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Smart Grid Integration for Power Quality in Grid System

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Abstract: The increase penetration of renewable energy, use of electronic load in to the electric grid which involves a challenge regarding the power quality issues and energy management**.** These penetrations will increase harmonic distortion, frequent switching of load will result in flicker. This paper presents an implementation of power control scheme & communication scheme in smart grid integration for maintaining power quality and for managing energy in the grid system. The integration of smart grid is equipped with voltage source converter attached to the renewable sources, conventional energy generators and storage systems. The primary power control scheme is the voltage source converters operated in current controlled mode with hysteresis control in order to maintain power quality requirements in distributed system .The secondary scheme involves the use of a distributed communication architecture based on Experimental Physics and Industrial Control system (EPICS) to manage all the information generated in grid system and help in a smart grid for managing energy norms. Test results are presented to demonstrate the effectiveness of the control and the communication architecture used for maintaining power quality in smart grid integration.

Keywords: Harmonic compensation**,** Renewable Energy Source Integration, Smart grid

I. INTRODUCTION

The current requirements relative to the energy efficiency and integration of new elements in the grid, such as renewable energy sources, electric vehicles and polluted load, require the development of a new kind of smart grid. The growths of renewable energy are mostly connected by power converters and electronic load, which introduces power quality issues. [1] Furthermore the distribution grid is design to distribute the electric energy generated by conventional plant mostly thermal plants. The introduction of distributed generation causes the number of issues regarding power quality, grid stability, and network load. Distributed generations can reduce these issue ,if it controlled appropriable. Global energy sector is largely dependent on combustion energy sources like fuel-oil and natural gas, which are becoming scarce. This fact together with the climate change and the sociological and economic challenges of the 21 century needs the electric network as a Smart Grid [2].

The Smart Grid utilizes smart energy meters, the integration of the renewable energies and electric vehicle chargers ,storage system etc. The smart grid needs the active participation of the client on the network, not only as a consumer but also as a producer. This objective requires a new control system more efficient, that takes in consideration the power quality of the grid, harmonic compensation and active and reactive power regulation

This new grid must have innovative technologies and services in energy control and data communication in order to get more efficient grid. This Smart Grid should regulate the different sources of energy with generation and storage options. It is necessary to include environmentally friendly sources, such as wind and solar generation, battery storages. Furthermore the smart grid will provide better power quality, improving power factor and it will respond for the system disturbances.[3]-[4].

II. SMART GRID SYSTEM MODEL

A smart grid distribution system , whose objective is to develop a power grid more efficient and reliable, improving safety and quality of supply in accordance with the requirements of the digital age. This smart grid network serves as a test plant to develop and validate the status of different generation and storage technologies and control strategies. The National Institute of Standards and Technology (NIST) provides a conceptual model as shown in Figure 1. The model defines seven important domains: bulk generation, transmission, distribution, customers, service provider. The deregulated environment faced by the

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electric utility industry and recent advances in technology, several distributed generation (DG) option are fast becoming economically viable. A huge number of recent events have created a new environment in the interconnection of electric power system. There is a public awareness of the environmental impacts of electric power generation, rapid increases in electric power demand , Significant advances in several generation technologies such as wind-electric generation, micro-turbines, fuel cells, and photo-voltaic than conventional coal, oil, and gas-fired plant. All the factors listed above have led to an increase in the development and utilization of distributed generation.

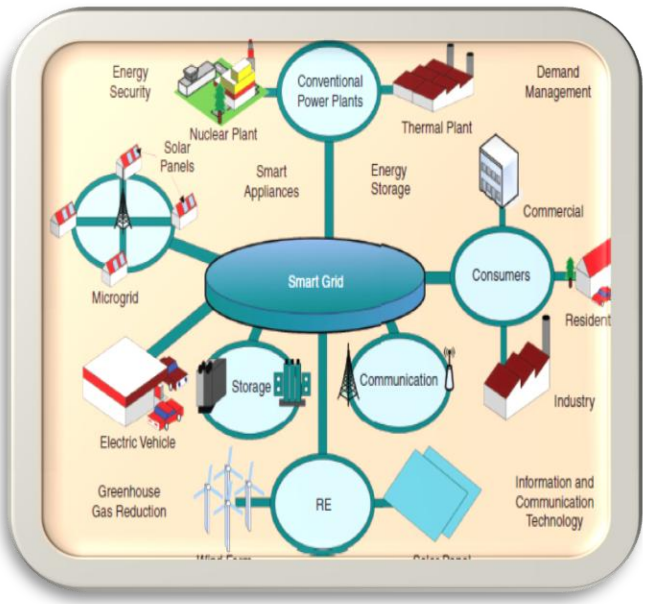

Fig. 1. Model of Smart Grid Integration.

III. SMART GRID TOPOLOGY FOR POWER QUALITY IMPROVEMENT

The Smart grid topology for power quality improvement is based current control voltage source inverter , which injects the current into the grid in such a way that the source current are harmonic free and their phase-angle with respect to source voltage has a desired value. The injected current will cancel out the reactive part and harmonic part of the load and induction generator current ,thus it improves the power factor and the power quality. To accomplish these goals, the grid voltages are sensed and are synchronized in generating the current command for the inverter. The proposed smart grid connected system is implemented for power quality improvement at point of common coupling (PCC), as shown in Fig. 2.

The grid connected system in Fig. 2, consists of wind energy generation system, solar system connected and battery energy storage system with power converter as a current operated voltage source inverter.

The system consist of primary control and secondary control.

1.*Primary control*: It consist of power electronics converter which can absorb or supply the active and reactive into the grid. The control allows the sharing of power between the power converter and to the grid. The use of these power converter has distinct benefit in the grid operation. The grid voltage control, harmonic reductions and in-phase operation are the power quality benefit that can be gain without excessive compromise.

2.*Secondary control*: It regulates the electrical parameter inside the grid by using a central controller with communications to each individual control and sends the output of its regulation through a communication system. Furthermore, the secondary control takes care of synchronization with network.

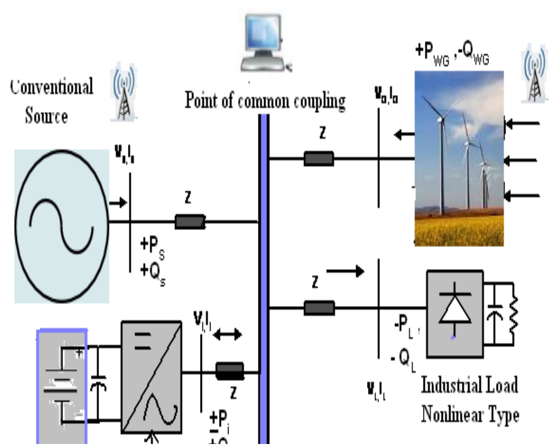

Fig. 2. Grid topology for Power Quality Improvement

IV. GRID COMMUNICATION ARCHITECTURE

The communications in the grid is based on EPICS (Experimental Physics and Industrial Control System), which is a set of open source tools focused on the development of distributed control systems in real time using the Ethernet to communicate the different EPICS devices .The communication architecture allows remote access to the facility through an IP network with high security , facilitating the operation and system diagnostics. The fundamental data of the installation can be viewed in

real time through a website; and locally, using the EPICS tools [5]-[8]. For this purpose the system requires an architecture to collect information of the smart grid, measuring devices across the net and in addition to connect the individual operator control (IOC) of the energy suppliers, which can be away to the control canter of the smart grid. Development of guideline for suitable IP protocol for smart

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grid application and identifying domain type is essential for reliability of power system. The communication architect is shown as in Fig.3.

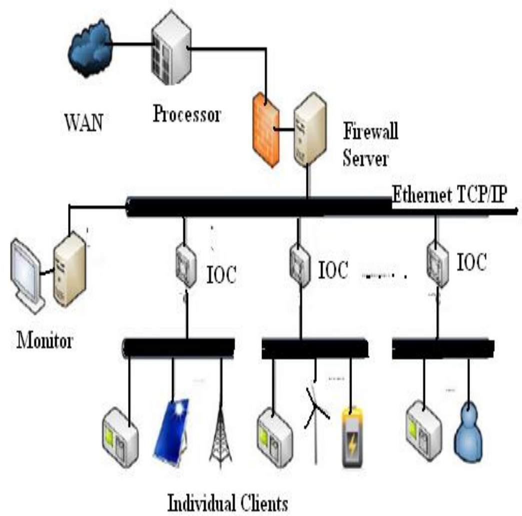

Fig. 3. Grid Communication Architect.

V. CONTROL TECHNIQUE

A block diagram with voltage source inverter with simple hysteresis control of the output current is shown in Figure 4.3. The reference current wave forms i_A^*, i_B^*, i_C^* with actual currents wave forms i_A, i_B, i_C are compared. The current errors $\Delta i_A, \Delta i_B, \Delta i_C$ are applied to the hysteresis current controllers that produce switching variable A,B,C for the inverter. The characteristic of switching function $S_A = f(\Delta i_A)$ of a current controller and other phase are shown in Figure 4.

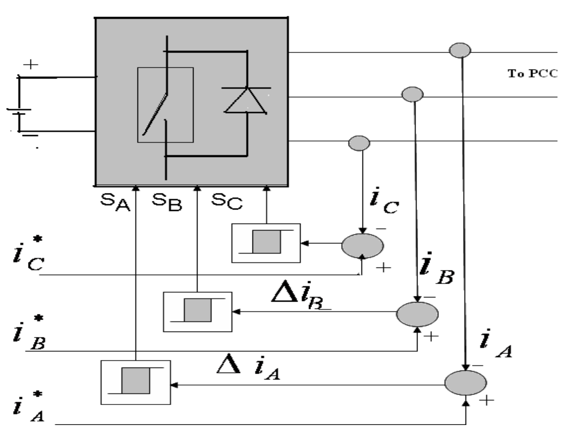

Fig. 4. Grid control Scheme.

The characteristic constitutes a hysteresis loop that can be described as

$$S_A = 0, if \Delta i_A < -\frac{h}{2} \quad (1)$$

$$S_A = 0, if \Delta i_A > \frac{h}{2} \quad (2)$$

Where, h denotes the width of the loop. If the $-\frac{h}{2} \le \Delta i_A \le \frac{h}{2}$, the value of the variable a remains unchanged. The characteristic of controllers for the other two phases are identical. The loop width, h can be the tolerance band for the controlled current i_{iA} since as long as the current error Δi_A remains within this band; no action is taken by the controller. If the error is too high i.e. the actual current is lower from its reference waveform by more than h/2, variable A assumes a value of one. These actions make the voltage V_{AN} equal to or greater than zero, which is a necessary condition for current i_{iA} to increase. The value of h affects the average switching frequency. More switching per cycle are imposed on each inverter switch when the controlled currents are to be kept within a narrow tolerance band. This output current waveform is shown in Figure 5.

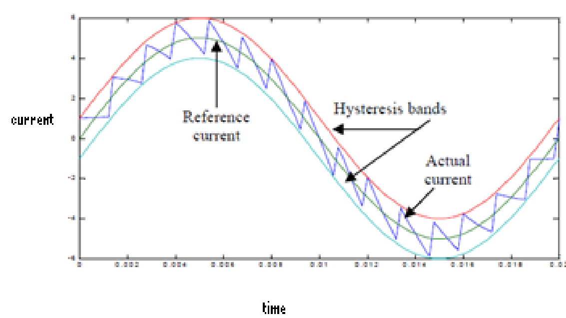

Fig. 5. Hysteresis controller.

VI.GRID SYSTEM SIMULATION

The grid control system for power quality improvement is simulated in MATLAB/SIMULINK with the parameter as under in table 1.1

TABLE I

S.No.	Simulation Parameter in the grid system	
1	Conventional Source	3ph,415Volt,50 Hz.
2	Line Inductance	0.5mH
3	Wind Generator	150kW,415V,50Hz,4-Pole
4	Wind Velocity	4m/s
5	DC Link(Storage Voltage)	800V,Capacitance-5microF.
6	Three Arm Bridge Power Converter	3-phase,1200V,50A,
7	Load	Non-linear type RC load

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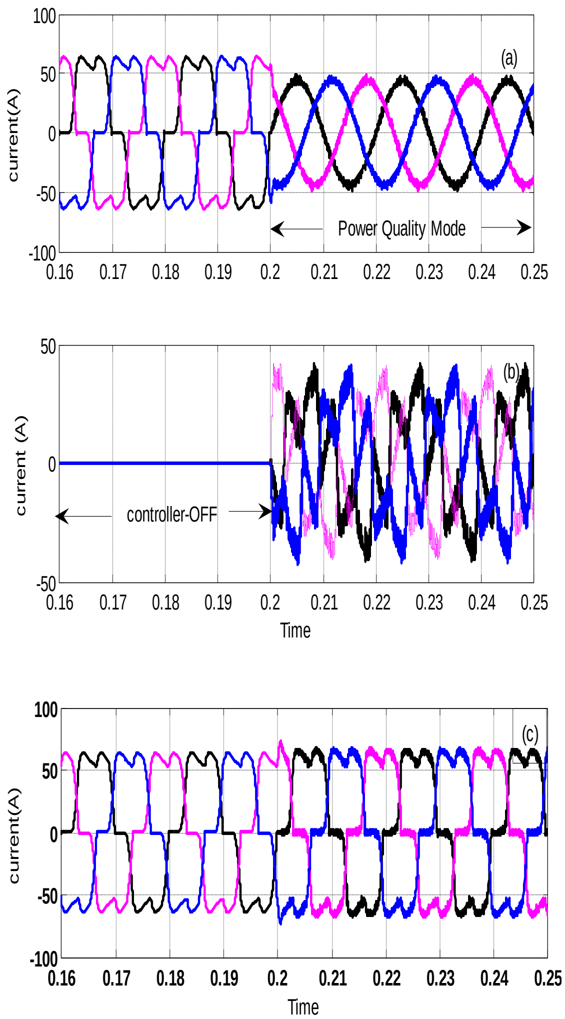
VI. SYSTEM PERFORMANCE

A non linear load is considered for the simulation of this system. These nonlinear loads in the system will affect and disturb the source current waveform. To have the source current in distortion free, the correct amount of current must be injected to cancel out this distortion effect. The performance of the system is observed by operating the controller for the power quality improvement for these critical loads. The inverter is switched 'on' at 0.2 sec .The source current I_s, inverter injected current I_{inv} , load current I_L are measured with and without controller operation. The current supplied from the source is made sinusoidal, harmonics-free as soon as controller is in operation and is shown in Figure 6 (a). The injected current supplied from the inverter is shown in Figure 6 (b). The load current in the system is shown in Figure 6 (c).During this interval the load current will be the addition of source current and inverter current. The PCC voltage is shown in Figure 6 (d)



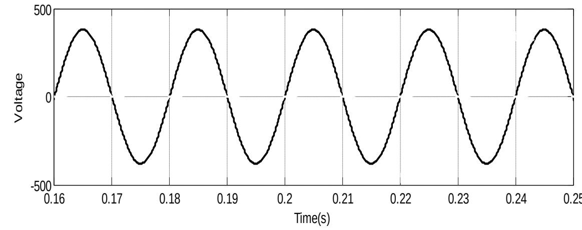


Fig.6 a) Source current b)Inverter Current c)Load current d) Voltage at PCC.

VIII. CONCLUSION

The smart grid system are complex with large number of diverse component connected a vast and geographically extended system and point out in the model. The paper presents power quality improvement deployed at the point of common coupling in the distribution system. Primary control consists of power converter and is operated as current control in the grid system so as to achieve power quality and distortion free at PCC. The power control scheme with hysteresis current controller of power converter is presented and results are highlighted. The secondary control regulates the electrical parameter inside the grid by using a central controller with communications to each primary control and sends the output of its regulation through a communication system. Furthermore, the secondary control takes care of synchronization with network.

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