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Improvements of Power Quality in Distribution system using FLC and STATCOM

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***Abstract*— In a three phase four wire (3P4W) distribution system, to compensate the power quality problems using a grid interfaced solar PV power generating system. In this system, consists of a SPV , Fuzzy based MPPT controller ,Boost converter, a three leg VSC, STATCOM and a transformer connected at AC mains with improve the power quality. A Fuzzy Logic Controller is used to track the maximum power point of a solar photo voltaic system through control of an IGBT switch of Boost converter. This system is used for compensation of non linear /linear unbalanced load at the point of common coupling appear as balanced linear load to the grid , and also to compensates the neutral current, harmonics currents. This concept is demonstrated with extensive MATLAB/Simulink simulation studies and validated through FLC and MPPT laboratory experimental results**

***Keywords*—** Solar Photovoltaic (SPV),Voltage Source Converter (VSC), STATic COMpensator (STATCOM), Fuzzy Logic Controller (FLC), Maximum Power Point Tracking (MPPT)

I. INTRODUCTION

Solar power system or Solar photovoltaic system is one of renewable energy system which using PV modules to convert sun light energy into electricity. The generated electricity can be either stored or directly used , into grid line or combined with one or more other electricity generators or more renewable energy source. Solar PV system is very reliable, environmental friendly and clean unlimited source of electricity that can suit a wide range of applications such as residence, industry, agriculture, livestock, etc. Due to intermittent in nature, there are numbers of potential challenges in integrates solar photovoltaic to grid[1]. Various MPPT algorithms have referred in below reference papers.

Maximum power point tracking (MPPT) is a technique that used to grid connected inverters, solar battery chargers use to get the maximum possible power from one or more photovoltaic(PV) devices, solar panels and arrays, though optical power transmitted systems can benefit from various technology. Solar cells have a various complex relationship between the solar irradiation, total resistance and temperature that produces a non-linear unbalanced output efficiency which can be verified based on the I-V curve. It is the main purpose of the MPPT system to sample based the output of the cells and apply the proper resistance (load) to obtain maximum power for any given environmental condition MPPT devices are typically integrated into an electric power converter system that provides filtering or voltage or current conversion, and regulation for various driving various loads, including power grids or motors.

The Perturbation and Observation (P&O) technique, the incremental conductance, the open circuit voltage method, the ripple based method are the most commonly used MPPT techniques. A good MPPT technique should produce a high efficiency at a low cost because PV systems will have to be mass produced. The Perturbation and Observation (P&O) technique is most widely used it is very simple , it requires only measurements of V_{pv} and I_{pv} and it is capable of tracking the maximum power point (MPP) quite accurately through variations in irradiance and temperature. As its name indicates , the P&O method works by perturbing V_{pv} and observing the impact of this change on the output power of the array. Fig 1is a flow chart of the P&O algorithm. At the each cycle, V_{pv} and I_{pv} are measured to calculate P(K) and the value of P(K) is compared to the value of P(K-1) calculated at the previous cycle. If the output power has increased, is adjusted further in the same direction as in the previous cycle. If the output power has decreased, is perturbed in the opposite direction as in the previous cycle. is thus perturbed at every MPPT cycle. When the maximum power point is reached, oscillates around the optimal value . This causes a power loss that increases with the step size of the perturbation. If this step width is large, the MPPT algorithm responds quickly to sudden changes in operating conditions[3]. On the other hand, if the step size is small the losses under stable or slowly changing conditions will be lower but the system will not respond quickly to rapid changes in temperature or irradiance.

A FLC is a stable as well as fast. Nowadays four wire distribution system, there is a neutral current, which neutral currents overloading and consisting of both fundamental and harmonic frequencies. In this new research work, a new configured solar photovoltaic generating system is proposed to compensate the load current harmonics and load unbalance at distribution level using MPPT based fuzzy logic controller. In this proposed scheme, STATCOM is one of the FACTS

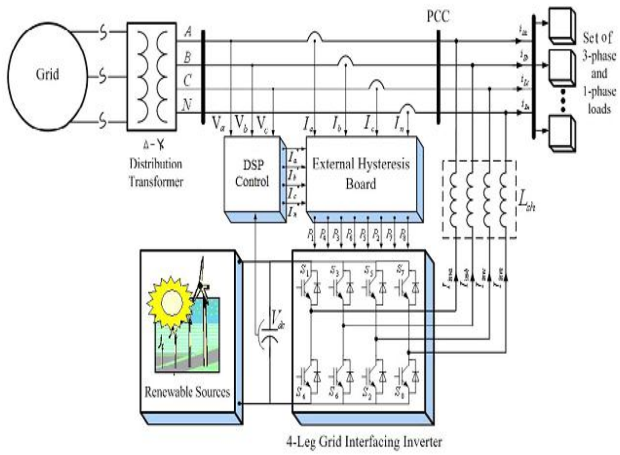

FIG 1: SCHEMATIC OF RENEWABLE BASED DG SYSTEM

device, is used to reduce the harmonics in the distribution side. It is connected at a point of common coupling with battery energy storage system to mitigate the power quality issues[5].

The paper is arranged as follows: Section II describes the system configuration. Section III expounds the design and modelling of the proposed system. Section IV discusses the extensive experimental test results and finally, concludes the paper in Section V.

II. SYSTEM DESCRIPTION

In the proposed configuration of 25kW SPV power generating is given in Fig.1. In the proposed system consists of a solar photovoltaic array, a DC-DC boost converter, MPPT based fuzzy logic controller and Voltage source converter(VSC) working as a STATCOM, it is connected with a transformer which is used to neutralize the neutral current. In the solar PV array is integrated with the boost converter and using MPPT , to boost the voltage of solar PV array. In the voltage source converters consists of three components are IGBTs, dc capacitor, source inductor. In the DG system, the voltage source inverter is a key element and delivers the generated power, at when it interfaces the renewable energy sources to the grid. Usually at variable low dc voltage, photovoltaic energy sources and fuel cell generate power. Before connecting on dc link, these renewable energy sources needs power conditionings to generated power. The VSC is modelled to provide load balancing , to compensate reactive power and eliminate the harmonics along with PV power generation with efficient fuzzy based MPPT controller.

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III. DESIGN AND MODELLING OF THE PROPOSED SYSTEM

In the proposed system has three phase 25kW SPV generating system have voltage source converter (VSC) which consists of AC inductors, insulated Gate Bipolar Transistor(IGBT) and DC capacitors. To compensate the current , depending upon the requirement design VSC ratings and also to design the DC capacitor and IGBT requirements.

A. Sample Modelling of Solar Photovoltaic Panel

To design a 25kW peak power tracking capacity of SPV array. Solar cells are connected in series to design a solar PV array. Open circuit voltage of the solar cell is 0.5V to 0.6V and short circuit current (I_{sc}) is 4A[5-9].

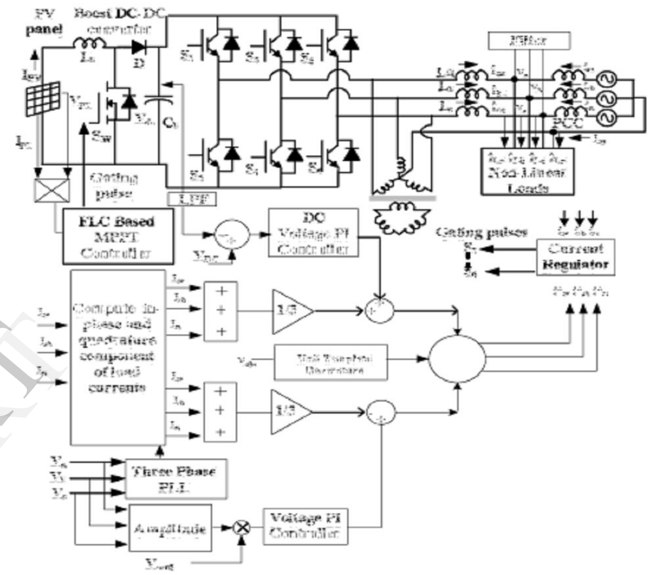

FIG 2: PROPOSED DIAGRAM

In the solar PV is an active power has generalized equation is given as,

$$P_{max} = V_{max} * I_{max}$$

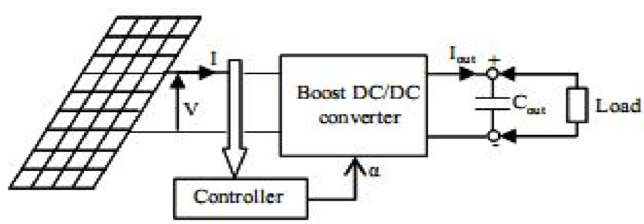

FIG 3: PROPOSED BLOCK DIAGRAM OF SOLAR PV

In the proposed system consists of solar panel, Fuzzy Logic Controller(FLC), boost converter and grid connected load. In the DC-DC converter , which is mainly used to interfaced the solar PV panel output to the grid connected load.

IV. Control Strategy

A. *Control the Boost DC-DC Converter*

In the main purpose for the use of DC-DC Boost converter is Maximum power point tracking. Voltage of the DC link is maintained by Voltage Source Converter. In the FLC input variables are chosen as the differential variation of power d*p* and differential variation in voltage d*v* is with respect to variation of power and voltage d*p*/d*v*.

The chosen two inputs are given as,

$$\frac{dp}{dv} = \frac{p_n - p_{n-1}}{v_n - v_{n-1}} \qquad (1)$$

$$dp = p_n - p_{n-1} \qquad (2)$$

(2)

Where *n* is the working current state and *n*-1 is being previous state. To compared the working current state and previous state, which of magnitude inputs are d*p*/d*v* and d*p*. In the MPPT , chosen one of the methods of P&O , with an increment and decrement of the output of Fuzzy Logic. In figure shows the membership function of fuzzy control rule base, output and input of variables[9-12].

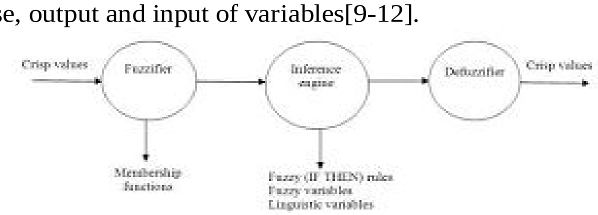

FIG 4: FUZZY LOGIC CONTROLLER

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B. *Control the three phase VSC*

In the voltage source converter is used $I_{cos\varphi}$. The load current is (i_{la}, i_{lb}, i_{lc}) and AC grid current(i_a, i_b, i_c) and DC link voltage , which are sensed and after fed back to the controller. The $I_{cos\varphi}$ algorithm is used to generated the load current active components. Grid currents reference are generated with help of in phase components.

The expression of the load currents is given by,

$$i_{La} = \sum I_{Lan} \sin(nwt - \emptyset_{an}) \quad (for\ n = 0,1\ to\ \alpha) \qquad (3)$$

$$i_{Lb} = \sum I_{Lbn} \sin(nwt - \emptyset_{bn}) \quad (for\ n = 0.1\ to\ \alpha) \qquad (4)$$

$$i_{Lc} = \sum I_{Lcn} \sin(nwt - \emptyset_{cn}) \quad (for\ n = 0.1\ to\ \alpha) \qquad (5)$$

Where in all phases, $I_{L\,(abc)^n}$ is the amplitude of n^th harmonic current, $\emptyset_{(abc)^n}$ are the phase angles of n^th harmonic current, $I_{L(abc)}$ are the load currents.

C. *Referred Grid currents In phase component*

In load currents, the fundamental component of active power amplitude is expressed as,

$$I_{La} = \sum I_{La1} \cos(\emptyset_{a1}) \qquad (6)$$

$$I_{Lb1} = \sum I_{Lb1} \sin(\emptyset_{b1}) \qquad (7)$$

$$I_{Lc1} = \sum I_{Lc1} \sin(\emptyset_{c1}) \qquad (8)$$

At zero crossing, a set of LPF is mainly used to amplitude the extract load current component of the in-phase unit .

D. *STATCOM*

A STATCOM or static synchronous generator operated as a shunt connected static var compensator whose capacitive or inductive output current can be controlled independent of the ac system voltage. From STATCOM to grid , the three phase injected current will be cancelled the distortion caused by the solar PV panel and linear load the three phase inverter based on IGBT is connected to the grid, which through the transformer . The inverter provides the compensated current to the demanded reactive power and nonlinear load[13-16].

The controller of the inverter is transferred into real power from batteries. So the STATCOM is mainly used to reduce the third order harmonics and reactive power. This system is connected at the point of common coupling to improve power quality. The STATCOM is used to injects the compensated current of variable frequency and magnitude at the bus of common coupling .

The system terminal voltage are given as,

$$V_a = V_m \sin(\omega t) \qquad (9)$$

$$V_b = V_m \sin(\omega t - 2\pi/3) \qquad (10)$$

$$V_c = V_m \sin(\omega t - 4\pi/3) \qquad (11)$$

and the load current respectively are given as,

$$i_{La} = \sum I_{Lan} \sin(n(wt) - \theta_{an}) \qquad (12)$$

$$i_{Lb} = \sum I_{Lbn} \sin(n(wt) - 2\pi/3) \qquad (13)$$

$$i_{Lc} = \sum I_{Lcn} \sin(n(wt) - 4\pi/3) \qquad (14)$$

IV. SIMULATION RESULTS

At 0.2 sec, if load balancing occurs, to removing one phase . In during load balancing, increasing the AC grid currents smoothly. Now using voltage source converter , to compensates the reactive power and the active power of the loads is supplied by the AC mains. The grid neutral current proper compensating the system it is observed to zero. At 0.55 sec, solar pv intensity is decreased and the loads active power from AC mains. In figure shows that the solar PV current, solar PV voltage are decreased at 0.55 sec PV generation is also decreased. Using VSC, source voltage and source current of reactive power are in same phase. Under load variations, the ac mains load current and neutral current are also depicted.

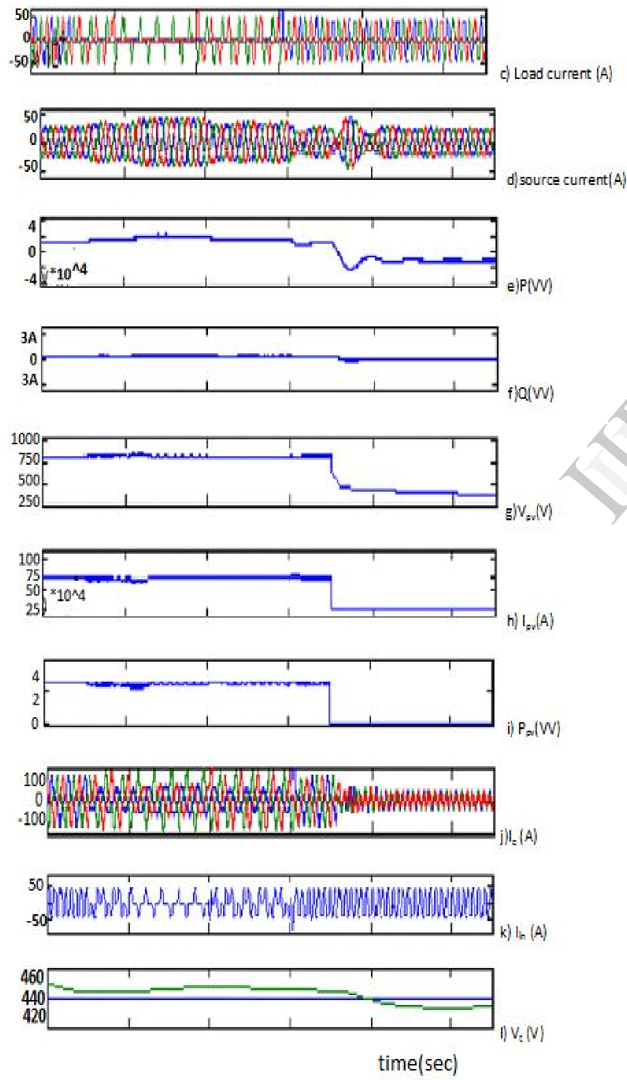

FIG 5: PERFORMANCE OF PROPOSED SYSTEM AT LOAD BALANCING AND LINEAR UNBALANCED LOAD

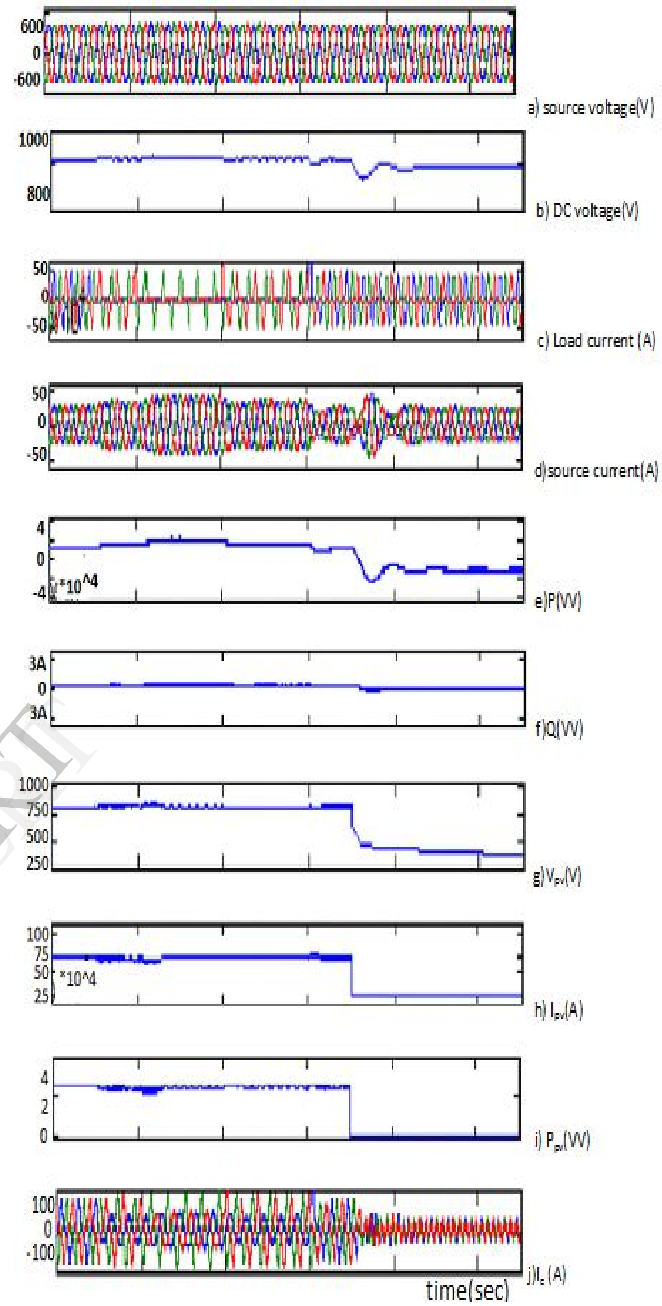

FIG 6 PERFORMANCE OF PROPOSED SYSTEM AT LOAD BALANCING AND LINEAR UNBALANCED LOAD .

At 0.05 sec, under unbalanced load condition , the AC grid are sinusoidal and leveled.Under unbalanced load currents, resulted load neutral current of the fundamental zero sequence current is circulated in the star-delta(Y-Δ) transformer and the grid current in neutral is maintained at zero. The THD of the AC grid current , load current and load voltageare given in Fig.

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V. Conclusions

In the propose system configured, the performance of solar PV grid interfaced power generating system using VSC have been tested load for reactive compensation, to eliminate the third order harmonics, neutral current elimination and load levelling .in the Fuzzy Logic controller is based on Mamdani FLC . without affecting or damaging its normal operation of real power conditioning , the grid interfacing inverter can be utilized effectively. There is no need of adding additional power conditioning equipment eliminates & to improve the power quality at point of common coupling. Using Fuzzy logic tool box, FLC is designed and using MATLAB/Simulink, simulation are performed. STATCOM is used to eliminate the harmonics including third order zero sequence harmonics.

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