DPQC Interlinked Power Quality Improvement in A Grid Connected Wind Energy System

Y.Venkata Ramana Reddy [1], M.Ramesh [2]

[1] M.Tech Scholar, Department of E.E.E, Newton's Institute of Engineering,Macherla, India

[2] Asst. Professor, Department of E.E.E, Newton's Institute of Engineering,Macherla, India

Abstract- **The power wind energy source varies due to environmental condition. 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 in switching operation. The power quality problems when wind turbine installed to grid side is demonstrated here. In this Paper a Distributed Power Quality Controller (DPQC) is connected at a point of common coupling with a battery energy storage system to rectify the power quality problems. The entire system has been simulated MATLAB/SIMULINK. The simulation results show that DPQC control scheme gives the good results.**

Index Terms- DPQC; PQ: WEG;

I. INTRODUCTION

To have sustainable growth and social progress, it is necessary to meet the energy need by utilizing the renewable energy resources like wind biomass, hydro co-generation etc. To protective the distributed power system by maintaining sustainable improvement, it is necessary to tap the renewable energy sources .Now days the power quality is an essential customer focused measure and is greatly affected by the operation of a distribution and transmission network. There has been an extensive growth and quick development in the utilization of wind energy in recent years.

The individual units can be of large capacity up to 2MW, feeding in to distribution network, particularly with customers connected in close proximity. Today more than 2800 wind generating turbines are successfully operating all over the world. In the fixed- speed wind turbine operation, all the fluctuation in the wind speed are transmitted as fluctuations in the mechanical torque electrical power on the grid and leads to large voltage fluctuations. During the normal operation, wind turbine produces a continuous variable output power. These power variations are mainly caused by the effect of turbulence, wind shear, and tower-shadow and of control system in the power system. Thus, the network needs to manage for such Fluctuations. The power quality issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage saq, swells, flickers, harmonics etc.

However the wind generator introduces disturbances in to the distribution network. One of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid system. The induction generator has inherent advantages of cost effectiveness and robustness. However induction generators require reactive power for magnetization. When the generated active power of an induction generator can be significantly affected.

In normal operating system we need a control circuit for the active power production. For reducing the disturbance we use a battery storage system. This compensates the disturbance generated by wind turbine. A DPQC has been proposed for improving the power quality. The DPQC technically manages the power level associated with the commercial wind turbines. This system produces a proper voltage level having power quality improvements. The wind energy system is used to charge the battery as and when the wind power is available.

The basic components of the DPQC are two voltage source inverters (vsi's) sharing a common dc storage capacitor, and connected to the power system through coupling transformer. The proposed DPQC control scheme for grid connected wind energy generation for power quality improvement has following objectives.

- Two voltage source inverters and connected to the power system through coupling transformer
- Unity power factor and power quality at point of common coupling bus.
- Real and Reactive power support only from wind generator and batteries to load.

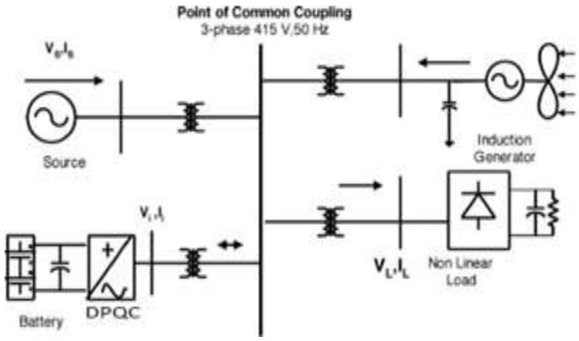


Fig.1. Grid connected system for power quality improvement

II.POWER QUALITY ISSUES

Perfect power quality means that the voltage is continuous and sinusoidal having constant figures of Amplitude and frequency. Power quality can be expressed in terms of physical characteristics and properties of electricity. It is most often described in terms of voltage, frequency and interruptions.

1.Grid side power quality issues:

The power quality problems in the grid side that affect the WEG (Wind Electric Generator) are mainly concerned with the quality of voltage that is being supplied by the utility

(a) Voltage Variations: Voltage variation has implications on both real and reactive power associated with wind farms. A decreased voltage condition increases the current through the generator, making line losses to increase. Decreasing voltage also affects the power factor as the capacitive VAR generated out of the installed capacitor decrease as voltage decreases.

- Voltage Sag/Voltage Dips.
- Voltage Swells.
- Short Interruptions.
- Long duration voltage variation

(b) Frequency Variations: The variation in frequency affects the power generation in WEG to a large extent changing the aerodynamic efficiency. Frequency changes lead to imperfect tip speed ratios and reduced aerodynamic efficiencies. These leads to decrease the energy capture and output power of wind turbines.

(c) Voltage transients: Large transient's voltage could be created due to switching of capacitors using mechanical switches, which are the integral part of WEG for reactive power compensation. These internally generated transients could result in damage to sensitive electronic devices of the WEG control system.

(d) Voltage unbalance: Voltage unbalance is caused due to large unbalanced loads. The unbalance in voltage causes negative sequence currents to flow in induction machines, causing overheating.

2. WEG side power quality issues:

Power quality issues that affect the WEG are mainly concerned with the quality of current that is being drawn or generated by the WEG's

(a) Reactive power consumption: Reactive power consumption in a wind farm is mainly due to the use of induction generators for energy saving. The basic principle of Induction generators is that they consume reactive power to set up the excitation or magnetic field in order to generate real power. This reactive power consumption leads to increased transmission and distribution losses.

(b) Generation of current harmonics: Current harmonics are generated due to soft starting of induction generators during motoring mode. This distorts the voltage on the line and affects all the consumers connected to the line.

(c) Injection of fluctuating power: Power in wind by nature is varied and is checked by annual, monthly, daily and hourly variations. This results in generation and supply of a power that is fluctuating and leading to operational problems.

III WIND POWER EXTRACTION WITH BATTERIES

The proposed wind energy extraction from wind generator and battery energy storage with distributed network is configured on its operating principle and is based on the control strategy for switching the inverter. The DPQC based current control voltage source inverter injects the current into the grid in such a way that the source current are harmonic free and there is phase difference with respect to source voltage has some desired value. The current is injected which will cancel out the reactive part and harmonic part of the load and induction generator current, improves both power factor and the power quality, The proposed system is implemented for power quality improvement at point of common coupling (PCC) , as shown in Fig.

1. The grid connected system in Fig. 1, shows wind energy generation system and battery energy storage system with DPQC.

A. Wind Energy generating system

The wind generating system (WEGS) consists of turbine, induction generator, interfacing transformer, and rectifier to get dc bus voltage. For constant dc bus voltage, the power flow is represented with constant dc bus current. In this configuration, wind generations constant speed topologies with pitch control. The induction generator is used in this simplicity, does not need a separate field c use constant and variable loads, and has n for short circuit. The available wind energy system presented as below in (1).

$$P_{wind} = \frac{1}{2}\rho A V^3 \text{ ------------------------ } (1)$$

Where ρ (kg/m3) is the air density and A swept out by turbine blade, Vwind is the wind speed in m/s. There is no possibility to extract all kinetic energy of wind, thus it extracts a fraction of this power in wind this is called power coefficient Cp of the wind turbine, and is given in.

$$P_{mech} = C_p P_{wind} \text{ ——————————— } (2)$$

Where Cp is the power coefficient, depend on which type and its operating condition of wind turbine. The coefficient can be expressed as a function it's of tip speed angle. The mechanical power produce by wind turbine is given in.

$$P_{mech} = C_p \frac{1}{2}\rho A V^3 \text{ -------------------- } (3)$$

Where R is the radius of the blade (m)

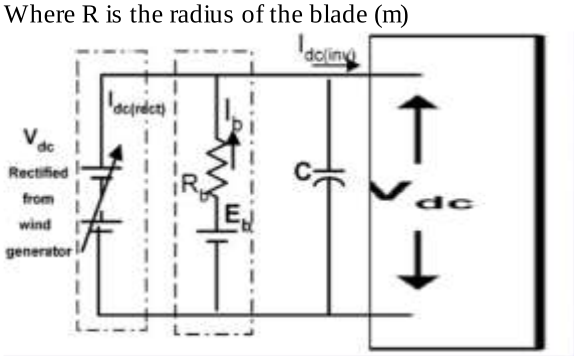


Figure.2. Dc link battery storage and wind generator

A. DC Link for Battery storage and Wind Energy Generator

The battery energy storage system (BESS) is used as an energy storage element for the purpose of voltage regulation. The BESS maintain dc capacitor voltage constant and is suited for DPQC since it rapidly injects or absorbed reactive power to stabilize the grid system. It also controls the fast rate of distribution and transmission system. When a power variation occurs in the system, the BESS can be used to control the power variation by charging and discharging operation. The battery is connected in shunt to the dc capacitor of DPQC.

The battery storage and WEG's are connected across the dc link as shown in Fig.2. The dc link consists of capacitor which decouples the wind generating system and ac source (grid) system. The battery storage will get charged with the help of wind generator. The use of dc link capacitors is more efficient, less expensive and is represented as follows.

$$C \frac{dV_{dc}}{dt} = I_{dc(rec)} - I_{dc(inv)} - I_b \quad (4)$$

Where C is dc link capacitor, Vdc is rectifier output voltage, Idc (rec) is dc-side rectified current, Idc (inv) is inverter side dc current and Ib is the battery current. The battery storage is connected to series connected dc link voltage source Eb and resistance Rb. Then its voltage varies with the charging status of the battery. The terminal voltage Vdc is given by

$$V_{dc} = E_b - I_b * R_b \quad (5)$$

Where battery current is represented by Ib.

C. DPQC-current controlled device:

The DPQC is a combination of static compensator and static series compensation. It acts as a shunt compensating and a phase shifting device simultaneously. The DPQC consists of a shunt and a series transformer, which are connected via two voltage source converters with a common dc-capacitor. The dc-circuit allows the active power exchange between shunt and series transformer to control the phase shift of the series voltage. This setup as shown in figure.3. provides the full controllability for voltage and power quality. The series converter needs to be protected with a thyristor bridge. Due to the high efforts for the voltage source converters and the protection, a DPQC is getting quite expensive, which limits the practical applications where the voltage and power quality control is required simultaneously

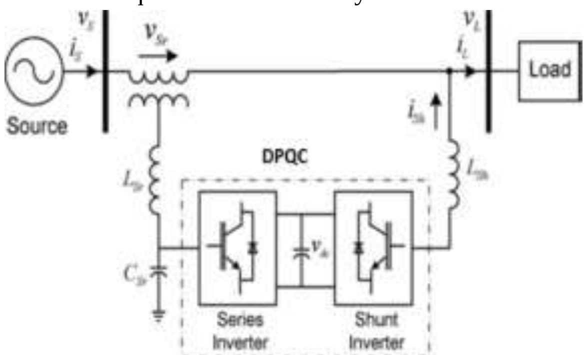


Fig.3. Principle configuration of a DPQC

According to the controlled strategy the DPQC compensator output is varied so as to maintain the power quality standards in the grid system. Current control strategy is included in the control scheme so that it defines the functional operation of the DPQC compensator in the power system. DPQC using insulated gate bipolar transistor is proposed to provide reactive power support, to the nonlinear load to the induction generator in the grid system. The operational diagram of the combination of a static compensator and static series compensation.

IV CONTROL SCHEME OF SYSTEM

The control scheme with battery storage and micro wind generating system utilizes the dc link to extract the energy from the wind. The wind generator is connected through a step up interfacing transformer and to the rectifier bridge so as to obtain the dc voltage

Also a lead acid cell battery is used for maintaining the dc bus voltage constant. Thus the inverter is implemented successfully in the distributed system. The control scheme approach is based on injecting the current in to the grid using hysteresis band current controller. Using such techniques controller keeps the control system variables between the boundaries of hysteresis are and thus gives correct switching signals for the inverter operation. Fig.4. shows the control scheme for generating the switching signals to the inverter.

The control algorithm needs the measurement of several variables such as three-phase source current iSabc for each phases, dc bus voltage Vdc, and inverter current Iiabc with the help of measurement sensors.

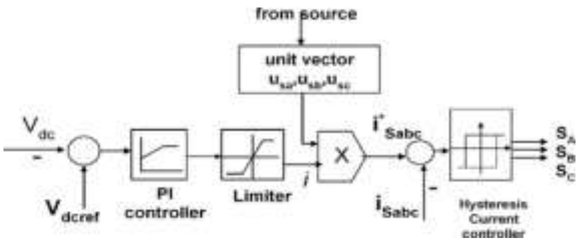


Fig.4.Control circuit for switching inverter circuit

The current control unit receives an input of reference current i*Sabc and actual current iSabc is measured from each phases respectively, which are subtracted so as to activate the operation of the inverter in current control mode.

A. Grid Synchronizations

In the balance three-phase system, source amplitude RMS voltage (Vsm) is calculated at the sampling frequency from the source phase voltages and is expressed as sample template Vsm as in

$$V_{sm}=\sqrt{\frac{2}{3}}\{V_{sa}{}^2 + V_{sb}{}^2 + V_{sc}{}^2\}$$

The in-phase unit vectors are obtained from ac source phase voltage and the RMS value of unit vector Usa, Usb, Usc as shown in

$$Usa = \frac{V_{sa}}{V_{sm}} \; ; \; Usb = \frac{V_{sb}}{V_{sm}} ; \; Usc = \frac{V_{sc}}{V_{sm}}$$

From the in-phase unit voltage template, in-phase generated reference currents are derived using

$$i^* = I.U_{sa};\; i^* = I.U_{sb}\,;\; i^*=I.U_{sc}$$

Where I is proportional to the magnitude of filtered source voltage for each phases and also the output taken from proportional-integral controller (PI).

This ensures that the source current is controlled to obtain sinusoidal signal. For the grid synchronization of inverter, unit vector plays the key role. This method is robust, simple, and favorable as compared with other methods.

When the grid voltage source fails the wind generator operates as stand-alone mode. In these cases, the voltage sensors sense the condition and it will transfer the micro switches for the generation of reference voltage from wind generator system. The generated voltage reference without any supply gets switched to the stand-alone reference generator after voltage sensing at the point of common coupling (PCC). It is a unit voltage vector which can be realized by using DSP or microcontroller .Hence, the inverter maintains the continuous power for the critical load.

B. Hysteresis Based Current Controller

Current control based hysteresis controller is used in this particular scheme. The reference current is generated as in and the actual current is detected by current sensors that are subtracted for obtaining current errors for a hysteresis based controller. ON/OFF pulse signals for IGBT switches of inverter are derived from hysteresis current controller. When the measured current is higher than the generated reference current, it is necessary to get negative inverter output voltage so that corresponding switches are commutated. Thus output voltages are decreased so that the output current reaches the reference current. Also, if the measured current is less than the reference current, positive inverter output voltage are obtained by commutating particular switch Thus output current increases to the reference current. Hence, the output current will be within a band around the reference one. The switching function SA for phase 'a' is expressed as follows.

$i_{sa} > (i_{sa}^{*} + HB)$ then $S_A^{+} = 0$ and $S_A^{-} = 1$
$i_{sa} < (i_{sa}^{*} - HB)$ then $S_A^{+} = 1$ and $S_A^{-} = 0$

Where HB is a hysteresis current-band, similarly the switching function SB, SC can be derived for phases ''b'' and ''c,'' respectively. The current control mode of inverter injects the current into the grid in such a way that the source currents are harmonic free and their phase-angles are in phase with respect to source voltage. The reactive and harmonic part of load side is cancel out by the injected current at shunt part. Thus, overall it reduces harmonic content and improves the source current quality at the PCC. As soon as battery energy system is fully charged with the help of micro- wind generator, the power transfers take place.

SYSTEM PARAMETERS:Table1

S.NO	Parameters	Rating
1	Grid Voltage	3-phase, 415V, 50Hz
2	Induction	3.35KVA, 415V, 50Hz, P=4,
	Motor/Generator	Speed = 1440 rpm, Rs = 0.01Ω
		Rr = 0.015Ω, Ls = 0.06H, Lr = 0.06H
3	Line Series Inductance	0.05mh
4	Inverter Parameters	DC Link Voltage = 800V, DV Link Capacitance = 100μF Switching frequency = 2kHz
5	IGBT Rating	Collector Voltage = 12000V, Forward current = 50A, Gate Voltage =20V, Power dissipation = 310W
6	Load parameter	Non-linear Load = 25kW.

The source voltage is sensed and synchronized in generating the desired reference current command for the inverter operation. Hysteresis band based current control technique is simple and its implementation is not expensive. The controller has fast response since it has negligible inertia and delay. In figure 5 the controller output is seen. The source current with and without DPQC operation is shown in Fig.6. The FFT analysis with and without controller is seen in figure 7.

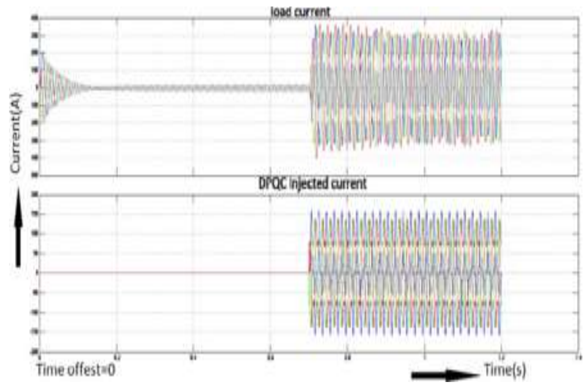


Fig.5.DPQC Output

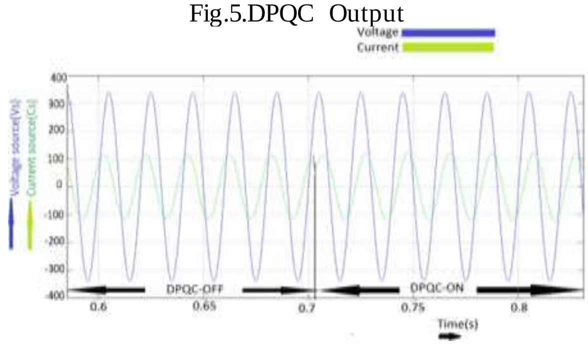
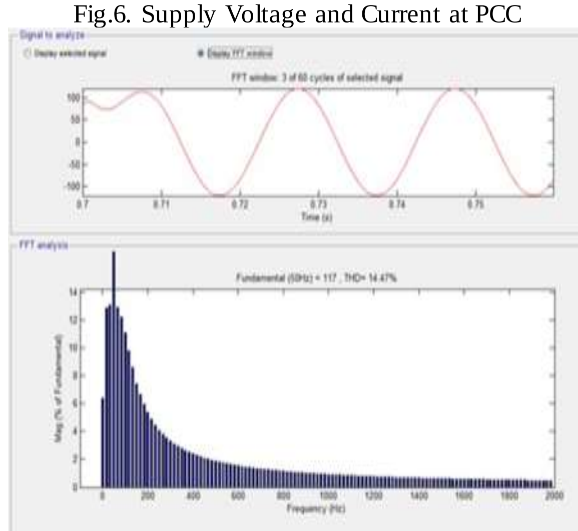


Fig.6. Supply Voltage and Current at PCC



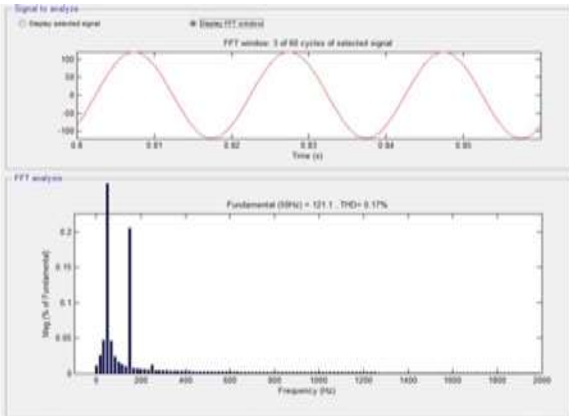


Fig.7.The FFT analysis with and without controller

VI. CONCLUSION

Proposed study on wind energy conversion scheme using battery energy storage for nonlinear load includes interface of inverter incurrent controlled mode for exchange of real and reactive power. The hysteresis current controller is used to generate the switching signal for inverter in such away that it will cancel the harmonic current in the system. This scheme improves power factor and also make harmonic free source current in the distributed network at the point of common connection. The wind power exchange is regulated across the dc bus having energy storage and is made available under the steady state condition. This also makes real power flow at instantaneous demand of the load. Rapid injection or absorption of reactive/real power flow in the power system can be made possible through battery energy storage and static compensator. Battery energy storage provides rapid response and enhances the performance under the fluctuation of wind turbine output and improves the voltage stability of the system. The utility can view each power plant simultaneously and accurately by using online smart meter. This scheme thus provides the system to operate both in power quality mode as well as in stand-alone.

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