SINUSOIDAL PULSE WIDTH MODULATION BASED ADAPTIVE DC LINK VOLTAGE FOR CPI VOLTAGE VARIATIONS

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Abstract— This proposed model has a three-phase two step grid tied SPV (solar photo voltaic) topology. The main step is the boost converter, which fills the need of MPPT (maximum power point tracking) and sustaining the solar dc voltage to input of the PV inverter, while the second step is a two-level VSC (voltage source converter) serving as PV inverter which transfers power from a boost converter into the grid. The model likewise utilizes an adaptive voltage at DC link which is made adaptive by modifying reference DC interface voltage as per CPI (common point of intersection) voltage. Reduction of switching power losses are done through adaptive DC link voltage control. A sustained forward term for solar contribution is utilized to improve the dynamic response and the system is verified considering realistic grid voltage changes for under voltage and over voltage. The performance of proposed system is tested through MATLAB/Simulink.

Keywords— PV array, MPPT, SPWM, CPI voltage variations, DC-DC Boost Converter, Adaptive DC Link, Voltage source converter.

1. INTRODUCTION

Now a day's the majority countries are focusing on non-conventional energy sources as yield beneficial of pollution free, less cost and sufficient in nature. The process and repairs cost of generating power with non-conventional energy sources involves less difficult operation as well easy organization with grid. The non-conventional energy sources like solar and wind are being widely used as cogeneration to meet the needs of housing and commercial uses. These distributed sources have require new power electronic coherence and control techniques for rising efficiency and power quality [1-2].PV solar energy systems are classified into 2 types; there are grid interfaced and standalone system. In standalone PV systems different problems are related to battery storage energy [3-4]. As compared to standalone systems grid connected system has some advantages of effective power utilization. A grid side and PV system side need technical requirements to fulfill the safety of the PV installer and grid reliability. PV grid connected systems with some techniques are solving the issues like electromagnetic interference and harmonics distortion necessities, islanding [5-6]. Inverter is the main equipment in Grid connected system for converting DC into AC power. Only 30% -40% of power is produced from the PV panel so, for producing more power from PV panel MPPT techniques are required. In current years, no. of methods has been developed for detecting peak power [7]. Perturb and observe technique is easy implement and easy control mechanism. Main problem of P&O technique is unable to identify the peak power during unexpected changes in climate condition [8]. Frictional open-circuit voltage (FOCV) and short-circuit current (FSCC) [9-10] methods are simple and effective to obtain the peak power. Both FSCC & FOCV methods are results more power loss. INC (Incremental Conductance) MPPT is quick, accurate and easy to implement.INC conductance MPPT gives best results during unexpected changes in climate conditions. The grid connected PV system causes for generation loss by tripping case. From under and over voltages grid connected VSCs is protected. The under and over voltages nominal range is around 0.9 to 1.1 pu respectively [11]. For converter may lose control, voltage losses at converter and converter grade etc. for this reason the range of under and over voltages are small. Generally the under voltage is observed at peak load conditions. Several researchers proposed a two stage PV generation scheme [12], [15]. The chopper circuit can used a primary step which works for the determination of MPPT. The PV system works at MPP point by changing converter duty cycle. The step two is 3-phase VSC which provide the power into the distribution system. The DC link voltage maintain as constant for1-phase two step grid tied PV systems is proposed in [12]. Moreover, voltage at DC link maintains constant for 3-phase PV generation system is proposed in [13] [14]. In [15] hybrid filters losses are compact by making adaptive DC link. According to reactive power requirements of filters the voltage at DC link can be altered [16]. The 3-phase peak line voltages are less than the reference voltage of DC link for VSC current control. The 1-phase grid linked current control converter has some limitation is represented in [17]. The DC link voltage reference is retained above the maximum acceptable CPI voltage variation. For CPI voltage variations the constant voltage at DC link gives worst resultant. This paper represents a modest control structure for grid linked PV array with adaptive voltage at DC link for voltage changes at CPI. The primary stage is boost converter and secondary stage two level VSC. The constant DC link voltage has some limitations so adaptive voltage at dc link for VSC is proposed. The interfacing inductor losses at high frequency and switching power losses are reducing by adaptive DC link voltage. By introducing PVFF word in VSC to get a quick dynamic response in DC link voltage.

This paper is methodized as follows: Section 2 illustrates the system topology. In Section 3 control configuration is presented. Discussion on simulation results are clarified in Section 4. Lastly, conclusions are presented in Section 5.

2. System Topology

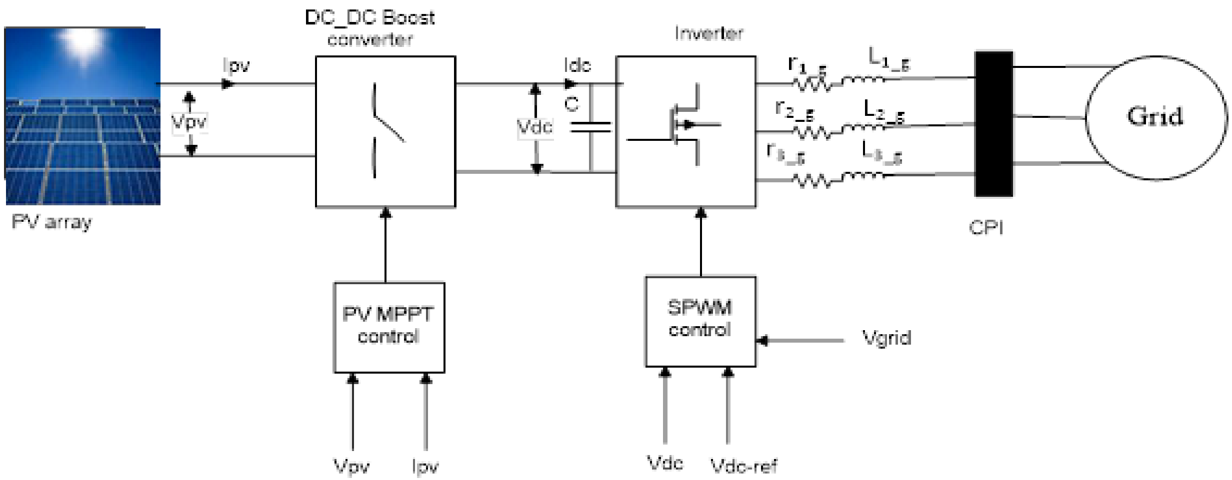

Fig.1. Block diagram of proposedSinusoidal Pulse Width Modulation based Adaptive voltage at DC Link.

The projected system configuration is shown in fig1. A sinusoidal pulse width modulation of an adaptive voltage at DC link for CPI voltage changes is divided into two stages. The primary stage is DC-DC converter with helping of MPPT. The secondary stage is DC-AC converter with two-level 3-phase VSC. The boost converter input is linked to PV array, and then the maximum power from PV array is obtained by using INC MPPT. The VSC input can connect an output of the boost converter at DC link. Based on the CPI voltage variations the DC link voltage at VSC can be slowly varied. The IGBT switches are used in 3-phase VSC. For reducing high frequency switching ripples, ripple filter can be placed between output of VSC and CPI.

3. Control Configuration

Control approach of the scheme is divided into two portions. The PV array output terminals are given to the input of boost converter. Boost converter input voltage is obtained from the MPPT algorithm then transfer to input of VSC. Maximum power at the DC link is inverted to CPI at UPF (Unity Power Factor). The system is controlled on boost converter input and output voltages are varying according to detected variable of the circuit. The INC MPPT is used to predict the reference voltage PV system voltage. The PLL (phase lock loop) fewer control is suggested for the VSC control. By using PVFF term reference grid current amplitudes are estimated and voltage error is produced by PI controller. The 3-phase VSC output currents and predictable grid voltages must be synchronized. The impedance voltage (V_p) and Irg are used in SPWM voltage controller for generating the switching pulses to VSC. The control approach of sinusoidal pulse width modulation with an adaptive voltage at DC link for CPI voltage changes with and without PVFF is shown in fig2, fig3.

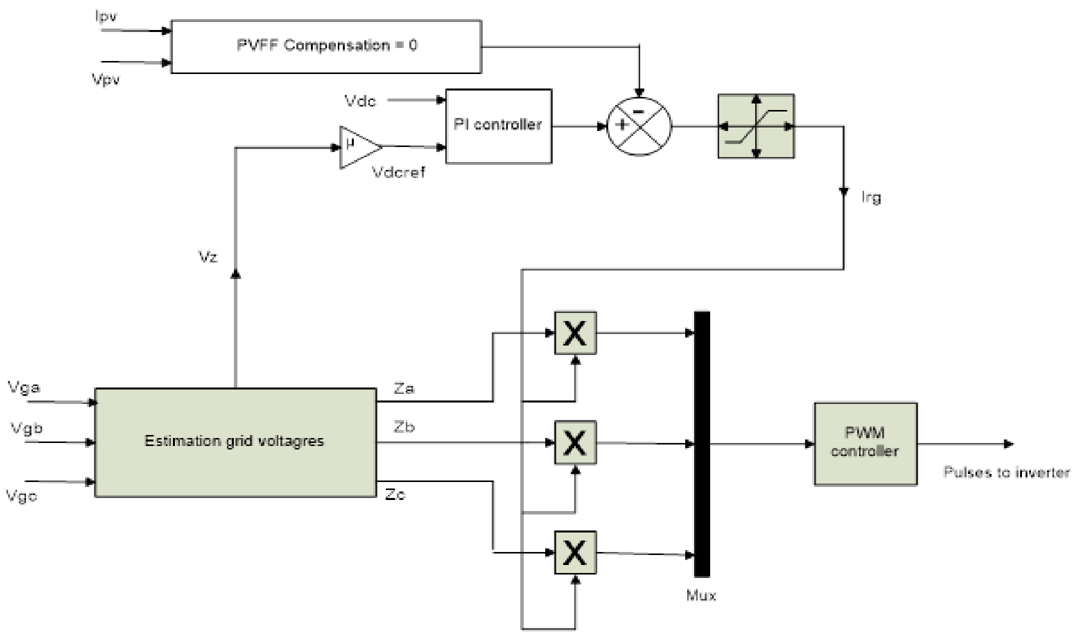

Fig2. Sinusoidal Pulse Width Modulation technique without PVFF

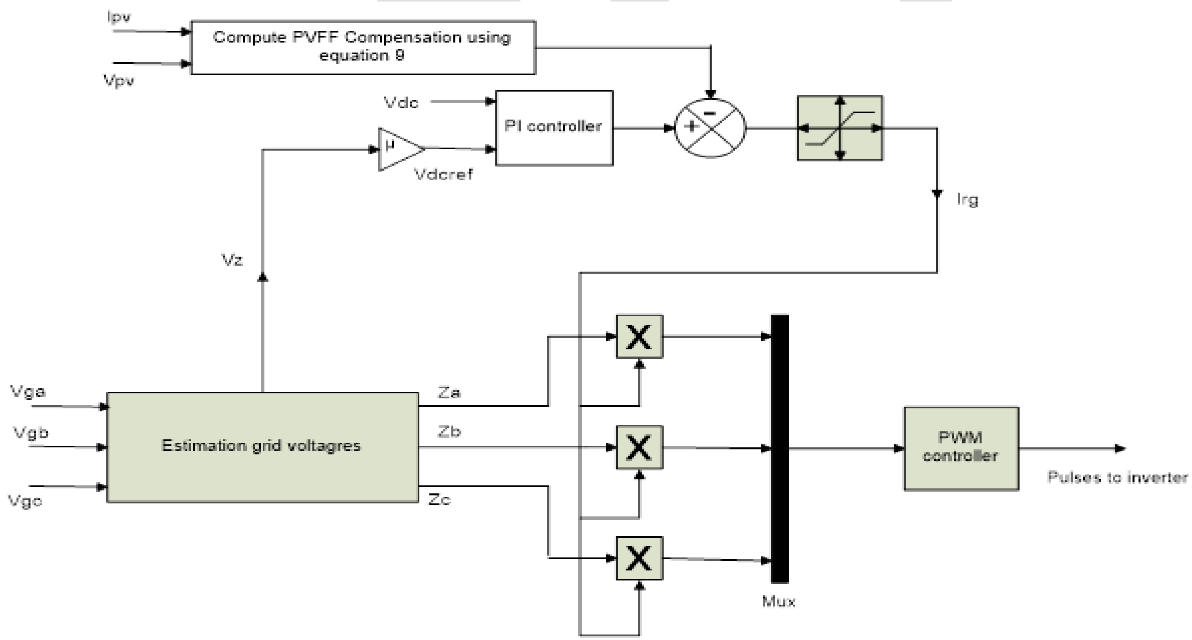

Fig3. Sinusoidal Pulse Width Modulation technique with PVFF

I. *Incremental Conductance MPPT*

The INC algorithm is reducing error between instantaneous conductance and INC conductance of PV array. INC MPPT algorithm estimate the peak power by differentiate the power output of PV panel with PV voltage is shown in equation 1

$$\frac{dP_{pv}}{dV_{pv}} = \frac{d(I_{pv} * V_{pv})}{dV_{pv}} = I_{pv} + V_{pv}\frac{dI_{pv}}{dV_{pv}} \qquad (1)$$

At MPP solution of the above equation is zero, negative solution gives right of the MPP and positive gives left side of the MPP are shown in equation 2, 3 and 4.

$$\frac{\Delta I_{pv}}{\Delta V_{pv}} = \frac{-I_{pv}}{V_{pv}} \qquad (2)$$

$$\frac{\Delta I_{pv}}{\Delta V_{pv}} < \frac{-I_{pv}}{V_{pv}} \qquad (3)$$

$$\frac{\Delta I_{pv}}{\Delta V_{pv}} > \frac{-I_{pv}}{V_{pv}} \qquad (4)$$

II. VSC control approach

The VSC control algorithm is presented in fig2and fig3. The VSC control algorithm main objective is maintain DC link voltage to set reference value. The maximum power at DC link voltage is inject into the grid at UPF with the respect CPI. The grid currents are estimated for controlling the VSC output currents. In phase unit vectors are multiplied with estimated grid currents to keep stable and sinusoidal grid currents. The voltage at DC link (Vdc), line voltages at CPI (Vga, Vgb and Vgc) and the grid currents (Iga, Igb and Igc) are detected. The in-phase unit vectors are expected from phase voltages (V_p) and it is expected from line voltages at CPI. Za, Zb and Zc are the estimated unit vectors.

Estimated CPI voltage amplitudes are,

$$V_p = \sqrt{\frac{2(Vga^2 + Vgb^2 + Vgc^2)}{3}} \qquad (5)$$

Estimated 3-phase unit vectors,

$$Z_a = \frac{V_{ga}}{V_p}, Z_b = \frac{V_{gb}}{V_p}, Z_c = \frac{V_{gc}}{V_p} \qquad (6)$$

For output current of VSC is properly control, the line voltage must be less than the DC link voltage of VSC. The voltage at DC link $V_{dc\,ref}$ is varies with respect to the CPI voltage.

$$V_{dc\,ref} = \mu\sqrt{3V_z}\,, \quad \text{where } \boldsymbol{\mu}>1 \qquad (7)$$

The CPI voltage must be less than the 10% of DC reference voltage. Drip through switches, interfacing inductor resistances are considered for appropriate current control. Later in the projected work $\boldsymbol{\mu}$ is considered as 1.1.The DC link voltage is set to reference of DC link voltage by PI controller. The difference between reference voltage and DC voltage are given to PI controller. For study state PI controller output is considered as loss component, grid currents amplitudes are contain of 2 quantities which are the input from the PV array and loss components. Estimated loss component is,

$$I_{loss}(k) = I_{loss}(k = 1) + K_p\{(V_e(k) - V_e(k-1)\} + K_i V_e(k) \qquad (8)$$

The PVFF word for PV system impact on grid currents is predictable for various changes in PV irradiation and grid voltages and gets quick dynamic response. The estimated PVFF word as,

$$I_{PVg} = \frac{2P_{pv}}{3V_z} \qquad (9)$$

The CPI output currents can expected and considered grid currents direction. Grid loss is drawn where PVFF is served into grid. Estimated grid currents amplitude is,

$$I_{rg} = I_{loss} - I_{PVg} \qquad (10)$$

The amplitude of grid current is estimated I_{rg} is multiplied with the grid voltages, amplitude of 3-phase(V_p)is given to unit delay 1/z then connected to pulse generator for generating the switching pulse to VSC.

4. Discussion on Simulation results

I. *Case 1(PV system without feed forward loop)*

The system act below sudden change in irradiation from 1000 w/m^2 to 500 w/m^2 without the PV feed forward compensation. Shown in fig4 (a), the scheme under steady state condition with solar PV irradiation change at time t=0.3s. The grid power can balanced and sinusoidal but the Ig(A) are decreased due to irradiation change at time t=0.3s are shown in fig4 (a). The PV array current Ipv(A) and voltage Vpv(V) are shown in fig4 (a) for PV irradiation can changed 1000 w/m^2 to 500 w/m^2. The PV array power for different irradiation at time t=0.3s as shown in fig4 (a). It can be detected that the dynamic response PV array system for unexpected change in irradiation level to well suggested system. The PI controller constructed system have been show more deviation and lengthier time to settle as compare suggested system in DC link voltage without PV feed forward based control approach with compensation. The voltage at Dc link Vdc (V) is reformed from 620V to 585Vfor different irradiation at time t=0.3s is shown in fig4 (a). The suggested system control approach as soon as reached the next formal and it's reducing the grid power.

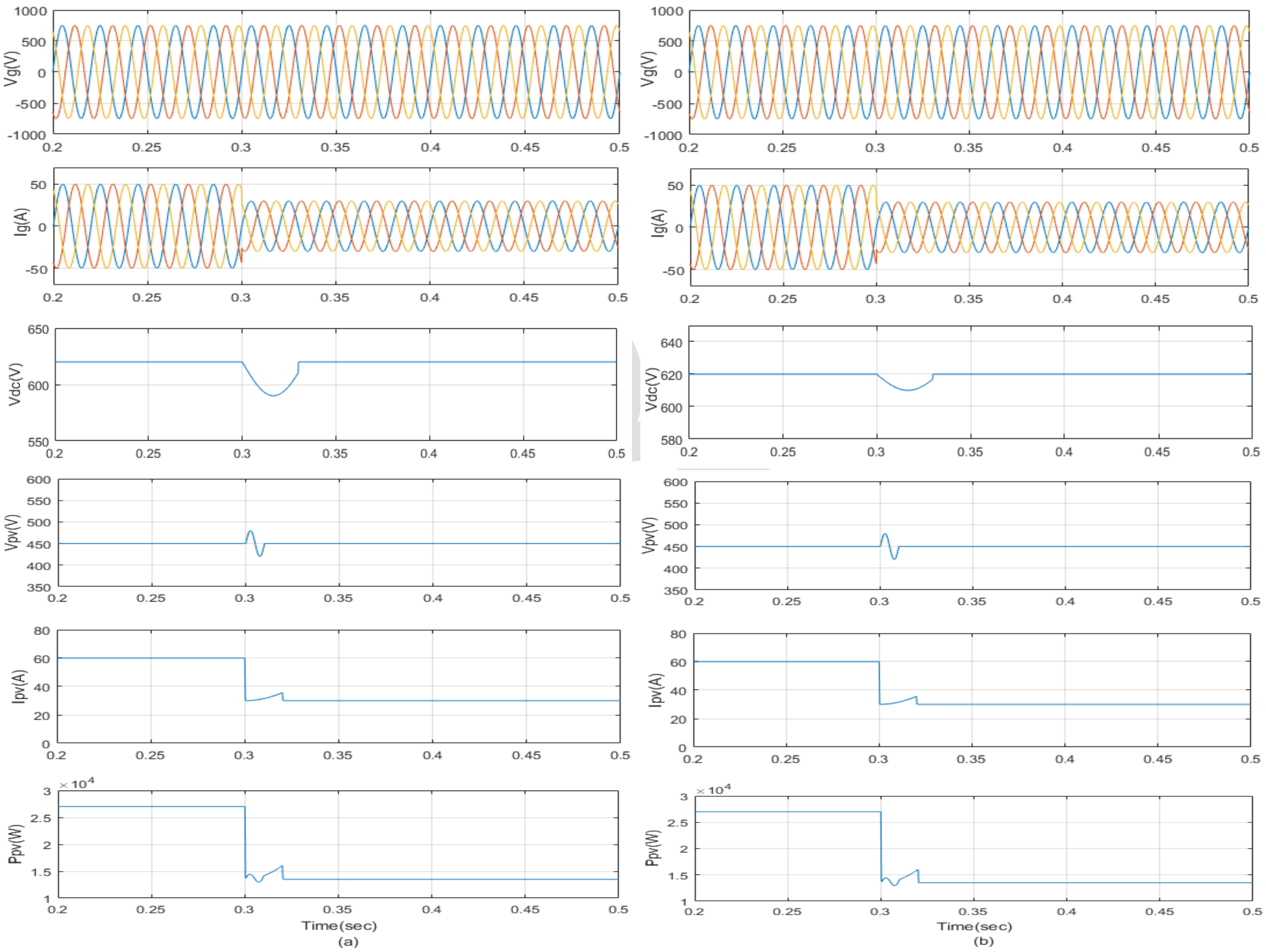

Fig.4simulation results for (a) variation in irradiation of PV array without PV feedforward loop, (b) variation in irradiation of PV array with PV feedforward loop.

II. *Case2 (PV system with feed forward loop)*

The system act as under sudden change in irradiation from 1000 w/m^2 to 500 w/m^2 with the PV feed forward compensation. Shown in fig4 (b), the scheme under steady state condition with solar PV irradiation change at time t=0.3s. The grid power can balanced and sinusoidal but the Ig(A) are decreased due to irradiation change at time t=0.3s are shown in fig4 (b). The PV array current Ipv(A) and voltage Vpv(V) are shown in fig4 (b) for PV irradiation can changed 1000 w/m^2 to 500 w/m^2. The PV array power for different irradiation at time t=0.3s as shown in fig4 (b). It can be detected that the dynamic response PV array system for sudden change in irradiation level to well suggested system. The PI controller based system have been show less deviation and settling time is less as compare suggested system in DC link voltage with PV feed forward based control approach with compensation. The voltage at Dc link Vdc (V) is changed from 620V to 610V for different irradiation at time t=0.3s is shown in fig4 (b). The suggested system control approach as soon as reached the next formal and it's reducing the grid power.

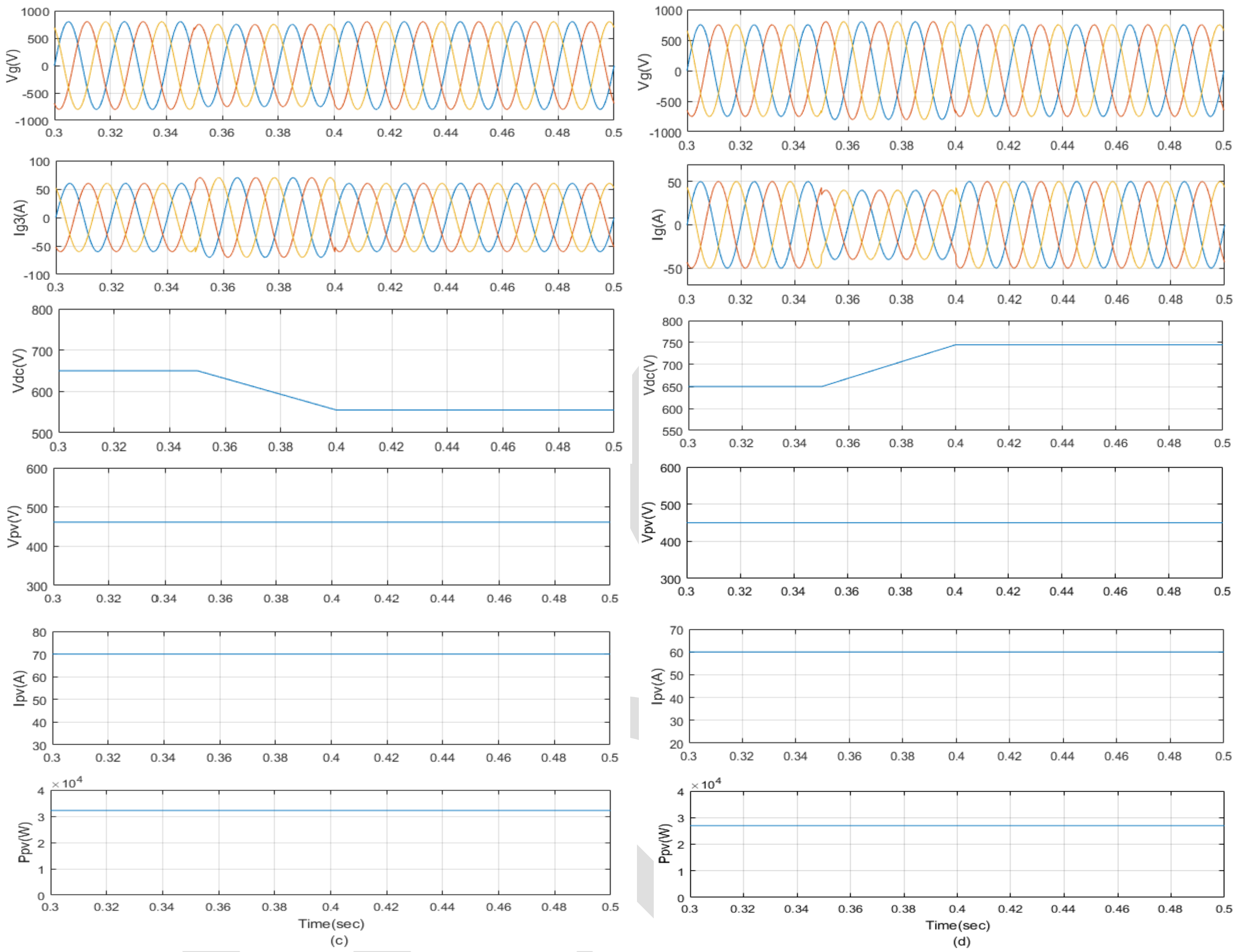

Fig.5simulation results for (a) Under voltage at CPI (415 V to 350 V), (b) Over voltage at CPI (415 V to 480 V).

III. Case 3 (Under Voltage Operation)

The system act as under voltage operation at CPI in steady state and dynamics. The CPI operating voltage is 415V up to time t=0.35s. At CPI the voltage Vg (V), will be decreased to 350V after the time t=0.35s are shown in fig5 (a). The CPI voltage variation is effect on the DC link voltage. The sinusoidal and balanced grid currents Ig (A) are maintained however the grid currents can be increased at time t=0.35s are shown in fig5 (a). No variations is observed at PV system voltage Vpv(V), PV system current Ipv(A), PV system power Ppv(W) are shown in fig5 (a).

IV. Case 4 (Over Voltage Operation)

The system act as over voltage operation at CPI in steady state and dynamics. The CPI operating voltage is 415V up to time t=0.35s. At CPI the voltage Vg(V), will be increased to 480V after the time t=0.35s are shown in fig5 (b). The CPI voltage variation is effect on the voltage at DC link. The sinusoidal and balanced grid currents Ig(A) are maintained however the grid currents can be decreased at time t=0.35s are shown in fig5 (b). No variations is detected at PV system voltage Vpv(V), PV system current Ipv(A), PV system power Ppv(W) are shown in fig5 (b).

5. CONCLUSION

A three-phase grid connected two-stage system has been developed for solar PV system. To control the boost converter composite InC based MPPT algorithm is used. The CPI voltage variation for the different ranges can be demonstrated by proposed topology. Control of grid tied VSC has been proposed by using a modest and novel adaptive DC link voltage control. The CPI voltage changes makes voltage at dc link is adaptive which helps in reduction of losses in the system. For obtains fast dynamic response a PV array feed forward term is used. A feed forward compensation of DC link voltage control loop has been established and evaluated. The PV array feed forward term is selected for the change in PV power and CPI voltage changes. The grid tied VSC strategy is tested on the knowledge of adaptive voltage at DC link, for the given PV array and the same control mechanism can be extended to connected grid interfaces to devices such as, STATCOM, D-STATCOM etc. The simulation results have established the feasibility of suggested control algorithm.

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