PERFORMANCE EVALUATION OF SHUNT ACTIVE FILTER FOR PHOTOVOLTAIC GENERATION SYSTEM FOR IMPROVING POWER QUALITY

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Abstract - Power quality issues are one of the growing problems for conventional energy source. This paper involves the design and analysis and simulation of Shunt active power filter for Photovoltaic (PV) generation system and power quality improvement. Typical grid connected Photovoltaic system includes Photovoltaic system, DC to DC Converters, inverter, battery, related power electronics devices and loads. Inverter operates as a Shunt Active Power Filter (SAPF) and adopted with Non-linear control scheme woks on synchronous reference frame theory in order to compensate the Current harmonics, reactive power & supply voltage fluctuation. Maximum Power Point Tracking (MPPT) technique is provided to control boost converter. The battery charging and discharging which is useful for grid back-up sources during peak demand of energy. The overall system is analyzed by applying balanced and unbalanced linear and nonlinear load condition and corresponding reading of before and after compensation is checked. All the simulations are carried out in MATLAB/SIMULINK environment and in each case, results demonstrating the power quality improvement in the system.

Keywords-Solar, Shunt Active power filter, inverter, MATLAB /SIMULINK

I. INTRODUCTION

Renewable sources of energy are one of the emerging technology. Power quality issues and its mitigation play important role in grid connected system. A grid connected photovoltaic system will be interacted with utility grid. If the power quality of the network is not bad then any load connected to it will run satisfactorily and efficiently. If the power quality of the network is bad, then loads connected to it will fail or will have a reduced lifetime, and the efficiency of the electrical installation will reduce.

Increase in non-linearity causes different undesirable features like low system efficiency and poor power factor. Due to presence of linear and nonlinear loads the changing impedance means that the current drawn by the non-linear load will not be sinusoidal even when it is connected to a sinusoidal voltage. These non-sinusoidal currents contain harmonic currents that interact with the impedance of the power distribution system to create voltage distortion that can affect both the distribution system equipment and the loads connected to it. So to reduce the current harmonics shunt active power filter is to be used which is connected in parallel to grid. Grid connected photovoltaic system generation systems needs harmonic compensation, control of unbalanced current, an improved power factor, and anti-islanding methods [3]. Grid connected PV system yields different kind of challenges so it is necessary to develop power electronics devices with modern control strategy.

II. POWER FILTER TOPOLOGIES

Based on the particular application, active power filters can be classified such as [2].
1. Based on Converter topology
   • Voltage source Converter
   • Current Source Converter
2. Based on filter topology
   • Shunt active filter
   • Series active filter
3. Based on Number of Phases
   • Two-wire (single phase) system.
   • Three or four-wire three-phase system
III. GRID CONNECTED PHOTOVOLTAIC SYSTEM

Figure 1 Shows a Block diagram of grid Connected System. The system consists of a solar PV array [1], DC/DC boost converter and DC/AC converter. The PV array and is connected to the DC-side of the Voltage Source Inverter (VSI) through the boost converter.

Fig 1: Block diagram of PV system interfaced with the grid

The PV array is regulated by a DC/DC boost converter to a fixed dc output, and is used to provide the power required for the load. The inverter operates as a shunt active power filter (APF) [3] and adopted with non linear control scheme in order to compensate voltage unbalances, harmonics, reactive power and supply voltage fluctuation.

IV. SHUNT-CONNECTED ACTIVE POWER FILTER

Figure 2 shows the Shunt active power filters which compensate load current harmonics by injecting equal-but opposite harmonic compensating current. It works similar to static compensator [4].

The shunt active power filter operates as a current source injecting the harmonic components generated by the load.

Ideal compensation requires the mains current to be sinusoidal and in phase with the source voltage, irrespective of the load current nature. The desired source currents, after compensation, can be given as

\[ i_{sa} = I_{sp} \sin wt \]  
\[ i_{sb} = I_{sp} \sin (wt+120) \]  
\[ i_{sc} = I_{sp} \sin (wt+120) \]

The rotating synchronous-frame proportional-integral (PI) controller is used in three-phase inverters to obtain a zero steady-state error[5]

V. MODELING OF THREE PHASE ACTIVE POWER FILTER

A. Synchronous Reference frame model

\[ L_c \frac{di_{cd}}{dt} = L_c w i_{cq} - d_{nd} v_{dc} v_d \]  
\[ L_c \frac{di_{cd}}{dt} = -L_c w i_{cd} - d_{nd} v_{dc} v_q \]  
\[ C_{dc} \frac{dv_{dc}}{dt} = -d_{nd} i_{cd} + d_{nd} i_{cq} \]

Where \( i_{cd}, i_{cq} \) denotes the inverter currents expressed in the (d,q,0) synchronous frames, \( v_d, v_q \) are the d-q components of source voltages, \( d_{nd}, d_{nq} \) are the d-q components of the switching state function. \( v_{dc} \) is the DC bus voltage of the inverter and \( w \) the main angular frequency[5]

B. DC bus voltage regulation

In order to mention the DC bus voltage level; at a desired value acting on active component \( i_d \) can compensate the losses through the inverter components

\[ i_{dc} = \frac{v_{dc}}{d_{md}} - \frac{v_{dc}^2}{4 d_{nd}^2} \left( \frac{V_{dc}}{a} \right) \]
The output of the PI controller \((e_{dc})\) is added to the active components to take care of regulation of the DC bus voltage and the losses in the inverter.

C. Current controller

The aim of current controller is to compensate harmonics, reactive power and unbalances.

The control law is given by the relations

\[ \begin{align*}
    d_{nd} &= -u_{d} + L_{c}w_{i_{sq}} - L_{c}w_{i_{sq}} + v_{d}/v_{dc} \quad (8) \\
    d_{qd} &= -u_{d} + L_{c}w_{i_{sd}} - L_{c}w_{i_{sd}} + v_{q}/v_{dc} \quad (9)
\end{align*} \]

VI. DESIGN PARAMETERS OF SOURCE AND LOAD

<table>
<thead>
<tr>
<th>Source voltage and Frequency</th>
<th>120V, 50Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nonlinear Load: Universal bridges (Number of Bridges 2,3)</td>
<td>Snubber Resistance=10, Snubber Capacitance=10³,</td>
</tr>
<tr>
<td>Linear Load</td>
<td>Resistance=30ohm Inductance=10mH</td>
</tr>
</tbody>
</table>

Table 1. Design Parameters

VII. SIMULINK CIRCUIT

Figure 3 shows the entire system is modeled on MATLAB™ R2011a and Simulink™.

Simulink Model of Control Scheme of Inverter

Figure 4 shows control scheme of the inverter which generate currents that are opposite to the undesirable components in the load currents and, improve the power factor at the PCC. An indirect non linear control technique of the three-phase inverter is proposed.

It is based on the calculation of the positive sequence component of the unbalanced load current inverter current expressed in \((d,q,0)\) synchronous frame. \(V_d, V_q\) are the \(d,q\) components of source voltages. \(d_{nd}, d_{qd}\) are the \(d,q\) components of switching state function. \(V_{dc}\) is bus voltage of inverter.

VIII. SIMULINK RESULTS

The Matlab/ Simulink software tool is used to test the results.

During the photovoltaic model simulation, the temperature parameter [1] was set at constant value 25°C and the irradiance parameter was set at 1000 W/m² respectively. PV array Output Voltage 242V and Current 82A as shown in Figure 5.

Fig 5: Output Voltage, current, power Waveforms of PV array.
IX. CONCLUSION

In this paper, the performance evaluation of shunt active filter for photovoltaic generation system for power quality improvement is analysed. Three phase inverter operates as Shunt active filter works in multifunctional way, which avoids the use of passive filter that could affect the performance of compensation system. Use of this filter helps in reducing the current harmonics introduced by nonlinear loads and intern helps in improving the power factor at PCC. The THD of source current is below 5% as per condition of harmonics limits imposed by IEEE standards.

REFERENCES