Integration of Renewable Energy - Challenges in Smart Grid

Sadhana A. Bhonde, Sanjay B. Bodkhe

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 challenges and power quality approach in smart grid integration for maintaining grid quality at point of common coupling in grid distribution system. The integration of smart grid is equipped with voltage source converter, renewable sources, conventional energy generators and storage systems. The 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. Test results are presented to demonstrate the effectiveness of the control technique that is used for maintaining power quality in smart grid integration.

Index Terms— Harmonic compensation , Renewable- Energy Source Integration, Smart grid.

I. INTRODUCTION

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. The reduction of the carbon footprint, utilization of clean energy is a main goal in integration of renewable energy. In the energy sector this is reflected in the growth of renewable energies and power plants. The distribution grid are mainly connected by wind, photovoltaic (PV), and battery systems. The growths of renewable energy are mostly connected by power converters and electronic load, which introduces power quality issues .The energy saving load like energy saving light bulbs, industrial control motors are mostly connected by power electronics which introduce power quality issues. Furthermore the distribution grid is designed to distribute electric energy generated by thermal power plants to the customers. The introduction of distributed generation causes a number of issues regarding power quality, grid stability and network load . The distributed generation , however, also reduce those issues, if controlled appropriately [1]–[6] . This new grid must have innovative technologies and services in energy control, communication in order to get more efficient grid.

The paper is organized as follows. Section-II introduces the Regulation for power quality and grid integration. Section-III introduces the power quality issues in the grid system. Section-VI describes the grid approach for power quality. Section-V describes the topology for control technique for power quality improvement. Section VI describes the Simulated result and conclusion of the scheme presented in Section-VII.

II. POWER QUALITY MEASURES

Depending on the country there are different standards that regulate the Power Quality, for integration of distributed generation into the grids. The European standard EN 50160 defines the characteristics of the voltage at the point of common coupling (PCC) of grid. The given values are the limits that can be expected during normal operation. It defines the characteristics of the voltage regarding frequency, voltage change, flicker, unbalance and harmonics. Table I , shows the different limits defined for continuous Phenomena in low voltage grids.

Table I.

Phenomenon	Limit LV
Frequency	50Hz $\underline{+}$ 1% for 99.5% of time.
Voltage Change	$\underline{+}$ 5% of nominal voltage
Flicker	Long term flicker magnitude $P_h \leq 1$
Unbalance	Negative sequence component has to be within 0 to 2% of positive sequence component for 95% of 10 min mean values.
Harmonics	THD ≤ 4%

Many countries in Europe and other parts of the world are developing or modifying interconnection rules and processes for renewable through a grid code . The grid codes have identified many potential adverse impacts of large scale integration of renewable sources. The risk of voltage collapse for lack of reactive power support is one of the critical issues when it comes to contingencies in the power system. The low voltage ride through (LVRT) capability, which is one of the most demanding requirements that have been included in the grid codes and shown in Figure 1.0

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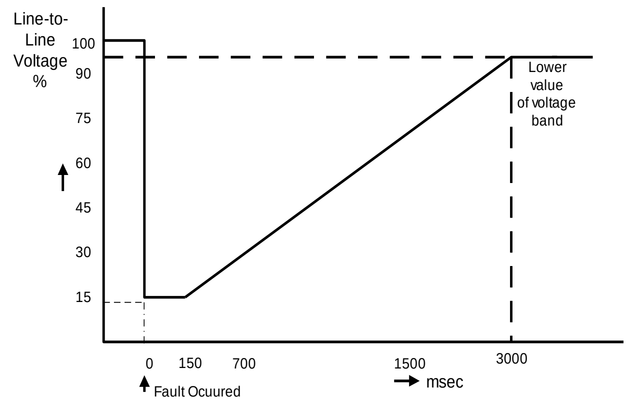

Fig. 1.0 Low voltage ride through (LVRT) capability

It defines the operational boundary of a wind turbine connected to the network in terms of frequency, voltage tolerance, power factor, fault ride through is regarded as the main challenges to the wind turbine manufactures.

III. POWER QUALITY ISSUES

Power Quality issues are highlighted as under

A. Hormonics

Harmonics in the power system are no new phenomenon, it results from the operation of power electronic converters .It has increase in magnitude due to the increasing use of power electronics. Distributed generation with power electronic converters like PV systems or wind power systems can have negative impact on the harmonic magnitude within a distribution grid. Passive harmonic filters and active filtering techniques are used as remedial solutions. Standards that limit the allowed harmonic disturbances of equipment connected to the grid can be used to prevent their occurrence. Unfortunately they consider only sinusoidal voltage wave forms. In order to evaluate harmonics correctly, the standards have to consider certain voltage harmonics and non linear behavior [7]-[8].

B. Transient

Transients are mostly caused by lightning. Connecting or disconnecting a considerable amount of power generation to the network, however, can cause transients if large current flows are allowed. Careful design of generators can limit these currents to acceptable magnitudes. Transients can cause overvoltage protection equipment to trip or to be destroyed.

C. Flicker

The term flicker refers to a visual effect caused by voltage variations below a certain frequency. These voltage variations cause lighting equipment to flicker. If this flicker is visible to humans, it is classified as relevant flicker according to EN 50160. The exact limits for flicker is define in the standard EN 61000-2-2. Wind power plants and photovoltaic systems have to be tested regarding their flicker influence on the network. Energy saving light bulbs are less sensitive to flicker as they are connected by power electronic converters.

D. Frequency

Most electrical equipment does rely on a stable network frequency. To sustain a stable frequency, generation has to match the load. Currently, rotating generators in power plants impose the frequency to the grid, while distributed generation synchronizes to this frequency. Regularly distributed generation disconnects if the frequency drops below 47.5 Hz . If they are not able to provide more power their rotation speed and therefore the network frequency will drop further. Fault ride through can be used to stabilize the frequency in case of failures. If the frequency exceeds 50.2 Hz, distributed generation has to modulate their power in order to reduce the frequency rise.

E. Unbalance

In optimal operation the voltage sine curves of the three phases differ by 120° exactly and have the same amplitude. Every deviation from that condition is called unbalance. This unbalanced is caused by the single phase connection of loads and generators to the low voltage grid. It can, depending on its severity, have serious negative impacts on transformers, controls, distributed three phase generators and power electronic devices. Small loads and generators have little impact on the systems balance and are regularly compensated by loads or generators connected to another phase somewhere in the distribution network. If, however, a number of smaller generators is connected to the same phase in the network, they can have significant influence. Unbalance can be addressed by a balanced connection of loads and generators. One phase connection of loads and generators should be compensated by the coordinated connection of similar equipment to other phases nearby. To reduce unbalance, the control strategies for three phase inverters in the grid that will able to reduce unbalance.

F. Voltage

Voltage is the most important parameter for the operation of electric appliances. In traditional low voltage networks, the transformer provides nominal or slightly higher voltage to ensure the voltage to be within the authorized range at any position within the grid. The connection of distributed generation however increases the voltage locally. This may lead to a violation of the upper voltage limit. Voltage regulation is the main challenge of distributed generator integration into the low voltage grid, especially at the end of feeders and in rural areas. The voltage at PCC is influenced locally by the grid impedance and the power flow due to loads and generation. The relationship between the voltage rise ΔV at PCC and the generated and absorbed active and reactive power and the impedance of the cable (Z = R + jX) in lightly loaded networks. The power values are positive for generation and negative for consumption.

$$\Delta V = \frac{(P_{generated} + P_{absorbed})*R + (Q_{generated} + Q_{absorbed})*X}{V} \quad (1)$$

It can be seen that active power consumption lowers, while active power generation increases the voltage. The same is valid for reactive power. Reactive power is needed for the magnetization of inductors. The reactive power needed within the network is regularly provided by the doubly-fed asynchronous induction machines, synchronous motor at power plants. The effect of voltage drop due to the consumption of reactive power, however, can be used to deliberately lower the voltage at distributed generation connection points by increasing their reactive power draw. In this context, however,

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the X/R relation of the network has to be considered. While X/R >> 1 for transmission systems, it is around one or even lower for low voltage distribution systems. Reactive power control in low voltage networks can be seen critical, as high reactive power flow would be necessary in order to lower the voltage considerably. The additional reactive power contributes to the network load and leads to additional costs . To keep the voltage within the desired range is to use on-load tap changers (OLTC). Line drop compensation (LDC) can be used to control the OLTC to keep the voltage at a point in the feeder constant. The FACTS equipment like STATCOMs can be used to control the voltage by reactive power control.[9]-[17].

IV. GRID APPROACH FOR POWER QUALITY

The Smart grid approach 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.

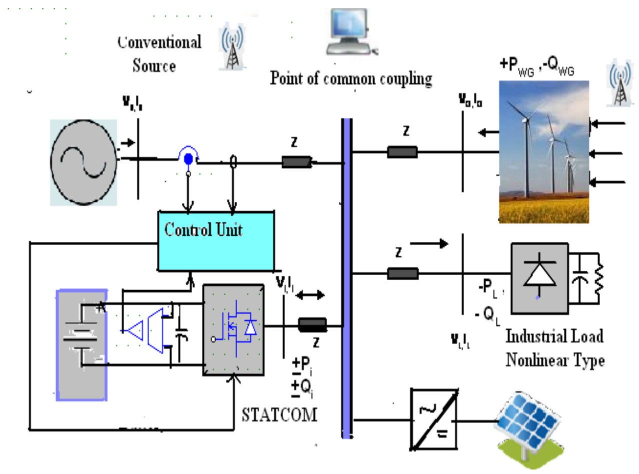

Fig. 2. Grid topology for Power Quality Improvement

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 control voltage source inverter.

V. CONTROL TECHNIQUE

A block diagram with voltage source inverter with simple hysteresis control of the output current is shown in Figure 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 Δi_A , Δi_B , Δi_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 for phase A and respectively B and C-phases.[14]-[15].

The characteristic constitutes a hysteresis loop that can be described as

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

$$S_A = 0, if \Delta i_A > \frac{h}{2} \qquad (3)$$

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.

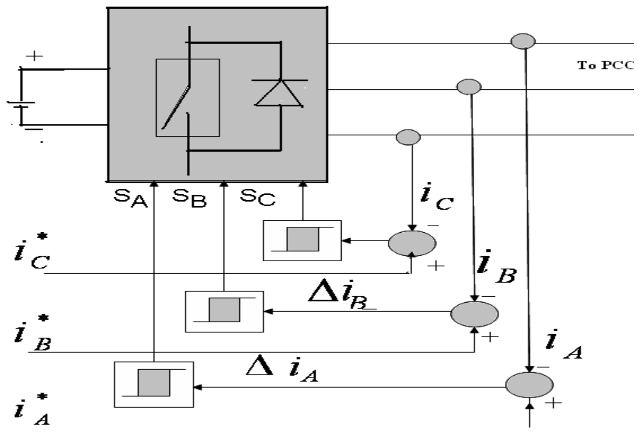

Fig. 3. Voltage Source Inverter with hysteresis controller

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.

VI. SIMULATION OF GRID SYSTEM

The grid control system for power quality improvement is simulated in MATLAB/SIMULINK with the source of three-phase , 415Volt,50Hz ,with nonlinear type RC load. 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 4 (a). The injected current supplied from the inverter is shown in Figure 4 (b). The load current in the system is shown in Figure 4 (c).During this interval the load current will be the addition of source current and inverter current. The PCC voltage is shown in Figure 4 (d).

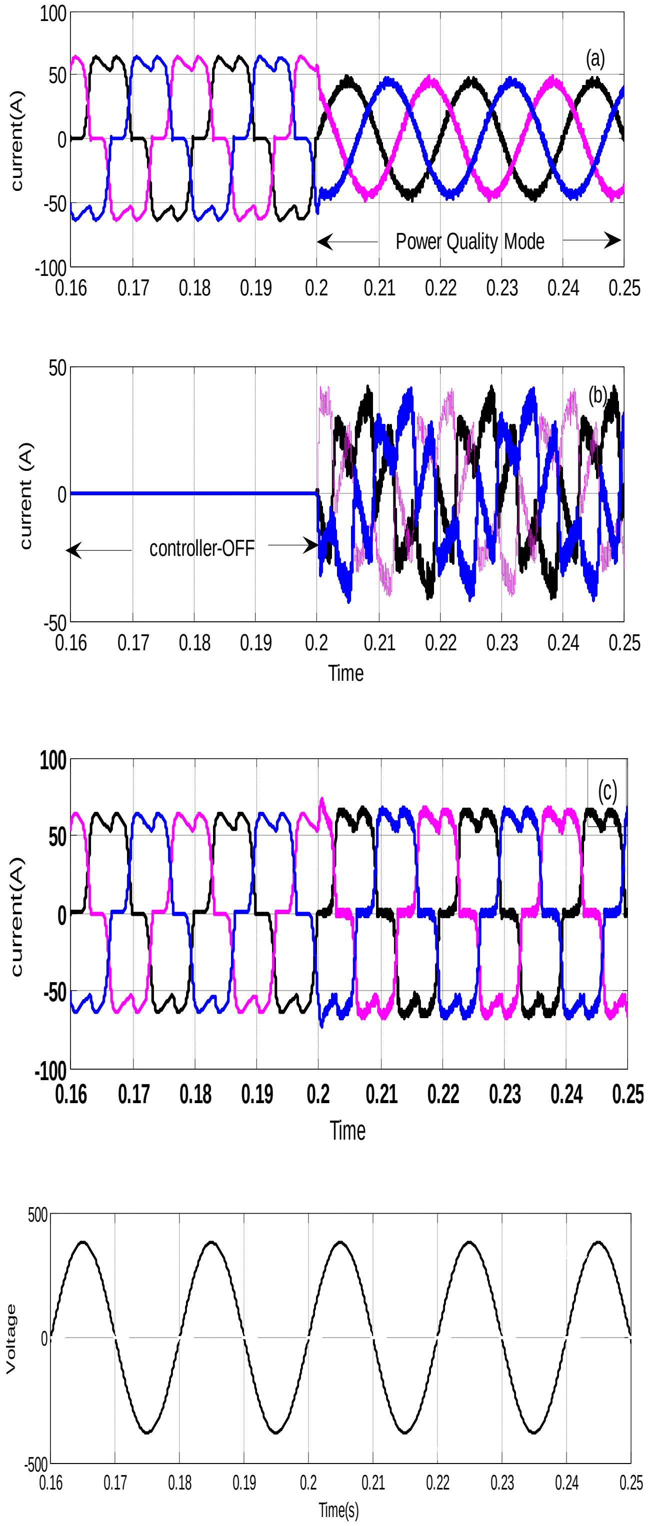

Fig. 4 a) Source current b)Inverter Current c)Load current d) Voltage at PCC

VII. CONCLUSION

The integration of distribute generator and relevant loads into the distribution network involve a typical challenges regarding grid power quality and network loading. Currently only generation is considered to fulfill requirements regarding these issues. To ensure safe operation and to improve the power quality with distributed generation, relevant loads and storage battery have to offer additional capabilities.The paper presents power quality improvement deployed at the point of common coupling in the distribution system. The 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 for execution of power quality issues and results are highlighted.

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