Fault Analysis of Grid Connected Solar Photovoltaic System

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Abstract: Photovoltaic (PV) array is used to convert the energy from the sun to electrical energy. With the best installation method the photovoltaic system could not guarantee the system is protected to fault and its effects. The existence of fault in the grid system may cause a drop in the outputs and will drop even lower with saturation of photovoltaic devices in the system. This paper presents the effects of faults inside the grid–connected PV system with symmetrical and unsymmetrical being tested for this purpose and compares the results obtained. To observe the effects of these faults, a model of grid–connected PV system is built using MATLAB⍰ 2012b/Simulink with the help of Simscape and SimPowerSystems toolboxes. PV system is developed in order to make the photovoltaic sourcing the system. With the help of a booster, the PV system voltage output is regulated and linked to a three–phase inverter circuit. Analyses are made on different conditions like standalone operation, varying load, varying irradiation. Lastly, faults are injected to the connection of inverter, transmission line and grid. System is observed for changes in the power, voltage and current waveforms.

Key word*:* Solar photovoltaic system, Faults, Matlab.

1. INTRODUCTION

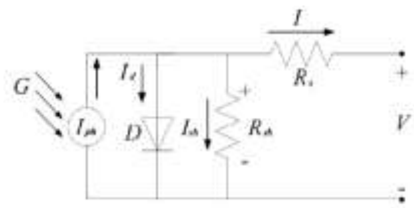
Maximum energy consumption overloads the power station. The solution is to go in for Distributed Generation (DG) using renewable resources like wind and solar, the advantage is energy produced in the close area of customer is consuming energy thus minimizes the loss in the transmission lines.

Nowadays solar energy technology is more efficient and environmentally friendly energy resource. The major advantage is there are no moving parts in system, thus having a long lifetime and low maintenance requirement.

The PV system is connected to the grid using an inverter which converts DC to AC, hence called as Grid connected PV system. During daytime generated electricity is used immediately or supplied to the grid. In the evening the electricity is drawn from the grid using the net metering system. The main goal of the project is to analyse and model PV generating system that are grid connected working under both voltage and current synchronization, control and also to calculate the amount of power produced by the designed MATLAB/SIMULINK model for a given set of irradiation values and to expand the effectiveness of solar photovoltaic system. The MPPT method, i.e. incremental conductance will be implemented for better efficiency of the PV system. The effect of variation of irradiance and variation of load on PV system is analysed. The grid disturbances effects on a grid connected PV array are studied. A fault is any abnormal condition in a power system. The steady state operating mode of a power system is balanced 3-phase a.c. However, due to sudden external or internal changes in the system, this condition is disrupted.

2. SOLAR PHOTOVOLTAIC MODEL

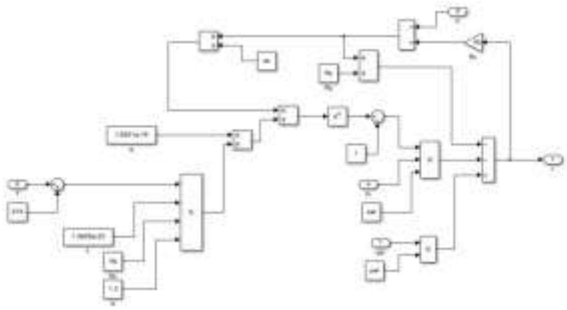
An ideal solar cell can be considered as a current source with current produced directly proportional to solar radiations falling on it. The output of the current source is directly proportional to the solar energy (photons) that hits on the solar cell (photocurrent *Iph*). The single diode equivalent circuit of solar cell is represented in below figure. The practical behaviour of cell is deviated from ideal due to the optical and electrical losses.



The output current of PV source is given by,

$$I = I_{ph}N_p - I_d - I_{sh}$$

I_d is diode current, I_{ph} is the PV module current, I_{sh} shunt resistance current, N_p number of cells in parallel, corresponding Matlab Simulink model is shown below



3. FAULT ANALYSIS

Most of the faults on the power system lead to a short-circuit condition, at this condition heavy current (called short circuit current) flows through the equipment, causing considerable damage to the equipment and interruption of service to the consumers.

Faults in PV system can be identified in two side of the system: DC side and AC side, the interface between this is DC/AC inverter that connected to grid. The classification of faults is shown in Figure.

1. *Symmetrical faults*

The symmetrical fault happens when all the three conductors of a 3-phase line are brought collected instantaneously into a short-circuit condition, all three lines are short-circuited ($L — L — L$) or all three lines are short-circuited with an earth connection at the fault ($L — L — L — G$). This type of fault gives rise to symmetrical currents i.e. equal fault currents with 120^0 displacements

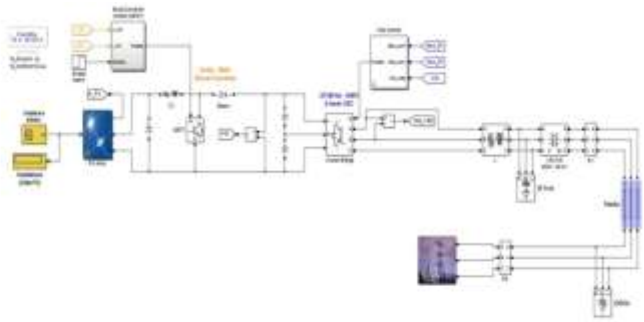
2. *Unsymmetrical faults*

The common faults on the power system are of unsymmetrical nature; the most common type is short-circuiting from one line to ground. When such a fault occurs, it gives rise to unsymmetrical currents *i.e.* the magnitude of fault currents in the three lines are different having unequal phase displacement.

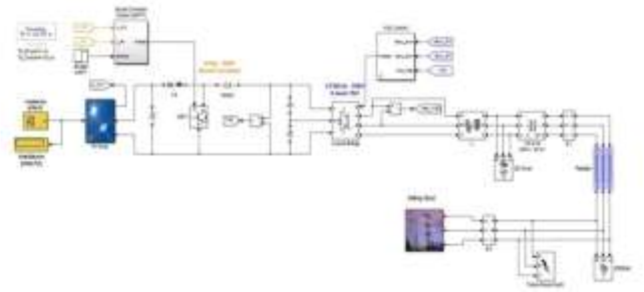
On the occurrence of an unsymmetrical fault, the currents in the three lines become unequal. The term 'unsymmetrical' applies only to the fault itself and the resulting line currents. There are three ways in which unsymmetrical faults may occur in a power system.

a) Single phase-to-ground fault ($L — G$)
b) Phase-to-Phase fault ($L — L$)
c) Double phase-to-ground fault ($L — L — G$)

3. SIMULINK MODELS



Grid connected Solar PV



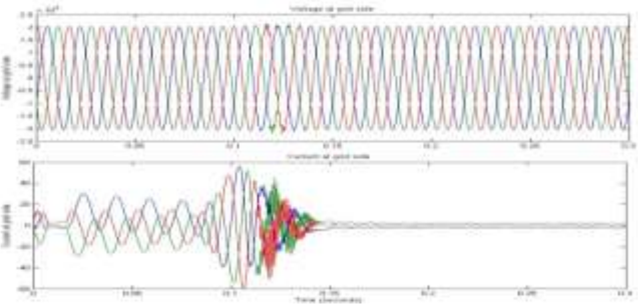
Grid Connected Solar PV with symmetrical fault at transmission line

4. SYMMETRICAL FAULTS ON GRID CONNECTED PV SYSTEM

Matlab/Simulink model is simulated under three phase to ground fault under different locations of grid connected PV system. L-L-L-G fault Simulation is accomplished under normal conditions (Irradiation is $1000W/m^2$, Temperature kept 25^0C). The fault duration is 0.06sec i.e. 0.02 to 0.08sec.

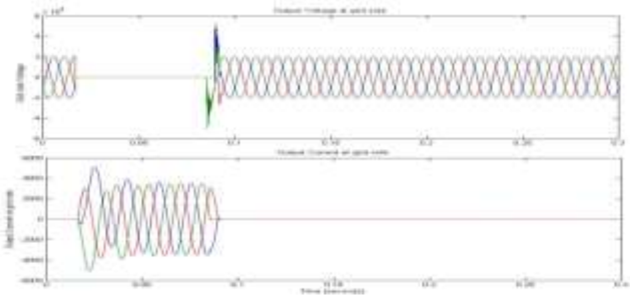
a) *L-L-L-G fault at Inverter side*

LLLG fault occurred at inverter side, there is no much change in output voltage of Grid side but because of some switching actions can observe small variations of voltage at end of fault occurrence. Current in phase B and C rises to 30A and 15A respectively which is higher than nominal current 1.8A.



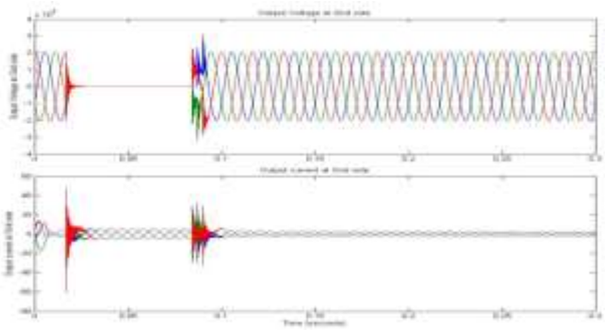
b) L-L-L-G Fault at Transmission line

LLLG fault occurred on transmission line. At the fault time voltage in each phase of the line falls to 4V. At fault clearing time, Voltage in phase A rises to 52.5kV because of switching action. The current in phase A rises to 5110A and other phase currents are 3470A which is higher than nominal current 1.8A. Later system regains to its normal state.



C) L-L-L-G Fault at Grid side

LLLG fault occurred at grid side. At the fault time voltage in each phase of the line falls to 50V and at fault clearing time voltage in phase A rises to 28kV because of switching action. The current in phase C rises to 28A and other phase currents are 5A during fault time which is higher than nominal current 1.8A. Later system regains to its normal state.

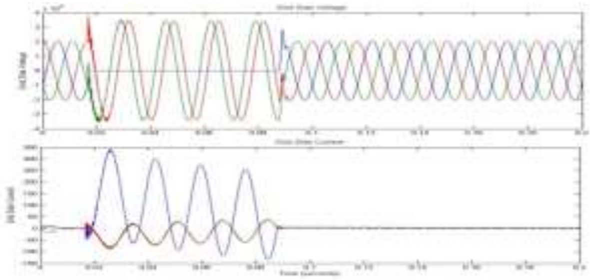


5. UNSYMMETRICAL FAULTS ON TRANSMISSION LINE

Matlab/Simulink model is simulated under different fault conditions. All type of faults are accomplished under normal conditions

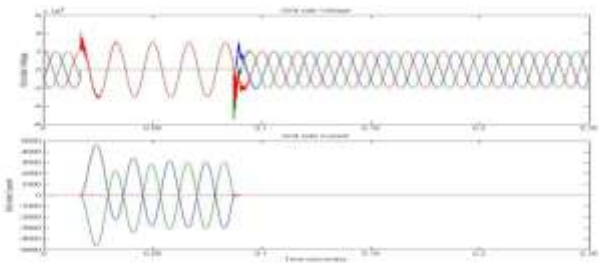
a) Line to Ground Fault

Line to ground fault is occurred at 0.02sec on phase A. It is observed that voltage in phase A is 0V during fault period and voltage on other phases is 34kV which is higher than nominal voltage 20kV. By the same time current dangerously reaches to 337A and current at other phases are about 35A at fault duration, which is higher than normal current 1.8A.



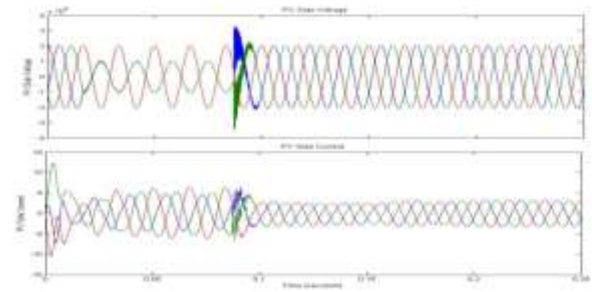
b) Line to Line Fault

Line to Line fault is occurred at 0.02sec between phase A and phase B. It is observed that voltage with phase A and B is 10kV during fault period and voltage phase C is 20kV, at 0.08sec voltage in phase A extremely rises to 30kV because of switching action. By the same time current dangerously reaches to 4500A in phase A, 3000A in phase B, and 3A in phase C at fault duration, which is higher than normal current 1.8A.



c) Line to Line Ground Fault

Line to Line Ground fault is occurred at 0.02sec between phase A and phase B. It is observed that voltage with phase A and B is 0V during fault period and voltage phase C is 30kV. By the same time current dangerously reaches to 4500A in phase A, 3000A in phase B, and 0A in phase C, which is higher than normal current 1.8A.



6. CONCLUSION

The performance of Solar photovoltaic is studied by the effect of variation of irradiance by keeping load constant and effect of variation of load under different irradiations. Finally the behavior of system is analyzed under unsymmetrical faults (L-G, L-L, and L-L-G) at transmission line and behavior of the system under symmetrical fault condition (L-L-L-G) at different locations of the PV system. From the fault analysis it is concluded that faults on transmission line has more severe effects on system than at any other location.

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