# Optimal & Fast Placement of DG Unit CPF Method Using MATLAB Toolbox PSAT

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***Abstract* - The voltage stability problem is occurring while increasing the loading parameters on power system network buses. One of the reasons of increasing the loading parameter is consumption of reactive power. Distributed generator has capacity for absorbing and injecting both active and reactive power in the distribution network and so many other benefits from DG unit. By placing the DG in system at right bus, there would be improvement the voltage stability margin and improvement voltage profile for each load bus. Continuation power flow method is used as power flow and finds the most sensitive bus for voltage collapse by the help of PV curve. IEEE 14 bus system is used for study and analysis in MATLAB tool box PSAT.**

***Index Terms* - Distributed Generator (DG), Voltage stability, PV curve, Voltage stability margin (VSM), Continuation power flow (CPF) method, and Voltage profile.**

## I. INTRODUCTION

Voltage stability phenomena are most important part for any distribution network in power system. Major Black out cases is generating by voltage instability phenomena. There are so many times black out cases are occurring in the world. In the histories, the blackout was doing so many times due to voltage collapse. Show in table 1 the history of the black out in the all over the word.

*Table -1 History of blackout in the word*

| Sr | date of blackout | place and system of blackout |
|---|---|---|
| 1 | 09-November-1965 | U.S.A. ,Canada |
| 2 | 19-December-1978 | French system |
| 3 | 28-December-1982 | Florida |
| 4 | 04-August-1982 | northern Belgium |
| 5 | 27-December-1983 | Swedish |
| 6 | 12-January-1987 | French system |
| 7 | 11-March-1999 | brazil |
| 8 | 28-September-2003 | Italy |
| 9 | 18-August-2005 | Indonesia |
| 10 | 16-November-2009 | brazil, Paraguay |
| 11 | 31-July-2012 | India |

As shown in the table 1, all the blackout phenomena are occur due to large loading on the system. When the system was, being the over loaded then the voltage stability violated and system voltage has been collapse and black out the system.

The main purpose of DG is to maintain voltage profile and obtained maximum steady state voltage stability index [1][2][3][4]. DG improves voltage profile at different power factor [5]. For improving the voltage profile, Sometime capacitor bank is also used with DG [6]. For the placing the distributed generation, it is necessary to maintain the location and rating of DG on network. DG is capable for reducing losses and maintains transient stability also [7][8].

This paper is based on placement of distributed generator unit using continuation power flow method [1]. The continuation power flow method is the power full tool for load flow study. Because it has predictor and corrector step method it will reduce the chances of singularity of jacobian. From using CPF method finding the week bus of maximum loading bus and allocate the DG at that bus.

## II. DISTRIBUTED GENERATION

DG include so many different definition from different point of views on small- scale technologies such as photovoltaic (PV), fuel cells, micro-turbines, or small wind turbines are installed and designed for primarily back- up and to serve a single end users site[9][10]. DG is encompassing any generation and it is built near consumers' load as per its requirement of size or energy source shown in Figure 1 and 2.

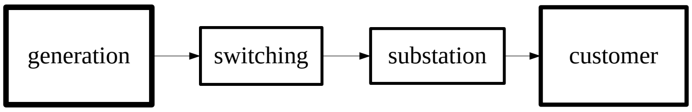


Fig. 1: Schematic Diagram of Conventional Electricity Generation And Distribution

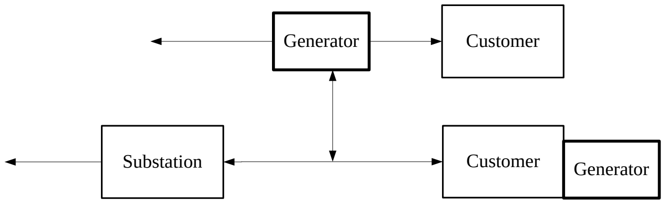


Fig. 2: Schematic Diagram of the Distributed Generation Closer To the Customer

Distributed generation (DG) gives so many benefits as electrical loss reduction, technological innovations, environmental impact benefit, better power quality, economical operation, reliable service; the grid has to be available as backup supply new decentralized market construction etc. But the main interesting concepts are technological innovations, changing economic and environments. International Energy Agency IEA [11] enlists the five main factors that contribute to this evolution, such as constraints on the Construction of new transmission lines, developments in distributed generation technologies, the electricity market liberalization, and concerns about climate change, increased customer demand for highly reliable electricity shown in table 2. DG can reduce the line losses by either supplying or absorbing active or reactive power [12][13].

Table 2- Distributed Generator Benefits and Service [10]

| | | Benefit | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Energy cost saving | Savings in T&D losses and congestion costs | Deferred generation capacity | Deferred T&D capacity | System reliability benefits | Power quality Benefits | Land use Effects | Reduced vulnerability to terrorism |
| DG Services | Reduction in Peak Power Requirements | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | Provision of Ancillary Services<br>o Operating Reserves<br>o Regulation<br>o Black start<br>o Reactive Power | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| | Emergency Power Supply | Yes | Yes | No | No | Yes | Yes | No | No |

### DG Technology

All types of DG technology and technical characteristics are described in table 3 DG unit is capable of reactive or active power control base on main three technologies: [1][14][15][16]

i. Synchronous Generator
ii. Asynchronous Generators
iii. Line-Commutated and Self-Commutated Converters

These three technologies are used in different types of DGs like: Reciprocating engines, Micro turbines, Industrial combustion turbines, Phosphoric acid and proton exchange membrane fuel cells, Photovoltaic, Wind turbine systems

Table 3 the characteristics of DG

| technique Type | diesel reciproc ting generator | natural gas reciprocating generator | Micro-turbine | natural gas fuel turbine | fuel cell | Solar | wind power |
|---|---|---|---|---|---|---|---|
| **power efficiency (LHV)** | 30-43% | 30-42% | 14-30% | 21-40% | 36-50% | 6%-19% | 2%-34% |
| **total operation efficiency** | 80-85% | 80-85% | 80-85% | 80-90% | 80-85% | 45%-60% | 40%-78% |
| **pollution level(gm/bhp-hr)** | NOx:7-9 C0:0. 3-0. 7 | NOx: 0. 7-13 C0:1-2 | NOx: 0. 7-13 C0:1-2 | NOx:<9 50ppm C0:<15 5Oppn | NOx:<0.02 C0 :< 0. 01 | Nothing | Nothing |
| **reliability level** | high | high | No experiment | high | High | not high | not high |
| **main application fields** | Back-up unit for industrial, commercial, public institutions | Generator-driven cogeneration plant | CHO | peak clipping | Residents' install electricity, CHP | Residential, commercial electricity and power supply in remote areas | power supply in remote areas and Platea zone |
| **schedulable** | schedulable | schedulable | Schedulable | schedulable | schedulable | not schedulable | not schedulable |

## III. VOLTAGE STABILITY

"Voltage stability is the ability of a power system to maintain steady acceptable voltages at all buses in the system under normal operating conditions and after being subjected to a disturbance."[17]

A system enters a state of voltage instability when a disturbance due to increase in load, the system changes causes voltage quickly being drop, automatic system of controlling unit fail to halt the decay [17]. The voltage decay may take just a few seconds or ten to twenty minutes. If the decay continually, steady-state voltage stability will have violated and voltage collapse will occur Generation and transmission units have definite capacities that are peculiar to them. These limits should not be exceeding in a healthy power system. Voltage stability problem arises when the system is heavily loaded that causes to go beyond limitations of power system [18]. The main factor causing instability is the inability of the power system to meet the demand for reactive power [17] [19].

## IV. PV CURVES

The PV curves represent the voltage variation with respect to the variation of load reactive power. This curve is produced by a series of load flow solutions for different load levels uniformly distributed, by keeping constant the power factor. With increasing the power network the time taken to generate PV curve is also increase because of processing time of load flow is increase [20]. PV curve give information about the voltage stability index and voltage collapse point. Shown in Figure 3 it indicate stability region of any network and voltage collapse point. The PV voltage stability analysis gives the transfer limits by a PV study. Another purpose of PV study is to analysis the voltage stability, screens the entire system, and identifies disturbances that may have the potential to cause a major system blackout or create contingency situation [21].

## V. CONTINUATION POWER FLOW (CPF) METHOD

CPF method is represented as follow [22]

**Formulation power flow**

The continuation power flow is tracing the solution path for nonlinear system by prediction and correction steps. Considering the non-linear equation

$$F(\delta, V, \lambda) = 0 \tag{1}$$

The $\lambda$ presents the load parameter witch limitation is presented by

$$0 \leq \lambda \leq \lambda_{critical}$$

Conventional equations for each bus i is as follows

$$P_{G\,i} - P_{L\,i} - P_{T\,i} = 0 \tag{2}$$

$$Q_{G\,i} - Q_{L\,i} - Q_{T\,i} = 0 \tag{3}$$

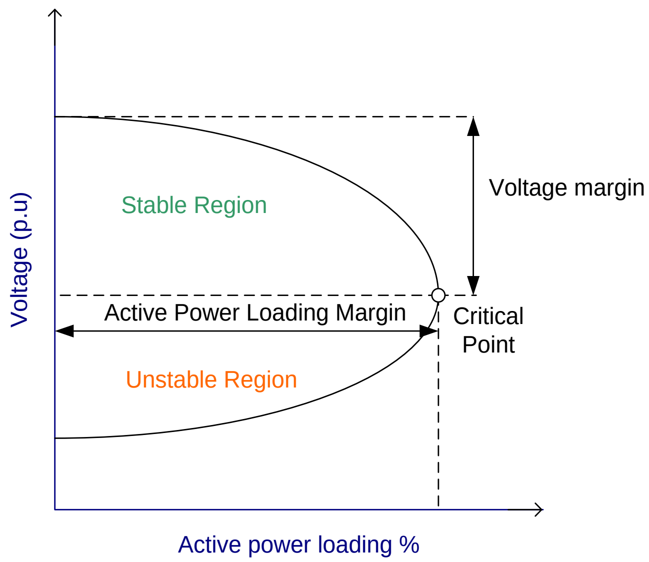


Fig. 3: PV Curves

Where,

$P_{Gi}$, $Q_{Gi}$ are scheduled active and reactive generation values,
$P_{Li}$, $Q_{Li}$ are scheduled active and reactive load values.
$P_{Ti}$ is the net active power injection given by

$$P_{Ti} = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\delta_i - \delta_j - \theta_{ij})$$

$Q_{Ti}$ is the net reactive power injection given by

$$Q_{Ti} = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\delta_i - \delta_j - \theta_{ij})$$

**Predictor step**

The prediction step is taking base on step-size along the direction of the tangent at the previous solution point. The tangent is found as:

$$dF\ (\delta\ ,\ V\ ,\ \lambda) = 0 \tag{4}$$

Now taking partial derivation of (4)

$$(\partial F / \partial \delta)\ (d\delta) + (\partial F / \partial V)\ (dV) + (\partial F / \partial \lambda)\ (d\lambda) = 0 \tag{5}$$

In matrix form,

$$[(\partial F/\partial \delta)(\partial F/\partial V)(\partial F/\partial \lambda)] \begin{bmatrix} d\delta \\ dV \\ d\lambda \end{bmatrix} = 0 \tag{6}$$

In equation (6) right side vector is known as the tangent vector, say t.

$$\begin{bmatrix} (\partial F/\partial \delta)(\partial F/\partial V)(\partial F/\partial \lambda) \\ Z_k \end{bmatrix} [t] = \begin{bmatrix} 0 \\ \pm 1 \end{bmatrix} \tag{7}$$

$Z_k$ is a row vector with all elements equal to zero, but $k^{th}$ element is equal to one and

Tangent vector t = $\begin{bmatrix} d\delta \\ dV \\ d\lambda \end{bmatrix}$

For finding the tangent vector

$$[t] = \begin{bmatrix} (\partial F/\partial \delta)(\partial F/\partial V)(\partial F/\partial \lambda) \\ Z_k \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ \pm 1 \end{bmatrix} \tag{8}$$

After solving (8)

$$\begin{bmatrix} \delta^* \\ V^* \\ \lambda^* \end{bmatrix} = \begin{bmatrix} \delta \\ V \\ \lambda \end{bmatrix} + \sigma \begin{bmatrix} d\delta \\ dV \\ d\lambda \end{bmatrix} \tag{9}$$

Equation Where " * " denotes the predicted solution

**Corrector step**

Corrector step is taking after predicting step size selection of tangent vector.

$$x = \begin{bmatrix} \delta \\ V \\ \lambda \end{bmatrix} \tag{10}$$

$x \in R^{2n_1+n_2+1}$ **OR** $x \in R^{2n-N_g-N_s}$

Where,

n1 and n2 are the number of PQ and PV- buses respectively,
n = Total no. of buses in the given system,
Ng = No. of generator (PV) buses and
Ns = No. of slack bus in the given system

This equation, which is augmented, by one equation in original set of equations sets the value of one of the state variables:

$$x_k = \mu \tag{11}$$

Thus new set of equations is:

$$\begin{bmatrix} F(x) \\ x_k - \mu \end{bmatrix} = [0] \tag{12}$$

**VI. CASE STUDIES**

For analysis, MATLAB tool box PSAT is used. The one line diagram of 14-bus IEEE system shown in Figure 4 in this Figure, the main generator is connected to the bus 1 and bus 2. Bus 1 is treated as slack bus where bus 2 is treated as generation bus or PV bus. Other generators are connected to the bus 3, 6 and 8, which are synchronous compensator. These three buses are purely load buses.

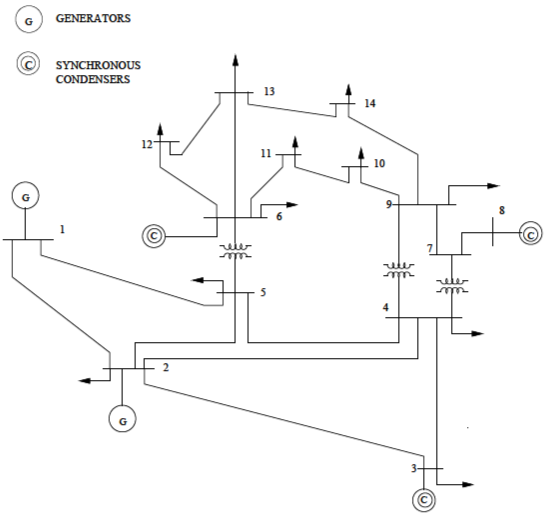


Fig. 4: IEEE 14 bus systems

After the running CPF for 14 bus system, voltage magnitude of bus 4, 5, 9 10 and 14 is down than other buses as shown in Figure 5. PV curve is describing the steady state stability of each load bus as in Figure 6. PV curve of each individual bus is indicate bus no 5, 10 ,and 14 are the critical for voltage collapse that mean DG placement at these buses are most preferable.

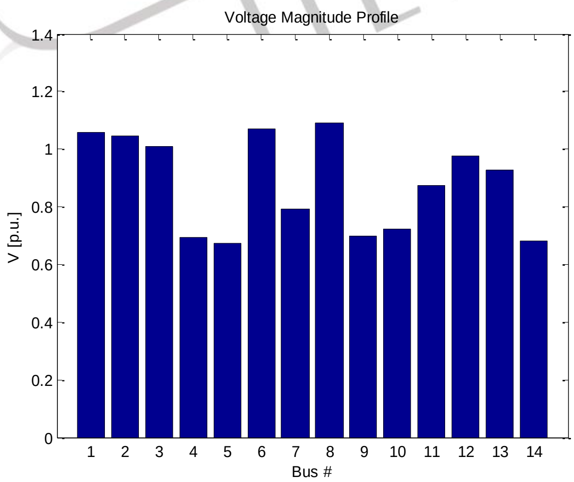


Fig. 5: Voltage profiles of all buses

If we assume system is operated at 1 p.u loading parameter than maximum lambda is 2.5159 and voltage stability margin is 60.20% as per following equation.

$$VSM = \frac{\lambda_{max} - \lambda_{op}}{\lambda_{max}} \tag{13}$$

Where, $\lambda_{op}$ system actual operating loading value

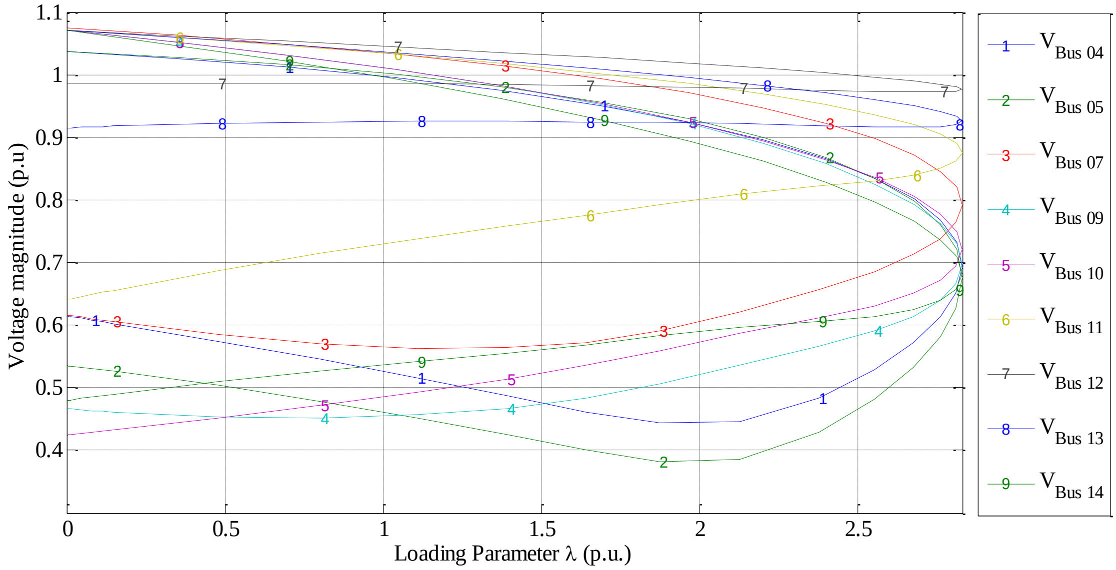


Fig. 6: PV Curve of each load buses without DG

Here, Solar Photo-Voltaic generator with constant PQ model is used as DG which is capable for generating 25MW active power and 20MVar reactive power with 15sec Inverter time response.

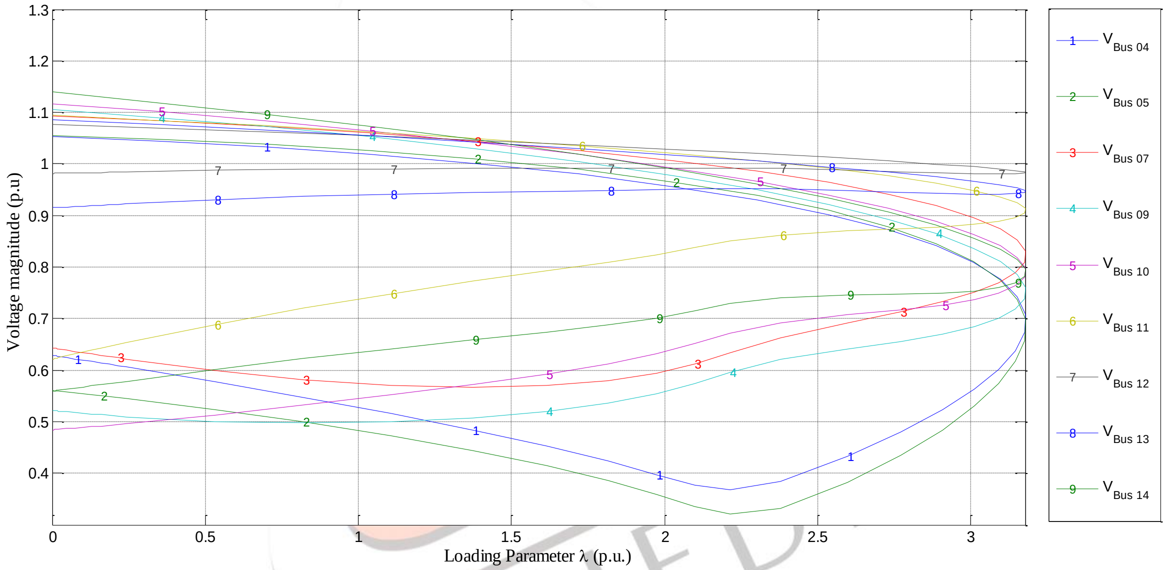


Fig. 7: PV Curve of each load bus with DG at 5th, 10th and 14th bus

With penetration of DG, there will be improve the maximum load ability of system and voltage stability of each bus and improve voltage profile of system also as shown in Figure 7,8 and 9. Figure 8 indicate the voltage stability margin of system and Figure 9 indicates the improvement in voltage profile of each bus.

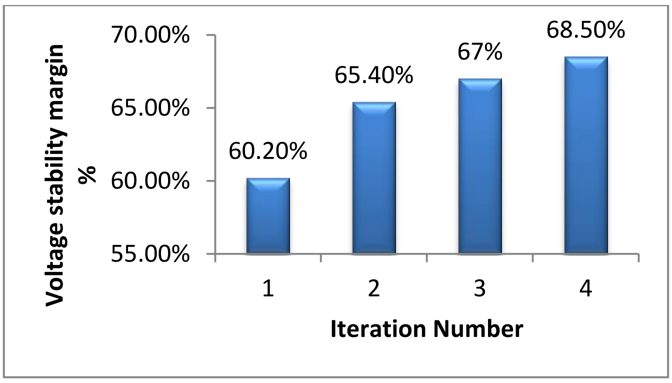


Fig. 8: voltage stability margin of system

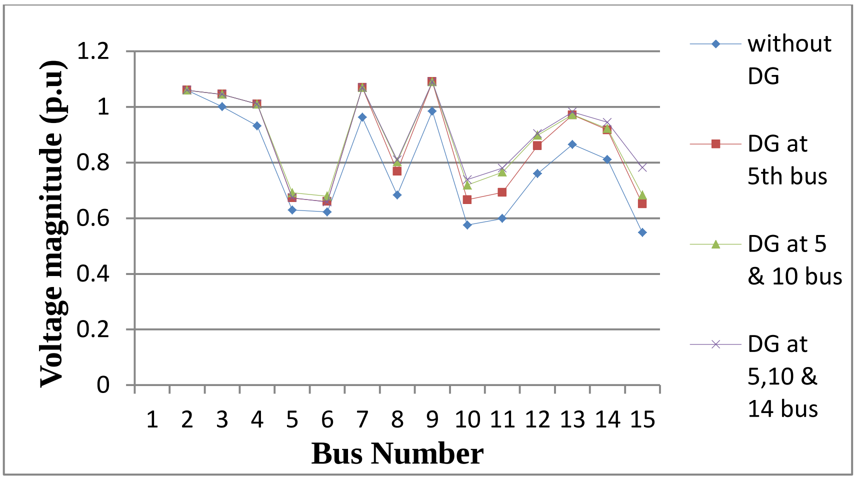


Fig. 9: voltage profiles

## VII. CONCLUSION

Distributed generation unit is capable for injecting and absorbing the reactive power then it would be improve the reactive power flow. Resultant of increasing the reactive power flow, voltage profile of each bus and loading capacity of system are increase due to increasing the system stability margin.

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