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Integration of Hybrid Renewable Energy Using Active Compensation for Distributed Generating System

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ABSTRACT: In this paper a new reference generation technique to integrate renewable energy to the grid is proposed. The increase in power demand is met by the renewable energy and distributed generation. The power electronic components are widely used to mitigate the current harmonics, reactive power compensation and regulate load voltages. This converters require a DC link which is supplied from the renewable energy resources (solar and wind). This hybrid renewable energy resources act as the voltage source and they also inject active power generated by the renewable energy resources. In this paper a active compensator is used to compensate the reactive power, reduce harmonic in the source current and injects the active power from the renewable energy resources to the grid. This simulation studies are carried out and analyzed for single phase using MATLAB/ SIMULINK tool

KEYWORDS:.Terms-Distribution Generation (DG) , Solar Photovoltaic(PV),Total Harmonic Distortion(THD),Hybrid Renewable EnergySystem(HRES) .

I.INTRODUCTION

Indian power sector is facing challenges and despite significant growth in generation over the years, it has been suffering from shortages and supply constraints. Energy and peak load shortages were 7.8 % and 13 % respectively in the year 2012-03. The per capita electricity consumption in India is about 400 kWh/year, which is significantly lower than the world average of around 2,100 kWh/year. As GDP growth accelerates to an ambitious 8 to 10 %, the shortage of power will become more severe. With reference to above power and energy scenario, Ministry of Power (MoP) and Ministry of Non-conventional Energy Sources (MNES), Government of India, has been promoting viable renewable energy technologies including wind, small hydro and biomass power, energy conservation, demand side management etc. MNES has been promoting various sources of renewable energy since 2000. Out of total existing generation capacity, nearly 72% is contributed by thermal power. With a need for sustainable economic growth, the Government of India, through the Ministry of Non-Conventional Energy Sources (MNES), is encouraging and catalysing the growth of renewable energy based power including biomass, wind, hydro, solar photo-voltaic etc. It is expected that a judicious mix of centralised fossil fuel power plants and decentralised renewable energy based power plants will lead to an environmentally friendly augmentation of the power sector in India.

Electrical load of modern power systems contain the combination of linear and nonlinear loads. In recent years, use of solid state electronics, as switching devices of power electronic converters are being increased vastly. As a result, power system networks are subject to high level of harmonics. Although, the fast-switching power electronics devices have several advantages, these systems suffer from the problem of drawing harmonics and reactive component of current from the sources and offer highly nonlinear characteristics. The currents drawn by these electrical loads have a wide spectrum that includes: fundamental reactive power, third, fifth, seventh, eleventh and thirteenth harmonics in large quantities and other higher frequency harmonics in small percentage.

One of the well known methods to generate electricity on plant is installing a Distributed Generation (DG). As a list of distributed generators one can refer to synchronous and combustion turbines which functions with high-energy fossil

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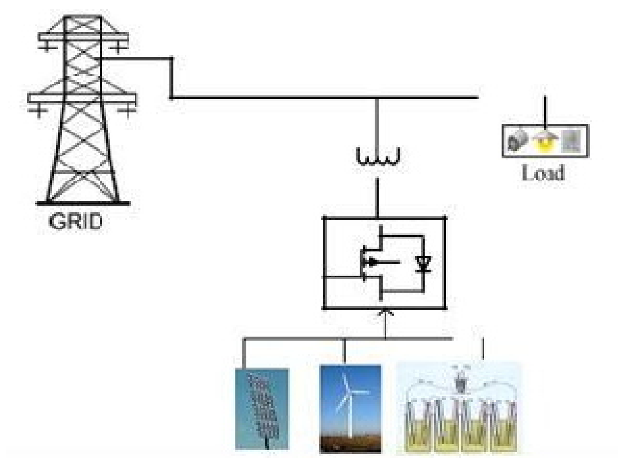
fuels such as oil, propane, natural gas, gasoline or diesel, and wind turbines. It is predicted that Distributed Generation (DG) will be common in futures power systems as a result of the existence of a large demand of generating electricity from renewable energy resources such as wind power, biogas, and Photovoltaic (PV).

In this paper we use shunt converter to inject the active power to the grid from the distributed hybrid renewable source and simultaneously the shunt converter also perform the reactive power compensation and reduce the current harmonic distortions. The reference generation is based on the instantaneous power theory. The simulation studies are carried out with the hybrid renewable source of energy.

II.DISTRIBUTED GENERATOR USING SHUNT CONVERTER

In general, DG can be defined as electric power generation within distribution networks or on the customer side of the network which are physically distributed. The flow of power in the distributed generation system is bidirectional that the power can flow from the grid to the load and when the power is generated by the distributed generation like PV system, wind energy system or fuel cell is of sufficient quantity the power can be feed back to the grid. The power generated from the PV system can be directly connected through the DC-AC converters to the AC bus of the grid as a shown in Fig. 1

Alternative design is based on using a DC-DC boost converter to step up the DC voltage and extract the available maximum power, and then the use of DC-AC converters . Normally the grid connected load used in the distributed system is single phase, therefore the use of single phase in verter topology is more important. The single phase inverter can be used in domestic purpose so by putting a small distributed generation like PV panels on the roof top of the house s and commercial buildings, this energy can be feed to the grid by a large number of PV panels to pull out large amount of electrical power onto the grid.



B. Sola r PV Module

Incident sunlight can be converted into electricity by photovoltaic conversion using a solar panel. A solar panel consists of individual cells that are large-area semiconductor diodes, constructed so that light can penetrate into the region of the p-n junction. The junction formed between the n-type silicon wafer and the p-type surface layer governs the diode characteristics as well as the photovoltaic effect. Light is absorbed in the silicon, generating both excess holes and electrons. These excess charges can flow through an external circuit to produce power. Figure 2 shows the equivalent circuit to describe a solar cell. The diode current is given as

$$Id= Io\ (eqVd/kT - 1) \qquad (1)$$

It is clear that the current I that flows to the external circuit is

$$I= Isc - Io\ (eqVd/kT - 1) \qquad (2)$$

where ISC is short circuit current, I0 is the reverse saturation current of the diode, and A is temperature-dependent constant, A=q/kT [1]. If the solar cell is open circuited, then all of the I_{sc} flows through the diode and produces an open

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circuit voltage Voc of about 0.5-0.6V. If the solar cell is short circuited, then no current flows through the diode, and all of the short-circuit current I_{sc} flows through the short circuit.

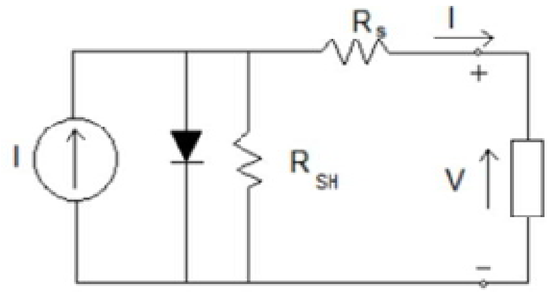

Figure 2 equavalent circuit of solar cell

Since the Voc for one solar cell is approximately 0.5-0.6V, then individual cells a panel" to produce more usabl levels. Most solar panels are made to charge 12V batteries and consist of 36 individual cells (or units) in series to yield panel Voc -20V≈18.The voltage for maximum panel power output is usually about 16-17V.Each 0.5-0.6V series unit can contain a number of individual cells in parallel, thereby increasing the total panel surface area and power generating capability.

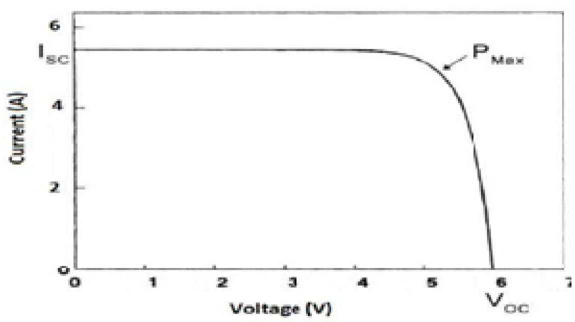

Figure 3. I-V Characteristics of Solar Panel

Figure 3 illustrates the I-V curve and power output of a solar panel. If no load is connected with solar panel which is sitting in the sun, an open circuit voltage Voc will be produced but no current follows. If the terminals of the solar panel are shorted together, the short-circuit current I SC will flow but the output voltage will be zero. In both cases, no power is delivered by the solar panel. When a load is connected, we need to consider the I-V curve of the panel and the I-V curve of the load to figure out how much power can be delivered to the load. The maximum power point (MPP) is the spot near the knee of the I-V curve, and the voltage and current at the MPP are designated as Vm and Im. For a particular load, the maximum point is changing as the I-V curve is varying with the temperature, insolation, and shading. Because solar power is relatively expensive, it is important to operate panels at their maximum power conditions. In fact DC-DC converters areoften used to "match" the loa equivalent resistance of the panel to maximize the power from the converter.

C. Wind Turbine Model

The wind turbines are classified in to two types based on their speed namely Fixed speed wind turbines and variable speed wind turbines. The fixed speed wind turbines uses the induction motor on the other hand the variable speed wind turbine uses Doubly Fed Induction Generator (DFIG) and Permanent Magnet Synchronous Generator (PMSG). This type of variable generator uses two converters machine side converter and grid side converter. Thin type of turbine are used to connect the generated power to the grid. The operating speed of variable speed wind turbine

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varies from 1000-1500 rpm.

The grid side converters are rectifiers which converts the generated power into DC and on the other side the grid side converter uses the inverter which converts the DC power into AC power. The grid side converter uses pwm inverters which used to reduce the harmonic generated due to the conversion and the power in injected to the grid. Hear the PMSG generator is used to convert the kinetic energy present in the wind is to electric energy. The simple model of PMSG present in the MATLAB/SIMULINK is used to model the wind turbine. The basic equation of the wind turbine are given below.

The stator flux-linkage equation are

$$V_{qs}^r = R_q i_{qs}^r + \rho\lambda_{qs}^r + \omega_r\lambda_{ds}^r \quad (3)$$

$$V_{ds}^r = R_d i_{ds}^r + \rho\lambda_{ds}^r + \omega_r\lambda_{qs}^r \quad (4)$$

Where

$$\lambda_{qs}^r = L_s i_{qs}^r + L_m i_{qr}^r \quad (5)$$

$$\lambda_{ds}^r = L_s i_{ds}^r + L_m i_{dr}^r \quad (6)$$

Hence the electromagnetic torque of the PMSM is given by

$$T_e = \frac{3}{2}\frac{P}{2}\{\lambda_{ds}^r i_{qs}^r - \lambda_{qs}^r i_{ds}^r\} \quad (7)$$

On substitution of the flux linkage in terms of inductance and current yields the torque equation which is shown below

$$T_e = \frac{3}{2}\frac{P}{2}\{\lambda_{af}^r i_{qs}^r + (L_d - L_q) i_{qs}^r i_{ds}^r\} \quad (8)$$

In the PMSM torque of the motor plays the major role and also the speed of the wind. The variables in the power generation are the torque and the wind speed. If this two parameters are varied in the Simulink model the output power also varies proportionally.

III.REFERENCE CURRENT EXTRACTION

In literature the reference generation for three phase is widely used to generate the reference current for the control of converter using synchronous frame theory and instantaneous reactive power theory The instantaneous power theory is also used in the reference generation of the single phase converter using p-q theory. The d-q theory is generally used for the reference current generation in three-phaseThe instantaneous power consumed by the load is give by

Pl = Vs .il (9)

This instantaneous power is a sum of average power and the oscillatory power component as defined below.

Pl = Pavg + Posc (10)

This power is then passed through a low pass filter or a moving average filter to filter out the oscillatory component of the power. The net real component of the current required to from the source can be written as

Ilp= (Pavg - Ppv)/Vrms (11)

The maximum power generated by the PV system P pv is subtracted from the average power to find out the net real component of the current given by (7). The ilp must be phase-locked with the voltage so that the phase between current and voltage must be same for unity power factor. The required compensating current ic(t).can be calculated by subtracting the ilp (or iref(t)) from the load current il(t), as defined by (9).

IV.SIMULATION RESULT

The simulation is carried out by using power system simulator MATLAB/SIMULINK. The simulations are carried out for a shunt converter to inject active power and load reactive and harmonic compensation. The load considered is a rectifier type non-linear load connected in series with a R-L elements.

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The figure 4 represents the waveform of the source current. From the waveform we can observe that the waveform of the source current in distorted due to the non-linear load. As said earlier the generator supplies its power to the non-linear load. In the below graph the X-axis represents the time period and the Y-axis represents the amplitude of the source current.

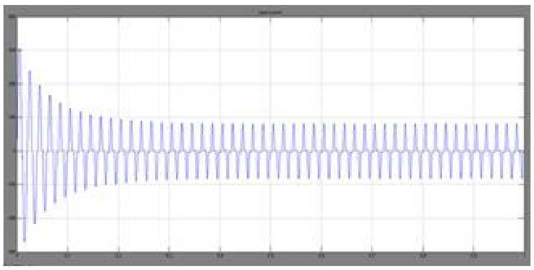

Figure 4 Load current for uncompensated distribution system.

Now the figure 5 and 6 shows the voltage waveform of the source side and load side voltage waveform. Figure 5 shows the source side voltage waveform and figure 6 shows the load side voltage waveform. From the wave form it is observed that there is a phase shift in the load side voltage waveform. this phase shift is due to the presence of the inductor in the transmission line.

In the figure 5 the X-axis represents the time period and Y-axis represents the amplitude of the voltage. The peak to peak source side voltage is 300v

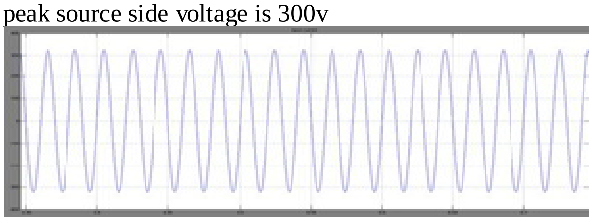

Figure 5 Source Side Voltage

Similarly in figure 6 the X-axis represents the time period and Y-axis represents the amplitude of the voltage. The peak to peak source side voltage is 280v. We can observe an voltage drop of 20v because of the resistance present in the transmission line.

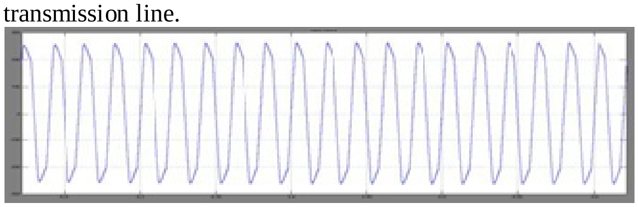

Figure 6 Load Side Voltage

The figure 7 represents harmonic analysis done in the MATLAB/SIMULINK. The harmonic analysis is done for the source side current waveform and the start time was taken to be 0.2sec and the no of cycles observed is 30 cycles. The Total Harmonic Distortion was found to be 65.48%. The compensating current is supplied by the shunt converter as shown in Fig. 8.

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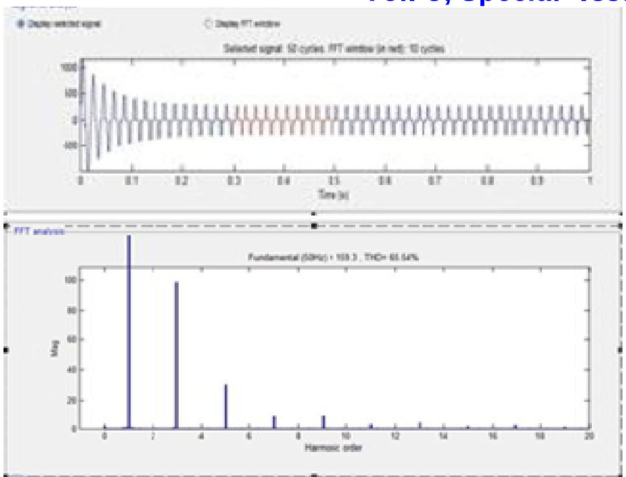

Figure 7 FFT Analysis of Transmission Line

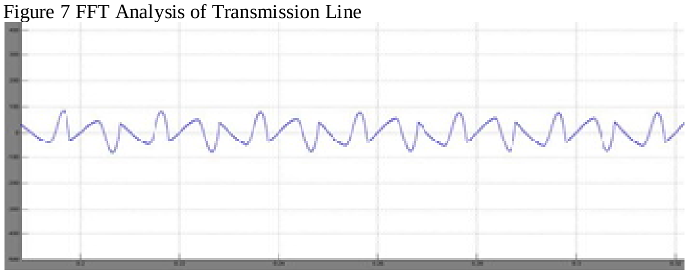

Figure 8 injecting current waveforms.

Figure 10 represents the output waveform of the circuit model shown in the figure 9 hear we can observe that the source current waveform is sinusoidal. This is sinusoidal because of the impact of the integration of hybrid renewable energy to the short transmission line. The source voltage and the load voltage waveform does not change it remains unchanged. For all the graph X-axis is the time period and the Y-axis is the amplitude of voltage. The source current is in phase with the load voltage so we can obtain unity power factor.

Figure 10 represents the FFT analysis of the source current after the integration of the hybrid renewable energy to the transmission line. On executing the the analysis taking the start time period 0.3s for the 30 cycles it was found that the Total Harmonic Distortion was 4.28%. the graph is shown below

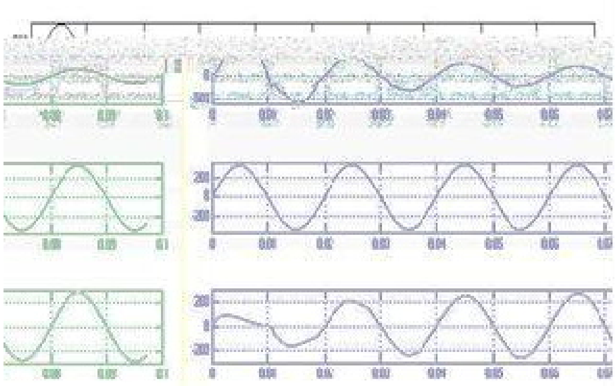

Figure 9 source current and load current waveforms after injuction of injucting current.

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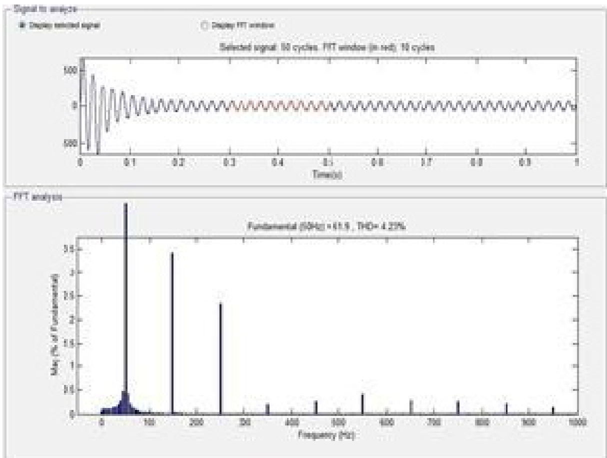

Figure 10 FFT Analysis of Current Waveform

The figure 10 represents the harmonic analysis of the source current waveform in which the THD is reduced to 4.27 %.The THD value less than 4% is said that the power delivered is quality power.

V.CONCLUSION

In this paper the hybrid renewable energy source is integrated by the use of shunt converter. The shunt converter serves the two purposes successfully, one it improves the power quality problem due to the non linear load like the harmonics and the reactive power compensation, secondly, it injects the active power generated from the HRSE system. The results shows with the integration of the HRSE power can be easily done by keeping the source current sinusoidal and at unity power factor.

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