

Under Frequency Load Shedding with Application of Heuristic Algorithm

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Abstract— Load shedding is considered the method to be applied in emergency situations to prevent black-out and to maintain the stability of the power system. The traditional load shedding methods are complex and cannot be expanded. This paper proposes a new load shedding method based on heuristic algorithms to overcome the above limitations. One of the important characteristics of this method is that amount of loads shed and load placement shed at each bus are determined and implemented according to plans corresponding to the cases when the problems occur. This contributes to reduce the operation and recovery time of the system when the problem occurs. Case studies proposed in this paper include: generator failure, the bus failure when the system operates at 80%, 90% and 100% of maximum capacity. The method proposed is tested on the IEEE 37 bus system, using PowerWorld software and the simulation results proved the effectiveness of the method.

Keywords— Load Shedding; Heuristic Algorithm; The Power System Stability; Under Frequency; Recovery Time; Generator Failure

I. INTRODUCTION

Voltage and frequency are the two most important parameters affecting the stability of the power system. When there is instability the frequency or voltage will cause disturbance and if it extends disturbance that lead to the collapse of the system. Therefore, the need to quickly put the parameters on which the original value or re-establish a new stability point is very important in order to minimize the system collapse. When all the available controls cannot maintain stable power system frequency, load shedding method is applied in emergency situations to maintain the power system stability or restore steady state the fastest.

The traditional load shedding methods based on under frequency or voltage relay [1], [2] the results are often less accurate, the amount of load is shed sometimes so large in a step, the plans do not have the flexibility to increase the number of load shedding steps or take a long time [4], [5]. To increase the efficiency of load shedding, some load shedding methods based on frequency or the rate of change of frequency (df/dt) [6], voltage, sensitivities QV at each load bus. However, this case shows the processing speed algorithm is too slow [7].

The load shedding algorithm proposes below aims to load shedding based on heuristic algorithm to resolve the limitations of previous studies. One of the important characteristics of this method is that amount of loads shed and load placement shed at each bus are determined and implemented according to plans corresponding to the cases when the problems occur. This contributes to reduce the operation and recovery time of the system when the problem occurs.

II. APPROACH METHOD

A. Heuristic Algorithm

Heuristic algorithms often show quite natural, close to the way of thinking and acting of human beings. The function of heuristic is search from a available target, it provides information from neighboring nodes to serve the search results for targeted needs identified. Heuristic algorithms based on the basic principles:

- The principle of exhaustion intelligent: A criterion of this principle is when the search area is too large, it must seek to limit the maximum search area to quickly identify problems and produce results soon.
- Principle greedy: release criteria are obtained optimal standards of big problems to select for each solve step within the limits of each region.
- Principle of order: the criteria set out implementation actions are based on search structure predefined order.

To problems are solved the fastest and shortest path, Greedy principle is often used. Specifically as follows:

- From the start node, list all distance traveled from the starting point to the node n two level of the system, and then choose the shortest path.
- When go to a node level 2 is also in accordance with the above principle, list all the way from the current location node next to the node and also according to the selection criteria shortest path. Programming will be done until there is no node to go.

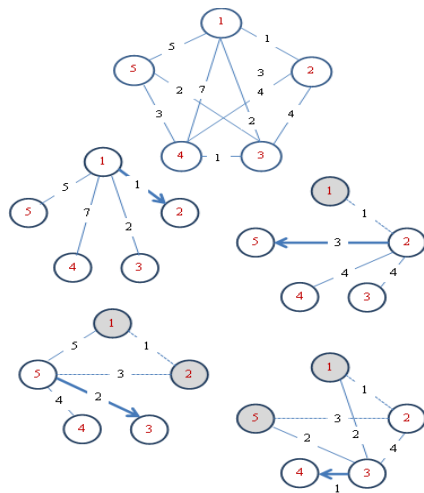


Fig. 1. Describe heuristic algorithm

III. CALCULATION, EXPERIMENTS, THE SIMULATION ON THE TEST SYSTEM

Experiments on typical systems IEEE with $f=60\text{Hz}$ include 37 buses 9 generators shown in Fig. 3.

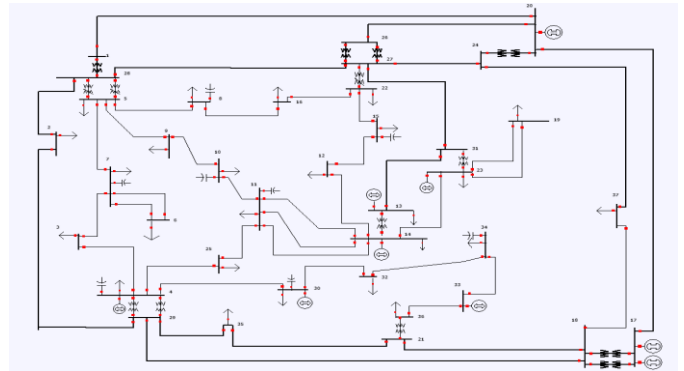


Fig. 2. 37 buses 9 generators test system

B. The application of heuristic algorithm for load shedding

The proposed method uses the "decision tree" to implement load reduction. The goal of the "decision tree" is to find the shortest way to recover the system with the fastest time from a predefined node. The idea of the method is implement load shedding through from the search node cause problems in areas that have been identified before. The implementation of this model is effective because it avoids having to calculate the optimal the whole system. After identifying the node causes the problem, the level of disturbance is estimated using the rate of change of frequency. Load location is shed at each bus has been determined based on the calculated voltage change at each load position when problems occur.

Step 1: Search node /generator is faulted.

Step 2: Determine the unbalanced load based on equations of motion of the rotor:

$$\frac{2H_{eq}}{f_o} \frac{df_n}{dt} = P_{diff} = P_{mn} - P_{en} \quad (1)$$

Where: H_{eq} is the equivalent inertia constant of the generators; f_o is the nominal frequency of the system; P_{diff} is the difference in the generated power and the load power; P_{mn} is the mechanical shaft power for n machines, P_e is the electrical power for n machines.

Step 3: calculate dV/dt to determine priority load. Bus has dV/dt magnitude greater is shed before.

Step 4: Load shedding until recovery frequency close to the value of the original steady state.

Flowchart algorithm load shedding based on Heuristic is presented in Fig. 2.

Case studies proposed in this paper include: generator failure, the bus failure when the system operates at 80%, 90% and 100% of maximum capacity. Corresponding to each case will build "decision tree" in load shedding to restore the parameters return to the original steady state.

Consider the case loss a generator at bus No. 4 when the system is operating 80% of maximum capacity, use PowerWorld software to simulate and observer getting results when apply traditional load shedding programs and the load shedding program proposed. Result frequency graph when the power system is not load shedding is shown in Fig. 4. Frequency graphs after applying the previous load shedding methods are shown in Fig. 5, Fig. 6.

The obtained results, the frequency before using the load shedding program is 59.6 Hz, after application proposed load shedding program, the frequency has improved to a stable value near 60 Hz (59.99 Hz) in 24s. Compare with the case load shedding common: load shedding based on frequency and voltage sensitivity, loads are shed according to ascending order [7], follow the steps based on the change of frequency [3], comparing the results presented in Table 1.

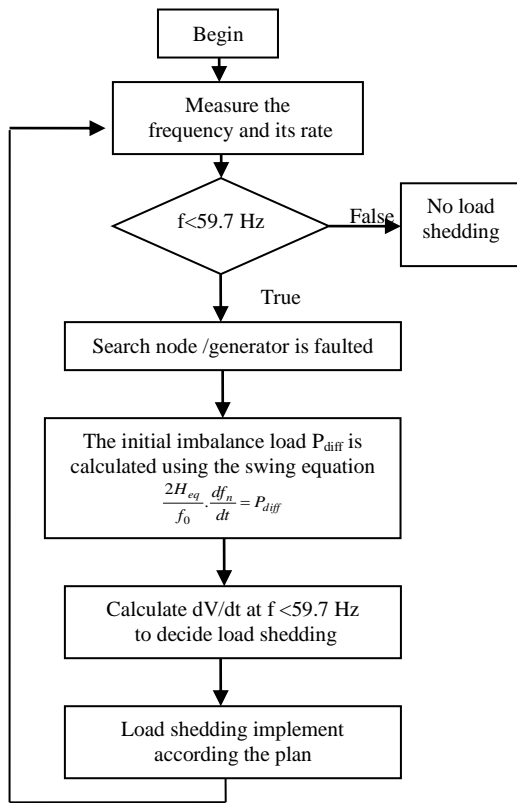


Fig. 3. Flowchart algorithm load shedding based on Heuristic algorithm

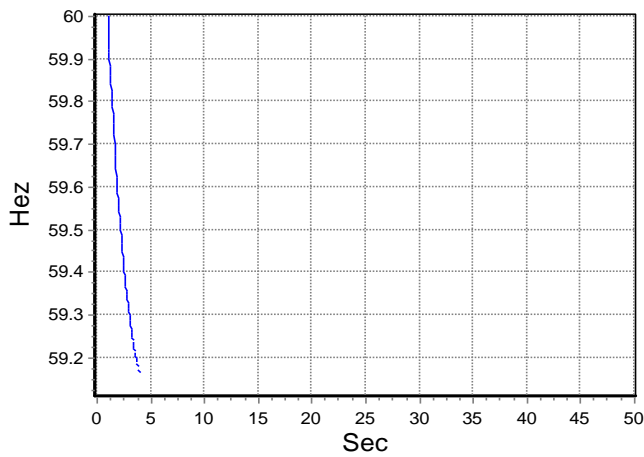


Fig. 4. Frequency of system in case of failure at the generator bus 4

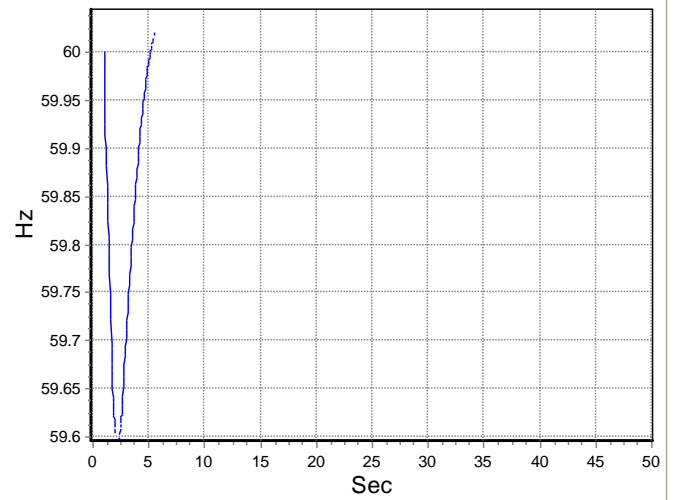


Fig. 5. Load shedding based on frequency and voltage sensitivity

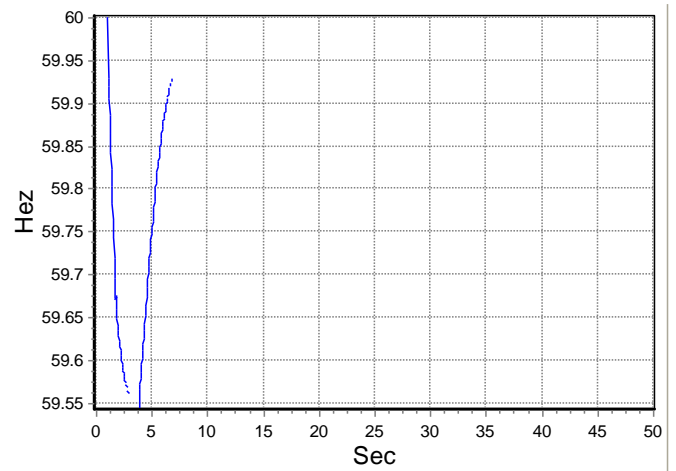


Fig. 6. Load shedding based on these steps based on the change of frequency

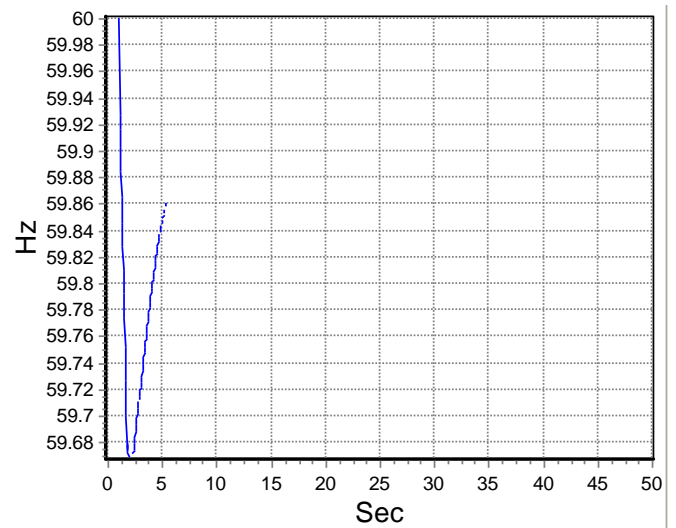


Fig. 7. Frequency of system after using load shedding based on Heuristic algorithm

Consider the case bus No.17 is failed to short-circuit problem when the system is operating 80% of maximum capacity, use Powerworld software to simulate and observe getting results from the load shedding program proposed.

Result frequency graph when the power system is not load shedding is shown in Fig. 8.

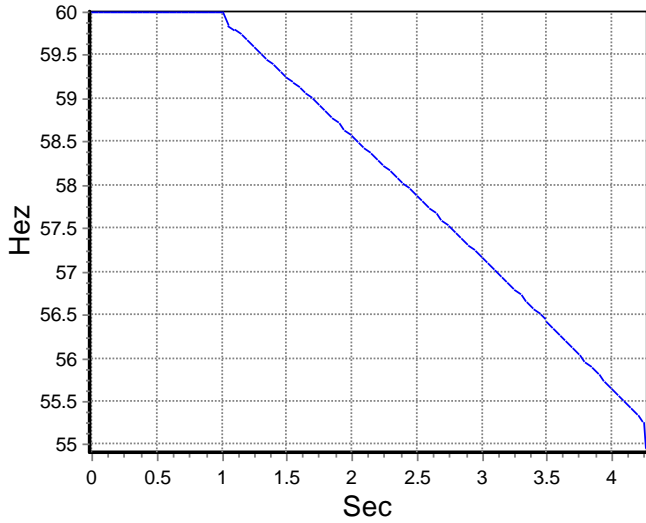


Fig. 8. Frequency of system in case of problems at the bus

TABLE I. RESULTS OF THE COMPARISON BETWEEN THE METHODS LOAD SHEDDING IN CASE OF GENERATOR FAILURE

Methods load shedding	Recovery frequency (Hz)	Load Shedding capacity (MW)	Recovery time (s)
Load shedding based on frequency and voltage sensitivity	59,99	149,1	30
Load shedding based on these steps based on the change of frequency	59,94	127.14	13
Load shedding based on ascending order	59,98	140	15
Load shedding based on Heuristic algorithm	59,9	119.83	10

Frequency graph after applying the traditional load shedding program: loads are shed according to ascending order is shown in Fig. 9.

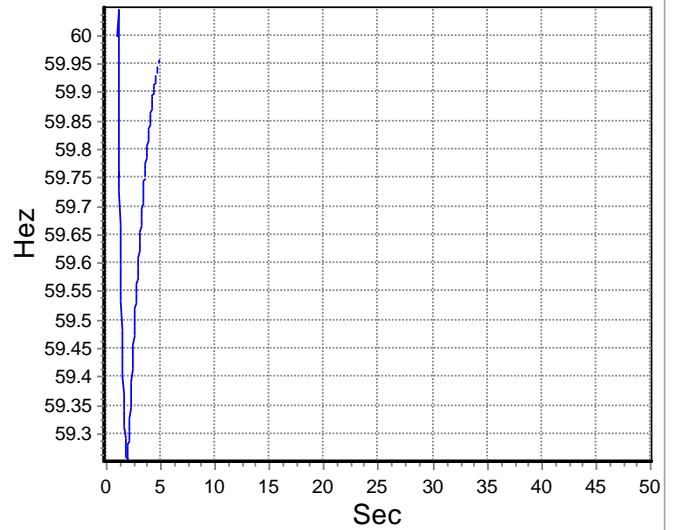


Fig. 9. System frequency after applying the load shedding program the order ascending load

Frequency graph after applying the proposed load shedding program is presented in Fig. 10.

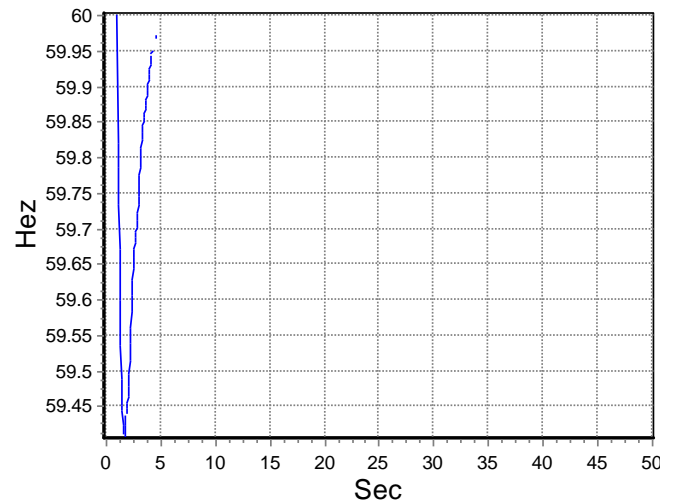


Fig. 10. Frequency system after applying the load shedding program according to Heuristic algorithm

The obtained results, if the load shedding is not implementing, the power system will black out. After applying the load shedding program proposed, the frequency has improved to a stable value close to 59.97 Hz within 12 seconds faster than the case load shedding in order to the smallest value being shed before. "Decision tree" diagram is shown in Fig. 11.

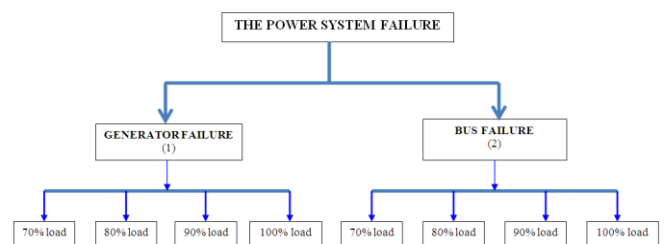


Fig. 11. Decision tree diagram when there is a problem on power system

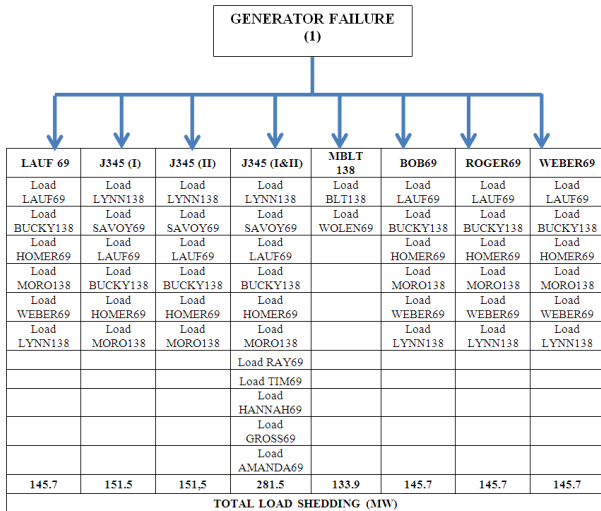


Fig. 12. Decision tree diagram when a generator is faulted and load reaches 70% of maximum capacity

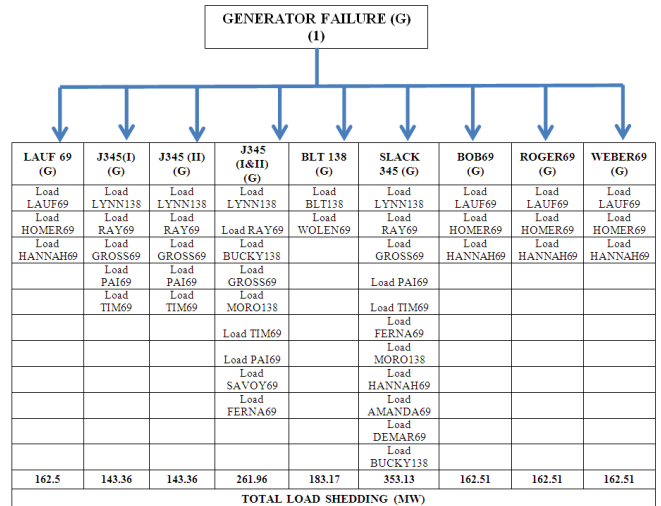


Fig. 15. Decision tree diagram when a generator is faulted and load reaches 100% of maximum capacity

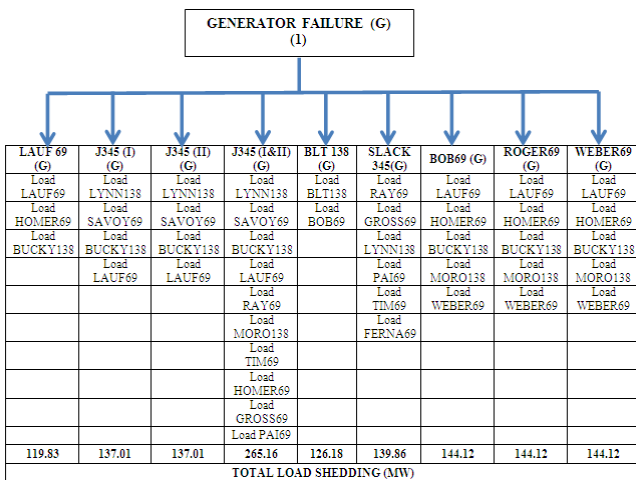


Fig. 13. Decision tree diagram when a generator is faulted and load reaches 80% of maximum capacity

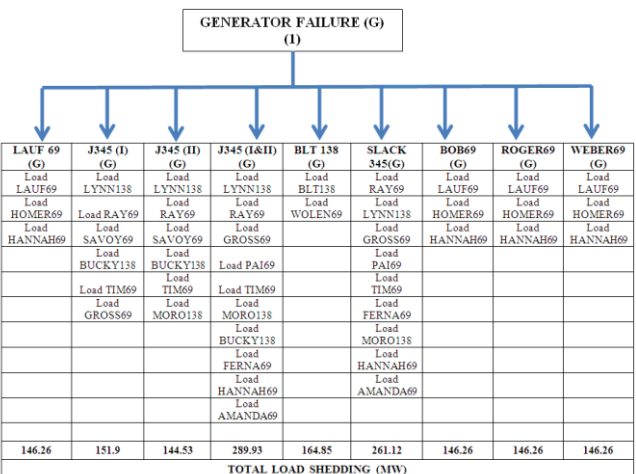


Fig. 14. Decision tree diagram when a generator is faulted and load reaches 90% of maximum capacity

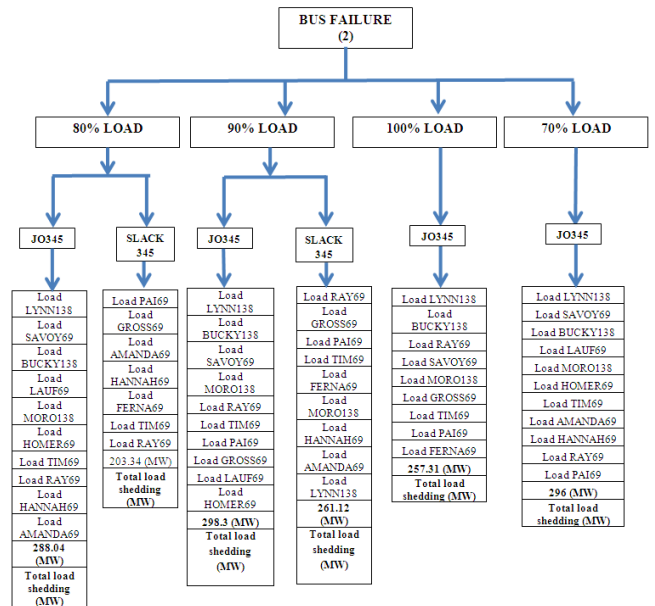


Fig. 16. Decision tree diagram when a bus is faulted

IV. CONCLUSIONS

Load shedding based on Fuzzy-AHP algorithm is applied in the emergency situations to maintain stability of the power system. The number of loads nodes and load shedding position at each node were predetermined. The implementation of strategic control with this method contributed to simplifying the operation, reducing the total power load shedding and decreasing the economic damage in emergency.

Simulation results showed that although the recovery time was a little longer but Fuzzy-AHP algorithm allowed capacity-lower load shedding than the AHP algorithm demonstrated the effectiveness of the proposed method.

Load shedding method based on Heuristic algorithm is applied in emergency situations to maintain the stability of the power system. The important characteristics of this method is that amount of loads shed and load placement shed at each bus are determined and implemented according to plans corresponding to the cases when the problems occur. This contributes to reduce the operation and recovery time of the system when the problem occurs.

The simulation results show that the amount of capacity load shedding less and faster recovery time than previous methods demonstrate the effectiveness of the proposed method.

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