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Power Quality Enhancement of Solar Photovoltaic System Using LCL Filter

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***Abstract* - Grid-connected photovoltaic systems are increasingly attracting the attention of industry and academia as a means of providing an alternative to conventional fossil-fuel generation and pollution free power. This project aims to improve the power quality level of a grid-tied PV distribution system using shunt active power filter along with adaptive current control technique. In this work fuzzy controller used to destroy the voltage and current harmonics in a grid-tied PV system. A reference current generation strategy is implemented to mitigate the current harmonics by extracting the fundamental constituents from the nonlinear load currents. MCCF is employed to separate the FC from the distorted grid voltages and eliminates the voltage harmonics during extremely polluted grid voltage condition. The comparative analysis is analyzed to check the effectiveness of the proposed hybrid control scheme with existing and adaptive control techniques in respect of power quality, better dc offset rejection, better FC and frequency extraction, and grid synchronization. Power converters play an essential role in Photovoltaic system to maximize the power transfer to the electrical grid. However, the generated harmonics in the grids due to these power converters and nonlinear loads are considered one of the encountered problems to overcome. This paper presents a decoupled control of PV field real power and reactive power injected to the high voltage network via a PWM inverter by using fuzzy logic controllers.**

Keywords: Power grid, Fossil-flue, PV distribution.

I. INTRODUCTION

Due to ever growing integration of PV systems and nonlinear loads into the grid, power quality issues are degrading and draw more consideration. Various control techniques are developed for power production and power quality enhancement using a Solar Energy Conversion System (SECS). A PV system operating in the MPPT (Maximum Power Point Tracking) mode and connected to a three phase grid incorporating with shunt Active Power Filter (APF). In this work the photovoltaic generator is operated to produce electricity from the solar arrays and feeding to the utility network. At the same time the APF is employed to enhance the power quality of the studied PV system using d–q theory. In, a system composed of series and shunt inverters connected back to back by a DC-link was suggested. This system is able to compensate voltage and current related problems both in inter-connected mode and islanding mode by injecting active power to the grid. In, the authors suggested a distortion reduction scheme, utilizing a fed forward single-phase, generation-side power conditioner with a structure that can be expanded for use in a three phase system and can work independently under imbalanced condition to compensate the plant's output current distortion, so that the total current flow to the grid is sinusoidal. In, to improve the power quality and the system efficiency, a double-tuned parallel resonant circuit has been proposed to attenuate the second and fourth order harmonics at the inverter DC side.

In this case a modified carrier based modulation technique for the current source inverter was proposed to magnetize the DC-link inductor by shorting one of the bridge converter legs after every active switching cycle. In, a detailed method for selecting the LCL filter parameters and the control of the three-phase PV grid-connected inverter has been studied. Patra et al, have addressed a comparative assessment for power quality that can be achieved with two types of circuits; dual stage that consists of boost based VSI (circuit type I) and a single stage using ZSI (circuit type II). In this, an online fuzzy logic controller is applied to ensure a powers decoupled control of a large scale grid connected PV system. Moreover, a hybrid control technique is suggested to enhance the power quality of the studied solar photovoltaic energy conversion system.

II. METHODOLOGY

The power that is produced from the PV array is converted by employing the power electronics devices. And the various nonlinear loads are also connected at the load side which draws the nonlinear current from the supply side. Because of the presence of these, the harmonics are produced in photovoltaic system. These harmonics reduces the quality of real power that is being pumped into the grid.

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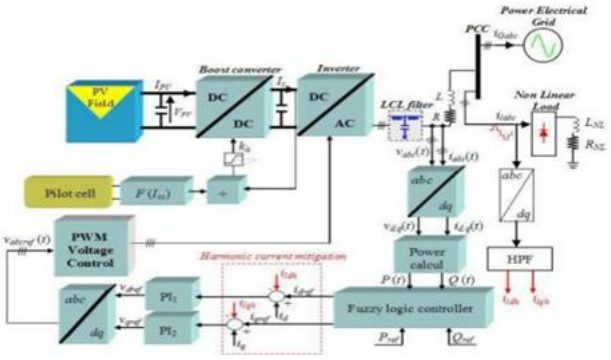


Harmonics that is created has a dangerous effect on solar PV system. So, an efficient filter unit is necessitated to filter out these harmonics and improve power quality. The scheme of the studied SECS is presented in Fig. It is formed by the PV system and the nonlinear load which are connected together at the Point of Common Connection (PCC). Many types of MPPT algorithms used to maximize the PV system output power had been developed in the literature which can be divided into two types: classical methods, such as Perturbation and Observation (P&O), Incremental Conductance (IC), Pilot Cell (PC), and Constant-Voltage Constant-Current (CVCC); and artificial intelligent techniques, Neural Networks (NNs), Fuzzy Logic (FL), Neural-Fuzzy (NF), Genetic Algorithms (GAs), Particle Swam Optimism (PSO) and Sliding Mode (SM).

The base impedance of the system must be given for choosing the LCL filter parameters in order to avoid resonance, voltage drop and reactive power problems.

$$Z_b = \frac{E_n^2}{P_n}, \quad (1)$$

$$C_b = \frac{1}{\omega_n Z_b}, \quad (2)$$

$$L_b = \frac{Z_b}{\omega_n}, \quad (3)$$

Where En is the line to line RMS voltage, ωn is the grid frequency and Pn is the active power absorbed by the converter in rated conditions. The criteria of LCL filter design are described as followings:

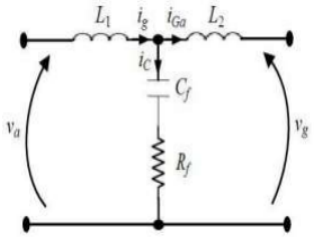
1. The total inductance value of both inverter side inductor and grid side inductor should be lower than 10 % of base inductance value to limit the voltage drop at inductors during the operation:

$$L_T \le 0.1 L_b. \quad (4)$$

2. The filter capacitance value should be less than 15% of the base capacitance in order to limit the reactive power at the rated power:

$$C_f \le 0.15 C_b. \quad (5)$$

3. The resonance frequency should be in the range between ten times of line frequency and one half of switching frequency to avoid the resonance problem:



$$10 f_n \le f_{res} \le 0.5 f_s. \quad (6)$$

Using LCL filter, seen in Fig, the resonance frequency depends only on filter parameters:

$$f_{res} = \frac{1}{2\pi}\sqrt{\frac{L_1 + L_2}{L_1 L_2 C_f}}. \quad (7)$$

The damping resistor is expressed as follows:

$$R_f = \frac{1}{3\omega_{res} C_f}. \quad (8)$$

Moreover, inverter-side inductor can be calculated according to Eq. (9):

$$L_1 = \frac{V_g}{2\sqrt{6} f_s \Delta i}, \quad (9)$$

where Δi is the current ripple peak which can be chosen as 0.15~0.25 of the rated current. In this paper, the current ripple is selected as 20 % of the rated current.

$$\Delta i = 20\% I_{rated} \quad (10)$$

In this case a ratio (r = 0.46) between the inductance at the inverter side and the one at the grid side has been chosen. One can write:

$$L_2 = r L_1. \quad (11)$$

Thus, the calculated LCL parameters set used condition used is depicted in Table 2, where the values of L1. L2 and Cf are obtained.

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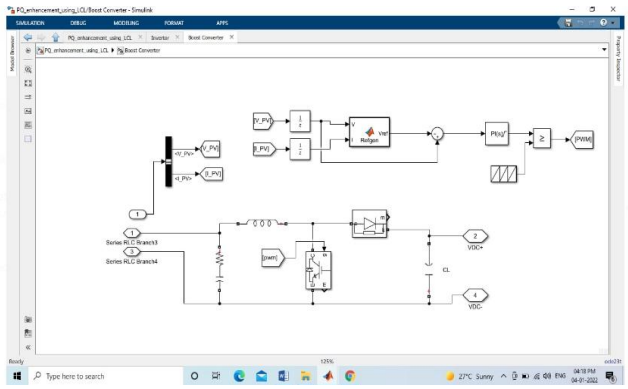

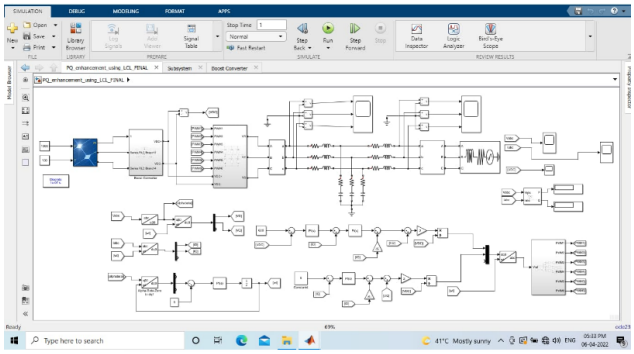

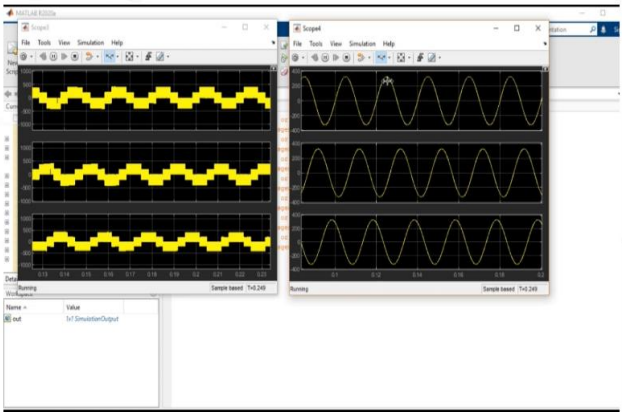

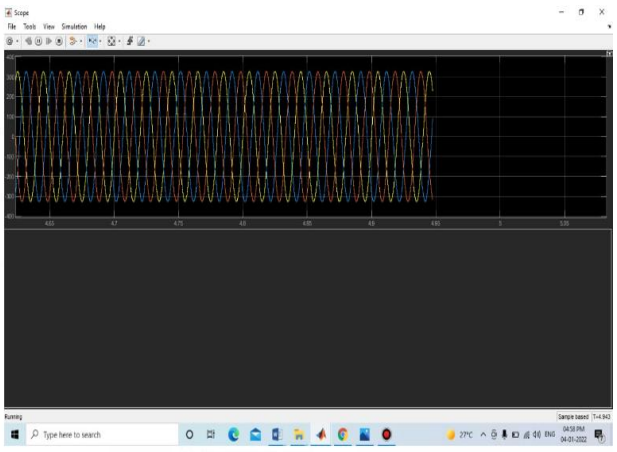

III. RESULTS AND CONCLUSION

In this project, a detailed model of a double stage GCPV system is constructed and simulated. The voltage source inverter control system effectively controls and maintains capacitor dc-link voltage to 500V. The reactive or wattles power which is being inserted into utility grid is almost zero thereby keeping the power factor (PF) to unity. The LCL filter that is designed effectively filters out the harmonics and improves the power quality by ten times approximately. By employing the LCL filter the grid output voltage harmonics are decreased from 0.59 to 0.08 percent, whereas the grid output current harmonics are reduced from 10.71 to 1.17 percent and the VSI current harmonics are decreased from 10.70 to 4.9 percent. The real power quality which is inserted into the utility grid is enhanced to significant value. Henceforth, the discussed PV plant with the robust control mechanism and the premium power quality can be employed in residential, industrial and commercial purposes.

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