Impact on Fuse Settings and Size of Photovoltaic Distributed Generation Source Due to Fault Current

B.V. Surya Vardhan, Mohan Khedkar, Nitin Kumar Kulkarni

Abstract--- Fault current contribution due to Grid connected Photovoltaic (PV) source has become a crucial factor in deciding the settings of protection equipments like fuse, circuit breaker etc. especially where there is a high level of penetration of PV, estimated in Megawatts. Setting of protection equipment, size of PV source to be interfaced with the grid depends on the magnitude of fault current from PV source, A inverter based distributed generation (PV) is considered here, it has limited fault current contribution but as grid penetration level increases fault current contribution becomes significant. This paper aims at determining the change in relay settings due to addition of PV sources and also determining the size (MVA rating) of PV source w.r.t. to its fault current contribution to avoid the existing setting changes of protection equipments. For this analysis ,a Real time system of Katol PV transmission Solar Power plant near Nagpur is taken. Using Single line to ground fault given at Grid side, the system is analysed &simulated in MATLAB Simulink environment. The simulation results show that, relay settings and Size (MVA rating) change considerably due to addition of PV, into grid.

Keywords--- Photo- Voltaic (PV), Inverter, fault current contribution, protection settings, Distributed Generation (DG).

I. INTRODUCTION

India's optimistic target to generate 175 GW [1] through Renewable Energy by 2022 has brought lots of urgency in the creating efficient and rigid PV systems .Conventional power system is often designed to operate without DG i.e. the protection settings, the calculations of faults, Stability etc. are set accordingly. But with more and more PV systems and other DGs like wind energy systems being connected to the grid, the calculation of the system parameters becomes more complicated, but nevertheless there are methods in place which can make the process easy and affordable. Small size of the DG often does not create any problems as they produce a very small fault current which hardly disturbs protection settings, With Large size of DG, fault current contribution can't be neglected as it has huge impact in deciding protection setting and Size of DG at different locations. This paper aims at determining the fuse setting due to addition of PV source. Section,II, III, IV deals with the Grid Integration, where Section

II deals with grid interface, Section III with MPPT (DC-DC control and Section IV deals with Inverter control, Section V and Section VI explains the fault current contribution of the assumed PV and hence using formulae estimated size of the PV that should have been in the system which might have avoided the protection setting changes.

II. GRID INTERFACE

If everything is put in a nutshell, the generated power from PV is controlled by Maximum Power Point Tracking (MPPT) for Maximum Power. MPPT acts as a controller to D.C–D.C converter, which can be either buck or boost or buck boost. The output of this converter is fed to DC to AC converter which is controlled by a controller .Complete block diagram is shown in fig.1.

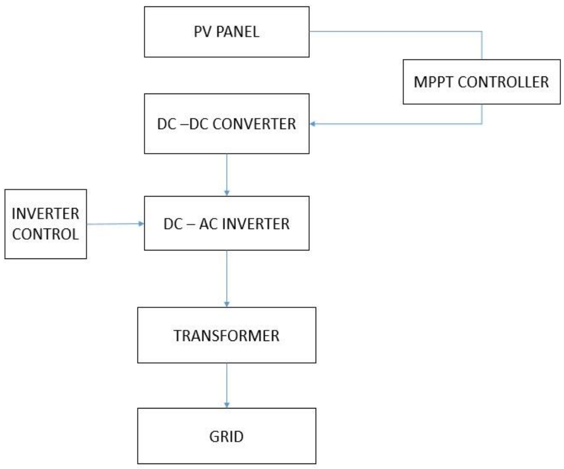

Fig. 1: Overview of Grid Connection

Generally d-q controllers are used where active power is stored in d axis and reactive power is stored in q axis. The output is injected into the grid using PLL so as to match required frequency, voltage and other factors of the grid MPPT controller used here is designed by Incremental conductance method considering efficiency neglecting cost. [3,4].

III. DC – DC CONTROLLER (MPPT CONTROLLER)

The MPPT controller used here is using incremental conductance method. It compares slope of PV curve to depict the maximum power from the PV panel .Fig.2.govern the outcome of incremental conductance method.

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B.V. Surya Vardhan, PG Student, Deptt. of Electrical Engg., VNIT, Nagpur. (e-mail: suryavardhan93@gmail.com)

Mohan Khedkar, Professor and Head, Deptt. of Electrical Engg., VNIT, Nagpur. (e-mail: mohankhedkar@eee.vnit.ac.in)

Nitin Kumar Kulkarni, Research Scholar, Deptt. of Electrical Engg., VNIT, Nagpur. (e-mail: nitinkulkarni@students.vnit.ac.in

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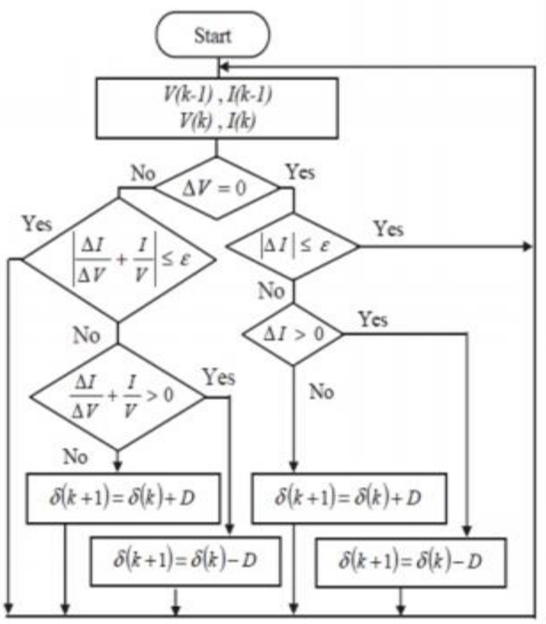

Fig. 2: Flow chart INC Method

Fig.3. is the model developed in Matlab Simulink for Incremental conductance Method.

IV. THREE PHASE INVERTER CONTROL

Inverter takes input as DC power from DC- DC controller and converts it into AC Power which is fed to the grid through a transformer. The grid principle states that the current obtained from the output of the inverter which in turn is passed through transformer should be in phase with the grid voltage .So the controller is designed in such a way that the current is in phase with the voltage of the output[3]. So a reference of the current is taken in the controller and it is compared with currents and voltages obtained from the output of PV panel passing through a proper sine function and phase shift blocks. The current reference is sinusoidal, it becomes very difficult for controller sense a AC reference, so dq controller technique is used to convert it into DC parameter .To put in a nutshell, first of all the time domain parameters are converted into spatial coordinate system or non-time domain axes These spatial parameters are called α and β .which are again converted into d and q axis with reference to a certain angle, which is synchronized with respect to α and β axis. In this way AC parameters are being converted to DC parameters. Complete structure is given in Table I and Table II.Fig.4. is the matlab Simulink model developed for Inverter control.

Table I: Foreword Transformation

abc to α and β axis	3 phase AC to 2 phase AC
α and β axis to d and q axis	2 phase AC to 2 phase DC

Once these D.C parameters are used for comparisons and once the utilities of D.C components are finished, the parameters are again converted into A.C parameters.

Table II: Reverse Transformation

Following transformations are used:-

$$\begin{bmatrix} R\alpha \\ R\beta \end{bmatrix} = \begin{bmatrix} 1 & -0.5 & -0.5 \\ 0 & 0.866 & -0.866 \end{bmatrix} \begin{bmatrix} Ra \\ Rb \\ Rc \end{bmatrix}$$

$$\begin{bmatrix} Rd \\ Rq \end{bmatrix} = \begin{bmatrix} \cos\rho & -\sin\rho & R\alpha \\ \sin\rho & \cos\rho & R\beta \end{bmatrix} \begin{bmatrix} \; \end{bmatrix}$$

Where R –Vectors of different components on that particular axis.

ρ- Angle between the d q axis and α,β axis.

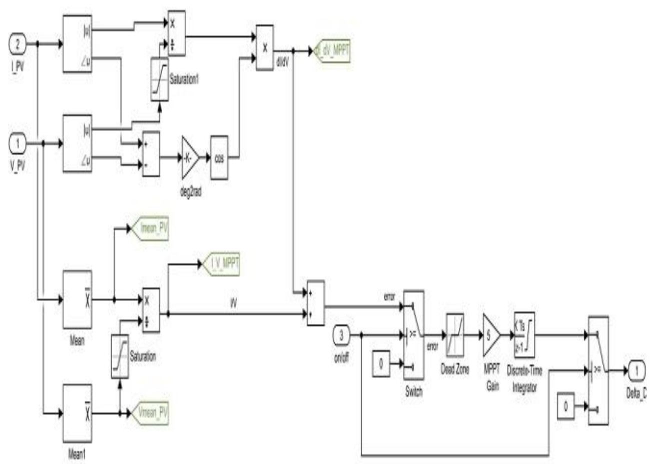

Fig. 3: MPPT Incremental Conductance Method Simulink Diagram

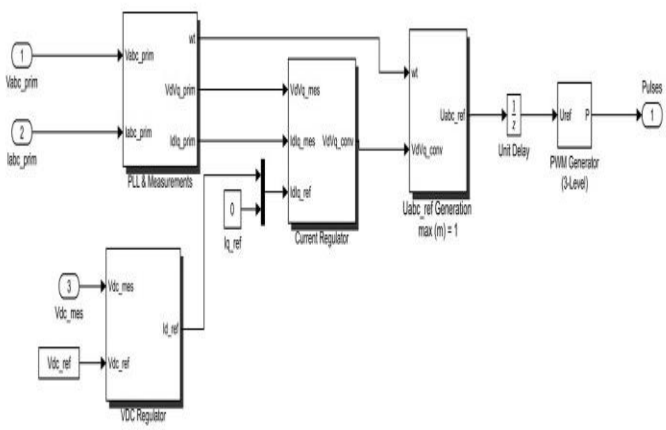

Fig. 4: VSC Control Simulink Diagram

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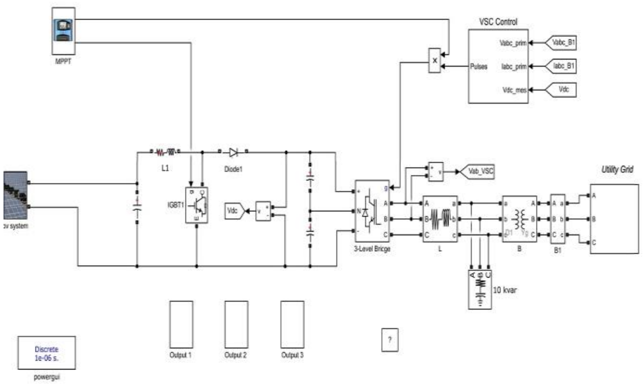

Fig. 5: Grid connected PV using Simulink

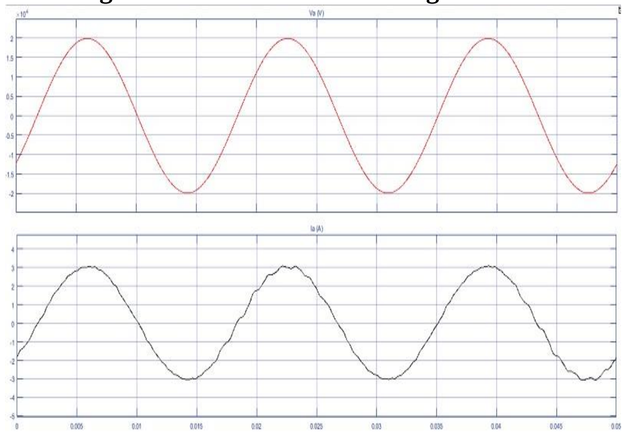

Fig. 6: Variation of Scaled Power of the Grid

For finding the value of ρ the output voltage samples are taken instead of current samples so that the d component of current is in phase with the output voltage, which satisfies the grid principle. To remove errors and make ρ stable PLL is used, It removes any minute q axis component. It also provides a closed loop for calculation of ρ so that the parameter is more stable and rigid. In this way inverter is controlled. Results are obtained when the process is implemented in MATLAB as shown in Fig.5. and results are obtained in Fig.6.. where current is in phase with voltage and satisfies the grid principle. It can be observed that voltage is in phase with current which satisfies the grid principle and it can be said satisfactorily that PV is connected to Grid. Fig.7.contains power injected inside the Grid.[5,6]

V. EFFECT OF PV ON GRID DURING FAULT

Generally power flows from a central grid to a distribution power flow system .But introduction of PV disturbs the radial nature of the system .In some cases power starts flowing in reverse direction or upstream. If fault current is not detected with a proper algorithm, then there can be maloperation of protection components. During Fault PV source cups in supplying current along with the grid. Generally when grid disconnects due to fault PV source is tripped by an anti –islanding technique to provide safety to personal and equipment .The allowable time to trip as per IEEE 1547 std. is 2sec [7].As per fault analysis the fault current depends on Pre- Fault voltage and the machine transient and sub transient reaction .The setting of the protection equipments is often determined by the sub transient reactance. Suppose if a fault is occurring at the upstream of the protection component, then the current flows upstream and finally current receiving systems like motor will behave as current generating system i.e. generator. The capacity of the system will be reduced. If fault occurs on the other side i.e. downstream faults, then actual fault current which is seen by the generator will be reduced which again creates a case of maloperation of Protection components. Fault current study of PV is often used in few important studies such as selecting size of PV, and deciding the settings of the protection components. Fig.8. shows the zone representation of real time system of Katol PV transmission Nagpur, where PV is placed in each zone one by one and observations are made.. For protection system default values are considered, for the sake of convenience.The zone description is strictly with respect to the practical system. The consequence fault analysis is done in Matlab Simulink. The Katol Solar power plant consists of 20MW capacity which is fed by 8 groups of converter. Each group of Inverter feds 2520 MW which is shown in the Fig .A fault is given and results are calculated according to the formulae used in part IV.

VI. A. DESPRICTION OF SIZE OF PV ACCORDING TO PROTECTION SETTINGS

Generally settings of the protection equipment are changed according to the size of PV inserted .But this system often creates trouble especially when inserted in system where a grid is established with all settings, and the concept of smart metering also fails as the size of the PV is varied continuously if the compatibility is given to the user. So researchers often recommend the regulators to set a certain size of DG, beyond which it should not be permissible. It will allow the settings to be static and the size of DG will not be varied beyond a certain level, which avoids unnecessary complications in the system. (1) is used to calculate the current flown through DG (PV source) once fault occurs in the system.[5-10]. (PV is referred as DG in (1) and (2))

$$I_{DG}=10^{\frac{\log t-b}{a}}-I_{SC} \qquad (1)$$

I_{DG} - Current flown form DG when fault has occurred
t – Recloser tripping time
I_{Sc} - Short Circuit Current
a, b – curve constants

Since the voltage rating of the DG is known (V_{DG}), the size of the DG can be calculated from (2)

$$MVA\ rating\ of\ DG = 1.732 \times I_{DG} \times V_{DG} \qquad (2)$$

Using the above formulae the results are obtained as shown in Tables III, IV, V and VI using MATLAB program.

Table III: Fuse Settings without Interfacing PV Source

Zones of protection	Relay	Isc (A)	I_{DG} (A)	t-fast (Sec)	t-slow (Sec)	t-Relay (Sec)	b
1	1	5000	0	0.11	0.26	0.19	6.05

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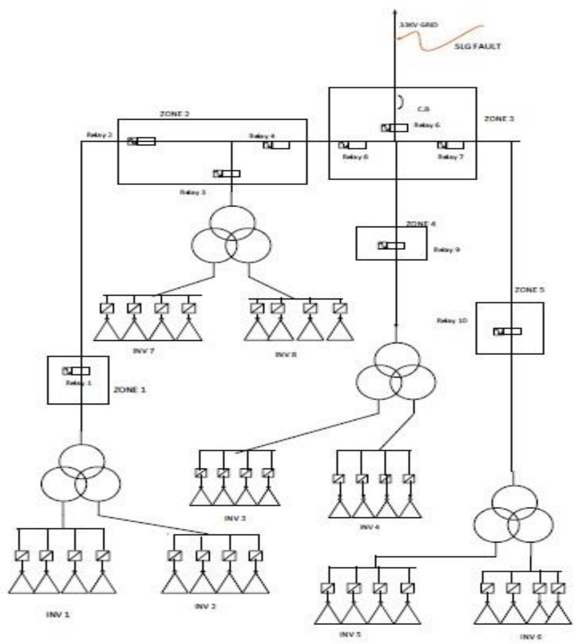

Table IV: Fuse Settings with Interfacing PV Source

Zones of protection	Relay	I_{DG} (A)	t-fast (Sec)	t-slow (Sec)	t-Relay (Sec)	b
1	1	700	0.13	0.28	0.205	6.13
2	2	700	0.13	0.28	0.205	6.13
2	3	600	0.18	0.34	0.26	5.4
2	4	350	0.19	0.44	0.34	5.2
3	6	200	0.24	0.52	0.38	5.1
3	7	100	0.31	0.55	0.43	5.0
3	8	350	0.19	0.44	0.34	5.2
4	9	400	0.16	0.48	0.39	5.8
5	10	100	0.31	0.55	0.43	5.0

Table V: Calculation of Power

Zones Of Protection	RELAYS	I_{DG} (A)	V_{DG} (KV)	Power (KW)
1	1	700	0.23	161
2	2	700	0.23	161
2	3	600	0.23	138
2	4	350	0.23	80.5
3	6	200	0.23	46
3	7	100	0.23	23
3	8	350	0.23	80.5
4	9	400	0.23	92
5	10	100	0.23	23

VII. CONCLUSION

In this paper a Real time system is taken and integrated with the Grid and consequent fault current contribution is calculated. So it can be concluded that as PV penetrates into the grid protection settings and size of PV source change considerably. This study is very relevant as the penetration of PV into low voltage and medium voltage grids is increasing rapidly. Table III and IV show how DG is affecting the protection settings of different fuses, which fulfils the aim of this paper. Based on the trail error analysis and simulations, maximum size of PV source that must be added to the grid, so that protection settings doesn't necessarily needs to be altered is given in Table V.

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