few of the merits and features for the distributed generation in secondary distribution system.Loads during extensive outages when sunlight is not available large battery bank supply storage capacity is needed which leads to more expensive one and same way becomes low efficient one. A battery based system which costs from 30 to 50%which is more than the battery less grid tied system it costs about 50% more based on its Battery bank size and other components.

ANNEXURE

Table-1. Induction generator specification.

Base voltage	**210V**(rms)
Base Current	10A(rms)
Rated Power	0.25p.u(KW)
No. of Poles	4

Table-2. Specification for Grid connected PV array.

Open Circuit Voltage(V_{oc})	0.22P.U
Short Circuit Current(I_{sc})	0.47P.U
Peak Power	0.08P.U

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Table-3. Grid Connected PMSG specification.

Base Voltage	100V(rms)
Base Current	10A(rms)
Rated Power	0.75p.u(KW)
No. of Poles	12

Nomenclature

V_{oc}	Open-circuit voltage of Photovoltaic arrays
V_S i_{ref}	Stator voltage of PMSG Reference Current
V_b	Output voltage of the DC-to-DC Boost converter
V_R	Output voltage of the Rectifier
V_{pv}	Photovoltaic array terminal voltage
V_m	Maximum voltage for the Photovoltaic array
V_{GRID}	Inverter output voltage
$i_{ql}i_{dl}$	Load current of d-axis and q-axis
i_{sc}	Short circuit current for Photovoltaic array.
I_S	Stator current of Permanent magnet synchronous generator.
I_R	Output of rectifier current.
I_b	Output current for DC- to-DC boost converter.
i_{dc}	DC link current.
i_{GRID}	Inverter output current.
i_{pv}	Photovoltaic output current.
I_d	Current through the internal diode of the PV array.

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