ARPN Journal of Engineering and Applied Sciences

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RESTORATIVE PATH SELECTION FOR POWER SYSTEM NETWORK USING FLOYD WARSHALL ALGORITHM

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ABSTRACT

Power system network can undergo outages during which there may be a partial or total black out in the system. To minimize the interruption of power supply to consumers, proper switching of power lines is required. Identification of power flow path in the network is the difficult task of the load dispatching centre. Practically the power system operators used the predefined rules in identifying the power flow path; sometimes it leads to cascaded outage. Hence the reason for failure of restoration may be the wrong identification of the power flow path. The scope of the proposed work is to identify the optimal power flow path using Floyd Warshall Algorithm (FWA) with additional constraints. This algorithm is selected in the shortest path algorithms because in single execution, it finds the shortest path between all pairs of vertices. Software has been created in order to identify the restoration path in a sample 5 bus system and obtained the results for a practical Chennai 230kV network.

Keywords: power system network, service restoration plan, Floyd Warshall Algorithm, shortest path.

1. INTRODUCTION

The problem of restoration after complete blackout is a complex decision making and control problem for power system operators. The power supply interruption may be due to some serious faults in the system or due to some abnormal condition. Whenever power interruption takes place it is imperative to bring back the system promptly to its initial state or to an optimal operating network. The problem of obtaining a target network is called power system restoration. It consists of two steps, the first step is to determine an optimal configuration and the second step is to prepare a sequence of switching operations (restoration plan) in order to bring the faulted network into the obtained target system. The restorative procedure must consider the safety, minimum restoration time and minimal adverse impact to the consumers. In practical situations the power system operators are under severe stress to restore the affected area into service as soon as possible. So a guidance or predetermined path is required to transmit the power from the generating station to load demand that too through the optimal path. So far FWA is not used to solve the problem of finding the optimal path in the power system network. An attempt is made to find the optimal path in the power system network to enhance the power system restoration process.

Research works are carried out for the optimal route selection in transportation industry. Basabi Chakraborty *et al*. attempted to implement the genetic algorithm in car navigation system for finding the several alternate routes by considering the different criterion such as shortest path by distance, path with minimum number of turns, path passing through mountain or by the side of the river [1]. Yasushi *et al*., proved that the dijkstra algorithm can beat genetic algorithm and an extended data structure for dijkstra algorithm is suggested to find the optimal route by considering the constrains such as shortest path, fewest intersection, fewest traffic signals and least congested road and also compared the performance of this algorithm with the genetic algorithm [2]. Liu *et al*. proposed an algorithm for quasi optimal route selection other than the shortest path and used the knowledge of road network to find the routes with predefined concept of easiness [3]. Kanoh *et al*., refined the search rate and the quality of solutions which is improved by giving directions to the search using viruses so that the real car navigation system is effective [4-6]. The shortest path problem is formulated as a multi objective optimization problem by considering the necessary constraints, and then extended dijkstra algorithm is applied by Egashira *et al*., [7]. Tianrui Li, *et al*., proposed a new efficient algorithm named Li-Qi, for the single source shortest path problem in graph theory to find a simple path of minimum total weights from a designated source vertex to each vertex [8]. It is based on ideas of the queue and the relaxation. Sudhakar *et al*. determined the optimal configuration of the distribution network by using dijkstra algorithm. The developed algorithm is tested on a sample three feeder system and a practical test system also [9]. Sudhakar *et al*. also applied prims algorithm for the power flow path identification in the distribution network. To validate the methodology it has been applied to IEEE 16 bus test system [10].

So far the shortest path finding algorithms are used in the transportation industry, recently dijkstra and prims algorithms are used in the power system area. But the path obtained from FWA may be the shortest one but cannot be guaranteed as the best one. So the optimal path can be found by incorporating the additional constraints like capacity of transmission line, shortest path by distance (minimum loss), power balance and priority of loads. In this paper, the extended version of FWA is used to find the optimal path from each power station to load demand dynamically.

2. SHORTEST PATH ALGORITHMS

The algorithms are used to find the minimum weighted or most efficient path in the network. In graph theory, it is used to identify a path between two vertices (or nodes) such that the sum of the weights of its constituent edges is minimized. This problem is called the single pair shortest path problem. In the graph, the shortest path from a source vertex to all other vertices are called single source shortest path problem. The shortest paths from all vertices in the graph to a single destination vertex is called single destination shortest path problem. The shortest path between every pair of vertices is called all pairs shortest path problem. Dijkstra's algorithm finds solution in the single pair, single source and single destination shortest path problem. Bellman Ford algorithm obtains solution in the single source problem if the edge weights are negative. Johnsons's algorithm identifies the solution in all pairs shortest path problem.

Floyd Warshall Algorithm

The FWA is a graph analysis algorithm for identifying the shortest path in a weighted graph. The shortest path between all pairs of vertices is obtained in a single execution of the algorithm. It is an example of dynamic programming. It will consider negative weights too.

Pseudo code for FWA

This pseudo code assumes an input graph of N vertices.

```
for i = 1 to N
for j = 1 to N
if there is an edge from i to j
dist [0][i][j] = the length of the edge from i to j
else
dist [0][i][j] = INFINITY
for k = 1 to N
for i = 1 to N
for j = 1 to N
dist [k][i][j] = min(dist[k-1][i][j], dist[k-1][i][k] + dist[k-1][k][j])
```

This will give the shortest distances between any two nodes, from which shortest path may be constructed. By applying this algorithm only shortest path by distance can be found. This shortest path cannot solve the restoration problem. So the additional constraints are also added to the existing FWA to restore the power in the network efficiently.

3. IMPLEMENTATION OF FWA IN THE AREA OF POWER SYSTEM

Problem Formulation

The objective of this work is to reconfigure the unenergized network by maximizing the amount of power restored through the optimal path with minimum losses.

Objective function

Maximize the amount of power restored.

Subjected to the following constraints:

a) Shortest distance

The impedance of the line is considered as the weight of the line. The length of the line is less then the losses are also reduced.

b) Power balance

The generated power should be equal to the load and losses.

c) Capacity of the line

The transmitted power should be below the capacity of the line.

d) Priority of loads

Among the available paths, higher weight age is given to the important load bus within the restorative path.

The above algorithm is applied to 5 bus system and then it is applied to practical 230kV network.

4. ILLUSTRATIVE EXAMPLE FOR EXECUTION OF FWA

Consider the sample 5 bus system which has one generator in bus 1 and another in bus 4 as shown in Figure-1 and the nodal diagram is shown in Figure-2. Here the FWA is applied by assuming the weight as the product of branch impedance, and the distance between the generating station and the load. Based on the algorithm execution, the results are obtained for the sample bus system for which the step by step procedure is given below.

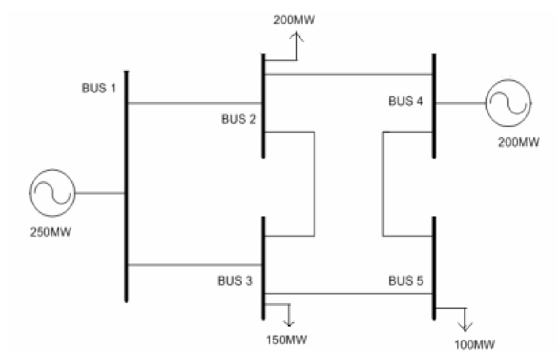

Figure-1. Sample 5 bus system.

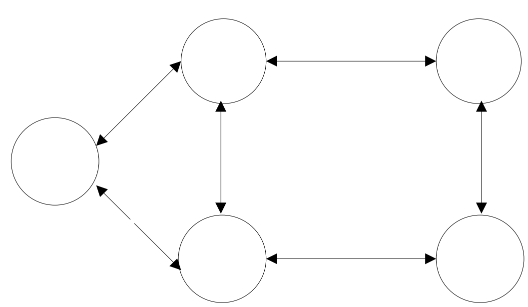

Figure-2. Nodal diagram for sample 5 bus system.

VOL. 7, NO. 4, APRIL 2012 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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Step 1: Interspace 1 between all other nodes in hope of finding the shortest path and the corresponding distance table is shown in Table-1. If the found path distance is less than the available path, then replace the value of distance in the distance table and add the path in the hash table. Likewise interspace 2, 3, 4 and 5 between all other nodes and the corresponding table is shown in Tables 2, 3, 4 and 5, respectively. The table shown in Table-5 gives the shortest distance between all pairs of nodes.

Table-1. Distance table after interspacing1.

	S1	S2	S3	S4	S5
S1	0	45	50	0	0
S2	45	0	30	40	0
S3	50	30	0	0	30
S4	0	40	0	0	20
S5	0	0	30	20	0

Table-2. Distance table after interspacing 2.

	S1	S2	S3	S4	S5
S1	0	45	50	85	0
S2	45	0	30	40	0
S3	50	30	0	70	30
S4	85	40	70	0	20
S5	0	0	30	20	0

Table-3. Distance table after interspacing 3.

	S1	S2	S3	S4	S5
S1	0	45	50	85	80
S2	45	0	30	40	60
S3	50	30	0	70	30
S4	85	40	70	0	20
S5	80	60	30	20	0

Table-4. Distance table after interspacing 4.

	S1	S2	S3	S4	S5
S1	0	45	50	85	80
S2	45	0	30	40	60
S3	50	30	0	70	30
S4	85	40	70	0	20
S5	80	60	30	20	0

Table-5. Distance table after interspacing 5.

	S1	S2	S3	S4	S5
S1	0	45	50	85	80
S2	45	0	30	40	60
S3	50	30	0	50	30
S4	85	40	50	0	20
S5	80	60	30	20	0

Step 2: Now the path between the desired source and the demand can be retrieved from the final distance table and also from the hash table and that path is the shortest path by distanced only.
Step 3: Check the priority of the loads for the shortest path.
Step 4: Check the capacity of the selected shortest path and if capacity is satisfied, set capacity as true, else set capacity as false.
Step 5: Check the power balance equation for the shortest path. If power balance is satisfied, set satisfied, else set power balance as unsatisfied.
Step 6: If power balance is unsatisfied or if capacity is false, search for an alternate path in the hash table and go to step 3 else go to step 7.
Step 7: Display the final path as the optimal path.
Based on the above algorithm a computer program for extended FWA has been written in C-Language and the results are given in the section 6.

5. COMPUTATIONAL PROCEDURE OF THE FWA FOR IDENTIFICATION OF OPTIMAL PATH

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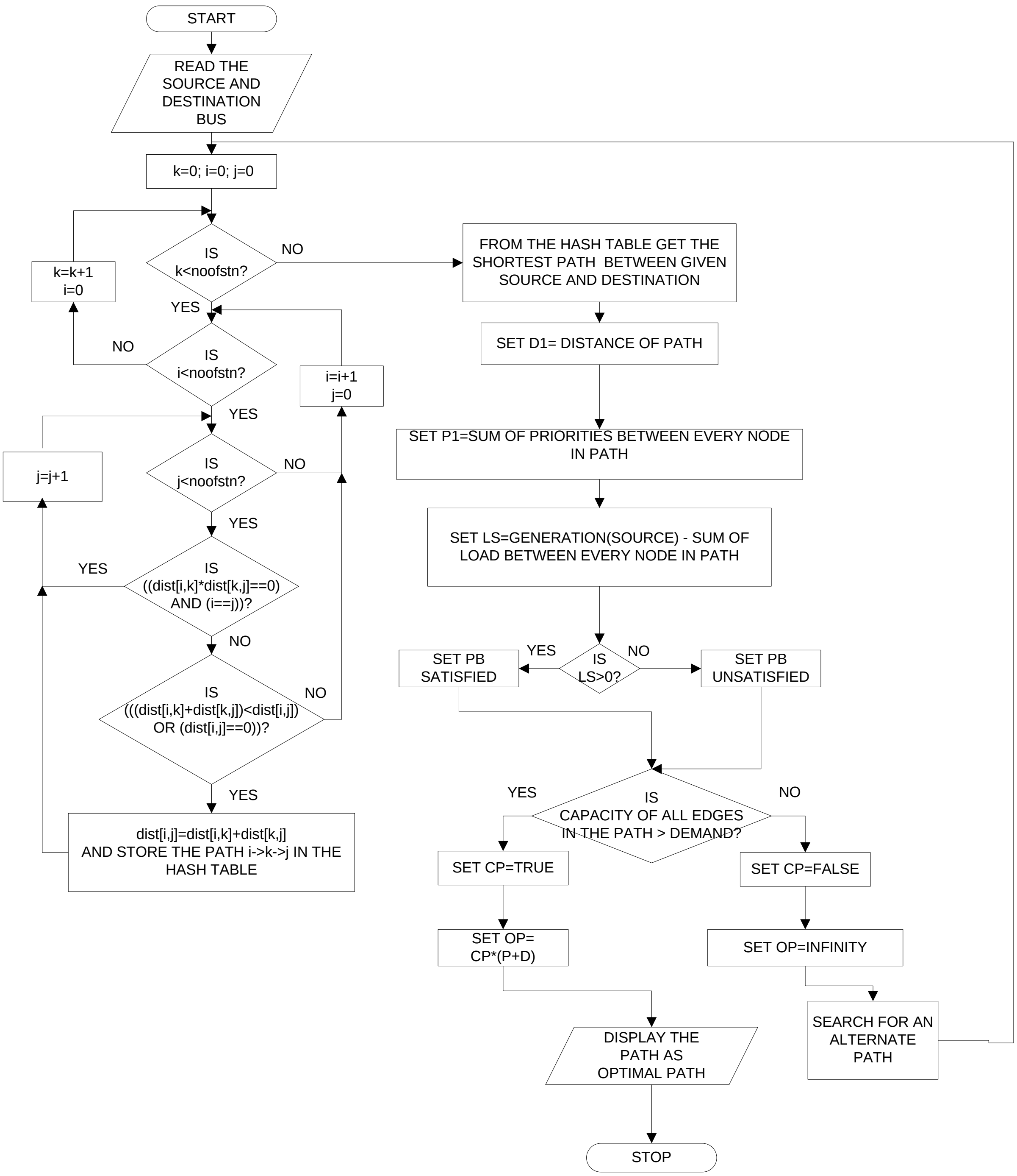

Figure-3. Flow chart for identification of optimal path.

6. NUMERICAL RESULTS

For sample 5 bus system

In order to validate the FWA it has been applied to sample 5 bus system and then to Chennai 230 kV practical network. The software is developed in C Sharp language and it can work under dynamical environment. The input screen allows the operator to select the generating station and the load bus. There are options to view and edit the distance, priority, capacity of the line, load and generation values of the bus in the database. The output screen is used to display the optimal path between the given generating station and the load bus. Table-6 gives the computed results of optimal path of the sample 5 bus system. Through this optimal path, the power can be transmitted efficiently so that the restoration process can be enhanced.

Table-6. Optimal path for the sample 5 bus system.

Node		Path
From	**To**	**Optimal path**
1	2	1→2
1	5	1→3→5
1	3	1→3
4	2	4→ 2
4	3	4→5→3
4	5	4→5

For Chennai 230kV network

The Chennai 230 kV Network, a load dispatching centre allocates electricity to more than one million customers in Chennai metropolitan city in India. The network has one black start generator of capacity 120 MW which can be used to crank the other non black start generators. The network is tied with the national grid of India. The national grid (bus 18) supplies 220 MW of power through the Neyveli power station. The network has a total installed capacity of 2300 MW and it is shown in Figure-4. The FWA is applied to the practical network and the optimal path is given in Table-7.

Table-7. Part of the computed results for Chennai 230kV network.

Node		Path	
From	**To**	**Optimal path**	**Other available paths**
1	6	1→5→6	1→2→5→6 1→3→2→5→6
2	10	2→1→10	2→5→10 2→3→1→10
14	16	14→15→13→10→16	14→15→17→16 14→15→13→17→16
19	10	19→13→10	19→13→17→7→10 19→13→17→16→10
18	6	18→17→7→10→6	18→17→16→10→6 18→17→7→10→5→6

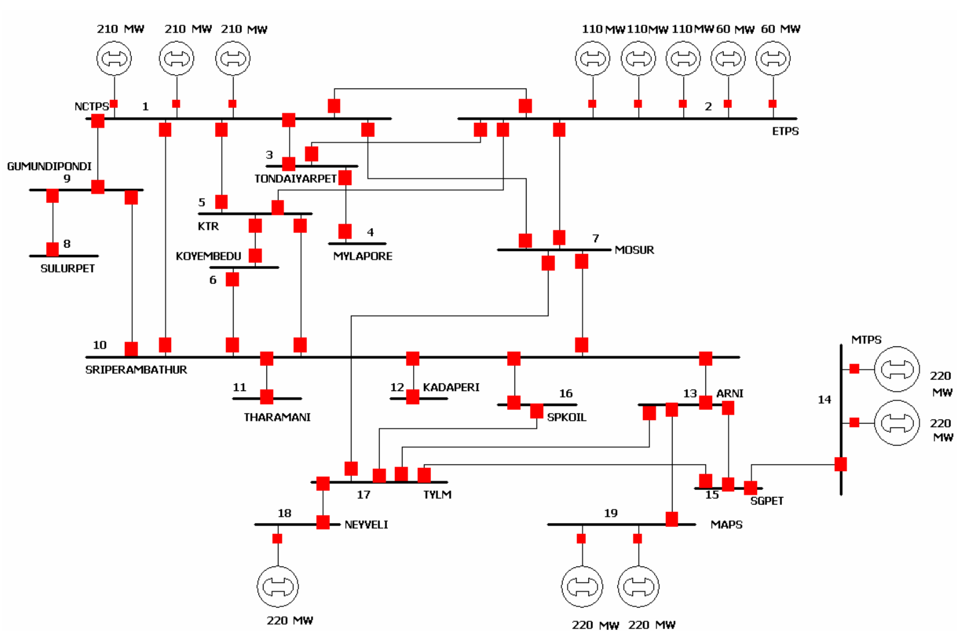

Figure-4. Chennai 230kV practical network.

Based upon this guidance the power can be transmitted through the optimal path which reduces the outage and enhances the restoration in the network effectively.

7. CONCLUSIONS

When a fault occurs in the power system network, we need to divert the power through the other transmission lines. This diverted path of power flow during fault condition or partial black out condition should be of minimum impedance in order to reduce the losses in the network and also the transmitted power should be below the capacity of the line and the generating power should meet the load and losses. Then only the power can be sent through the restorative path. That's why along with the distance as a constraint, the capacity, power balance is also considered. While restoring the power the priority of load has to be considered to implement the reconfiguration of power system network efficiently. So the additional constraints are added to the FWA and the software is developed for the execution of optimal path identification in C# language. An extended version of FWA is applied to find the optimal path in the power system network where the other routing algorithms can only find the shortest path by distance. This extended FWA can work under dynamical environment also.

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