PERFORMANCE OF A THREE PHASE TWO STAGE GRID TIED FEED FORWARD TERM BASED SPV WITH DIFFERENT CONDITIONS

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ABSTRACT

This paper deals with a three-phase two-stage grid tied SPV (Solar Photo Voltaic) system. The first stage is a boost converter, which serves the purpose of MPPT (maximum power point tracking) and feeding the extracted solar energy to the DC link of the PV inverter, whereas the second stage is a two-level VSC (voltage source converter) serving as PV inverter which feeds power from a boost converter into the grid. The proposed system uses an adaptive DC link voltage which is made adaptive by adjusting reference DC link voltage according to CPI (common point of interconnection) voltage. The adaptive DC link voltage control helps in the reduction of switching power losses. A feed forward term for solar contribution is used to improve the dynamic response. The system is tested considering realistic grid voltage variations for under voltage and over voltage. The simulation results are carried out with help of MATLAB simulation software.

Key Words: MPPT, Solar Photo Voltage, CPI, Feed Forward Term.

1. INTRODUCTION

The electrical energy has a vital role in development of human race in the last century. The diminishing conventional primary sources for electricity production have posed an energy scarcity condition in front of the world. The renewable energy sources such as solar, wind, tidal etc are few of such options which solve the problem of energy scarcity. The cost effectiveness of any technology is prime factor for its commercial success. The SPV (Solar Photovoltaic) systems have been proposed long back but the costs of solar panels have hindered the technology for long time, however the SPV systems are reaching grid parity [1], [2]. The solar energy based systems can be classified into standalone and grid interfaced systems. The energy storage (conventionally batteries) management is the key component of standalone system. Various problems related to battery energy storage standalone solar energy conversion systems are discussed in [3]–[6].

Considering the problems associated with energy storage systems, the grid interfaced systems are more preferable, in case the grid is present. The grid acts as an energy buffer, and all the generated power can be fed into the grid. Several grid interfaced SPV systems are proposed in past addressing various issues related to islanding, intermittency, modeling etc [7]–[9]. With growing power system, the attention is moving from centralized generation and radial distribution to distributed generation. The distributed generation can bring in several advantages such as reduction in losses, better utilization of distribution resources, load profile flattering etc [10]–[15]. The authors demonstrated various control methods for maximum power tracking from solar system [16]-[20]. In this proposed paper discussed to produce maximum energy output from the given resources and also to reduce the losses in the system using adaptive dc link voltage.

2. SYSTEM CONFIGURATION

The system configuration for the proposed system is shown in Fig.1. A two stage system is proposed for grid tied SPV system. The first stage is a DC-DC boost converter serving for MPPT and the second stage is a two-level three phase VSC. The PV array is connected at the input of the boost converter and its input voltage is controlled such that PV array delivers the maximum power at its output terminals. The output of boost converter is connected to DC link of VSC. The DC link voltage of VSC is dynamically adjusted by grid tied VSC on the basis of CPI voltage. The three phase VSC consists of three IGBT legs. The output terminals of VSC are connected to interfacing inductors and the other end of interfacing inductors are connected to CPI. A ripple filter is also connected at CPI to absorb high frequency switching ripples generated by the VSC. The incremental conductance based MPPT is fast, accurate and easy to implement. In this project, a composite InC based MPPT method is used. The composite InC method is a combination of fractional Voc and InC based method. Simulation parameters are given in the table.3.

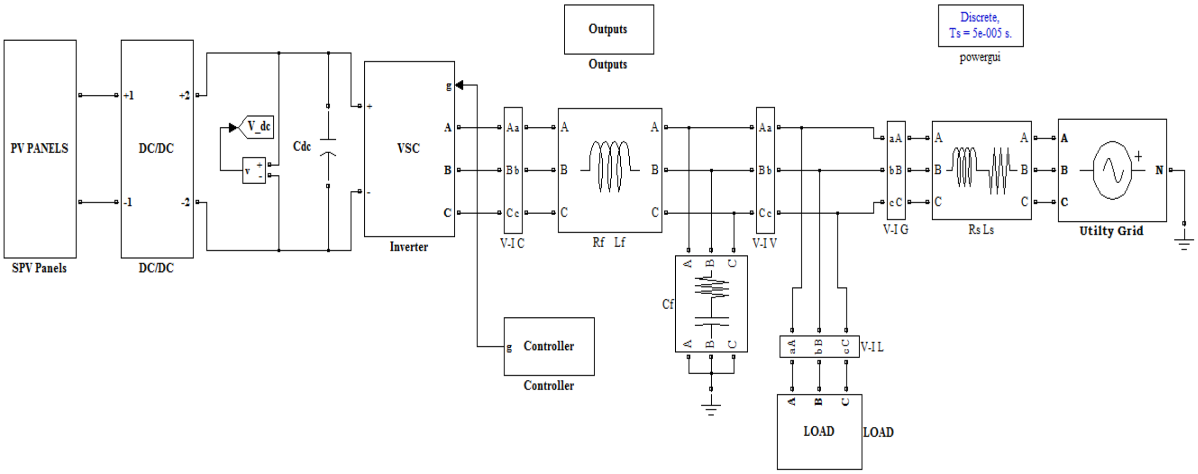

Fig.1 Simulink model of a three phase grid tied SPV system with Adaptive DC link voltage for CPI voltage variations

3. SIMULATION RESULT AND DISCUSSION

3.1 PERFORMANCE UNDER SUDDEN CHANGE IN SOLAR INSOLATION WITHOUT FEED FORWARD TERM

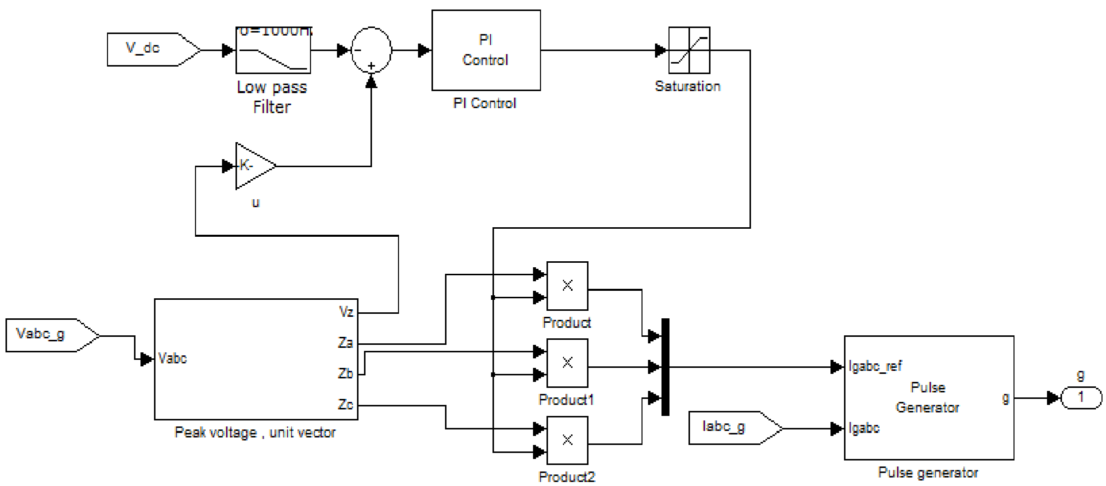

Fig.2 Simulink model for controller of VSC without feed forward term

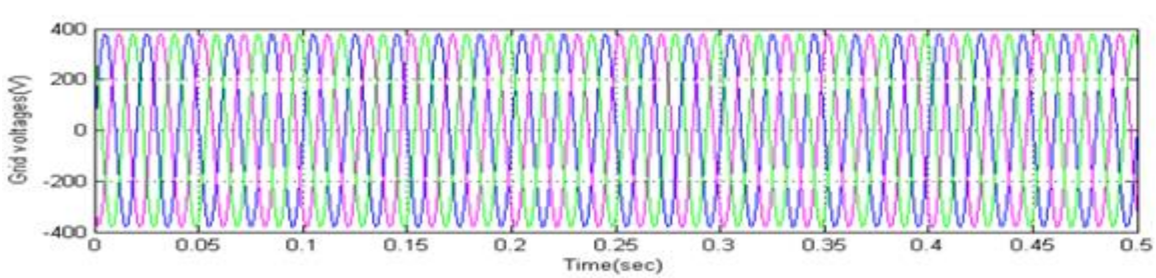

Fig.3 Grid Voltage Waveform for without FFT

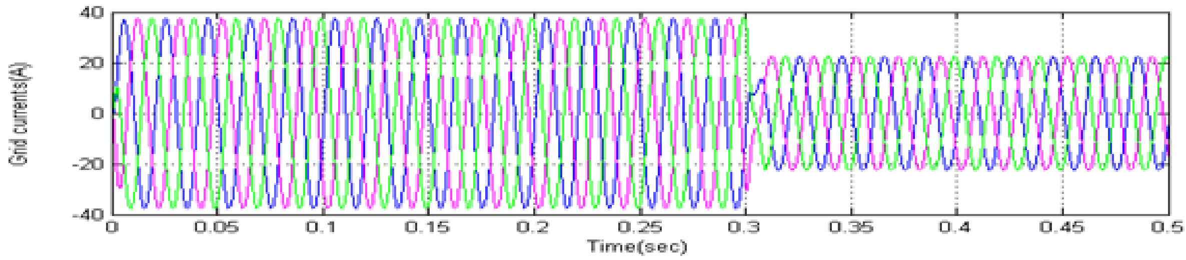

Fig.4 Grid Current Waveform for without FFT

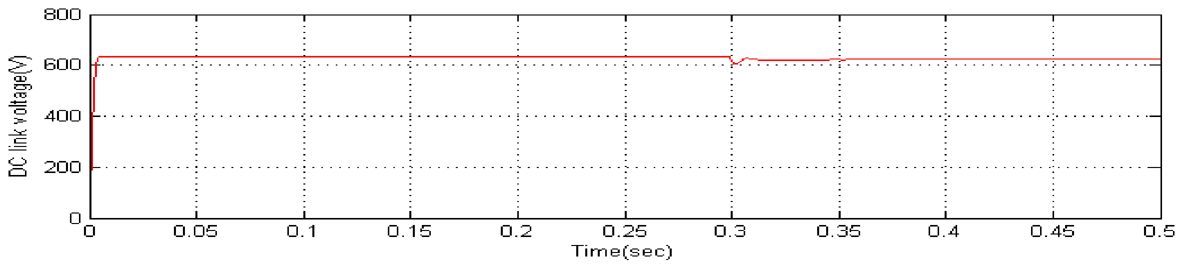

Fig.5 DC link Voltage Waveform for without FFT

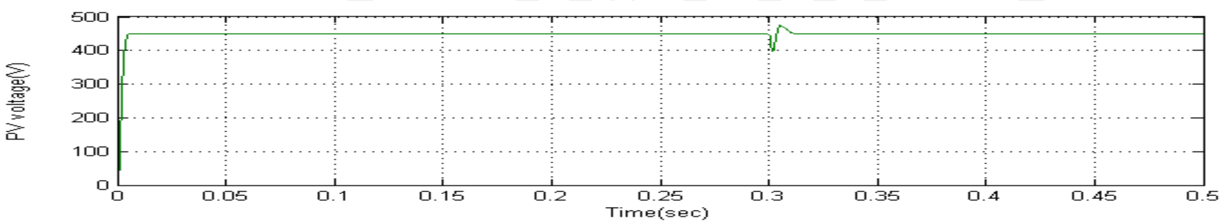

Fig.6 PV Voltage Waveform for without FFT

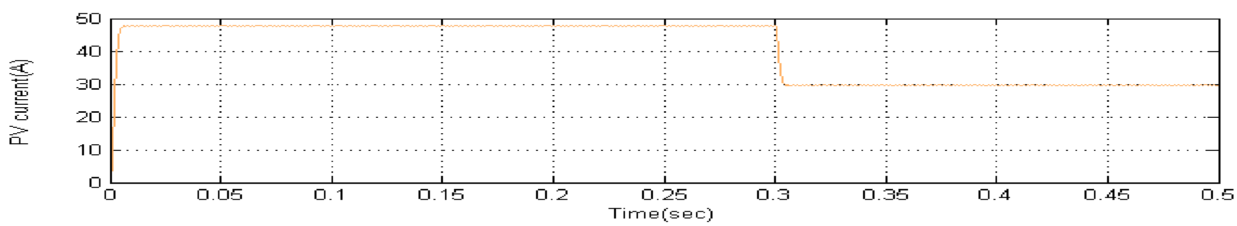

Fig.7 PV Current Waveform for without FFT

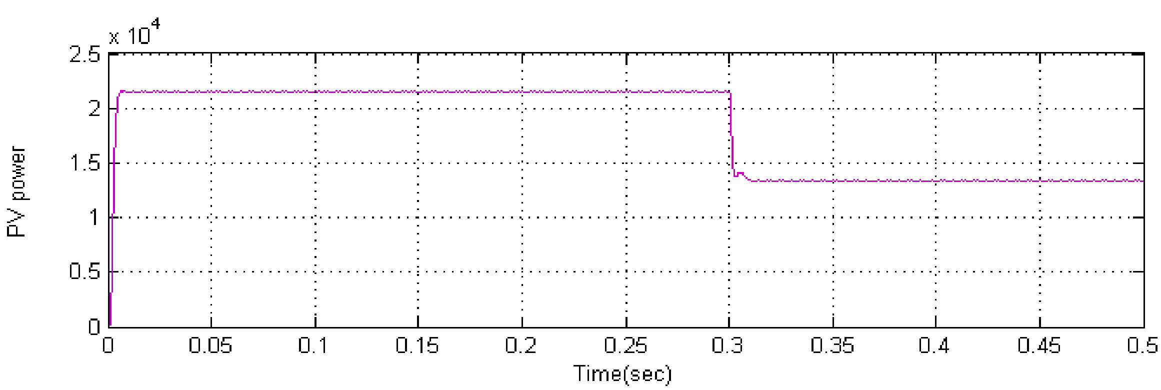

Fig.8 PV Power Waveform for without FFT

From Fig.3 to Fig.8 shows the performance of proposed system under sudden change in insolation without feed forward compensation respectively. Before time t = 0.3s, the system is working under steady state condition with SPV insolation. The PV array current decreases due to decrease in insolation and so is the PV array power. The values are tabulated from table.1.

3.2 PERFORMANCE UNDER SUDDEN CHANGE IN SOLAR INSOLATION WITH FEED FORWARD TERM

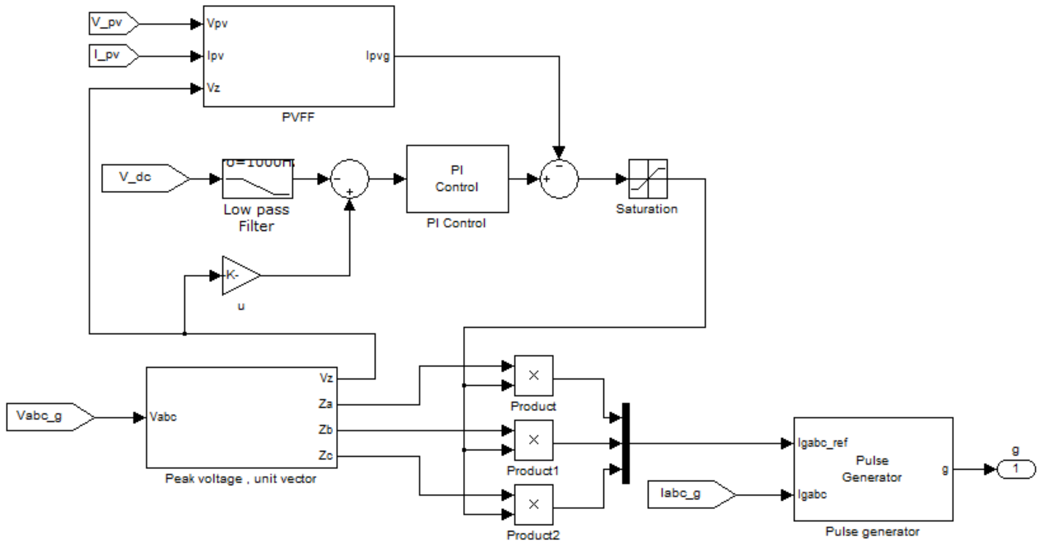

Fig.9 Simulink model for controller of VSC with feed forward term

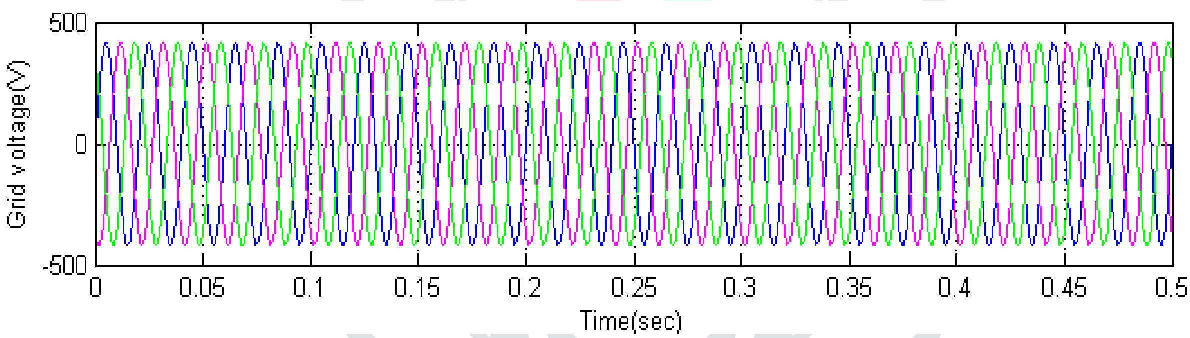

Fig.10 Grid Voltage Waveform for with FFT

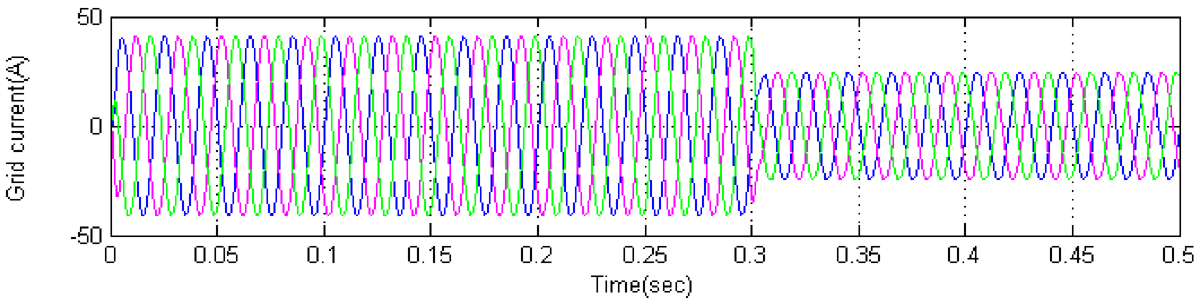

Fig.11 Grid Current Waveform for with FFT

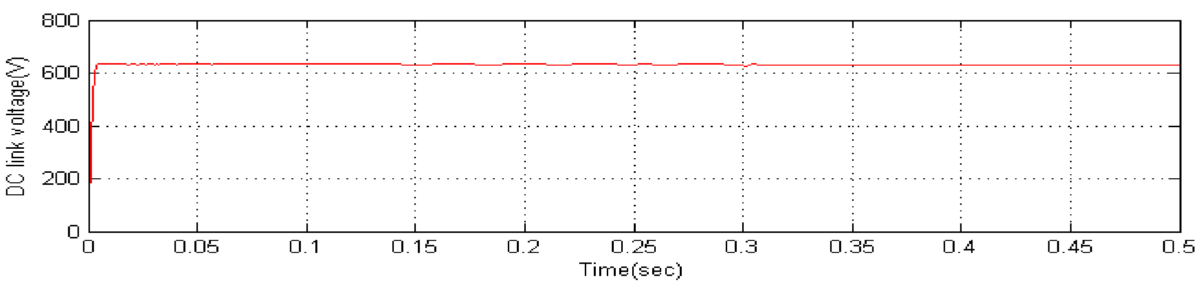

Fig.12 DC link Voltage Waveform for with FFT

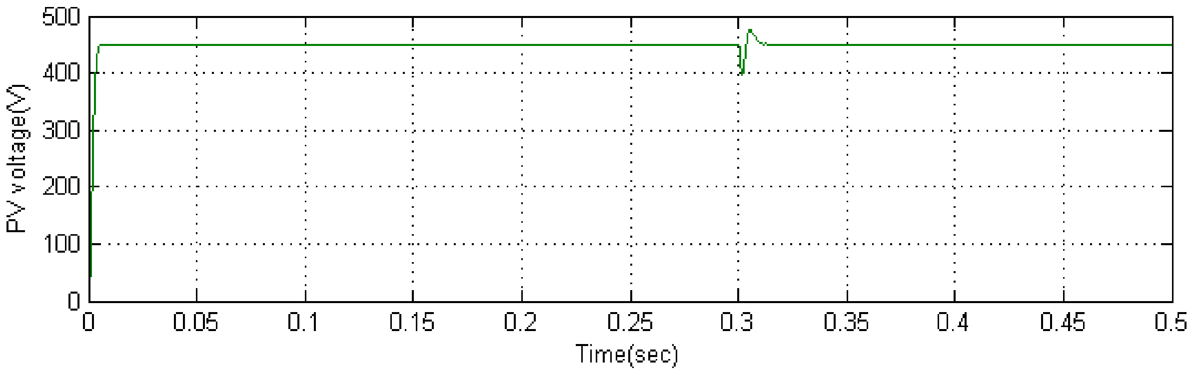

Fig.13 PV Voltage Waveform for with FFT

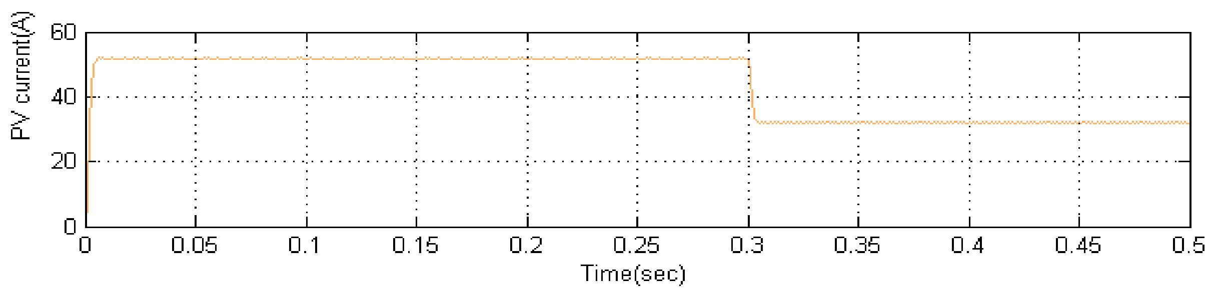

Fig.14 PV Current Waveform for with FFT

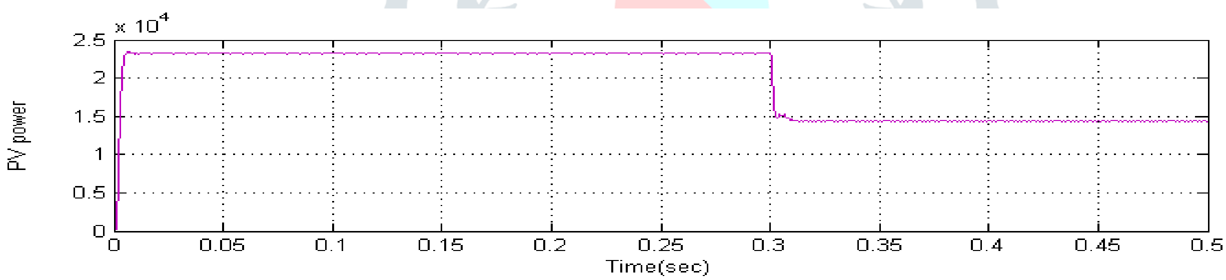

Fig.15 PV Power Waveform for with FFT

From Fig.10 to Fig.15 shows the performance of proposed system under sudden change in insolation with feed forward compensation respectively. It can be easily observed that the dynamic response for sudden change in insolation level is better for proposed system. The DC link voltage for only PI controller based system shows more deviation and longer time to settle as compared to proposed system with feed forward compensation based control approach. The system with proposed control approach soon reaches the next state and it feeds the reduced power into the grid Performance of with feed forward term values are tabulated in table.1.

	Performance of Sudden Change in Solar Insolation Without Feed Forward Term		Performance of Sudden Change in Solar Insolation With Feed Forward Term	
	Before 0.3 sec	After 0.3 sec	Before 0.3 sec	After 0.3 sec
Grid Voltage (V)	390	390	415	415
Grid Current (A)	38	22	42	26
DC link Voltage (V)	630	610	640	640
PV Voltage (V)	440	445	440	445
PV Current (A)	48	30	52	32
PV Power (W)	$2.2x10^{+4}$	$1.35x10^{+4}$	$2.3x10^{+4}$	$1.45x10^{+4}$

Table.1 Comparison of without FFT and with FFT

3.3 PERFORMANCE FOR UNDER VOLTAGE OPERATION

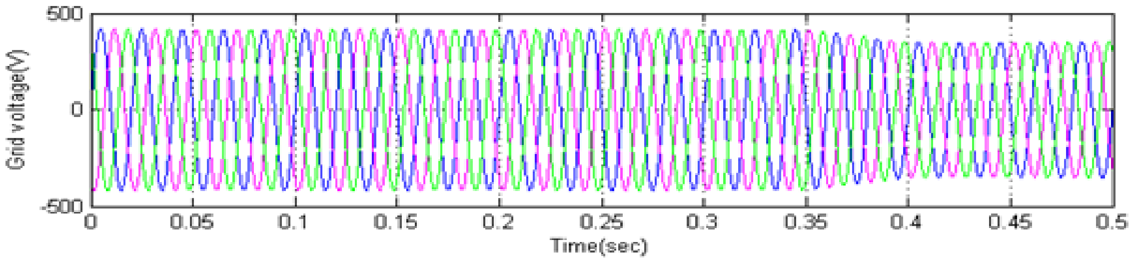

Fig.16 Grid Voltage Waveform for Under Voltage Operation

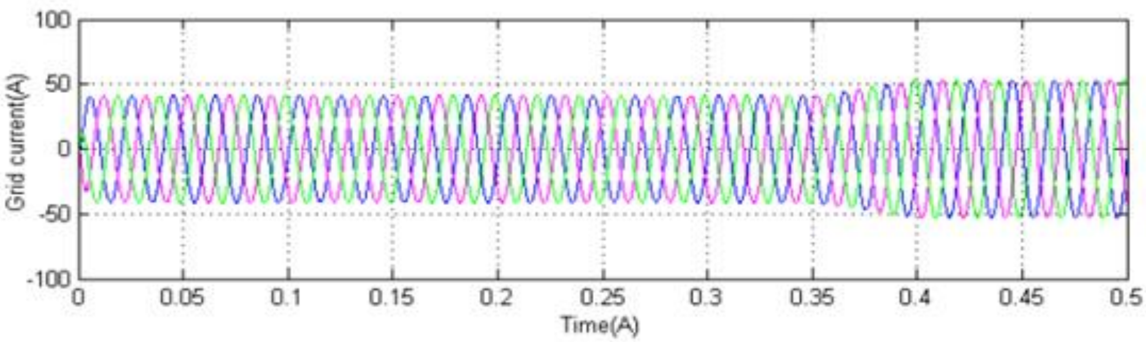

Fig.17 Grid Current Waveform for Under Voltage Operation

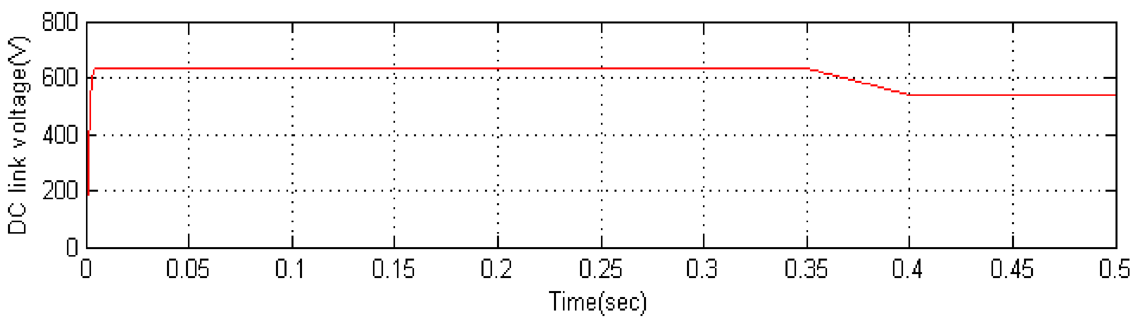

Fig.18 DC link Voltage Waveform for Under Voltage Operation

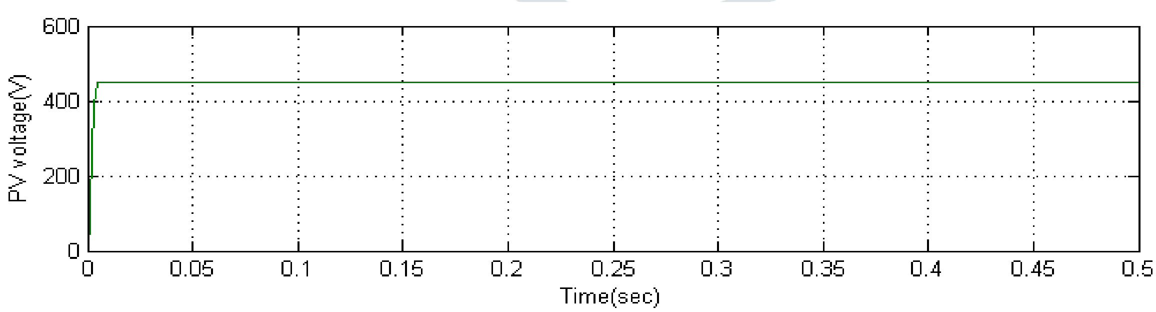

Fig.19 PV Voltage Waveform for Under Voltage Operation

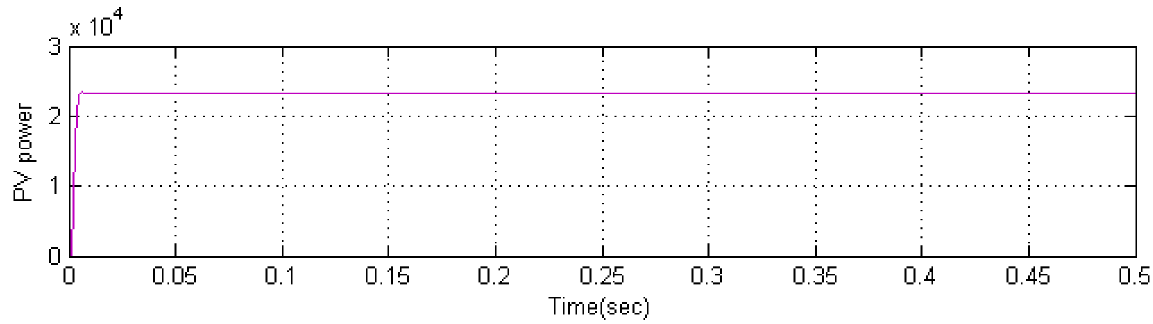

Fig.20 PV Power Waveform for Under Voltage Operation

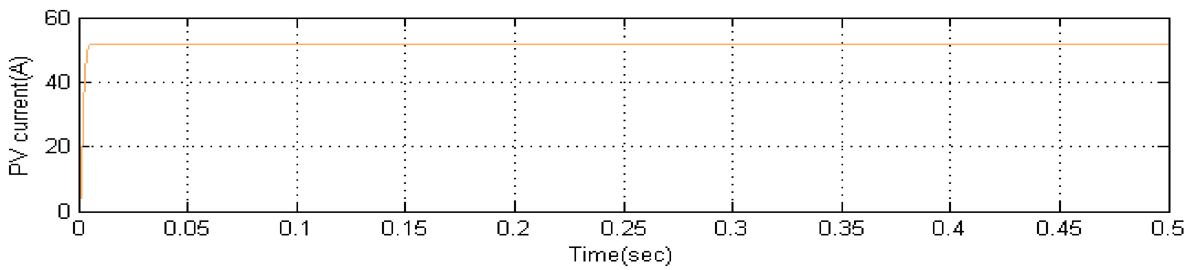

Fig.21 PV Current Waveform for Under Voltage Operation

From Fig.18 to Fig.21 shows the steady state and dynamics performance of the system for under voltage operation at CPI. Before time t = 0.35 s, the system is operating at CPI voltage of 415 V. The CPI voltage decreases from 415 to 350 V during 0.35 s to 0.4 s. The adaptive nature of DC link voltage can be observed. The DC link voltage also decreases with the decrease in CPI voltage. The grid currents are maintained balanced and sinusoidal all the time however, an increase in grid currents is observed to feed the same PV power at reduced voltage. All the values are tabulated from table.2.

3.4 PERFORMANCE FOR OVER VOLTAGE OPERATION

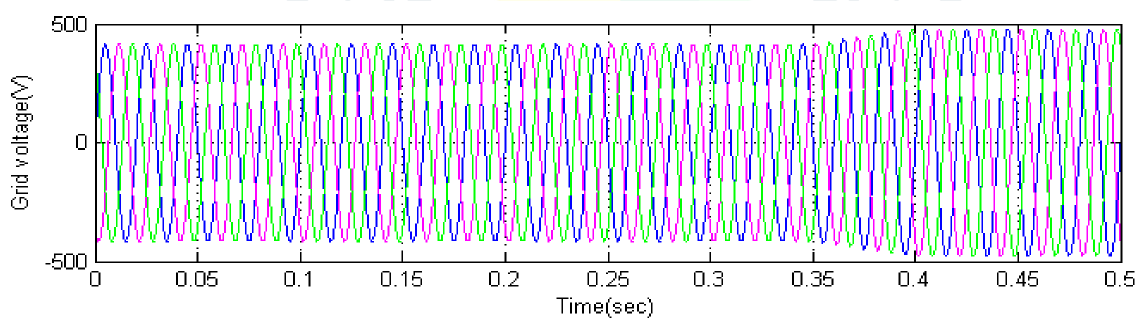

Fig.22 Grid Voltage Waveform for Over Voltage Operation

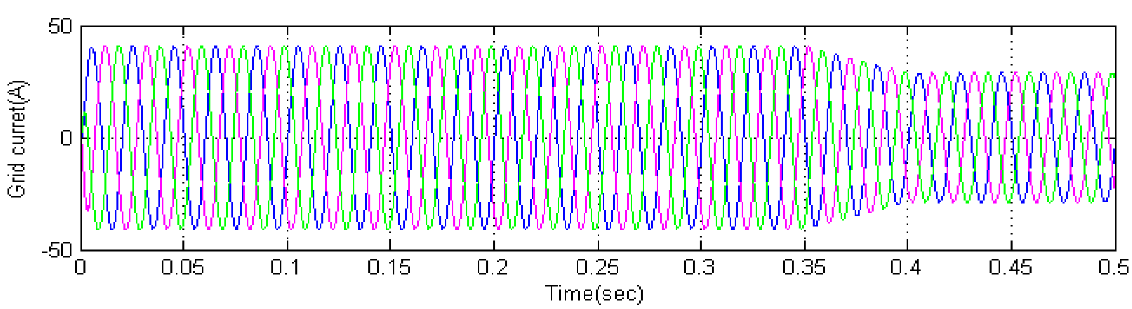

Fig.23 Grid Current Waveform for Over Voltage Operation

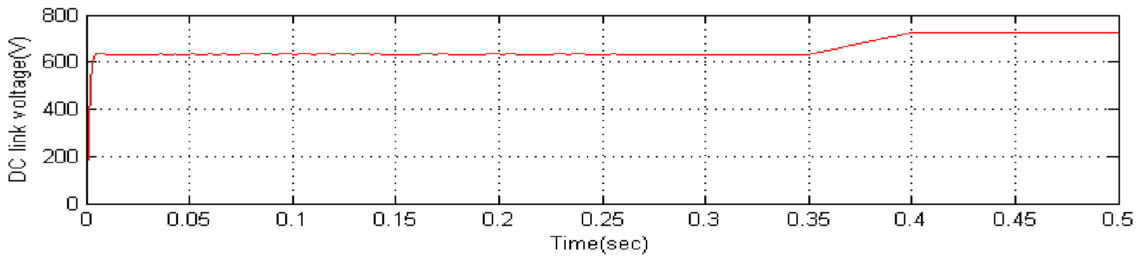

Fig.24 DC link Voltage Waveform for Over Voltage Operation

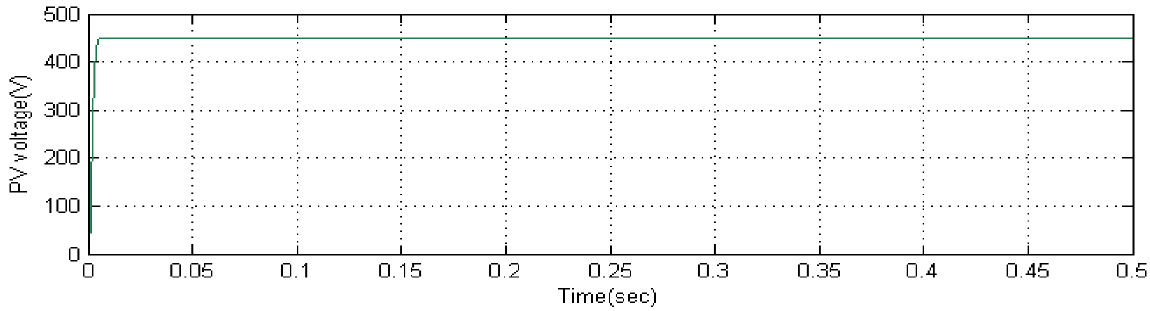

Fig.25 PV Voltage Waveform for Over Voltage Operation

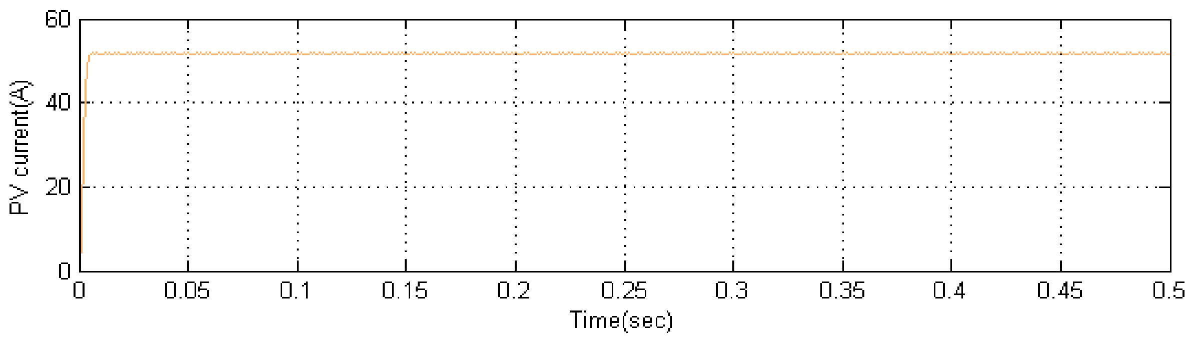

Fig.26 PV Current Waveform for Over Voltage Operation

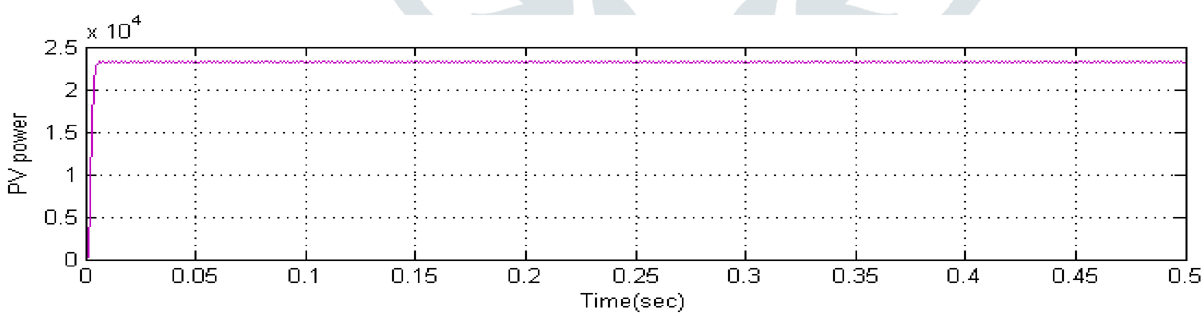

Fig.27 PV Power Waveform for Over Voltage Operation

From Fig.22 to Fig.27 shows the steady state and dynamics performances of the system for over voltage operation at CPI. Before time t = 0.35 s, the system is operating at CPI voltage of 415 V. The CPI voltage increases from 415 to 480 V during 0.35 s to 0.4 s. The DC link voltage also increases with an increase in CPI voltage, which shows the adaptive nature of DC link voltage. The grid currents are maintained balanced and sinusoidal all the time however, a decrease in grid currents is observed to feed the same PV power at the increased voltage. No appreciable effect is observed on PV array voltage (Vpv), PV array current Ipv), and PV array power (Ppv). All the values are tabulated from table.2.

	Performance for Under Voltage Operation		Performance for Over Voltage Operation	
	Before 0.3 sec	After 0.3 sec	Before 0.3 sec	After 0.3 sec
Grid Voltage (V)	415	350	415	480
Grid Current (A)	42	50	42	34
DC link Voltage (V)	620	540	640	720
PV Voltage (V)	440	440	440	440
PV Current (A)	52	52	52	52
PV Power (W)	$2.4x10^{+4}$	$2.4x10^{+4}$	$2.45x10^{+4}$	$2.45x10^{+4}$

Table.2 Comparison of under voltage performance and over voltage performance

Three-phase grid voltage	415V
Frequency	50Hz
Supply inductance	2.42mH
Supply resistance	0.76ohms
Interfacing inductor	4Mh
Ripple filter	R=5ohm, C=5µF, Kp=1, Ki=2.1
PV array open circuit voltage	500V
PV array short circuit current	70A
PV array peak power	25kw
µ	1.1

Table.3 Simulation Parameters

4. CONCLUSION

A two-stage system has been proposed for three-phase grid connected solar PV generation with different conditions. For first stage of boost converter operation, InC based MPPT algorithm is used. The performance of proposed system has been demonstrated for wide range of CPI voltage variation. A simple and novel adaptive DC link voltage control approach has been proposed for control of grid tied VSC. The DC link voltage is made adaptive with respect to CPI voltage which helps in reduction of losses in the system. Moreover, a PV array feed forward term is used which helps in fast dynamic response. The PV array feed forward term is so selected that it is to accommodate for change in PV power as well as for CPI voltage variation.

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