REAL-TIME APPROACH FOR ENHANCEMENT OF VOLTAGE STABILITY USING DISTRIBUTED GENERATION

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Abstract- Instability in a power system may be manifested in many ways depending on the system configuration and its operating mode. Voltage instability in power distribution systems could steer to voltage collapse and hence the 'power blackouts' or abnormal low voltages. It is necessitate to be aware of the strength of buses to enhance the voltage stability of the system. This paper resolves and confer about the 'voltage stability of power distribution system' and little endeavor to employ photovoltaic DG for voltage stability enhancement.

Index Terms- Voltage stability, PV Module, Distributed generation.

I. INTRODUCTION

Distributed generation (DG) can be regarded as carrying power to the load. Distributed generator assures the generation of electricity with high efficiency and low pollution. In contrast to large central power plants, Distributed generator can be installed nearby the load. Distributed generator ratings range from 5 kW to several hundreds of kW. Maintenance cost for embedded generation such as fuel cells and photovoltaics is utterly low as it lacks the moving parts. Numerous present day developments have optimistic entry of power generation and energy storage at the distribution level. A few of the major ones are listed below:

- Several technologies with reduced environmental impacts and high conversion efficiencies have been invented.
- Advent of efficient and cost-effective power electronic interfaces to improve power quality and reliability.
- Ability to control a number of components and subsystems effectively using state-of-the-art computers to manage loads, demands, power flows, and customer requirements.

Several DG technologies are in the process of diverse development stages, it includes micro turbines, photovoltaic systems (PV), wind energy conversion systems (WECS), gas turbines, gas-fired IC engines, diesel engines, and fuel cell systems. Integration of DG as an existing utility outcomes the benefits of line loss reduction, reduced environmental impacts, peak shaving, increased overall energy efficiency, relieved transmission and distribution congestion, voltage support.

The DG has constituted a challenge and chance for developing miscellaneous novel technologies in power generation. The presented work in this paper confer about the primary factors that led to an escalated interest in DG. DG diminishes line losses and arbitrates an increased voltage profile of the system.

II. VOLTAGE STABILITY

Voltage stability is a major concern in planning and operating the power systems. It is renowned that a collapse in voltage and its instability leads to huge failures in the system. With the origination of power markets, more and more electric utilities are facing voltage stability – imposed limits. The problem of voltage stability is the inability of the power system to facilitate the reactive power or the egregious consumption of the reactive power by the system itself. It can be made clear that reactive power problem is a dynamic phenomenon [1, 2].

Voltage stability analysis many a time demands the inspection of lot of system states and many contingency scenarios. It is this reason that made the approach to steady state analysis more feasible, and it also provides an insight of the problems as for voltage and reactive power. A number of special algorithms are put forth in the literature of voltage stability analysis using static approach; however these approaches are laborious and does not provide sensitivity information useful in a dynamic process. Voltage stability is indeed a dynamic phenomenon.

Voltage stability and voltage collapse have often been seen as a steady-state "viability" problem befitting for static (power flow) analysis. The ability to transmit reactive power from production sources to consumption sinks throughout the steady operating conditions is a major aspect of voltage stability. The network's maximum power transfer limit is not necessarily the voltage stability limit.

Voltage stability or collapse is a dynamic process. The word "stability" implies a dynamic system. A power system is a dynamic system. In contrast to rotor angles (synchronous) stability, the dynamic stability mainly involves the loads and the means for voltage control. Voltage stability has been called load stability.

Power system stability is the capability of a system to regain its normal state of equilibrium after subjected to a disturbance. The major concern in the evolution of stability, is the behavior of the power system when

subjected to a transient disturbance. The disturbance may either be small or large. Small disturbance in the form of load changes takes place continually and the system adapts itself to the altering conditions. The system must be capable of surviving numerous disturbances of a serve nature, such as short –circuit on transmission line, loss of a large generator or load, or loss of a tie between two sub systems.

Power system network can be divided in to three major sub networks, such as: (i) generation sub network, (ii) transmission sub network and (iii) distribution sub network. Generation sub network mainly constitutes 3-phase synchronous generators, transmission sub network mainly constitutes 3- phase transmission network and distribution sub network mainly constitutes distribution system including loads. These loads can be either static or dynamic such as synchronous motors and induction motors etc. or composite loads.

There are two forms of instability concerns in power systems: the loss of synchronism between two synchronous machines, and the stalling asynchronous loads. The power system stability can be grouped into three categories: steady-state stability, transient stability and dynamic stability. The power system voltage stability analysis will be carried out majorly based on p-v curves and q-v curves [8].

III. VOLTAGE INSTABILITY

Voltage instability is the absence of voltage stability and results in progressive voltage drops (or increases). Usually Voltage stability incorporates large disturbances (including rapid increases in load or power transfer). Furthermore the instability is practically always a periodic decrease in voltage.

Voltage instability in a power system exists due to shortage in the reactive power. It either arises at the sources due to VAR output limit or impotence of the network to deliver the real power due to shortage of local reactive power at the network locations. The primary & secondary forms of voltage instability are source dependent & network dependent respectively.

A system enters the state of voltage instability when a hike in load demand or alterations in the system conditions results in progressive and uncontrollable decline in voltage. Load variations or contingencies in general causes voltage collapse. This paper considers voltage collapse due to load variations.

Power transmission capability has traditionally been limited by either angle stability or by the thermal loading capabilities of the lines. But with the developments in faster short circuit clearing times, rapid and effective excitation systems and developments in numerous stability control devices and the problems associated with transient instability of the system have been largely reduced. However, voltage instability limits are more prominently significant in the context of a secure power system operation.

IV. PV MODULE

The evolution of present day renewable energy sources is continuously increasing because of the critical situation of the chemical industrial fuels such as oil, gas and others. Thus, the renewable energy sources have become the most important contributor of the total energy consumed in the world. The field of photovoltaic (PV) or solar energy has experienced a remarkable growth for past two decades in its widespread use from stand alone to utility interactive PV systems. In fact, the demand for solar energy has increased from 20% to 25% over the past 20 years [3], increasing the market for PV systems worldwide. In fact, nowadays, solar PV provides around 4800 GW and in between 2004 and 2009, grid connected PV capacity reached 21 GW and is increasing at an annual average rate of 60%.

PV cells are environmental friendly without emission of pollutants, convert sunlight directly to electricity. They are basically made up of a PN junction, Figure: 1 shows the photocurrent generation principle of PV cells. In fact, when sunlight is incident on the cell, the photons are absorbed by the semiconductor atoms, releasing electrons from the n-layer. These free electrons finds its paths through an external circuit toward the positive layer resulting in an electric current from the positive layer to the negative one.

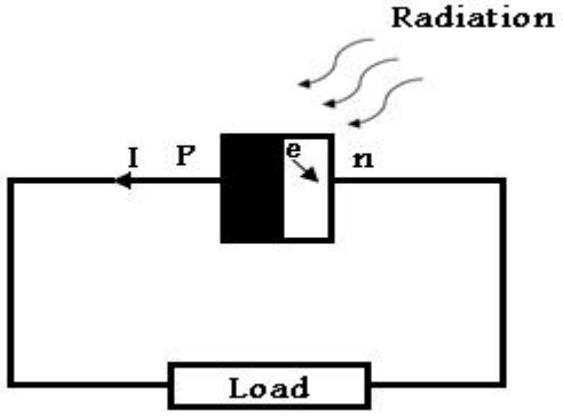


Figure: 1 Photocurrent generation principle

Typically, a PV cell generates a voltage around 0.5 to 0.8 volts depending on the semiconductor and the built-up technology. This voltage is low enough as it cannot be effused. Therefore, to be benefited from this technology, large number of PV cells (involving 36 to 72 cells) are connected in series to form a PV module. These modules can be interconnected in series and/or parallel to form a PV panel.

Solar cells consist of a p-n junction fabricated in thin wafer or layer of semiconductors, whose

electrical characteristics differ very little from a diode represented by the equation of Shockly [4]. Thus the simplest equivalent circuit of a solar cell is a current source in parallel with a diode as shown in Figure2.

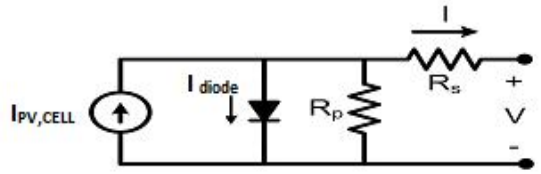


Figure2: Equivalent Model of a Photovoltaic Cell

$$I = I_{PV,CELL} - I_{diode} = I_{PV,CELL} - I_{0,CELL}[\exp(\frac{q*V}{\alpha*K*T}) - 1]$$

Where:

- IPV,cell is the current generated by the incident light.
- Idiode is the Shockley diode equation.
- I_0, cell [A] is the reverse saturation or leakage current of the diode [A].
- q is the electron charge [1.60217646 * 10-19C].
- k is the Boltzmann constant [1.3806503* 10-23J/K].
- T [K] is the temperature of the p-n junction
- α is the diode ideality constant which lies between 1 and 2for mono crystalline silicon.

In general, a unique point is present on the I-V or P-V characteristics as shown in Figure3, called maximum power point (MPP), at which the entire PV system (array, converter, etc…) operates with maximum efficiency and produces its maximum output power. Therefore maximum power point tracking (MPPT) techniques are needed to maintain the PV array's operating point at its MPP [4].

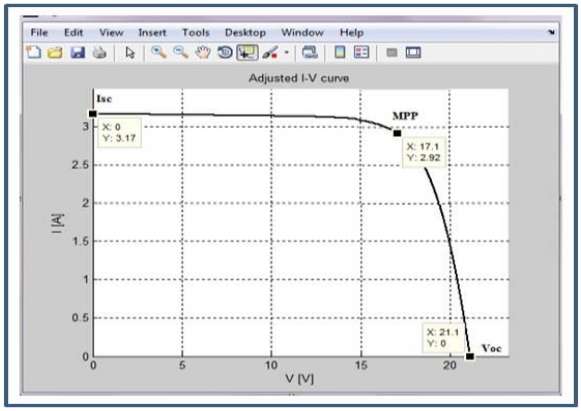


Figure: 3 Characteristics of I-V, P-V Curve of a Practical Photovoltaic Device

V. DISTRIBUTED GENERATION

Distributed Generation appears to be like electric power generation source connected directly to a distribution network or on the customer side of the meter [6].

Distributed Generation can also be referred as On-site Generation or Dispersed Generation or Embedded Generation or Decentralized Generation as shown in Figure: 4.

Distributed generation (DG) generally depicts small-scale generators, with a capacity ranging from 5 kW to several hundreds of kW's, that produce electricity at a site nearer to the customers or that are tied to an electric distribution system. Distributed generators not only contain synchronous generators, but also induction generators, reciprocating engines, micro turbines (combustion turbines that run on high-energy fossil fuels such as oil, propane, natural gas, gasoline or diesel), combustion gas turbines, fuel cells, solar photovoltaic's and wind turbines [7].

VI. PICTORIAL REPRESENTATION OF DG SYSTEM

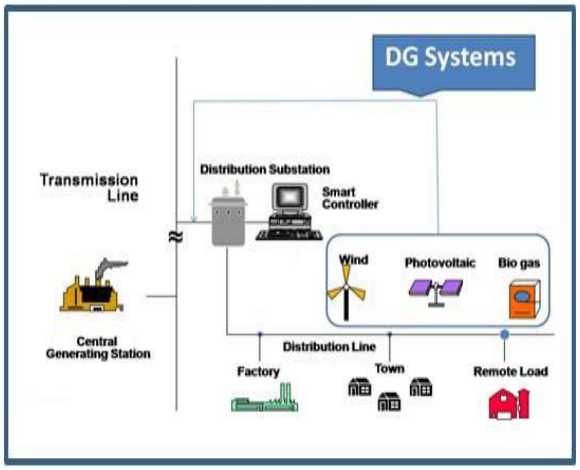


Figure: 4

VII. CIRCUIT DESCRIPTION

A 3-Feeder Approximated Distribution Networks (ADN) Scheme as shown in Figure- 5.

ADN is developed by considering three feeders of different lengths and following pre-requisites; let the lengths of feeder 1, 2, 3 ABC, ABDE, ABDFG are considered as L1, L2, L3 respectively and are related as L1<L3<L2. ADN is feeds two categories of loads namely Fixed and Variable Loads. These loads are merely the approximations of domestic lighting loads and motor loads. The time varying nature of loads can be examined by considering variable load option. A tolerance limit of the network is considered to be about ± 5%. Resistance and inductance with fixed and variac type are considered in the system. A supply voltage (Vs) of 230V is stepped down to 115v using a step down transformer and then fed into the considered three feeders of different lengths in the system. The Table-1 and 2 shows Variations of loads without distributed generation (WODG) and with distributed generation (WDG) respectively Table 1

shows supply voltage (Vs) and supply current(Is),and Table 2 shows the three feeder voltages and wattages.

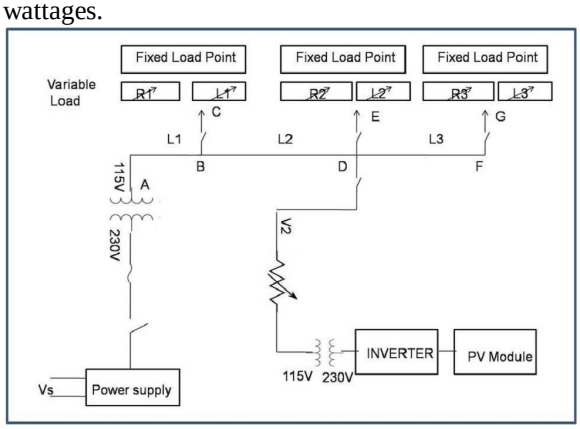


Figure: 5

Table-1

V_s		I_s	
WODG	WDG	WODG	WDG
107	109	15.7	12.8
106	108	15.7	12.9
105	107	16	13
104	107	16.3	13.3
105	107	14.6	11.5
105	107	13.6	11

From Table-2 it is clear that an increase in load at feeder 2 increases the non-permissible voltage drop in the system, leading to instability. Therefore a necessity arises to improve the voltage profile, this can be attained by using FACTS devices, but using DG gives more reliable voltage profile than any other methods of maintaining stability. A photo voltaic system is considered as DG, the output of photo voltaic cell is connected to node point D through inverter and step down transformer as shown in Figure: 5. Therefore, the voltage at that load point is improved due to the impact of DG placed at feeder 2, the voltage at remaining feeders is also gets increased. Thus the voltage stability margin of the system is enhanced.

Table-2

V_1		V_2		V_3	
WODG	WDG	WODG	WDG	WODG	WDG
105	107	108	111	104	106
104	106	107	110	103	105
103	105	106	109	102	104
101	104	104	108	100	102
102	104	105	108	101	103
103	104	106	108	101	103
W_1		W_2		W_3	
WODG	WDG	WODG	WDG	WODG	WDG
40	40	260	280	45	50
40	60	310	320	65	65
100	120	240	360	90	90
140	160	360	400	105	110
140	170	350	370	130	135
170	170	350	370	130	135

The prototype arrangement is shown in Figures: 6, 7 and 8 below. Figure: 6 shows front view of the system connections Figure: 7 shows the side view and Figure-8 shows the solar panel arrangement.

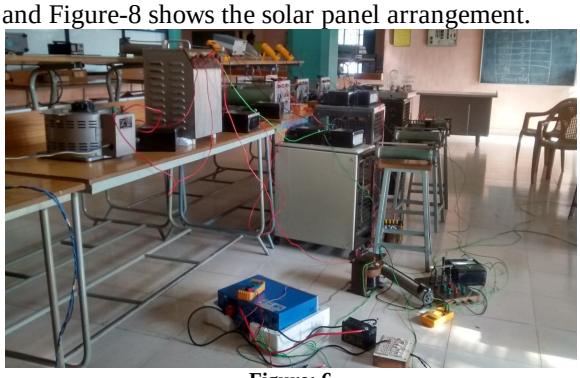


Figure: 6

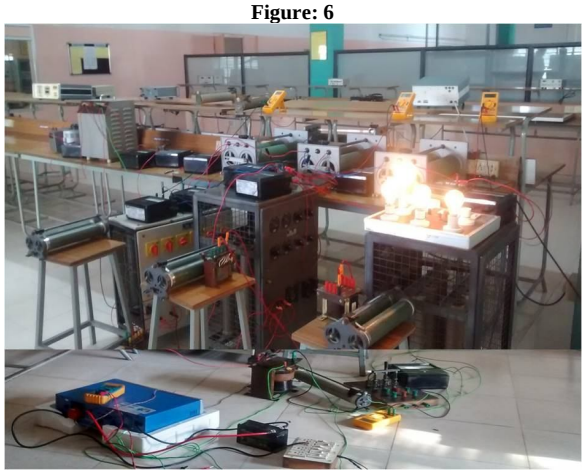


Figure: 7

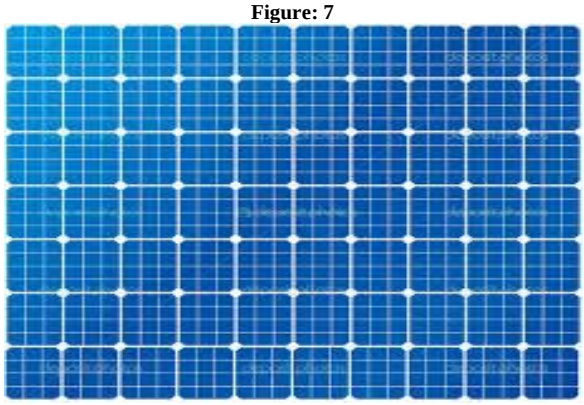


Figure: 8.

VIII EXPERIMENTAL SPECIFICATIONS

Table-3

S.No	Resistances	Ω
1	R1	o.4
2	R2	0.6
3	R3	0.5

Resistive Load

Table-4

S.No	Inductance	Henry
1	L1	50mH
2	L2	100mH
3	L3	150mH

Inductive load

Table-5

S.no	Lamp Type	Wattage
1.	Incandescent Lamp	380

Lamp load

Table-6

S.No	Resistances	Wattage
1	Variable R1	5Kw
2	VariableR2	3Kw
3	VariableR3	380w

Variable load

Table-6

S.no		
1	Pmp	150wp
2.	Voc	22V
3.	Isc	9.09A
4.	Vmp	17.60V
5.	Imp	8.5A

PV-Module

IX. EXPERIMENTAL RESULTS

Table-7

V_1		W_1	
WODG	WDG	WODG	WDG
105	107	40	40
104	106	40	60
103	105	100	120
101	104	140	160
102	104	140	170
103	104	170	170

Voltage &Power consumption at node1

Table-7 shows the Voltage and Power consumption at node-B (Figure-5), at node-1 showing 105 V with respect to power 40W without DG and by incorporating DG system at node-D as shown in Figure-5 the voltage value increases to 107V with respect to same power 40W, for different values the voltage and power are graphically represented as shown in Figure-9

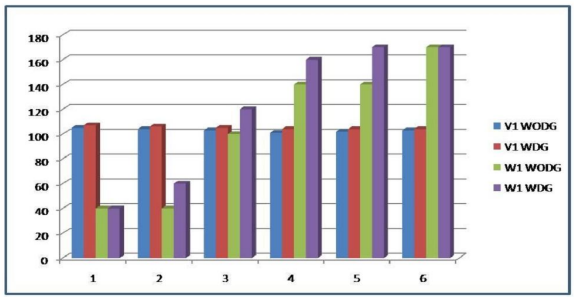


Figure: 9

Table-8

V_2		W_2	
WODG	WDG	WODG	WDG
108	111	260	280
107	110	310	320
106	109	240	360
104	108	360	400
105	108	350	370
106	108	350	370

voltage &Power consumption at node2

Table-8 shows the Voltage and Power consumption at node-D (Figure-5), at node-1 the voltage value is 108 V with respect to power 260W without DG and by incorporating DG system at node-D as shown in Figure-5 the voltage value increased to 111V with respect to power 280W, for different values the voltage and power are graphically represented as shown in Figure-10

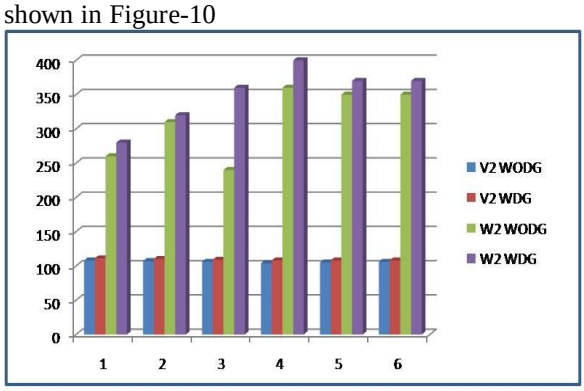


Figure: 10

Table-9

V_3		W_3	
WODG	WDG	WODG	WDG
104	106	45	50
103	105	65	65
102	104	90	90
100	102	105	110
101	103	130	135
101	103	130	135

Voltage &Power consumption at node3

The Table-9 shows Voltage and Power consumption at node-E (Figure-5), at node-1 the voltage value is 104 V with respect to power 45W without DG and by incorporating DG system at node-D as shown in Figure-5 the voltage value increased to 106V with respect to power 50W, for different values the voltage and power are graphically represented as shown in Figure-11

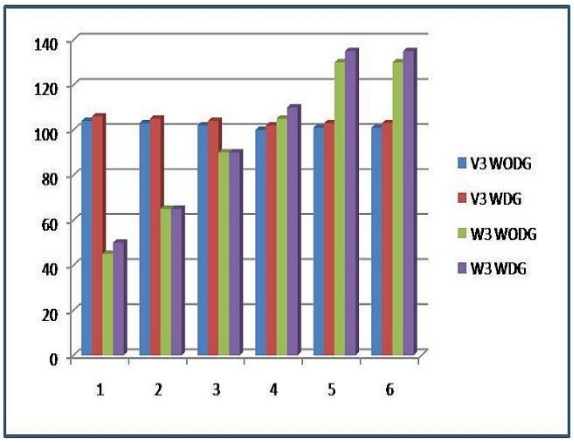


Figure-11

Table-10

V_1		V_2		V_3	
WODG	WDG	WODG	WDG	WODG	WDG
105	107	108	111	104	106
104	106	107	110	103	105
103	105	106	109	102	104
101	104	104	108	100	102
102	104	105	108	101	103
103	104	106	108	101	103

Voltages at all three nodes

The Table-10 shows Voltages at all node-B, node-D and node-E (Figure-5), at node-B the voltage value is 105 V, at node-D the voltage value is 108 and at node-E the voltage value is 104 without DG, now by incorporating DG system at node-D as shown in Figure-5 the voltage value increased to 107V at node-B, 111V at node-D and 106 V at node-E, for different values the voltage at node-B, node-D, node-E are graphically represented as shown in Figure-12

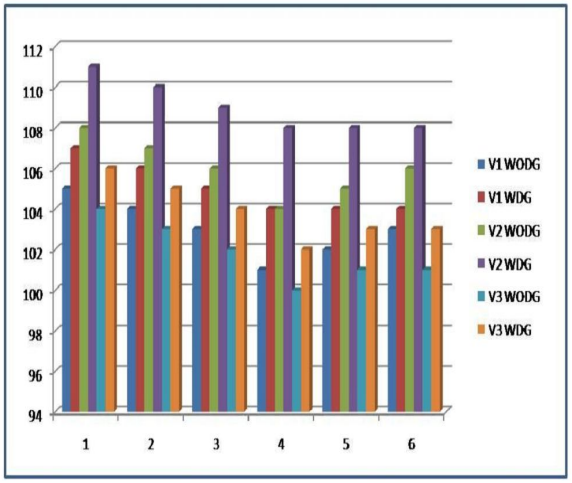


Figure-12

CONCLUSION

A real time measurement based voltage stability analysis for monitoring of the power distribution systems is presented and verified experimentally. It can be concluded due to increase in load at feeder -2 the voltage drop got increased which is not permissible in the system i.e., leading to instability. Therefore it is necessary to improve a voltage profile. In this case it has been accomplished by placing DG at appropriate node i.e. at node-D. So that it gives reliable voltage profile. Placing DG at node-D increases the voltages at node-B and node-E in addition to node-D.

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