Harmonic Filtering & Power Stable Grid Connected DG System with Feed Back Loop

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Abstract - Optimal design of distributed generation (DG) unit interfacing converters to actively compensate harmonics, are essential in meeting the interconnection standard requirement for grid-connected voltage source converters. proposed current controller has two well decoupled control branches to independently control fundamental and harmonic DG currents, local nonlinear load harmonic current detection and distribution system harmonic voltage detection are not necessary for the proposed harmonic compensation method. Hence the main aim of the study is to attenuate higher order harmonics along with the reduction in switching losses to ensure sinusoidal current injection into the grid. Further, the different switching schemes for single phase full bridge inverter are studied and compared to get the switching scheme which gives lesser switching losses. The LCL filter is designed accordingly and optimal inductance and capacitance values are obtained. Novel small signal model of a three phase grid connected VSI has been derived and its relevant transfer functions have been deduced from it so as to analyze the system for designing a controller and also bode plots have been plotted. Stability Analysis of Grid-Connected Inverters with an LCL Filter Considering Grid Impedance and comparative study between unipolar and bi-polar switching scheme for grid-connected inverter system is also done. The improvements in the power quality and reduction in the harmonic distortions is achieved using Feed Back Loop. Simulation is done in MATLAB SIMULINK environment for feasibility of the study.

Keywords - Harmonic Distortion, Feed Back Loop, Power Quality, Filter.

I. INTRODUCTION

Wind is an abundant renewable source of energy, which is usually obtained by converting part of the kinetic energy in the moving air into electricity. Wind renewable energy is also a clean energy source, that is, operating without producing carbon dioxide, sulfur dioxide, particulates or any other type of air pollution[1-2]. Demand for electrical energy from renewable sources is rapidly increasing as industrialized societies are becoming more aware of and concerned about fossil fuel shortage and environmental impacts [3]. Besides hydro-power, which is already well established, wind energy is by far one of the most technically advanced and promising renewable energy sources. In many countries, the potential for wind energy production exceeds by far the local consumption of electricity. By 2005, the worldwide capacity had been increased to 58,982 megawatts and the World Wind Energy Association expects 120,000 MW to be installed globally by 2010. Germany is the leading producer of wind power with a capacity of 18,428 megawatts in 2005, which accounts for 6% of German electricity in the same year [4].

Recently, with the technological improvement in new materials, fabrication technology, as well as new wind blade, gear box and induction generator designs and manufacturing methods, both the size of wind turbine blades and the volume of commercial production have been steadily increasing to the point where typical peak output is currently in the range of several megawatts [5-6]. In this case, the grid integration of large wind renewable energy becomes significant and arouses great interest from the society [2].

However, increased penetration of dispersed and distributed wind energy creates a new serious uncontrollable scenario in electric power grid system. On one hand, dynamic variations and wind velocity excursions cause excessive changes in prime mover power and the corresponding electrical power injected into the grid utility network. Depending on intensity and rate of wind changes, difficulties with generator output frequency variations and severe generator voltage stabilization could result in possible loss of excitation and frequent shutdowns as well as severe power quality issues, such as voltage distortions and variations in its output electrical energy [7].

On the other hand, based on economic and aesthetic considerations, wind farms and distributed wind generation schemes are usually planned and installed in rural, mountain and coastal areas with annual favorable wind utilization regimes, where the distribution/utilization electric grid networks are usually of radial structure and are electrically weak with low short circuit ratios [7- 8].

II. CONTROL OF GRID AND FILTER DESIGN

A design of a current controller along with active and reactive power control in order to ameliorate the power quality in the grid is shown. This technique intends to overcome the hitches faced by the conventional controller working under unbalanced conditions of the grid. The control strategy adopted counterbalances the distortions in grid voltage by injecting sinusoidal current to the grid through a MRF PI controller strategy [9]. For the active and reactive power control, cross coupling is done in order to decouple the *d-q* components and thus helping in effective control of the active and reactive power independently.

Optimal design of LCL filter for grid interfaced distributed power generation system is studied. For that, initially normal design is considered. Higher request LCL channels are crucial in gathering the interconnection standard necessity. The IEEE 1547-2008 determinations for high-frequency current ripple are utilized as a real imperative ahead of schedule in the outline to guarantee that all resulting improvements are still agreeable with the models. The output filter helps in reducing the harmonics in generated current caused by semiconductor device switching. There are various types of filters. The simplest one is the filter inductor connected to the inverter's output. But various combinations of inductor and capacitors like LC or LCL can be used. The schematic diagram of a single phase grid connected inverter along with LCL filter The L-Filter is the first order filter with attenuation 20dB/decade over the entire frequency range. Hence this type of filter is suitable for converters with high switching frequency, where the attenuation is sufficient. On the other side, inductance greatly decreases dynamics of the whole system converter filter [2]. The LCL-filter is a third order filter having attenuation of 60db/decade for frequencies above full resonant frequency, hence lower switching frequency for the converter switches could be utilized . Decoupling between the filter and the grid connected inverter having grid side impedance is better for this situation and lower current ripple over the grid inductor might be attained. The LCL filter will be vulnerable to oscillations too and it will magnify frequencies around its cut-off frequency.

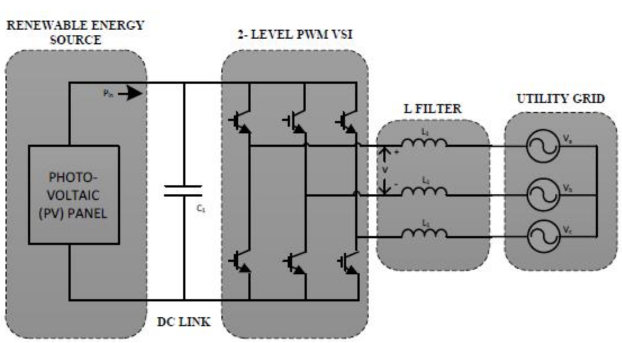

Fig. 1.1. Schematic diagram of Grid Connected PWM Inverter

The schematic diagram of three phase grid-connected PWM inverter is shown in Fig. 2.1, which consists of dc link capacitor, IGBT switches and filter circuit in the grid side.

Assume that the three phase loop resistance R and L are of the same value, affection of distribution parameters are negligible and switching loss and on state voltage drop is negligible.

III. PROPOSED MODEL

Distributed generation (DG) based on renewable energy sources are basically small scale power generation units (typically ranges from 20 kW to 20 MW) and they are located at the end user without long distance transmission line. As a result, it reduces the transportation cost of generation and consumption points are close to each other. It is feasible to implement interfaces having ability to operate in grid connected as well as in isolated mode without grid connection which is called micro grids [2]. The basic structure of a Distributed Power Generation System (DPGS) is illustrated in Fig.1.1. The input to the DPGS can be sources like wind firm, solar panel, geothermal, tidal turbine, and small plants as portrayed in the above figure. Then back to back converters are connected so as to control the output voltage and frequency due to inconsistency of the input sources to meet the load or grid requirements Moreover, it provides bidirectional power flow between the sources and grid. The role of input side converter is to extract the maximum power from the renewable source and to provide the power to grid side converter. The role of grid side converter is to control the power flow to the grid and to maintain the output voltage and frequency at the desired level.

The system is synchronised with the grid through a filter known as grid filters. These filters require high switching frequencies to acceptably attenuate switching harmonics particularly in weak grid where the grid voltage is sensitive to load variations. In most cases control design for the three phase PWM inverter involves two steps and these are choice of modulation strategy which corresponds to open loop control and design of dynamic close loop control. However, reactive power control is one of the key issues to deal with in DPGS. From the investigation of the blackout occurred in U.S. and Canada in 2003 it was found that the cascaded outages of several transmission lines and generating units could have been avoided if controllable reactive power was available [3]. This project has taken an attempt to derive the small signal model of a single phase inverter in isolated mode and its performance with different controllers. Further, the work is extended to modelling of three phase grid connected VSI and its relevant transfer functions have been deduced from the model so as to analyse the system performance for designing a controller through well-known bode plots. The studied system is modelled and simulated in the MATLAB-Simulink environment.

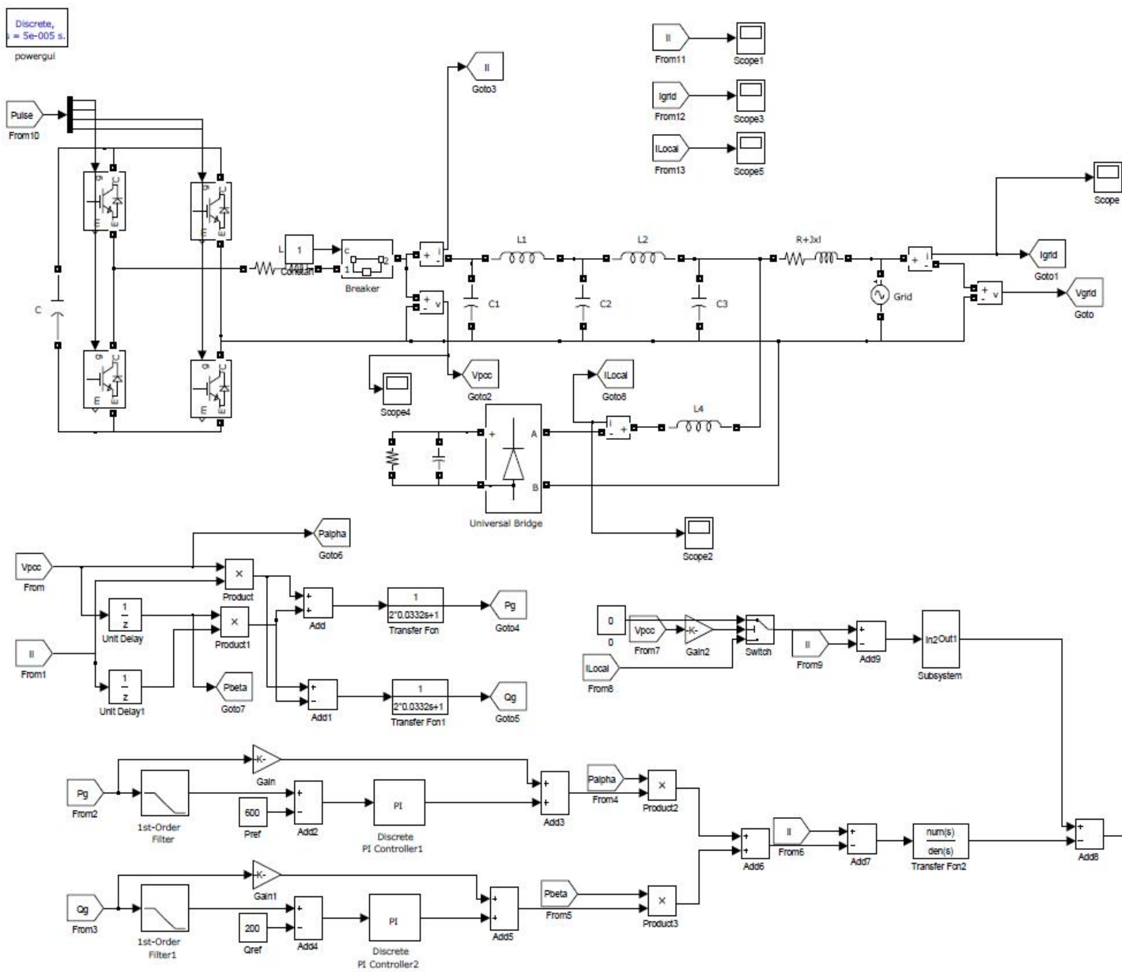

Fig. 3.1 Proposed Model

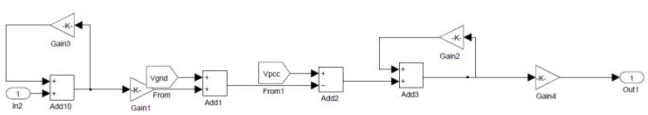

Fig. 3.2 Sub System of the Proposed Model

IV. SIMULATION OUTCOMES

In order to verify the correctness of the proposed control strategy, simulated and experimental results are obtained from a single-phase DG unit. First, the DG unit with a local diode rectifier load is tested in the simulation. The configuration of the system is the same as shown in Fig. 4.1 and PoC is connected to a stiff controlled voltage source (to emulate the main grid) with nominal 50 Hz frequency. The main grid voltage contains 2.8% third and 2.8% fifth harmonic voltages. In this simulation, the reference power is set to 600W and 200 var. For the DG unit operating under local load harmonic compensation mode, its fundamental current reference adjusted by (10) is shown in Fig. 5.5. As the DG unit also provides 200 var reactive power to the grid, it can be seen that the fundamental current reference is slightly lagging of the PoC voltage.

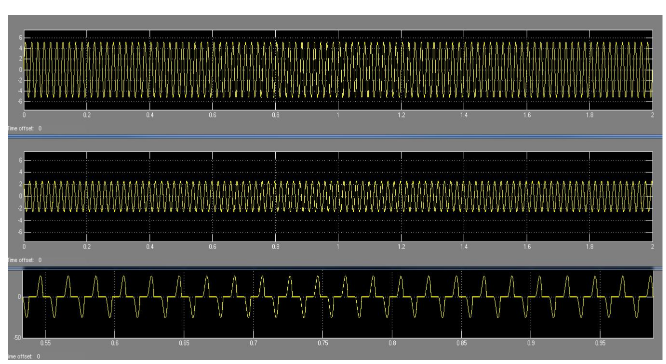

Fig. 4.1 Waveforms of the Proposed System

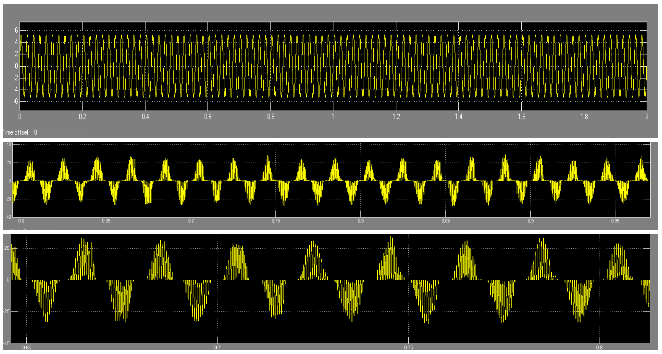

Fig. 4.2 Current Waveforms after Applying Proposed Model

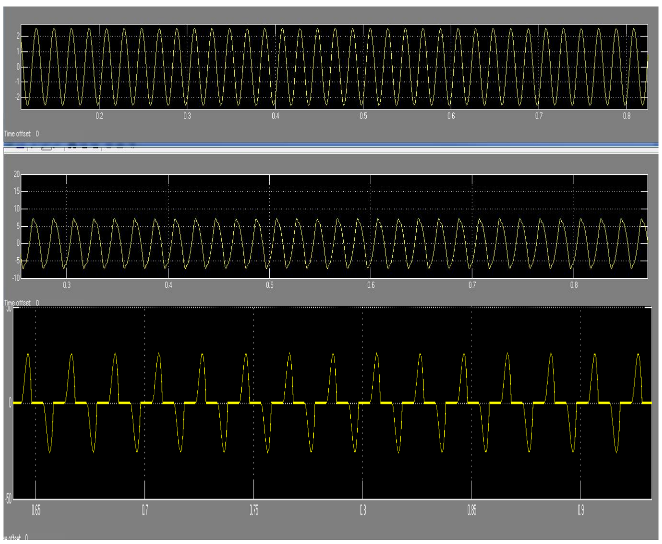

Fig. 4.3 Improved Waveforms of the Currents

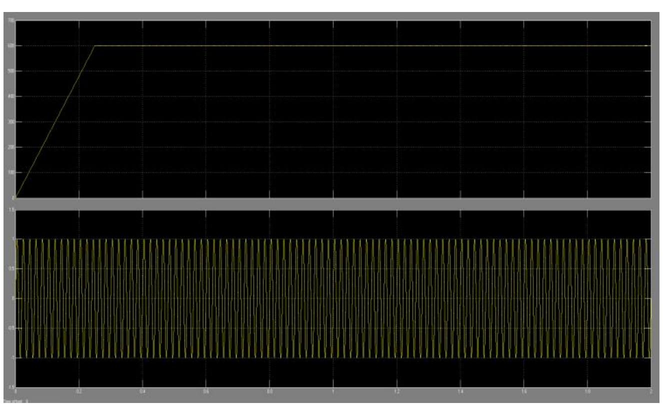

Fig. 4.4 Active and Reactive Powers

The effectiveness of the proposed closed-loop power control strategy is verified Figure, where the real and reactive power is calculated by (13) and (14).When the conventional open-loop power control in (6) is applied, it can be noticed that the DG output real and reactive power control is not accurate. On the other hand, as the proposed control strategy regulates DG output power in a closed-loop manner, it guarantees zero steady-state power tracking error.

V. CONCLUSIONS AND FUTURE SCOPE

From the obtained results it is concluded that proposed Feed Back Loop based controller gives less THD% in output voltage in case of both linear as well as nonlinear load as compared to PI voltage controller. In addition to that observation feasibility of the study with theoretical results the modeling was extended to three phase grid connected inverter with LC filter. From the derived small signal model transfer functions were derived and bode plots were plotted to study stability. The effect of resonance was observed from the bode plot of control to output voltage transfer function. A control strategy was developed based on the model and its step responses were plotted. Based on the small signal model of three phase grid connected inverter controller can be developed in order to regulate active and reactive power during grid abnormalities. Optimal LCL filter design with Feed Back Loop along with switching loss reduction is presented. Hence, the optimal filter is designed considering THD% and ripple factor. And for that value of inductor different switching losses are studied. The analysis showed that for meeting the same THD requirement with a given filter, the optimal switching scheme saves up to 36.5% under “best-case” conditions compared to the fixed switching frequency scheme. Thus, using this scheme can reduce the size of the heat sink or, for an existing heat sink design, reduce the temperature of the switches and possibly extend the inverter life. The total LCL filter loss per phase was plotted. These loss curves were used to find the most efficient LCL filter design. A frequency domain analysis to design the control systems, system stability and the control scheme of the grid current based on the averaged small-signal model is studied. The resistive component in the grid impedance is able to improve the stability margin of the grid-connected system. The work done so far considers only few aspects. Some aspects of stability like dynamic stability have not been taken into consideration and also power quality issues.

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