Hybrid grey wolf optimization with Bat Algorithm for Power Loss Reduction in Electrical Distribution System

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Abstract:
During emergencies, spinning reserve capacity is shared, contributing to the continuity of service. This extensive interconnection of large scale power systems has resulted in the formulation of many new concepts in power system planning and operation. The gradient and BAT methods and Hybrid BAT with (grey wolf optimization) GWO of solving In result show the percentage of loss all distribution of power in configured ,BAT and GWO_BAT approach using different bus system like 33 and 36 bus system in proposed approach show the significance improve by 37% and 38.23% but only BAT algorithm 33% and 34% because its not optimize using only local transmission which not able global optimization

Keywords: transmission, distributed ,line ,loss, optimization

I. INTRODUCTION

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The energy plays a vital role for all the humans as the it can neither be created nor it get destroyed but it can move/transform from one place to other. The modern living has realized the increased importance of energy as the life is moving faster, there is big need for fast communication, fast transport and manufacturing processes. So, energy industry forms one of the biggest consumer market [1, 2]. The use of electric power system requires an alternative generation because of its large demand by the consumers. The electricity cost is calculated based on different proportions such as 50% for fuel consumption, 25% for distribution, 20% for generation, and % for transmission which has created an alert to use or generate the alternative resources of power. For the levels of distribution, the ratio of reactance to resistance (X/R) is low when compared to levels of transmission which has resulted in high power losses and voltage magnitude dip along the distribution (radial) lines. The distribution systems must be able to provide energy/electricity to each consumer at an appropriate form of voltage rating. The modern forms of power are complex in nature with multiple load centres and generating stations interconnected through the transmission and distribution networks. The main objective of the energy based power system is energy generation and to deliver the energy/power at to its customers at its rated voltage-based value with minimum losses [3].In case of heavy loading condition, the reactive form of power flow is the major cause of losses, thus reducing the levels of voltage simultaneously. So, there is occurs a big need to minimize real losses of power and to improve the level of voltage in distribution systems. In such cases, a variation occurs in the network configuration usually varying by the operation based on switching meant for transferring the load among the feeders. Basically there are two switches used in distribution systems; one is normally closed switch that usually connects two line-based sections and the other is the normally open switch placed on tie lines connecting two of the primary feeders in the section. The optimized form of network configuration represents a topological feeder structure by changing the open/closed sectionalizing status and tie-line switches with minimized losses, saving the distribution system radial structure [4, 5].Generally speaking, the reconfiguration mechanism of network is a basic need to provide service to multiple customers in case of faulty condition or for the purpose of its maintenance, to minimize the real power losses, and to maintain load balance avoiding overloading conditions of network.

The electrical power distribution represents the final stage of power delivery. It usually carries power or electricity from the transmission system to its customers on individual basis. When the distribution system gets connected to transmission system, it lowers the transmission voltage to a medium form of voltage lying between 2KV and 35KV with the help of transformers used in the system [6]. The primary lines of distribution carries medium voltage to the transformers in the distribution section placed near customer's location.

The study of power flow popularly known as load flow helps in determining the bus voltages (steady-state), transformer tap settings, active and reactive power flows, voltage set points for generator exciting regulator, circuit loading, losses in system, and system performance in case of emergency condition. It also determines the initial motor start-up based voltage profile [8]. The power systems operate critically under slow transforming conditions that may be analysed using steady-state operation. This type of analysis provides a starting platform to other type of analysis such as under heavily loaded system, the disturbances that cause instability but it may not have any effect in case of lightly loaded conditions. The analysis of power flow is the major core area for the analysis of power systems like additional planning, facilities of generation, and transmission-based expansions. The problem of such systems can be dictated as follows: a network with critical power loads with some specified restrictions on the voltages and the power generation solving for the un-specified generation, unknown bus voltages, and network components based complex power flow. In addition, the individual component losses in total are evaluated. Further, the conditions of overloads and voltages along with allowable tolerances are checked very often. So, for the study of load flow analysis, generally a balanced three-phase operation is usually assumed. The network planning for medium voltage and Load flow calculation usually involves the following steps:

1. To determine the values of element for the components of passive networks.
2. To determine the values and locations of all power (complex) loads.
3. To determine the generation constraints and its specifications.
4. To develop a mathematical model that particularly describes network power flow.
5. To check constraint violations.
6. To compute all the system bus voltages.
7. To determine the transmission lines based reactive and the real power flows in the network.

The calculations of the load flow are generally carried to maintain system stability while it's running operation and determines optimal or possible selection grid component selection like machine regulators automatic control setting, transformers' voltage regulators etc. The inputs to be determined are the currents and/or voltages and/or the reactive/active power at the generator's port or the customer's port. The cables and the over-head line form the significant elements of the network [10, 11]. To carry simple grid-based calculations, few elements of the circuit are used for a specified task.For low line voltages, mostly there is work done by the ohmic resistance and for high line voltages, the longitudinal impedance is to be considered for the operational purpose and for long lines, the capacitive components must be kept in mind [13]. In order to classify the overloading of the equipment and the voltages at the busbar, the given limit values along with network operator are jointly provides as follows:

Table.1.1 Network equipment description

Network equipment description	**Degree of loading**
-	%
rated load	< 80
heavy load	≥ 80, < 100
over load	≥ 100

Table.1.2 Voltage level description

Voltage level description	**Voltage more than % nominal voltage**
-	%
bus bar voltage is ok	≥ 94, ≤ 106
bus bar voltage is to low	< 94

The load flow can also be calculated with some of the most commonly used methods such as Newton-Raphson, Extended Newton-Raphson, Gauss-Seidel, Power iteration method, and DC flows [14].

1.1.2 Voltage Stability

It is defined as the power system ability to maintain steady-state system voltage at all the buses in the operating system after the subjection of disturbance from initial condition of operation. It basically carries issues. One is the maximum load ability estimation and the critical power computation leading to voltage collapse. In large typical networks, the load flow analysis is used very commonly [12, 13]. This section carries the analysis of power/load flow with its voltage stability application to understand the concept of voltage stability indices. The voltage stability index helps in computing the bus proximity very sensitive to the mechanism of voltage collapse in distribution systems. The distribution line interchanged power equations active and reactive equations of power is basically used to develop the index for stable process and hence, it only requires solution based on power flow study at its necessary power equations [15]. The mathematical representation of voltage stability index based on distribution line model as shown in fig. is presented as follows:

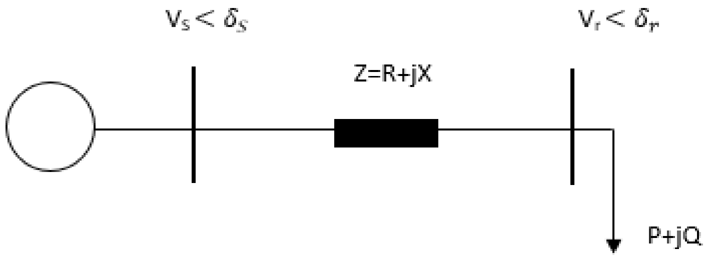


Figure 1.3: Single Line Diagram: Two bus distribution system

The quadratic equation which is commonly in load flow analysis are used for calculating the sending end line voltages and these can be written in a generalized form given as:

$V_r^4 + 2V_r^2(PR + QX) - V_s^2V_r^2 + (P^2 + Q^2)|Z|^2 = 0 \ldots\ldots\ldots (1)$

From equation (1), the active and the reactive power at the line receiving end can be written as

$$P = -\cos(\emptyset_Z)\,V_r^2 \pm \frac{\sqrt{\cos^2(\emptyset_Z)\,V_r^4 - V_r^4 - |Z|^2Q^2 - 2V_r^2\,QX + V_s^2V_r^2}}{|Z|} \ldots\ldots\ldots 2(a)$$

$$Q = -\sin(\emptyset_Z)\,V_r^2 \pm \frac{\sqrt{\sin^2(\emptyset_Z)\,V_r^4 - V_r^4 - |Z|^2P^2 - 2V_r^2\,PX + V_s^2V_r^2}}{|Z|} \ldots\ldots\ldots 2(b)$$

From equation 2(a) and 2(b), the values of real (P) and reactive powerswill exist at receiving end based on the following condition.

$$\cos^2(\emptyset_Z)\,V_r^4 - V_r^4 - |Z|^2Q^2 - 2V_r^2\,QX + V_s^2V_r^2 \geq 0 \ldots\ldots\ldots\ldots 3(a)$$

$$\sin^2(\emptyset_Z)\,V_r^4 - V_r^4 - |Z|^2P^2 - 2V_r^2\,PX + V_s^2V_r^2 \geq 0 \ldots\ldots\ldots 3(b)$$

Performing the summation at each side of equation 3(a) and 3(b)

$$2V_s^2V_r^2 - 2V_r^2(PR + QX) - |Z|^2(P^2 + Q^2) \geq 0 \ldots\ldots\ldots\ldots\ldots (4)$$

Thus with the help of equation (4), it is observed that there is some reduction/decrease with increased line impedance and power transferred and thus it can be used for maintaining the bus stability index for the case of distribution network system is given as:

$$SI\,(r) = 2V_s^2V_r^2 - V_r^4 - 2V_r^2(PR + QX) - |Z|^2(P^2 + Q^2) \ldots\ldots (5)$$

II. RELATED WORK

Carmen LT, et.al [1] presented an article with a methodology to evaluate the DG unit installation impacts on the system reliability, electric losses, and the system's voltage profile in distributed networks. The voltage profile and losses were evaluated based on the method of power flow along with generator representation in the form of PV buses. The evaluation based on the reliability indices relied on analytic methods that was modified to handle or safeguard multiple generation. This type of methodology was used to evaluate DG capacity influence on the system performance for distinct type of generation based expansion with planned alternatives.

Ha, Le Thu, et.al [2] explored the study considering the integrating possibility of two large wind farms into a sub-transmission network. It also analysed the impacts on the voltage stability and network losses considering the impacts when there was an increase in network loading of the system. The study was carried with the help of computer analyses performed on custom-designed radial type of power system.

U. Eminoglu, et.al [3] presented a voltage stability index for identification of voltage collapse attractive sensitive bus in distribution system (radial). The index developed was based on transformed active and reactive power line distribution. The analysis of the index was tested distinct operating conditions of load and voltage levels of sub-station. The results suggested that the index proposed was of reliable nature which was easily applicable to the radial type network distribution.

Wenzhong Gao., et.al [4] presented an approach based on multi-objective optimization methodology for determining distributed generators optimized location in electricity market with deregulated environment as the optimized location of DGs is considered as the most suitable panel or zone which has been identified based on the variations of real and reactive power flow sensitivity variations.

Alonso, M, et.al [5] presented a methodology for DG unit's optimal placements in the power networks to assure the maximum load-ability conditions, voltage profile. This type of strategy aims to find system based components configuration meeting the required system reliability considering the limits of stability. The study indicates that the formulations proposed have shown the best way to find out the best buses where the distributed generator units (additionally) enhance the voltage stability and the capability of power transfer under certain contingencies.

Viswanadh, M. M. G., et.al [6] studied an Optimization technique using Particle Swarm Optimization and an analytical approach used to determine the size of the wind generator and its placement optimally. A backward forward sweep load flow conventional method was used for the calculation purpose. The results obtained from two of the approaches were compared and voltage profile of different buses such as 69-bus, 13-bus and 33-bus in the distribution network was obtained.

Gagandeep Kaur, et.al [7] proposed a work which determines the optimized DG capacity to be connected to the system existing. A line based voltage stability index (VSI) which was obtained by a load flow method (conventional) solution which accurately calculated the operating point proximity to the voltage collapsing point and hence it validates the proposed method significance. The optimised DG value obtained boosted the system's maximum load ability. The method proposed was tested on standard bus system IEEE-14 bus system and the simulation was done using C++.This type of method contains a good methodology for identification of DG rating and the best location.

D. Sattianadan, et.al [8] presented a study on minimizing the process of power loss with the placement of distributed generators (DGs) in distribution-based network. The DG location is generally found using voltage stability index and the corresponding calculation of power loss is done by the running process of power flow and the results were obtained using Particle Swarm Optimization. The simulation was performed over 33 bus Distribution System by analysing distinct load models.

Q. S. Chua, et.al [9] considered the real time system implementation methods of monitoring that was able to provide power system based time warning before the occurrence of voltage collapse. In this work, different types of line voltage stability indices (LVSI) have been differentiated to overcome the effectuality which determines the power system weakest lines. The LVSI have been accessed using IEEE 14-Bus and IEEE 9-Bus system for practicability validation. This paper work also contributed real-time voltage stability monitoring implementation using Artificial Neural Network (ANN). The results demonstrated the indices evaluation using ANN methodology for predicting the system based voltage collapse.

K.R. Devabalaji, et.al [10] proposed the work with the main objective to reduce the power loss in total along with maintenance and satisfaction of all the constraints. The implementation of LSF i.e. Loss Sensitivity Factor was done to pre-determine the capacitor optimal location. An effective use of BAT algorithm (biologically-inspired) has been done to pinpoint the capacitor banks optimal location. The method proposed was tested on IEEE 34-bus distribution system to observe the effectiveness and performance of the proposed technique.

Chaw Su Hlaing, et.al [11] presented an approach based on voltage stability index utilizing an analogy of combined sensitivity factor to optimally place and size a DG multi-type using 48-bus Belin distribution test system with the objective of power losses reduction and the improvement of voltage profile with the placement of type 2 DG than the type 1 based DG placement i.e. DG generation using both real and reactive powers. It reaches a point where the increment in DG number results in improving voltage profiles and minimizing the power losses of the system.

Pyone Lai Swe, et.al [12] considered for types of DGs in their proposed work. With its types, one DG was installed at location to reduce the total losses i.e. the real and the reactive power losses occurred during the operation. The main objective was to evaluate the size and to observe or identify the Dg optimum corresponding location to reduce the real and reactive losses and to improve the primary distribution voltage profile. With this type of method, it was able to obtain maximum reduction of losses for optimally placed DGs in the network.The DG based optimized sizing was calculated an exact type of loss formula along with an efficient approach to determine the DG optimized placement. The performance of the proposed method was demonstrated in Belin Substation in Myanmar on a 36-bus radial type distribution system which was validated with different sizes of the DGs in the network.

Yorukoglu, Sinan, FuadNasibov, et.al [13] conducted a study of distinct distribution system losses, Turkish electricity distribution network based privatization process, and percentage of current losses. In SYSTEM distribution network topology, possible alternations decreased the losses (non-technical) using analytical methods and the best form of strategy against losses was determined for distinct customer characteristics and network topologies with the help of AHP method.

Salah Kamel, et.al [14] this paper investigated the DSTATCOM impact over the performance of Upper Egypt electrical realistic network. The analysis was done using NEPLAN commercial software and the network was selected using 20 buses with 22/0.4 kV distribution transformers (20) and two of the voltage (medium) distribution points. The network was studied with and without forms of D-STATCOM showing the impact over the performance of the network regarding voltage magnitude control, total reduction active power losses, and the stability of the voltage.

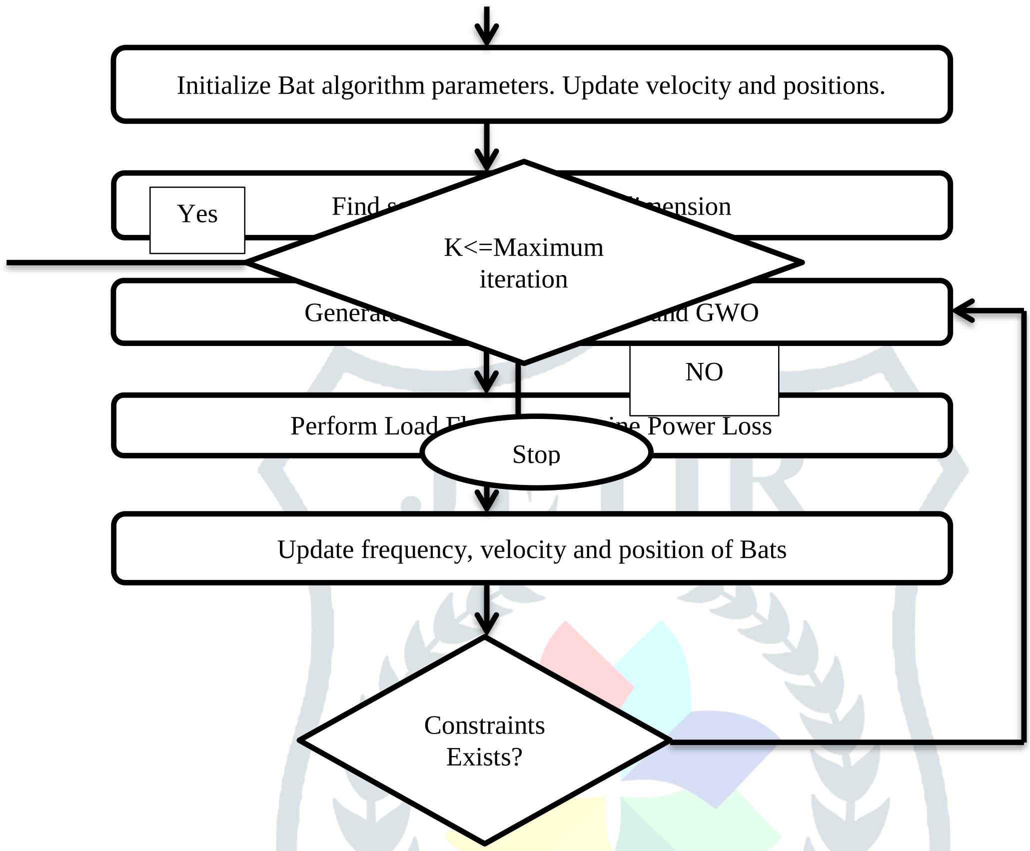
Sultana, U., et.al [15] conducted acomprehensive study for optimized DG placement by considering minimized power/energy losses, voltage profile improvement,and voltage stability enhancement. The researchers made an attempt to provide a summary of existing methods and presented a deep analysis helping the energy planners to decide what type of objectives and factors of planning were required for optimum allocation of DG.

YalishoGirmaLoaena [16] provided a deep study on the issues related to power system like distribution system based on energy loss and its reduction techniques, reactive power flow along with its compensation, indicators of voltage quality such as regulation of voltage and voltage unbalance. In order to achieve the tasks, the existing form of distribution system based on study site has been designed using a Power Factory Software named DIgSILENT and the process of simulation was performed under balancing and unbalancing operating conditions. The measurement using Clamp-on meter was done to find the line to line voltages and the load demand.

Patel, J. S., R. R. Patel, et.al [17] conducted a novel approach utilizing generated power with the help of distributed generation in case of primary distribution network such that the DG incorporation installed with capacity reduce the losses occurring in the overall system. The method of DG location and sizing using Genetic Algorithm was presented. A very simple load flow technique for accuracy was described and technique proposed was implied over two of the systems. One is the 2. 69 Bus Distribution System and the other is the IEEE 34 Bus distribution System using a software MATLAB tool.

A. V. Sudhakara Reddy, et.al [18] proposed an algorithm popularly known as a Grey Wolf Optimization (GWO) algorithm to overcome the issues related to feeder reconfiguration with the help of fitness function corresponding to power distribution systems based optimized switch combination to overcome the issues related to reconfiguration including the real power loss reduction.

III. THE PROPOSED METHOD



4.2 Algorithm

Grey Wolf Optimization: It is a meta-heuristic algorithm which simulates the leadership hierarchy and hunting behavior of wolves. The fitness of the wolves measured in the form of alpha, beta and delta. The figure 1.2 given below shows the hierarchy level of the wolves.

Grey wolves have the ability of memorizing the prey position and encircling them. The alpha as a leader performs in the hunt. For simulating the behavior of grey wolves hunting in the mathematical model, it is assumed that the alpha (α) is the best solution, the second optimal solution is beta (β) and the third optimal solution is delta (δ). Omega (ω) is assumed to be the candidate solutions. Alpha, beta and delta guides the hunting while position is updated by the omega wolves by these three best solutions considerations [37].

Encircling prey

Prey encircled by the grey wolves during their hunt. Encircling behavior in the mathematical model, below equations is utilized [37].

$$\vec{A}(T+1) = \overrightarrow{A_P}(T) - \vec{X}.\vec{Z}$$
$$\vec{Z} = |\vec{Y}.\overrightarrow{A_P}(T) - \vec{A}(T)|$$

Where,

$\vec{Z}$ and $\vec{X}$ are vectors that are calulated by above given equation.

T←iterative number

$\vec{A}$←grey wolf position

$\overrightarrow{A_P}$←prey position

$$\vec{X} = 2x.\vec{r_1} - x$$
$$\vec{Y} = 2\vec{r_2}$$

Where

$\vec{r_1}$and$\vec{r_2}$←random vector range[0,1]

The x value decrease from 2 to 0 over the iteration course.

$\vec{Y}$←random value with range [0,1] and is used for providing random weights for defining prey attractiveness.

Hunting

For grey wolves hunting behavior simulation, assuming α, β, and δ have better knowledge about possible prey location. The three best solutions are firstly considered and then ω (other search agents) are forced for their position update in accordance to their best search agent position. Updating the wolve's positions as follows [37]:

$$\vec{A}(T+1) = \frac{\overrightarrow{A_1} + \overrightarrow{A_2} + \overrightarrow{A_3}}{3}$$

Where $\overrightarrow{A_1}, \overrightarrow{A_2}, and\ \overrightarrow{A_3}$ are determined,

$$\overrightarrow{A_1} = |\overrightarrow{A_\alpha} - \overrightarrow{X_1}.Z_\alpha|$$
$$\overrightarrow{A_2} = |\overrightarrow{A_\beta} - \overrightarrow{X_2}.Z_\beta|$$
$$\overrightarrow{A_3} = |\overrightarrow{A_\delta} - \overrightarrow{X_3}.Z_\delta|$$

Where $\overrightarrow{A_\alpha}, \overrightarrow{A_\beta}, and\ \overrightarrow{A_\delta}$← first three best solution at a given iterative T

Z_α, Z_β, and Z_ω are determined,

$$\overrightarrow{Z_\alpha} \leftarrow |\overrightarrow{Y_1}.\overrightarrow{A_\alpha} - \vec{A}|$$
$$\overrightarrow{Z_\beta} \leftarrow |\overrightarrow{Y_2}.\overrightarrow{A_\beta} - \vec{A}|$$
$$\overrightarrow{Z_\delta} \leftarrow |\overrightarrow{Y_3}.\overrightarrow{A_\delta} - \vec{A}|$$

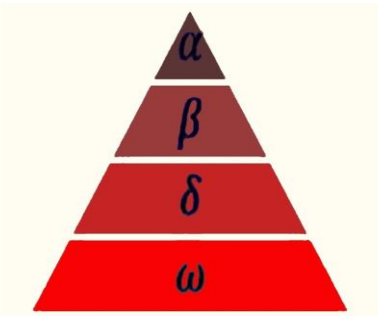


Figure 4.2: Hierarchy levels of the wolves.

1) The first level wolver are called are alpha wolves which are dominant in nature and all other wolves follow their orders. Alpha are the best decision makers having the best fitness value in the whole pack and are also the leaders of the pack
2) The second level wolves are the beta wolves and also called as subordinate wolves which help in decision making in alpha and also the other members of the pack.
3) The third level wolves are the delta wolves which work after the beta wolves. Delta wolves are considered when the beta wolves are not working properly. These wolves are also called as scouts.

4) The fourth and the last level of the hierarchy are related to the omega wolves. Omega wolves have low fitness value and are considering at the last. Omega wolves are also known as scapegoats.

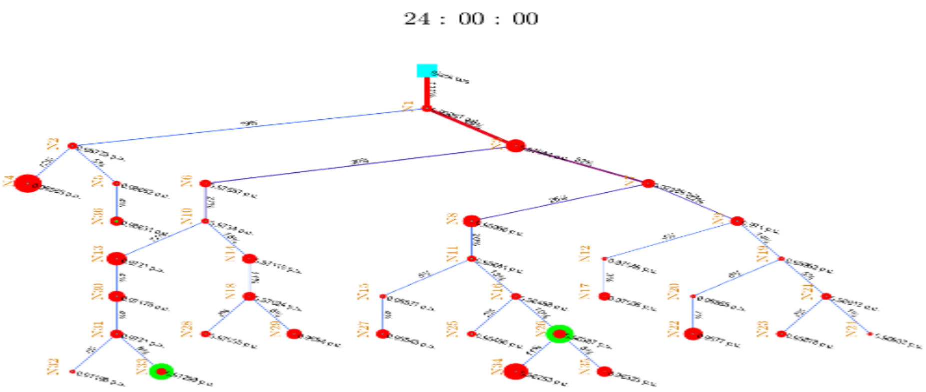
GWO: Modified Version

The normal grey wolf optimizer is of very flexible nature and provides good results during the operation of testing on benchmark functions and other issues mentioned in literature. The operators such as crossover and mutation are very well known operators i.e.population-based. These operators are used for designing the modified version of GWO by implementing them in its simplified version for achieving better results.

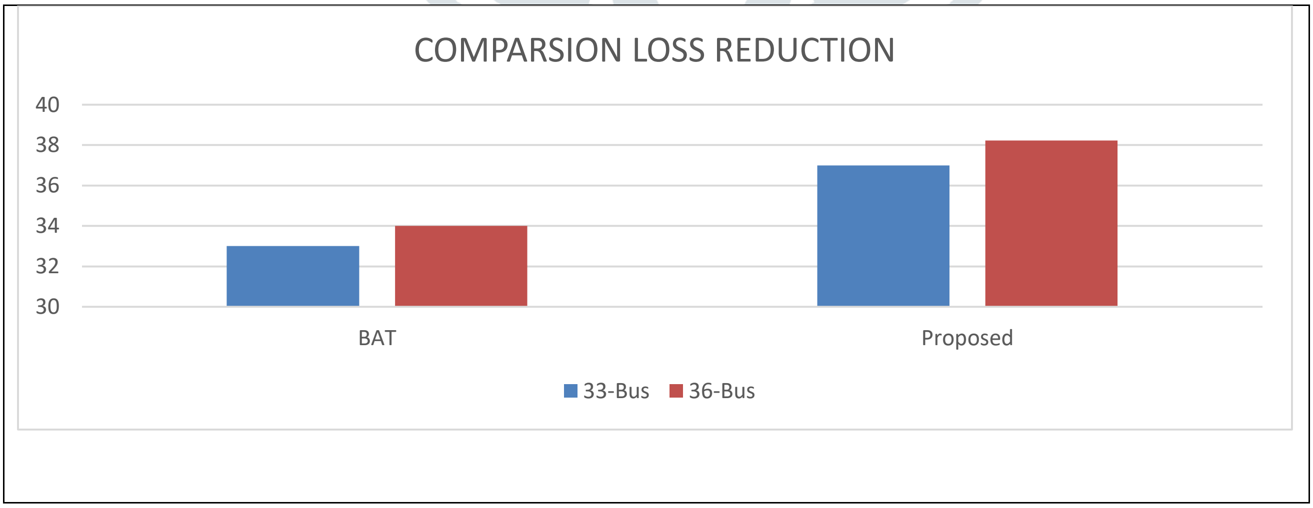
(a) Crossover: It provides improvement in the process by the method of interchanging the values that occur between two of the arrays or strings which is done by selecting cross-site and then performing the function of swapping among two parts of strings or arrays. It helps in obtaining two types of new strings. The mechanism of crossover act as first operator i.e. applied on Grey wolves' population and the probability of crossover is firstly defined for each population. The cross-site is randomly chosen from population size matrix and after that the values get swapped. This process is repeated for each of the population.

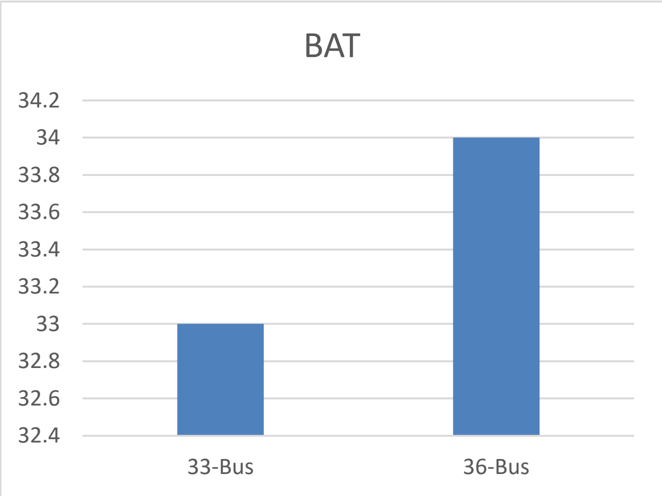
(b) Mutation. It is performed after the crossover process is done. It completely nullifies some of the values by making them to reach its initial form or zero state. It acts as a second operator to be applied over matrix based on the mechanism of grey wolf. Generation of mutation matrix based on zeroes and ones is formulated in accordance to mutation probability i.e. multiplied with matrix of grey wolf i.e. from one element to other where some of the values may vary.

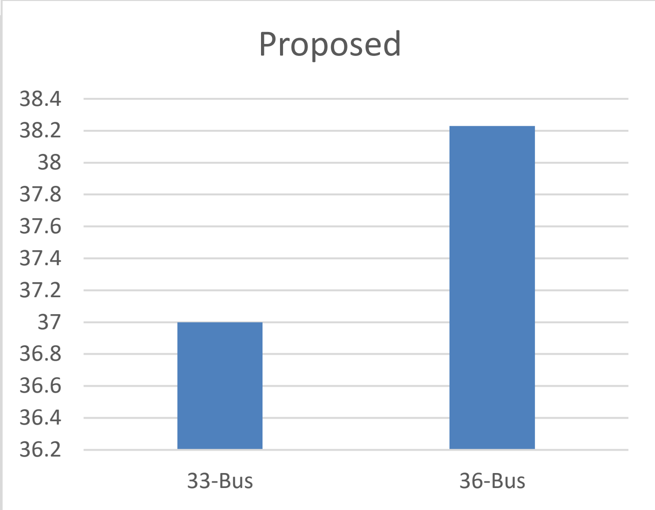
IV. RESULTS



Bus System	without Configured	BAT	Proposed
33-Bus	0	33	37
36-Bus	0	34	38.23







CONCLUSION

A new approach to give more meaningful numbers was considered by solving a related problem, that of Maximum Supply Capacity. An iterative solution using linear programming and based on an incremental network model lead to the exact optimal solution. The N numerical results indicated that for the sample power system used, the linear approximation of LPOF Formulation was accurate enough for practical purposes. In graph5.3 show the percentage of loss all distribution of power in configured ,BAT and GWO_BAT approach using different bus system like 33 and 36 bus system in proposed approach show the significance improve by 37% and 38.23% but only BAT algorithm 33% and 34% because its not optimize using only local transmission which not able global optimization

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