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Temporary Overvoltage Mitigation and Re-Connection of Inverter after Fault in a Grid-Connected Photovoltaic System

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***Abstract*—This paper presents a mitigation strategy for temporary over voltages caused by grid connected photovoltaic system. Single line to ground fault followed by islanding is a severe cause of temporary over voltage.So, by using a mitigation strategy, the magnitude of temporary over voltage is reduced. After the fault, inverter is reconnected to supply power to the grid. By the use of half bridge converter (HBC) in the power electronic circuit, it is found out that neutral current can be reduced. The whole system is simulated in PSCAD/EMTDC software environment.**

***Keywords—Distributed Generator (DG), fault, Islanding, Temporary overvoltage mitigation, Photovoltaic (PV) system*.**

I. INTRODUCTION

Among renewable energy systems, photovoltaic system has an important role.The photovoltaic system can be installed on the low voltage and medium voltage parts of the system. The two main contributors for overvoltage in low voltage (LV) and medium voltage (MV) distribution networks are faults and islanding [1]. Distributed generator (DG) induced TOVs are severe when a single line to ground (SLG) fault is followed by an islanding incident. This case is considered in this paper. It has been identified in some literatures [3], [4] that neutral connections and effective grounding of the DGs are inefficient to mitigate DG induced TOVs.Surge arresters [2] are only effective against large but short-term overvoltages.The DG induced TOVs destruct surge arresters since they last for long duration.So, this paper introduces a strategy for mitigating the DG induced TOV and it is done by regulating the modulating signals. And after the fault, inverter is reconnected to supply power to the grid.

To increase the efficiency of PV system, maximum power point tracking (MPPT) is used. There are several MPPT techniques. The disadvantage of Perturb and observe method is that it is difficult to track the maximum power under varying atmospheric conditions. Whereas, Incremental conductance (IC) [5] can track increasing as well as decreasing irradiance conditions and also it offers higher steady state accuracy and environmental adaptability.

II. SYSTEM DESCRIPTION

A block diagram representing a grid connected PV system is shown in fig.1.It consists of a PV generator which is connected to the dc side of a three phase voltage source inverter (VSI).The MPPT regulates dc link voltage. The inverter used here is a four legged inverter. The fourth leg acts as a half bridge converter (HBC) for neutral current elimination. The three phase VSC performs TOV control and reactive power control.

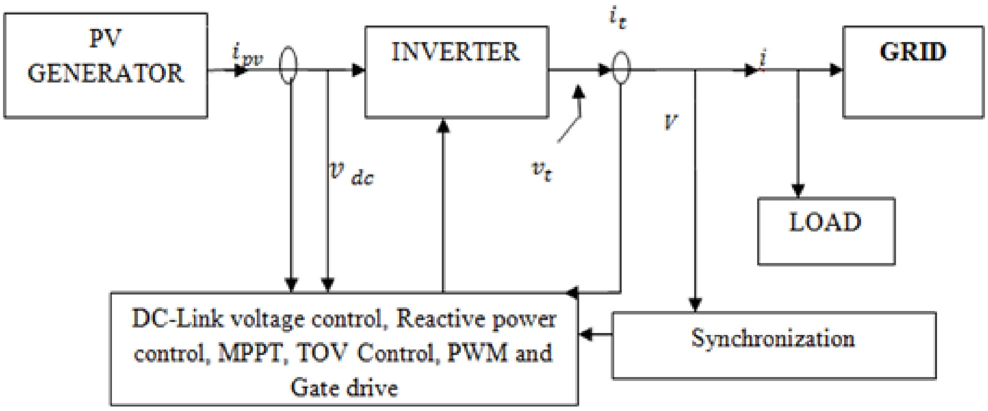

Fig.1 Block diagram representing grid connected PV system

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To model PV cells, it is important to accurately determine the equivalent series resistance, R_s and the shunt resistance, R_{sh}.The determination of both resistances by trial and error and through iterative techniques lack accuracy.

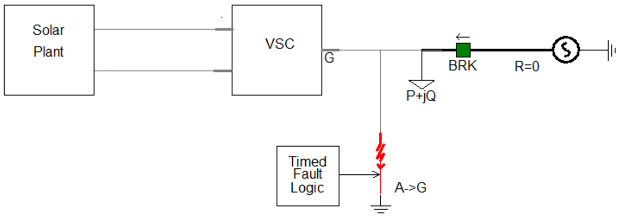

Fig.2 PSCAD model of the grid connected PV system with fault applied

So, here the modeling has been done by using the standard data sheet parameters of PV panels [6] and predicts all the unknown parameters through the determination of diode ideality factor, *n*.

The PSCAD model of the grid connected PV system with fault applied is shown in fig.2. A local load and a breaker are connected at the grid side. The fault applied is single line to ground fault. When the fault strikes the system, the grid protection circuitry detects the fault and opens the breaker; BRK leading to an islanding incident which leads to a severe TOV.So inorder to reduce the TOV, a strategy is used as shown in fig.3.The peak values of the three grid phase voltages are measured and the normalized peak value is given to corresponding piecewise linear transfer characteristics which produces the saturation limit. If the peak value of the corresponding grid phase voltage is smaller than the acceptable value, then the saturation limit is set as unity. On the other hand, if the grid phase voltage exceeds the acceptable value, the saturation limit is set as smaller than unity. Thus the limit of modulating signal is smaller, for larger overvoltage. This will prevent the voltage from rising further and limits the voltage magnitude.

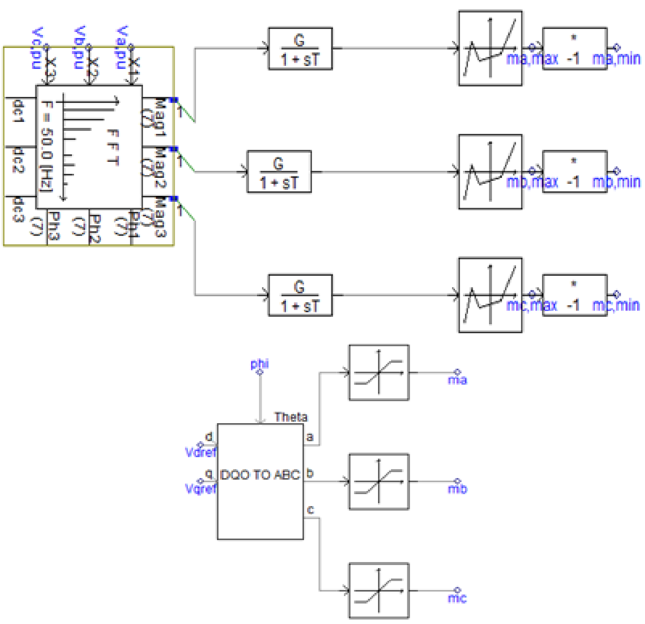

Fig.3 TOV mitigation strategy in PSCAD

Fig.4 shows three phase VSC and HBC connected to the grid.PWM control and hysteresis current control are used for VSC and HBC respectively.PV is interfaced with the grid through a transformer and it has Y/YG configuration. By using HBC in the circuit, there is no need of a large split capacitor bank for connecting the neutral point of the transformer and the neutral current of the transformer is eliminated by HBC. The PV system with a Δ/YG transformer experiences more inverter side overvoltages and smaller grid side overvoltages. As a large zero sequence current circulates in the Δ windings, the voltage waveforms will get distorted and Δ/YG transformer does not provide a one-to-one relation between the VSI ac side terminal voltages and grid phase voltages. Whereas in a system with Y/YG transformer, each grid side phase voltage can be independently controlled by a corresponding inverter side voltage. So, due to lower effectiveness of Δ/YG transformer, it is replaced by Y/YG transformer.

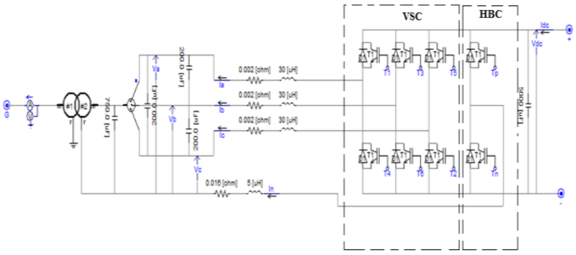

Fig.4 VSC and HBC connected to grid

III. CONTROL OF VSC AND HBC

To eliminate the neutral current, the neutral current reference is set as zero and it is compared with the actual neutral current, and then fed to a hysteresis current controller as shown in fig.5. The signal produced from the hysteresis controller switches the upper IGBT and its complementary signal will switch the lower IGBT.

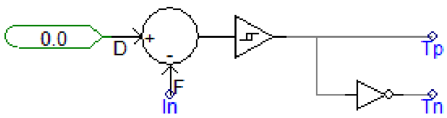

Fig.5 Control of HBC

PWM control is used for switching VSC. The modulating signal produced using TOV mitigation strategy and triangular wave are compared using a comparator as shown in fig.6 and the corresponding signal produced from each comparator will switch the upper IGBTs and the corresponding complementary signals from each comparator will switch the lower IGBTs. Inverter is disconnected from the grid after a particular time by using timed breaker logic in order to prevent the sending of power during fault.

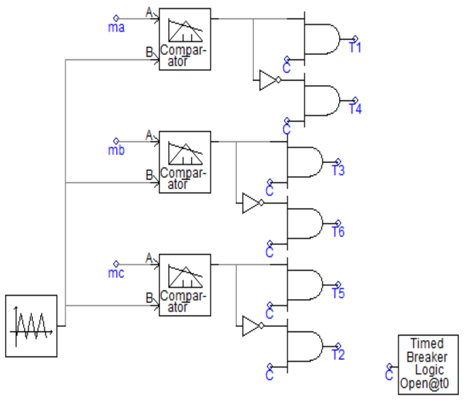

Fig. 6 Control of VSC

IV. SIMULATION RESULTS

The whole system is simulated in PSCAD/EMTDC software environment. In the following graphs, it is assumed that an SLG fault strikes the system at *t*=0.5s, then the grid protection circuitry detects the fault and opens the breaker at *t*=0.55s leading to an islanding incident. The PV system continues to energize the system until it is disabled by its islanding detection scheme till *t*=0.65s.So, after t=0.65s,there is no sending of power to the grid.

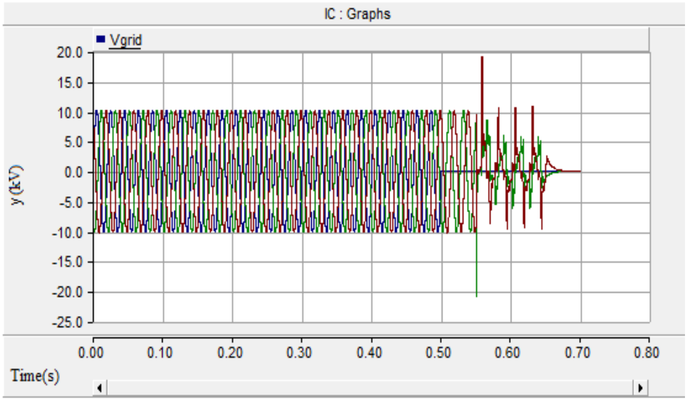

Fig.7 Grid-side voltage without TOV mitigation strategy

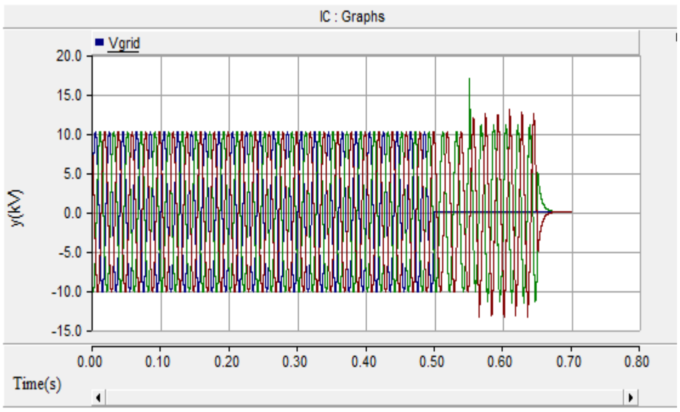

Fig.8 Grid-side voltage with TOV mitigation strategy

Fig.7 and fig.8 shows grid side voltages with and without using TOV mitigation strategy. Without using the strategy, the temporary overvoltage rises to about 1.7pu whereas, by using the strategy, it is observed that voltage can be limited to about 1.3p.u.The voltage is not balanced after the formation of island.

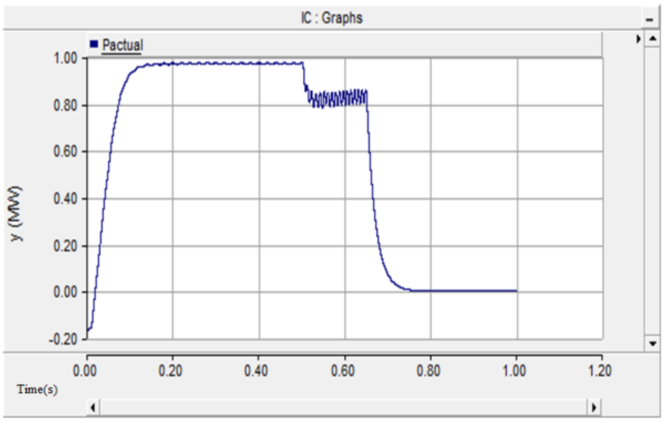

Fig.9 PV system power output

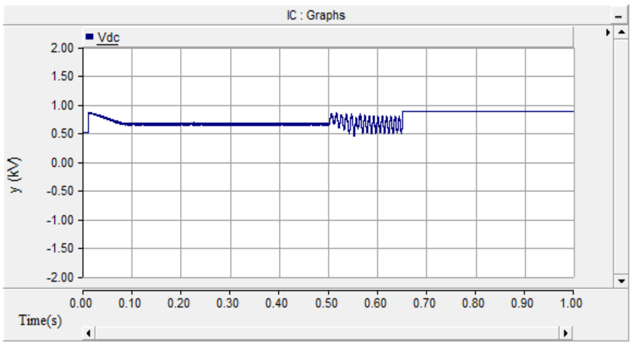

Fig.10 DC link voltage

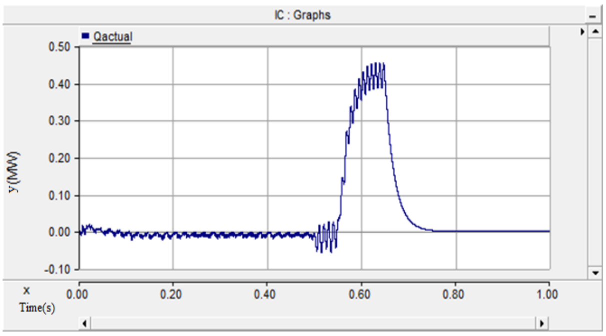

Fig.11 Reactive power

The power rating of PV is 1.0 MVA.As shown in fig 9, during faulted condition the power reduces and after *t*=0.65s, the power is zero.Fig.11 shows the reactive power. During normal condition, it is zero and when fault strikes the system, it rises. Fig.10 shows the dc link voltage. Due to imbalance caused by the fault and islanding incident, the dc link voltage shows double frequency pulsations.

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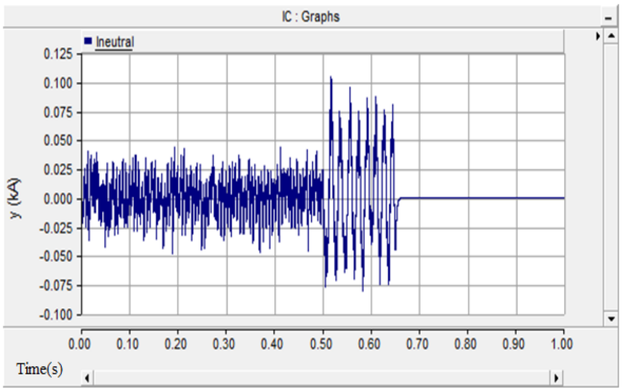

Fig.12 HBC ac side neutral current

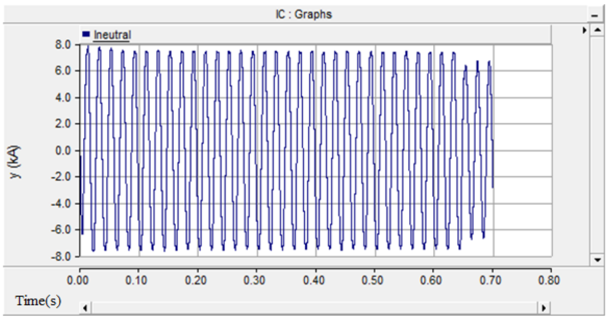

Fig.13 Neutral current without using HBC

Fig.12 and 13 shows neutral current obtained with and without using HBC respectively. The neutral current has got reduced from 7kA to 0.1kA by using HBC in the power electronic circuit.

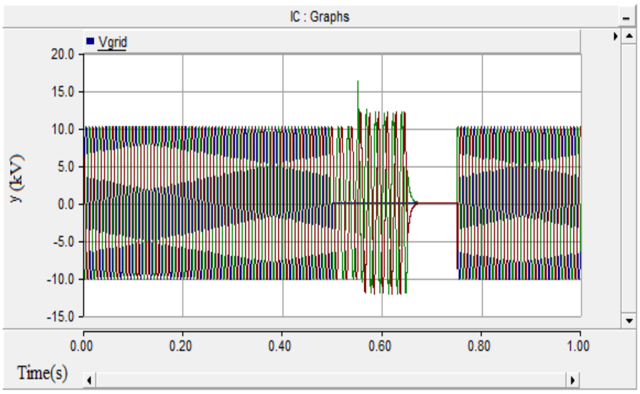

Fig.14 Grid side voltage with reconnection

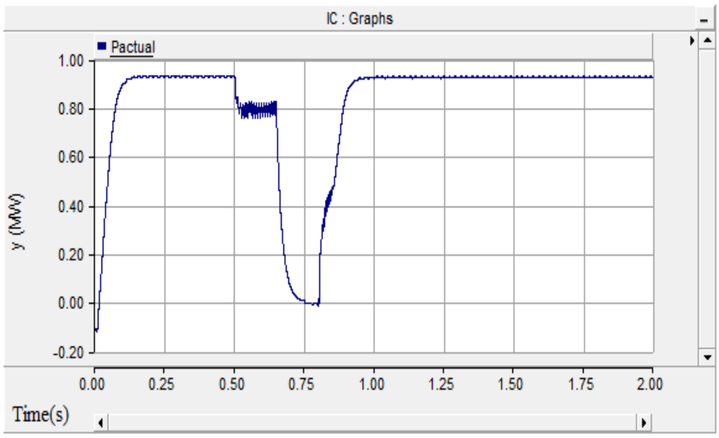

Fig.15 PV power output with reconnection

Fig.14 and 15 shows the grid side voltage and PV power output with reconnection of inverter after fault respectively. It is important to send power to the grid after the fault.So, the breaker, BRK is closed at t=0.75s and inverter is reconnected to the grid at t=0.8s.

V. CONCLUSION

This paper shows a TOV mitigation strategy to limit the TOV subsequent to an SLG fault followed by an islanding incident. The effectiveness of the strategy was demonstrated in PSCAD/EMTDC software environment. The result shows that by including HBC into the circuit, the neutral current was limited to some extent and the reconnection of inverter supplies power to the grid after fault.

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