Adaptive Pi Controller Based Control of Spu for Maintaining Constant Cpi Voltages

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Abstract

Solar photo Voltaic (SPV) systems based grid interfacing systems involve two stage power conversions. This conversion requires Maximum Power Point Tracking (MPPT) based boost converter that can supply a constant DC link voltage with a SPV as its input as the first stage. The second stage conversion involves a two-level Voltage Source Converter (VSC) that serves as an inverter which feed power from the boost converter to the grid. To meet the grid requirements the voltage at the Common Point of Interconnection (CPI), the voltage of the inverter must be made equal to the voltage of CPI. This can be done adjusting DC link voltage of stage one of the converter. This can be achieved by using anadaptive feed forward Proportional and integral Controller (PI). The advantage of this controller is that it improves dynamic response, reduces the switching losses and provides robust response under grid voltage variations. The performance of the system is verified with the help of MATLAB based simulation studies and the case studies are presented.

1. Grid Interfaced Systems

1.0 Introduction

The importance for sustainable energy sourceshas been increasing for the past two decades becauseof scarcities of fossil fuel and global warming.Nowadays the most admirable energy sources outall renewable energy sources are wind energy andsolar energy because of advancement in powerelectronics techniques. Especially Solar electricenergy became most popular because of advisementin manufacturing technologies and cost advantages In solar energy system inverter is the main partwhich converts DC power obtained from solar cellsin to AC power to fed in to the Grid. NowadaysMultilevel inverters are drawing attention fromresearchers and manufacturers due to their morebenefits over conventional three level pulse widthmodulated inverter [PWM] inverters. They offerimproved output waveforms, smaller filter size, lowerEMI, lower total harmonic distortion (THD), and others

The three common topologies for multi level inverters are as follows:

1) Diode clamped (neutral clamped)

2) Capacitor clamped (flying capacitors) and 3) Cascaded H-bridge inverter

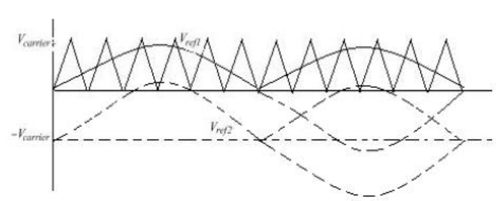

Figure 1.1: Carrier and Reference Signals.

In addition, several modulation and control strategies have been developed or adopted formultilevel inverters, including the following :multilevel sinusoidal (PWM), multilevel selective harmonic elimination, and space-vector modulation

A typical single-phase five-level inverter adopts full-bridge configuration by using approximate sinusoidal modulation technique as the powercircuits. The output voltage then has the followingfive values: zero, +1/2Vdc, Vdc,-1/2Vdc and –Vdc(assuming that Vdc is the supply voltage). Theharmonic components of the output voltage aredetermined by the carrier frequency and switchingfunctions. Therefore, their harmonic reduction islimited to a certain degree.

To overcome this limitation, this paper presents a13 level PWM inverter whose output voltage can berepresented in the following 13 levels: zero, +1/12Vdc, +1/6 Vdc, +1/4 Vdc, +1/3 Vdc, +5/12 Vdc, +1/2Vdc, -1/2Vdc, -5/12Vdc, -1/3Vdc, -1/4Vdc, -1/6Vdc and -1/12Vdc. As the number of output levels increases,the harmonic content can be reduced. This invertertopology uses two reference signals, instead of onereference signal, to generate PWM signals for theswitches. Both the reference signals Vref1 and Vref2 areidentical to each other, except for an offset valueequivalent to the amplitude of the carrier signalVcarrier, as shown in Fig.1. Because the inverter isused in a PV system, a proportional–integral (PI)current control scheme is employed to keep theoutput current sinusoidal and to have high dynamicperformance under rapidly changing atmosphericconditions and to maintain the power factor at nearunity. Simulation and experimental results arepresented to validate the proposed inverterconfiguration.

THE PHOTOVOLTAIC SYSTEM

A PV system consists of a number of interconnected components designed to accomplish a desired task, which may be to feed electricity into the main distribution grid, to pump water from a well, to power a small calculator or one of many more possible uses of solar-generated electricity. The design of the system depends on the task it must perform and the location and other site conditions under which it must operate. This section will consider the components of a PV system, variations in design according to the purpose of the system, system sizing and aspects of system operation and maintenance.

SYSTEM DESIGN

There are two main system configurations – stand-alone and grid-connected. As its name implies, the stand-alone PV system operates independently of any other power supply and it usually supplies electricity to a dedicated load or loads. It may include a storage facility (e.g. battery bank) to allow electricity to be provided during the night or at times of poor sunlight levels. Stand-alone systems are also often referred to as autonomous systems since their operation is independent of other power sources. By contrast, the grid-connected PV system operates in parallel with the conventional electricity distribution system. It can be used to feed electricity into the grid distribution system or to power loads which can also be fed from the grid.

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It is also possible to add one or more alternative power supplies (e.g. diesel generator, wind turbine) to the system to meet some of the load requirements. These systems are then known as 'hybrid' systems.

Hybrid systems can be used in both stand-alone and grid-connected applications but are more common in the former because, provided the power supplies have been chosen to be complementary, they allow reduction of the storage requirement without increased loss of load probability. Figures below illustrate the schematic diagrams of the three main system types.

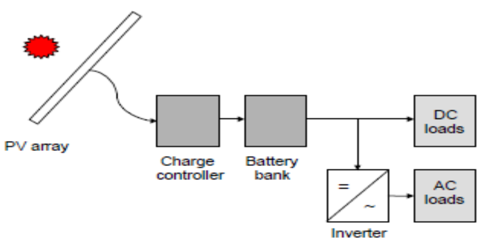

Fig.Schematic diagram of a stand-alone photovoltaic system.

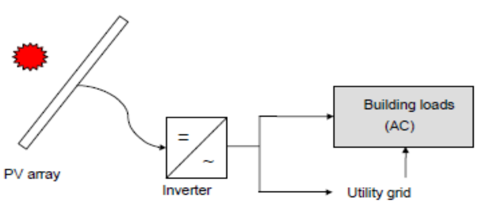

Fig.Schematic diagram of grid-connected photovoltaic system.

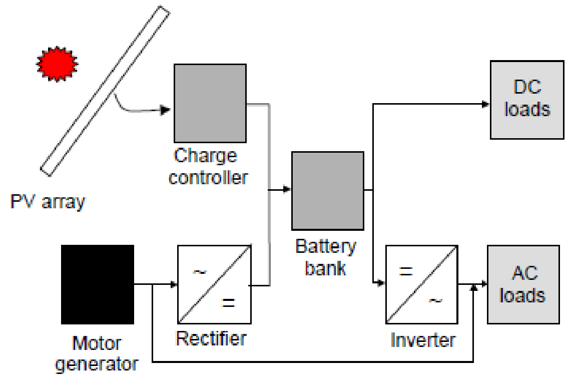

Fig. Schematic diagram of hybrid system incorporating a photovoltaic array and a motor generator (e.g. diesel or wind).

Modeling and Case study

The use of two stage SPV generation system has beenproposed by several researchers.Conventionally aDC-DC converter is used as first stage which serves the purposeof MPPT. The duty ratio of DC-DC converter is so adjusted thatPV array operates at MPP point. The second stage is a grid tiedVSC (Voltage Source Converter) which feeds the power intothe distribution system. A single phase two stage grid tied PVgeneration system with constant DC link voltage is shown. Moreover, the three phase grid tied PV generation systemwith constant DC link voltage control is also shown in [21],[22]. The concept of loss reduction by adaptive DC link voltagefor VSC in hybrid filters is shown in [23], [24] wherein, the DClink voltage is adjusted according to reactive power requirementof filter. However, in the proposed system the DC link voltageof VSC is made adaptive with respect to CPI voltage variation.

Moreover, the circuit topologies in both the systems are different. Therefore, the work presented in [23], [24] is very differentfrom the proposed work.For proper control of VSC currents, the DC link voltage reference is set more than peak of three phase line voltages. Thelimitation for current control in single-phase grid connectedconverter is shown in [25]. Considering the variation of CPI(Common Point of Interconnection) voltage, the reference DClink voltage is kept above the maximum allowable CPI voltage.

Therefore in case of fixed DC link voltage control for VSC, thesystem always operates at a DC link voltage corresponding toworst case condition.

The system configuration for the proposed system is shownin Fig. 1. A two stage system is proposed for grid tied SPVsystem. The first stage is a DC-DC boost converter serving forMPPT and the second stage is a two-level three phase VSC.

The PV array is connected at the input of the boost converterand its input voltage is controlled such that PV array delivers the maximum power at its output terminals. The outputof boost converter is connected to DC link of VSC. The DClink voltage of VSC is dynamically adjusted by grid tied VSCon the basis of CPI voltage. The three phase VSC consists ofthree IGBT legs. The output terminals of VSC are connected tointerfacing inductors and the other end of interfacing inductorsare connected to CPI. A ripple filter is also connected at CPIto absorb high frequency switching ripples generated by theVSC.

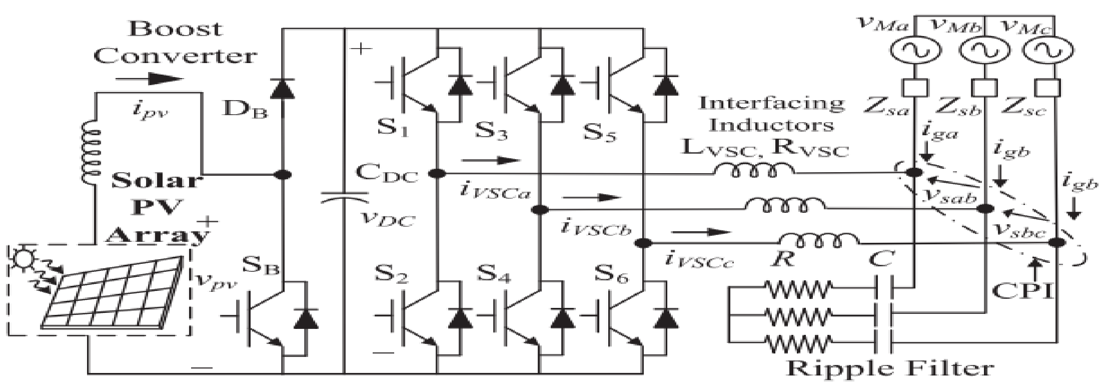

Figure : System Configuration under consideration

Model SIMULATION

With the available stability conditions the simulation model for the system configuration shown in fig 1 is presented in figure 2. The System parameters are presented in table 1.

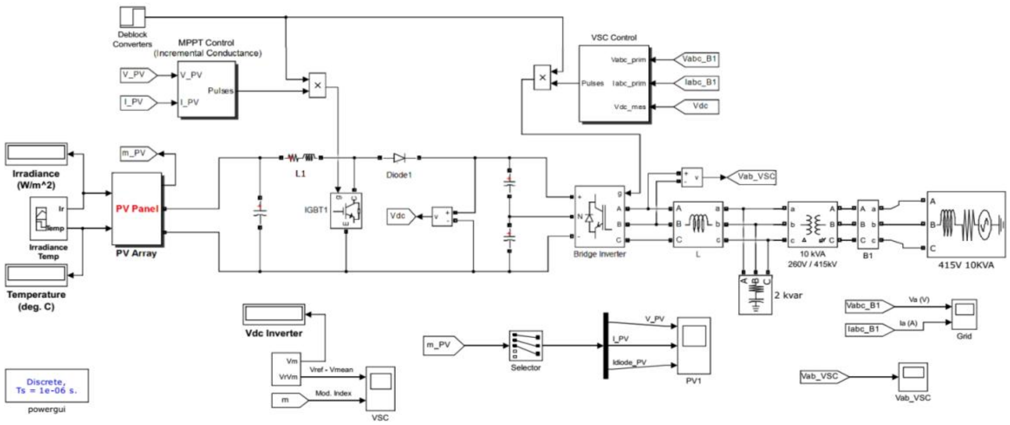

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Figure 2: MATLAB based schematic of Transformer less boost Converter

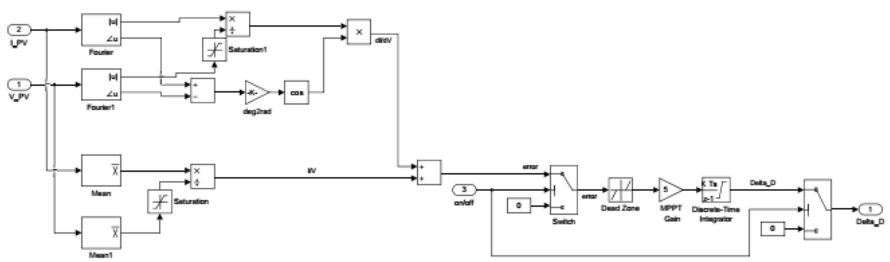

Figure 3: MATLAB based model of MPPT Controller

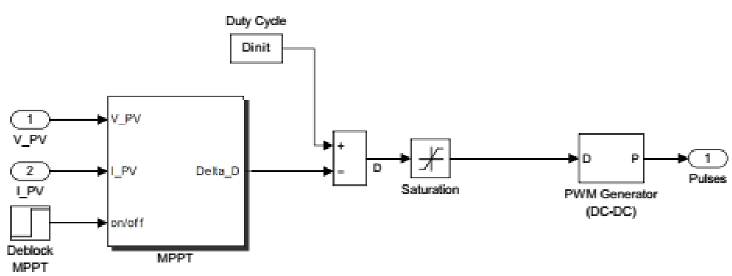

Figure 4: MPPT Controller used for generation trigger pulses to DC – DC converter

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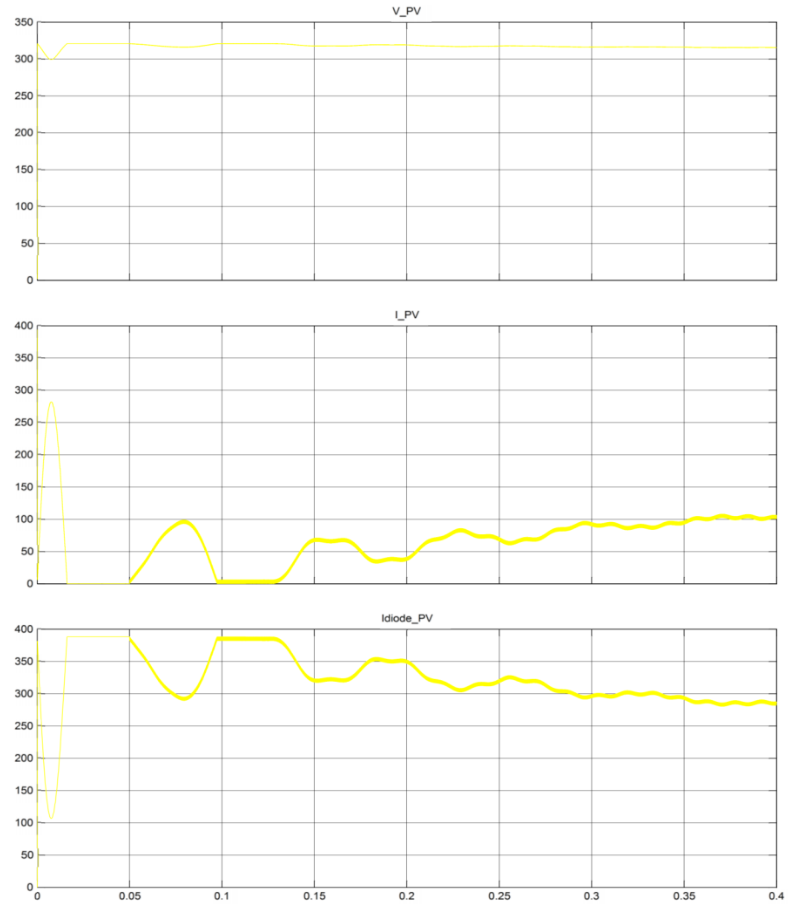

Figure 5: Voltages and currents of MPPT based PV Cell

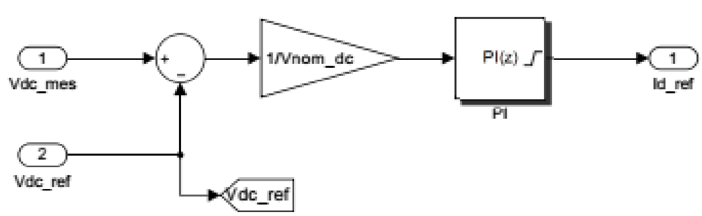

Figure 6: Block Diagram of DC Voltage regulator

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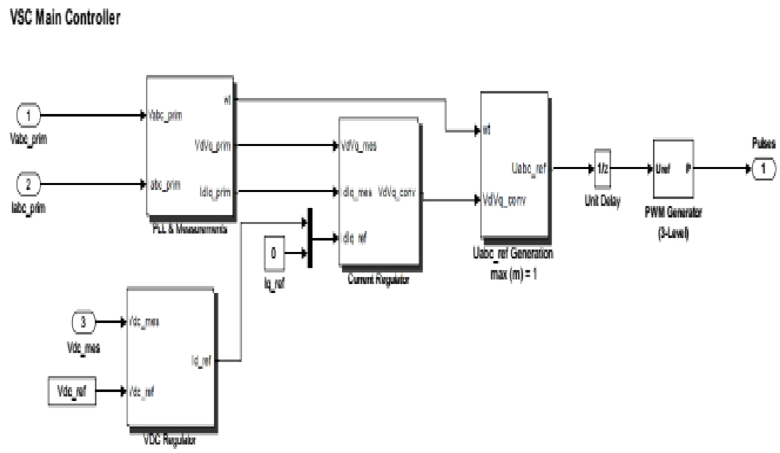

Figure 7: Block Diagram of Voltage Source Converter

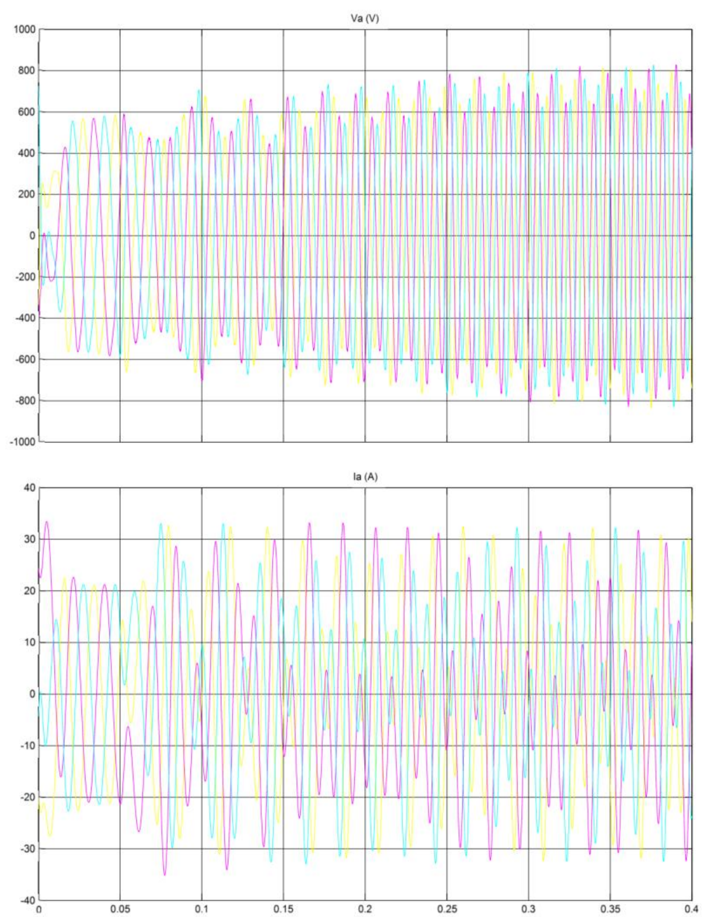

Figure 8: Voltage and currents supplied by Voltage Source Converter

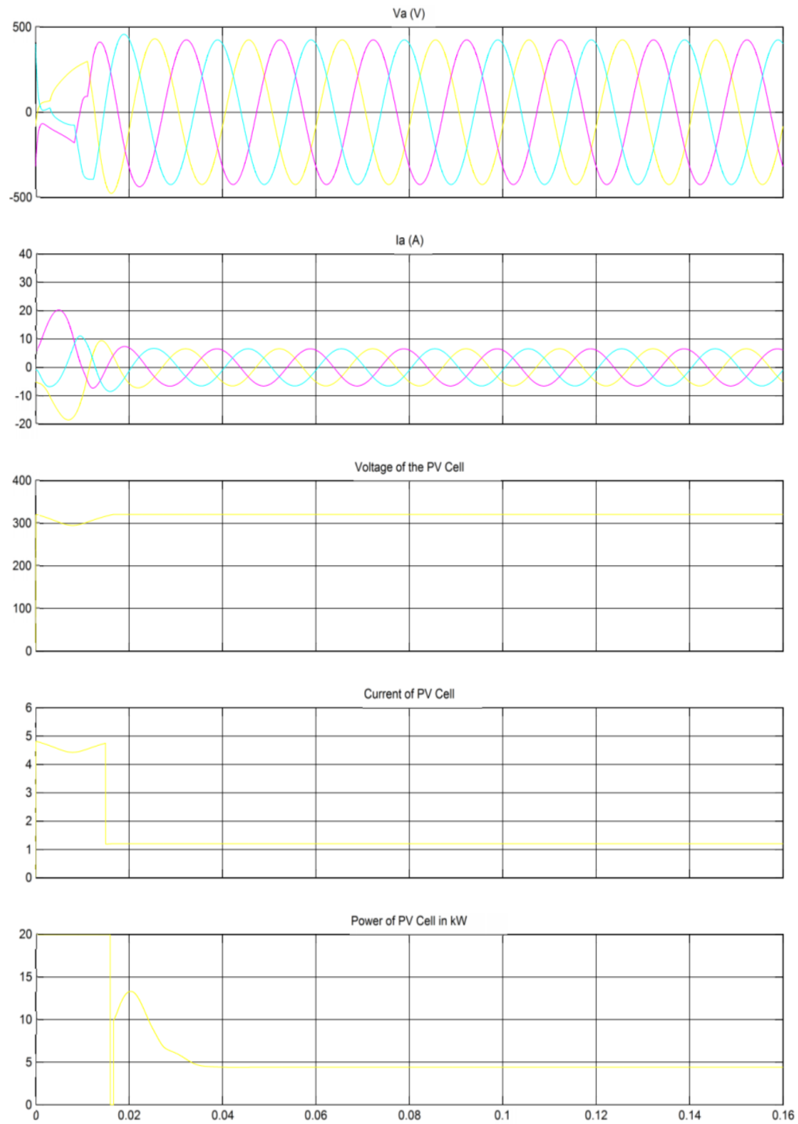

Figure 9: Simulated performance for change in solar insolation without feedforward for PV contribution

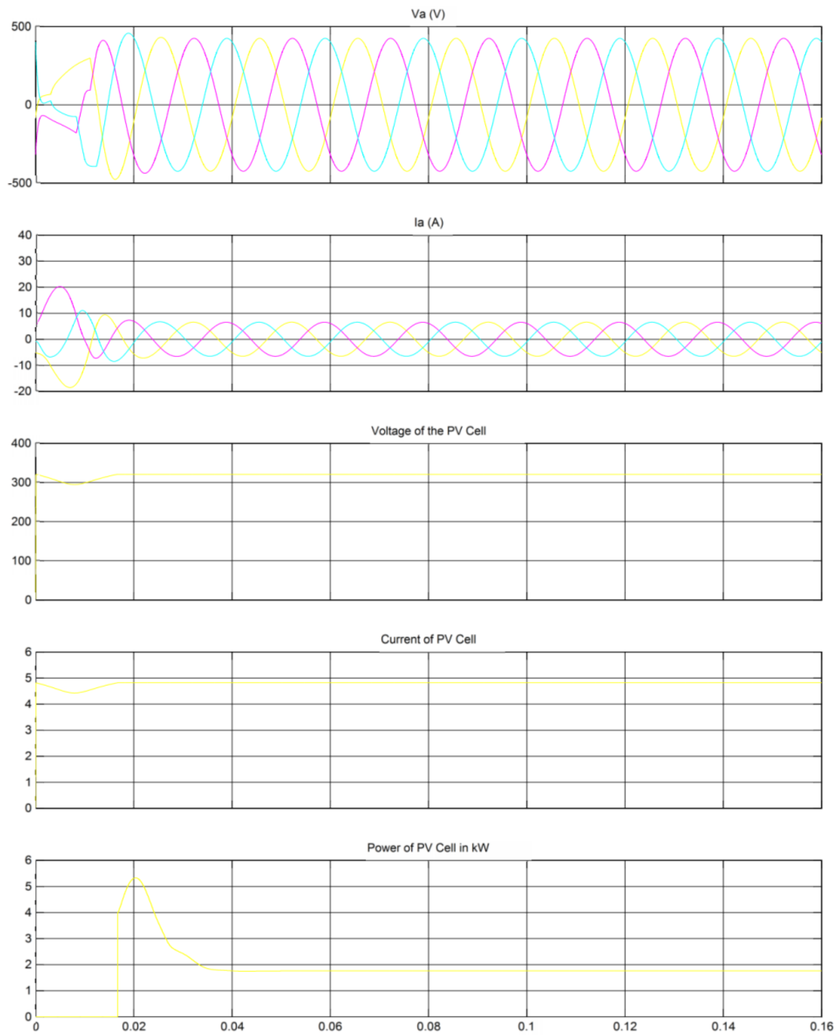

Figure 10: Simulated performance for change in solar insolation with feedforward for PV Contribution

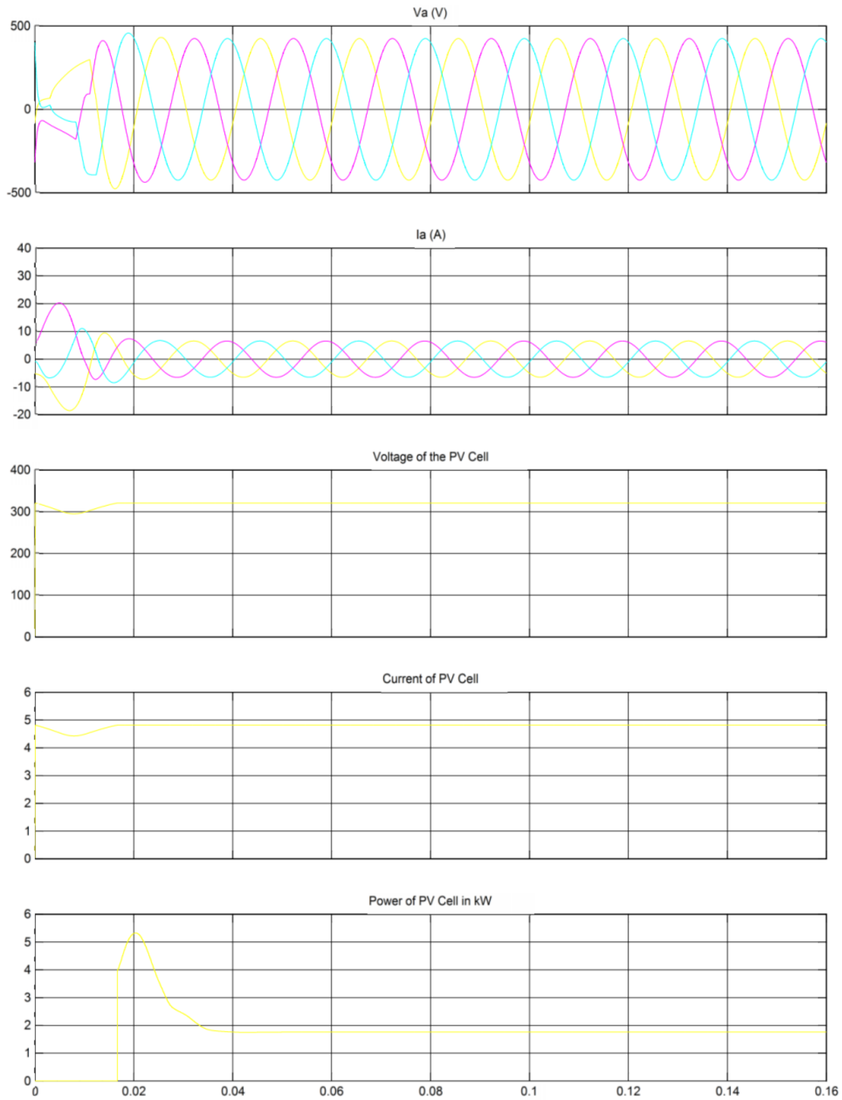

Figure 11: Simulated performance fornormal to under voltage (415 V to 350 V),

Conclusion

A two-stage system has been modeled for three-phase gridconnected solar PV generation. A composite InC based MPPTalgorithm is used for control of the boost converter. The performance of proposed system has been demonstrated for widerange of CPI voltage variation. A simple and novel adaptiveDC link voltage control approach has been proposed for control of grid tied VSC. The DC link voltage is made adaptivewith respect to CPI voltage which helps in reduction of lossesin the system. Moreover, a PV array feed forward term is usedwhich helps in fast dynamic response. An approximate linearmodel of DC link voltage control loop has been developed andanalyzed considering feed forward compensation.

The PV arrayfeed forward term is so selected that it is to accommodate for change in PV power as well as for CPI voltage variation. Afull voltage and considerable power level prototype has verified the proposed concept. The concept of adaptive DC link voltage has been proposed for grid tied VSC for PV application however, the same concept can be extended for all shunt connected grid interfaced devices such as, STATCOM, D-STATCOM etc.This system yields increased energy output using the same model just by virtue of difference in DC linkvoltage control structure.

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