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# OPTIMAL PLACEMENT OF DISTRIBUTED GENERATION FOR LOSS REDUCTION IN DISTRIBUTION SYSTEM

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## ABSTRACT

Due to the increasing interest on renewable sources in recent times, the studies on integration of distributed generation to the power grid have rapidly increased. Distributed generations (DGs) play an important role in distribution networks. Among many of their merits, loss reduction and voltage profile improvement can be the salient specifications of Distributed generations (DG). Non-optimal locations and non-optimal sizes of Distributed generations (DG) units may lead to increase losses, together with bad effect on voltage profile. Proper location of Distributed generations (DGs) in power systems is important for obtaining their maximum potential benefits. Distributed generation (DG) units reduce electric power losses and hence improve reliability and voltage profile. Determination of appropriate size and location of Distributed generation (DG) is important to maximize overall system efficiency. In this project, Newton raphson method optimization technique has been presented to determine the appropriate size and proper allocation of Distributed generation (DG) in a distribution network.So, this project focus towards, at determining optimal DG allocation and sizing as well as analyzing the impact of Distributed generation (DG) in an electric power system in terms of voltage profile improvement and line loss reduction

**KAY WORD**—Analytical approach, distributed generation, optimal Placement, power loss.

## INTRODUCTION

In all sectors around the world, electricity consumption is rapidly increasing. One possible means of satisfying the rapid growth in electricity demand is to promote the widespread employment of distributed generation (DG) as there continues to be strong interest in operating it in parallel with a utility distribution system. Some positive benefits of the installation of distributed generation (DG) are system energy loss reduction, voltage profile augmentation and reliability enhancement. Distributed generation (DG) is flexible to install Also renewable energy-based distributed generation (DG) can play a key role in building sustainable energy infrastructure. As, generally, distribution systems are designed purely to deliver power to consumers, introducing distributed generation (DG) will change a distribution network's characteristics due to its bi-directional power flow. If its penetration level is too high, a voltage rise problem may occur due to its reverse power flow and improper sizing and inappropriate placements of distributed generation (DG) may lead to higher power losses in a system than is the case in one which has no distributed generation (DG). Therefore, the integration of a significantly large amount of distributed energy resources (DER) may cause operational conflicts for a power distribution network. As a result, in order to ensure the reliable, stable and efficient operation of a power distribution system, distributed generation (DG) planning is essential.

Distributed Generation (DG) is a promising solution to many power system problems such as voltage regulation, power loss, etc. Distributed generation is small-scale power generation that is usually connected to or embedded in the distribution system. Numerous studies used different approaches to evaluate the benefits from DGs to a network in the form of loss reduction.

This paper implements the IDENTIFICATION OF OPTIMAL DG LOCATIONS BY SINGLE DG PLACEMENT. This method first evaluates the voltage profile using the Newton-Raphson method and then it calculates the total $I^2R$ loss of the system. After that by placing the DG at each bus, it evaluates the corresponding total $I^2R$ losses and hence obtained the optimal placement of DG for loss reduction and best suited voltage profile evaluation.

## DISTRIBUTION GENERATION (DG) TECHNOLOGIES

Some DG technologies are mature and have been in use for decades. Each also has very different cost and performance characteristics.

### Fuel Cells

Fuel cells generate power electrochemically in process that is similar to a battery, except that instead of generating electricity from stored chemicals, fuel cells generate electricity when hydrogen to deliver to the cathode and oxygen is delivered to the anode of the cell. Hydrogen atoms split into a proton, which passes through the electrolyte to the cathode, and an electron which travels through the external circuit creating DC current. The hydrogen input to the fuel cell can come from various sources however most application use a chemical process called steam reforming of natural gas which extract the hydrogen from the steam and the gas. Several different materials are can be used for the electrochemical process, providing a distinction among the various fuel cell system types. Fuel cell are more expensive than the other DG technologies, however they offer great advantages in certain application. Fuel cells provide almost no polluting emissions and deliver highly reliable power of quality. Fuel cell range in size from around 5 to 2000 KW. A typical single family home would require fuel cell around 3 to 8 KWs. Fuel cells is also quite and some version have the greatest electricity efficiency of all the DG technologies. While fuel cells are in the earliest stages of commercialization the rapid cost reduction which have been achieved over the last several years and which are expected to continue to suggest that fuel cells will be highly competitive in many DG application

## Micro- turbines

Micro-Turbines are small gas turbines. Design is similar to those of a gas turbine, except that most micro-turbines recover some of the exhaust heat to preheat air used in combustion. Micro-turbines range in size from 30KW to 500KW and can be integrated to provide higher electric output and greater reliability. Micro-turbines are compact, quiet and provide high quality power and emission levels, however their costs are greater than reciprocating engines. In the Nordic countries, micro-turbines are expected to be operated in combined heat and power mode. The reason for this is that the cost of power is close to the cost of heat. For each produced kilowatt-hours of heat. The micro-turbines could also be used for shaving, standby power, capacity addition, stand-alone generation and other. In the case of capacity addition the short time from decision and order to operation will be a heavy argument for DG with micro turbine in the future. Most micro-turbine use a turbine mounted on the same shaft as the compressor and a high speed generator rotor. The rotating components can be mounted on a single shaft that points up to 9600 rpm. The high frequency AC at gird frequency.

### Wind Power

In a wind turbine, the kinetic energy of steaming air is converted to electric power. The size of wind turbines has increased rapidly during the past two decades, the largest units being now about 4 MW. For the smaller units, the typical construction is fixed speed stall regulated turbine. Units largest than 1 MW are equipped with variable system, in order to withstand the increased mechanical stresses. Single units are typically connected to a medium voltage network. For larger wind parks connection to high voltage (HV) grid is necessary. The most common generator type is the asynchronous generator. If an asynchronous generator is directly connected to the generator, a soft-starter is needed in order to minimize the larger currents at the generator startup. During normal operation, directly connected generator many still because some increase in the flicker level and in the variation of the active power flow.

### Photovoltaic

Photovoltaic (PV) system converts the sunlight directly to electricity. PV technology is well established and widely used for power supplies to sites remote from the distribution network. Photovoltaic systems are commonly known as solar panels. PV solar panels are made up of describe cells that convert light radiation into electricity connected together in series or parallel. Current units have efficiencies of 24% in laboratory conditions and 10% in actual use. The maximum theoretical efficiency that can be attained by a PV cell is 30% PV units are connected to network applying invert. This kind of agreement will potentially cause harmonics unless they have been filtered active filters property. On the other hand, the inverters of PV system could operate, in the future active filter to reduce low order harmonics in the distribution system.

**Reciprocating Engine**

Reciprocating engine have been used for decides in distributed generation application and are by far the most widely used prime mover. Otto cycle and compression-ignited engines are the most common types of reciprocating engines. Engines, which range in size from less than 1 KW to more than 50MW, have electric efficiencies ranging from 25 to 50 percent. For DG application reciprocating engines provide low cost solution and relatively high efficiencies and high availability however maintenance requirements can be high and diesel –fired units have high emission. Natural gas-driven units provide significantly lower emission levels and while somewhat expensive, emissions can be added to reciprocating system

**Internal Combustion Engines**

The most commonly installed distributed generation facilities today are small diesel or combustion turbine units ranging from 50 to 5,000 KW. Lower cost unitsare typically diesel fueled and used for emergency applications. Higher cost units are typically natural gas or biogas-fueled and used for combine heat and power application. While diesel units emit more air pollutant than gas fired units or central generation, they can be valuable for reliability purposes. Load management, and system control purposes. Because they have much lower capital costs and diesel fuel is already available, they are used today for far more application than any other DG technologies. Main applications include diesel–fueled emergency / standby power. Peak shaving and natural-gas fueled engines for combined heat and power applications.
The available small-distributed generation technologies in the market with their application are shown in table 2.1.

| **Options for small–scale Distribution Generation ( DG ) type** | **Size range (KW)** | **Electrical efficiency (%)** | **Application** |
|---|---|---|---|
| Reciprocating Engines | 5-7000 | 25-45 | Backup power, base load, grid support and support and peak shaving |
| Fuel cell | 1-10000 | 40-65 | Co-generation, grid support |
| Photovoltaic | <1-100 | 5-15 | Base load, peak shaving |
| Strirling Engine | 1-25 | 12-20 | Vehicle, refrigeration, aircraft, space |

## SIGNIFICANCE OF PRESENT STUDY

Losses in power systems depend on the current flow in the line and also line parameters. The real power loss is $I^2r$, and the reactive power loss is $I^2x$. These losses are unwanted due to the fact that they reduce system efficiency and increase cost of electricity. Although system losses are unavoidable, they can minimized by planning and operating distribution network s in an optimal way. An integration of the DG in to distribution system contributes significantly to losses reduction. This is due to the fact that the DG provides local support to the total load, and thus reduces the power flow in the system. Since the system efficiency is usually assessed in in term of real power losses, only the DG effect on real power loss reduction is considered in this work.
In order to increase the efficiency of the distribution electrical networks, loss reduction Techniques are drawing more attention. Reduction of power losses by Distribution Generation (DG) sources is becoming a popular technique worldwide. Since an integration of DG into distribution system will alter the power flows, it is obvious that the power losses in the system are also affected. DG is utilized for improving the system voltage profile, power quality, system reliability and security, etc. from the economy point of view, the size of DG is small compared with the size of centralized generation. This makes the DG easier to install, and it requires less capital investment as well as operating and maintenance cost.

**Newton Raphson Method:**
In application of the Newton Raphson Method, we have to first bring the equations to be solved to the form f(x1,x2,...xn)=0,where x1,x2…xn are the unknown variables to be determined. Let us assume that the power system has n1 PV buses and n2 PQ buses. In polar co ordinates the unknown variable to be determined are.

**Steps for Newton-Raphson method:**
**Step1**: $\delta i$ the angle of the complex bus voltage at bus i, at all the PV and PQ buses. This gives us n1+n2 unknown variables to be determined.
**Step2**: |Vi|, the voltage magnitude of bus i, at all PQ buses. This gives us n2 unknown variables to be determined. Therefore the total number of unknown variables to be computed is n1+2n2 for which we n1+2n2 consistent equations to be solved. The equations to be solved are given by

$$\Delta Pi = Pi,sp - Pi,cal = 0$$

$$\Delta Qi = Qi,sp - Qi,cal = 0$$

Where, $\Delta P$=Active power residue $\Delta Q$= reactive power residue
$Pi,sp$ =specified active power at bus i
$Qi,sp$=Specified reactive power at bus i

## Algorithm for N-R method:

**Step1:** Formulate Bus Admittance Matrix Y bus.
**Step2:** Assume initial voltages as follows Vi=|Vi, sp|∠0 (at all PV Buses) where Vi,sp=Specified voltage value Vi=1∠0 (at all PQ buses)

**Step3:**At (r+1) th iteration calculate Pi(r+1),at all the PV and PQ Buses and calculate Qi(r+1) at all the PQ buses using Vi(r) values. The formulae to be used are

Pi,cal=Gii|$Vi$|2+$ViVk(Gik*cosnk=1k\neq i\delta ik+Bik*sin\delta ik)$

Qi,cal=Bii|$Vi$|2+$ViVkGik*sinnk=1k\neq i\delta ik-Bik*cos\delta ik)$

**Step4:** Calculate the power mismatches i.e. Power residues $\Delta Pir$ =$Pi$,$sp-Pi$,$calr$+1 (at PV and PQ buses) $\Delta Qir$ =$Qi$,$sp-Qi$,$calr$+1 (at PQ buses)
**Step5:** Calculate the Jacobian [J(r)] using Vi(r)
**Step6:**Compute $\Delta\delta(r)\Delta$|$Vr$ ||$V$| = 1[$Jr$ ]*$\Delta P(r)\Delta Q(r)$
**Step7:**Update the variables as follows- $\delta ir$+1 =$\delta ir$ +$\Delta\delta i(r)$ (at all buses) |Vi(r+1)|=|Vi|(r)+Δ $Vi$ $(r)$
**Step8:** Go to step 3 and iterate till the the power mismatches are within the acceptable limits.

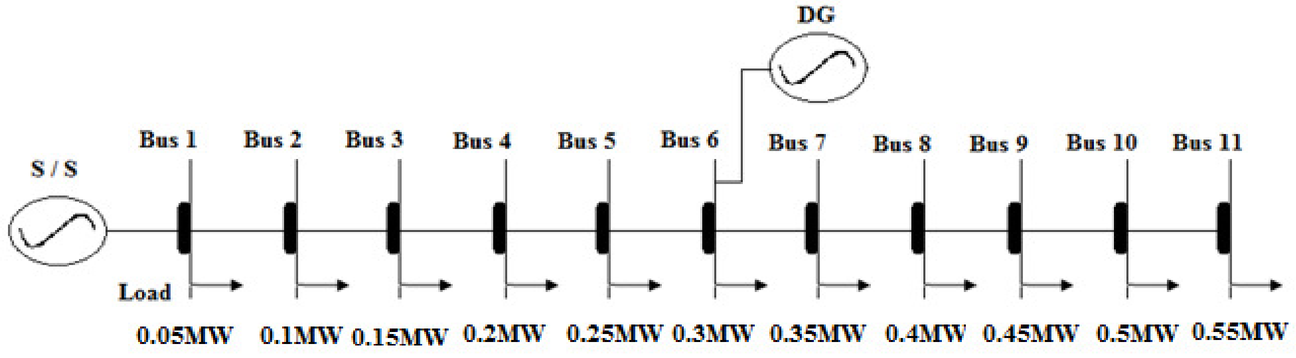
### 3.3.2.3 Formation of Jacobian:

$$\begin{bmatrix} \vdots \\ \Delta P_n^0 \\ \vdots \\ --- \\ \vdots \\ \Delta Q_n^0 \\ \vdots \end{bmatrix} = \begin{bmatrix} \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \frac{\partial P_n}{\partial \delta_{n-1}} & \frac{\partial P_n}{\partial \delta_n} & \frac{\partial P_n}{\partial \delta_{n+1}} & \vdots & \vdots & \vdots & \frac{\partial P_n}{\partial |V_{n-1}|} & \frac{\partial P_n}{\partial |V_n|} & \frac{\partial P_n}{\partial |V_{n+1}|} & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ - & --- & --- & --- & - & -- & -- & --- & --- & --- & - \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \frac{\partial Q_n}{\partial \delta_{n-1}} & \frac{\partial Q_n}{\partial \delta_n} & \frac{\partial Q_n}{\partial \delta_{n+1}} & \vdots & \vdots & \vdots & \frac{\partial Q_n}{\partial |V_{n-1}|} & \frac{\partial Q_n}{\partial |V_n|} & \frac{\partial Q_n}{\partial |V_{n+1}|} & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \end{bmatrix} . \begin{bmatrix} \Delta\delta_{n-1}^0 \\ \Delta\delta_n^0 \\ \Delta\delta_{n+1}^0 \\ --- \\ \Delta|V_{n-1}|^0 \\ \Delta|V_n|^0 \\ \Delta|V_{n+1}|^0 \end{bmatrix}$$

There are some formulas given below for making the Jacobian in NR load flow method. These are...

1) $\partial Pi\partial\delta i$= -Qi-Bii|$Vi$|$^2$
2) $\partial Pi\partial\delta k$= $ViVk$ ($Gik*$sin$\delta ik-Bik*cos\delta ik$)
3) $\partial Pi\partial Vk$|$Vk$|= $ViVk$ ($Gik*cos\delta ik+Bik*$sin$\delta ik$)
4)$\partial Pi\partial$|$Vi$||$Vi$| = Pi+Gii|$Vi$|$^2$
5) $\partial Qi\partial\delta i$= Pi-Gii|$Vi$|$^2$
6) $\partial Qi\partial\delta k$=− $ViVk$ ($Gik*cos\delta ik+Bik*$sin$\delta ik$)
7) $\partial Qi\partial$|$Vi$||$Vi$| = Qi-Bii|$Vi$|$^2$
8) $\partial Qi\partial$|$Vi$| $Vk$ = $ViVk$ ($Gik*$sin$\delta ik-Bik*cos\delta ik$)

## 11 Bus of Radial Distribution System Network



## SUMMARY AND CONCLUSIONS

This paper started from the observed renewed interestin small-scale electricity generation. Existing small-scalegeneration technologies are described and the majorbenefits of using small-scale distributedgeneration are discussed. The different technologiesare evaluated in terms of their contribution to the listedbenefits.Small-scale generation is commonly called distributed Generation and we try to derive a consensusdefinition for this latter concept. It appears that there isno agreement on a precise definition as the conceptencompasses many technologies and many applicationsin different environments. In our view, the bestdefinition of distributed generation that generallyapplies seems to be 'an electric power generation sourcethat is connected directly to the distribution network oron the customer side of the meter'. Depending on theinterest or background of the one confronted with thistechnology, additional limiting aspects might be considered.A further narrowing of this 'common divider'definition might be necessary depending on the researchquestions that are looked at. However, the general andbroadly understandable description as proposed here, isrequired to allow communicating on this concept.

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