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OPTIMAL DG UNIT PLACEMENT FOR LOSS REDUCTION IN RADIAL DISTRIBUTION SYSTEM-A CASE STUDY

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ABSTRACT

Distributed generators are beneficial in reducing the losses effectively compared to other methods of loss reduction. In this paper optimal DG unit placement using fuzzy logic is discussed. The optimal size of the DG unit is calculated analytically using approximate reasoning suitable nodes are determined for DG unit placement. Voltage and power loss reduction indices of distribution system nodes are modeled by fuzzy membership functions. Fuzzy inference system containing a set of rules is used to determine the DG unit placement. DG units are placed with the highest suitability index. Simulation results show the advantage of optimal DG unit placement compared optimal capacitor unit placement. Compared to capacitor placement it is giving very good reduction not only in power loss but also it is improving voltage regulation.

Keywords: distributed generation, DG unit, capacitor, power loss.

1. INTRODUCTION

Distribution system provides a final link between the high voltage transmission system and the consumers. A radial distribution system has main feeders and lateral distributors. The main feeder originates from substation and passes through different consumer loads. Laterals are connected to individual loads. Generally radial distribution systems are used because of their simplicity. Power loss in a distribution system is high because of low voltage and hence high current. The over all efficiency can be improved using DG units.

1.1. Loss reduction in distribution systems

There are many methods of loss reduction techniques used like feeder reconfiguration, capacitor placement, high voltage distribution system, conductor grading, DG unit placement. All these methods are involved with passive element except DG unit placement. Both DG units and capacitors reduce power loss and improve voltage regulation. But with DG s loss reduction almost double that of Capacitors.

1.2. Methods of reducing loss using DG unit

Many methods have come in recent times on DG unit placement [5] proposed a method to calculate the size of DGs analytically by using exact loss formula which requires lot of computation compared to the proposed analytical method. Many authors like [1] mentioned the allocation of DG units using genetic algorithm. They have not considered the optimum size; they have addressed the problem in terms of cost [3]. They have iteratively increased size of the DG at all buses and then they calculated the losses, based on loss calculation they ranked the nodes.

Top ranked units are selected for DG unit placement. Here a new analytical method is used to calculate the size of the DG units. A new of method of minimizing the loss associated with the active component of branch currents by placing optimal DG units at proper locations. Here cost function is not considered. Considering the cost function involves the deviation of exact size of the DG unit at suitable point.

1.3. Fuzzy logic

There are many uncertainties in various power system problems .Because of this it becomes very difficult to stick to mathematical formulae alone. To over come this, fuzzy set theory has been applied to many power system problems. Using fuzzy expert system a set of heuristic rules is used to determine the Dg unit placement suitability index at each node in the distribution system. Rules are defined to determine the suitability of a node for DG unit placement.

2. DG UNIT INSTALLATION

The problem of DG unit placement consists of determining the locations and sizes and number of DG units to install in a distribution system such that maximum benefits are achieved while operational constraints at different loading levels are satisfied.

2.1. Distribution losses

The total power loss in a distribution system having a 'b' number of branches is given by:

$$P_L = \sum_{i=1}^{b} I_i^2 R_i \qquad (1)$$

Ii is the current magnitude and R_i is the resistance. Ii can be obtained from load flow study. The branch current has two components: active (I_a) and reactive (I_r).

The loss associated with these two components can be written as:

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$$P_{LP}=\sum_{i=1}^{b} I_{ai}^2R_i; \quad (2)$$

$$P_{LQ}=\sum_{i=1}^{b} I_{ri}^2R_i \quad (3)$$

For a given configuration of a single source radial network the loss P_{LP} associated with the active component of branch currents cannot be minimized because all the active power must be supplied by the source at the root bus. This is not true if DG units are to be placed at different nodes for loss reduction. That is real power can be supplied locally by using DG units of optimal size to minimize P_{LP} associated with the active component of branch currents.

2.2. Analytical method

The method proposed first identifies a sequence of nodes to be compensated. The sequence is determined by repetitive application loss minimization technique by a singly located Dg unit.

Once the sequence of nodes to be compensated is identified, the corresponding optimal size at the compensated nodes can be determined simultaneously by minimizing the loss saving equation.

2.3 Loss minimization by singly located DG unit.

Considering a single source distribution system with 'n' branches. Let a Dg be placed at bus 'm' and 'β' be a set of branches connected between the source and Dg unit buses. If the Dg unit is placed at bus 'x' the 'β' consists of branches x1, x2, xn. The Dg unit supplies real current I real and for radial network it changes only the active component of current of branch set 'β'. The current of other branches is not affected by the Dg unit. The new active component of current

$I_{ai}\,(new) = I_{ai}+D_i * I_{DG}$
$Di = 1$ if branch $i\varepsilon\ \beta$
$= 0$ otherwise.

I_{pi} is the active component of current of ith branch in the original system obtained from the load flow solution.

The loss $P_{La}^{\ com}$ is associated with the active component of branch currents in the compensated system.

$$P_{La}^{com} = \sum_{i=1}^{b}(I_{ai}+D_iI_{DG})^2\, R_i \quad (4)$$

Savings in Active power loss is:

$$S = P_{La}- P_{La}^{com} = - \sum_{i=1}^{b} (2D_iI_{ai}I_{DG}+D_i^{\ 2}I_{DG})^2\, R_i \quad (5)$$

To minimize the loss Eq. (5) is differentiated w.r.t I_{DG} and equated to zero. It results in:

$$I_{DG} = - \frac{\sum_{i=1}^{b} (D_iI_{ai}R_i)}{\sum (D_iR_i)} \quad (6)$$

Distributed generator size

$$P_{DG} = V_m\, I_{DG} \quad (7)$$

The process can be repeated for all the buses to get the highest possible loss saving for a singly located DG unit.

Same procedure is repeated for optimal size of capacitor by optimizing the power loss related reactive component of branch current [10].

2.4. Radial distribution load flow analysis

Conventional load flow studies like Gauss-seidal and fast decoupled load flow Newton raphson methods are not suitable for distribution system load flows because of high R/X ratio. A new radial load flow method for distribution systems that offers better solution was proposed in ref [10].

The main features of this method are:

1) The initial voltage at all nodes is assumed to be the voltage specified at the source node.
2) No complicated calculations are involved
3) Loads are represented by constant power.
4) Evaluation of simple algebraic expression of receiving end voltages.
5) Convergence is obtained by, even for ill conditioned system.

2.5. Algorithm

There are many computational steps involved in finding the optimal DG size and location to minimize losses in a radial distribution system are:

1) Run the load flow program. Select the bus where the maximum loss and low voltage is using fuzzy logic tool box. Corresponding DG size is calculated using eqs, respectively.
   Repeat this for all the buses except the source bus. Identify the bus using the fuzzy logic that provides highest loss saving.
2) Compensate the bus with the highest loss with the corresponding Dg unit found from eq. (7).
3) Repeat the steps 1) and 2) to get the next DG size and hence sequence of buses to be compensated.
4) Once the sequence of buses is known determine the optimum DG unit sizes and the corresponding loss saving.

Since the system load is time variant and load duration curve of the system can be approximated .It is assumed that load level is constant. The above algorithm provides the optimal DG sizes and locations for a given load level.

2.6. Fuzzy logic implementation

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to stick to mathematical formulae alone. To over come this, fuzzy set theory has been applied to many power system problems. Using fuzzy expert system a set of heuristic rules is used to determine the Dg unit placement suitability index at each node in the distribution system. Rules are defined to determine the suitability of a node for DG unit installation. Those rules are expressed in the following form:

IF premise (antecedent), THEN conclusion (consequent).

For determining the suitability of Dg unit placement at a particular node, a set of multiple antecedent fuzzy rules has been established. The inputs to the rules are the voltage and power loss indices.

The fuzzy variables, power loss index, voltage and Dg unit suitability are described by the fuzzy terms high, high-medium/normal, low-medium/normal or low. These fuzzy variables are described by membership functions. Dg units are placed at the nodes with the highest suitability. Voltage and power loss reduction indices of distribution system are modeled by fuzzy member ship functions.

FIS editor receives inputs from the load flow program. Several rules may fire with some degree of membership. FIS is based on Mamdani max-min and max-prod implication methods of inference. These methods determine the aggregated output from the set of triggered rules.

The max-min method involves truncating the consequent membership function of each fired rule at the minimum membership value of all the antecedents. A final aggregated membership function is achieved by taking the union of all the truncated consequent membership functions of the fired rules.

For the DG unit placement problem, the resulting Dg unit suitability membership function μ_d of node i for k fired rules are given by:

$M_d(i)$ max [min [$\mu_p(i)$, $\mu_v(i)$]]

Where $\mu_p(i)$ and $\mu_v(i)$ are the membership functions of the power loss index and voltage, respectively.

After calculating the suitability membership function, it is to be defuzzified in order to determine the node suitability ranking. The centroid method of defuzzification is used.

The problem of DG unit placement consists of determining the locations and sizes and number of DG units to install in a distribution system such that maximum benefits are achieved while operational constraints at different loading levels are satisfied.

3. SIMULATION

The proposed method of loss reduction by Dg unit placement was tested on a Distribution system consisting of 33 buses. Optimal sizes of DG units and capacitors are calculated at each and every bus. Optimal location is obtained using FIS editor. It has given the locations 26th and 31st buses. Results are shown for 26th bus. Capacitor and DG unit sizes are shown in Figures 2 and 4. Voltage profiles at different nodes are shown in Figures 3 and 5 with capacitor placed 26th bus and DG unit placed at 26th bus, respectively. Voltage profile improvement is very good with DG unit placement compared with that of Capacitor Unit placement. Total Real power losses and Total reactive power losses with capacitor and with DG Unit are compared with without any compensation. These are tabulated in Table-2 and Table-3. Capacitor size at 26th bus is and DG size at 26th bus is 1642.56 KVAR and 2395.6KW. The results are compared with ref [5].

4. CONCLUSIONS

With the help of FIS editor optimal location of the DG unit is found where real power loss is more and voltage is low. Using analytical method the sizes of the DG unit is found and placed at optimal location which is reducing power loss almost 100% so is reactive power loss. There is very good improvement in voltage levels also. The results are tabulated in Table-1 and Table-2 compared with DG unit, with Capacitor and without any compensation. Optimal size of capacitor at 26th bus is 1642.56KVAR and DG unit is 2395.6KW.

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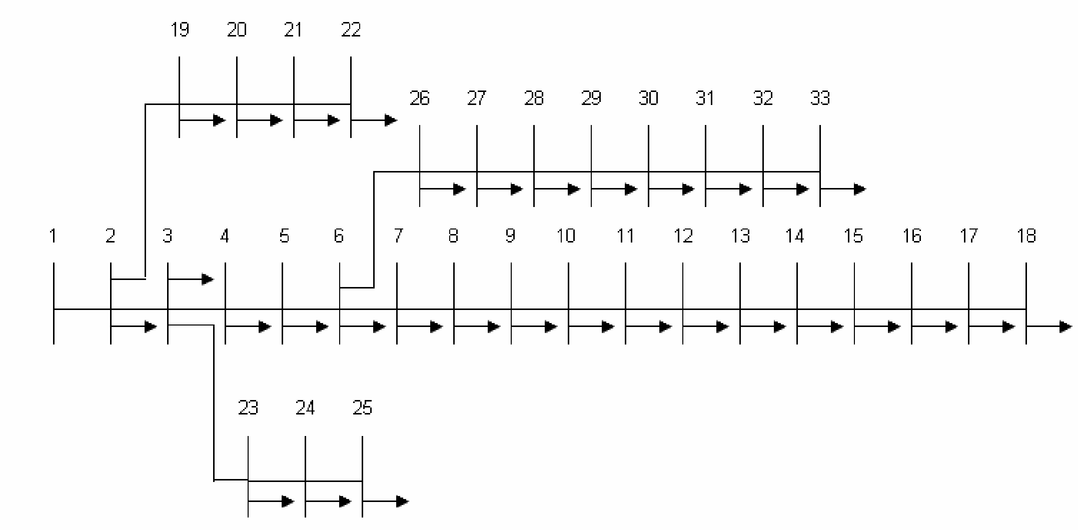

Figure-1. IEEE 33 bus test system.

Table-1. Capacitor and DG unit sizes for 26th bus.

Capacitor size in KVAR	DG size in KW
1642.56	2395.6

Table-2. Real power loss comparison with capacitor and with DG unit.

Real power losses without compensation (KW)	**Real power losses with capacitor** (KW)	**Real power losses with DG unit** (KW)
289.55	227.05	154.19

Table-3. Reactive power loss comparison with capacitor and with DG unit.

Reactive power losses without compensation (KW)	**Reactive power losses with capacitor** (KW)	**Reactive power losses with DG unit** (KW)
194.2517	155.0150	110.28

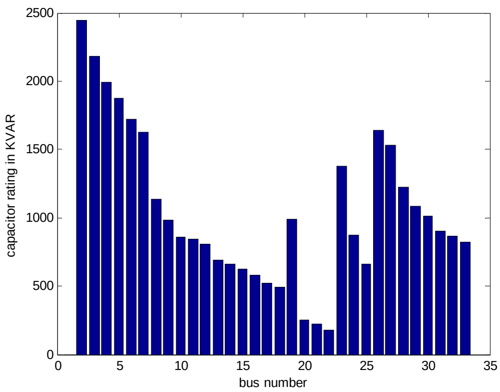

Figure-2. Capacitor sizes using analytical method with capacitor at 26th bus.

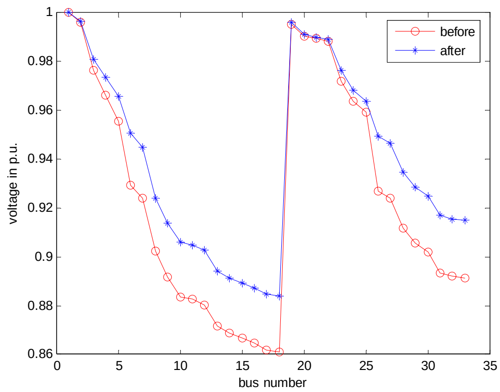

Figure-3. Voltage variation at different nodes.

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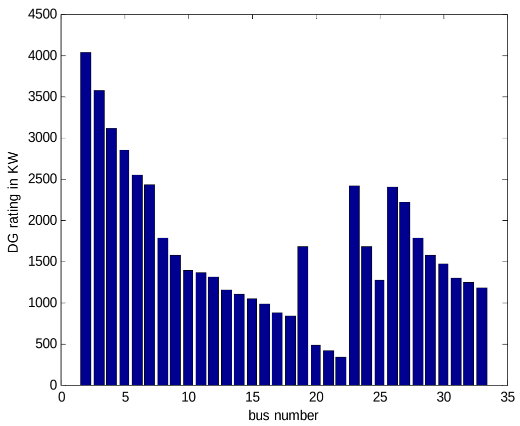

Figure-4. Dg unit sizes using analytical method.

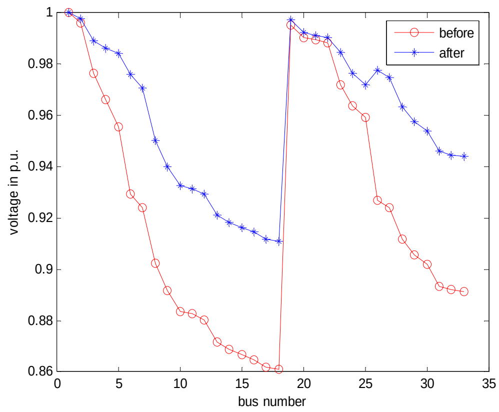

Figure-5. Voltage variation at different nodes with DG unit at 26th bus.

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