Minimum Load Shedding For Improving Total Loss During Line Outage Contingency Using Evolutionary Programming Technique

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Abstract—**This paper presents a methodology for solving minimum load shedding problem during line contingency by using Evolutionary Programming (EP) technique in order to minimize the losses and maximize the minimum voltage in the power system. This case study has been developed through the Evolutionary Programming (EP) technique using MATLAB software. This study tested two fitness. They are the maximization of minimum voltage and the total losses minimization. Comparison in the results obtained was made in order to determine the best fitness function to be used in solving the minimum load shedding problem. The proposed technique was tested on the IEEE 30-bus reliability test system.**

Keywords-component: Minimum load shedding, total loss, line contigency, Evolutionary Programming (EP).

I. INTRODUCTION

Whenever there is any disturbance in power systems, the conditions of the system must be altered to make sure the system is in operation. As the system is not in a position to cater to its loads, owing to a generator shutdown or the opening of an important tie line, the frequency and voltages in the system reduce below normal specified limits. Load shedding can be used in order to avoid this problem. It is an effective corrective control action that disconnects the loads of the system according to certain priority to steer the power system from the existing potential dangers with the least probability of disconnecting the important loads [1]. A definite schedule for load shedding is prepared with the indication of the loads which must be dropped first and which is last [2]. Load shedding is considered as the last-resort tool for use in extreme situation and usually the less preferred action to be adopted. However, this is a vital in order to prevent the system from collapsing and it becomes a common practice for electric utilities around the world. If the system because a particular load was not shed, that load goes down anyway, carrying the rest of the system with it.

In general, load shedding can be defined as the amount of load that must be removed instantly from the power system to keep the remaining portion of the system operates. There are three main parameters that must be considered in doing load shedding. They are:

- The amount of load to be shed
- The location of load to be shed
- The timing of the load shedding event

Excessive load shedding will trip the load too much and can cause unnecessary power outage problem. Tripping too much load may result in transitioning the system from an under-voltage to an over frequency condition as the resulting system will have more generation than load.

A lot of techniques have been proposed so far to obtain the minimum load shedding such as Artificial Neural Network (ANN), Particle Swarm Optimization (PSO) and Artificial Immune System (AIS). This paper will focus on development of minimum load shedding for total loss and minimum voltage improvement during line contingency using the Evolutionary Programming (EP) technique. The location and amount of load to be shed were determined by EP. This study shows that by implementing the EP technique, several positive results, such as minimizing the total loss and maximizing the minimum voltage, appeared.

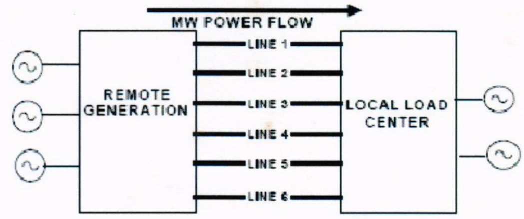

Figure 1. Power System with Remote Generation

As example, there are 6 lines available for power transmission as shown in Figure 1. When there is line outage at line 6, the power transmitted through 6 lines will be reduced to 5 lines, resulting in increment of VAR losses. If the reactive power support is not available at the load centre, the voltage will be going down [3].

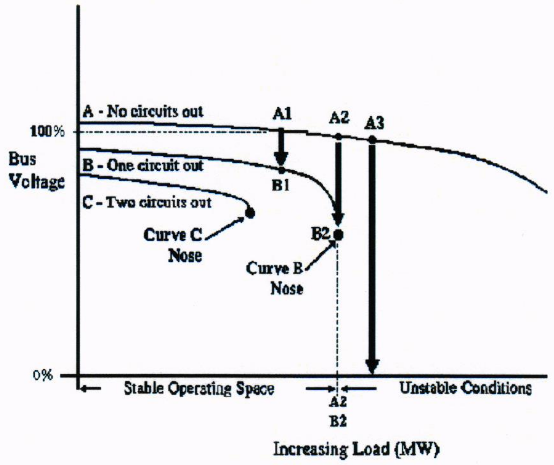

Figure 2. Real Power (MW) versus Voltage(V)-Nose Curve

In figure 2, the voltage curve of A remains steady as local load increase. The conditions of the system are secure and remain stable to the left of point A1. As the number of circuit outage increase, the bus voltage started to decrease [3].

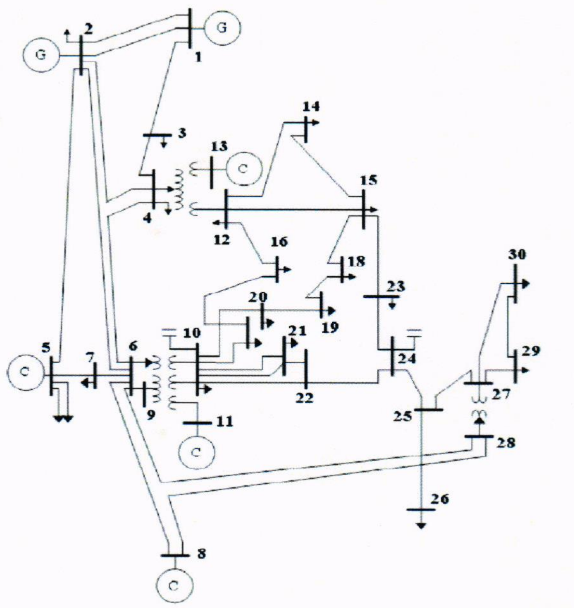

Figure 3. IEEE 30 bus reliability system

II. EVOLUTIONARY PROGRAMMING

Evolutionary Programming technique is a stochastic optimization method in the area of evolutionary programming. It uses the mechanics of evolution to produce optimal solution to a given problem [4]. It seeks for the optimal solution by developing a population of candidate solutions over a number of generations or iterations. A new population is formed from the existing population through a process of mutation. This process produces a new batch of solutions by perturbing each component of existing solution by a random amount. The degree of the optimality of each candidate solutions or individuals is measured by their fitness, also known as the objective function of the problem.

The candidate solutions in each population were merged together to get a whole new population. The new population then was being sorted in ascending or descending order according to the number of the best solution through a process named ranking. The best population gained from the ranking process is regarded as the next generation. Through the ranking process, an optimal population is gained with optimum chance of surviving compared to poorer one.

A. Generating Initial Population

The first process in this EP is the generating the initial population. During this process, 20 initial population is formed by generating a set of random bus number called L1, L2 and L3 which satisfy the constraint that have been set in order to avoid violation in the operating system. This set of bus number is restricted for the load bus only and the value of each load bus is different from one another. P1, P2 and P3 represent the real power needed to be shed for each load bus respectively. From the real power, reactive power to be shed, noted as Q1, Q2 and Q3 can be calculated using the Equation 1. The power factor of the system is assumed to be 0.85 and the stable limit for this system is set between 0.95 p.u and 1.1 p.u.

$$Q = P\tan(\cos^{-1} pf) \quad \text{.................................} \quad (1)$$

B. Mutation Process

Mutation is a method to execute the random number to produce offspring. An offspring in the population is determined by Equation 2 and Equation 3.

$$\eta_i'(j) = \eta_i(j)\exp(\tau' N(0,1) + \tau Nj(0,1) \quad \text{.....(2)}$$

$$P_i'(j) = P_i(j) + \eta_i'(j) Nj(0,1) \quad \text{..............} \quad (3)$$

Where;

$$\tau = \left((2(n)^{1/2})^{1/2}\right)^{-1} \quad and \quad \tau' = (2(n)^{1/2})^{-1}$$

The offspring produced from the mutation process are tested for any constraints violation. The offspring that satisfy the constraint was selected for the next process.

C. Rank and Selection

The offspring gained from the mutation process are merged (combined) with the parent populations. The selection process totally depends on the objective function of total loss minimization and maximizing the minimum voltage. All of the members were sorted in ascending and/or descending order to produce the best twenty or the strongest twenty populations for the next generation.

D. Convergence Test

In order to obtain the optimal solutions, a stopping criterion is created. It was done by evaluating the difference of maximum fitness and minimum fitness. This criterion is created to certain value. If the stopping criterion is not achieved, the process will be repeated until it converged. For this project, a stopping criterion is created as below:

Tlossmax – Tlossmin < 0.5; for total loss (Tloss) minimization

Vmin(max) – Vmin(min) < 0.01; for minimum voltage (Vmin) maximization

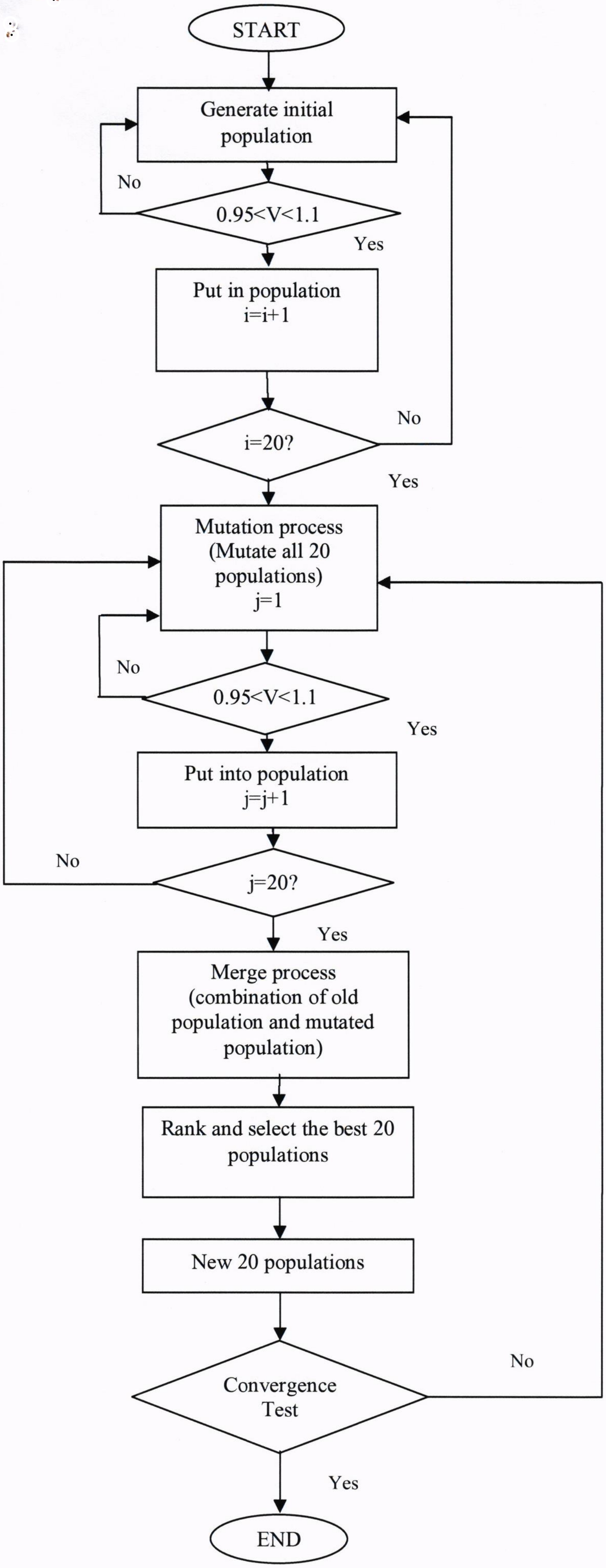

Figure 4. Flowcharts of Evolutionary Programming

III. RESULT AND DISCUSSION

Evolutionary Programming technique has been developed in this study and tested on IEEE 30-bus reliability test system. The objectives are to minimize the total losses and to maximize the minimum voltage. Two objective functions were used to determine maximum load shedding.

The best minimum load shedding solution was obtained from a 10 times test runs with different initial random seed numbers. Table I below shows the best results after 10 times test runs for each objective functions.

TABLE I. TABLE OF THE BEST RESULT FOR EACH OBJECTIVE FUNCTIONS USING EP

3 Load Bus	Vmin (p.u)	Tloss (MW	Tshed (MW)
Min Tloss	0.99	14.757	25.811
Max Vmin	1.005	15.622	15.851
Difference	0.015	0.8650	9.960

The result for EP technique were plotted in tables and histogram graphs for comparison and to identify the best values that can be achieved using the techniques stated above with different objective functions as shown in Table II, Figure 5, Table III, and Figure 6.

TABLE II. TABLE OF MINIMUM TOTAL LOSSES USING EP

Number of Running	Vmin (p.u)	Tloss (MW)	Tshed (MW)
1	1.005	16.231	10.060
2	1.001	15.062	18.775
3	0.987	16.292	12.823
4	0.988	15.899	14.151
5	0.989	16.117	15.599
6	1.002	15.052	18.999
7	0.991	16.013	13.545
8	**0.99**	**14.757**	**25.811**
9	0.998	15.628	15.527
10	0.997	16.335	10.368

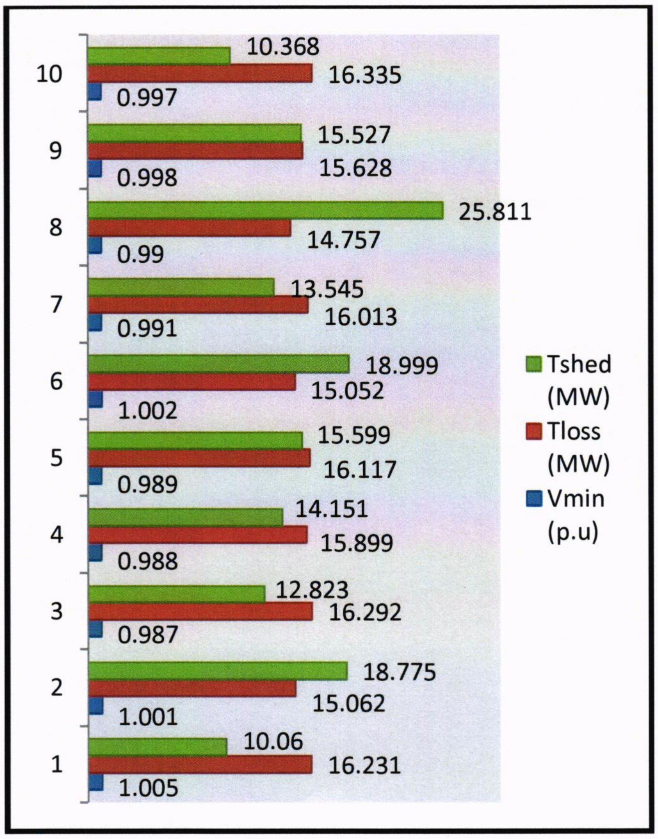

Figure 5. Graph of minimum total losses using Evolutionary Programming

From Figure 5 above, it was found that the best minimum generation losses can be achieved when using Evolutionary Programming technique with minimum total losses as objective function.

TABLE III. TABLE OF MAXIMIZATION OF MINIMUM VOLTAGE USING EP

Number of Running	Vmin (p.u)	Tloss (MW)	Tshed (MW)
1	0.997	16.377	12.304
2	**1.005**	**15.622**	**15.851**
3	1.001	15.369	19.808
4	0.994	16.387	10.548
5	0.997	16.589	7.813
6	0.999	15.326	21.081
7	0.999	16.849	8.501
8	1.004	16.775	6.883
9	0.998	16.99	6.391
10	1.004	15.816	13.527

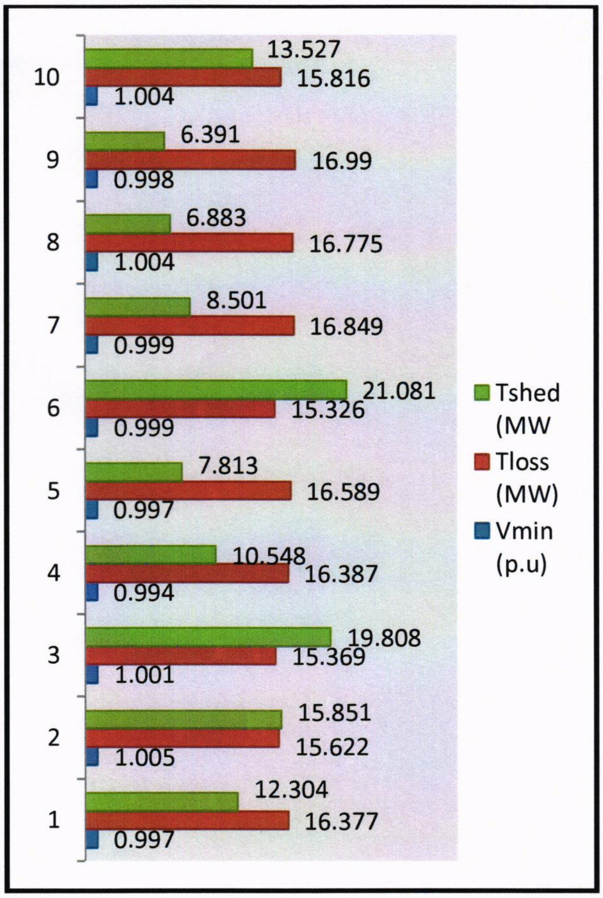

Figure 6. Graph of maximization of minimum voltage using Evolutionary Programming

From Figure 6 above, it was found that the best maximization of minimum voltage can be achieved when using Evolutionary Programming technique with minimum voltage as objective function.

TABLE IV. TABLE OF THE RESULTS FOR COMPARISON THE BEST MINIMUM TOTAL LOSSES AND MAXIMIZATION OF MINIMUM VOLTAGE USING EP

Objective Function	Vmin (p.u)	Tloss (MW)	Tshed (MW)
Tloss (MW)	0.99	14.757	25.811
Vmin (p.u)	1.005	15.622	15.851
Difference	0.015	0.8650	9.960

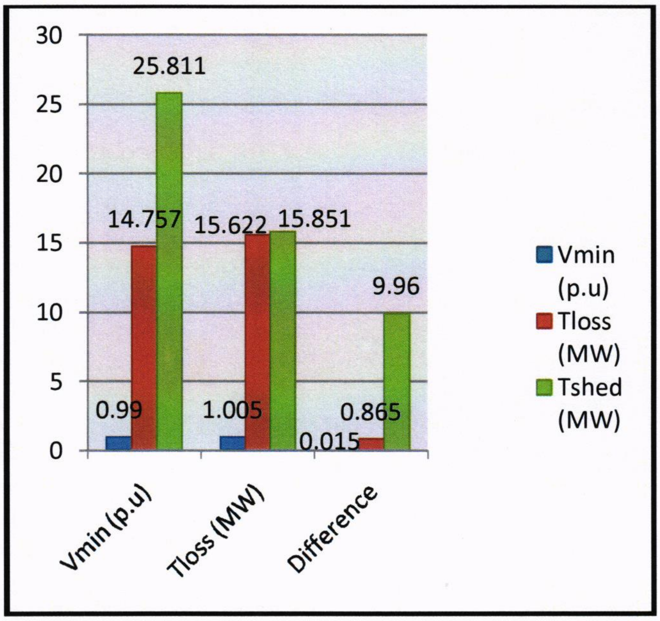

Figure 7. Graph of comparison the best minimum total losses and maximization of minimum voltage among objective functions using Evolutionary Programming

Figure 7 shows the results of Evolutionary Programming for total losses minimization and maximization of minimum voltage by using different objective functions. From the figure above, the minimum voltage and total loss for both objective functions are nearly the same with the differences of 0.015 p.u and 0.8650 MW respectively. The total load to be shed shows a large difference which is 9.960 MW. The objective function of maximization the minimum voltage (Vmin) shows lower value of total load to be shed which is 15.851 MW compared to the minimization of total losses which is 25.811 MW. The lower amount of total load to be shed shows less electrical disturbance on the consumer side. Therefore, this Evolutionary Programming technique is suitable to be applied for objective function of maximizing the minimum voltage.

IV. CONCLUSION

The Evolutionary Programming technique has been applied in solving minimum load shedding problem in this project. It consisted of two objective functions. They were the total losses minimization and maximization of minimum voltage.

The comparison shows that the objective function of minimum voltage maximization is the best objective function compared to the other objective function which gave lower amount of total load to be shed.

Based on the results, the Evolutionary Programming is the most effective technique in solving the minimum load shedding problem. It can be concluded that the total generation losses in the system has been minimized after solving the minimum load shedding problem using Evolutionary Programming.

V. FUTURE DEVELOPMENT

For future development, the Evolutionary Programming is proposed to be run on bigger distribution network and smaller accuracy to achieve optimum result. Furthermore, this technique is possible to be combined with other optimization technique in solving the load shedding problem. Further explorations in minimizing the amount of load to be shed and minimizing the computation time can also be proposed.

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