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Design of Dynamic Voltage Restorer and Active Power Filter for Unbalanced and Harmonic Distorted Grid

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ABSTRACT

Generally, the non-conventional energy sources are being extensively used in case of power electronic converter based distribution systems. This paper mainly focuses on the wind energy system integrating with grid connected system and also improvement of power quality features. The wind energy power plant is modelled based on associated equations. For improving this power quality problems, this paper proposes the concepts of shunt converter controllers. This paper extended with PQ-theory controller based STATCOM to improve the current harmonic distrotions. And also the results are compared for this cases. Thus with such a control, a balanced load currents are obtained even in the presence of non-linear load. The experimental setup is done in Matlab and verified the simulation results.

Keywods: DVR distributed generated system (DG), distribution system, and renewable energy.

I. INTRODUCTION

Generally, with increase in the power demand due to increase in population, utilization, the Generation of power was really a challenge now a day. Due to high utilization of non-conventional energy sources as a one of the distribution energy source, may causes the stability problems such as voltage regulation and other power quality problems. Therefore, the power electronic based forced commutated converters are preferred in distribution system for maintaining the system stability, reliable performance and efficient work and also improvement of reliability of power at pcc.

The current distortions in non-linear load may result same distortions in the system voltages and in some cases also shows the serious effect on power system. Generally, these problems in power system are more complicated and also have face the troubles for identifying the problem in case of grid interconnection of wind energy system. If this problems continuous, it's mainly causes the damage of system and also reduces the system efficiency. The improvement of power quality is obtained by controlling the transmission parameters such as magnitude of the system voltage, line impedance and load angle. Depending on the control capability and connection of the compensating device to the system, these converters are classified into two ways called as shunt and series converters.

A shunt device is a compensating device i.e. which is connected between the grid connected point called as PCC and the ground. Shunt converter has the capability of either generate or absorb reactive power at the point of connection. Because the bus voltage magnitude can only be varied within certain limits, controlling the power flow in this way is limited and shunt devices mainly serve other purposes.

Figure 1 shows the basic diagram for the shunt connected inverter based grid connected system.

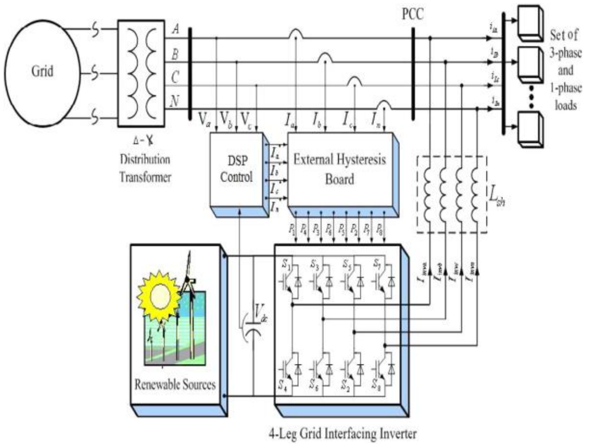

Figure 1. basic schematic diagram for the proposed renewable energy system.

Grid Interconnection of Wind Energy System

Recently grid connected wind system have been spreading in residential areas and in industrial areas. So we have to find a suitable MPPT technique that gives a better power output when connected is to find out. For a grid connected system there are certain factors that have been considered such that DC-AC conversion with highest output power quality with the proper design of filters System main controlling factors like MPPT. Grid interface inverters which transfers the energy from the wind energy generation system to the grid by maintaining constant of dc link voltage. For a grid connected system the utility network mainly demands for better power quality and power output. In the case of voltage fluctuations control of grid parameters is very difficult. So for a wind system that is connected to a grid first stage is the boosting stage and the second stage is DC-AC converter. An output filter is usually employed which reduces the ripple components due to switching problems. The problem associated with the grid connected system is that the dc link voltage that must be oscillates between the two levels which depends on the operating climatic conditions (ambient temperature & irradiance) in which inverter which acts us a power controller between the dc link and the utility. Dc link is generally used to isolate between the grid side and the inverter side so that we can control both wind system and grid separately. All the available power that can be extracted from the wind system is transferred through the grid

Wind Energy System

The generation of electrical power is obtained mainly in two ways i.e one is conventional source and other is non- conventional energy sources. The generation of electricity using non-renewable resources such as coal, natural gas, oil and so on, shows great impact on the environment by production of pollution from their general gases. Hence, by considering all these conditions the generation of electricity is obtained from the renewable energy sources.

Basically, out of all renewable energy sources the wind turbine plays an important role for generating electricity. And also from economical point of view the wind turbine has low maintainece cost because it needs no fuel so that it is pollution free. Mostly, in present world 50-60 percent of energy is generated from wind turbine as compared with all other renewable energy sources.

The typical layout of wind power generation as shown below.

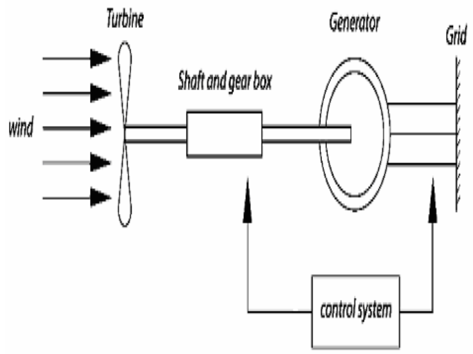

Figure 2. basic schematic diagram of wind turbine

The wind turbine converters wind energy to electrical energy and the generator mechanical shaft power is obtained by the following expression:

$$P_m = 0.5\rho A C_p v^3$$

And the coefficient of power also plays a key role for wind system and the basic minimum value of power coefficient is 0.5. The power coefficient is obtained by the ratio of tip speed ratio to pitch angle. The pitch angle is the angle is used for aligning the turbine blades with respect to its longitudinal axis and changing of wind direction. The tip speed ration is defined as ratio of linear speed of the rotor to the wind speed.

Figure 3 shows a typical waveform for coefficient of power with respect to the tip speed ratio. The maximum achievable range of TSR is from 0.4 to 0.5 for turbine with high speed and from 0.2 t0 0.4 for turbine with low speed.

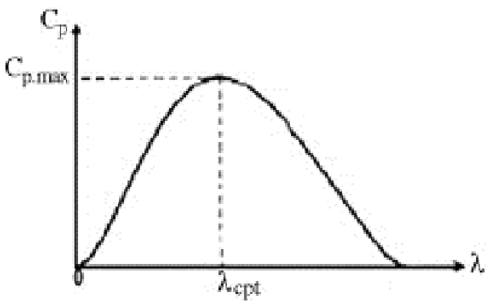

Figure 3. Power coefficient Vs Tip Speed Ratio

Operation of Dynamic Voltage Regulator

In order to protect the power system components from the general fault conditions such as voltage sags, the dynamic voltage restorer plays a key role as compared with the other compensating techniques. And also the efficiency of for this converter is high and provide reliable operation.

The dynamic voltage restorer is a one of the type in series converter of facts devices. The main function of this series converter is to inject extra voltage to the transmission system for regulating the voltage across load. The location of dynamic voltage restorer is generally located in distribution side i.e. between distribution feeder and load. The schematic diagram of the dynamic voltage restorer is shown in figure 4.

And the basic components used for constructing the dynamic voltage restorer are listed below.

The general configuration of the DVR is mainly consists of the following components such as,

i. an boosting transformer
ii. A filter for reducing harmonic
Iii. The battery energy Storage system
Iv. A Voltage Source Converter
v. DC charging circuit
vi. A control diagram for controlling DVR based on reference voltages and actual load voltages with the help of PWM technique. In this a general PI controller is used for controlling the error value.

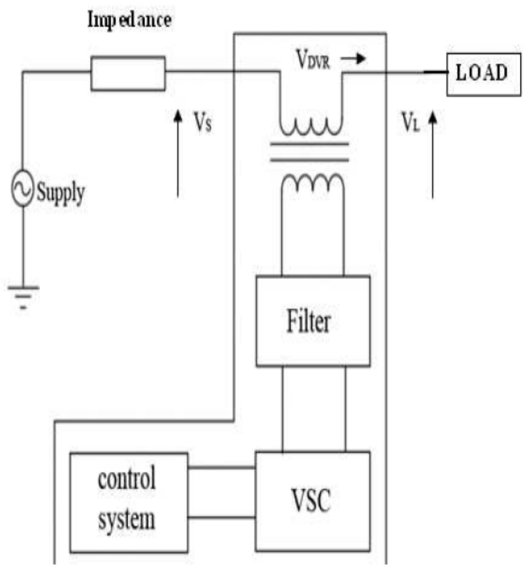

Figure 4. basic structure of dynamic voltage restorer.

The aim of dynamic voltage restorer is used for compensate the changes in voltage dynamically. The voltage generated by a forced commutated converter is to inject the line through a series transformer called as boosting transformer.

The basic operation of dynamic voltage restorer can be explained in mainly three modes such as: one is protection mode, second one is standby mode, and third one is injection/boosting mode.

1. **Protection mode:** if in any situation the load current is increased more than its permissible value, due to fault condition or short circuit on load side, the dynamic voltage regulator will be isolated from the by the use of bypassing switches S1 and S2.
2. **Standby Mode: (VDVR= 0):** in case of this standby mode the boosting transformer secondary winding is short circuited, with this the DVR is unable to inject any compensating values.
3. **Injection/Boost Mode: (VDVR>0):** In this case of injection mode the transformer called as injection transformer, the DVR have the capability of injecting voltage for compensating the power quality problems.

In-phase compensation method for dynamic voltage restorer

This In-phase compensation method is the straight forward method. This in phase method provides that the injected voltage is maintained in phase with the supply voltage irrespective of the load current and pre-fault conditions. Generally, the phase angles between the pre-sag and load voltages are different but also it has the capability of maintaining the power quality by compensating the load voltage.

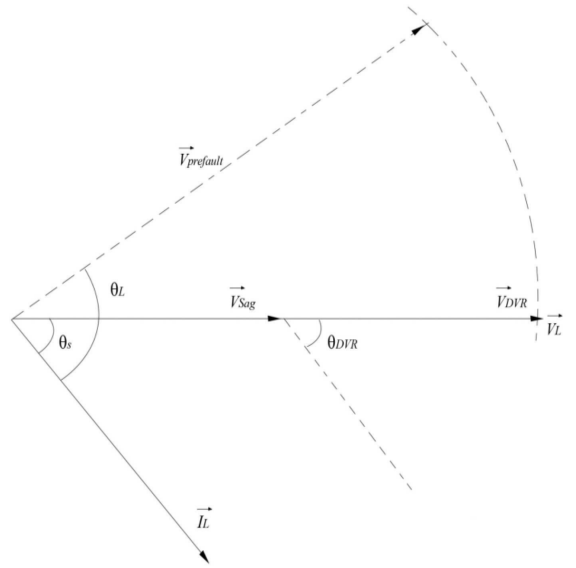

Figure 5. In-phase compensation method

The main function of dynamic voltage restorer is to protect the sensitive load on consumer side and power system components during fault conditions. The location of DVR is identified based on the sensitive loads. If a fault occurs on the transmission line, then the DVR placed in series with the transmission line. If there is any presence of fault in the transmission system, then it causes the changes in load voltage. Due to this change the load may be affected. So, for compensating this problem the dynamic voltage restorer injects the extra voltage through the power electronic converter which is anti-phase voltage to the voltage during fault. The basic controlling diagram for generating appropriate pulses to three phase converter is as shown in figure 5.

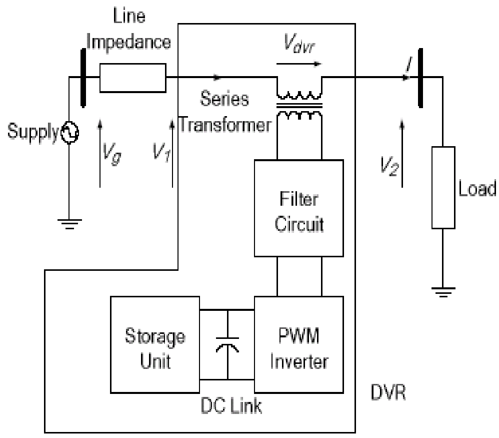

Figure 6. Block Diagram of General DVR Circuit

Basically, the three phase load voltages are transformed to the two phase rotating reference frame using parks transformation technique. And also the source voltage at the point of common coupling is converter to direct and quadrature axis components using parks transformation. These source and load voltages are compared and applied to PI controller. The error obtained is used for generating gate firing signals to the voltage source converter.

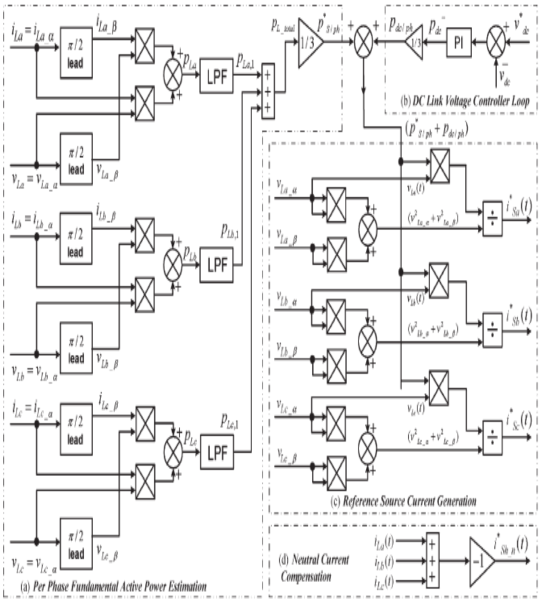

Figure 7. Control Diagram for statcom converter

Simulation Study

The simulation is done based on the fig 1, and it shows in figure 9 and the obtained power quality is shown below simulation waveforms.

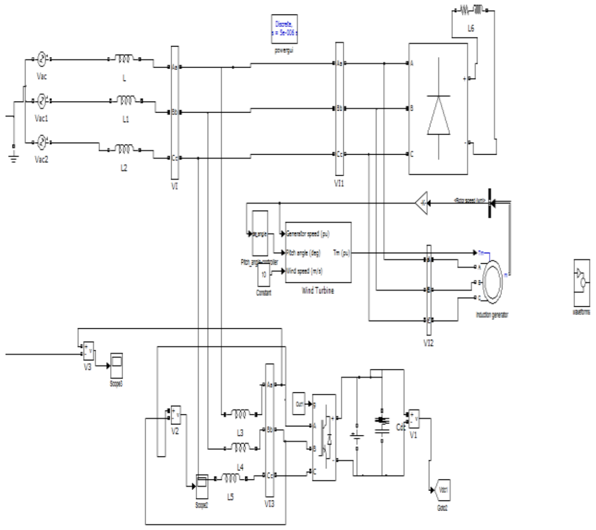

Figure 8. Over All Circuit Diagram in Simulation with Sub Systems

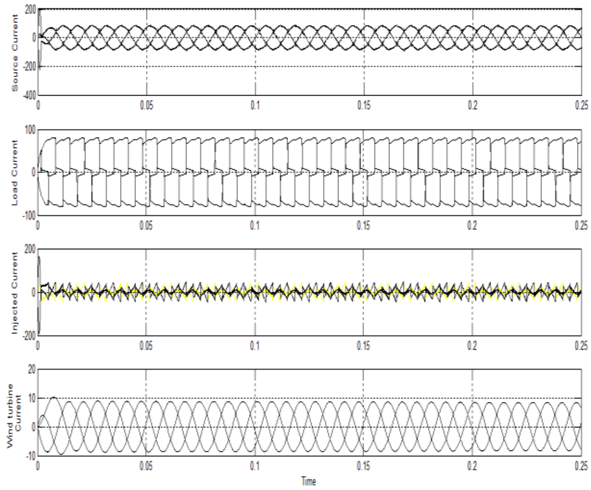

Figure 9. simulation result for current.

Figure 9 shows the results that source current, load current, and shunt converter current and current from the wind system.

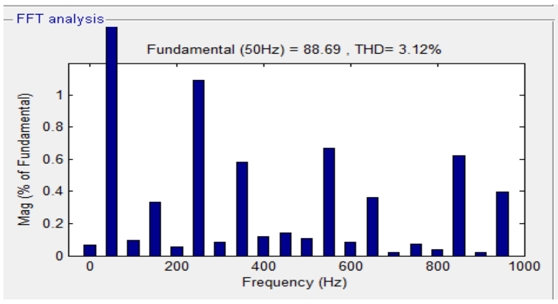

Figure 10. FFT analysis for Source current

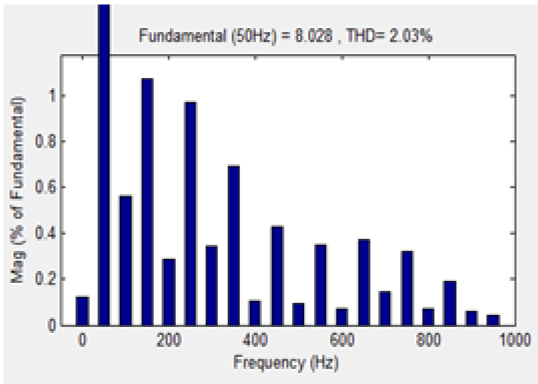

Figure 11. FFT analysis for Source current with PQ Theory.

II. CONCLUSION

Finally, this paper proposes a novel concept of grid interfaced wind power generation system along with the DVR controller for improving system stability thereby improved the reliability. This paper also shows the concept of power quality problems and their problem effect on the consumer and electric utility systems are presented. Therefore, distortions in currents are eliminated and maintained voltage and current are in same phase for improving power factor so that and reactive power demand for the wind generator and load at PCC in the grid system. Hence, the integrated wind generation and FACTS device have shown the outstanding performance in maintaining the PQ profile as per requirement. The operation of the DVR based grid connected wind energy system were practically developed and implemented in Matlab/Simulink and observed the simulation results. With this proposed PQ theory based statcom controller the THD is reduced to 2.03%.

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