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Service Restoration in IEEE 30 Bus System by Utilizing Evolutionary Programming and Trapezoidal Function to tackle unsupplied Customers

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Abstract: Power flow analysis is the backbone of power system analysis and design. The existing works in the power system have to prevent the failure of the system due to unforeseen conditions to guarantee the security of the system. To address this problem, we propose a modernist method for System Reconfiguration and Fault Restoration of IEEE 30 bus system. This proposed technique, used for governing relative errors simultaneously is based upon Evolutionary programming and Fuzzy Trapezoidal member ship function. Moreover, to tackle the work of faulty one, we efficiently choose an alternate Transformer from the available work group, which minimizes the total number of service breakage problem. The results of the proposed technique are efficient in the IEEE 30 bus network model this revealed by distributed power flow.

Keywords: Evolutionary Programming, Fuzzy trapezoidal Membership Function, Triangular fuzzy trapezoidal membership function, Distributed Energy Resources (DER), Document Management System (DMS), Distribution System Operator (DSO), optimal DG placement (ODGP), ordinal optimization (OO).

1. INTRODUCTION

The changes in the conventional ways of generation, transmission and distribution of power have brought along new challenges to the power industry. The challenges of power industry include the Distributed Energy Resources (DER) [1] [2], improvement of delivered power quality, environmental concerns over conventional and centralized methods of power generation, privacy of consumer's for complex system [3]. To hold this challenges of power industry, it is necessary to build will collect and generate energy locally from the sun, wind [4], garbage, agricultural and forestry waste, ocean waves and information and security of the system against external cyber or physical attacks, economics of power systems, from maintenance costs to equipment renovation, network expansion and need for better control schemes tides, hydro and geothermal, enough energy to provide for their own power needs as well as surplus energy that can be shared [5] .In this new era electric power has become a fundamental part of the infrastructure of modern society, with most of daily activity is based on the assumption that the desired electric power is readily available for utilization. In the near future, electric supply to houses, offices, schools and factories is taken for granted. In order to hold the situation there is a need for complex power distribution system to provide the required electricity to the customers [6] [7]. Due to the increase of electricity need, the demand of efficient and high quality power is escalating in the world of electricity. Today's power systems are highly complex and require suitable design of new effective and reliable devices in deregulated electric power industry for flexible power flow control [8].

Nevertheless, traditionally there should be a way for each problem likewise for power flow control distribution systems comes as a solution. The main task of distribution system analysis has been to solve the power flow for one specific point in time, which is the predicted peak demand. To increase DG connectivity and also to harness the generated renewable energy efficiently there is a need for active distribution management systems (DMS). [9] [10].

State estimation should obviously be at the heart of the DMS technology. However, a large part of the system, particularly the distribution segment, continues to operate in an unmonitored fashion, adversely affecting the accuracy and quality of the state estimator and therefore its usefulness. This introduces bottlenecks in carrying out a range of substation and feeder automation tasks that rely on the quality of the state estimator [11] [12]. State estimation for a distribution system is to estimate the state of the distribution system reliably, accurately and completely using its measurement information. Since the distribution system has its own characteristics compared with the distributed resources, the state estimation for the distribution system is very different from that for the distributed resources, [13] [14]. Distributed generation (DG), which consists of distributed resources, can be defined as electric power generation within distribution networks or on the customer side of the network [15] [16].

Decision about DG placement is taken by their owners and investors, depending on site and primary fuel availability or climatic conditions. Although the installation and exploitation of DGs to solve network problems has been debated in distribution networks, the fact is that, in most cases, the distribution system operator (DSO) has no control or influence about DG location and size below a certain limit [17] [18]. However, DG placement impacts critically the operation of the distribution network. Inappropriate DG placement may increase system losses and network capital and operating costs. On the contrary, optimal DG placement (ODGP) can improve network performance in terms of voltage profile, reduce flows and system losses, and improve power quality and reliability of supply [19] [20]. After the placement of DG and connected to power system, the improved state need to be measured. The measured placement for power system state estimation is one importance problem for reducing investment cost. Also, the state estimation time is low when the number of measurement is low. Thus, the objective is to make the low investment cost for measurement system that the number of measurement should be low. [21], [22].

Power flow analysis is necessary for planning, operation, economic scheduling and exchange of power between utilities. Power flow analysis is a pivotal tool involving numerical analysis applied to a power system. In this analysis, iterative techniques are wielded to solve the problem. To consummate this analysis this paper proudly proposes a modernist method for System Reconfiguration and Fault Restoration of a distribution network. Which incorporate plenty of steps depends on the size of system. This process is onerous and consumes a lot of times to perform by hand. The rest of the paper is organized as follows: Section 2 reviews previous works related to the Power systems and risks faced during Power distribution. Section 3 describes the proposed system. Section 4 presents experimental results and comparative analysis of the proposed system. Finally Section 5 draws the conclusions.

2. RELATED WORK

Daniel E. Olivares *et al.* [23] proposed a brief review of the existing energy management system (EMS) architectures for micro grids, identifying the main advantages of each approach, and has proposed a centralized EMS architecture for implementation on isolated micro grids in stand-alone mode of operation. Some relevant considerations and procedures for the model fine-tuning and performance evaluation have also been presented. Future work will concentrate on the implementation and testing of the proposed architecture. Pavlos S. Georgilakis *et al.* [24] presented a thorough description of the state-of the-art models and optimization methods applied to the ODGP problem, analyzing and classifying current and future research trends in this field. The most common ODGP model has the following characteristics: 1) installation of multiple DGs; 2) the design variables are the location and size; and 3) the objective was the minimization of the total power loss of the system. The solution methodologies for the ODGP problem are classified into three major categories: analytical, numerical and heuristic methods. The most frequently used techniques for the solution of the ODGP problem are the genetic algorithm and various practical heuristic algorithms. Future research areas include coordinated planning, dynamic ODGP, uncertainties and stochastic optimization, active network management, and islanded operation.Y. M. Atwa *et al.* [25] proposed a probabilistic planning technique for optimally allocating different types of DG (i.e., wind-based DG, solar DG, and biomass DG) into the distribution system so as to minimize annual energy losses. Specifically, this technique was based on generating a probabilistic generation-load model that includes all possible operating conditions; hence, this model can be accommodated into a deterministic OPF formulation. The proposed planning technique has been applied to different scenarios for a typical rural distribution system provided by a local utility company. The results reveal that regardless of the combination of the renewable resources used to calculate the optimal fuel mix, there was a significant reduction in the annual energy loss for all scenarios proposed. Also for all scenarios, the proposed technique guarantees the optimal fuel mix for loss minimization during the entire planning period and ensures that, for all possible operating conditions, no system constraints will be violated.

R.A. Jabr *et al.* [26] presented an ordinal optimization (OO) method for specifying the locations and capacities of distributed generation (DG) such that a trade-off between loss minimization and DG capacity maximization was achieved. The OO approach consists of three main phases. First, the large search space of potential combinations of DG locations was represented by sampling a relatively small number of alternatives. Second, the objective function value for each of the sampled alternatives was evaluated using a crude but computationally efficient linear programming model. Third, the top-s alternatives from the crude model evaluation are simulated via an exact non-linear programming optimal power flow (OPF) programme to find the best DG locations and capacities. OO theory allows computing the size of the selected subset such that it contains at least k designs from among the true top-g samples with a pre-specified alignment probability AP. This study discusses problem-specific approaches for sampling, crude model implementation and subset size selection. The approach was validated by comparing with recently published results of a hybrid genetic algorithm OPF applied to a 69-node distribution network operating under Ofgem (UK) financial incentives for distribution network operators.

Hristiyan Kanchev *et al.* [27] proposed a determinist energy management system for a microgrid, including advanced PV generators with embedded storage units and a gas microturbine. The system was organized according to different functions and was implemented in two parts: a central energy management of the microgrid and a local power management at the customer side. The power planning was designed according to the prediction for PV power production and the load forecasting. The central and local management systems exchange data and order through a communication network. According to received grid power references, additional functions are also designed to manage locally the power flows between the various sources. Application to the case of a hybrid supercapacitor battery-based PV active generator was presented. Gyeong-Hun Kim *et al.* [28] proposed a three-phase four-leg VSI based LUC has been proposed for stand-alone micro grid when it has serious unbalance load. The concept of the proposed LUC directly compensates unbalance current of the load using a three-phase four-leg VSI, and its control algorithm has been also proposed which has dc-link voltage controller, current controller, and strategy to generating PWM. The modeling and simulations of the micro grid including the proposed system are carried out using PSCAD/EMTDC, and the real operation data of Mara-island's micro grid in Korea was applied to the simulation. The simulation results demonstrate that the proposed three-phase four-leg VSI based LUC increases stability of the stand-alone micro grid under unbalance load conditions.

3. Implementing Evolutionary Programming and Trapezoidal Function for system restoration to rectify Unsupplied Customers

The Proposed System Design and Methodology are explained in this Section, which concerns its ultimate design and the features. The overall process design of the proposed system is illustrated in Fig.1. The goal of the proposed work is to leverage techniques from artificial intelligence and operations research to replace current rule-based systems for system restoration with robust, flexible optimization technology, capable of delivering higher-quality solutions with a greater degree of autonomy. It also aims in the service restoration problem, the preoccupation in finding a new configuration that minimizes the number of unsupplied customers is not only evaluation criterion. It is also important to minimize the number of necessary switching operations, minimalize the overload of equipment and reduce the system restoration time due to obvious technical reasons. So, in

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this case, we have a multi objective decision problem, because minimizing the number of switching operations and minimizing the overload of equipment leads generally to a conflict with the process of restoring service. In this work, the multi objective solution strategy is improved using an evolutionary approach through a fuzzy set with trapezoidal membership function for the different competing objectives appearing in the global objective function.

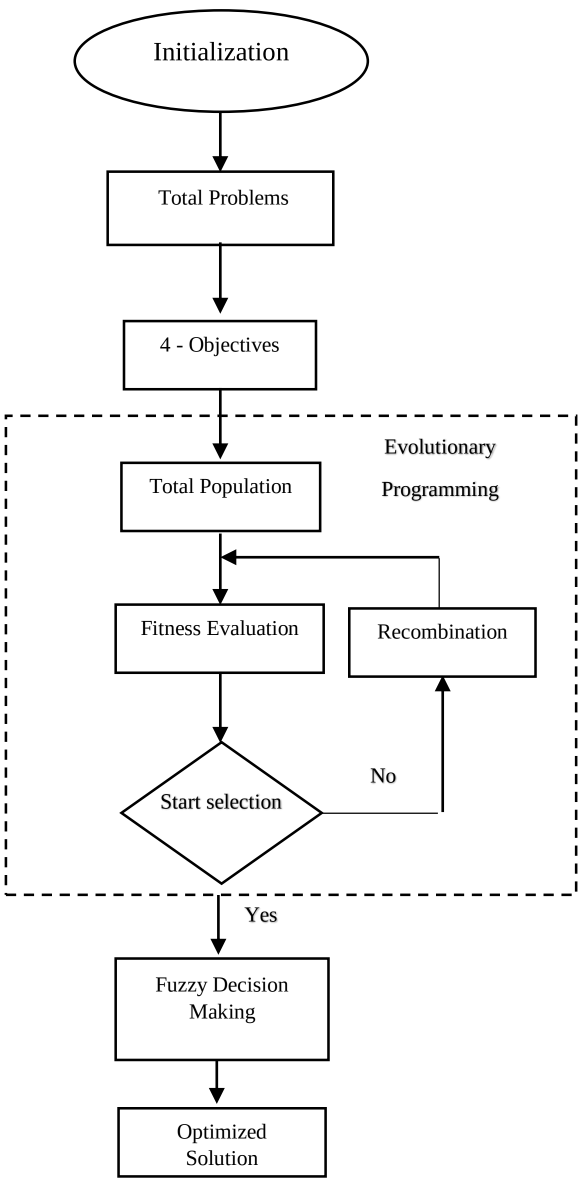

Figure 1: Proposed work

Multi-objective optimization problems have many objectives and trade-off between the objectives exist. And it is a Deep truth that we never have a situation in which all the objectives can be simultaneously satisfied in the Best possible way. The various objectives aimed at the optimization problem for the proposed work are: To minimize the number of unsupplied customers, to minimize the number of switching operations, to minimize the overload of equipment's, to minimize the system restoration time. For quenching the problems occurred in the form of objective function in the IEEE 30 bus system. The four objectives described below are integrated into an objective function through appropriate weighting factors.

a. Sensing existence of Unsupplied Customers

In an IEEE 30 Bus electrical power transfer from generators to consumers through the grid system is stable, reliable and economic. The power flow in a radial distribution system with a large number of buses is to be solved and, hence, development of a special program for radial distribution studies becomes necessary for an uninterrupted power flow to the customers. When a flow of power is blocked to the customer in a bus system, this could be spot out by this objective. For rectify this situation the blocked location is sensed for further evaluation, that is illustrated in the equation 1.

$$F_1(\bar{X}) = \sum_{i1}^{b1} L_i - \sum_{i \in B} L_i \qquad (1)$$

Where,

$\bar{X}$ - is switch state vector of network under consideration for service rest oration.

$i.e. \bar{X} = [SW_1, SW_2, SW_3, \ldots\ldots, SW_N]$

N_s - Total number of switches in the network

b_1 - number of energized buses in the network before fault

L_i - load on i^{th} bus

B - Set of energized buses in the restored network

From equation (1), it is assumed that in a 'n' bus power system, the buses are numbered from 1 to n and in the Pre-fault case, all the buses in the network are energized. Therefore 'b_1' is equal to 'n'. However, in the Post-fault scenario, all the buses would not be necessarily energized. Hence, 'B' would contain only the energized buses. For example, in a 5 bus system, $b_1 = 5$ and if, in the Post-fault case, bus 3 cannot be energized, then $B = (1, 2, 4, 5)$. Thus the unsupplied customers are identified here

b. Evaluation of Switching Operations

Generally there are two types of switching operations followed in Power system distribution networks namely Manually-controlled switching operations and Remotely-controlled switching operations. Remotely controlled switching operations are controlled by the Control center connected to the Power distribution networks. Manually controlled switching operations are carried out by Human Personnel such as Linemen. One of the objectives in the proposed system pronounces the urge to minimize number of switching operations for the restoration problem. In this case, Minimization of both manually and remotely controlled switching operations is required.

$$F_2(\bar{X}) = \sum_{j=1}^{N_m} |SWM_j - SWMR_j| + \sum_{j=1}^{N_a} |SWR_j - SWRR_j| \qquad (2)$$

Where,

N_m -Number of manually controlled switches

SWM_j-Status of j^{th} manually controlled switch in network just after fault

$SWMR_j$-Status of j^{th} manually controlled switch in the restored network

N_a -Number of remotely controlled switches

SWR_j -Status of j^{th} remotely controlled switch in network just after fault

$SWRR_j$-Status of j^{th} manually controlled switch in the restored network

Equation (2) should be utilized for the achievement of power flow in a distributed system with minimum switching operations. This equation provides different paths into the Evolutionary programming system for better power flow with minimum number of switches.

c. Refrain from Overload of Equipment

During the Power distribution network restoration, Overloading of equipment occurs due to the process of gathering of power from the nearest feeders or transformers. Such Overload of Transformers or Feeders are reported as quite normal ones. Since they are of Brief duration, any temperature rise is accessible resulting in no harmful effect on the network components. Continuous overloads in the network components are more destructive and must be cut off by protective devices before they damage the distribution system or system loads. To get rid of this defect, one of the objective in our proposed system is the minimization of overloading of equipment's.

$$F_3(\bar{X}) = \left(\frac{TL_{i,j}^{opt} - TL_{i,j}}{TL_{i,j}^{opt}}\right) \quad \forall i = 1,2,\dots,N_s \;;\; \forall j = 1,2,\dots,N_t \qquad (3)$$

Where,

$TL_{i,j}^{opt}$- Optimal value of the load to be shared by the j^{th}transformer when i^{th}branch opened.

$TL_{i,j}$ – Load of j^{th}transformer when i^{th} branch opened.

N_s - Total number of switches in the network.

N_t- - total number of transformers in the network.

The equation (3) detect the entire system for identifying the presence of any over loaded equipment's in the entire system. If any possibility for occurrence or presence of overloaded equipment's in the power flow system it detect and gave information into the Evolutionary programming system.

d. Diminishing Restoration Time

Sidestepping the Dissatisfaction of the Public is far from reach. On the other hand, minimizing the amount of Time needed to restore a Power system helps reduce the Economic cost and the Resentment of the Public over the interruption of service is definitely significant. The important objective in Power distribution network is the

Restoration problem. This will highly depend on the Time taken for restoring the network from fault occurred due to Disasters. The Technical contributions for minimizing the restoration time is given as follows:

$$F_4(\bar{X}) = \sum_i P_i * \int_0^{T_i} UnservedPower_i(t)dt \qquad (4)$$

Where,

P_i - Probability value of the scenario

T_i - Time required for the completion of last repair in scenario i

As mentioned above, the proposed system has Multi-Objective optimization problem. Multi-objective optimization methods as the name suggests, deal with finding Optimal and flawless solutions to problems having multiple objectives. So in this Critical sort, the User is never satisfied by finding one solution that is optimum with respect to a Single Criterion. Due to the Multiplicity in solutions, these problems were adduced to be solved suitably using Evolutionary Algorithms. The Multi-Objective optimization using Evolutionary algorithm is explained in the following Section:

3.1. Multi-Objective Optimization Using Evolutionary Programming

At the time of the execution of the proposed work, if the Objective function Sense for the existence of the Unsupplied Customers then the evolutionary program runs for obtaining the optimized result. Evolutionary Programming (EP) is employed for designing, searching and optimization of bus system more thoroughly. It is implemented in the prediction of Multi-Objective Optimization in an IEEE 30 bus system. Then, EP has undergone Initialization of population process in which various objectives and different states of the system and its power flow has been evaluated. While evaluating the objective function, if it detect any presence of problems. Then the EP searches for the optimal solution by evolving a population of objectives over a number of generations of the objectives.

During each generation of problems, a new solution should be formed from the existing population of objectives by implementing the EP. The operator produces a new solution by perturbing each objectives of the current solution in a random manner. The strength of each of the solution is determined by its fitness that is evaluated from the objective function of the optimization problem. The selection process is done through the tournament scheme, in which solution from a population compete with each other. The individuals that obtained the most numbers of wins will be selected as the new robust solution. The competition scheme must be such that the fittest solution from EP will have a greater chance to survive, while weaker solution coming right after that will be eliminated. Through this, the population evolves towards the global optimal solution. Processes involved in the EP implementation are sequentially solution generation and selection tournament. The overall process of EP implementation is given in the form o flow chart as shown in Figure 2.

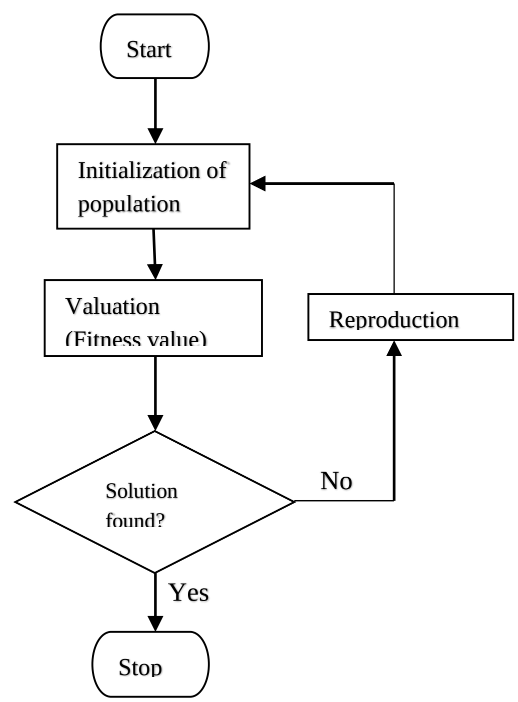

Figure 2: Over view of Evolutionary Programming

From fig 2, it can be inferred that the algorithm assigns an Initial set of population. In case of Setback to the desired population, framing a new set of population and feeding it as input to the Evolutionary Programming Algorithm. In Population initialization all the objectives are considered. When the first objective found any unsupplied customers then the EP executes the other objectives for gathering solutions for the problems. From all the solutions gathered the Fitness value for each objective can be derived. By evaluating the Fitness value, checking is made to see whether it is marching towards Solutions. This Procedure will lay path for remarkably great Solutions provided the Constraints are not violated. As shown in the figure 2, EP begins its search with a set of solution initialized randomly in a given bounded space. Thereafter, EP is allowed to search anywhere in the real space. Each solution is determined by calculate its objective function value F(x). Then, a fitness value is calculated by some user-defined transformation of the objective function. However, the fitness function can also be the same as the objective function. After each solution is assigned fitness value should be calculated.

Input: *t*he Set of Objective functions

Output: S_{best}

Initialize: r = 0, upper and lower bounds f_i^{min} and f_i^{max}

    Initialize: membership function $\mu f_i(0) = 1$

Population←InitializePopulation($F_1(\bar{X})$), $F_2(\bar{X})$, $F_3(\bar{X})$, $F_4(\bar{X})$)

    While (not violating constraints)

    best←$Min_{x \in \Omega}$ {$Max_{i=1,2,\ldots N\Omega}(\bar{\mu} f_i - \mu f_i)$}

    Children←Φ

    For ($Parent_i$ € Population)

        $Child_i$←Mutate ($Parent_i$)

        Children←$Child_i$

    End

        If ($\mu f_i(\bar{x})$ within limit)

        Evaluate Population (Children)

        S_{best}←GetBestSolution (Children, best)

        union←Population + Children

        Else

        r = r+1

        $\mu f_i(\bar{x})$=new value,i= 2,3,4,….N

        End if

    End while

Return(S_{best})

Algorithm 1: Evolutionary programming

The above Algorithm lights the way, abducting the Best solution from the available set without violating the Applied constraints. Initially the Input parameters are taken and Iterative pointer ‘r’ is set to the Initial value 0. The upper and lower bound values for each objective functions are chosen and also a strict monotonous biased function is needed for formulating the membership function $\mu f_i(x)$.

Selection of Values for f_i^{min} and f_i^{max}, the lower and upper bound value can be made on the basis of the constraints that are to be satisfied for the induced problem.

Let $\mu f_i(0)=1$, the initial expected value of each objective functions. The Evolutionary Programming Algorithm has to be applied to minimize the objective functions as

$$S_{best} = \underset{x\in\Omega}{Min}\ \{\underset{i=1,2,3,\ldots N\Omega}{Max}(\overline{\mu f}_i - \mu f_i(\bar{x}))\} \qquad (5)$$

Where, Ω is the solution space of $\bar{x}$, N_Ω is the number of total objective function and $\overline{\mu} f_i$ is the Decision maker's Expected Value.

The Values of $\bar{x}$, $f_i(\bar{x})$ and $\mu f_i(\bar{x})$ are computed and they are assessed with the available constraints and if they are satisfactory further process can be carried on else set the iterative pointer as r=r+1 and choose a new expected value for $\mu f_i(x)$ where i ranges as $i=1,2,\ldots N_\Omega$. Again the evolutionary programming algorithm is carried on for the obtained values and the process repeated as much time till the predefined constraints are not violated. The final output can be the optimized value for $\bar{x}$, $f_i(\bar{x})$ and $\mu f_i(\bar{x})$ where i ranges from 1 to N_Ω.

By taking the Objective Function as the Input Parameters, the Evolutionary Programming Algorithm exactly contributes the Optimization of possible paths to replace the Faulty transformer or fault to quench the customer problem.

3.2. Fuzzy trapezoidal Membership Function Calculations

In the proposed Fuzzy Trapezoidal Membership Function, it evaluate the fitness of the buses (paths) derived from the evolutionary programming. From this fitness result the proposed function chooses best path to rectify the objective problems

Overview of Fuzzy logic:

A fuzzy set F in a universe of discourse D is defined as the following set pair

$$F = \{\mu F(D): x\epsilon D\} \qquad (6)$$

Where, μ F (x) : D [0,1] is a mapping called the membership function of fuzzy set A and μ A the degree of belongingness or membership value or degree of membership of x (x)is called X in the fuzzy set A. we write (1) in the following form

$$F = \{\mu F(X)/x: x\epsilon D\} \qquad (7)$$

For brevity, however, we often equate fuzzy sets with their membership functions i.e. instead of a fuzzy set

A characterized by μF(x) we will often say fuzzy sets μ_A. Example: Suppose D = {6, 2, 0, 4}. A fuzzy set of D may be given by F = {0.2/6, 1/2, 0.8/0, 0.1/4}

Construction of membership function is based on the system design data and choice of the suitable shape. There are many shapes of membership functions. However, the application context dictates the choice of the suitable shape. For the problem domain addressed in this study, system components have maximum and minimum value that cannot be exceeded. Therefore, any candidate member ship function shape should have two extreme bounds with zero and hundred as range values. Triangular and trapezoidal shapes are the simplest MF shapes that meet this requirement.

The membership function of the triangular fuzzy set 'F' can be represented by a triple (q; r; p), where q is called the center of the triangular fuzzy set F; r is called the left vertex of the triangular fuzzy set F; p is called the right vertex of the triangular fuzzy set F.

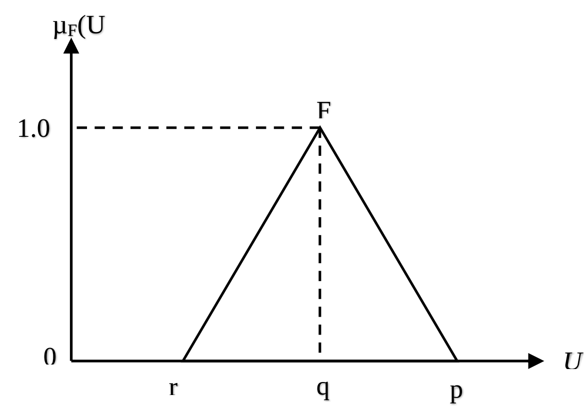

Figure 3: Triangular Fuzzy trapezoidal membership function

$$triangle(x: p, q, r) = \begin{cases} 0 & x < p \\ x - p/q - p & p \le x \le q \\ r - x/r - q & q \le x \le r \\ 0 & x > r \end{cases} \qquad (8)$$

The membership function of the trapezoidal fuzzy set can be represented by a function of a vector x, and depends on four scalar parameters p, q, r and s as given by

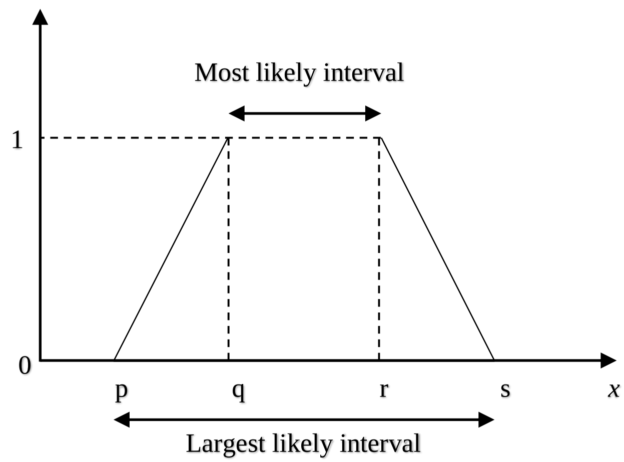

Figure 4: Trapezoidal Membership Function

$$g(x{:}\,p,q,r,s) = \begin{cases} 0 & x < p \\ x-p/q-a & p \le x \le q \\ 1 & q{\le}x{\le}r \\ s-x/s-r & r{\le}x{\le}s \\ 0 & s{\le}x \end{cases} \qquad (9)$$

Let g(p), g(q), g(r), g(s) be the Four limit values that are prefixed based on the constraints. The Aim of Evolutionary Programming Algorithm is to exactly predict the Output value that should fall under this limit. The Values that cross this limit should be discarded and the optimized one that flows under the limit has to be focused keenly as the Optimized Solution.

Optimized Solution opt(S) can be illustrated using the following equations:

$$\text{Opt(S)} = \begin{cases} S_{best},\, where\ g(p) \le S_{best} \le g(s) \\ 0, otherwise \end{cases} \qquad (10)$$

Where, Opt(S) – optimized best path

From the Fuzzy Trapezoidal Membership Function we got optimized path while any connection break down is caused in the IEEE 30 bus system. Our proposed Triangular Fuzzy Trapezoidal Membership Function evaluates the fitness of the buses derived from the evolutionary programming. From this fitness result the proposed function chooses best path for rectify the objective problems.

4. Experimental Results

The proposed technique is implemented in MATLAB platform, and it is evaluated by utilizing optimization algorithm. The Optimization Algorithm applied here works effectively in choosing an alternate Transformer from the available work group to tackle the work of faulty one. The objective of this work is to develop a tool for power flow analysis that will assist for the analysis within the IEEE 30 bus system. The tool is applicable for both Single and Multiple Fault cases. To evaluate this optimization algorithm we compare it with Particle Swarm Optimization. We have checked the performance of our proposed optimization algorithm by using some statistical measures. Experimental results show that comparing the performance of our proposed optimization algorithm and Particle Swarm Optimization, our proposed optimization algorithm exhibit very good performance.

The comparative analysis describe that the performance of our proposed optimization algorithm is high when compared to the Particle Swarm Optimization. It represents the comparison is done between PSO and Proposed Method based on Time (vs) No. of faults, Load (vs.) Frequency, Number of Visited Nodes (vs.) Number of Faults, Time (vs.) Power Flow and Time (vs.) Load not supplied. From these performances Analysis of all parameters we came to know that the performance of the proposed optimization algorithm based technique is higher than the Particle Swarm Optimization (PSO).

Power flow

$$P_f = \left(|v_i||v_j|\right)\sin(\delta 1 - \delta 2) \qquad (11)$$

Where $\delta 1 - \delta 2$ = power angles of equivalent machines of the two areas

v_i and v_j are the voltage flow between buses

Frequency

$$F = \int_0^t (\Delta F1 + \Delta F2 + \Delta P_f)\,dt \qquad (12)$$

Where ΔF = Change in frequency

ΔP_f = Change in tie line power

Load

$$L = P_G - P_R \quad (13)$$

P_G – Generated power

P_R – Required power

In figure 5, Comparison is done between the PSO and the proposed method in terms of Number of faults detected with respect to increase in Time duration. It can be seen that the proposed method has less number of Faults with increased time. Time determines the duration taken by the algorithms for rectify problems.

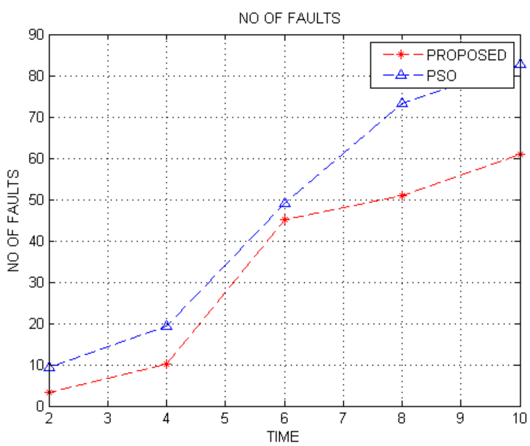

Figure 5: Comparison of PSO and Proposed Method based on Time (vs) No. of faults

Figure 6 given below shows that proposed method increases in frequency with increased load. From the Graph, it can be convinced that proposed method outstands when compared to PSO with increased load and frequency. The load and frequency is evaluated by the equations (12) and (13).

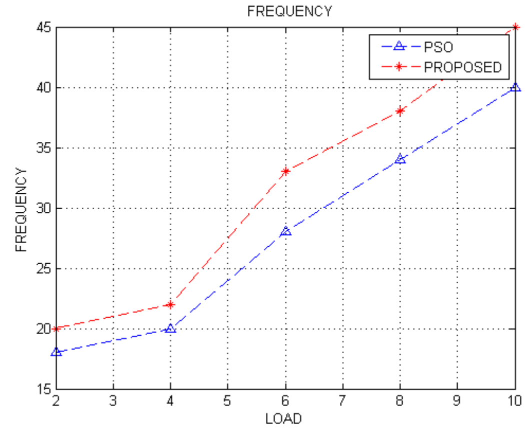

Figure 6: Comparison of Proposed Method with PSO in case of Load (vs.) Frequency

Figure 7 depicts the situation that occurs with the Proposed system and PSO such that when number of visited nodes increases, the number of fault detection increases in case of our proposed system with accurate fault detection. Number of visited nodes determined by the Bus number of faults and the Total number of Faults is estimated by the first objective [Equation (1)].

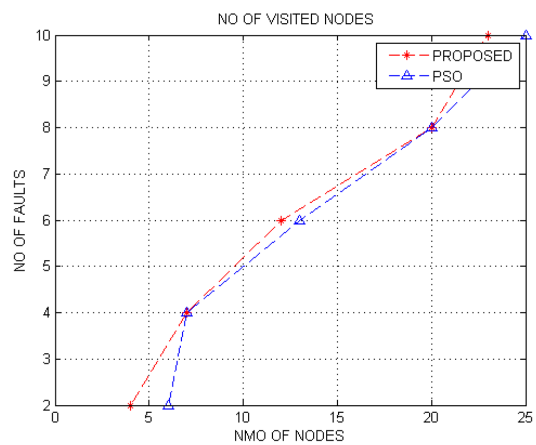

Figure 7: Comparison of Proposed Method with PSO in Number of Visited Nodes (vs.) Number of Faults

The Graph in Figure 8 clearly sketches the way of increased power flow for the proposed system than the PSO when time increases. From the figure, it is Crystal clear that the proposed system provides increased power flow than PSO with increases in time. Time determines the duration taken by the algorithms for rectify problems. The power flow is evaluated by equation (11).

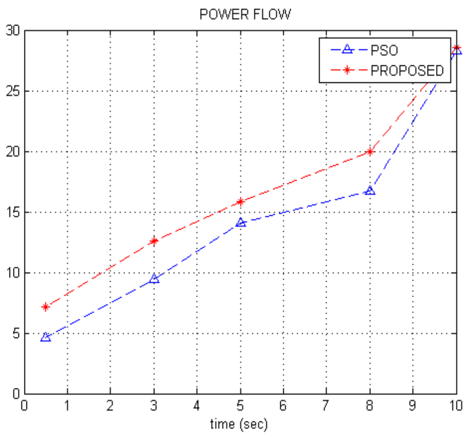

Figure 8: Comparison of Proposed System with PSO for Time (vs.) Power Flow

From fig 9, it is seen Clear-cut that the proposed system works efficiently with increased load supply for the faulty regions and requires less number of switching operations to renew power supply to the faulty areas. Time determines the duration taken by the algorithms for rectify problems and the load not supplied is evaluated by the nodes with failure of supply.

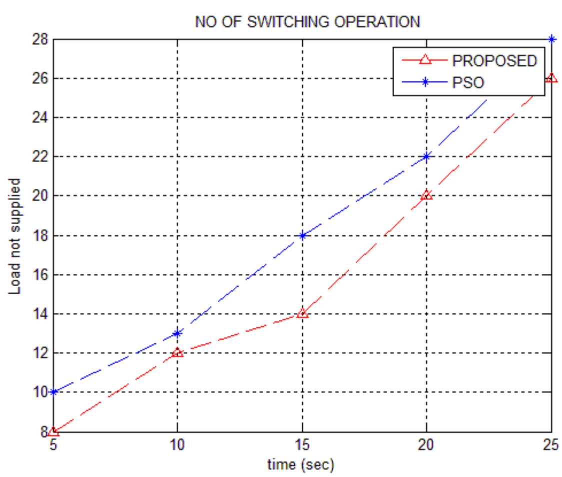

Figure 9: Comparison of Proposed System with PSO based on Time (vs.) Load not supplied

By analyzing the above Graphs, the Efficacy of the proposed system in effective replacement of faulty transformer can be pointed out. The Proposed system is compared with the PSO based on different parameters. The Performance of proposed system is higher than the PSO in each case and it guarantees the implementation of the proposed method in faulty transformer replacement with Nearest Alternative in Real Time system which is most welcome.

5. Conclusion

Power flow or load-flow studies are important for planning future expansion of power systems as well as in determining the best operation of existing systems. In proposed work, a most welcome, Evolutionary programming technique is developed for solving the Service Restoration problem in the IEEE 30 bus system. Manually controlled switches and remotely controlled switches Load of equipment's and restoration time are considered as Objective functions which help in applying restoration plan practically in Short Time Duration. The Proposed Evolutionary Programming based technique does not require weighting factors as in Conventional Optimization techniques. Moreover the Proposed technique overcomes the Demerits of PSO and ACO. Based on larger number of Simulation studies, it has been found that the Evolutionary Programming based technique performs far better than conventional PSO. The proposed methods Evolutionary Programming based technique jointly with Fuzzy trapezoidal function is most suitable for Real time implementation both in terms of Accuracy and Speed.

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