International Journal of Advance Research in Science and Engineering
Volume No 06, Special Issue No. (02), September 2017, ICITTESE-17
www.ijarse.com
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Adaptive ANN based STATCOM and DVR for optimal integration of wind energy with grid using permanent magnet synchronous generator

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ABSTRACT

Injection of the wind power into an electric grid affects the power quality. The performance of the wind turbine and thereby power quality are determined on the basis of measurements and the norms followed according to the guideline specified in International Electro-technical Commission standard, IEC-61400. The influence of the wind turbine in the grid system concerning the power quality measurements are-the active power, reactive power, variation of voltage, flicker, harmonics, and electrical behavior of switching operation and these are measured according to national/international guidelines. The project study demonstrates the power quality problem due to installation of wind turbine with the grid. In this proposed scheme STATIC Compensator (STATCOM) & DVR is connected at a point of common coupling to mitigate the power quality issues. The STATCOM & DVR control scheme for the grid connected wind energy generation system for power quality improvement is simulated using MATLAB/SIMULINK in power system block set.

Keywords:-STATCOM,DVR ,FLICKER, POWER QUALITY.

I. INTRODUCTION

In the last couple of decades, the creation, implementation and perfection of renewable energy has occurred. It has progressed through time with increasing reliability. The integration of renewable energy such as wind, photovoltaic, fuel cell, and tidal to the grid solved many problems and replenished the exceeding and ascending need for electrical energy but created plenty more. The issue of power quality is of great importance to the wind turbine. There's a need to find solutions to these problems, using different technologies such as smart meters, monitoring system, controllers, remote ability. The integration of wind energy into a weak system is a challenge; voltage fluctuation, voltage dips, swells and swags are created due to the uncontrollable resource and the nature of the PMSG (Permanent Magnet Synchronous Generators) on the already weak system. This causes stability issues, reliability and power quality issues which need to be solved.

A Power Quality

(1) International Electro Technical Commission Guidelines:

The International Electro-technical Commission (IEC) gives the procedures for determining the power quality characteristics when a wind turbine is involved .

(2) Voltage Variation:

Wind speed and induction generator torque are the main cause of voltage variations. These voltage variations are directly related to real and reactive power variations. Voltage Sag/Dips/Swell, Short Interruptions and Long duration voltage variation are common voltage variation issues. The amplitude of voltage fluctuation depends on grid strength, network impedance, phase-angle and power factor of the wind turbines.

(3) Harmonics

Harmonics are created due to power electronic switching devices in the system. The harmonic content in a voltage or current should be under the limit at the Point of Common Coupling (PCC). The IEC-61400-21 establishes a guideline to base the study of harmonics on. The filtering by rapid switching largely reduces the lower order harmonic current, but the remaining current will have higher order frequency content which can be easily filtered-out.

(4) Consequences of the Issues

The power quality issues damage equipment such as Microprocessors, Programmable Logic Controllers (PLC's),Variable Speed Drives (VSD's) and delicate control systems. It may cause the tripping of Contactors and protection devices. It can lead to stopping sensitive equipment such as PC's, and even stop the process of plants.

B Permanent Magnet Synchronous Generator

The dynamic model of the permanent magnet synchronous generator (PMSG) in the d-q axis is given by :

$$V_q = -(R_s + pL_q) i_q - \omega_r L_d i_d + \omega_r \Phi$$

$$V_d = -(R_s + p L_d) i_d + \omega_r L_q i_q$$

Where, Rs and Ld,q are the machine resistance and inductance per phase. Vq and Vd are the 2-axis machine voltages. iq and id are the 2-axis machine currents. Φ is the amplitude of the flux linkages established by the permanent magnet, ωr is the angular frequency of the stator voltage, and p = d/dt.. The electromagnetic torque is written as:

$$T_e = 1.5\, P\, [(L_d - L_q)\, i_q i_d - \Phi\, i_q]$$

Where, P is number of pole pairs.

C Static Synchronous Compensator (STATCOM)

(1)STATCOM Model

The STATCOM has been reported to improve the power quality in power systems with PMSG integration of wind type . STATCOM can be implemented to regulate the voltage as a shunt compensator for the WTIG. It is a Battery Energy Storage System (BESS) connected to a DC link capacitor which itself connected to a Voltage Source Converter (VSC).The STATCOM is shunt connected and uses in this paper a Hysteresis current control

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method to inject a current in the system to counter the harmonics created by the non-linear load and the WTIG. The basic STATCOM model is shown in below figure.

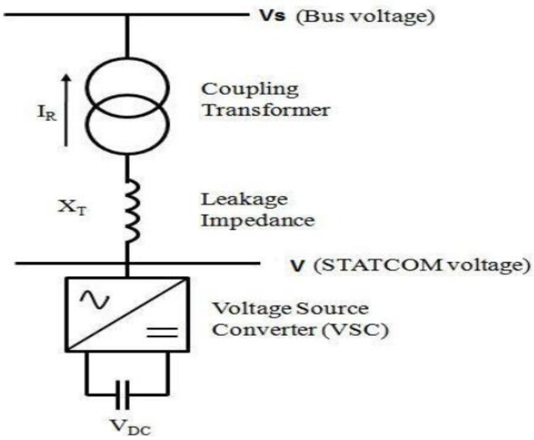

Fig 1 Basic statcom model

(2) Reference current generation

To get a reference current to use in the STATCOM control we need a topology for grid coordination. This paper uses these formulas to synchronize the reference currents to the grid voltage of the infinite bus, which is a bus with theoretical voltage of 1 per unit (p.u.) with infinite stability. If we take the 3 phase RMS voltages (V*sa*,V*sb*,V*sc*) and is expressed, as sample template *Vsm*, sampled peak voltage, as in (1).

$$V_{\rm sm} = \left\{ \frac{2}{3} \left(V_{\rm sa}^2 + V_{\rm sb}^2 + V_{\rm sc}^2 \right) \right\}^{1/2}$$

Then the unit vectors are generated from the source—are shown in (2).

$$u_{\rm sa} = \frac{V_{\rm Sa}}{V_{\rm sm}}, \quad u_{\rm sb} = \frac{V_{\rm Sb}}{V_{\rm sm}}, \quad u_{\rm sc} = \frac{V_{\rm Sc}}{V_{\rm sm}}$$

Then the reference currents will be as in (3):

$$i_{\rm Sa}^* = I.u_{\rm Sa}, \quad i_{\rm Sb}^* = I.u_{\rm Sb}, \quad i_{\rm Sc}^* = I.u_{\rm Sc}$$

This creates a fixed sinusoidal reference current synchronized with the grid without using a Phase Locked Loop (PLL). This method is simple, robust and favorable as compared with other methods.

(3)Hystersis control

The actual currents are detected subtracted from the reference current and obtain current error. This error is compared by a relay that gives an ON OFF signal for the IGBT switching if the error is higher or lower than a previously set band.

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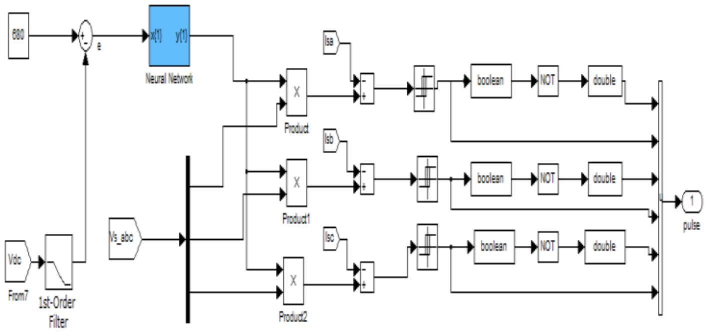

Fig 2 Statcom control strategy

For phase A we have the following switching logic:

• if Isa - Is∗a <−hb , then we need to inject a current and Sa =1

• if Isa - Is∗a >hb , then we need to absorb current then Sa=0.

Phase B and phase C work in the same way; 'hb' is the hysteresis band. The wider the hysteresis band is the larger the error, the smaller the hysteresis band the smaller the error but this means the need for very fast switching and higher rating devices.

D Dynamic Voltage Regulator (DVR)

(1)DVR Model

The DVR is used to protect critical or sensitive loads by mitigating the effects of voltage sags or swells on the distribution feeder due to faults in the system by maintaining constant voltage magnitude. It is basically a BESS connected to an inverter which itself is connected to an injection transformer that is mounted in series with the 3 phase sensitive load.

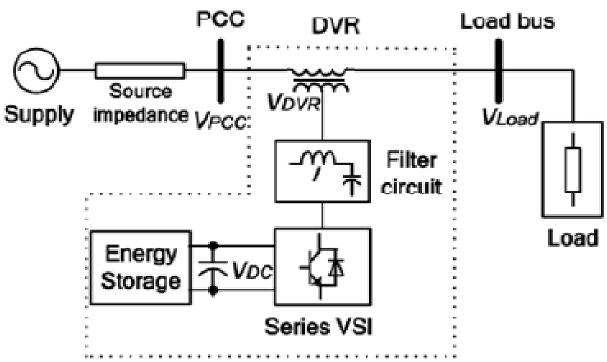

Fig 3 Basic DVR topology

The DVR can compensate voltage sags by injecting reactive power or real and reactive power. This depends on the depth and width of the sag or swell.

(2) DVR control : As for the control of the DVR many techniques exist to control the voltage injection, the chosen one is the Space Vector Pulse Width Modulation (SVPWM) which is proven very effective and gives a better result than conventional PWM in terms of THD and power quality. The reference phasor consists of: phase, frequency and magnitude components. All will vary to some point during normal network operation .The

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ISSN (O) 2319 - 8354
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block diagram of the control system used is shown in Fig.3. The control system of a DVR plays an important role, with the requirements of fast response in the face of voltage sags and variations in the connected load. This paper uses an open loop control for the DVR system using PLL. The PLL is to synchronize the DVR with the power system by generating a reference voltage to be compared with the actual one.

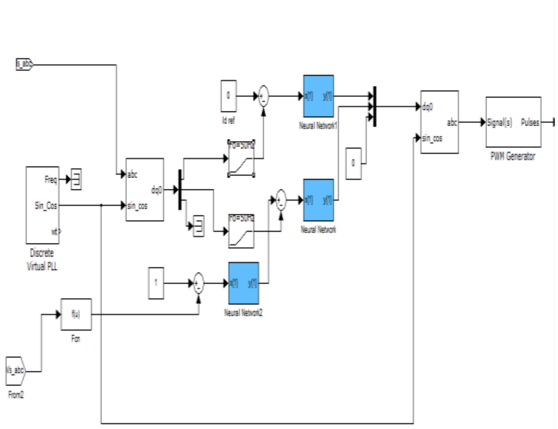

FIG 4 DVR CONTROL STRATEGY

II. SYSTEM IN STUDY

The system of study is shown in Fig.5

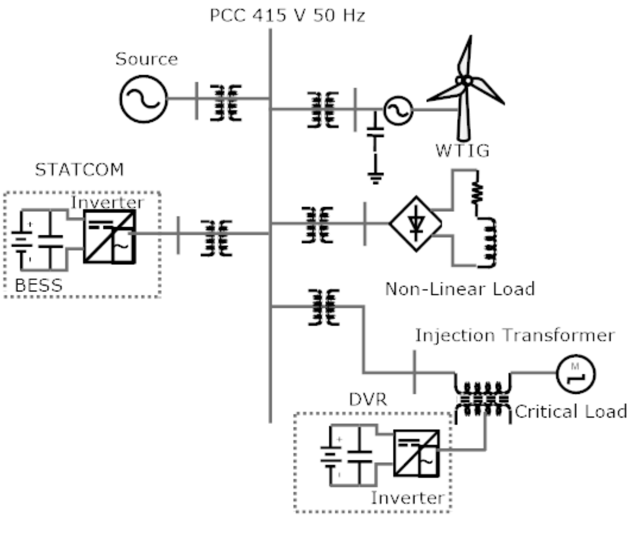

Fig 5 Proposed system in study

We have to study our system at the PCC, which is the interest of this kind of research. Studying at the PCC will give an idea of the system behavior at any other Bus. Fig. 3 shows the grid or the infinite bus connected to the PCC, it shows the WTIG, a non-linear load for harmonics generation. The DVR and STATCOM are used for Active filtering. They cancel the effect of voltage sags and swells by injecting a voltage into the system, and remove the harmonics by injecting a current into the system.

Fig. 6 will show the system model in MATLAB/SIMULINK

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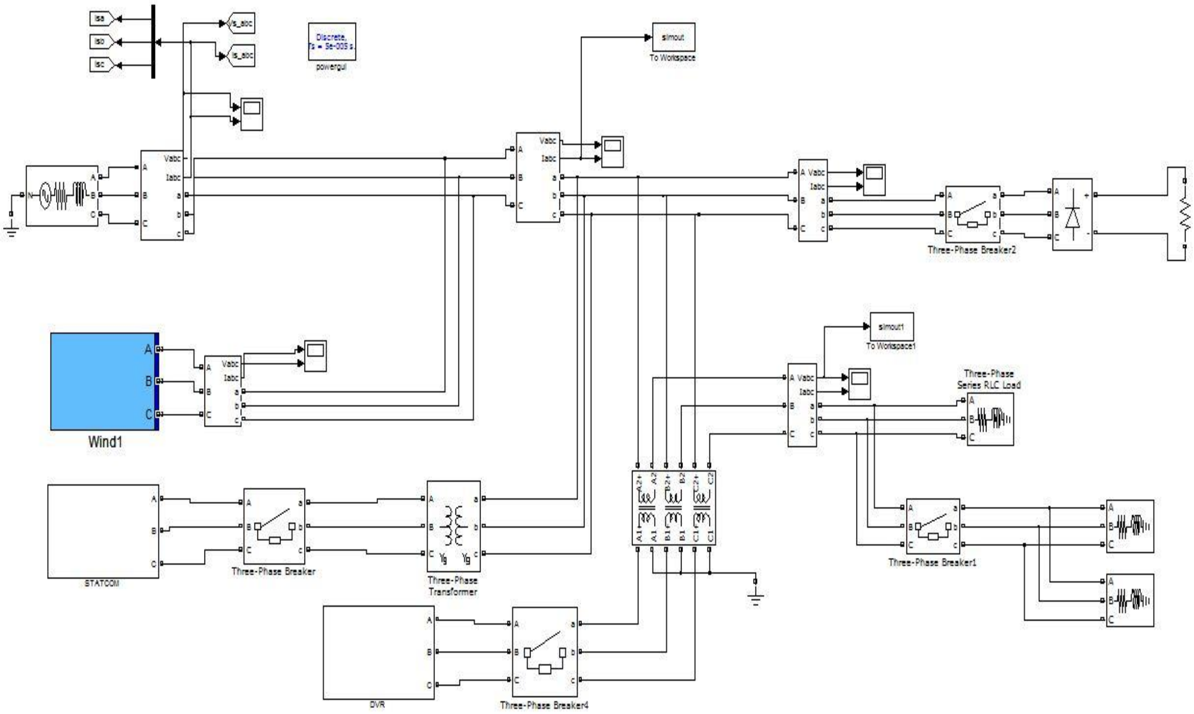
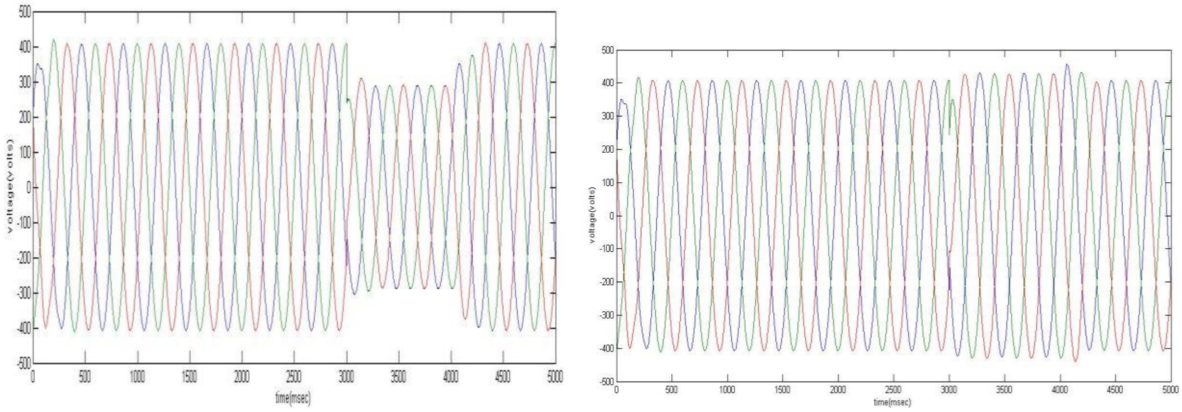


Fig 6 MATLAB SIMULINK modeled system

III. SIMULATION AND RESULTS

(A)DVR operation

When a wind turbine is initially connected to the grid, it needs reactive power for the induction generator to start producing electric power. This causes the voltage to drop at the PCC. At this instant the DVR should start its operation and compensate for the voltage drop at the critical load.



(a) (b)

Fig. 7. a) Voltage drop at PCC when wind turbine is starting, b) Voltage at Critical load Bus (with DVR compensation),

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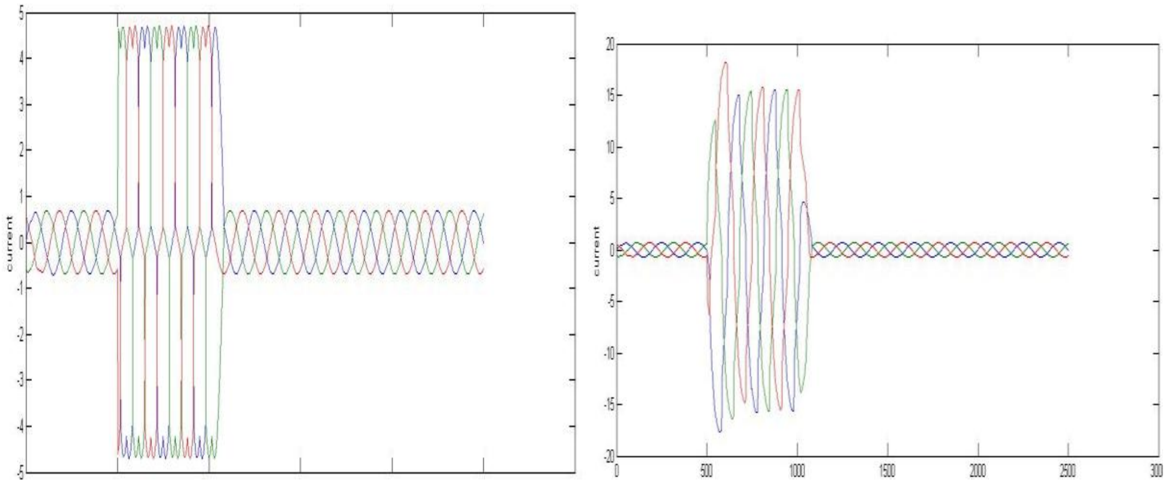
(B)STATCOM operation

After the wind turbine is initialized and running and after the Non-Linear load is connected to the system, the voltage and current at the PCC will be distorted and need to be filtered. Here the STATCOM (Active filter) is activated and will inject the exact current into the system needed to cancel the effect of the harmonics. This reference injected current is generated by the hysteresis control technique.



(a) (b)

Fig 8 (a)load current at pcc when wind turbine is connected. (b)load current with STATCOM compensation.

IV. CONCLUSION

This paper examined the STATCOM hysteresis control technique for harmonic cancelation with load tracking in a system where a wind turbine is present and it examined the work of the SVPWM operated DVR when connected to a critical load from the same system. It used a separate control for the STATCOM and the DVR interchanging their roles. This gives room to the subject of combining the two without having overlapping problems. This paper used as non-linear loads simple AC to DC rectifiers, another subject to be examined in the future is changing the non-linear load type.

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AUTHOR PROFILE

Priyanka Sahu received B.E. degree in Electrical engineering from CCET Bhilai in 2013 and completed M.E.in power electronics from RCET Bhilai 2016 batch. Worked as an assistance professor at GIMT durg department of electrical engineering.Presentely working as Asst.Prof.in CIET Raipur.