Renewable Energy Source Integrated at Distribution Level for Power Quality Improvement

P. Srikanth[1], Dr.N.Sambasiva Rao[2], I.Prasanna Kumar[3]
PG Scholar, Dept. of EEE, NRI Institute of Technology, Agiripalli (M), Vijayawada, India[1]
Professor, Dept. of EEE, NRI Institute of Technology, Agiripalli (M), Vijayawada, India[2]
Assistant Professor, Dept. of EEE, NRI Institute of Technology, Agiripalli (M), Vijayawada, India[3]

ABSTRACT:

Today, Increase the demand of Renewable energy resources (RES) in distribution systems because total energy demand is supplied by the burning of fossil fuels and it is limited. In this paper presents a control strategy of three phase four wire grid interfacing inverter to effectively utilize the renewable energy Source with grid. Controlling of inverter in such a way that to utilize the following function 1)compensate load current (i.e. reduce harmonics), 2compensate load voltage (i.e. reduce harmonics), 3)compensate load reactive power and load neutral Current. The Renewable Energy Source may be Solar or Wind depends on distribution system voltage level. All these works of the inverter is done either individually or combined to over come the unbalanced effects of all types of linear, nonlinear ,balance or unbalance loads at distribution level. This new control concept is demonstrated with extensive.

KEYWORDS: Fuels, Renewable energy resources, Reduce harmonics

I.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. Since the past decade, there has been an enormous interest in many countries on renewable energy for power generation. The market liberalization and government's incentives have further accelerated the renewable energy sector growth.

(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 can now be actively controlled to enhance the system operation with improved PQ at PCC. However, the extensive use of power electronics based equipment and non-linear loads at PCC generate harmonic currents, which may deteriorate the quality of power.

Generally, current controlled voltage source inverters are used to interface the intermittent RES in distributed system. Recently, a few control strategies for grid connected inverters incorporating PQ solution have been proposed. In an inverter operates as active inductor at a certain frequency to absorb the harmonic current. But the exact calculation of network inductance in real-time is difficult and may deteriorate the control performance. A similar approach in which a shunt active filter acts as active conductance to damp out the harmonics in distribution network is proposed. A control strategy for renewable interfacing inverter based on – theory is proposed. 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 (APF) are extensively used to compensate the load current harmonics and load unbalance at distribution level. This results in an additional hardware cost. However, in this paper authors have incorporated the features of APF in the, conventional inverter interfacing renewable with the grid, without any additional hardware cost. Here, the main idea is the maximum utilization of inverter rating which is most of the time underutilized due to intermittent nature of RES.

II.DISTRIBUTED GENERATION

Distributed generation, also called on-site generation, dispersed generation, embedded generation, decentralized generation, decentralized energy or distributed energy generates electricity from many small energy sources. Currently, industrial countries generate most of their electricity in large centralized facilities, such as fossil fuel (coal, gas powered) nuclear or hydropower plants. These plants have excellent economies of scale, but usually transmit electricity long distances and negatively affect the environment.

Most plants are built this way due to a number of economic, health & safety, logistical, environmental, geographical and geological factors. For example, coal power plants are built away from cities to prevent their heavy air pollution from affecting the populace. In addition, such plants are often built near collieries to minimize the cost of transporting coal. Hydroelectric plants are by their nature limited to operating at sites with sufficient water flow. Most power plants are often considered to be too far away for their waste heat to be used for heating buildings.

Low pollution is a crucial advantage of combined cycle plants that burn natural gas. The low pollution permits the plants to be near enough to a city to be used for district heating and cooling. Distributed generation is another approach. It reduces the amount of energy lost in transmitting electricity because the electricity is generated very near where it is used, perhaps even in the same building. This also reduces the size and number of power lines that must be constructed. Typical distributed power sources in a Feed-in Tariff (FIT) scheme have low maintenance, low pollution and high efficiencies. In the past, these traits required dedicated operating engineers and large complex plants to reduce pollution. However, modern embedded systems can provide these traits with automated operation and renewable, such as sunlight, wind and geothermal. This reduces the size of power plant that can show a profit.

A. DISTRIBUTED ENERGY SYSTEMS

Today, new advances in technology and new directions in electricity regulation encourage a significant increase of distributed generation resources around the world. As shown in Fig.1 the currently competitive small generation units and the incentive laws to use renewable energies force electric utility companies to construct an increasing number of distributed generation units on its distribution network, instead of large central power plants. Moreover, DES can offer improved service reliability, better economics and a reduced dependence on the local utility. Distributed Generation Systems have mainly been used as a standby power source for critical businesses. For example, most hospitals and office buildings had stand-by diesel generation as an emergency power source for use only during outages. However, the diesel generators were not inherently cost-effective, and produce noise and exhaust that would be objectionable on anything except for an emergency basis.

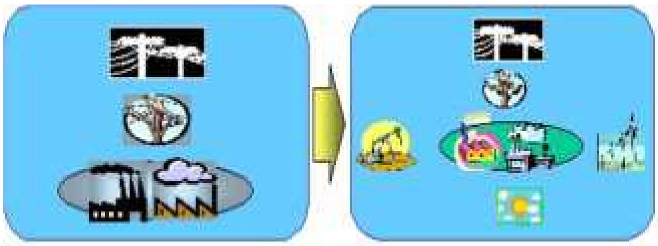


Fig 1. A large central power plant and distributed energy systems

Meanwhile, recently, the use of Distributed Energy Systems under the 500 kW level is rapidly increasing due to recent technology improvements in small generators, power electronics, and energy storage devices. Efficient clean fossil fuels technologies such as micro-turbines and fuel cells, and environmentally friendly renewable energy technologies such as solar/photovoltaic's, small wind and hydro are increasingly used for new distributed generation systems.

These DES are applied to a standalone, a standby, a grid-interconnected, a cogeneration, peak shavings, etc. and have a lot of benefits such as environmental-friendly and modular electric generation, increased reliability, high power quality, uninterruptible service, cost savings, on-site generation, expandability, etc. The major Distributed Generation technologies that will be discussed in this section are as follows: micro-turbines, fuel cells, solar/photovoltaic systems, and energy storage devices.Micro-turbines, especially the small gas fired micro turbines in the 25-100 kW that can be mass-produced at low cost have been more attractive due to the competitive price of natural gas, low installation and maintenance costs. It takes very clever engineering and use of innovative design (e.g. air bearing, recuperation) to achieve reasonable efficiency and costs in machines of lower output, and a big advantage of these systems is small because these mainly use high-speed turbines (50,000-90,000 RPM) with air foil bearings. Therefore, micro turbines hold the most promise of any of the DES technologies today.

In general, almost one acre of land would be needed to provide 150 kW of electricity, so solar/photovoltaic systems will continue to have limited applications in the future. Energy storage devices such as ultra capacitors, batteries, and flywheels are one of the most critical technologies for DES. In general, the electrochemical capacitor has high power density as well as good energy density. In particular, ultra capacitors have several benefits such as high pulse power capacity, long lifetime, high power density, low ESR, and very thin and tight. In contrast, batteries have higher energy density, but lower power density and short lifetime relative to ultra-capacitor. So hybrid Power System, a combination of ultra-capacitor and battery, is strongly recommended to satisfy several requirements and to optimize system performance. Recently storage systems are much more efficient, cheaper, and longer than five years ago. In particular, flywheel systems can generate 700 kW for 5 seconds, while 28-cell ultra capacitors can provide up to 12.5 kW for a few seconds. In the past, the electric utility industry did not offer various options that were suited for a wide range of consumer needs, and most utilities offered at best two or three combinations of reliability-price. However, the types of modern DES give commercial electric consumers various options in a wider range of reliability-price combinations. For these reasons, DES will be very likely to thrive in the next 20 years, and especially, distributed generation technologies will have a much greater market potential in areas with high electricity costs and low reliability such as in developing countries.

B. Configurations for DES

Case I: A Power Converter connected in a Standalone AC System or in Parallel with the Utility Mains Fig.2 show a distributed power system which is connected to directly load or in parallel with utility mains, according to its mode. This system consists of a generator, an input filter, an AC/AC power converter, an output filter, an isolation transformer, output sensor (V, I, P), and a DSP controller. In the Figures a distributed generator may operate as one of three modes: as in fig.2 standby, fig.3a peak shaving, and fig.4 a standalone power source. In a standby mode shown in figures a generator set serves as a UPS system operating during mains failures. It is used to increase the reliability of the energy supply and to enhance the overall performance of the system.

The static switch SW 1 is closed in normal operation and SW 2 is open, while in case of mains failures or excessive voltage drop detection SW 1 is open and SW 2 is simultaneously closed. In this case, control techniques of DES are very similar to those of UPS. If a transient load increases, the output voltage has relatively large drops due to the internal impedance of the inverter and filter stage, which frequently result in malfunction of sensitive load. Fig.4 can serves as a peak shaving or interconnection with the grid to feed power back to mains.

In both modes, the generator is connected in parallel with the main grids. In a peak shaving mode, this generator is running as few as several hundred hours annually because the SW 1 is only closed during the limited periods. Meanwhile, in an interconnection with the grid, SW 1 is always closed and this system provides the grid with continuous electric power. In addition, the converter connected in parallel to the mains can serve also as a source of reactive power and higher harmonic current components.

In a standalone AC system shown in Fig. the generator is directly connected to the load lines without being connected to the mains and it will operate independently. In this case, the operations of this system are similar to a standby mode, and it serves continuously unlike a standby mode and a peak shaving mode.

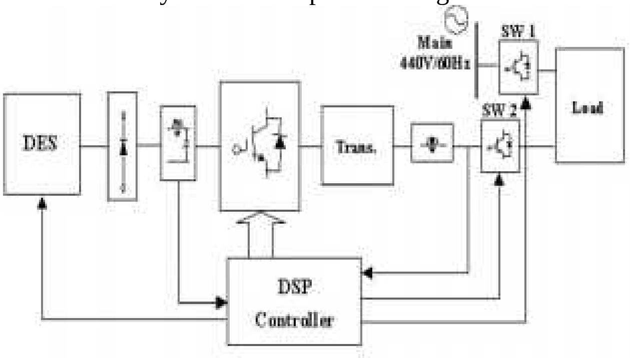


Fig.2 Block diagram of a standby mode

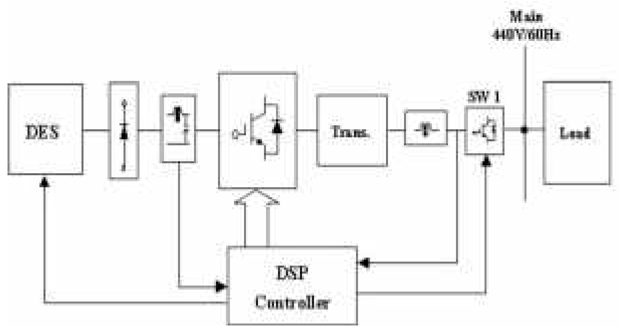


Fig.3 Block diagram of a peak shaving m

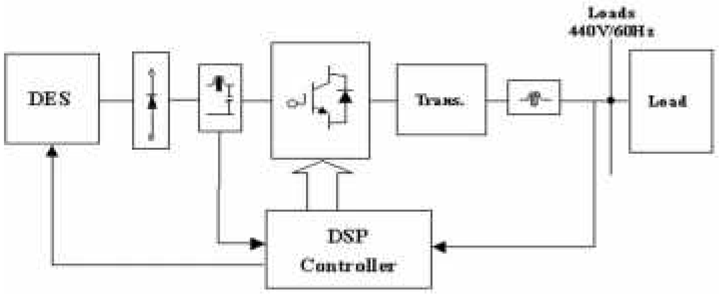


Fig.4 Block diagram of a standalone mode

The output voltage of the generator is fed to a DC/AC converter that converts a DC output of the generator to be fixed voltage and frequency for utility mains or loads. The DSP controller monitors multiple system variables on a real time basis and executes control routines to optimize the operation of the individual subsystems in response to measured variables. It also provides all necessary functions to sense output voltages, current, and power, to operate protections, and to give reference signals to regulators. The output power of the converter is controlled according to the reference signal of the control unit. As described above, in order to compensate for reactive power and higher harmonic components or to improve power factor, the active power (P) and reactive power (Q) should be controlled independently. Moreover, the above system needs over-dimensioning some parts of the power converter in order to produce reactive power by the converter at rated active power.

III.MODELING AND CONTROL OF INVERTER INTERFACED DG UNITS

Basically each DG unit may have DC type or rectified generation unit (Fuel cell, solar cell, wind turbine, micro turbine…), storage devices, DC-DC converter, DC-AC inverter, filter, and transformer for connecting to loads or utility in order to exchange power. Model and dynamic of each of this part may have influence in system operation. But here for simplification it is considered that DC side of the units has sufficient storage and considered as a constant DC source. Hence only DC-AC inverter modeling and control investigated in this paper.A circuit model of a three-phase DC to AC inverter with LC output filter is further described in Figure As shown in the fig.5:, the system consists of a DC voltage source (Vdc), a three- phase PWM inverter, an output filter (Lf and C with considering parasitic resistance of filter- Rf). Sometimes a transformer may be used for stepping up the output voltage and hence Lf can be transformer inductance.

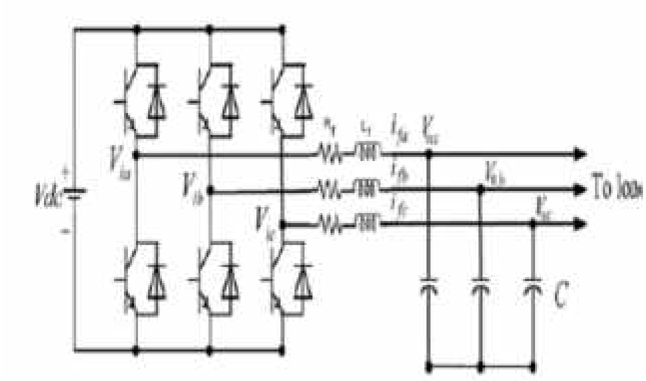


Fig 5:PWM inverter diagram

There are two ways for controlling an inverter in a distributed generation system

A. PQ INVERTER CONTROL

This type of control is adopted when the DG unit system is connected to an external grid or to an island of loads and more generators. In this situation, the variables controlled by the inverter are the active and reactive power injected into the grid, which have to follow the set points Pref and Qref, respectively. These set points can be chosen by the customer or by a central controller. The PQ control of an inverter can be performed using a current control technique in qd reference frame which the inverter current is controlled in amplitude and phase to meet the desired set-points of active and reactive power. With the aim of Park transform and equations between inverter input and output, the inverter controller block diagram for supplying reference value of Pref and Qref is as Fig 6.For the current controller, two Proportional-Integral (PI) regulators have been chosen in order to meet the requirements of stability of the system and to make the steady state error be zer. With this control scheme, it is possible to control the inverter in such way that injects reference value of Pref, Qref into other part of stand-alone network. When the output voltage is needed to be regulated, the PV control scheme that is similar to PQ mode with feedback of voltage used to adjust Qref.

This controller has to act on the inverter whenever the system is in stand-alone mode of operation. In fact in this case it must regulate the voltage value at a reference bus bar and the frequency of the whole grid. A regulators work in order to keep the measured voltages upon the set points. Moreover the frequency is imposed through the modulating signals of the inverter PWM control by mean of an oscillator. A simple PI controller can regulate bus voltage in reference value with getting feedback of real bus voltage. Fig.7: outlines this control strategy. In this case it is obvious that the DG unit should have storage device in order to regulate the power and voltage.

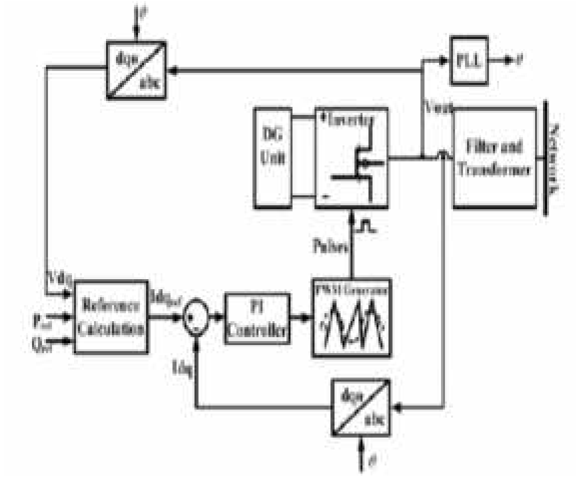


Figure 6. PQ control scheme of inverter

B. VF INVERTER CONTROL

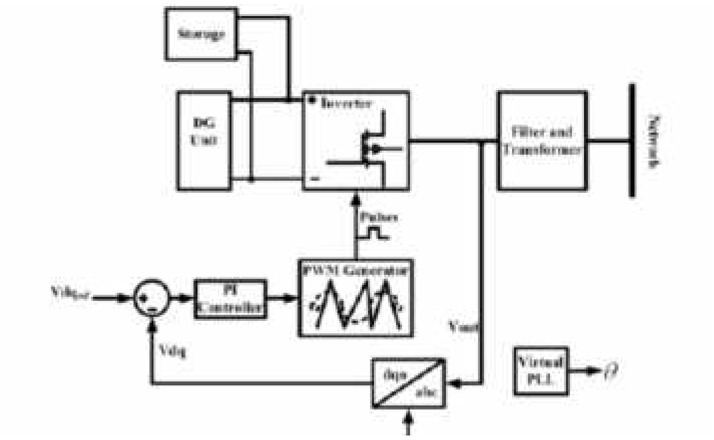
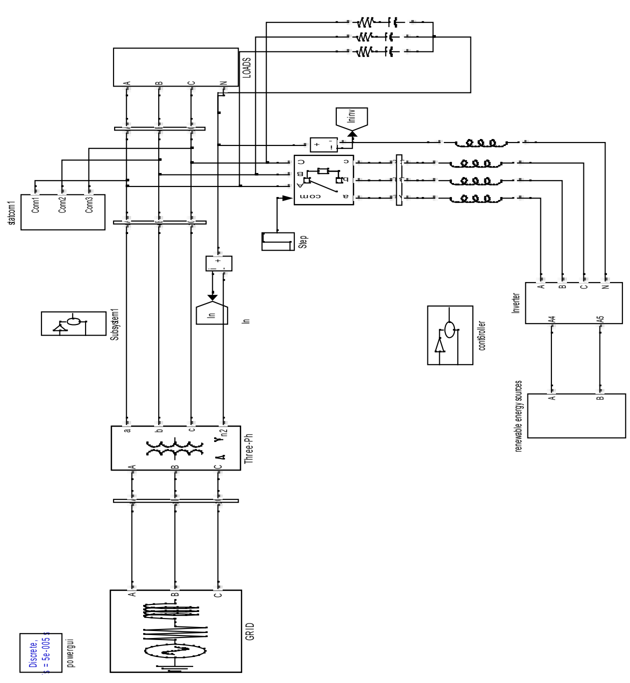


Figure 7: Vf control scheme of inverter

IV.MATLAB DESIGNS OF CASE STUDY AND RESULT



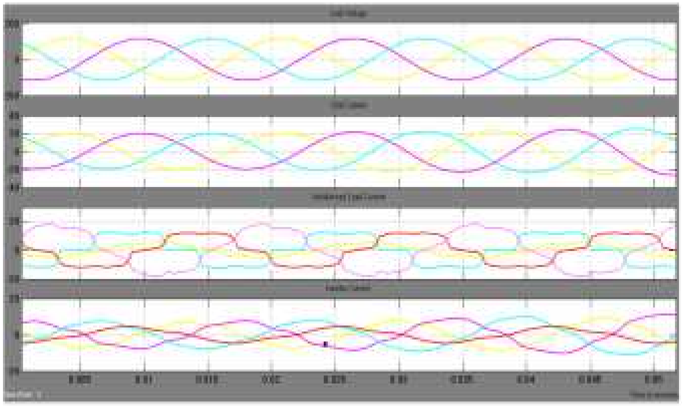


Fig8 : Simulation results: (a) Grid voltages, (b) Grid Currents (c) Unbalanced load currents, (d) Inverter Currents

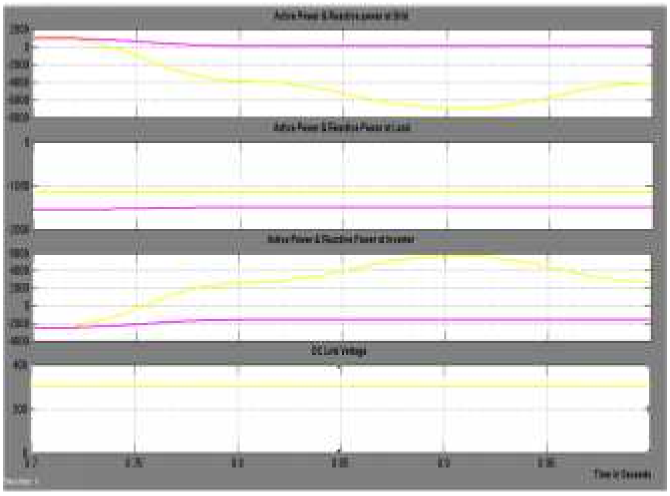


Fig 9:Simulation results: (a) PQ-Grid, (b) PQ-Load, (c) PQ-Inverter, (d) dc-link voltage

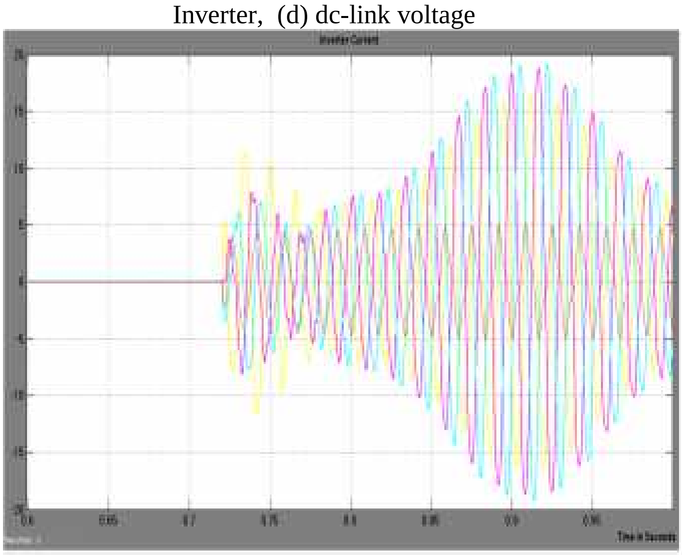


Fig 10: Inverter Current

V.CONCLUSION

This Project 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 DG system, filters and D-STATCOM. It has been shown that the grid-interfacing inverter can be effectively utilized for power conditioning without affecting its normal operation of real power transfer. The filters can mitigate the harmonics in the output of the inverter and the D-STATCOM can compensate the voltage at the distribution level. This approach thus eliminates the need for additional power conditioning equipment to improve the quality of power at PCC. Extensive MATLAB/Simulink simulation as well as the DSP based experimental results have validated the proposed approach and have shown that the grid-interfacing inverter can be utilized as a multi-function device.The authors can conclude on the topic discussed and proposed. Future enhancement can also be briefed here.

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