Improved Optimal Reactive Power Dispatch using Hybrid Convex Optimization Algorithm

Yoginder Singh[1] Harkamaldeep Singh[2]
[1, 2] Electrical Engineering department
G.G.S College Of Modern Technology Kharar

Abstract-

In this paper, different optimization methods like Particle Swarm Optimization (PSO), Genetic Algorithm (GA) etc. are discussed and compared for optimal location, type and rating of devices. bus system IEEE30 these two-bus systems replace fact on effective place in case of congestion. After congestion increase of loss on different loads. In Optimization reactive losses placement improve the congestion and reduce loss. In table 5.1 analysis of different three methods like genetic algorithm (GA), particle swarm optimization (PSO), and hybrid proposed approach particle swarm optimization and genetic algorithm (PSO-GA). In proposed approach improve the cumulative or average loss. In analysis show when increase the load losses will increase because of congestion in lines will increase and its effect on voltage unstable and its magnitude will reduce and loss will increase. So, reduce the loss by reduction of congestion by placement of Optimization reactive losses in effective location. Propose approach optimizes the location by global and local optimization. But comparative 30 bus system reduce the reactive losses than 41 bus system because of possibility of more line congestion and increase reactive losses.

Keywords- *Distributed Generation, Balance of System, Distribution Transformer, Optimal DG Placement*

I. INTRODUCTION

Currently it is widely accepted that the construction of large generation centers is no longer the best option to supply the increment of electric load. High costs related to the construction of new generation centers, state policies aimed at reducing the production of greenhouse gases, and legal issues, such as obtaining environmental permits for the construction of new transmission lines, are some of the main reasons that have driven the growth of small scale generation located close to actual load consumption, also known as Distributed Generation (DG). Distributed generation can also be encompassed within a much larger scope, the Distributed Energy Resources (DER) concept [1, 2] [3, 8]. DER refers to a variety of small, modular electricity-generating or storage technologies that can be aggregated to provide power necessary to meet regular demand and are installed at distribution level; distributed energy resources also include demand-side management (i.e. energy efficiency and demand response). Electric power distribution is the final stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers. Distribution substations connect to the transmission system and lower the transmission voltage to medium voltage ranging between 2 kV and 35 kV with the use of transformers. *Primary* distribution lines carry this medium voltage power to distribution transformers located near the customer's premises. Distribution transformers again lower the voltage to the utilization voltage used by lighting, industrial equipment or household appliances. Often several customers are supplied from one transformer through *secondary* distribution lines. Commercial and residential customers are connected to the secondary distribution lines through service drops. Customers demanding a much larger amount of power may be connected directly to the primary distribution level or the sub-transmission level [4, 5, 6, 7, 13].

1.1 Power Systems General Structure

Figure 1 shows the general structure of power systems [16].

1. Large Generation Centers: The great majority of electrical energy is produced using large generation units clustered in remote sites, far from final consumption points. Different technologies have traditionally been used to produce electrical energy in a large scale, such as nuclear, natural gas, coal, hydro, etc

2. Transmission System: The transmission system consists of a set of lines, substations, and equipment designed to connect large generation plants and consumption centers, power consumption is mainly carried out in cities and industrial areas.

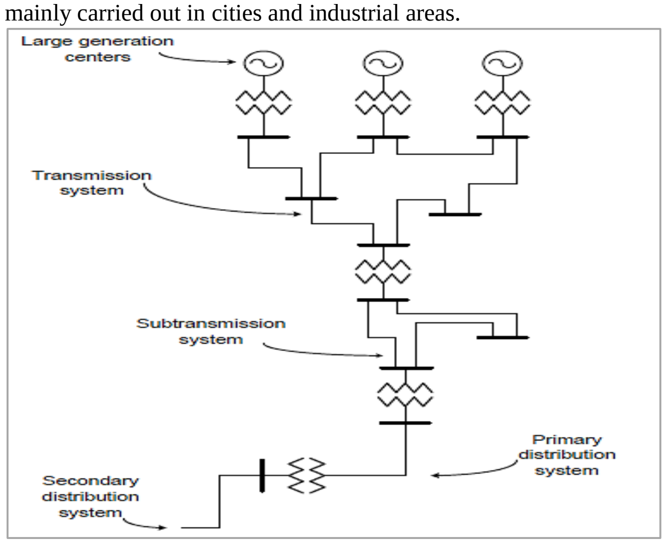


Figure 1: Power delivery system structure [16]

3. Sub-transmission System: The lines that compose the sub-transmission system cover shorter distances than those in the transmission system; for that reason, they operate at lower voltage levels (e.g. 132, 66, and 45 kV).

4. Primary Distribution System: The first component of the primary distribution system is the distribution substation, where the energy delivered by the transmission and sub-transmission system is received and a new voltage reduction is performed.

5. Secondary Distribution System: The secondary distribution system consists of step-down (MV/LV) distribution transformers and low-voltage lines (e.g. 400 and 230 V) that deliver the energy to low power customers, such as commercial and residential loads.

1.2 Electrical Power Distribution System

Distribution of electric power is done by distribution networks. Distribution networks consist of following main parts [10, 11, 12]:

- Distribution substation: The stepped-down voltage from the substation is carried to distribution transformers via feeder conductors.
- Feeders: A feeder is a conductor which connects the substation (or localized generating station) to the area where power is to be distributed.
- Distribution Transformers: A distribution transformer, also called as service transformer, provides final transformation in the electric power distribution system. It is basically a step-down 3-phase transformer. Distribution transformer steps down the voltage to 400Y/230 volts.
- Distributor conductors: A distributor is a conductor from which tapping's are taken for supply to the consumers. The current through a distributor is not constant because tapping's are taken at various places along its length.

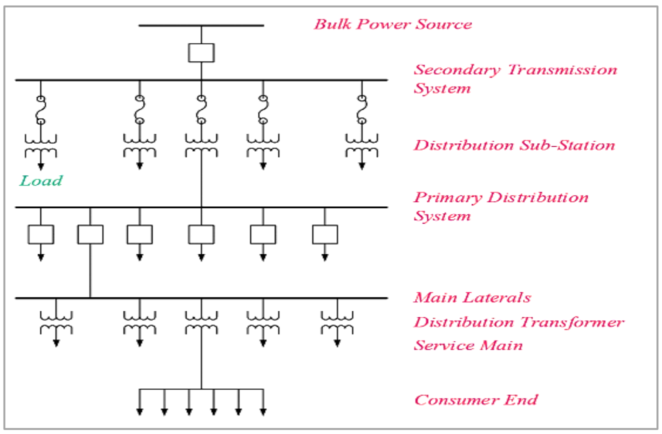


Figure 2: A typical electric power distribution system [14]

1.3 *Structure of Distribution System*

The distribution substation is the interconnection element between the distribution system and the upstream power delivery system. At the substation the step-down (HV/MV) transformer reduces the sub transmission voltage level to an appropriate value. for primary distribution lines. Different protection, switching, and measurement equipment is installed at the substation to ensure a safe operation.

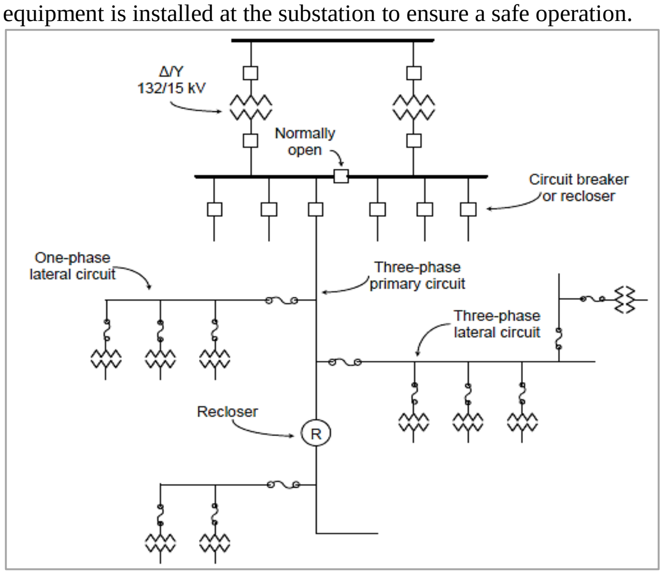
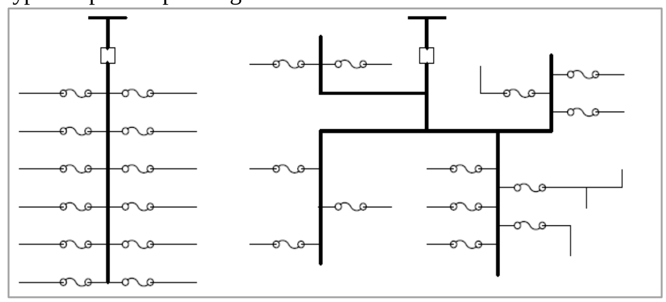


Figure 3: Typical distribution system configuration [16].

1.3.1 Distribution System Primary Circuits

1. Single Feeder Configuration: Under this configuration all power demanded by laterals and secondary circuits is served by a single primary line; in case of failure or any other event that forces the feeder to be out of service (e.g. maintenance), all loads will experience a service interruption. The single feeder layout can also present a branched-configuration, where several branches stem from the original feeder in order to cover a larger area.

2. Open-loop Configuration: In the open-loop configuration two feeders parting from the same substation are connected at their end terminals through a normally-open tie-switch. Figure 5 presents a typical open-loop configuration.



a) Simple feeder b) Branched-configuration

Figure 4: Single feeder configuration [17]

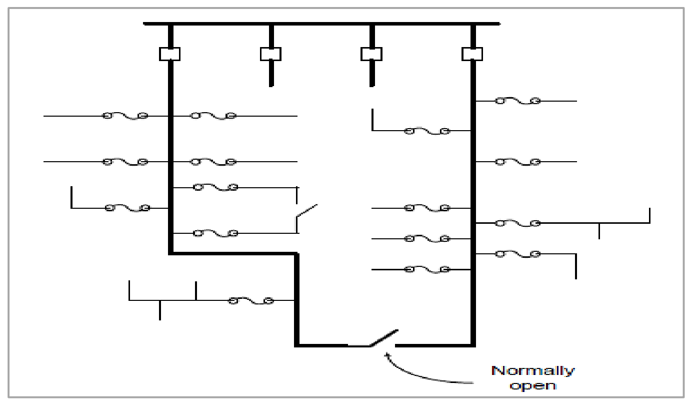


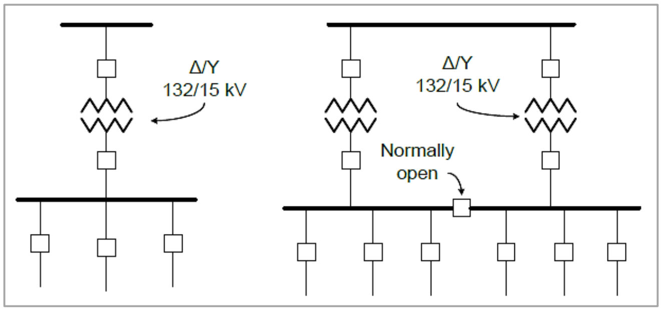
Figure 5: Open-loop configuration [17]

1.3.2 Distribution System Substations

The configuration of a distribution substation will depend on the type of system served (urban, suburban, or rural); load level and desired reliability will affect the substation's design and auxiliary equipment required [15].

1. Rural Substation: Substations designed for rural systems present a simple configuration; they consist of a single high-voltage and medium-voltage bus. Due to low load levels, a single transformer is enough to supply the entire power demand; transformer protection will depend on the transformer's rated power.

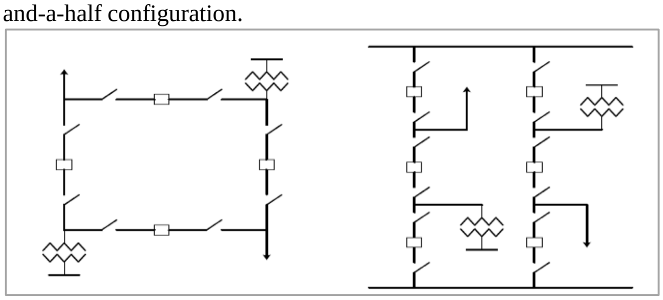
2. Suburban Substation: Suburban systems present higher load levels than rural systems; therefore, more than one transformer will be necessary to serve the total system load. Suburban substations have a single bus on the high-voltage side, whereas each substation transformer has its own medium-voltage bus; medium-voltage buses are connected to each other through a normally-open tie-switch



(a) Rural substation (b) Suburban substation

Figure 6: Distribution substation configuration [17]

3. Urban Substation: The configurations in urban substations are more complex than those used for rural and suburban systems; two of the most common substation designs are the ring-bus and breaker-and-a-half configuration.



(a) Ring-bus (b) Breaker-and-a-half

Figure 7: Urban substation configuration

1.4 Requirements of a good distribution system

A considerable amount of effort is necessary to maintain an electric power supply within the requirements of various types of consumers. Some of the requirements of a good distribution system are [1, 8, 9, 14]:

*1. Proper voltage***:** One important requirement of a distribution system is that voltage variations at consumer's terminals should be as low as possible. The changes in voltage are generally caused due to the variation of load on the system. Low voltage causes loss of revenue, inefficient lighting and possible burning out of motor. High voltage causes lamps to burn out permanently and may cause failure of other appliances. Therefore, a good distribution system should ensure that the voltage variations at consumer's terminals are within permissible limits. The statutory limit of voltage variations is ± 5% of the rated value at the consumer's terminals.

2. Availability of power on demand: Power must be available to the consumers in any amount that they may require from time to time. For example, motors may be started or shut down, lights may be turned on or off, without advance warning to the electric supply company. As electrical energy cannot be stored, therefore, the distribution system must be capable of supplying load demands of the consumers. This necessitates that operating staff must continuously study load patterns to predict in advance those major load changes that follow the known schedules.

3. Reliability: Modern industry is almost dependent on electric power for its operation. Homes and office buildings are lighted, heated, cooled and ventilated by electric power. This calls for reliable service. Unfortunately, electric power, like everything else that is man-made, can never be absolutely and 100% reliable. However, the reliability can be improved to a considerable extent by:

- Interconnected system
- Reliable automatic control system
- Providing additional reserve facilities.

II. RELATED WORK

Abdhullah, Sinha Sheikh, et al. [1] The main goal of this research is to study various load balancing algorithms that are in use, now a days. Nature inspired algorithms are applicable in every aspect of technology. In this work, the review of a meta-heuristic technique, namely, BAT Algorithm is carried out. The comparison of all the load balancing techniques and BAT algorithm techniques are described in this paper. Attari et al. [2] Reconfiguration, by exchanging the functional links between the elements of the system, represents one of the most important measures which can improve the operational performance of a distribution system. Besides, reclosers use to eliminate transient faults, faults isolation, network management and enhance reliability to reduce customer outages. For load uncertainty a new method based on probabilistic interval arithmetic approach is used to incorporate uncertainty in load demand that can forecast reasonably accurate operational conditions of radial system distribution (RDS) with better computational efficiency. In this paper, the optimization process is performed by considering power loss reduction along with reliability index as objective functions. Simulation results on radial 33 buses test system indicates that simultaneous optimization of these two issues has significant impact on system performance. Amon et al. [3] In this paper a modified version of new Meta Heuristic algorithm based on Bat behavior is proposed to find the best system configuration with a low loss rate, we present two different approaches: reduction of search space and introduction of sigmoid function to fit the algorithm to the problem. The main advantages of the proposed methodology are: easy implementation and less computational efforts to find an optimal solution. To demonstrate its efficiency the proposed scheme is tested on 33 Bus distribution system and the results show loss reduction rate of 33%. Flaih, Firas MF et al. [4] In this paper the authors have proposed a method to reduce the power losses and therefore improve the voltage profile for low voltage (LV) distribution system that results in reduction of blackouts. The method involves the repositioning of the distribution transformer (DTR) from the existing location and the replacement of the overhead conductor cross section area for an existing low voltage distribution system (LVDS). This method has been applied to a 20-node low voltage radial distribution network in the general directorate of north distribution electricity (GDNDE), Iraq, where voltage profile and losses are unsatisfactory. Results demonstrate the effectiveness of the proposed method also in terms of the economic feasibility. It is observed that the system average voltage profile is improved by 15%, tail end voltage enhanced by 19.7% and losses are reduced by 78% for existing the LVDS. Spandana, K. et al [6] This paper is to enlighten the importance of restructuring of an existing Low Voltage Distribution System (LVDS) into High Voltage Distribution System (HVDS) which has a better voltage and loss profile and high quality of supply. In India, the average transmission and distribution losses have been officially indicated as 25% of the electricity generated, because of the fact of usage of long lengths of Low Voltage (LV) distribution lines. In HVDS these long length LV lines are replaced by High Voltage (HV) lines up to the Distribution Transformer (DTR) and then a small length LV line is extended to the consumers end. Due to the usage of long lengths of HV lines, there is no scope for unauthorized power pilferage unlike in LVDS. A large rated distribution transformer in LVDS is replaced by many numbers of small rated distribution transformers in HVDS. Adequate investment in efficient working of transmission and distribution systems in developing economies with high growth of electricity demand is an important objective. Hence to overcome all these problems, implementation of HVDS is considered as the best move to enhance the performance of a distribution system. Sarwar, Md, et al. [8] This paper presents a method to reduce the technical power loss in distribution systems. The high voltage distribution system is proposed to minimize the technical distribution losses. The analysis is done using CYMDIST. The developed methodology is carried on a Lalpura distribution feeder from the Palwal division (Haryana). The feeder is feeding to 89 Distribution transformers with 200 amperes peak load and having the length of about 76 km. The analysis reveals that converting the existing LVDS system for the agricultural load to HVDS system, there is net reduction in technical losses in the distribution system which in turn raises the efficiency of the system. Also, it shows the economic viability of the proposed technique. Babu, P. Ravi et al [9] This paper presents a new methodology for enhancing the distribution system performance by minimizing both technical and non-technical losses. Most of the utility companies in developing countries are victims of major revenue losses due to technical and non- technical energy losses. The non-technical losses are like electricity theft, unauthorized connections, irregular billing and the technical losses are I^2R power losses. These losses affect the quality of supply in terms of voltage magnitude, and more tariffs imposed on genuine customers. To improve the efficiency of supply, one of the recommendations is "Boosting the distributor phase voltage, say from 100% to 152% that is, 230V to 350V and stepping down to normal operating voltage (230V) at the consumer premises by using a special voltage regulator device". The methodology can reduce the technical and non-technical losses in the electrical distribution system to appreciable level. Hence the voltage profile can be improved by reducing the I^2R losses. As the normal operating voltage of any home appliances is 230V, in the proposed methodology the electrical distributor phase voltage is maintained up to 350V. So, if any domestic consumer tries to get unauthorized/illegal power tapping connection, the home appliances are getting damaged due to over voltage. Hence, with this approach there is no chance for power theft or unauthorized connections in the distribution system. When the electrical distributor operates with more voltage than the normal operating voltage, the I^2R losses in the distributor will be reduced considerably. Nidhiritdhikrai et al. [10] Accurate assessment of power loss in a low-voltage distribution system is still an important issue under present competitive environment. Even though, power flow analysis is still efficient to calculate technical power loss, it requires numerous data which may not be available for some utilities. For this reason, the loss assessment for a low-voltage distribution system is not easy when the demand of any customer load points is still unclear. Therefore, distribution utilities obviously require a more suitable algorithm with their available information to calculate their system power loss. This paper proposes an alternative algorithm to crop with this problem. The proposed approach has been tested with an actual system, a low-voltage distribution system with 16 customer load points. Khaniya, Dina et al. [11] This paper proposes the Newton Raphson power flow solution for three phases unbalanced and multiphase system for both radial and meshed topology. Different test cases have been simulated using the developed program to get satisfactory results. Developed program will be further used to investigate the voltage stability of distribution system. Georgilakis, Pavlos S et al. [12] The aim of the optimal DG placement (ODGP) is to provide the best locations and sizes of DGs to optimize electrical distribution network operation and planning taking into account DG capacity constraints. Several models and methods have been suggested for the solution of the ODGP problem. This paper presents an overview of the state-of-the-art models and methods applied to the ODGP problem, analyzing and classifying current and future research trends in this field. Hung, Duong Quoc et al. [13] This paper investigates the problem of multiple distributed generator (DG units) placement to achieve a high loss reduction in large-scale primary distribution networks. An improved analytical (IA) method is proposed in this paper. This method is based on IA expressions to calculate the optimal size of four different DG types and a methodology to identify the best location for DG allocation. A technique to get the optimal power factor is presented for DG capable of delivering real and reactive power. Moreover, loss sensitivity factor (LSF) and exhaustive load flow (ELF) methods are also introduced. IA method was tested and validated on three distribution test systems with varying sizes and complexity. Results show that IA method is effective as compared with LSF and ELF solutions.

III. THE PROPOSED METHOD

3.1 Proposed Methodology

Step 1: Initialize the Load/Power.
Step 2: Initialize the generator Load_Power.
Step 3: Allocate the generators and calculate the cost.
Step 4: Apply the PSO for optimization.
Step 5: If output of PSO is optimized then check the convergence otherwise Genetic algorithm starts it working with the following steps.

- *(a)* Initialize the chromosomes.
- *(b)* Cross over between chromosomes.
- *(c)* Apply Roulette Selection.
- *(d)* Check Optimization. If optimize then go to convergence Check otherwise loop is running until Objective form is not obtained.

Step 6: Check the convergence. If converge then check the cost features otherwise again initialize the particles and Repeat the step 5.
Step 7: If cost is less than Δ C then stop.

3.2 Proposed methodology: Flowchart

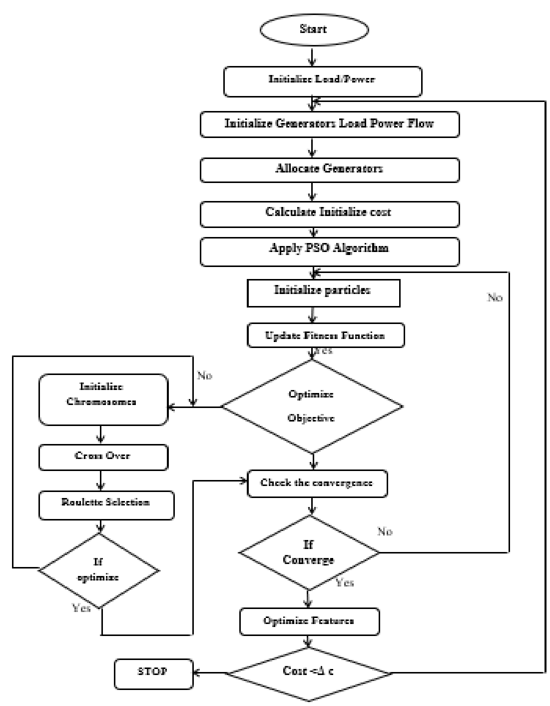


Figure 8: Proposed Flowchart

3.3 Proposed Algorithm

1. Genetic Algorithm: Genetic algorithm is a meta-heuristic algorithm which is used to solve the optimization problems in computing and artificial intelligence. It provides the optimized solution by using the concept of selection and evolution. Genetic algorithms are able to solve the complex problems and provide reasonable solution on them.

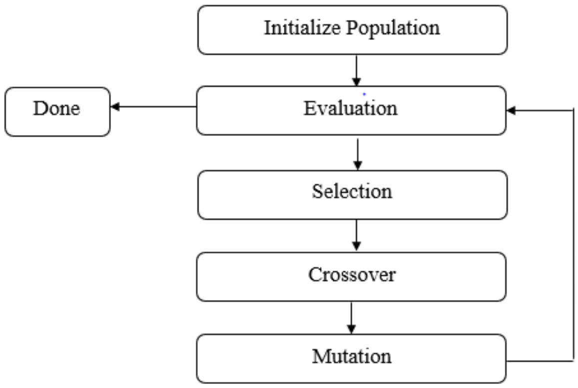


Figure 9: Flow chart of genetic algorithm

Genetic Algorithm

Step 1: Population← initialize Population
Step 2: Evaluate the population.
Step 3: S_{Best}← get best solution from population.
Step 4: while (! Stop condition())
Parents ← select parents(Population, $Population_{Size}$)
Child← ∅
For($Parent_1 Parents_2 \in Parents$)
$Child_1 Child_2 \leftarrow Crossover(Parent_1 Parents_2 \in P_{Crossover}$)
$Children \leftarrow Mutate\ (Child_1, P_{mutation})$
$Children \leftarrow Mutate\ (Child_2, P_{mutation})$
End
Evaluate the Population of Children
$S_{Best} \leftarrow get\ best\ solution\ (Children)$
Population←
$replace\ the\ \ least\ fit\ population\ (children) with\ new$
End
Return (S_{Best})

2. PSO: The algorithm keeps track of three global variables:

1. Target value or condition
2. Best Global Value (gBest) indicating which particle data is currently closest to the target
3. Stop value indicating when the algorithm should stop if the target is not found

Each particle is composed of:

1. Data representing a possible solution
2. A velocity value indicating how much data can be changed
3. A better personal value (pBest) indicating the closest the particle's data has ever reached the target

PSO

Step 1: In PSO model for each particle i in S do
Step 2: for each dimension d in D do
Step 3: //initialize each particle's position and velocity
Step 4: $x_{i,d} = \boldsymbol{Rnd}(\boldsymbol{x_{max}}, \boldsymbol{x}_{min})$
Step 5: $\boldsymbol{v_{i,d}} = \boldsymbol{Rnd}(-\boldsymbol{v_{max}}/3, \boldsymbol{v_{max}}/3)$
Step 6: end for
Step 7: //initialize particle's best position and velocity
$\boldsymbol{v_i}(k+1) = \boldsymbol{v_i}(k) + \boldsymbol{\gamma 1_i}(\boldsymbol{p_i} - \boldsymbol{x_i}(k)) + \boldsymbol{\gamma_{2i}}(G - \boldsymbol{x_i}(k))$
New velocity
$\boldsymbol{x_i}(k+1) = \boldsymbol{x_i}(k) + \boldsymbol{v_i}(k+1)$
Where
i- particle index
k- discrete time index
v_i –velocity of i^th particle
x_i – position of i^th particle
p_i- best position found by i^th particle(personal best)
G- best position found by swarm (global best, best of personal bests)
G $_{(1,2)i}$- random number on the interval[0,1]applied to the i^th particle
Step 8: $\boldsymbol{pb_i} = \boldsymbol{x_i}$
Step 9: // update global best position
Step10: if $\boldsymbol{f}(\boldsymbol{pb_i}) < \boldsymbol{f}(\boldsymbol{gb})$
Step 11: $\boldsymbol{gb} = \boldsymbol{pb_i}$
Step12: end if
Step13: end for

IV. RESULT ANALYSIS

4.1 Result Analysis

Table 1 Losses without optimization

FROM BUS	TO BUS	PI SENESTIVITY
5	7	-14.853
9	11	0
19	20	-6.457
24	25	-1.142
25	27	-4.694
8	28	-0.613
REAL LOSS	17.528	
REACTIVE LOSS	68.8888	

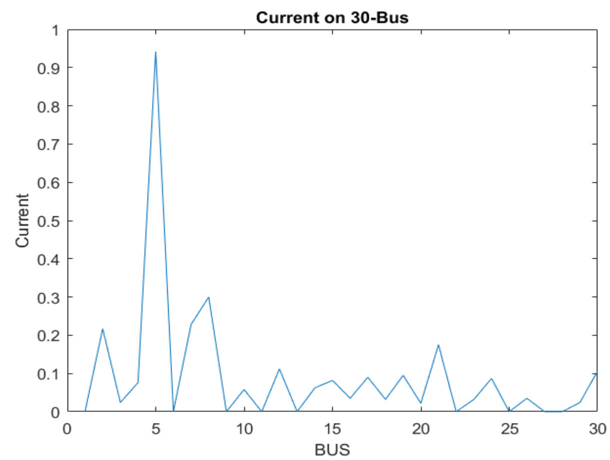


Figure 10: Current without optimization

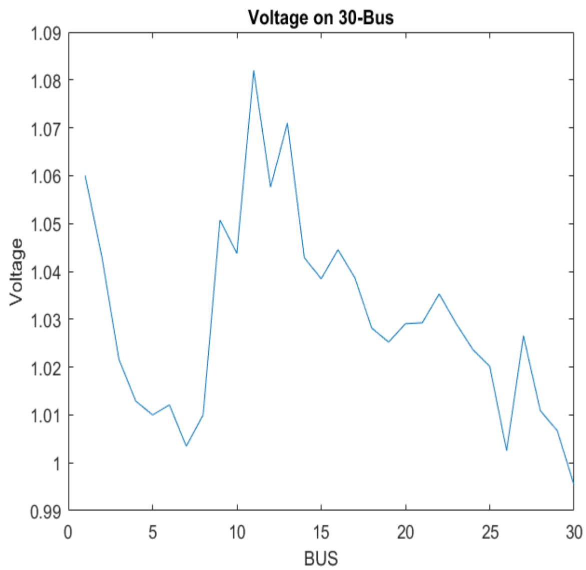


Figure 11: Power without optimization

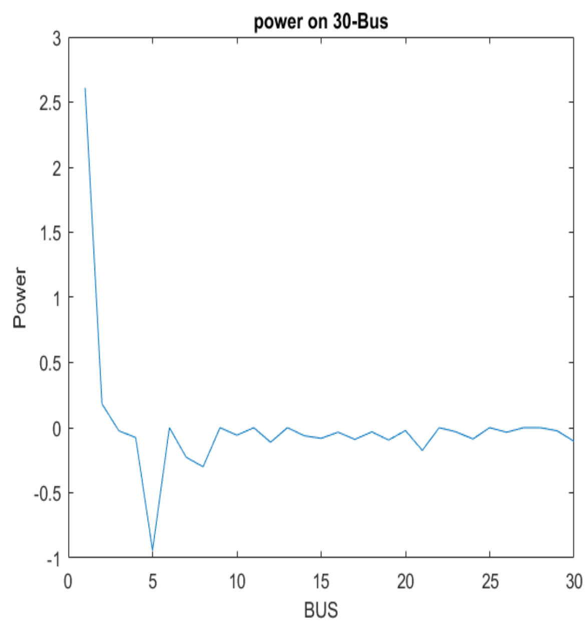


Figure 12: Power without optimization

Table.2 Losses in different power factors and generators

REACTIVE LOSSES	7.5MVA	17.5MVA	27.5MVA
REAL REACTIVE LOSSES(PF=0.8)	16.34	14.34	12.34
REAL REACTIVE LOSSES(PF=0.83)	15.45	13.45	11.23
REAL REACTIVE LOSSES(PF=0.86)	14.34	13.23	11.1
REAL REACTIVE LOSSES(PF=0.89)	13.23	12.34	10.34
REAL REACTIVE LOSSES(PF=0.9)	13.13	12.23	9.23
REACTIVE LOSS(PF=0.8)	67.45	69.34	62.34
REACTIVE LOSS(PF=0.83)	66.23	67.45	60.34
REACTIVE LOSS(PF=0.86)	67	66.34	58.45
REACTIVE LOSS(PF=0.89)	68	65.34	56.45
REACTIVE LOSS(PF=0.9)	66	63.45	67.45

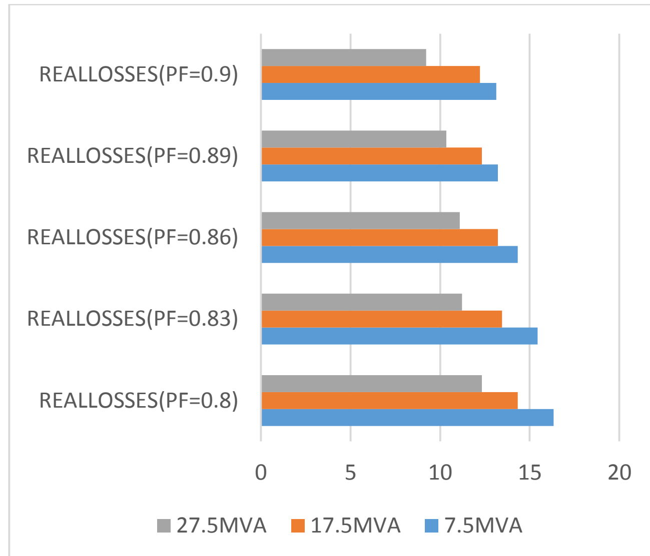


Figure 13: Real Losses in different power factors and generators

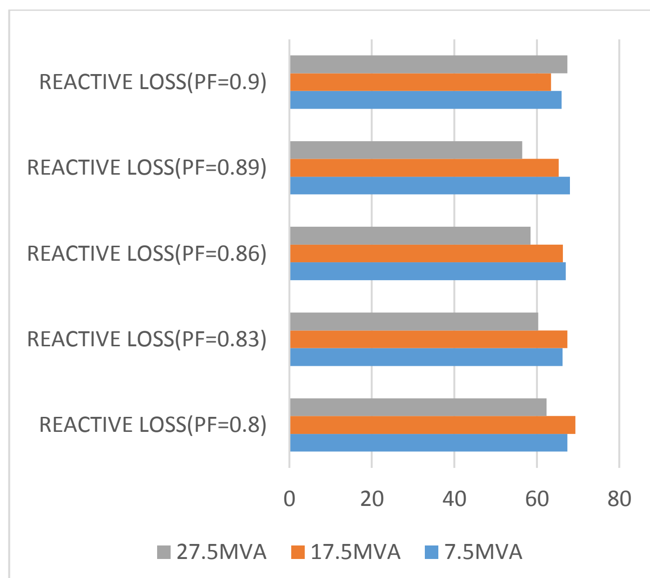


Figure 14: Reactive Losses in different power factors and generators

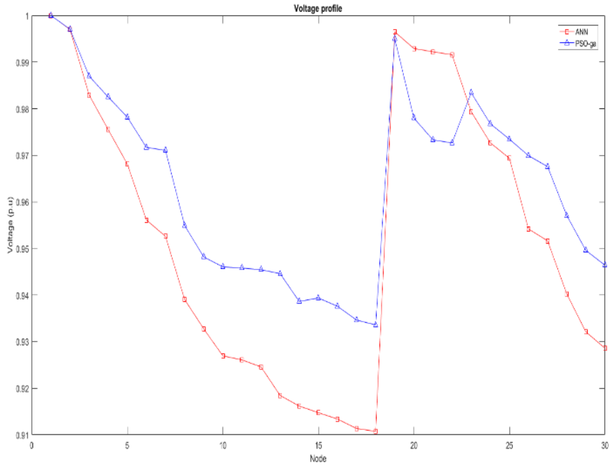


Figure 15: Voltage after different optimization

Table 3 Losses in different optimization

PARAMETERS	ANN	PSO-GA
LOCATION	[9 19]	[24 28]
LOSS	15.3422	12.333
COST	120	90
DGSIZE	[10.23 7.45]	[7.23 6.45]

IV CONCLUSION

Modern power system is dealt with overloading problem especially transmission network which works on their maximum limit. Today's power system network tends to become unstable and prone to collapse due to disturbances. Flexible AC Transmission system (OPTIMIZATION REACTIVE LOSSES) provides solution to problems like line overloading, voltage stability, reactive losses, power flow etc. OPTIMIZATION REACTIVE LOSSES can play important role in improving static and dynamic performance of power system. OPTIMIZATION REACTIVE LOSSES devices need high initial investment. Therefore, OPTIMIZATION REACTIVE LOSSES location, type and their rating are vital and should be optimized to place in the network for maximum benefit. In this paper, different optimization methods like Particle Swarm Optimization (PSO), Genetic Algorithm (GA) etc. are discussed and compared for optimal location, type and rating of devices. bus system IEEE30 these two-bus systems replace fact on effective place in case of congestion. After congestion increase of loss on different loads. In Optimization reactive losses placement improve the congestion and reduce loss. In table 5.1 analysis of different three methods like genetic algorithm (GA), particle swarm optimization (PSO), and hybrid proposed approach particle swarm optimization and genetic algorithm (PSO-GA). In proposed approach improve the cumulative or average loss. In analysis show when increase the load losses will increase because of congestion in lines will increase and its effect on voltage unstable and its magnitude will reduce and loss will increase. So, reduce the loss by reduction of congestion by placement of Optimization reactive losses in effective location. Propose approach optimizes the location by global and local optimization. But comparative 30 bus system reduce the reactive losses than 41 bus system because of possibility of more line congestion and increase reactive losses.

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