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LMF Based Control of Single Stage Dual Purpose Three-Phase Four-Wire Grid Connected SPV System with Reduced Rating VSC

Vivek Narayanan, Jayaprakash P[1]

Dept. of Electrical and Electronics Engineering, Govt. College of Engineering Kannur, India[1]

Abstract: A three-phase four wire grid connected Solar Photovoltaic (SPV) system consisting of a three leg voltage source converter (VSC) and a star/delta transformer is proposed. This topology provides injection of real power from PV panel as well as mitigate various power quality problems. The proposed topology uses a star/delta transformer hence the ratings of VSC reduced. It provides power factor correction by reactive power compensation along with harmonic elimination, load balancing and neutral current compensation in three phase four wire distribution system. The neutral point of load is connected to the neutral of star winding so that it provides a path to the zero sequence fundamental as well as harmonic neutral currents. It doesn't use additional DC-DC conversion stage and hence having higher efficiency as compared to double stage topology. The proposed grid interfaced SPV system consists of a SPV array, Voltage Source Converter, Star/Delta transformer, three phase grid and linear/nonlinear loads. The DC bus voltage of a three phase VSC is regulated for Maximum Power Point Tracking (MPPT) from the PV array. In this paper, a LMF (Least Mean Fourth) based control of a single stage dual purpose grid connected SPV system is proposed and simulation based on MATLAB and Simpower System Blockset demonstrates the dual purpose of the system.

Keywords: Solar photovoltaic, MPPT, voltage source converter, Star/delta Transformer, Neutral Current Compensation, UPF operation, harmonic elimination.

I. INTRODUCTION

Renewable energy sources are gaining importance day by day owing to its advantages compared to their conventional counterpart. Among various renewable energy sources like wind, solar, tidal, etc. solar power has the merit of ease of availability. Unlike most of the renewable sources of energy, conversion of solar power to electricity does not involve any moving parts and hence requires less maintenance. Solar photovoltaic (SPV) offers alternative sources of energy which is in general pollution free, environment friendly, sustainable and unlimited in nature.Grid connected solar photovoltaic (PV) system is emerging as a major research area due to the increase in the demand of renewable energy sources. Many grid interfaced converter topologies are available for integrating renewable energy source to the grid [1]. While integrating any of the renewable energy sources to the electric grid there are several problems being noticed. These are related mainly with power quality like power factor correction, reactive power compensation and voltage regulation.

Moreover, power quality problems at distribution level like harmonics, unbalanced supply,unbalanced loads, reactive power, load management etc. affect the operation of grid connected SPV systems [2]. However,while integrating any of the renewable energy source to the electric grid, it has to fulfil standard power quality requirements so that the grid is not polluted due to such an interface.

There are many three phase grid integratedSPV systems reported in the literature [3]. However, it has been shown by Barnes et.al [4], that a single stage topology is more effective than a double stage topology. One of the challenging task in grid connected SPV system is the extraction of maximum power from the solar PV panel. There are various MPPT algorithms are available for extracting the peak power and are discussed and compared in the literature [5-6]. In addition to the extraction of peak power it has to improve the power quality also [7]. That is Voltage Source Converter (VSC) switches are controlled such that maximum power from the panel is extracted and needs to improve the power quality also. There are several algorithms are developed for controlling the VSCs [8-12]. The SPV energy system compensates for linear and nonlinear loads with objectives of load balancing, harmonics elimination and correction of power factor to unity.

When the three phase four wire distribution system is supplying nonlinear load, the harmonics in currents and the unbalance in load increase the neutral current this may overload the neutral conductor of three-phase four-wire distribution system. There are several topologies are available for compensating the neutral currents, using three single-phase VSCs, three leg VSC with split capacitors, three leg VSC with zig-zag transformer etc. [13-14]. The proposed topology makes the use of Star/delta transformer for compensating the neutral current.

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In this paper, a LMF (Least Mean Fourth) based control of a single stage three-phase four-wire grid connected SPV system is proposed.The design of the system, control of the system, modelling and simulation, results and discussions and the conclusions are presented in the subsequent sections of this paper.

II. DESIGN OF PROPOSED SYSTEM

A SPV system integrated to a three phase grid having loads as shown in Fig. 1.The system components to be designed are SPV array, linear and nonlinear loads, DC bus voltage, DC link capacitance, IGBT (Insulated Gate Bipolar Transistor) based VSC rating, interfacing inductances, ripple filter and Star/deltatransformer.

A. Selection of SPV array

The details of SPV array model chosen is shown in Table. 1. The SPV array used here is modelled for maximum power capacity of 1.8 kW connected to a 415 V, 50 Hz, 3-phase system.

Table. 1. Details of SPV array model

I_{mp}	7.6 A	I_{sc}	8.25 A	I_{pv}	8.214 A
V_{mp}	26.3 V	V_{oc}	31.7 V	R_s	0.17593 Ω
P_{max}	200 W	I_o	$8.45*10^{-8}$ A	R_p	990.84 Ω

The number of SPV modules connected in series are estimated as,

$$n_s = \frac{V_{dc}}{V_{mp}} = \frac{220}{26.3} = 9 \text{ modules} \quad (1)$$

The number of SPV modules connected in parallel are estimated as,

$$n_p = \frac{P_{max}/V_{dc}}{I_{mp}} = \frac{1800/220}{7.6} = 1 \text{ module} \quad (2)$$

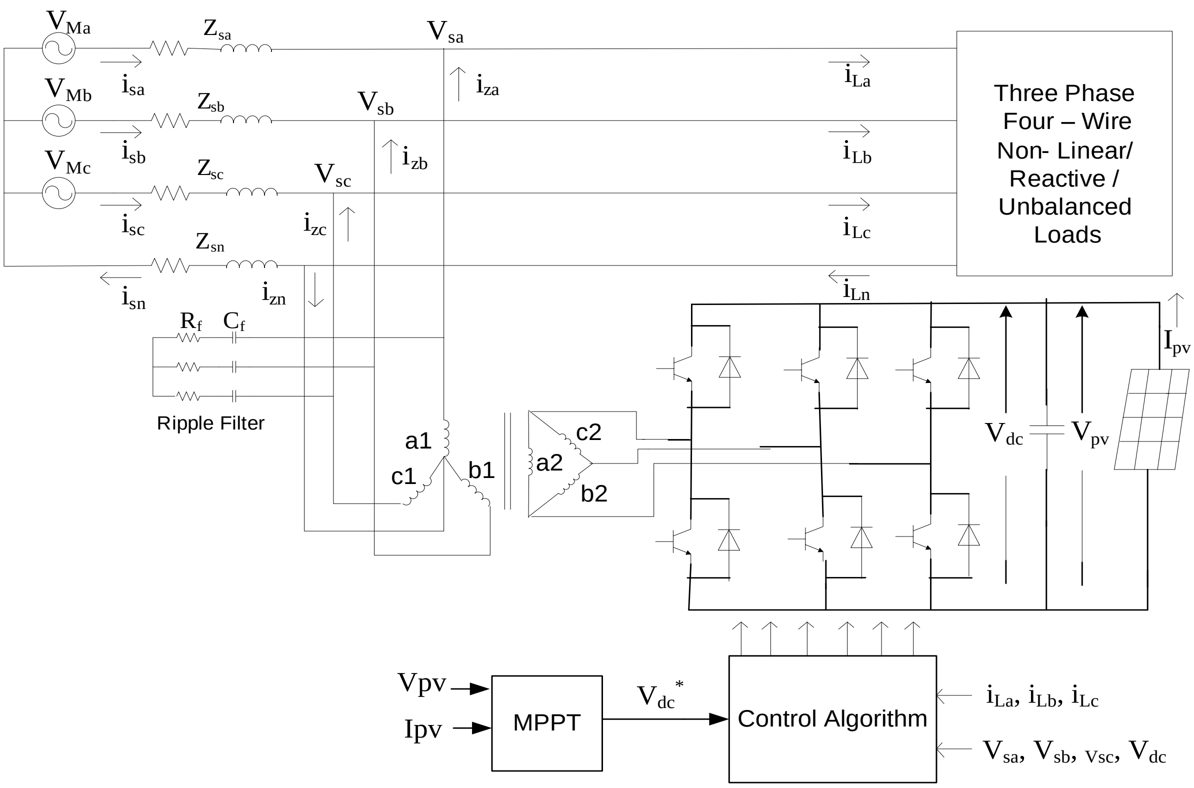

Fig. 1. Single stage grid connected solar PV system

Therefore, the SPV array with peak power capacity of 1.8 kWis modelled with 9 modules connected in series and 1 module is connected in parallel.

B. Selection of DC Bus Voltage

The value of DC bus voltage (V_{dc}) depends on the instantaneous energy available to the VSC. The DC busvoltage of VSC is computed as,

$$V_{dc} = \frac{2\sqrt{2}V_L}{\sqrt{3}m} = \frac{2\sqrt{2}*120}{\sqrt{3}*0.95} = 220 \text{ V} \quad (3)$$

Where, V_L is ac output line voltage of VSC and m is the modulation index. (Values considered here are m=0.95 and V_L=120 V). Thus V_{dc} obtained as 206.27 V and it is selected as 220 V.

C. Design and Selection of IGBT based VSC

Under dynamic conditions, the voltage rating (V_{sw}) of the devices (IGBT) is computed as,

$$V_{sw} = V_{dc} + V_d = 220 + 22 = 242 \text{ V} \quad (4)$$

Where, V_d is 10% over-shoot on the DC voltage (V_{dc}) under dynamic conditions. And the selected value of V_{sw} = 250 V.

The current rating (I_{sw}) is estimated as,

$$I_{sw} = 1.25*(I_{crpp} + I_{peak}) = 1.25*(0.06*8.25+8.25) = 10.93 \text{ A} \quad (5)$$

Where, I_{crpp} is the ripple current value with 6% ripple. So, the selected value of I_{sw} = 15 A.

D. Design and Selection of Interfacing Inductances

The value of the interfacing AC inductor is as,

$$L_f = \frac{\sqrt{3}mV_{dc}}{12*h*f_s*\Delta i} = \frac{\sqrt{3}*0.95*220}{12*1.2*10000*0.03*8.25} = 10.2\text{mH} \quad (6)$$

Where, h = 1.2 is the overloading factor, f_s = 10 kHz is switching frequency, and Δi is ripple current that is 3% of the peak current.

E. Design and Selection of VSC-DC Link Capacitance

The VSC-DC link capacitance value is evaluated as,

$$C_{dc} = \frac{P_{dc}/V_{dc}}{2*\omega*V_{dcrip}} = \frac{1800/220}{2*314*0.02*220} = 2961 \ \mu\text{F} \quad (7)$$

Where, V_{dcrip} is the % ripple voltage taken as 2% of the DC link voltage and ω = 2π*50=314rad/s is the angular frequency. So, the value of VSC-DC link capacitor is selected as 3000μF as it can stabilize the DC link voltage quickly during disturbances.

F. Design and Selection of Ripple Filter

The selected value of capacitor is C_f = 10μF and resistance is R_f = 5 Ω as designed in [15].

G. Star-Delta Transformer

The VSC is connected to the delta connected primary windings of the transformer. When the load having any zero sequence current, it will circulate within the delta windings. This circulating current and the compensating current to be provided by the VSC together decides the current ratings of the transformer windings. The secondary winding voltage is given as,

$$V_a = \frac{V_{LL}}{\sqrt{3}} = \frac{415}{\sqrt{3}} = 239.60 \text{ V} \quad (8)$$

The primary line voltage is chosen as 120 V. Hence the voltage ratio of the transformer is 120V:240V. Therefore three numbers of single phase transformers of each rating 1.2 kVA considering required load reactive power injection by the VSC, 120V/240V is selected for interfacing the VSC with the grid.

III.CONTROL OF THE PROPOSED SYSTEM

The proposed grid interfaced SPV system consists of mainly two control aspects. One is the MPPT algorithm, which is used to extract the maximum power from solar photovoltaic system under any operating conditions. Here Perturb & Observe (P&O) algorithm is employed for extracting the maximum power. Second is the controlling of VSCin such a way that improve various power quality, the main control functions includes load balancing, harmonics elimination, neutral current compensation,balancing grid currents and PFC. Here Least Mean Fourth algorithm is used to generating the gating pulses for the VSC.

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A. MPPT Control

There are several MPPT algorithms are available for extracting maximum power from the PV system. Compared to various MPPT algorithms the most often used one is the P&O technique due to its simplicity. This technique is based on the fact that at the MPP (maximum power point), the derivative of power w.r.t. the voltage is zero. When this condition is satisfies, the panel is operating at its maximum power and there is no perturbation occurs. When the derivative of power with respect to the voltage is greater or lesser than zero, then perturbation will occur and the panel operates at its maximum power. That is at any operating conditions the panel will operate at its maximum power. Here the panel voltage V_{pv} and panel current I_{pv} are processes to provide a reference voltage V_{dc}^*. This reference voltage is compares with the actual panel voltage and this error is processed by Proportional and Integral (PI) controller and the output of PI controller is used to maintain the DC link voltage.

B. Control Algorithm for Switching of VSC

The control algorithm of VSC focuses on generating the gatingsignals for the VSC-IGBT's.Least Mean Fourth is used for the controlling of VSCs. The structure of the LMF based control technique for the estimation of reference three phase grid currents as shown in Fig. 2. This control algorithm is sub-divided into small sections such as estimation of in-phase and quadrature unit templates from sensed PCC voltages, the extraction of the active and reactive fundamental components of the load currents as well as their weights, generating the three phase reference grid currents and generating the gating signals for switching of the converter.

i. Estimation of Unit Templates and amplitude of the Terminal Voltage

From the sensed three phase PCC line voltages (v_{sab}, v_{sbc}), the phase voltages are obtained as,

$$V_{sa} = \frac{2V_{sab} + V_{sbc}}{3} \quad (9)$$

$$V_{sb} = \frac{-V_{sab} + V_{sbc}}{3} \quad (10)$$

$$V_{sc} = \frac{-V_{sab} - 2V_{sbc}}{3} \quad (11)$$

The peak amplitude of terminal voltage (V_t) is estimated as,

$$V_t = \sqrt{\frac{2}{3}(V_{sa}^2 + V_{sb}^2 + V_{sc}^2)} \quad (12)$$

The in-phase unit templates are estimated as,

$$u_{pa} = \frac{V_{sa}}{V_t} \quad (13)$$

$$u_{pb} = \frac{V_{sb}}{V_t} \quad (14)$$

$$u_{pc} = \frac{V_{sc}}{V_t} \quad (15)$$

Moreover, the quadrature unit templates are derived from the in-phase unit templates (u_{pa}, u_{pb}, u_{pc}) as,

$$u_{qa} = \frac{-u_{pb}}{\sqrt{3}} + \frac{u_{pc}}{\sqrt{3}} \quad (16)$$

$$u_{qb} = \frac{\sqrt{3}u_{pa}}{2} + \frac{(u_{pb} - u_{pc})}{2\sqrt{3}} \quad (17)$$

$$u_{qc} = \frac{-\sqrt{3}u_{pa}}{2} + \frac{(u_{pb} - u_{pc})}{2\sqrt{3}} \quad (18)$$

ii. Estimation of Active and Reactive Loss Components

After the calculation of terminal voltage V_t, the voltageerror $V_{te}(n)$ of the voltage at the PCC and the referencevalue of terminal voltage (V_{tn} = 340 V peak of the amplitude of phase voltage) is fed to a PI controller. The error at thenth sampled instant is given as,

$$V_{te}(n) = V_{tn}(n) - V_t(n) \quad (19)$$

The output of PI voltage controller is the reactive loss component w_{cq}which is used to maintain the PCC voltage,

$$w_{cq}(n+1) = w_{cq}(n) + K_{pt}(V_{te}(n+1) - V_{te}(n)) + K_{it}V_{te}(n+1) \quad (20)$$

Where, K_{it} and K_{pt} are integral and proportional constants used in PI voltage controller.

Likewise, the DC voltage error V_{de} is calculated as the difference between the voltage DC reference V_{dc}* achieved from the MPPT and sensed DC voltage V_{dc} as,

$$V_{de}(n) = V_{dc}^*(n) - V_{dc}(n) \quad (21)$$

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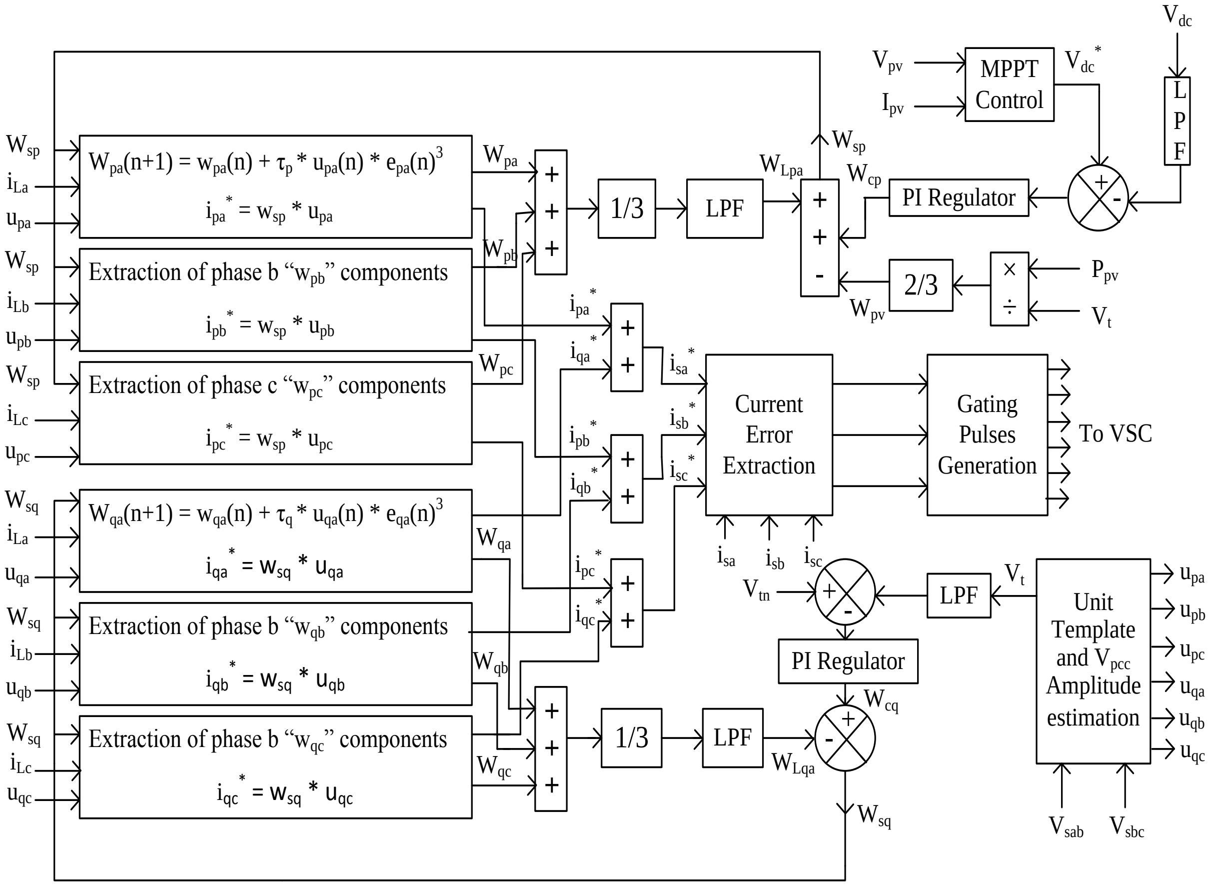

Fig. 2. Structure of LMF control algorithm

This estimated error is then fed to the PI voltage controller and the resultant is the active loss component w_{cp} which is regulating the DC link voltage is estimated as,

$$w_{cp}(n+1)=w_{cp}(n)+K_{pd}(V_{de}(n+1)-V_{de}(n))+K_{id}V_{de}(n+1) \quad (22)$$

Where, K_{id} and K_{pd} are integral and proportional constants used in DC PI voltage controller.
The feed forward term from the SPV system is given as,

$$w_{pv}(n) = \frac{2P_{pv}(n)}{3V_t} \quad (23)$$

Where, P_{pv} is extracted SPV power.

iii. Extraction of Weights of Fundamental Active and Reactive Load Current Components
The weight of fundamental active component of the load current of phase 'a' is evaluated as,

$$w_{pa}(n+1) = w_{pa}(n)+\tau_p u_{pa}(n)(e_{pa}(n))^3 \quad (24)$$

Where, $e_{pa}(n)$ is the error of adaptive component. Moreover, the factor used in the above equation, τ_p is the adaptation constant chosen appropriately to obtain desired results.
One can see that τ_p controls the behaviour of the algorithm, and that two important goals are competing: for fast convergence, one would use a large step-size τ_p, but to achieve low steady-state Mean Square Error (MSE), a smaller step-size would be better.

$$e_{pa}(n) = i_{La}(n)-u_{pa}(n)*w_{pa}(n) \quad (25)$$

Where, $w_{pa}(n)$, $i_{La}(n)$ and $u_{pa}(n)$ are the weight of active reference component, load current and in-phase unit template at the nth instant. Similarly, the weights of the fundamental active components of load currents of other two phases 'b' and 'c' are estimated as,

$$w_{pb}(n+1) = w_{pb}(n)+\tau_p u_{pb}(n)(e_{pb}(n))^3 \quad (26)$$

$$w_{pc}(n+1) = w_{pc}(n)+\tau_p u_{pc}(n)(e_{pc}(n))^3 \quad (27)$$

The weight of fundamental reactive component of the load current of phase 'a' is evaluated as,

$$w_{qa}(n+1) = w_{qa}(n)+\tau_q u_{qa}(n)(e_{qa}(n))^3 (28)$$

Where, $e_{qa}(n)$ is the error of adaptive component. Moreover, τ_q is the adaptation constant chosen appropriately to obtain desired results as,

$$e_{qa}(n) = i_{La}(n)-u_{qa}(n)*w_{qa}(n) (29)$$

Where, $w_{qa}(n)$, $i_{La}(n)$ and $u_{qa}(n)$ are the weight of reactive reference component, load current and quadrature unit template at the nth instant. Similarly, weights of fundamental reactive components of load currents of other two phases 'b' and 'c' are estimated as,

$$w_{qb}(n+1) = w_{qb}(n)+\tau_q u_{qb}(n)(e_{qb}(n))^3 (30)$$
$$w_{qc}(n+1) = w_{qc}(n)+\tau_q u_{qc}(n)(e_{qc}(n))^3 (31)$$

iv. Generation of Reference Three Phase Grid Currents

The total active weight component (w_{sp}) of reference three-phase grid currents is calculatedby adding the DC loss component to average fundamental active weight component and deducting the feed-forward SPV weight,

$$w_{sp} = w_{Lpa}+w_{cp}-w_{pv} (32)$$

Where,

$$w_{Lpa} = (w_{pa}+w_{pb}+w_{pc})/3 (33)$$

The active reference components of grid currents are expressed as,

$$i^*_{pa} = w_{sp} * u_{pa} (34)$$
$$i^*_{pb} = w_{sp} * u_{pb} (35)$$
$$i^*_{pc} = w_{sp} * u_{pc} (36)$$

Similarly, the total reactive weight component (w_{sq}) of the reference grid currents is calculated by subtracting the average fundamental reactive weight component to the AC loss component and is expressed as,

$$w_{sq} = w_{cq}-w_{Lqa} (37)$$

Where,

$$w_{Lqa} = (w_{qa}+w_{qb}+w_{qc})/3 (38)$$

The reactive reference grid current components are expressed as,

$$i^*_{qa} = w_{sq} * u_{qa} (39)$$
$$i^*_{qb} = w_{sq} * u_{qb} (40)$$
$$i^*_{qc} = w_{sq} * u_{qc}$$

Therefore, the total reference three-phase grid currents are given as,

$$i^*_{sa} = i^*_{pa} + i^*_{qa} (41)$$
$$i^*_{sb} = i^*_{pb} + i^*_{qb} (42)$$
$$i^*_{sc} = i^*_{pc} + i^*_{qc} (43)$$

v. Generation of Gating Signals using PWM Controller

To generate gating signals for switching of the VSC, anindirect current control technique is used with a hysteresis regulator. The error current signal is calculated from the difference between referencegrid currents (i_{sa}*, i_{sb}*, i_{sc}*) and sensed grid currents (i_{sa}, i_{sb}, i_{sc}). These error signals are then passed through the hysteresis controller for generating different gating pulses.

IV. RESULTS AND DISCUSSION

The proposed three phase four wire SPV power generating system integrated with the grid is modelled and simulated in MATLAB/Simulink with the help of simpower system toolbox under different conditions. The SPV array which is used here is modelled for maximum power capacity of 1.8 kW connected to a 415 V, 50 Hz, 3 phase system. The simulation is carried out for nonlinear and linear loads. For assessing the behaviour of the system, results involve significant signals such as grid voltages (v_{sabc}), grid currents (i_{sabc}), load currents (i_{Labc}), load neutral current (i_{Ln}), compensator neutral current (i_{Tn}), source neutral current (i_{sn}), reference grid currents (i_s*), compensator voltages (v_{spv}),

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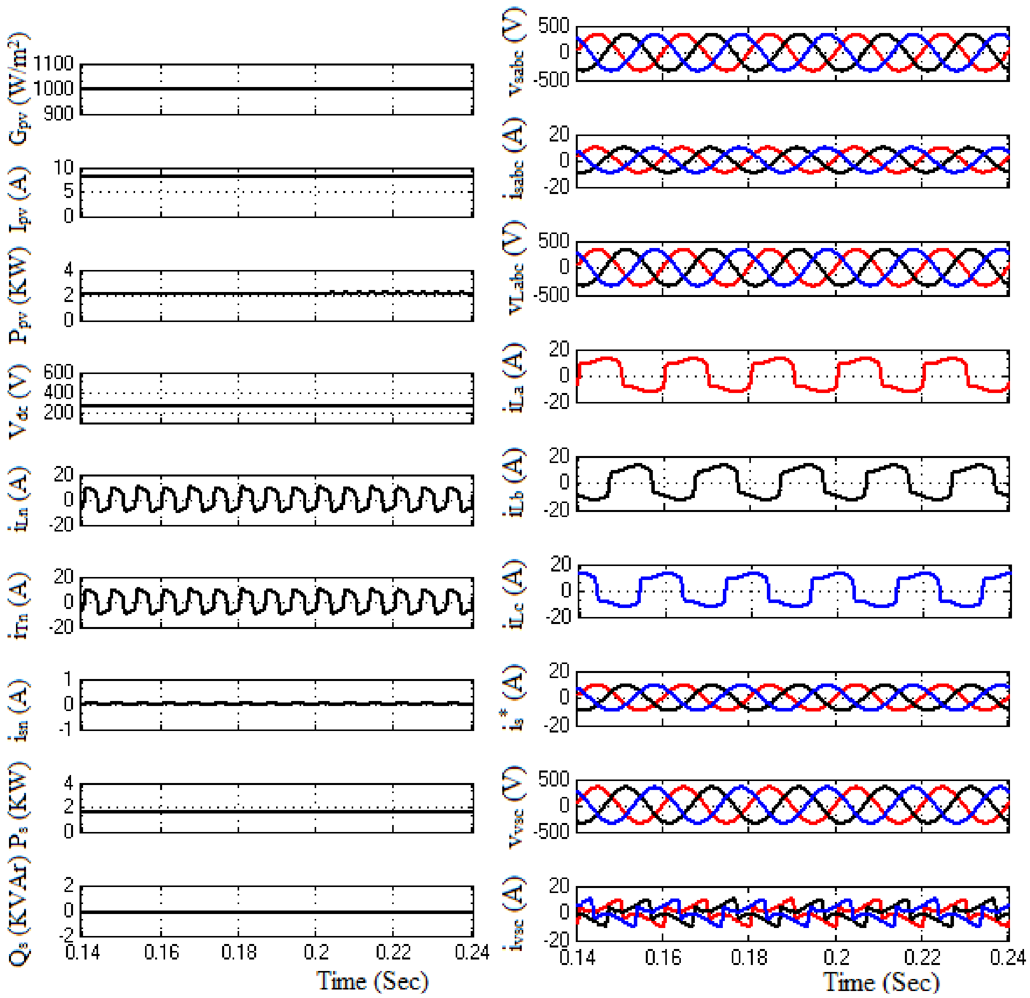
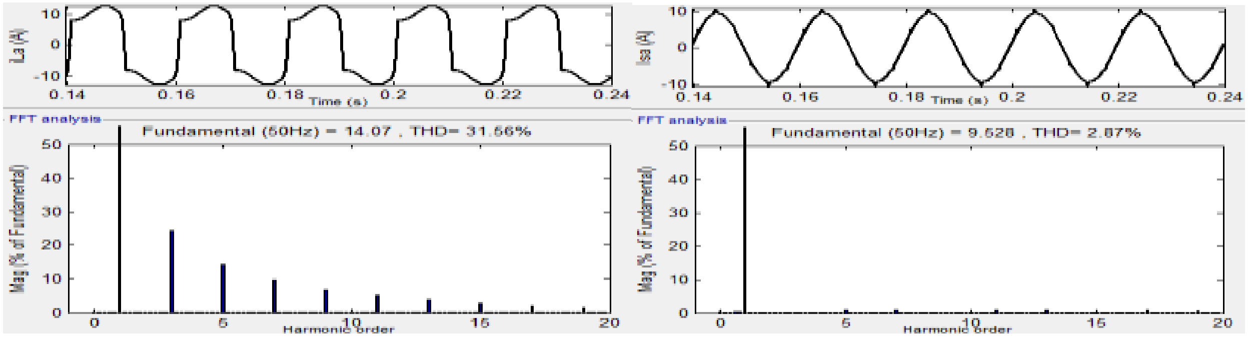
compensator currents (i_{spv}), VSC-DC link voltage (V_{dc}), SPV array DC current (I_{pv}), SPV array DC power (P_{pv}), source real power P_s and source reactive power Q_s.
The performance of three phase, four-wire grid connected SPV system using star/delta transformer for neutral current compensation is demonstrated for power factor correction, harmonic reduction, load balancing and maximum power point tracking of SPV system.

A. Steady State Performance under Non-linear Loads

The performance of three-phase four-wire grid connected SPV system comprising of three leg VSC and a star/delta transformer for unity power factor correction along with neutral current compensation and load balancing under non-linear load as shown in Fig. 3 (a-b).
Steady state performance is carried out for an insolation of 1000 W/m^2. The SPV current (I_{pv}), power (P_{pv}), dc link voltage (V_{dc}), load neutral current (i_{Ln}), compensator neutral current (i_{Tn}), source neutral current (i_{sn}), source real power (P_s), source reactive power (Q_s), voltage at PCC (v_{sabc}), balanced supply currents (i_{sabc}), load voltages (v_{Labc}), load currents, reference source currents (i_s^*), compensator voltages (v_{vsc}), and compensator currents (i_{vsc}) are demonstrated when the grid is supplying a nonlinear load.
It is observed that the DC link voltage is regulated to the desired valueby the MPPT algorithm for maximum power point tracking. The grid currents and grid voltages are found to be in phase. Thus power factor at source side is improved to unity. The fundamental zero sequence current of the load neutral current is circulated in the star/delta transformer and hence the source neutral current is maintained at nearly zero.
The waveforms of the load current and source current along with their harmonic spectra are demonstrated in Figs. 3 (c-d) respectively. The load current is non sinusoidal, because the load used is diode bridge rectifier with RL load.The source current is observed to besinusoidal even if the load is non sinusoidal. The total harmonic distortion (THD) of source current is 2.87% where as that of load current is 31.56%. That is the THD of the source current is reduced to less than 5% thus meeting the requirements of IEEE-519 standard [16].



(a) (b)

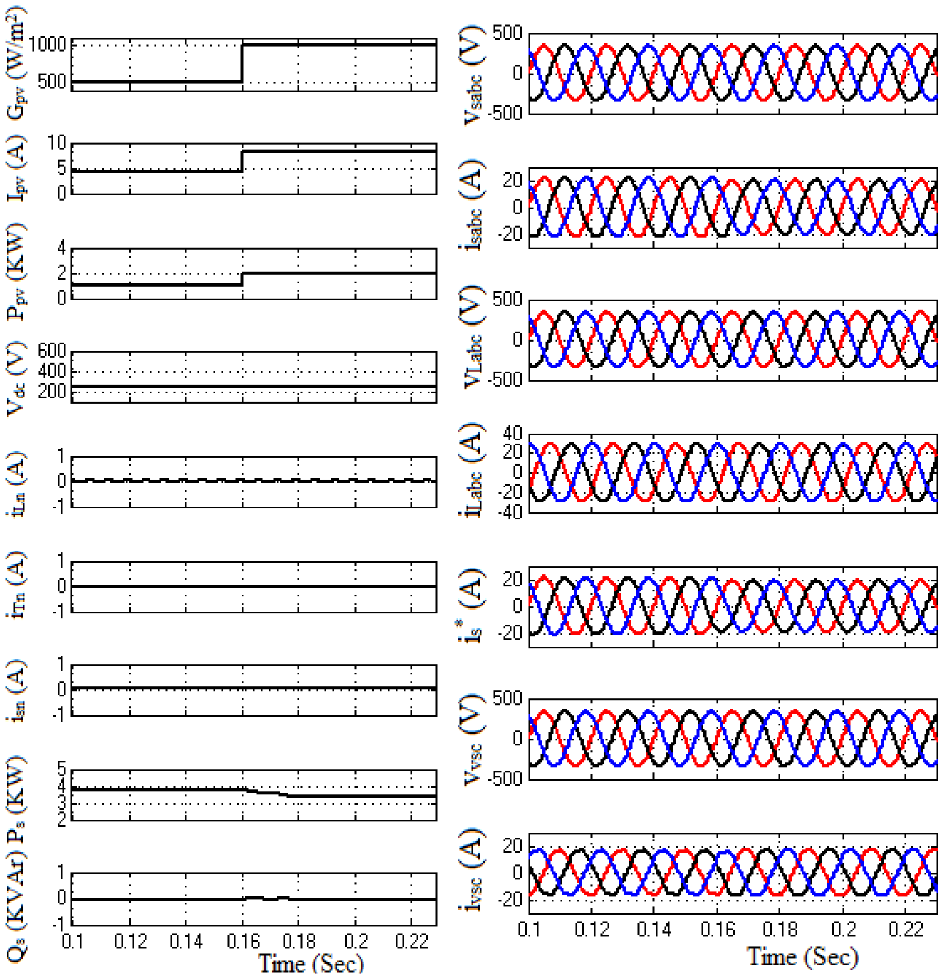


(c) (d)

Fig. 3. Steady state performance of three phase four wire grid connected SPV system with nonlinear load (a) Irradiation, PV current, PV power, dc link voltage, load neutral current, compensator neutral current, source neutral current, source real power and source reactive power. (b) Source voltages, source currents, load voltages, load currents, reference source currents, inverter voltages and inverter currents. (c) Load current and harmonic spectrum (d) Source current and harmonic spectrum.

B. Dynamic Behaviour of Grid Connected Topology under Variable Insolation

The dynamic behaviour of the grid connected topology under linear load when the insolation is changed from 500 W/m^2 to 1000 W/m^2 at 0.16 sec is shown in Fig. 4 (a-b).



(a) (b)

Fig. 4. Dynamic performance of three phase four wire grid connected SPV system with linear load under varying insolation (a) Irradiation, PV current, PV power, dc link voltage, load neutral current, compensator neutral current, source neutral current, source real power and source reactive power. (b) Source voltages, source currents, load voltages, load currents, reference source currents, inverter voltages and inverter currents.

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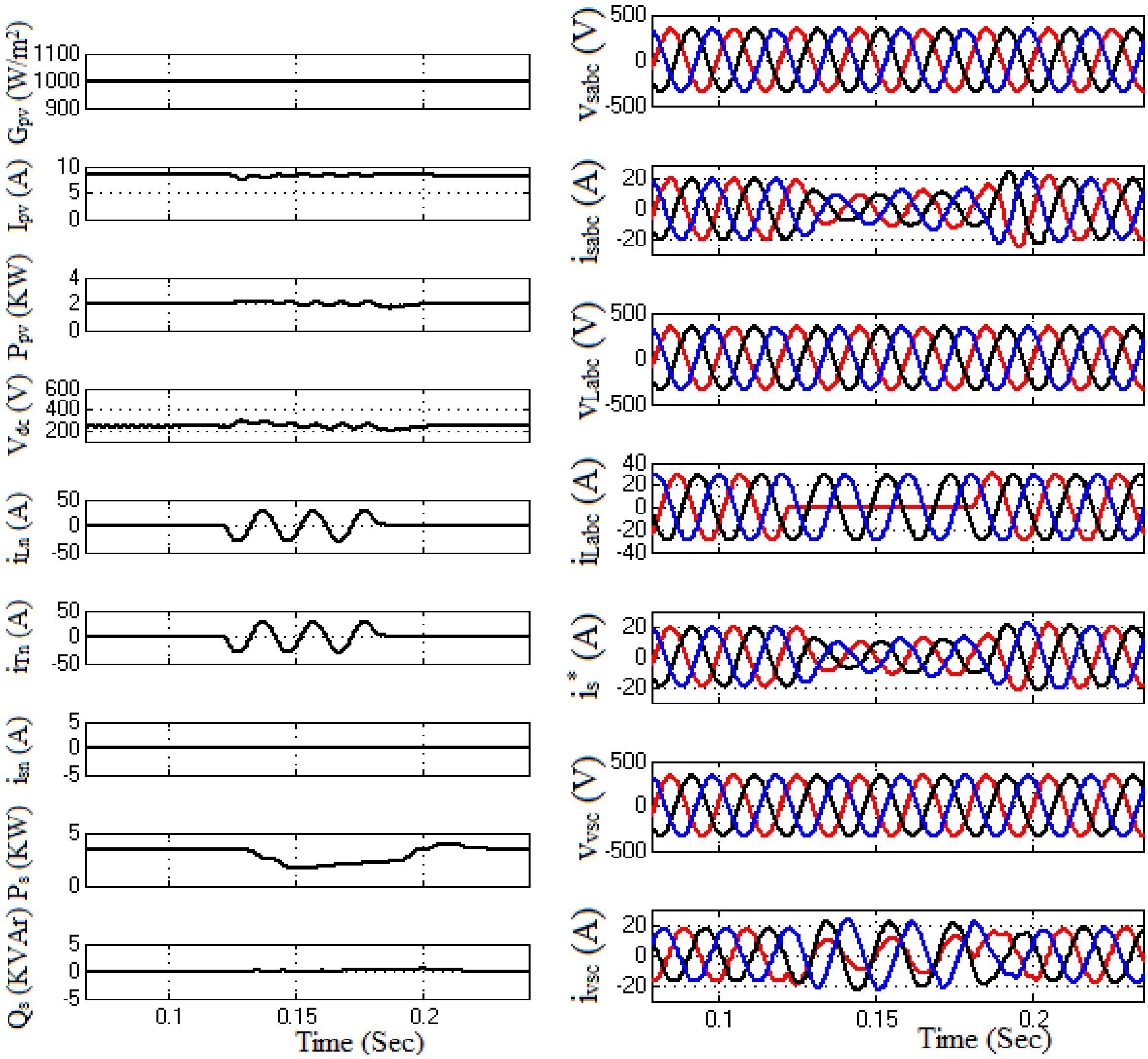
The panel power (P_{pv}), panel current (I_{pv}), dc link voltage (V_{dc}), load neutral current (i_{Ln}), compensator neutral current (i_{Tn}), source neutral current (i_{sn}), source real power (P_s), source reactive power (Q_s), voltage at PCC (v_{sabc}), balanced supply currents (i_{sabc}), load voltages (v_{Labc}), load currents (i_{Labc}), reference source currents (i_s^*), compensator voltages (v_{vsc}), and compensator currents (i_{vsc}) are demonstrated underlinear load. With the increase in the solar irradiance, the level of power (P_{pv}) which can be extracted from the SPV array as well as the value of SPV current (I_{pv}) are increased. And also it is observed that the dc link voltage is regulated to desired value. Since balanced linear load is used for the investigation so the load neutral current is zero. So the compensator and source neutral currents are also be zero. With the increase of insolation the grid current value is drops to a lower value and hence the source active power also reduced. The source voltages and source currents are in phase and hence power factor at source side is improved to unity.

C. Dynamic Behaviour of Grid Connected Topology under Unbalanced load

The dynamic behaviour of the grid connected topology in UPF mode of operation under unbalanced linear load from 0.12 to 0.18 sec is depicted in Fig. 5 (a-b). The performance is carried for an insolation of 1000 W/m^2. The SPV current (Ipv), power (Ppv), dc link voltage (V_{dc}), load neutral current (i_{Ln}), compensator neutral current (i_{Tn}), source neutral current (i_{sn}), source real power (P_s), source reactive power (Q_s), voltage at PCC (v_{sabc}), balanced supply currents (i_{sabc}), load voltages (v_{Labc}), load currents (i_{Labc}), reference



(a) (b)

Fig. 5. Dynamic performance of three phase four wire grid connected SPV system with unbalanced linear load (a) Irradiation, PV current, PV power, dc link voltage, load neutral current, compensator neutral current, source neutral current, source real power and source reactive power. (b) Source voltages, source currents, load voltages, load currents, reference source currents, inverter voltages and inverter currents.

source currents (i_s^*), compensator voltages (v_{vsc}), and compensator currents (i_{vsc}) are shown for unbalanced linear load. Even under the load unbalancing, the grid currents are maintained sinusoidal with grid voltages and hence the power factor is improved. The DC link voltage is regulated to desired value. It is observed that the load neutral current when there is any unbalance is circulated in the star/delta transformer and hence the source neutral current is maintained at nearly zero. During the load unbalance the grid current value is drops to a lower value and hence the source active power also reduced.

D. MPPT Operation

Fig. 6 and 7 givesI-V and P-V characteristics of the SPV system, which shows that the maximum power is extracted effectively from the SPV system at 220V. The dc link voltage is maintained at 220V by the MPPT algorithm and is shown in Fig. 5 (a).

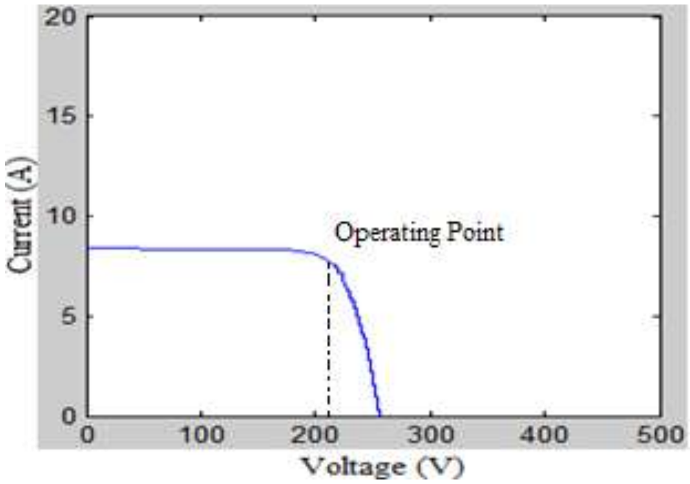


Fig. 6. I-V characteristic of SPV system

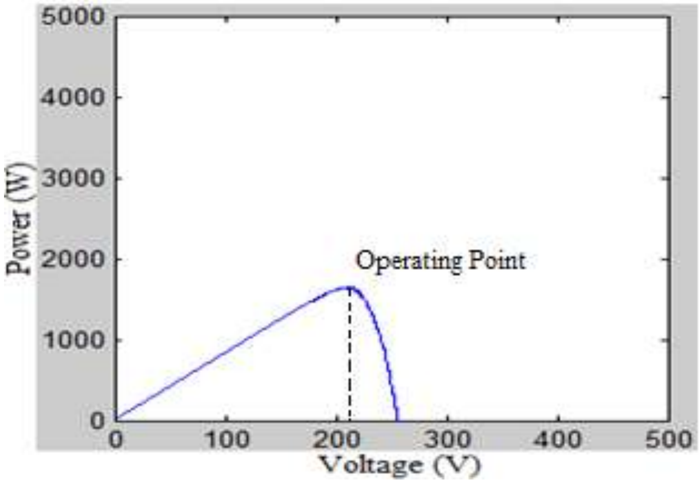


Fig. 7. P-V characteristic of SPV system

V. CONCLUSION

In this paper, a LMF based control of a three phase, four wire grid connected SPV system is proposed. The proposed system is demonstrating the two purposes and the first is the injection of real power from SPV panel with maximum power point tracking facility. As the topology is single stage, the overall efficiency of the system is high compared to a two stage system in which a dc-dc converter is also included. Secondly, the purpose of reactive power compensation, harmonic elimination, neutral current compensation and load balancing are also demonstrated. The proposed topology uses a Star/delta transformer for compensating the zero sequence fundamental and harmonic neutral currents. The THD of currents on the grid side is below 5% which is the IEEE-519 standard limit for THD.

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BIOGRAPHIES

Vivek Narayanan received his B.Tech degree in Electrical and Electronics Engineering (EEE) from Cochin University of Science and Technology (CUSAT). Currently he is doing M. Tech in Power Electronics and Drives (PED) at Govt. College of Engineering Kannur (GCEK).

Dr. Jayaprakash P received the B.Tech degree from the University of Calicut, Kerala, India, in 1996, and theM.Tech. degree from the Indian Institute of Technology Delhi, New Delhi, in 2003. He received his Ph.D from Indian Institute of Technology (IIT), Delhi. Currently he is Associate Professor in the Dept. of EEE at Govt. College of Engineering Kannur. His fields of interest are power quality and power electronics applications in power systems.