POWER QUALITY IMPROVEMENT OF GRID INTERCONNECTION OF RENEWABLE ENERGY BASED DISTRIBUTION SYSTEM

#1 S.NAGARAJU, M.Tech Student
#2 S.SHAMSHULHAQ, Assistant Professor
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
St. JOHNS COLLEGE OF ENGINEERING & TECHNOLOGY YERRAKOTA, YEMMIGANUR, KURNOOL, (A.P.)

ABSTRACT
As there is increase in load demand, the Renewable Energy Resources (RES) is increasingly connected in the distribution systems which utilizes power electronic Converters or inverters. In this project, grid interfacing inverter is installed in three phase four wire distribution systems. The use of non-linear loads in the power system will lead to the generation of current harmonics which in turn deteriorates the power quality. Hence, Active Power Filters (APF) are extensively used to compensate the current harmonics and load unbalance. The inverter can be controlled to perform as a multi-function device by incorporating active power filter functionality. Thus the existing inverter acts as a Shunt Active Power Filter that is capable of simultaneously compensating problems like current unbalance current harmonics and also of injecting the energy generated by renewable energy source. The inverter is controlled on the basis of hysteresis control and thus it can be utilized as a power converter injecting power generated from renewable energy resource to the grid and as a shunt active power filter to compensate the load disturbance.

Keywords: Power Quality, Renewable energy resources (RES), Active power filter (APF), distributed generation (DG), distribution system, grid interconnection, power quality (PQ), renewable energy

1. INTRODUCTION
Electric utilities and end users of electric power are becoming increasingly concerned about meeting the growing energy demand. Seventy five percent of total global energy demand is supplied by the burning of fossil fuels. But increasing air pollution, global warming concerns, diminishing fossil fuels and their increasing cost have made it necessary to look towards renewable sources as a future energy solution [1] [2]. Since the past decade, there has been an enormous interest in many countries on renewable energy for power generation. Renewable energy source (RES) integrated at distribution level is termed as distributed generation (DG). The utility is concerned due to the high penetration level of intermittent RES in distribution systems as it may pose a threat to network in terms of stability, voltage regulation and power-quality (PQ) issues. Therefore, the DG systems are required to comply with strict technical and regulatory frameworks to ensure safe, reliable and efficient operation of overall network. With the advancement in power electronics and digital control technology, the DG systems [6] can now be actively controlled to enhance the system operation with improved PQ at PCC. Generally, current controlled voltage source inverters are used to interface the intermittent RES in distributed system. A similar approach in which a shunt active filter acts as active conductance to damp out the harmonics in distribution network. In this strategy both load and inverter current sensing is required to compensate the load current harmonics. The non-linear load current harmonics may result in voltage harmonics and can create a serious PQ problem in the power system network. Active power filters are extensively used to compensate the load current harmonics and load unbalance at distribution level.
II. POWER QUALITY STANDARDS, ISSUES AND IT’S CONSEQUENCES

Power quality is the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment according to IEEE Std 1100. Various sources use the term "power quality" with different meanings. Other sources use similar but slightly different terminology like "quality of power supply" or "voltage quality".

2.1 Voltage and Current Variations

Voltage and current variations are relatively small deviations of voltage or current characteristics around their nominal or ideal values. The two basic examples are voltage magnitude and frequency. On average, voltage magnitude and voltage frequency are equal to their nominal value, but they are never exactly equal. The variation in voltage by smaller range is called voltage magnitude variation [6]. Increase and decrease of the voltage magnitude,

* Due to variation of the total load of a distribution system or part of it.

* Actions of transformer tap-changers.

* Switching of capacitor banks or reactors. Transformer tap-changer actions and switching of capacitor banks can normally be traced back to load variations as well. Thus the voltage magnitude variations are mainly due to load variations, which follow a daily pattern.

The influence of tap changers and capacitor banks makes that the daily pattern is not always present in the voltage magnitude pattern. The different types of voltage and current variations are

* Voltage Magnitude Variation
* Voltage Frequency Variation
* Current Magnitude Variation
* Current Phase Variation
* Voltage and Current Unbalance
* Voltage Fluctuation

2.2 Harmonic Distortion

The complementary phenomenon of harmonic Voltage distortion is harmonic current distortion. As harmonic voltage distortion is mainly due to nonsinusoidal load currents, harmonic voltage and current distortion are strongly linked. Harmonic current distortion requires over-rating of series components like transformers and cables. As the series resistance increases with frequency, a distorted current will cause more losses than a sinusoidal current of the same rms value.

III. SYSTEM MODELLING

A three-phase system is usually more economical than an equivalent single-phase or two-phase system at the same line to ground voltage because it uses less conductor material to transmit electrical power. Wye (star) configuration may utilize a fourth wire. The fourth wire, if present, is provided as a Neutral and is normally grounded. The '3-wire' and '4-wire' designations do not count the ground wire used above many transmission lines which is solely for fault protection and does not carry current under non-fault conditions. A four-wire system with symmetrical voltages between phase and neutral is obtained when the neutral is connected to the "common star point" of all supply windings. In such a system, all three phases will have the same magnitude of voltage relative to the Neutral. Other
non-symmetrical systems have been used. The four-wire wye system is used when ground referenced voltages or the flexibility of more voltage selections are required. Faults on one phase to ground will cause a protection event (fuse or breaker open) locally and not involve other phases or other connected equipment.

3.1. GRID INTERFACING INVERTER

A four leg VSI [5] that is capable of simultaneously compensating problems like power factor, current imbalance and current harmonics, and also of injecting the energy generated by renewable energy power sources with a very low THD. The grid-interfacing inverter can effectively be utilized to perform following important functions: 1) transfer of active power harvested from the renewable resources (wind, solar, etc.); 2) load reactive power demand support; 3) current harmonics compensation at PCC; and 4) current unbalance and neutral current compensation in case of 3-phase 4-wire system. The PQ constraints at the PCC can therefore be strictly maintained within the utility standards without additional hardware cost.

![Fig 2 Control of grid interfacing inverter](image)

The fourth leg of inverter is used to compensate the neutral current of load. The main aim of proposed approach is to regulate the power at PCC during: 1) PRES = 0; 2) PRES < total load power; and 3) PRES > total load power. While performing the power management operation, the inverter is actively controlled in such a way that it always draws supplies fundamental active power from to the grid. If the load connected to the PCC is non-linear or unbalanced or the combination of both, the given control approach also compensates the harmonics, unbalance, and neutral current. The duty ratio of inverter switches are varied in a power cycle such that the combination of load and inverter injected power appears as balanced resistive load to the grid. The regulation of dc-link voltage carries the information regarding the exchange of active power in between renewable source and grid. Thus the output of dc-link voltage regulator results in an active current. The multiplication of active current component with unity grid voltage vector templates generates the reference grid currents. The reference grid neutral current is set to zero, being the instantaneous sum of balanced grid currents. The grid synchronizing angle obtained from phase locked loop is used to generate unity vector template. The actual dc-link voltage is sensed and passed through a first-order low pass filter to eliminate the presence of switching ripples on the dc-link voltage and in the generated reference current signals. The difference of this filtered dclink voltage and reference dc-link voltage is given to a discrete-PI regulator to maintain a constant dc-link voltage under varying generation and load conditions.

3.2. LOADS AT DISTRIBUTION SIDE

At the distribution side four types of load is applied. Balanced, unbalanced, non-linear, induction motor. The balanced load can be considered as a resistive load. As it’s a three phase system each resistor is connected to phase. The voltage and current magnitude must be same in the balanced load. The unbalanced load has variations in current and in voltage magnitude. So, STATCOM is used which removes the unbalance in current and in voltage by supplying real power.

IV. SIMULATION RESULTS

In order to verify the proposed control approach to achieve multi-objectives for grid interfaced DG systems connected to a 3-phase 4-wire network, an extensive simulation study is carried out using MATLAB/Simulink.
A 4-legged current controlled voltage source inverter is actively controlled to achieve balanced sinusoidal grid currents at unity power factor (UPF) despite of highly unbalanced nonlinear load at PCC under varying renewable generating conditions. A RES with variable output power is connected on the delink of grid-interfacing inverter. An unbalanced 3-phase 4-wire nonlinear load, whose unbalance, harmonics, and reactive power need to be compensated, is connected on PCC. The waveforms of grid voltage (Va, Vb, Vc) grid currents (Ia, Ib, Ic, In), unbalanced load currents (IlA, Ilb, Ilc, Iln), and inverter currents (Ilna, Ilnb, Ilnv, Ilnv), are shown in Fig.3. The corresponding active-reactive powers of grid (Pgrid, Qgrid) load (Pload, Qload) and inverter (Pinv, Qinv) are shown in Fig. 3. Positive values of grid active-reactive powers and inverter active-reactive powers imply that these powers flow from grid side towards PCC and from inverter towards PCC, respectively. The active and reactive powers absorbed by the load are denoted by positive signs. Initially, the grid-interfacing inverter is not connected to the network (i.e., the load power demand is totally supplied by the grid alone). Therefore, before time \( t = 0.72 \) s, the grid current profile in Fig. 3(b) is identical to the load current profile of Fig. 3(c). At \( t = 0.72 \) s, the grid-interfacing inverter is connected to the network. At this instant the inverter starts injecting the current in such a way that the profile of grid current starts changing from unbalanced nonlinear to balanced sinusoidal current as shown in Fig. 3(b). As the inverter also supplies the load neutral current demand, the grid neutral current (In) becomes zero after \( t = 0.72 \) s. At \( s \), the inverter starts injecting active power generated from RES \( (P_{R E S} = P_{i n v}) \). Since the generated power is more than the load power demand the additional power is feedback to the grid. The negative sign of \( P_{grid} \), after time \( 0.72 \) s suggests that the grid is now receiving power from RES. Moreover, the grid-interfacing inverter also supplies the load reactive power demand locally. Thus, once the inverter is in operation the grid only supplies/receives fundamental active power. At \( t = 0.82 \) s, the active power from RES is increased to evaluate the performance of system under variable power generation from RES. This results in increased magnitude of inverter current. As the load power demand is considered as constant, this additional power generated from RES flows towards grid, which can be noticed from the increased magnitude of grid current as indicated by its profile. At \( t = 0.92 \) s the power available from RES is reduced. The corresponding change in the...
inverter and grid currents can be seen from Fig. 3. The active and reactive power flows between the inverter, load and grid during increase and decrease of energy generation from RES can be noticed from Fig. 4. The dc-link voltage across the grid interfacing inverter (Fig. 4(d)) during different operating condition is maintained at constant level in order to facilitate the active and reactive power flow. Thus from the simulation results, it is evident that the grid interfacing inverter can be effectively used to compensate the load reactive power, current unbalance and current harmonics in addition to active power injection from RES. This enables the grid to supply/ receive sinusoidal and balanced power at UPF.

V. CONCLUSION

This paper has presented a novel control of an existing grid interfacing inverter to improve the quality of power at PCC for a 3-phase 4-wire System. It has been shown that the grainer facing inverter can be effectively utilized for power conditioning without affecting its normal operation of real power transfer. The grid interfacing inverter with the proposed approach can be utilized to: i) inject real power generated from RES to the grid, and/or, ii) operate as a shunt Active Power Filter (APF). This approach thus eliminates the need for additional power conditioning equipment to improve the quality of power at PCC. Extensive MATLAB/Simulink simulation. When the power generated from RES is more than the total load power demand, the grid interfacing inverter with the proposed control approach not only fulfills the total load active and reactive power demand (with harmonic compensation) but also delivers the excess generated sinusoidal active power to the grid at unity power factor.

REFERENCES


