COST EFFECTIVE OPTIMAL SIZING AND SITING OF DG WITH LOSS FACTOR PRIORITY USING CCWPSO

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***Abstract:** The main aim of the paper is to reduce the costs of generation of power of DG as well as reduction in the supply intake from the substation with respect to reduction in the system real power losses and voltage profile improvement maintaining the stable limits of the system constraints using constriction and weighted factor coefficients of Particle swarm Optimization. As many researchers focused only loss reduction and some concentrated on voltage profile improvement and in this paper the loss reduction, voltage profile improvement as well as cost reduction of the operation of DG are taken as a single objective function within which highest priority given to cost reduction, next priority to loss reduction with voltage profile improvement. As a result we get the best cost effective optimal sizes of DG's or DG and their respective placement such that costs reduced in operating DG with good voltage profile improvement and the proposed method is tested on IEEE 33 bus system at different power factors.*

1. Introduction:

A power system may be divided into four parts: generation, transmission, distribution and consumption. In conceptional form the losses associated with each part of a typical thermal-electric power system, the efficiency of a steam power plant is primarily limited by the characteristics of steam and the basic thermal cycle. The capital investment and the operating point of a steam power plant also affect the efficiency of the power generation. The transmission loss of a power system is controlled both in system planning and in system operation. The level of transmission voltage influences most the loss in a transmission system. The manner of real and reactive power dispatching controls the transmission line loss in daily operation. It is the responsibility of the system planner to design a system with small losses. A system planner, at the same time, has the responsibility of maintaining economy and reliability. When the system is already built a power system operator must operate the system in a most economical manner; however, he also faces the system security, environmental and political constraints. Much of the work on the philosophy of power system planning and operation has been done in recent years. Capital spending is a limiting factor to reduce losses in a transmission system. The distribution system is radial in general. The level of distribution voltage and load density are the main factors concerning the distribution system loss. Distribution system losses vary within a relatively large range. In low load density areas we have seen losses as high as 20%. Economical considerations usually detect the level of losses of a distribution network. The efficiency of a typical power system load is difficult to define. For instance, the efficiency of a subway car is high during normal travel. Most of the energy loss occurs in the time of breaking.

Figure 1 Power transmission and distribution system

2. Loss in Generation, T&D Systems :

Factors effecting the efficiency of a steam power plant In order to reach a better understanding of the thermodynamics of steam power generation and its related efficiencies, the schematic diagram of a simplified steam power plant. Many factors influence overall thermal efficiency, but in general the efficiency of fossil fueled steam power plants currently in operation is limited to approximately 40%. The losses inherent in steam power generation are attributable to the following areas: Steam Generator 9% Turbine-condenser 44% Generator 2% Auxiliaries 5% Total losses 60% We note that, owing to the dissipation of the "heat of vaporization" of the low-pressure exhaust steam, the majority of the losses occur in the condenser. Although a cycle, which would directly compress the low-pressure turbine exhaust to boiler pressure, would eliminate this large energy loss of the working fluid, the design of such a cycle is thermodynamically impossible. The condenser has been developed to improve the efficiency of the steam cycle by allowing the steam to be expanded to a lower pressure (energy level). The lowest temperature to which a non-condensing steam cycle can reject heat is the saturation temperature (212 °F), corresponding to atmospheric pressure, while condensing steam cycles may reject heat to temperatures as low as 100 °F. Thus, the amount of energy utilized in the turbine is increased, while energy rejected is decreased, thereby improving efficiency. Another advantage of the closed condensing cycle is that the condensate is re circulated, using a minimum of make-up water, aiding in the close control of water chemistry which is required in high-pressure high-temperature steam cycles. A problem encountered with the condensing cycle is that, as exhaust pressure is lowered, the moisture in the last few turbine stages increases. If the moisture in the low-pressure stages of the turbine exceeds 10%, erosion of the turbine blades may become a serious problem.

3. TYPES OF LOSSES T&D SYSTEM:

There are two types of Transmission and Distribution Losses

1. Technical Losses
2. Non Technical Losses (Commercial Losses)

Technical Losses:

The technical losses are due to energy dissipated in the conductors, equipment used for transmission Line, Transformer, sub- transmission Line and distribution Line and magnetic losses in transformers. Technical losses are normally 22.5%, and directly depend on the network characteristics and the mode of operation. The major amount of losses in a power system is in primary and secondary distribution lines. While transmission and sub-transmission lines account for only about 30% of the total losses. Therefore the primary and secondary distribution systems must be properly planned to ensure within limits. The unexpected load increase was reflected in the increase of technical losses above the normal level Losses are inherent to the distribution of electricity and cannot be eliminated. There are two Types of Technical Losses.

a. *Permanent Technical losses*:

These losses include corona loss, leakage current losses, dielectric losses, Open circuit losses, loss caused by continuous load of measuring elements and control elements.

b. *Variable Technical losses*:

Variable losses vary with the amount of electricity distributed and are, more precisely, proportional to the square of the current. Consequently, a 1% increase in current leads to an increase in losses of more than 1%. Between 2/3 and 3/4 of technical (or physical) losses on distribution networks are variable Losses. By increasing the cross sectional area of lines and cables for a given load, losses will fall. This leads to a direct trade-off between cost of losses and cost of capital expenditure. It has been suggested that optimal average utilization rate on a distribution network that considers the cost of losses in its design could be as low as 30 per cent.

Non- Technical Losses:

Non-Technical losses, on the other hand, are caused by actions external to the power system or are caused by loads and condition that the Technical losses computation failed to take into account.

(i) Tampering with meters to ensure the meter recorded a lower consumption reading

(ii) Errors in technical losses computation

4. Loss Reduction:

The utility industry today has placed a high level of importance on improving efficiency. A proper review of losses experienced on a utility's system can provide valuable insight into ways to manage these losses and improve efficiency while reducing wholesale power costs, improving voltage levels, and freeing up system capacity, potentially reducing costly investment in system improvements.

Losses during peak times are of particular importance because this is when losses and their costs are typically at their highest. However, in today's world of hourly energy markets and transmission congestion charges, this is not necessarily always the case. Utilities now find themselves in a position where having knowledge of the average and incremental cost of power is no longer sufficient to determine the true cost of losses. Instead, the utility needs to be aware of the costs of power and delivery of that power during a myriad of widely divergent costing periods. To properly determine the true cost of losses, knowledge of when losses are being incurred on the system and the magnitude of those losses during different time periods are also needed.

a. Capacitor Placement

The initial step in loss reduction by the scientists and researchers worldwide is concentrated on the capacitor placement for reducing the reactive power loss which they considered as the main reason for real power loss which in turn results in generation of much real power than the real power demand to compensate the losses there by increasing the cost of generation, costs for the losses. Such that there many methodologies proposed by various scientists in the placement and in predicting the sizes of the capacitors and got very good results in reduction of real power losses, After the success in loss reduction by means of capacitor placement they concentrated in the voltage profile improvement and there after cost reduction in the operation and maintenance of the distribution system with installed capacitors.

b. Distributed Generation:

Origin:

Historically, central plants have been an integral part of the electric grid, in which large generating facilities are specifically located either close to resources or otherwise located far from populated load centres. These, in turn, supply the traditional transmission and distribution (T&D) grid that distributes bulk power to load centres and from there to consumers. These were developed when the costs of transporting fuel and integrating generating technologies into populated areas far exceeded the cost of developing T&D facilities and tariffs. Central plants are usually designed to take advantage of available economies of scale in a site-specific manner, and are built as "one-off," custom projects.

These economies of scale began to fail in the late 1960s and, by the start of the 21st century, Central Plants could arguably no longer deliver competitively cheap and reliable electricity to more remote customers through the grid, because the plants had come to cost less than the grid and had become so reliable that nearly all power failures originated in the grid Thus, the grid had become the main driver of remote customers' power costs and power quality problems, which became more acute as digital equipment required extremely reliable electricity. Efficiency gains no longer come from increasing generating capacity, but from smaller units located closer to sites of demand.

For example, coal power plants are built away from cities to prevent their heavy air pollution from affecting the populace. In addition, such plants are often built near collieries to minimize the cost of transporting coal. Hydroelectric plants are by their nature limited to operating at sites with sufficient water flow.

Low pollution is a crucial advantage of combined cycle plants that burn natural gas. The low pollution permits the plants to be near enough to a city to provide district heating and cooling. Distributed energy resources are mass-produced, small, and less site-specific. Their development arose out of:

1. Concerns over perceived externalized costs of central plant generation, particularly environmental concerns;
2. The increasing age, deterioration, and capacity constraints upon T&D for bulk power;
3. The increasing relative economy of mass production of smaller appliances over heavy manufacturing of larger units and on-site construction;
4. Along with higher relative prices for energy, higher overall complexity and total costs for regulatory oversight, tariff administration, and metering and billing.

Capital markets have come to realize that right-sized resources, for individual customers, distribution substations, or micro grids, are able to offer important but little-known economic advantages over central plants. Smaller units offered greater economies from mass-production than big ones could gain through unit size. These increased value due to improvements in financial risk, engineering flexibility, security, and environmental quality of these resources can often more than offset their apparent cost disadvantages. DG, vis-à-vis central plants, must be justified on a life-cycle basis. Unfortunately, many of the direct, and virtually all of the indirect, benefits of DG are not captured within traditional utility cash-flow accounting.

Figure 2 Localized distributed power generation system with alternate renewable sources

5. Proposed Method:

Here the most efficient method among all the existing PSO methods is considered which is simple and easy to implement and whose convergence criteria is far better than the existing methods which is the PSO with constriction coefficients and weighted factor addition. But here unlike the regular procedure of selecting random positions and random sizing there by initializing the swarms such that search procedure starts finding the local best positions and sizes and the global best position and size updation. Because of the regular procedure the time taken to run the programme is more as it involves selection from all the buses in the distribution system hence there is a chance of less convergence taking huge values between limits. So here in the proposed method the position of the placement of DG is decided by means of the calculation of Loss sensitive factors and the Voltage sensitive factors such that where there maximum among loss sensitive factor respective buses are selected as critical buses and are pre selected without involving its selection to PSO and only the for the optimal selection of DG size we use PSO such that much time gets saved which is used for finding the critical bus location for DG in regular methods as well as the convergence criteria is maximized. The proposed method in this paper is summarized as follows

A. Defining Objective function
B. Power flow solution
C. Estimation of total cost of Operation of DG
D. Finding Real power losses
E. Determining Loss sensitive factors
F. CCWPSO for Optimal sizing of DG

Objective function(ObF):

Here the objective function is a multi objective function with objectives of reducing real power losses and total cost of operation of DG

Minimize ObF = min (Real losses with DG +
Total cost of operation)

The objective function is evaluated in such a way that it should obey the limitations of the constraints.

1. DGmin(specified) < DG o/p power
   DGmax(specified) > DG o/p power
   Where DGmin = 75% of total apparent load
   DGmax = 5% of total apparent load
2. Vmin(specified) < Vbus < Vmax(specified)
   Where Vmin = 0.95pu
   Vmax = 1.0pu

Power flow solution:

Here the efficient technique for finding power flow is used which the forward and backward sweep load flow technique which is very simple and easy as it does not involves any complex calculations but only uses the topology of the distribution system such that it is accurate and fast convergent and the algorithm of the forward backward sweep method is as follows

Algorithm:
(Assume voltages as flat voltages i.e., 1pu at every node)
Step 1: Read the distribution networks line data and bus data
Step 2: Calculate the each node current, the relationship can be expressed as

$$I = [S/V]^* = [(P - jQ)/V^*]$$

Step 3: Calculate the BIBC matrix by backward sweep method
Step 4: Evaluate the branch current by using BIBC matrix

$$[IB]=[BIBC][I]$$

Step 5: Form the BCBV matrix by forward sweep method

$$[\Delta V]=[BCBV][IB]$$

Step 6: Calculate the Distribution Load Flow matrix

$$[DLF]=[BCBV][BIBC]$$

Step 7: Set iteration k=0
Step 8: Iteration k=k+1
Step 9: Update voltages by using these equations

$$[\Delta Vk+1]=[DLF]*[Ik]$$

$$[Vk+1]=[V0]+[\Delta Vk+1]$$

Step 10: If max $((|Vk+1| - |Vk|) > tolerance)$ go to step 6
Step 11: Calculate branch currents and node voltages
Step 12: Display the node voltage magnitudes and angle, branch current
Step 13: Stop

Total cost estimation of operation of DG:

The total cost of operation of DG includes the cost for the losses of the system after DG installation and the cost for the power taken from the substation along with costs for the generation of power from DG. Here the costs for the generation of power from DG is taken as 5$ and for the power taken from the substation is 4$ and cost estimation is done considering these assumpted costs.

Total cost of operation =
(Cost of power taken from substation *
losses with DG) +
(Cost of power drawn from DG*power output of DG)

Finding Real power losses:

From the results of (A) i.e., load flow solution using forward and backward sweep method the values of current at each branch is taken and from given line data the resistance corresponding to the line section is taken and by means of these we find the real power losses of the system with or without the installation of DG

Real power losses at each branch =
(IB*IB)* Resistance
Where IB = Branch current calculated from (A)
Resistance = Branch Resistance from given line data

Finding Loss sensitive factors and voltage sensitive factors:

For finding the loss sensitive factors initially when no DG is installed we calculate the effective load demand at each of the system nodes such that loss sensitive factors are calculated using the effective load demand calculated at each node from the last node.

Effective load demand beyond each node

Eldbn=**Σ** (load at bus n)+(load demand beyond bus n)

Now the loss sensitive factors at each of the line section are calculated as follows

Loss factor at each bus in power b

Lsfb = (2 * Eldbn * Resistance)/ Voltage

Note : Voltage = Voltage at receiving end node

After finding the loss sensitive factors at each node they are arranged in descending order such that bus with maximum loss factor is selected for DG placement,

Voltage sensitive factors at each bus:

After the arrangement of the loss factors in descending order refine the buses by applying voltage limits for the selected buses such that we take only buses whose voltage is between specified voltage limits of minimum voltage Vmin and maximum voltage limit Vmax in per uints.

6. CCWPSO (Constriction and weighted coefficient factor Particle swarm optimization) with loss sensitivity analysis:

As mentioned earlier in this method we use PSO only to find the optimum size of the DG which is to be installed at the selected most critical bus of the distribution system from the loss sensitive factor analysis and the algorithm procedure for finding the optimal size of DG is as follows

Step 1: Read line data and load data

Step 2: Calculate loss sensitive factors at each bus from the given data and find most critical buses

Step 3: Perform load flow solution analysis using forward and backward sweep method Before installing DG Mentioned in (A)

Step 4: obtain branch currents, bus voltages and real power losses from step 3

Step 5: Give initial Global best and worst sizes if DG (should be the maximum value)

Step 6: Give maximum iteration and start iterations

Step 7: Now initialize particles of swarm in random within the maximum and minimum specified DG output power limits and update velocity parameters.

Step 8: Now taking random bus from the top 10 critical buses obtained from step2 with respect to the random size obtained from the step 5 perform load flow solution analysis as mentioned in step 3.

Step 9: Obtain the real power losses from step 6, the position and size of step 6 taken as Initial personal best position and size, update velocity using 6(e) and update iteration and goto step 7

Step 10:Compare the results obtained from step 8 and update personal best position and best size in each iteration.

Step 11:Continue until maximum iteration is reached.

Step 12:Compare the obtained results from the obtained personal best position and best Size from the results of step 3 and step 5 and best of personal best values of position and size are taken as Global best position and Global best size.

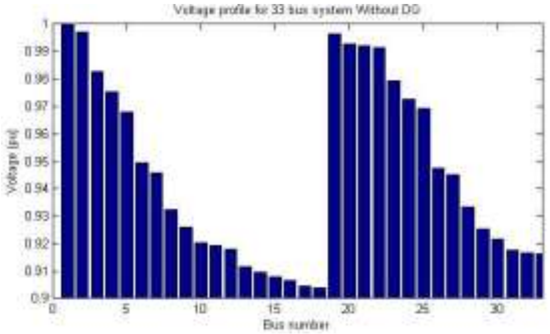
Step 13: Results obtained from Step 10 are compared with the Global best values at each iteration and update Global best position and Global best size of DG.

Step 14:The final results obtained from step 13 are the optimal global best position and the Global best size of DG such that least losses and good voltage profile is obtained at the obtained position and size.

Step 15: Total cost of operation of DG are calculated from the obtained results of best position and size at which losses are determined from Step 14

7. Simulation Results:

The proposed method i.e., CCWPSO is tested on IEEE 33 bus distribution power system using MATLAB2013a, which consists of 33 buses and 32 line sections with starting bus as a slack bus, Considered Base MVA and KV as 100 and 12.66. It is tested on two types of DG's i.e., DG which is capable of injecting only active power and which is capable of injecting both active and reactive powers. The obtained results are shown below



PSO Parameters:

Population	50
Maximum Iterations	10
Weighted coefficient	1.36
C1	2.05
C2	2.05
rand	Random variable between 0 & 1

Table 1 PSO parameters

The parameters that are taken in proposed method are mentioned in the above table, the population of the swarm are taken 50, the maximum number of iterations are taken 10 and can be changed as per requirement, the weighted coefficient parameter is taken as 1.36 from PSO method mentioned in 6(c), the cognitive coefficients or the constriction coefficients C1 and C2 are taken 2.05 from PSO method mentioned in 6(e) and the random variable is randomly selected by the system which in between 0 and 1. By means of the following parameters the proposed method is tested on two types of DG with unity power factor, Power factor and 0.866 power factor and compared to the remaining proposed methods it showed a greater change in voltage profile improvement and also in the total operation cost reduction and results are framed in figure 4, figure 5 and table 2 and table 3.

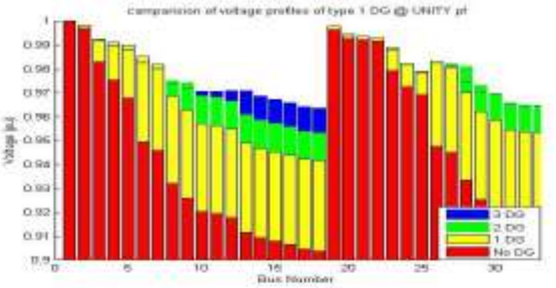


Figure 4 Voltage profile comparison for typ3 DG @unity power factor

Particulars	Before optim	After Optimization with unity power factor				
		PSO [14]	GA [13]	Proposed method		
				1 DG	2DG	3DG
Total R loses(KW)	210.84	116.26	110.98	111.1	88.1	78.9
Loss reduction(%)	-	45.16	47.36	47.3	58.2	62.5
V min (pu)	-	-	-	0.9386	0.9533	0.9635
Optimal location & Optimal size(MW)	-	(6) 2.4939	(6) 2.52	(6) 2.31	(29)1.35 (10)0.72	(30)0.71 (13)0.62 (6)0.95
Total S dg(KVA)	-	2493.9	2380	2310	2070	2280
DG power factor	-	Unity	Unity	Unity	Unity	Unity
Total cost of operation($)	-	12930.04	13043.76	11994.4	10702.4	11715.6

Table 2 comparison of results of 33 bus system with previous methods

Particulars	Before optim	After Optimization at 0.866 Power factor				
		PSO [14]	GA [13]	Proposed method		
				1 DG	2DG	3DG
Total R loses(KW)	210.84	68	78.9	78.9	43.8	29.7
Loss reduction(%)	-	67.74	62.5	62.5	79.2	85.9
V min (pu)	-	-	-	0.9509	0.9795	0.9820
Optimal location & Optimal size(MVA)	-	(6) 3.091	(6) 2.61	(6) 3.01	(28)1.33 (13)1.02	(30)0.80 (13)0.88 (6)1.27
Total S dg(KVA)	-	3091	2610	3010	2350	2950
DG power factor	-	0.82lag	0.95lag	0.866lag	0.866lag	0.866lag
Total cost of operation($)	-	15727	13365.6	15,365.6	11,925.2	14,868.8

Table 3 comparison of results of IEEE 33 bus system with previous methods for type 3 system

For DG type 1 distribution system:

The results of IEEE 33 bus system in comparison with the existing methods to the proposed CCWPSO method are tabulated in table 2 in which drastic change in the total cost of operation can be observed by the proposed method such that total cost of operation is reduced to 11,994.4$ in case of installation of 1 DG into the system, Total cost reduced to 10,702.4 $ in case of installation of 2 DG's into the distribution system, cost of operation is reduced to 11,715.6$ in case of installation of 3 DG's into the system. When compared to the existing previous methods the reduction in cost is greater in the proposed CCWPSO method.

For DG type 3 distribution system: @0.866 power factor:

The results of IEEE 33 bus system in comparison with the existing methods to the proposed CCWPSO method are tabulated in table 3 in which drastic change can be oberved in the total cost of operation by means of proposed method such that in case of installation of 1 DG into the system total cost of operation is reduced to 15,365.6$, in case of installation of 2 DG's into the distribution system total cost reduced to 11,925.2 $, case of installation of 3 DG's into the system cost of operation is reduced to 11,715.6$ in. When compared to the existing previous methods the reduction in the total operation cost is greater in the proposed CCWPSO method.

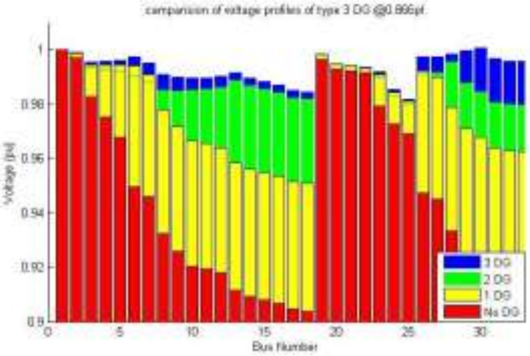


Figure 5 comparison of voltage profile of type 3 DG @0.866 power factor

***Conclusion*:**

In this paper a new improvised approach to determine the cost effective optimal placement and size of multiple distributed generation units in the radial distribution system such that it is more effective compared to the previously proposed techniques and the effective in the total operational cost reduction can be seen the results which are demonstrated on IEEE 33 bus radial distribution system, the type 3 DG that is the DG capable of real and reactive power injection system gives good performance than the type 1 DG system in case of loss reduction as well as the voltage profile improvement even though cost of operation in both cases differ slightly which concludes the proposed approach is accurate in determination of optimal location and size of DG, and takes very less time of run compared to remaining meta heuristic techniques the proposed technique is tested under balanced network configuration but can be extended taking into consideration for an unbalanced distribution network with change in load demand.

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