Power quality improvement of Distributed Generation systems using FACTS controllers

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***Abstract*—In present scenario the continuously increasing demand of electrical energy and the keen scarcity of renewable energy sources leads to the blossom of distributed generation (DG) system. The main difficulty is the harmonization of the DG to the power grid. Generally current regulated PWM voltage-source inverters (VSI) are used for synchronizing the utility grid with DG source. In this paper, STATCOM controller is proposed to enhance the power quality by minimizing the harmonics present in the power grid. The studied system is modeled and simulated in the MATLAB/Simulink environment and the results obtained.**

***Index Terms*—Harmonics, Power quality, PWM Inverter, STATCOM, Synchronization.**

I. Introduction

Inorder to meet the future power demands the distributed generation systems has gained more attraction because of its reliability and secured operations. Distributed generation (DG) refers to power generation at the point of consumption. Generating power on-site, rather than centrally, eliminates the cost, complexity, interdependencies, and inefficiencies associated with transmission and distribution. Like distributed computing (i.e. the PC) and distributed telephony (i.e. the mobile phone), distributed generation shifts control to the consumer.[1] Historically, distributed generation meant combustion generators (e.g. diesel gensets). They were affordable, and in some cases reliable, but they were not clean. While many people will tolerate dirty generation thousands of miles away from them, they think twice when it is outside their bedroom window or office door. Bloom Energy is a Distributed Generation solution that is clean and reliable and affordable all at the same time. Bloom's Energy Servers can produce clean energy 24 hours per day, 365 days per year, generating more electrons than intermittent solutions, and delivering faster payback and greater environmental benefits for the customer. And while other DG systems may require lengthy installations, sunny locations, or demand for consistent 24/7/365 heat load, Bloom's systems are easy and fast to install, practically anywhere. The power electronic front-end converter is an inverter whose dc link is fed by an ac/dc converter or by a dc/dc converter, according with the DG source type. The commercial front-end inverters are designed to operate either as grid-connected or in island mode. In grid-connected mode, the voltage at the point of common coupling (PCC) is imposed by the grid; thus, the inverter must be current-controlled. Coming to the grid-connected mode, almost all the commercial single-phase inverters for DG systems inject only active power to the grid, i.e., the reference current is computed from the reference active power $p*$ that must be generated. It is possible and can be convenient to integrate power quality functions by compensating the reactive power and the current harmonics drawn by specific nonlinear loads by means of implementing FACTS controller devices.

II. Literature Review

A. Distributed Energy Resources

Distributed energy resources (DER) are smaller power sources that can be aggregated to provide power necessary to meet regular demand. As the electricity grid continues to modernize, DER such as storage and advanced renewable technologies can help facilitate the transition to a smarter grids [2].

Deploying DER in a widespread, efficient and cost-effective manner requires complex integration with the existing electricity grid. Research can identify and resolve the challenges of integration, facilitating a smoother transition for the electricity industry and their customers into the next age of electricity infrastructure.

A Significant change of grid operators is effective integration of an increasing amount of renewable energy fueled generation whose output varies. Variation occurs year-to-year, season-to-season, minute-to-minute. Variable renewable energy types include wind, solar, ocean wave and tidal power [3].

B. Storage of Distributed Energy

For the foreseeable future, much or even more variable Renewable energy electricity production is expected to be

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from wind energy generation. Coincidentally there is increasing interest in distributed energy resources [DER].

This value proposition combines wind generation integration electricity storage benefits with "locational" benefits associated with distributed storage in the utility distribution system, at or near where electricity is used. Especially this value proposition entails use of distributed storage to store energy from central wind generation. The benefits and synergies are numerous. Using distributed storage to provide power closer to end-users provides more benefits than the same amount of power located further from end-users.

C. Grid Integration of DER power

Once the generated power received from various DERs should be connected with an inverter circuits towards feeding the power to utility.in our proposed work the single-phase grid connected inverter used is shown in Fig.1.Which is composed of a dc voltage source (VDC), four switches (S1-S4), a filter inductor (L_f) and utility grid (V_g). In inverter-based DG, the produced voltage from inverter must be higher than the Vg in order to assure power flow to grid. Since V_g is uncontrollable, the only way of controlling the operation of the system is by controlling the current that is following into the grid [4].

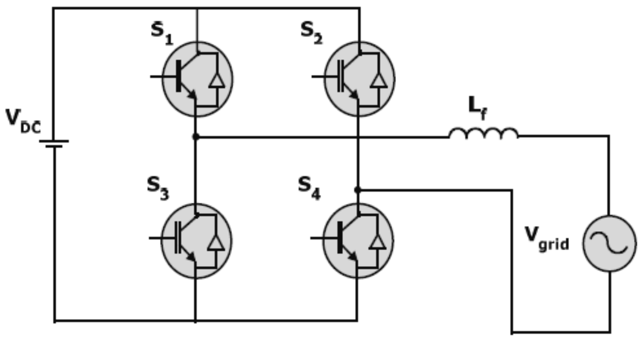

Fig.1.Sigle phase inverter connected to the grid

D. Inverter Control Scheme

Harmonic and reactive current control is a critical issue in day today power generation systems. Recently years, the control scheme with the VSI based current control is emerging, where the harmonic and reactive current detection module is no longer needed and the PWM based VSI inverter used here provides better harmonics elimination towards attaining the better power quality improvement by means of avoiding reactive power absorption by the grid.

III. PROPOSED METHODOLOGY

In our proposed scheme STATIC Compensator (STATCOM) is connected at a point of common coupling with a battery energy storage system (BESS) to mitigate the power quality issues. The battery energy storage is integrated to sustain the real power source under fluctuating wind power.

The STATCOM control scheme for the grid connected wind energy generation system for power quality improvement is simulated using MATLAB/SIMULINK in power system block set. The effectiveness of the proposed scheme relives the main supply source from the reactive power demand of the load and the induction generator. The development of the grid co-ordination rule and the scheme for improvement in power quality norms as per IEC-standard on the grid has been presented.

A. Battery Energy Storage system Implementation

The battery energy storage system (BESS) is used as an energy storage element for the purpose of voltage regulation. The BESS will naturally maintain dc capacitor voltage constant and is best suited in STATCOM since it rapidly injects or absorbed reactive power to stabilize the grid system. It also controls the distribution and transmission system in a very fast rate. When power fluctuation occurs in the system, the BESS can be used to level the power fluctuation by charging and discharging operation. The battery is connected in parallel to the dc capacitor of STATCOM. The STATCOM is a three-phase voltage source inverter having the capacitance on its DC link and connected at the point of common coupling. The STATCOM injects a compensating current of variable magnitude and frequency component at the bus of common coupling.

B. STATCOM-Control system and modules

The control system task is to increase or decrease the capacitor DC voltage, so that the generated AC voltage has the correct amplitude for the required reactive power. The control system must also keep the AC generated voltage in phase with the system voltage at the STATCOM connection bus to generate or absorb reactive power only (except for small active power required by transformer and inverter losses).

The control system uses the following modules:

1. PLL (phase locked loop) synchronizes GTO pulses to the system voltage and provides a reference angle to the measurement system. 2. Measurement System computes the positive-sequence components of the STATCOM voltage and current, using phase-to-dq transformation and a running-window averaging. Voltage regulation is performed by two PI regulators: from the measured voltage V_{meas} and the reference voltage V_{ref}, the Voltage Regulator block (outer loop) computes the reactive current reference I_{qref} used by the Current Regulator block (inner loop). The output of the current regulator is the α angle which is the phase shift of the inverter voltage with respect to the system voltage.

C. Switching frequency calculation

The power system stability is not involved, the quality of the power at load side is not good. It consists of more harmonics as well as unstable voltage. The voltage variation, flicker, harmonics causes the malfunction of equipments namely microprocessor based control system, programmable logic controller; adjustable speed drives, flickering of light and screen. It may leads to tripping of contractors, tripping of protection devices, stoppage of sensitive equipments like personal computer,

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programmable logic control system and may stop the process and even can damage of sensitive equipments. Thus it degrade the power quality in the grid. Inorder to avoid such circumstances the switching frequency can be bring into control to avoid the harmonic presence in power system.

The output voltage V_{dc} is

$$V_{dc} = L_f \frac{di_0}{dt} + V_g$$

The output current of the inverter is

$$i_0 = i_{ref} + e$$

$$T_{ON} = \frac{2L_f HB}{V_{dc} - V_g}$$

And

$$T_{OFF} = \frac{2L_f HB}{V_{dc} + V_g}$$

$$\frac{1}{f_s} = T_s = T_{ON} + T_{OFF}$$

The switching frequency can be obtained from the above equation

$$f_s = \frac{(V_{dc}{}^2 - V_g{}^2)}{4V_{dc} L_f HB}$$

D. *Design Parameters*

The designing parameter values of the proposed research work has been depicted in the table.1

S.No	Parameters	Ratings
1	Grid Voltage	3-phase, 415v, 50Hz
2	Induction Motor/Generator	3.35KVA,415V, 50 Hz, P=4, 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, DC link Capacitance = 200 μF, Switching frequency = 2 KHz,
5	IGBT Rating	Collector Voltage = 1200V, Forward current = 50A, Gate Voltage = 20V, Power Dissipation = 310W.
6	Load Parameter	Non-linear Load 25KW.

Table.1.Design Parameters of Proposed Work

Using the above mentioned parameters we have designed the proposed work with the aim of eliminating the harmonics presents in the single phase distributed generation system connected grid, so as to improve the power system stability towards improving the power quality of the DERs systems.

IV. SIMULATION WORK

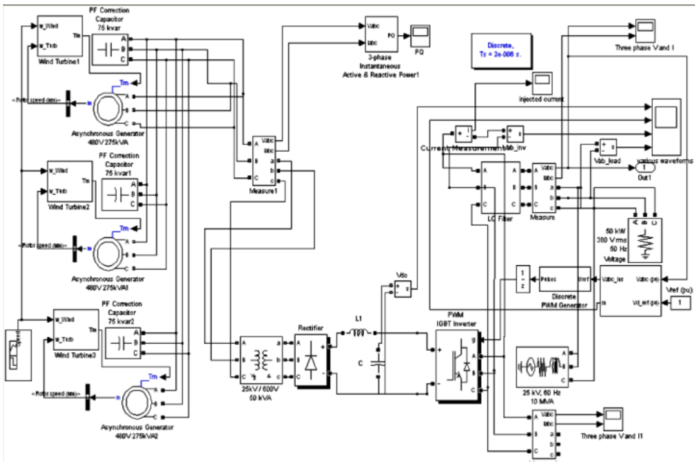

Fig.2. DG grid with STATCOM controller

The section reveals the distributed power generation connected grid with PWM inverter along with the STATCOM controller towards minimizing the harmonic contents present in the power system. In our proposed work for our consideration we have taken the wind power as a source for formation of single phase grid. The wind mill uses induction generator for generating the power. Generally the power system may have various kinds of inductive load connectivity at consumer ends, also the generator which we do used here in wind mill also inductive in nature, these things may lead absorption of reactive power from grid.at the point of common coupling that is where the grid and power source is being connected we introduced shunt controller STATCOM along with the BESS system for effective harmonic minimization and power system stability improvement.

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V. Results and Discussions

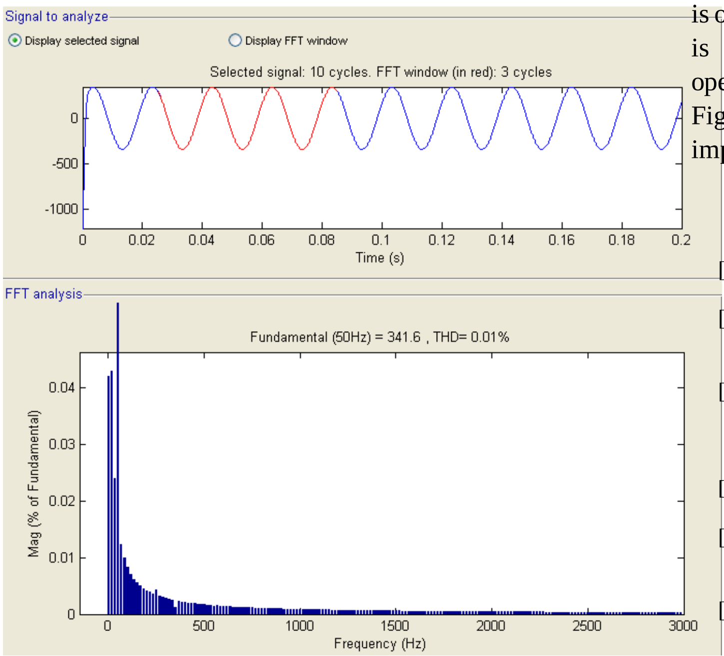

Fig.3.THD Analysis of Grid

The Fig.3.reveals that Total harmonic distortion of the power grid has been reduced by 0.01 % which is better when compared to the any other conventional controller implementations

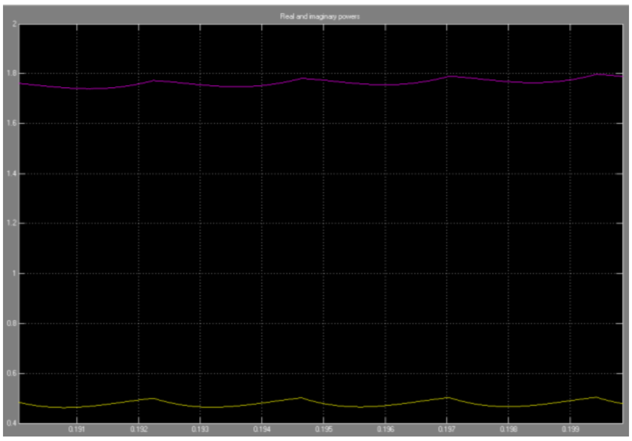

Fig.4.Real and reactive power flow of grid

The figure 4. Clearly shows that there is no much reactive power absorbtion found. And we have reduced the reactive power absorbtion by means of injecting current to the grid with the effective implementation of PWW-VSI inverter connected STATCOM-BESS system.

VI. Conclusion

It is observed that the source current on the grid is affected due to the effects of nonlinear load and wind generator, thus purity of waveform may be lost on both sides in the system. The inverter output voltage under STATCOM operation with load variation is shown in Fig. 4. The dynamic load does affect the inverter output voltage. This shows that the unity power factor is maintained for the source power when the STATCOM is in operation. The power quality improvement is observed at point of common coupling, when the controller is in ON condition. The STATCOM is placed in the operation at 0.7 s and source current waveform is shown in Fig. 3 with its FFT. It is shown that the THD has been improved considerably and within the norms of the standard.

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