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ScienceDirect

Procedia Technology 21 (2015) 438 – 442

Procedia Technology

SMART GRID Technologies, August 6-8, 2015

Harmonic and Reactive Power Compensation of Grid Connected Photovoltaic System

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Abstract

Distributed Generation (DG) is predicted to play an important role in the electric power system in near future. It is widely accepted that photo voltaic generation is currently attracting attention to meet users' need in the distributed generation market. In order to investigate the ability of photo voltaic (PV) units in distribution systems, their efficient modeling is required. This paper presents a dynamic model of a PV generation system. The increasing application of nonlinear loads may cause distribution system power quality issues. In order to utilize distributed generation (DG) unit interfacing converters to actively compensate harmonics, this paper proposes an enhanced control approach. In this paper, synchronous reference frame strategy has been chosen and a grid connected photo voltaic generation system (PVG) can send the active power to the grid, compensate harmonics and absorb the reactive power that the local loads generated. The converter controller models are implemented in the MATLAB / SIMULINK. The performance of the implemented PV model is studied with an isolated load. Synchronous reference frame strategy is used to generate current reference for compensation and conventional PI controllers are used for control. The strategy utilizes co-ordinate transformations to separate the reactive and harmonic content in the load current. The design of the closed loop controllers is kept simple by modelling them as first order systems. The simulation studies showed good results with the reactive current compensation giving almost ideal result of near unity power factor and harmonic currents getting compensated to a larger extent.
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Peer-review under responsibility of Amrita School of Engineering, Amrita Vishwa Vidyapeetham University

Keywords: Distributed Generation, grid-connected PV system, Power quality, Reactive power compensation, synchronous reference frame strategy.

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Peer-review under responsibility of Amrita School of Engineering, Amrita Vishwa Vidyapeetham University
doi:10.1016/j.protcy.2015.10.067

1. Introduction

Distributed Generation (DG) can be defined as electric power generation with in the distribution networks or on the consumer side of the network. To utilize interfacing converters to compensate harmonics an enhanced current control approach is introduced in [1]. With inverter control, the active and reactive power requirement of the load can be satisfied [2].Distributed generation (DG) units interfaced with static inverters are being applied and focused increasingly due to the fact that conventional electric power systems are being more and more stressed by expanding power demand, limit of power delivery capability, complications in building new transmission lines, and blackouts [5-9]. Power quality, safety and environmental concerns and commercial incentives are making alternative energy sources [3] [4] popular.Various control techniques are presented in [10]. This paper deals with the modelling, simulation and harmonics and reactive power compensation of grid connected PV based distributed generation. In the present study, the synchronous reference frame strategy is used to generate current reference for compensation and conventional PI controllers are used for control. The synchronous reference frame strategy utilizes co-ordinate transformations to separate the reactive and harmonic content in the load current. The control techniques proposed in [11] minimizes the number of measurements and sensors.[12] presents the operation of grid connected DG system driven by dc-dc step-up converter and a dc-ac voltage source inverter and the design, modelling and control of power converters for power quality improvement in a grid-connected DG system is presented in [13]

Nomenclature

Vdc	DC bus voltage
id*	Direct axis reference current
iq*	Quadrature axis reference current
Vpcc	Point of Common Coupling Voltage

2. Architecture of the proposed system

Grid connected PV based distributed generation system converts electrical energy in to same amplitude, frequency and phase with the power grid and also provide electrical energy to the local loads. The block diagram representation of the proposed system is shown in Fig. 1.

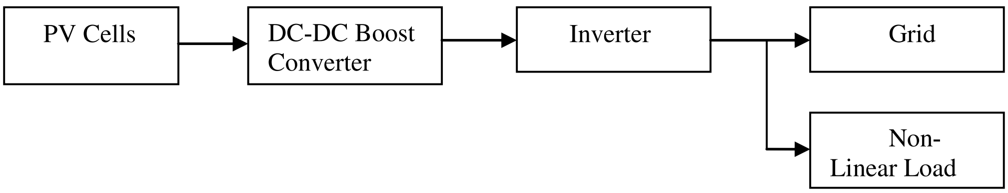

Fig. 1. Block diagram representation of the proposed system.

The basic element of grid connected PV system is the three phase inverter. Inverters are an important component of the grid-connected system whose role is to convert DC into AC of the same amplitude, frequency, and in phase with the grid. In addition, the inverters should be of high validity and reliability, and ensure the security of the local loads and the power grid. With the non-linear local loads widely used, the harmonic sources are more and more, and whose impact to power quality cannot be ignored. The control of mostly existent grid-connected system is to gain the unity-power factor, Voltage sag and swell, which can guarantee the efficiency of energy transfer, but ignored the need of compensating reactive power and harmonic with the principle of proximity. In this paper, based on the synchronous reference frame strategy, detection of reactive power and harmonic current, and the control strategy of inverters, a novel grid-connected system of DG is studied, which not only transfer the active power, but compensate harmonic current generated by the local loads and reactive power absorbed by them.

3. The grid-connected system

The basic operational principle of the grid-connected PV system is as follows:

It detect the grid voltage and current of local non-linear loads; It calculate and get command current signal including harmonic component and reactive component of load current, as well as the active component transporting to the power grid; It tracks the actual compensation current that the command current aroused, and compensate Harmonic and reactive component of the grid current, and offset harmonics and reactive component of load current and compensate the active component of grid current, and provide the active power the load and power grid. This paper proposes a grid connected PV system. It mainly composed of two parts, one is the circuit of detecting harmonic and reactive component, the other is the circuit generating the compensation current. Here the load current having three components – active, reactive and harmonic. The idea is to control the voltage source inverter in such a way as to make it deliver the reactive and harmonic currents demanded by the load. Hence the controller has to generate current reference, which involves computing the reactive and harmonic current absorbed by the load.

3.1 Current reference generation

The present study is based on the application of co-ordinate transformations to separate out the reactive and harmonic content of the load current. The strategy used is the synchronous reference frame (SRF) strategy. Once the current reference has been generated, the next work is to design the controller and the job of the controller is to make the output current of the voltage source inverter follow the current reference. Synchronous reference frame strategy is a popular method used in the generation of the current reference. It uses co-ordinate transformations to generate the current reference. It employs the well known Clarke's Transformation and Park's Transformation for this purpose. Clarke's transformation deals with just two equations in the place of three equations. Thus, it saves a lot of computational effort. Park's transformation is nothing more than finding the components of the load current along the direction of the voltage space vector and at quadrature to it.

3.2 Reference current generation in the d-q plane

In the above compensation procedure, the only place where a filter is used is the high pass filter in the d-axis. It is being implemented as a low pass filter whose output is subtracted from the original signal. Since the high pass filter has to block only the dc component, the cut-off frequency of the low pass filter will be set as say, 10 Hz. Now, the output of the low pass filter being dc, it will not suffer any magnitude or phase deviation. So, there needs to be no compensator anywhere. Thus, the Park's Transformation reduces the complexity in the implementation.

4. Simulation and results

Fig. 2 shows the P-V and I-V characteristics of the PV module with constant irradiance and constant temperature with the open circuit voltage of 20V and the short circuit current of 2.5A. For Simulation of grid connected PV system, an equivalent circuit of a solar cell as a current source parallel with a diode is considered. The output of the current source is directly proportional to the solar energy .In this simulation, PV array generates maximum power of 52.5W at open circuit voltage of 20V and short circuit current of 2.5A.This PV cells are fed to dc-dc boost converter which steps up the voltage .Grid integration of PV cell is done through the inverter. Inverters inject all active power generated by the PV system in to the power grid. The inverter behavior is commanded by the controller unit which fulfils reactive power control and high power quality. The inter connection between the PV array and inverter is operated by a dc link capacitor. The control of dc-link voltage Vdc balances the power flow in the system. The PV inverter is connected to the grid at the Point of Common Connection (PCC).

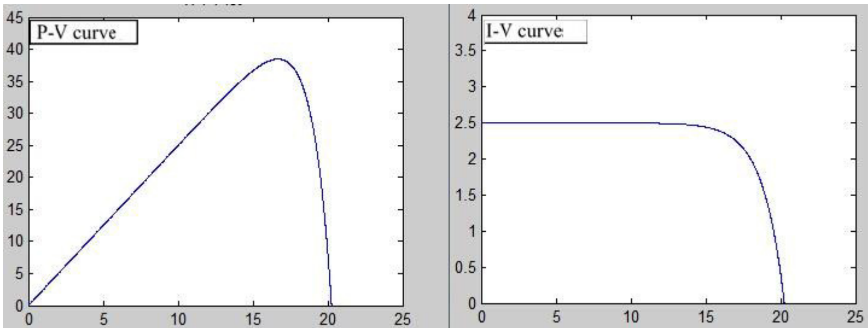

Fig. 2 PV and IV graph of PV array

The complete system model is simulated under the Matlab/Simulink environment. The output waveform of dc-dc boost converter with the PV as input to the converter is obtained and this voltage reaches 80V by t = 0.05 seconds. A diode rectifier supplies RL load in each phase. This nonlinear load draws harmonic currents from the grid continuously and this current is shown in Fig. 3. Fig. 4 shows the reference current which is to be tracked by the control circuit and Fig. 5 shows the tracking current.

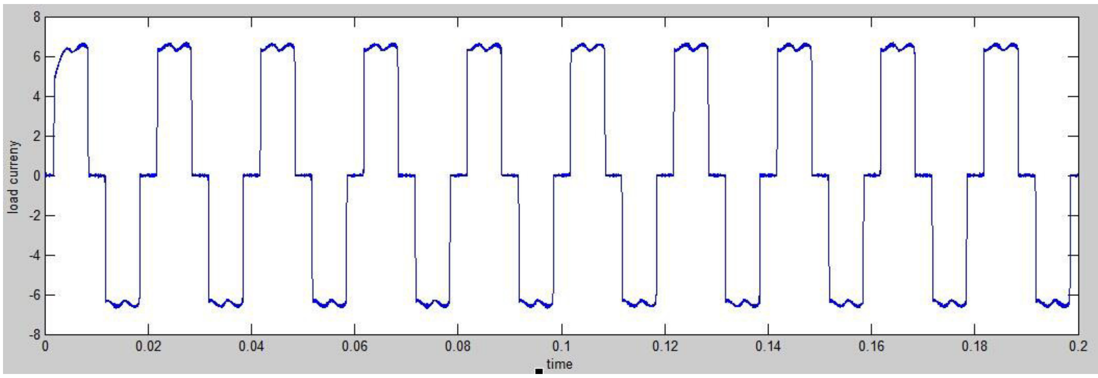

Fig. 3. Load current of one phase.

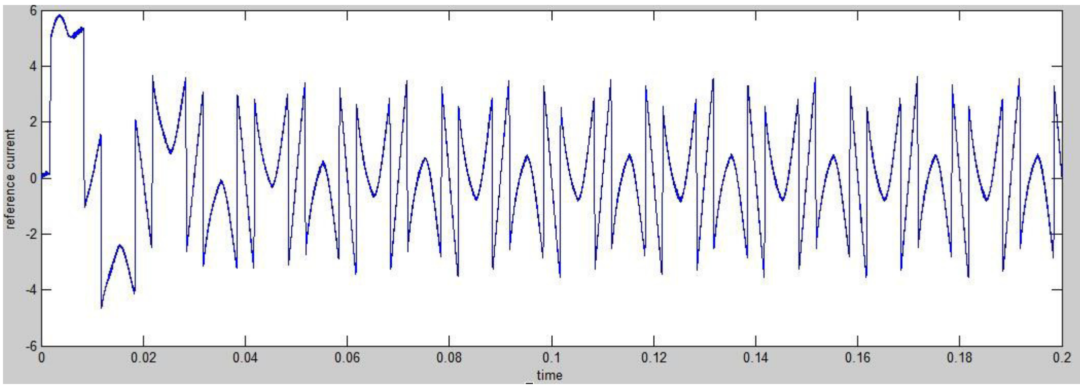

Fig. 4. Reference current.

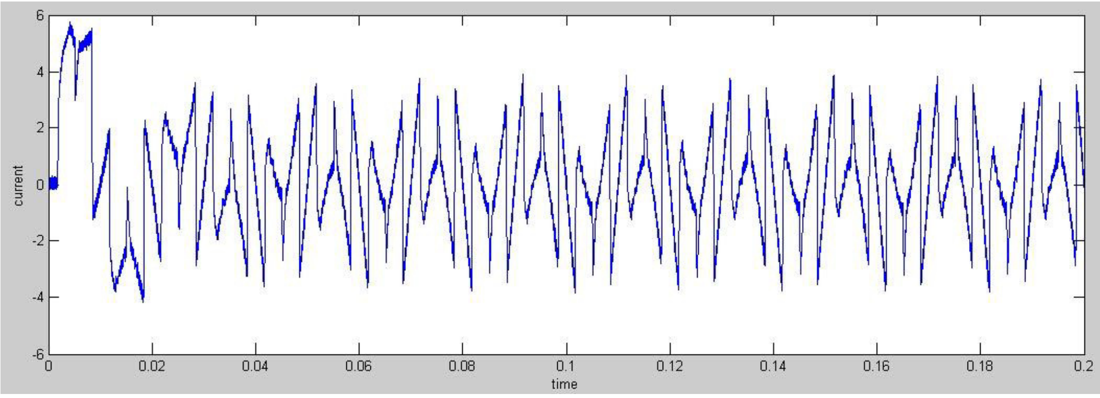

Fig. 5. Tracking current.

Results show that the reactive power Q drawn from the grid is maintained at zero from t = 0.05 seconds onwards. showing the reactive power compensation of load. DC bus voltage is mainatined constant. It is also seen that the grid voltage and current after compensation are inphase and the grid need not provide reactive and harmonic currents for the load.

5. Conclusion

Synchronous Reference Frame based controller for a grid connected PV system was simulated and the results were studied. The study shows that the system gives good dynamic performance under varying load conditions. Whereas the reactive current compensation gives highly favorable results, the harmonic performance depends largely on the load. Harmonics may not be completely compensated owing to the limitations posed by the inverter which can produce voltages only in a time-averaged sense. The presence of phase locked loop avoids the problems of synchronization between DG and grid.

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