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Effective Loss Minimization in Main Distribution System by Assignment of Numerous Distributed Generators

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ABSTRACT

This paper clarifies an effective improved methodology for numerous distributed generator-DG placement in main distribution system for loss reduction. Optimal location for distributed generator-DG is placed by Improved Analytical expressions and the optimal DG size calculated by Improved Analytical-IA method and loss sensitivity factor-LSF method. The effective method is totally based on IA expressions to formulate the optimal size of 4-types of different DG types and a methodology to select the best Placement for DG allocation. A technique to get the optimal power factor is submitted for DG capable of presenting real and reactive power these two methods are tested on two bus systems 33-bus and 69-bus radial distribution systems.

The output reliability of the DG is economical or non economical on the system will relays on the placement and size of the DG. DG has become most popular as it is seen to be the reliable option for solving bigger problem in energy industry which has attained the following goals like reduction of huge loss, decrease line losses, improving voltage profile at feeders and environmental effect are the overall advantages. The MATLAB simulation results gained gives the performance of the IA method over the LSF method.

Keywords: *Distributed Generator (DG), IA-Improved Analytical Method, LSF-Loss Sensitivity Factor, Optimal Size, Optimal Location.*

I. INTRODUCTION

The electricity produced globally is generated in large generating stations. These stations produce and transmit electricity through High voltage ac and dc systems then, at reduced voltage, transmit it through secondary distribution systems to consumers. A little electricity is created by distributed-generation plants. The competitor with large generating station, they produce power on a customer's spot or at a close by allocation utility, and supply power straight to the secondary distribution system. DG technologies include engines, small turbines, fuel cells, and photovoltaic systems. Although they represent a small share of the electricity market, distributed-generation technologies already play a key role: for applications in which reliability is crucial, as a source of emergency capacity, and as an alternative to expansion of a local network. In some markets, they are actually displacing more costly grid electricity. Globally increase in DG capacity was ordered in 2000 than for new nuclear power energy. Government policies favoring combined heat and power (CHP) generation, and renewable energy and technological development should assure growth of distributed generation. This kind of generation has the potential to alter fundamentally the structure and organization of our electric power system. Still market conditions in many countries check serious challenges to some clients, particularly those producing CHP power.

The glowing recognized technologies are Diesel and gas reciprocating engines and gas turbines. All the Industrial-sized engines and turbines can get fuel efficiencies in more of 40% and are low in cost per KW. Gigantic engines and turbines are the motivation for most new DG capacity installed in the time 2000, of roughly 20 GW or 10% of whole new generation capability. Other half of the capacity was left for standby use the demand for units for regular or peaking use is increased. Other DG technologies have yet to make a large commercial impact. Micro turbines are an up-to-the-minute technology. MT has lower emissions but higher capital cost than engines. Their fuel economy is similar to that of natural gas engines. At the same time, the emissions rate from existing distributed generation (except by fuel cells and PV) are higher than the “best available” central generation: a combined-cycle gas turbine with advanced emissions control.

Procedures can be planned that encourage distributed generators to trim down emissions. The exercise of economic instruments similar to carbon-emissions trading, for example, would present DG operators an encouragement to design and operate their services in ways that minimize emissions of conservatory gases. The effect on primary fuels depends on the underlying technology. Photovoltaic systems help diversify supply away from fossil fuels.

The technologies which depend on natural gas are intense directly or indirectly. Since much of the new investment in DG is for natural gas, the effect on fuel diversity in the power system is limited. The combined heat and power has the ability to intake consumption of fuel is low to help in energy security increasing. Similarly the usage of DG at particular places will make to get a solution for the bottleneck of distributers. Hence the high demand of energy transmission will be diminishing by high usage of DG so transmission line margins can put up.

Ultimately a power system based on a large number of reliable small generators can operate with the same reliability and a lower capacity margin than a system of equally reliable large generators. Responding of DG to the change in load fails can lead to a real minus point for the security of energy which will make the loss in main reserve power supplies by the network. This would be the case if most DG capacity is non dispatch able because of natural variability (wind and photovoltaic systems) or operating variability (CHP where power output is tied to heat demand).

The operators of the Nodal system have identified the expansion of wind and CHP as a reliability concern and are studying how best to address it. They contain optional that the operational run of the network may require to be decentralized by creating a scheme operator for every Nodal subarea. Significant R&D wealth is by now being heading for fuel cells and photovoltaic system. Investments are also needed to reduce the capital costs and improve the efficiency of micro turbines.

In spite of the limited dispersion of distributed power in today’s market, the potential will most likely see a progress to a much supplementary decentralized power system. It could emerge from the present system in three stages: accommodation of distributed generation in the current system.

The creation of decentralized network system that works in tandem with a centralized generation system; and a dispersed system where most power is generated by decentralized stations and a limited amount by central generation.. For example, new technologies are already being used to control output from distributed generation at several sites to respond to market conditions, creating a kind of “virtual utility.

Capability of DG is more to supply the demand without enhancing the capacity of already installed system of generation related to transmission and distribution. The overall cost of the DG is seen to be a heavy burden on the investors because of its compact modular equipment installation the other side of the traditional substation installation has the heavy initial cost and tedious installation of all the substation devices like the feeders etc.

The technical benefits include improvement of voltage, loss reduction, relieved transmission and distribution congestion, improved utility system reliability and power quality and increasing the durability of equipment, improving power quality, total harmony distortion networks and voltage stability by making changes in the path through which power passes .These settlement get the best possible DG size and location is selected.

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II. Formulation of Technique

A. Assignment of DG allocation

IA method is practiced here for the detail work. To check the effectiveness and applicability of the proposed method, loss sensitivity factor is employed for the placement of multiple DG .An algorithms is urbanized for the loss sensitivity factor procedure.

Losses for power a formula represents the final all real power system loss below

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N}[\alpha_{ij}(P_iP_j + Q_iQ_j) + \beta_{ij}(Q_iP_j - P_iQ_j)] \quad (1)$$

where

$$\alpha_{ij} = \frac{r_{ij}}{V_iV_j}\cos(\delta_i - \delta_j); \quad \beta_{ij} = \frac{r_{ij}}{V_iV_j}\sin(\delta_i - \delta_j)$$

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ith bus voltage Vi∠δi

ijth element of [Zbus] impedance matrix rij + jxij = Zij;

Active power injections Pi and Pj at the ith and jth buses,

Reactive power injections Qi and Qj at the ith and jth Buses,

Number of buses As N

At this point an effective methodology is proposed to discover the optimal location, size, and power factor of numerous DG units in distribution network. A brief description of the IA expressions And optimal power factors for single DG allocation are presented as follows:

a. Category Type-1 DG (i.e., 0 < PFDG < 1) is Capable to inject both real and reactive power (e.g. synchronous generator). The optimal size of DG at each bus i for minimizing losses can be given by (2) and (3)

$$P_{\mathrm{DG}i} = \frac{\alpha_{ii}(P_{\mathrm{D}i} + aQ_{\mathrm{D}i}) - X_i - aY_i}{a^2\alpha_{ii} + \alpha_{ii}} \quad (2)$$

$$Q_{\mathrm{DG}i} = aP_{\mathrm{DG}i} \quad (3)$$

in which

$$a = (\mathrm{sign})\tan\left(\cos^{-1}(PF_{\mathrm{DG}})\right)$$

sign = +1 DG injecting reactive power

$$X_i = \sum_{\substack{j=1\\ j\neq i}}^{n}(\alpha_{ij}P_j - \beta_{ij}Q_j) \quad Y_i = \sum_{\substack{j=1\\ j\neq i}}^{n}(\alpha_{ij}Q_j + \beta_{ij}P_j).$$

The aforementioned equations give the optimum size of DG for each bus *i*, for the loss to be minimum. With this assumption, the optimum size of DG for each bus, given by the aforementioned relations, can be calculated from the base case load flow (i.e., without DG case).This methodology requires the load flow to be carried out only two times for single DG allocation, one for the base case and another at the end with DG included to obtain the final solution.

b. Category Type 2 DG (i.e., 0 < *PFDG* < 1) is capable of injecting real power but consuming reactive power (sign = −1) (e.g., induction generators).

c. Category Type 3 DG (i.e., *PFDG* = 1, *a* = 0) is capable of injecting real power only (e.g. PV, micro turbines, and fuel cells which will be incorporated to the main grid with the assist of converters/inverters). The most favorable size of DG at each bus *i* for the least amount loss is given by summary (4)

$$P_{\mathrm{DG}i} = P_{\mathrm{D}i} - \frac{1}{\alpha_{ii}}\sum_{\substack{j=1\\ j\neq i}}^{N}(\alpha_{ij}P_j - \beta_{ij}Q_j). \quad (4)$$

d. Category Type 4 DG (i.e., *PFDG* = 0, *a* = ∞) is capable of delivering reactive power merely (e.g. synchronous compensators).

$$Q_{\mathrm{DG}i} = Q_{\mathrm{D}i} - \frac{1}{\alpha_{ii}}\sum_{\substack{j=1\\ j\neq i}}^{N}(\alpha_{ij}Q_j + \beta_{ij}P_j). \quad (5)$$

B. Power Factor Assortment

The two bus are considered in a model distribution system with the transmission line DG starting place and load are associated as shown in Fig. 3.1 the single load power factor is (*PFD*) is in use as

$$PF_D = \frac{P_D}{\sqrt{P_D^2 + Q_D^2}}. \quad (6)$$

The power factor of the lone DG inject (*PF*DG) is given as

$$PF_{\mathrm{DG}} = \frac{P_{\mathrm{DG}}}{\sqrt{P_{\mathrm{DG}}^2 + Q_{\mathrm{DG}}^2}}. \quad (7)$$

To locate the optimal power factor of DG unit for a radial multifaceted distribution system, a fast approach is planned. A repeated approach is also introduced to ensure the effectiveness of the speedy approach. It is motivating to note that, in all the three experiment systems used in this paper, the optimal power factor of DG units positioned for loss reduction is established to be closer to the power factor of the mutual load of individual systems.

1. Speedy Approach procedure:

The power factor of the joint load of the system (*PFD*) can be expressed by (6). The whole active and reactive power of the load demand is uttered as

$$P_D = \sum_{i=1}^{N} P_{\mathrm{Di}} \quad Q_D = \sum_{i=1}^{N} Q_{\mathrm{Di}}.$$

The likely minimum total loss can be achieved if the power factor of DG (*PF*DG) is chosen to be equal to that of the combined load (*PFD*). That can be spoken as

$$PF_{\mathrm{DG}} = PF_D. \qquad (8)$$

2. Recurring procedure:

In this technique, the optimal power factor is chosen by calculating a small number of power factors of DG unit (alter in a small step of 0.01) that are close to to the power factor of the combined load

C. DG size Optimization

The Distributed generator is located next to the most favorable site. The best possible DG size is chosen by changeable procedure of the DG in diminutive steps up and about to the peak where actual minimum loss of power is detected. The actual real loss of power can be designed by the algorithm back ward forward sweep.

III. Improved Analytical Method

Compute the fairly accurate loss for each case with the standards a and β of the base case. Assignment First, a single DG is extra in the system. After that the load information are updated with the first DG placed and then an additional DG is added.

Likewise the algorithm continue to allocate other DG units awaiting it does not satisfy at slightest one of the constraint in step 7 as described as follows .

The computational modus operandi to allocate multiple DG units On the basis of the IA terminology is described in feature

As follows

Step 1) Enter the numeral of DG units to install.

Step 2) Run the load flow for the base case and locate losses using (1).

Step 3) analyze the power factor of DG using (8) or enter the power factor of DG.

Steps 4) discover the optimal location of DG using the following steps.

a) Compute the optimal size of DG at each bus using (2) and (3).

b) Place the DG with the optimal size, as mentioned previous, at each bus one at a time. Calculate the estimated loss for each case using (1) with the values a and β of the base case

c) Locate the optimal bus at which the loss is at least

Step 5) discover the optimal size of DG and estimate losses using the following steps

a)Place a DG at the optimal bus obtained in step 4, *change this DG size in little step,Keep informed the values a and β, and compute the loss for each case using (1) by running the load flow.*

b)Pick and store the optimal size of the DG that gives the minimum loss.

Step 6) bring up to date load data after placing the DG with the finest size obtained in step 5

Step 7) Stop if either the following occurs:

a) The voltage at a particular bus is over the upper limit.

b) The total size of DG units is over the total load plus loss.

c) The maximum number of DG units is unavailable.

d) The new iteration loss is greater than the previous iteration loss. The preceding iteration failure is retained otherwise repeat steps 2 to 6.

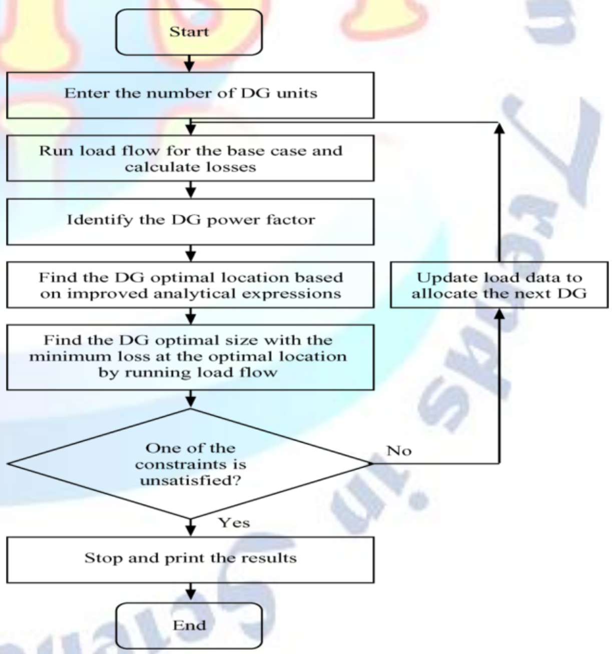

Fig: 1 Flow Chart of IA Method

IV. Loss Sensitivity Factor Method for DG Allocation

Now the sensitivity factor of active power loss is working to find the most sensitive buses to place DG units which are competent of injecting active power only (i.e., category type 3 DG). The sensitivity factor method is based on the principle of linearization of the original nonlinear equation around the initial operating point, which helps reduce the number of solution space. The LSF at the *i*th bus is derived from (1) with high opinion to active power injection at that bus

Step 1) Enter the number of DG units to be installed.
Step 2) Run the load flow for the base case and find losses using (1).
Step 3) Find the optimal location of DG using the following steps.
a) Find LSF using (9). Rank buses in descending order of the values of their LSFs to form a priority list.
b) Locate the highest priority bus.
Step 4) Find the optimal size of DG and calculate losses using the following steps.
a) Place a DG at the bus with the highest priority obtained in step 3, change this DG size in small step, update the values α and β, and calculate the loss for each case using (1) by running the load flow.
b) Select and store the optimal size of the DG that gives the minimum loss.
Step 5) Update load data after placing the DG with the optimal size obtained in step 4 to allocate the next DG.
Step 6) Stop if either the following occurs:
a) The voltage at a particular bus is over the upper limit;
b) The total size of DG units is over the total load plus loss;
c) The maximum number of DG units is unavailable;
d) The new iteration loss is greater than the previous iteration loss.

The previous iteration loss is retained; otherwise, repeat steps 2 to 5.

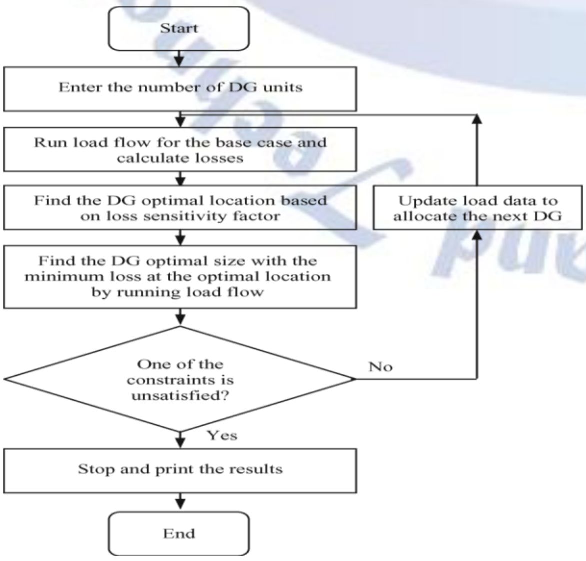

Fig: 2 Flow Chart of LSF Method

V. Simulation Results

The system has been studied with the help of MATLAB R2009a. The proposed system is tested on two test systems with varying sizes and complexities. 33bus system and 69 bus system are the two system bus used for the test radial distribution system with a total varied load in MW and MVAr .The primary bus is 33 bus systems and subsequent bus is 69 bus systems functioning with the methodology in use here for test. MATLAB support tool is preferred to sprint the test. Finally to select the ideal location for the DG and losses are obtained from the test. Although the tool can handle four different DG types and various load levels, the results of type 3 DG and type 1 DG at the peak load level, respectively, are presented.

A. Hypothesis

1. The highest number of DG units is three, with the dimension each from 250KW to the whole load plus loss.
2. The highest voltage at each bus is 1.0 p.u.

B. Considering 33-bus system

The model results of the most favorable location and best possible sizing of DG is made known in Table-A. The actual power loss of 33-bus system is 210.97kW without DG. In single DG assignment by LSF method the DG size is 850 kW, the real power loss is 145.7kW and in case of IA is 2600 kW, the actual power loss is 105.21 kW.

In case of 2 DG‟s assignment the DG size by LSF method 850 kW, 950 kW the actual power loss is 102.05 kW and in case of IA is2600kW,610kW the actual power loss is 87.07KW. In case of 3 DG‟s assignment by LSF Method is 850 kW, 950 kW, 890 kW the actual power loss is 87.65 kW and by IA Method is 2600 kW,610 kW,910 kW the actual power loss is 76.57kW.

TABLE-A

Assement of Various Methods in 33 Bus Systems

Methods	Installed DG	With out DG	With DG		
			1DG	2DG's	3DG's
LSF Loss sensitivity factor Method	Optimum Bus		18	18;33	18,3 3,25
	DG Size(KW)		850	850 950	850 950 890
	Loss(KW)	210.97	145.71	102.05	87.6 5
IA Improved Analytical Method	Optimum Bus		6	6,15	6,15, 24
	DG Size(KW)		2600	2600 610	2600 610 910
	Loss(KW)	210.97	105.21	87.07	76.5 7

C. Considering 69-Bus system

The model results of the most favorable location and best possible sizing of DG revealed in Table-B .The actual power loss of 69-bus system is 224.98 kW without DG. In single DG assignment by LSF method the DG size is 1440kW the true power loss is 112.11kW and in case of IA Method the DG Size is 1900 kW the true power loss is 81.26 kW. In case of 2 DG"s assignment the DG size by LSF method 1440 kW, 440 kW the real power loss is 100.56 kW and in case of IA method 1900 kW, 510 kW the true power loss is 69.58 kW

In case of 3 DG"s assignment the DG size by LSF method 1440 kW, 440kW, 400kW the actual power loss is 94.83kW and by IA method 1900kW, 510kW, 710kW the true power loss is 68.057kW.

TABLE-B

Assement of Various Methods in 69 Bus Systems

Methods	Installed DG	With out DG	With DG		
			1DG	2DG's	3DG's
LSF Loss sensitivity factor Method	Optimum Bus		65	65;2 7	65,2 7,61
	DG Size(KW)		1440	1440 440	1440 440 400
	Loss(KW)	224.98	112.1 1	100. 56	94.8 3
IA Improved Analytical Method	Bus		61	61,2 2	61,2 2,49
	DG Size(KW)		1900	1900 510	1900 510 710
	Loss(KW)	224.98	81.26	69.5 8	68.0 5

VI. Conclusion

The infrastructure of power is in insisting of interconnection of DG Distributed generation in the entire platform. Here the heat which is let out as waste is reutilized in perfect manner is the main plus point for the power reliability and energy efficiency enhancement, finally the DG popularity goes steadily up. As the figure of installation grow, it is significant that safety through the fulfillment to all local and national codes remains the key center of the installation.

The planned concept on DG allotment based on (IA) improved analytical scheme and (LSF) loss sensitivity factor technique has produced enough consequences regarding bus locations for DG allocation, based on optimal power losses the sizing and allocation are determined. Power losses were predictable at a variety of power factors using accurate Loss Formula. The results obtained were sensible. This scheme is based on IA terminology for judging the size of four unlike DG category types and an effective methodology to find the best location for DG allocation. The proposed IA method is effective as corroborated by LSF solutions in terms of loss reduction and computational time.

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