Optimal Power Flow Path Selection Using Different Shortest Path Algorithms

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Abstract - Efficient management of networks required that the shortest route from one point(node) to another is known; this is termed the shortest path. It is often necessary to be able to determine alternative routes through the network, in case any part of the shortest path is damaged or busy.
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 center.
The scope of the proposed work is to identify the optimal power flow path using three shortest path algorithms: Dijkstra's Algorithm, Bellman- Ford Algorithm(BFA)&Floyd Warshall Algorithm (FWA).Three algorithms were implemented in MATLAB. Comparative study and assessment of result is done.

Keywords: Dijkstra's Algorithm, Bellman-Ford Algorithm,FloydWarshall Algorithm, power system network, shortest path.

I. 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. An attempt is made to find the optimal path in the power system network to enhance the power system restoration process.

The shortest paths problem on graphs is one of the most widely-studied combinatorial optimization problems. Given an edge-weighted graph, a path from a vertex u to a vertex v is a shortest path if its total length is minimum among all u-to-v paths. The complexity of finding shortest paths seems to depend upon how the problem is formulated and what kinds of assumptions we place on the graph, its edge-lengths and the machine model. Most shortest path algorithms for graphs can be well-categorized by the following choices.

1. Whether shortest paths are computed from a single source vertex to all other vertices (SSSP), or between all pairs of vertices (APSP). One shouldalso consider the intermediate problem of computing shortest paths from multiple specified sources (MSSP).
2. Whether the edge lengths are non-negative or arbitrary.
3. Whether the graph is directed or undirected.
4. Whether shortest paths are computed using just comparison & addition operations,
or whether they are computed assuming a specific edge-length representation
(typically integers in binary) and operations specific to that representation.

Comparison-addition based algorithms are necessarily general and they work when edge-lengths are either integers or real numbers.

II. LITRATURE SURVEY

Research works are carried out[1] for the optimal route selection and, 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],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. [3-5],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 . [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. [7], 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. It is based on ideas of the queue and the relaxation. [8],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], 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.

III. 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

1.1 Dijkstra's Algorithm

Dijkstra's algorithm finds solution in the single pair, single source and single destination shortest path problem. The important point to be noted is that the edge weights have to be nonnegative. It outputs a vector □ where □□ is the shortest distance from □ to node □.

Here Time complexity depends on the implementation. It first find the closest node to □, and then the second closest one, then the third, etc.

Pseudo code for Dijkstra's algorithm

This pseudo code assumes an input graph of vertices.

```
for i=1 to v
dist[i]= infinity
previous node in optimal path is undefined
previous [i]= undefined
dist[source]= 0
Q= the set of all nodes in graph
u= vertex in Q with smallest distance in dist[]
if dist[u] = infinity
break;
all remaining vertices are inaccessible from source
remove  u from Q
for each neighbor v of u
alt = dist[u] + dist_between(u,v)
if  alt< dist[v]
dist[v] = alt
previous[v] = u
decrese-key v in Q
```

1.2 Bellman-Ford Algorithm

Bellman Ford algorithm obtains solution in the single source problem if the edge
weights are negative.It outputs a vector □ where □□ is the shortest distance from □ to node □

It can detect a negative-weight cycle. It is also extremely easy to code and its coding time is also less than a few minutes.

Pseudo code for Bellman-Ford Algorithm

```
Initialize ds =0 and dv =∞ for all v≠s
for k=1…..n-1;
for each edge u→v of cost c:
```

dv= min(dv,du+c)
for each edge u→v of cost c:
if dv> du +c:
then the graph contains a negative-weight cycle

1.3 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.

It outputs a matrix □ where □□□ is the shortest distance from node □ to □ .It can detect a negative-weight cycle. It is extremely easy to code and coding time less than a few minutes

Pseudo code for FWA

This pseudo code assumes an input graph of Nvertices.
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])

IV. IMPLEMENTATION OF SHORTEST PATH ALGORITHMS IN THE AREA OFPOWER 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 algorithms are applied to 5 bus system.

Consider two sample 5 bus systems, oneforDijkstra's and BFA(Fig 1), and another for FWA(Fig 2)which has generator in bus 1(Fig 1) and in bus 1 and bus 4 (Fig 2) and the nodal diagram is shown in Fig 3. Here the algorithmsare applied by assuming the weight as the product of branch impedance, and the distance between the generating station and the load.

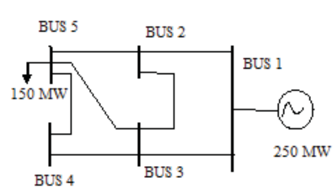

Fig 1

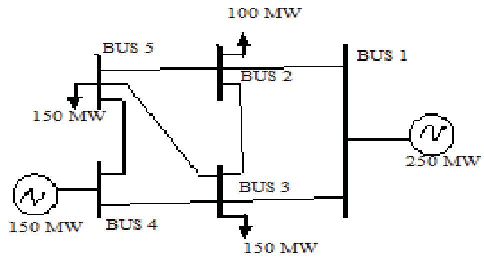

Fig 2

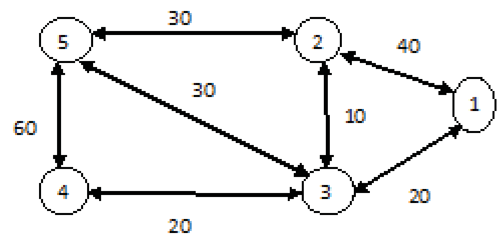

Fig 3

V. RESULTS:

In order to validate all the three algorithms it has been applied to sample 5 bus system. The software is developed in MATLAB for all the three algorithms. The output of the program are shown below one by one:

5.1 Dijkstra's algorithm:

Since Dijkstra's algorithm finds solution in the single pair shortest path problem, we select node 1 as source and node 5 as destination.

Fig 4 shows final shortest path graph using Dijkstra's algorithm and Table-1 shows the Optimal path.

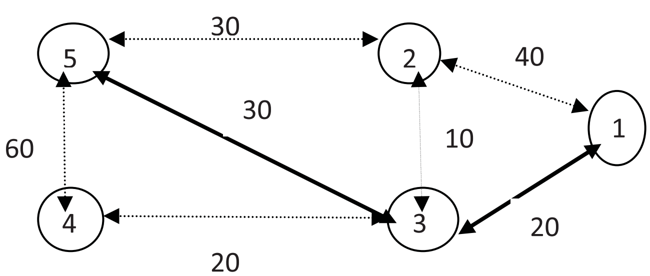

Fig 4

Table-1. Optimal path for the sample 5 bus system using Dijkstra's algorithm

Node		**Optimal Path**	**Total weight**
From	**To**		
1	5	1-3-5	50

5.2Bellman-Ford Algorithm:

SinceBellman-Ford algorithm also finds solution in the single pair shortest path problem, we select node 1 as source and node 5 as destination, the obtained result is shown below:

Destination →	1	2	3	4	5
Total path value →	0	30	20	40	50
Predessor Node →	—	3	1	3	3

Table-2.Optimal path for the sample 5 bus system using BFA

Node		Optimal Path
From	To	
1	5	1-3-5

5.3Floyd Warshall Algorithm:

Since FWA will find the shortest paths between all pair of vertices, we assume node 1 & node 4 as source and all other nodes are destination,the obtained result is shown below:

Table-3.Optimal path for the sample 5 bus system.

Node		Path
From	To	Optimal Path
1	2	1-3-2
1	3	1-3
1	5	1-3-5
4	2	4-3-2
4	3	4-3
4	5	4-3-5

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

VI. 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. Then only the power can be sent through the restorative path. That’s why above mentioned algorithms are appropriate to be used.

Both of these Dijkstra's algorithm and Bellman Ford functions solve the single source shortest path problem. The primary difference in the function of the two algorithms is that Dijkstra's algorithm cannot handle negative edge weights. Bellman-Ford's algorithm can handle some edges with negative weight. It must be remembered, however, that if there is a negative cycle there is no shortest path. FloydWarshall calculates shortest distance between all pairs of nodes.

That’s why Dijkstra’s algorithm and BFA can be used in a network where single source is to be considered. FWA is applicable to a network of any type because it finds shortest path between all pair of nodes present in a network. The software is developed for the execution of optimal path identification in MATLAB.

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