DESIGN AND PERFORMANCE ANALYSIS OF GRID CONNECTED SOLAR PV SYSTEM

A THESIS

submitted by

LAKSHMANAN S A

for the award of the degree

of

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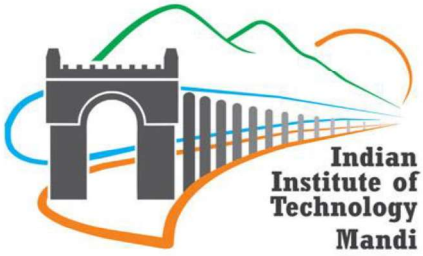

SCHOOL OF COMPUTING AND ELECTRICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY MANDI

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This is to certify that the thesis entitled "**DESIGN AND PERFORMANCE ANALYSIS OF GRID CONNECTED SOLAR PV SYSTEM**", submitted by me to the Indian Institute of Technology Mandi for the award of the degree of Doctor of Philosophy is a bonafide record of research work carried out by me under the supervision of **Dr. Bharat Singh Rajpurohit** and co-supervision of **Dr. Amit Jain**, CPRI Bangalore. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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This is to certify that the thesis titled**DESIGN AND PERFORMANCE ANALYSIS OF GRID CONNECTED SOLAR PV SYSTEM**, submitted by **LAKSHMANAN S A**, to the Indian Institute of Technology Mandi,for the award of the degree of Doctor of Philosophy, is a bonafide record of the research work done by him under our supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

The integration of photovoltaic (PV) power generation to the electric grid can result in several benefits including line loss reduction, increased overall energy efficiency, relieved transmission and distribution congestion, etc. Grid interconnection of PV systems is accomplished through the voltage source inverter (VSI), which converts DC power generated from PV modules to AC power. Filter is used at the output of the VSI to prevent the high-frequency switching ripples injected into the grid. The control of grid connected PV system and correct regulation of energy flow from the PV to grid still plays the most important role. Among the many control functionalities, a current controller is an important part that controls the VSI switching with a proper modulating operation. Moreover, the phase angle and frequency of the grid voltage should be properly synchronized with inverter voltage and it is achieved by using proper grid synchronization techniques. Power quality (PQ) improvement, effective filter design and grid voltage support functions are additional functionalities required to efficiently control the grid connected PV system. This thesis develops the control techniques to improve the performance of the grid connected PV system. Overall work has been completed in three sections.

First section is the study of grid connected PV system based on various aspects including PV cell model, PV characteristics, current control techniques and different standards for grid connected PV system. In this section, a novel current controller with grid harmonic compensation technique is proposed in order to effectively suppress the harmonics in the grid voltage. In order to effectively control the DC-link voltage, feed-forward compensation path is incorporated along with current controller.

A grid connected VSI with inductor-capacitor-inductor (LCL) filter based on input PV system can be treated as an active power filter (APF) and the control structure is considered as a distribution static compensator (DSTATCOM) to compensate the harmonic currents generated by various non-linear loads connected in the system. In the second section, a new improved active damping technique with decoupled synchronous

reference frame (SRF) current controllers using proportional-integrator (PI) plus harmonic-compensator (HC) are proposed for control of DSTATCOM with LCL filters in order to achieve effective load compensation. The proposed SRF PI and (PI+HC) current controllers show improved performance with high grade of protection to harmonics caused by non-linear loads connected in the system. Most of the controllers are based on SRF PI current controller and it has difficult coupling between *d* and *q* axis and hence decoupling is very tough. Therefore, a new technique based on active damped dual loop stationary frame current controllers using proportional-resonant (PR) plus HC is proposed for control of DSTATCOM with LCL filter in order to achieve operative load compensation. Decoupling process existed in the SRF current controller is ignored and also current controller design is simplified by using this proposed control approach.

Conventional grid synchronization approach based on SRF phase lock loop (PLL) is discussed and major drawbacks of the SRF PLL under grid voltage distortions are addressed. In the third section, a low-gain PLL is proposed by using adaptive moving average filter (AMAF) and the performance of the AMAF PLL is estimated under harmonics, phase jump, frequency unbalance on the grid voltage. In this section, sliding discrete Fourier transform (SDFT) based PLL and cosine loop up table (cLUT) along with SDFT PLL techniques are also proposed. The projected SDFT PLL and cLUT based SDFT PLL techniques show improved performance with high grade of protection to harmonics, phase jump and frequency deviation such that these have strong fundamental strength with enhanced phase and frequency estimation in the system.

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