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Grid fault Control Scheme for Peak Current Reduction in Photovoltaic Inverters during Voltage Sag

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Abstract: *In this paper presents a control scheme for grid interactive photovoltaic inverters to minimize peak current during unbalanced voltage sag. Power quality of a photovoltaic (PV) inverter deteriorates due to the presence of grid faults with voltage sag. In grid connected PV important feature is the ride-through capability, which allows the device to remain connected to the grid during different types of grid disturbances and avoid the need to disconnect. But during the voltage sag, the source should operate with increasing converter currents to maintain the injection of the generated power in the system. This abnormal operation may result in undesired system disconnections due to overcurrent during voltage sag. In this paper discuss a control scheme provide, controller for a PV three-phase inverter that ensures minimum peakvalues in the grid- injected currents during voltage sag.*

Keywords: *Renewable energy, photovoltaic (PV) inverter, grid fault, voltage sag, peak current*

I. Introduction

The need for renewable energy sources is increases because of the acute energy crisis in the world today. Existing centralized power generation units are insufficient to meet the continuously rising power demand. The wide gap generation and distribution location lead to fail in supplying power to the rural areas. This can be eliminated by the use of advancement in power electronics by providing instantaneous supply to the people by providing flexibility in source by placing the inverters.

One of the most promising renewable energy resources is solar energy. Within a variety of renewable and sustainable energy technologies, photovoltaic technology appears to be one of the most promising ways meeting the future energy demands as well as environmental issues. In the last decades, solar energy has been used as reliable energy for electric distribution. Use of the solar panel is the key component to convert solar energy to electrical energy. In the last decades,solar energy has been used as reliable energy source for electric distribution.

In the past, PV sources were mainly used in isolated and stand-alone applications. Nowadays the majority of the PV power sources are connected to the public grid. International standards are regulating the grid connection of photovoltaic systems, forcing the PV source to remain connected during short-time grid-voltage faults. As a result, during the voltage sag, the source should operate with increasing converter currents to maintain the injection of the generated power. This abnormal operation may result in undesired system disconnections due to overcurrent. These over currents, which can double the nominal values, can damage the power systems and switches as well as the interconnection lines, unless the source is disconnected. The overcurrent will flow until the sag is cleared or the switch that disconnects the source from the grid is opened after the regulated trip time. To avoid this overcurrent reference current generation can be used to inject current during sag.

II. Grid Fault Controllers

Voltage sag has become one of the major power quality concerns in recent years. As applications of power electronics in the commercial and industrial sectors grow rapidly, these sensitive loads can be easily interrupted byvoltage sags and the resulting losses are significant. During voltage sag, one or more phase voltages at the point of common coupling (PCC) are reduced and the currents supplied by the PV source must be increased in order to maintain the same amount of injected power as in nominal conditions. Thus, the PV system can be viewed as a high reliability current source that must inject all the generated power to the grid. The source should be able to override the large currents caused by temporary voltage sags, and continue feeding the grid according to the standards. This overcurrent, affect the nonlinear load connected to the system.

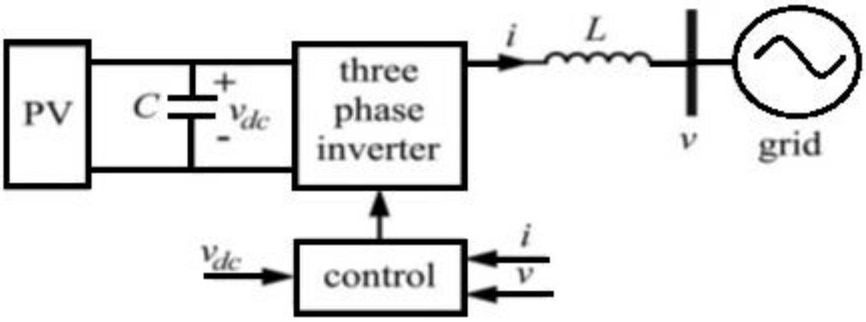

Figure: 2.1 Block diagram of grid-connected three-phase PV inverter

The different methods based on the reference current generation in grid fault controllers are [4],

1. Instantaneous Unity Power Factor Control (IUPFC)
2. Average Unity Power Factor Control (AUPFC)
3. Instantaneous Positive-Sequence Control (IPSC)
4. Average Positive-Sequence control (APSC)
5. Positive-Negative Sequence Compensation Control (PNSCC)

The 1st approach is the instantaneous unity power factor control (IUPFC), which must be used when the injectedcurrent i is required to follow exactly the voltage v. The second approach, the average unity power factor control, is implemented to avoid the appearance of current harmonics that increase the current THD in a grid connected system. Third, the instantaneous positive-sequence control (IPSC) gives an injected current that only follows the positive voltage sequence v+. Fourth, the average positive-sequence control (APSC) provides a current that follows the averaged positive-voltage sequence, avoiding the appearance of current harmonics in the system. And fifth, the positive negative sequence compensation control (PNSCC) gives a constant injected active power and low current THD [9].
Based on the equation α and β are given below,

$$i_r = \frac{P_r (v^+ + \alpha v^-)}{|v^+|^2 + \beta(1+\alpha) v^+ v^- + |v^-|^2} (1)$$

In this, discrete values α and β can be online changed in order to commute between the extreme power From the above five grid fault controllers, obtain ageneralized method for reference current generation;quality characteristics during the voltage sag. However, it isalso possible to use continuous values for α and β in order toachieve intermediate power quality characteristics. Where theinteger variable α takes values 1, 0, or -1, and the Booleanvariable β takes values 0 and 1.

Table 1: Definition of Discrete control parameters α and β

Strategy	***α***	***β***
IUPFC	1	1
AUPFC	1	0
IPFC	0	1
APSC	0	0
PSNC	-1	1

III. Control Strategy

The control scheme for minimize peak current during voltage sag to be design; In order to reduce the peak current to its minimum value, noninteger values areproposed for α and β when computing the expression of the reference currentvector i_r .A simple searching algorithm is used offline to find the optimumvalues of α and β for each unbalance factor n. With each pair alpha, beta fora given unbalance factor, the peak values over a line period are computed. It must be noted that the minimum peak value will be reached when $i_{apeak} = i_{bpeak}$. Then for each n, a single pair alpha, beta giving minimum peakcurrent values is stored in a look-up table. When sag is

detected, n iscomputed online .Then the appropriate values of α and βare retrieved fromthe look-up table and as per the value of n obtain the reference currents.
The voltage unbalance factor can be expressed as;

$$n = \frac{v^-}{v^+} \quad (2)$$

IV. Designing The Control Scheme

The field of overcurrent reduction solutions that based on the control scheme, which avoid any increase in the number of electronic devices. In the selection of a proper reference current is proposed to override grid faults and achieve different power quality requirements especially peak current during voltage sag. In this method proposes a controller for a PV inverter that ensures minimum peak values in the grid-injected currents during the voltage sag. This study is based on the generalized algorithm and design method is developed in order to search for the control parameter values that minimize the peak currents. Fig 4.1 shows the overview of grid connected pv system under fault.

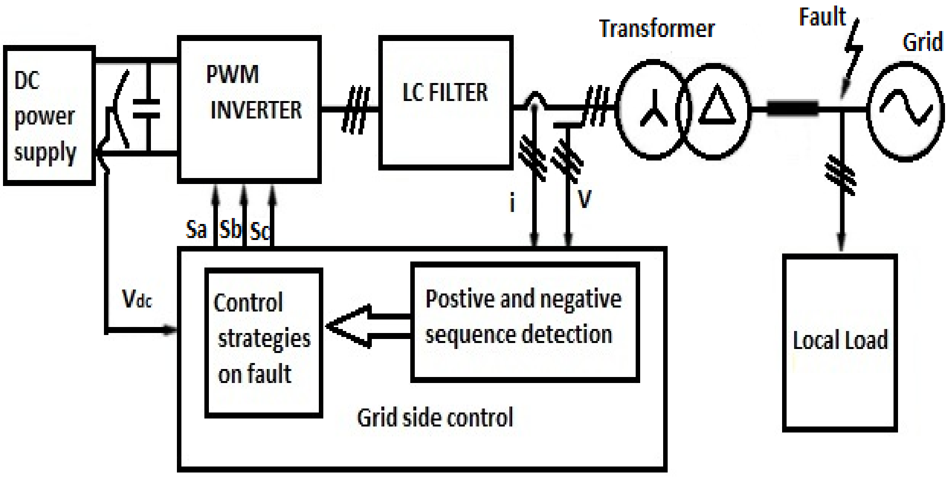

Figure: 4.1 Control strategies at faulty grid conditions

Fig: 4.2 show the control block diagram of the control scheme. When sag occur sag voltage is taken for the generation of reference current. Positive and negative sequence voltage is separated and unbalance factor n is calculated from equation (2).Then appropriative α and β values are retrieved from look up table and based on the value reference current $i_r$calculated from equation (1).Compare the value of i_r with i gating pulses giving to the controller.

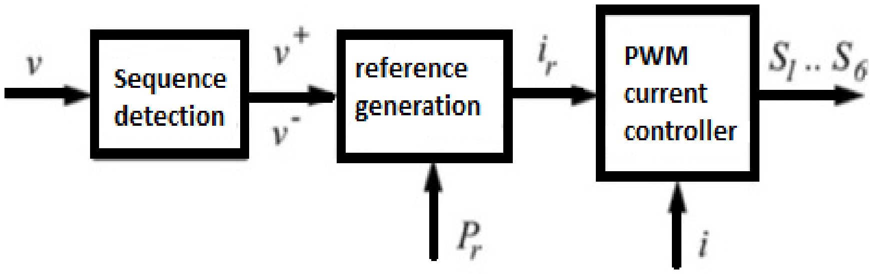

Figure: 4.2 Control block diagram

4.1 Detection of Positive and Negative Sequences

The grid voltage is a crucial issue in order to have full control over the power that is delivered from the DPGS to the grid. In this section, characterization is performed by means of a positive and negative sequence voltage detector based on a second-order generalized integrator.The proposed positive- and negative-sequence detection system that provides an effective solution for grid synchronization of power converters in the presence of grid faults. The calculation of the instantaneous symmetrical components on the alpha-beta reference frame makes it possible to use only two SOGIBPF [3]

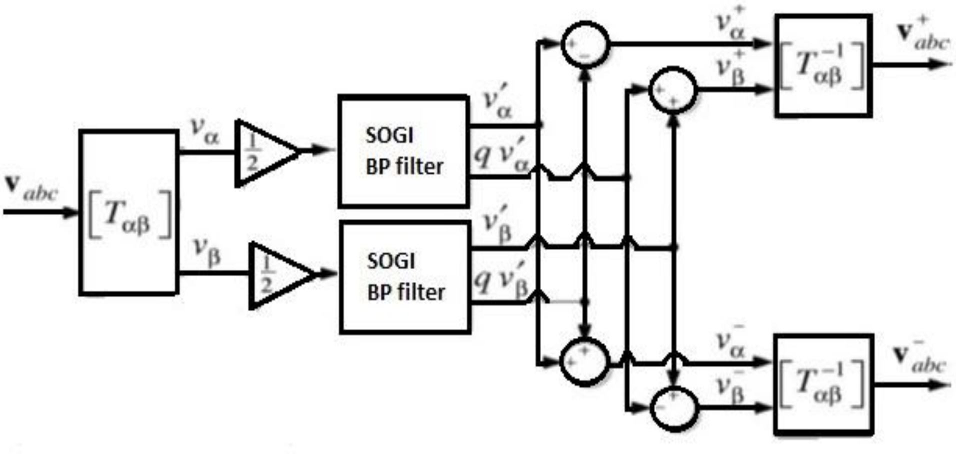

Figure : 4.3 Extracting the positive and negative sequences voltage of the grid

4.2 Current Controller

In this hysteresis controller (HCC) for three-phase pulse width modulation (PWM) voltage-source inverters (VSI) is used. The HCC is intrinsically robust to the load parameters variations, exhibits very fast transient performance, and is suitable for simple implementations

4.3 Circuit Parameters

Table 2: Simulation Parameters

Dc voltage	V_{dc}	230*V*
Power	P_r	2.3k
Capacitor	C	1.8mF
Inductor	L	5mH
Grid side oltage	V	380V,50Hz
Sampling frequency	f_s	10KHz

4.4 Simulink model

In the simulation a PV three-phase three-wire inverter full-bridge as the power converter dc source configured to provide an active power of 2.5 kW at its maximum power point. The inverter was connected to the dc source through a dc-link capacitor. The sequence detection algorithm reported in was used in this study to obtain the positive- and negative-voltage sequences.A PWM hysteresis current controller was used as the modulation scheme The switching frequency was set to 10 kHz, according to the limits expected for the insulated gate bipolar transistors (IGBTs) bridge characteristics

When implementing the controller, the amplitudes of the positive and negative sequences V^+ and V^-, necessary to evaluate the depth of the sag, n, are calculated by on the basis of the stationary reference frame (SRF) theory[3] .The unbalance factor n is easily derived and the optimal values of α and β are given using interpolation in a look-up table and used with equations to obtain the reference current i_r.

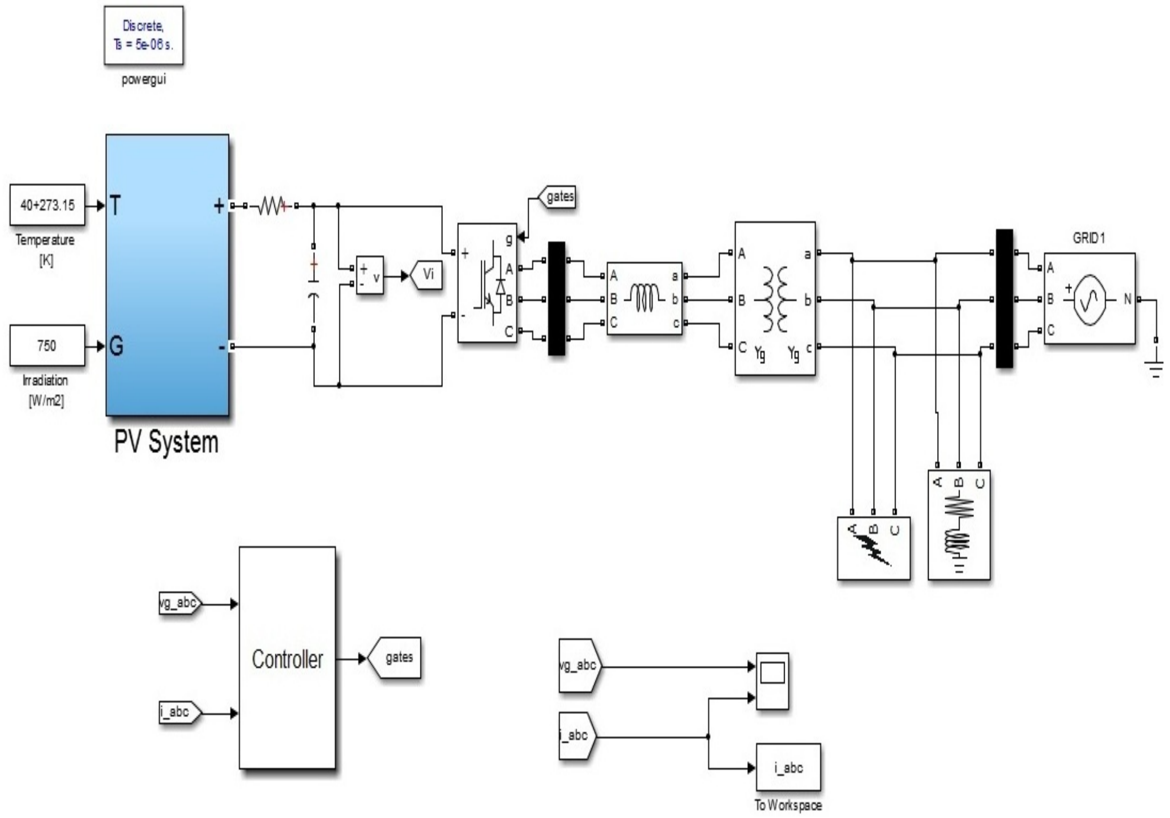

Figure:4.4 Simulation model of generalized control scheme

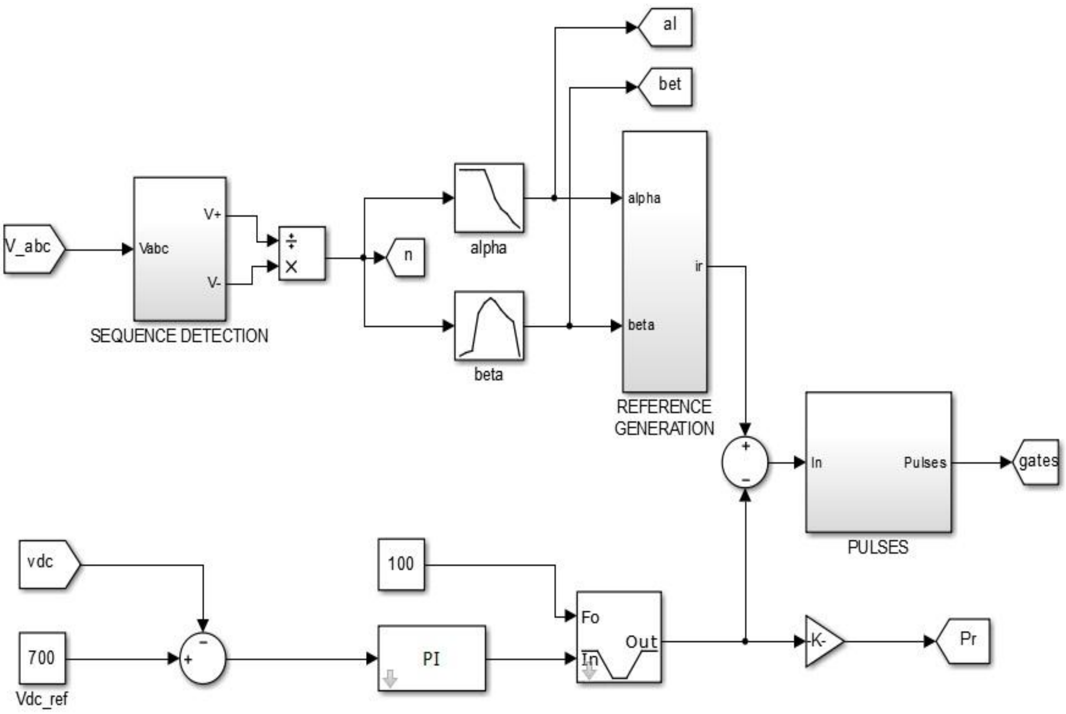

Figure: 4.5 Controller section of reference current generation

4.5 Result Analysis

Result analysis of grid connected pvsystem during voltage sag in uncompensated system and peak currentreduction methods are given below the fig:7& fig:8.

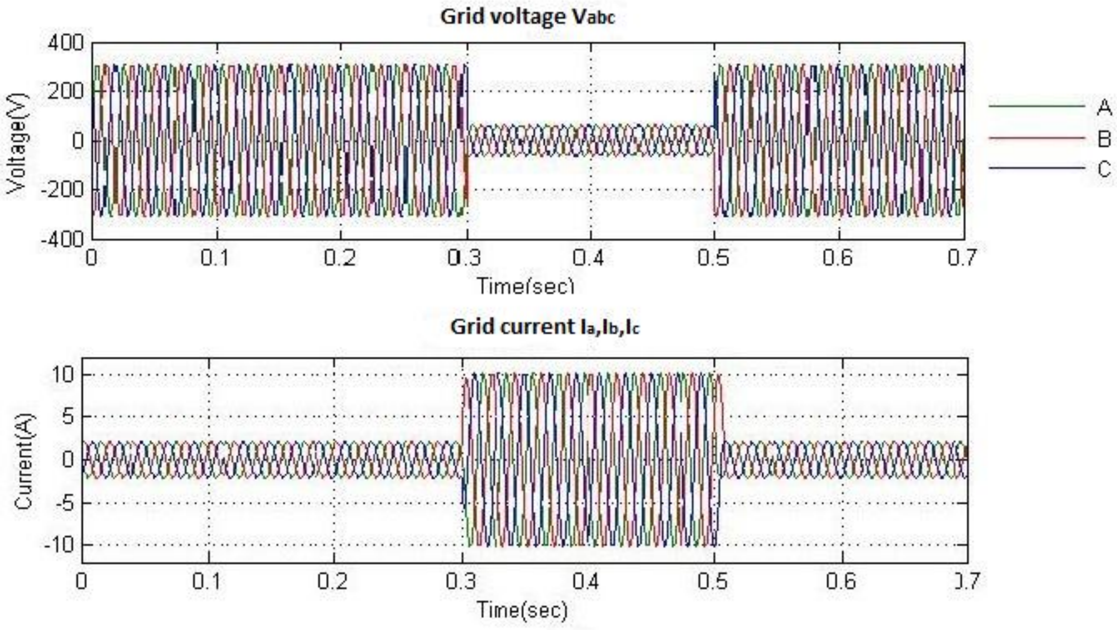

Figure: 4.6 Grid voltages and current during voltage sag without compensation 0.3sec-0.5sec

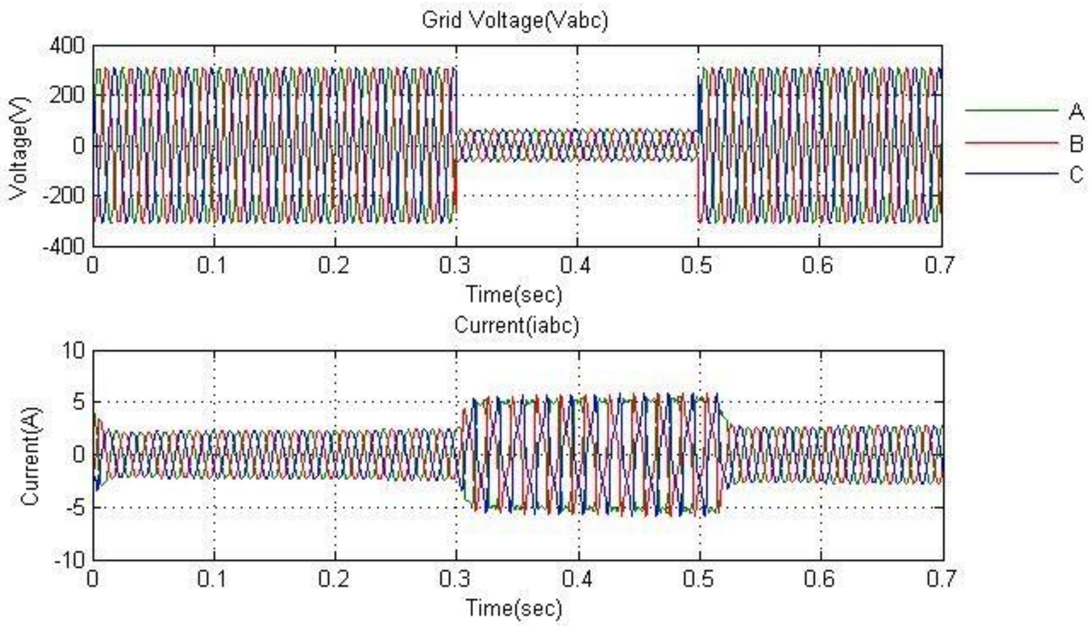

Figure: 4.7 Grid voltage and current during voltage sag with peak current compensation 0.3sec-0.5sec

As per fig: 4.6show the output wave form of grid connected pv inverter without any compensation. From the output it is clear that large peak current is introduced in system. It'sabout 5 times larger than the normal value. These peak current during sag badly affect the system. So that to reduce the peak current during sag a reference current generation method is incorporated to the system to reduce the peak current. By this reference current generation peak current compensation method we can reduce the peak current. The output wave form of voltage and current using the compensation method is shown in the fig: 4.7.From the figure it is clear that the level of peak current during voltage sag is reduced by this compensation method.

V. Conclusion

This paper has presented a controller for a PV three-phase inverter, which ensures minimum peak values in the grid-injected currents during voltage sags. The comparison with a reference control shows that the peak current values are considerably reduced by using the control scheme.Positive and negative sequence separation DSOGI FLL method is used. In this method on the stationary and orthogonal reference frame, permitting elimination of the zero-sequence component, this cannot be controlled in three-phase three-wire power converters. Analyze wave form, distortion is present with the control scheme & reduction of distortion is necessary.

A control scheme for peak current reduction during voltage sag in grid connected PV inverter was analyzed & simulated. The converter can overcome deeper sags without the disconnection caused by harmful overcurrent during grid fault condition.

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