IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

Impacts Of Distributed Photovoltaic Units On Distribution System Power Quality

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Abstract: The Solar double diode mathematical equation are simulated with maximum power tracking technique using perturb and observer technique .Using this maximum power output obtained without changing any physical constraints of solar cell. The above method simulated using Matlab for obtaining the predictable physical behavior of a PV module and array of 1MW capacity. The load flow analysis developed using Forward and Backward Sweep algorithm.. It is flexible and easy to adapt to any changes in any Radial distribution system at a tolerance of 0.0001 is developed.

Index Terms – Solar PV, Forward and Backward Sweep, Power Quality

I. INTRODUCTION

Electric Power is foremost components for the economic growth and welfare of nations. As the populace expands, interest for power is expanding in the nation and it will upsurge further in expected years. Karnataka state framework has 2 crore-establishment limit and accomplished over 95% electrification. The power request of the state is always expanding alongside exclusive standard of consumers. State has taken many initiatives to increase power generation through inexhaustible powered sources like solar, wind and Biomass distributed generation (DG). Karnataka has commissioned 200MW solar power station in 60 taluks with a total capacity of 1200MW.

MATHEMATICAL MODELING OF DOUBLE DIODE PV CELL

The prototypical shown in Figure 2.1 is a single diode model of PV cell in which core loss of the current is negligible. A diode and light generated current source is shunt connected. Using Kirchhoff‟s laws, output current I_{PV} is

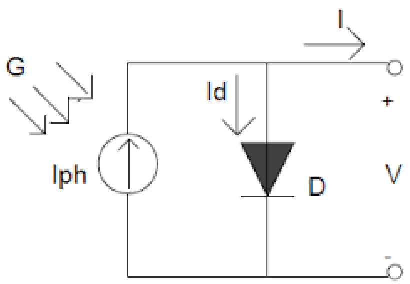

Figure1: Ideal Single Diode Model

$$I_{PV} = I_{ph} - I_d$$

I_{ph} ->photocurrent, I_d -> diode current, I_d is proportional to the saturation current given by the equation

$$I_d = Io[\exp\left(\frac{V}{A.Ns.Vt}\right) - 1]$$

V -> diode voltage, Io-> leakage current of the diode (A), Vt -> the thermal voltage .Ns-> total number of PV cells in series, A -> ideality factor, it is a constant and depends on the technology used. The thermal voltage a is given by equation 3

$$a = \frac{Ns.A.k.Tc}{q} = Ns.A.Vt$$

The efficiency of PV cell depends on the series resistance Rs and the shunt resistance RP considering these the PV module as in Figure 2 and 3. Considering RS equation 2 becomes.

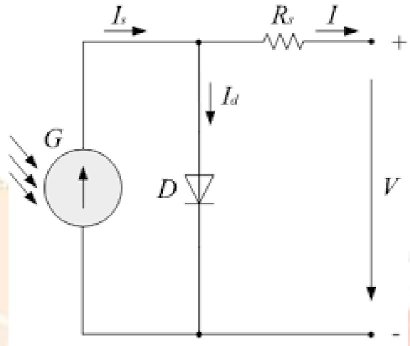

Figure2: Single Diode model with series resistor

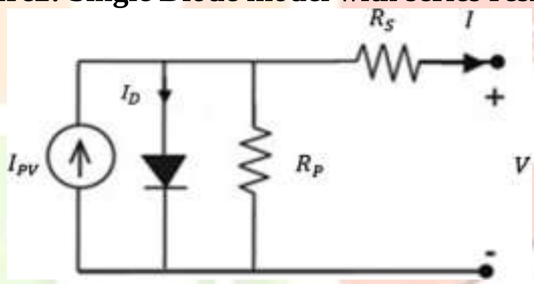

Figure 3: Single Diode model with Series and Parallel Resistor

$$I_d = Io[\exp\left(\frac{V+I.Rs}{a}\right) - 1$$

Applying Kirchhoff Current law to circuit in Figure 3, current I_{PV} with I_P->Leakage current in RP is:

$$I_{PV} = I_{ph} - I_d - I_p$$

Therefore the output current with Ns will be:

$$I_{PV} = I_{ph} - Io\left[exp\frac{V+I.Rs}{a} - 1\right] - \frac{V+R_sI}{R_P}$$

As per the Figure. 1, at the standard test conditions (STC) the output current for single diode model is given by:

$$I_{PV} = I_{ph} - I_o[exp\frac{V}{a_{ref}} - 1]$$

Similarly, for double diode model the circuit is as shown in Figure 4.

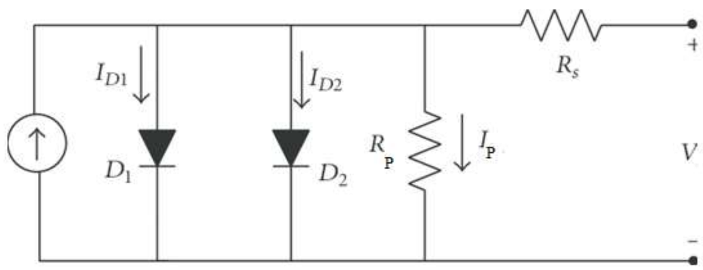

Figure 4: Double Diode Model

$$I_{PV} = I_{ph} - I_{s1}\left[exp\frac{V + I_{PV}.Rs}{a} - 1\right] - I_{s2}\left[exp\frac{V + I_{PV}.Rs}{a} - 1\right] - \frac{V + R_s I_{PV}}{R_P}$$

Equation (8) present I_{PV} considering manufacturers parameters data for $V_{oc.ref,}$, other, for PV technology, as A and T_c some other constants. Identity factor "a" and value dependents on definite temperature.

2. MPPT MODELING OF PV PANEL

The voltage and current Vmpp and Impp are considered respectively for the maximum power point (MPP). The following equation deduced based on double diode output current equation (7) [6]:

$$I_{mpp} = I_{ph} - Io\left[exp\frac{Vmpp+Impp.Rs}{a} - 1\right] - \frac{Vmpp+R_s Impp}{R_P}$$

The model described by equation (9) constructed using MATLAB/ Simulink as in Figure 3.

P&O MPPT Algorithm Analysis and Implementation

To obtain the maximum power point the PV array perturbed by adding slightly until it reaches maximum point. To initiate by considering V1 and I1 values of the solar module, the output power P1 is calculated. Again, a small perturbation is included to get ΔV. The next power value P2 obtained by considering V1 and I1 values of the solar module. If power output P2 obtained is positive, perturbing takes place in the same direction. As soon as the power output P2 becomes negative, by adding negative increment the output power value comes back towards the maximum power point. The oscillation of the system starts at the maximum power point. Hence, controller brings the voltage V of the solar module to perform on this maximum power [6].

Solar module maximum power tracked without changing any physical constraints of solar cell. The above method designed using Matlab for obtaining the predictable physical behavior of a PV module and array.

3. RADIAL BACKWARD AND FORWARD SWEEP (RBF) BASED LOAD FLOW ALGORITHM

Iterations of backward and forward sweep established by load flow algorithm:

1. First, the bus and lateral indexing are prepared.

2. Then RBF organizations of end nodes are done according to the indexing.

3. All the end nodes voltages are initialized aimed at the three phases (allowing for the nominal voltage as base voltage).

4. Allowing the RBF arrangement the backward sweep for the first iteration starts.

5. **Backward sweep**

(a) The end node of lowest RBF order is considered.

(b) Such as the node voltage is known, so the current inserting at this node by loads, shunt capacitors and DGs can be designed.

(c) Then the current injection at the node is calculated by applying KCL at current node. As this is the end node, the incoming downstream branch must add no current.

(d) Formerly by the initialized voltage and the total current , voltage and current injection at the next node over and done with the branch amongst current node and next node is aimed.

(e) Go to 5(b) and track the same process until the branch off node of current sub lateral or lateral has gotten.
(f) The calculation of voltage and current at the current sub lateral or lateral are stationary and the RBF order is incremented by one and goes to 5 (b) until source node has reached.
(g) If the node is source node, and RBF instruction value becomes full, it means that the backward sweep for first iteration ends.
(h) Therefore from backward sweep the branch off current of laterals and sub laterals are put in storage for calculating the node voltages in forward sweep.

6. Forward Sweep

(a) The forward sweep starts through the indicated substation secondary voltage, and the current injected by the substation to the system stored as branch off current of the central feeder during the backward sweep.
(b) Therefore, it is easy to calculate the voltage of the downstream node and the current flowing over and done with the downstream branches of the main feeder.
(c) Through this, voltages at the points from where the laterals are branching off from this main feeder or laterals or sub laterals are stored as branch off voltages of corresponding laterals.
(d) Now if the end node of that core feeder or the lateral or the sub lateral reaches, RBF instruction is decreased by one and go to 6 (b) until the calculation of the lateral of RBF instruction one reaches.

7. Successively after completion of the backward and forward sweep for the first iteration, end node voltages are modernized.

8. The new end node voltage is equalled with the previous initialized end node voltages (only for first iteration) or the end node voltages of the earlier iteration.

9. These associated end node voltages values are less than a small error value, it means that the load flow has converged then go to 5 and look after the backward and forward sweep repeatedly considering the new end node voltages.

Formulated Algorithm for Load Flow Calculation

The algorithm of backward forward sweep is has shown in flow chart in Figure.2.10 and algorithm is as given below

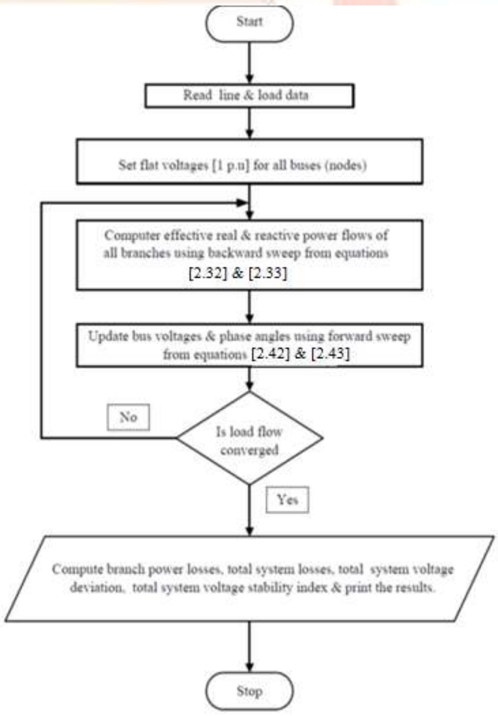

Figure 5: Flow Chart of Radial Distribution System using FB Sweep Algorithm

4. RESULTS AND DISCUSSION

In this work, the data for solar design is taken from the network coupled solar photovoltaic power plant installed in a village Belakavadi, Mandya district in the Karnataka as shown in Figure 6. The power plant has a capacity to fetch a solar radiation per day of 6.10 kWh/sq.mt plot area is about 25 Acres. Irradiation from solar ranges from 15 to 40 degree centigrade, 15 degree tilt angle and energy generated for year is 8.142 MU with 18.6% CUF [5].

The solar panel specification of photovoltaic power plant is as shown in the table 2.1 below, each panel is having a Wattage of 220W, 360V and open circuit current is 7.6A and Mon crystalline type PV panel is used and 22560 modules are used.24 number series panels and 940 parallel panels combination are connected in series parallel combination. The tilt angle of PV module is 15 degree output of each panel is 250KW.

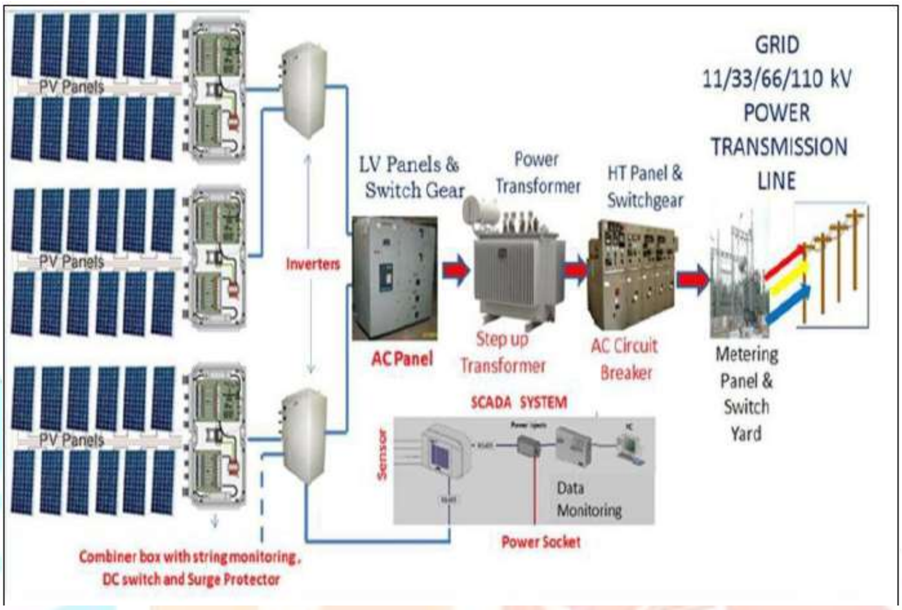

Figure 5: Block Representation of 5MW Solar Power Plant

Table 1: Solar Panel Specification

Watt	220 Watt
Voltage	360 Volts
Current	7.6 A
Type	Monocrystalline
No's of module	22560 no's
No's of modules per MW	4512 no's
Detail of series/parallel combination	24 no's in series, 940 no's in parallel string
Efficiency	14.3%
Temperature	Min 15 o and Max 40 deg c
Dimensions of single module(mm)	1655(L) × 995(w) × 50(T) mm Area of single panel = 1646725 (mm) Area of single panel = 1.64 meter²
Tilt angle(slope) of PV Module	15 degree
Wind speed rating	150 Km/h
Mounting	Fixed Type
Output of the PV array to be connected to the PCU	Nominal 250 KW
Protective device	400 Volts under voltage relay

The mathematical equation of double diode model developed in equation (2.8) modeled using simulink modeling as shown in Figure 6.

$$I_{PV} = I_{ph} - I_{s1}\left[exp\frac{V + I_{PV}\,.Rs}{a} - 1\right] - I_{s2}\left[exp\frac{V + I_{PV}\,.Rs}{a} - 1\right] - \frac{V + R_s I_{PV}}{R_P}$$

The parameter for PV module chosen based on their variation of temperature and light availability as shown in table 2. At temperature of 25^0C and an irradiance of 1000W/M2. For 1MW, the solar panel designed in the simulation shown .The characteristic such as IV and PV, obtained from the designed PV model shown in figure 7 and 8 respectively.

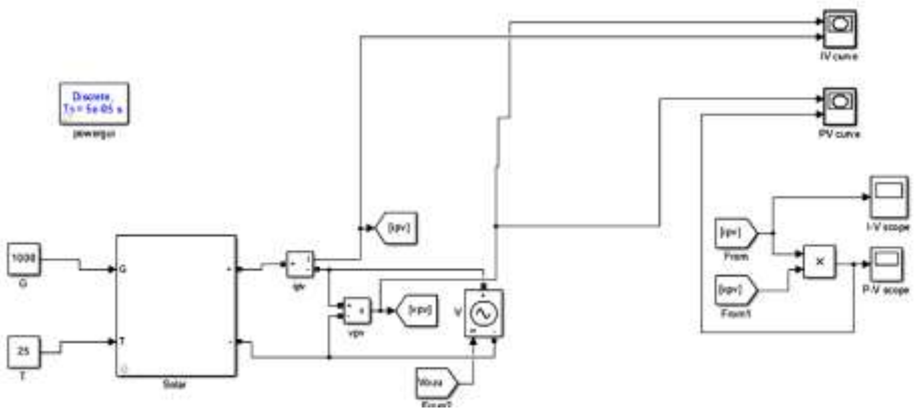

Figure 6: Simulink Grouped Subsystem of PV Model

Table 2: Solar Double Diode Model Data

Sl. No.	Parameter Name	Value
1	Irradiance	1000W/M^2
2	Temperature	25°C
3	Number Modules in Series	40
4	Number of Modules on Parallel	60
5	Number of Cells Connected in Series	36
6	Open Circuit Voltage (V_{oc})	32.6 V
7	Short Circuit Current (I_{sc})	8.2 A

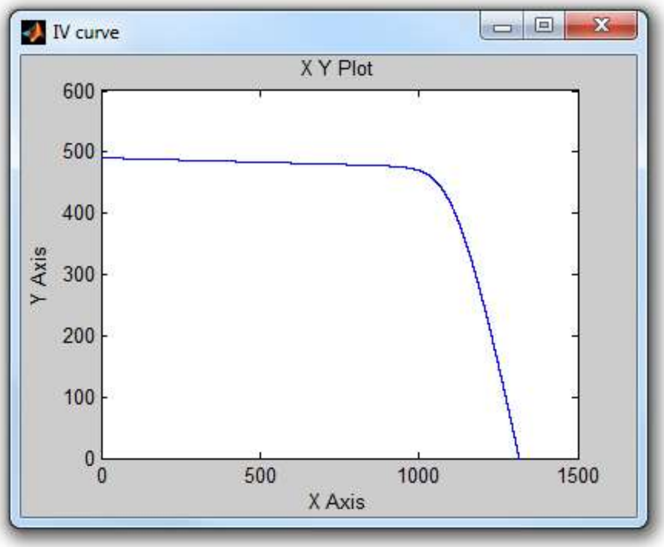

Figure 7: IV Curves of Double Diode Model

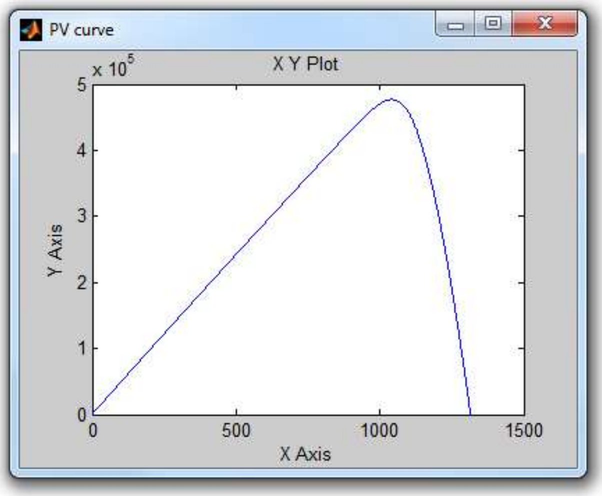

Figure 8: PV Curves of Double Diode Model

IMPACT OF DISTRIBUTED SOLAR PHOTOVOLTAICS ON 13-BUS RADIAL DISTRIBUTION SYSTEM POWER QUALITIES

Solar generators are significantly growing in India in the view of increasing economic capacity in most states. It provides improved grid reliability and power quality. But on low tension grid, which is not designed considering the expansion causes power quality issues. The issues created when solar generated power is injected into the grid are DC injection, harmonics and flickers [12].
Harmonics – the Total Harmonic Distortion(THD) ,voltage distortion limit is less than 5% , Current distortion limits dependence on the ratio of short circuit current to the load current,

Flickers - Voltage varying randomly from 90% to 110% of nominal voltage produces flickers. Its limit is less than 16A for low voltage equipment.

DC injection- The DC current inside the LV AC causes overheating and harmonics. Its limit is 0.5% of the full rated voltage

To study the impact of solar photovoltaic generator on 13- bus system when solar is injected to grid, the effect of solar injection on test system analysed. Figure 9 shows the Voltage THD with distributed solar system injected to 13-Bus Test system, the Voltage THD varies from 2.11% to 9.53 %, THD level is maximum at bus 12 and minimum at bus 2.11%. Figure 2.26 shows the current THD with distributed solar system injection to test system, it varies from 0.91% to 25.80%, THD level is maximum at buses 2,3,4,7.10 and 11 and minimum at bus 6. It indicates that as the solar is injected to the grid the power quality issues arises and it need to be considered while injecting solar to the grid.

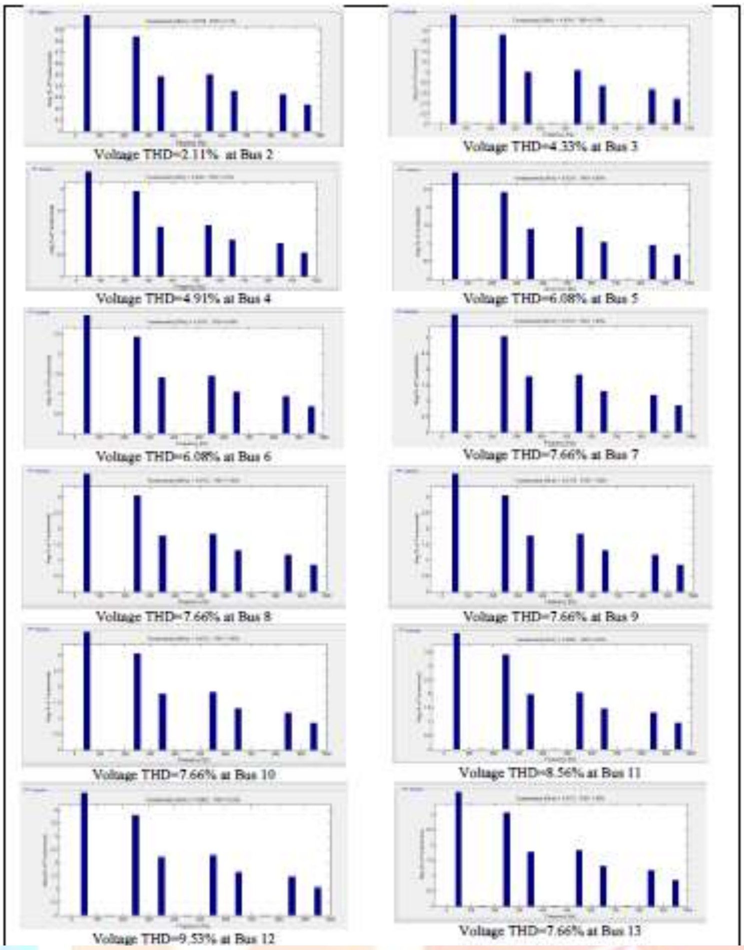

Figure 9 : Voltage THD Varies from 2.11% to 9.53% with Solar DG

5. Conclusion

The Solar double diode mathematical equation are simulated with maximum power tracking technique using perturb and observer technique .Using this maximum power output obtained without changing any physical constraints of solar cell. The above method simulated using Matlab for obtaining the predictable physical behavior of a PV module and array of 1MW capacity. The load flow analysis developed using Forward and Backward Sweep algorithm. The power flow of the distribution system, total Active Power Line Loss and Reactive Power Loss obtained using FBS algorithm. It is flexible and easy to adapt to any changes in any Radial distribution system at a tolerance of 0.0001 is developed.

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