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Power Flow Control and Communication in Autonomous Distribution System using Tie-Set Graph Theory and Johnson's Algorithm

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Abstract

Micro grid distribution system planning is important to ensure that the growing need of electricity is met by the distributors. Planning starts at customer level, Individual power producers (IPPs) are the part of the power management system, as low power generated by the IPPs should reach the consumer through the shortest path in order to reduce the feeder line losses in low voltage distribution networks. Therefore, proper planning of the distribution system is very important to maintain continuity of power. While Planning Distribution System (DSP) the concept of graph theory can be used such that it involves selection of all possible paths through the graph between each pair of vertices. It compares the paths that exist between each pair of vertices until an optimal shortest path between two vertices is achieved. In this work selection of optimal shortest path is obtained using Johnson's Algorithm. Several optimization techniques have been implemented to solve the problem of identification of shortest path. The work presented in this paper is yet another approach to address the same issue. To validate the proposed method, it is implemented on IEEE 8 bus system and simulation carried out using MAT LAB with results obtained for bidirectional power flow.

Keywords: *Autonomous, Distribution Network, Bidirectional Power Flow, Distributed Control, Distributed Generation, Tie- Set Graph Theory, Johnson's Algorithm.*

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INTRODUCTION

In the past, mathematical approach was used for path optimization in distribution system such as branch and bound method, mixed integer programming dynamic programming and geographical information systems (GIS) facilities, which were found effective. Determination of the graph is so common that the term could describe a lot of events and objects of everyday life. The graph theory is, the language of modern discrete mathematics used to address the issue of energy conservation. The applied graph theory is used to rationalize the structure of a given power network along with installed capacity. The graph theory provides the skeleton graph of the shortest path to reduce the transmission losses and hence increase the operational efficiency.

Johnson's algorithm is proposed to obtain the all possible shortest paths among the vertices. This method will provide the information about all the nodes and impedance between the adjacent nodes. Power is transfer between any nodes with shortest distance effectively.

The information and communication technology (ICT) is used to communicate between the each node to ease the power flow amongst the nodes and also smart meter in the consumer premises to record the incoming and outgoing power from each node.

The proposed method is applied in mesh distribution system. Electricity distribution problems are studied in each tie-set focusing on bidirectional power flow in the distribution network. The power flow control is to be done depending on the consumer demand. The IPP are the source of power they produces the power and through shortest path it should reach the consumer.

In this method it provides all possible shortest paths between each nodes and the power transfer depending upon the user requirement. Smart meters and their logical connection in the distribution network provides the information of deficiency and excess of electricity at each point is possible to be recognized by using smart meters as well as have excess electricity can distribute power to the points which requires electric power.

To make all IPP's in one autonomous network and power generated in them is utilized by their consumer, the power flow and control should be in proper way this can be done by tie set graph theory and

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power flow through shortest path between nodes using Johnson's algorithm.

Tie-set graph

The tie set graph theory is discussed on a bi-connected graph, and applicable to a mesh network. The proposed theory is well suited for the autonomous grid. This concept has potential to be applied to future smart grid networks. Application of the tie-set concept in distributed control has two major advantages as follows

Easy Communication: The power flow is to be bi-directionally on a power grid, there is a need to communicate information of such as demand and supplies in a certain unit. Based on loop structures, message passing can be realized within a loop. Therefore, by sending a message in a circle periodically, each node can receive information of other nodes in a loop.

Reduction of Loss: The longer the distance between a point of demand and supply there is more feeder loss, hence to reduce the distribution loss the power flow should be through shortest path. Thus power reduces the power wheeling.

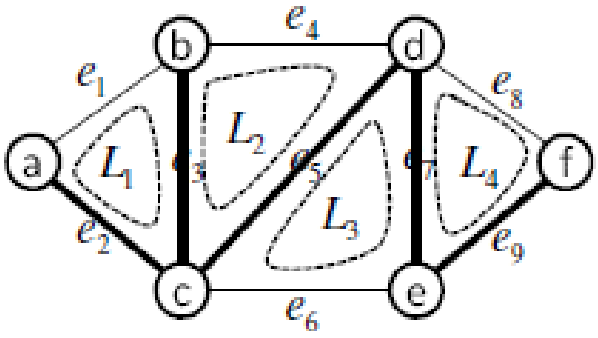


Fig.1 An example of fundamental system of tie-sets

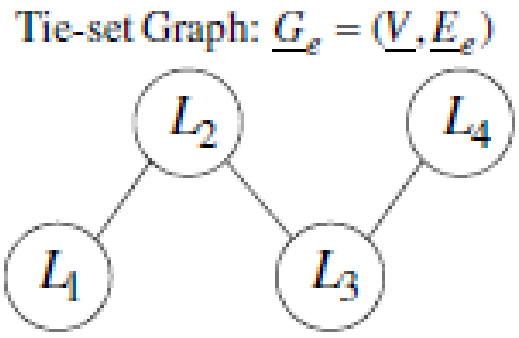


Fig.2. An e- tie-set graph corresponding to tie-set of Fig1

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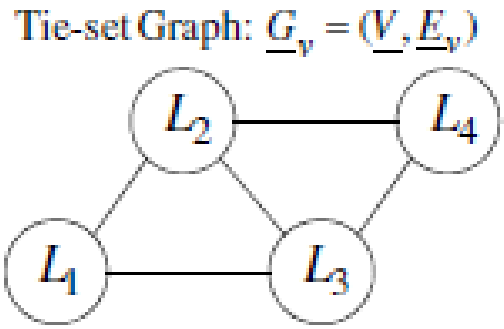


Fig.3. tie-set graph corresponding of tie-set of Fig.1

For a given bi-connected and undirected graph $G = (V,E)$with a set of vertices $V = \{v1, v2, ...,vn\}$ and a set of edges$E = \{e1, e2, ..., em\}$, let $Li = \{ei1, ei2, ..., eik\}$ be a set ofedges which constitutes a loop in G. The set of edges Li is called a ”tie-set” as shown in Fig.1.

Analysis of Tie-set Graph

A graph G = (V, E) is defined as a tie-set graph, where a set of vertices V corresponds to a fundamental system of tie-sets {L1, L2, ...,Lμ}, and a set of edges E corresponds to a set of edges {e(Li, Lj)}, (i _= j), which represent the connections among tie-sets. There are two ways to determine (Li, Lj) by focusing on a relation between two fundamental tie-sets (Li, Lj).

1. E-Tie-set Graph Ge= (V ,Ee): If _(Li, Lj) is determined by the set of common edges of Li and Lj, Ge= (V ,Ee) is denoted as e-tie-set graph as shown in Fig.2
2. V-Tie-set Graph Gv= (V, Ev): If _(Li, Lj) is determined by the set of common vertices of Li and Lj, Gv= (V ,Ev) is denoted as v-tie-set graph as shown in Fig.3. Each fundamental tie-set of a given graph G is uniquely mapped to the specific tie-set graph Ge, and Gv.

The relation among the tie-sets is substituted for E. To avoid discrepancy of information among nodes, Gv is more appropriate than Ge. If procedures are conducted in a certain tie-set, adjacent tie-sets should not conduct any procedures since discrepancy among tie-sets occurs.

After a tie-set Li finishes its procedures, the processor should notify the updated information to each adjacent tie-set Lj defined by a relation of ev (Li, Lj). If a problem which cannot be solved in one tie-set is emerged, the tie-set contacts adjacent tie-sets connected via e ∈ E to seek for aid

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to solve the problem. For instance the shortage of electricity in certain tie-set can be resolved by obtaining power from adjacent tie-sets.

Johnson's algorithm is a graph theory algorithm that identifies the shortest path in a weighted graph with positive or negative edge weights. It assists in determining transitive closure of a relation R. The Johnson's algorithm derives all possible paths through the graph between each pair of vertices. It compares the paths that exist between each pair of vertices until an optimal shortest path between two vertices is achieved.

Problem Definition

The purpose of this research is to save energy in the grid, which will be the optimization of the structure of the electrical network in the power supply system, namely minimizing the distance of power flow in the electric power network system using graph theory.

Using tie set graph theory and Johnson's algorithm to the mesh network in distribution system identifies the all the shortest path between the nodes.

The proposed method is tested on the IEEE 8 bus system with 13 vertices with bi connected network. The simulation is carried out in MAT LAB graph theory functions. The results obtained are graphical representation between the nodes for the shortest distance, line weight matrix, path and its weight.

RESULTS AND DISCUSSION

The proposed method is experimented on the bi connected graph of 8 node 13 vertices with positive line weights indicated on the graph. Each individual node is power producer and consumer.

Figure 4 shows the bi connected undirected graph with line weight. Figure 5 shows the simulated bi connected oriented graph with lines weights indicated on it.

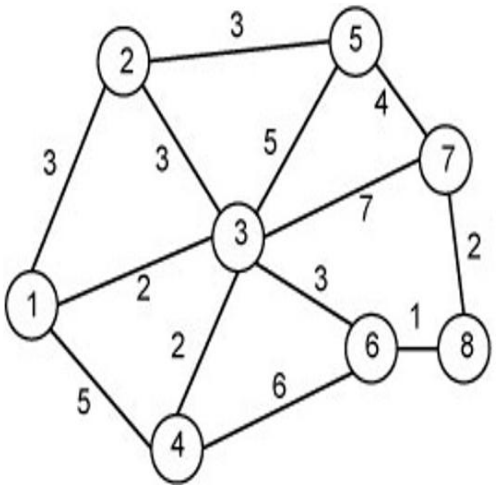


Fig.4. bi connected graph

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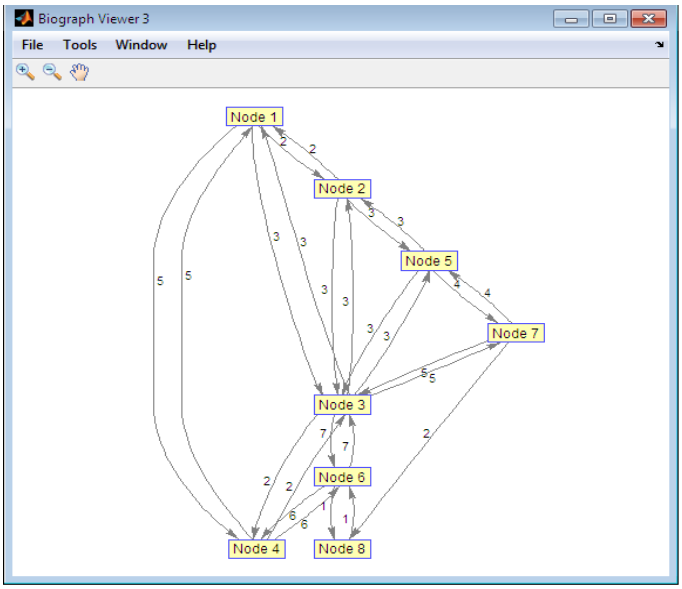


Fig.5 simulated bi connected graph

The simulation result consists of the shortest path with all possible paths between the node with their lines weight and path. The Fig.6 show power flow between node 1 to 6 and node 6 to 1 with line weight and path. This simulation shows that the power flow will be in either direction with same path of shortest alternative path. The Fig.10 shows simulated graph of power flow between node 1 to 7. The Fig.12 shows the power flow from node 7 to 1 through same path or the shortest alternative path with their line weights and path.

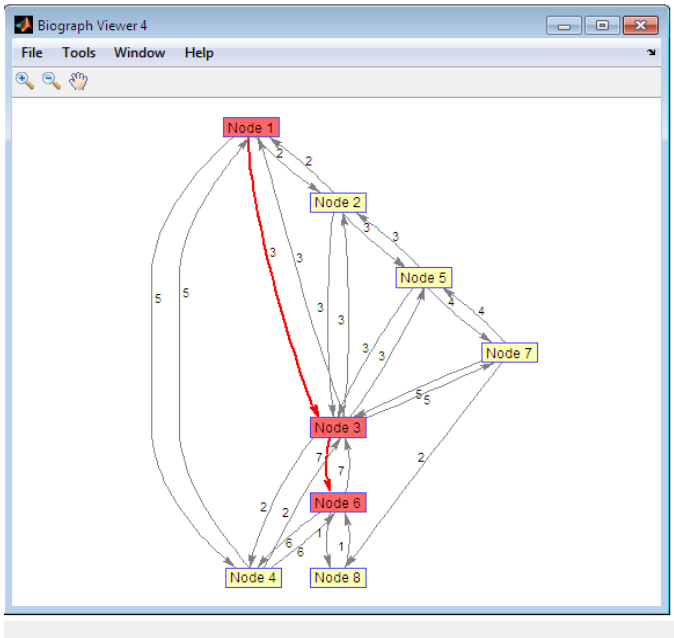


Fig.6 simulated shorest path between 1 to 6

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```
ans =

     0     2     3     5     5    10     8    11
     2     0     3     5     3    10     7    11
     3     3     0     2     3     7     5     8
     5     5     2     0     5     6     7     7
     5     3     3     5     0    10     4    11
    10    10     7     6    10     0    12     1
     8     7     5     7     4    12     0    13
    11    11     8     7    11     1    13     0


dist =

    10


path =

     1     3     6
```

Fig.7 line weight matirx, distance & path

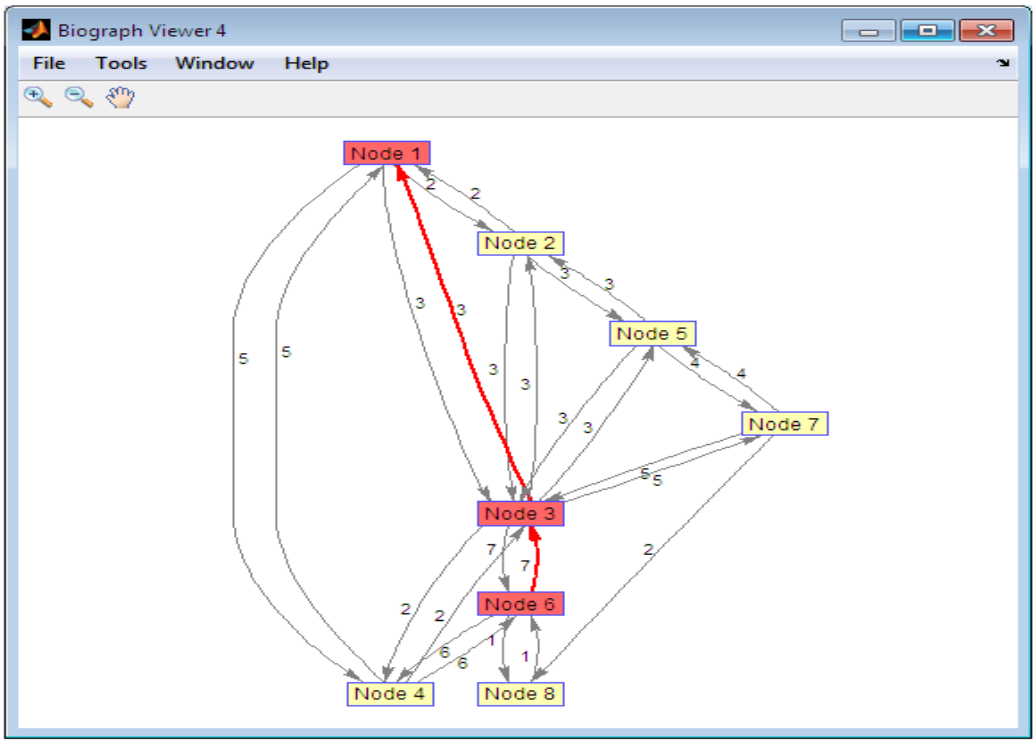


Fig.8 simulated shorest path between 6 to 1

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```
ans =

     0     2     3     5     5    10     8    11
     2     0     3     5     3    10     7    11
     3     3     0     2     3     7     5     8
     5     5     2     0     5     6     7     7
     5     3     3     5     0    10     4    11
    10    10     7     6    10     0    12     1
     8     7     5     7     4    12     0    13
    11    11     8     7    11     1    13     0


dist =

    10


path =

     6     3     1
```

Fig.9 line weight matirx, distance & path

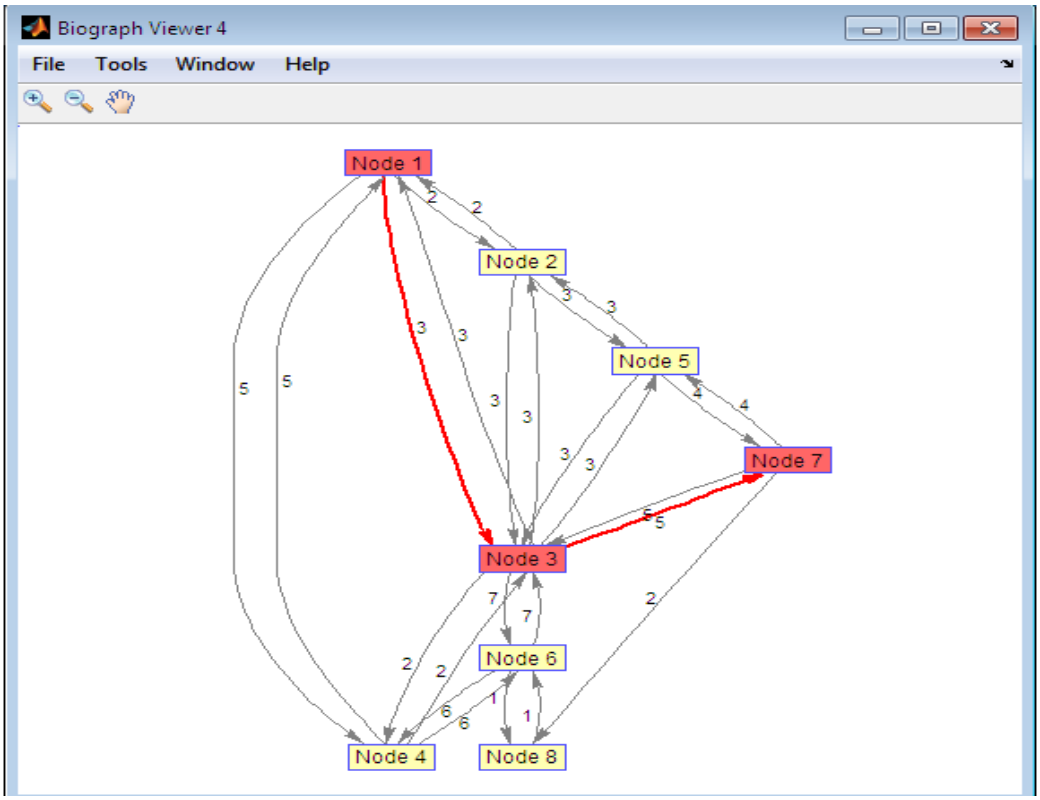


Fig.10 simulated shorest path between 1 to 7

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```
ans =

     0     2     3     5     5    10     8    11
     2     0     3     5     3    10     7    11
     3     3     0     2     3     7     5     8
     5     5     2     0     5     6     7     7
     5     3     3     5     0    10     4    11
    10    10     7     6    10     0    12     1
     8     7     5     7     4    12     0    13
    11    11     8     7    11     1    13     0


dist =

     8


path =

     1     3     7
```

Fig.11 line weight matirx, distance & path

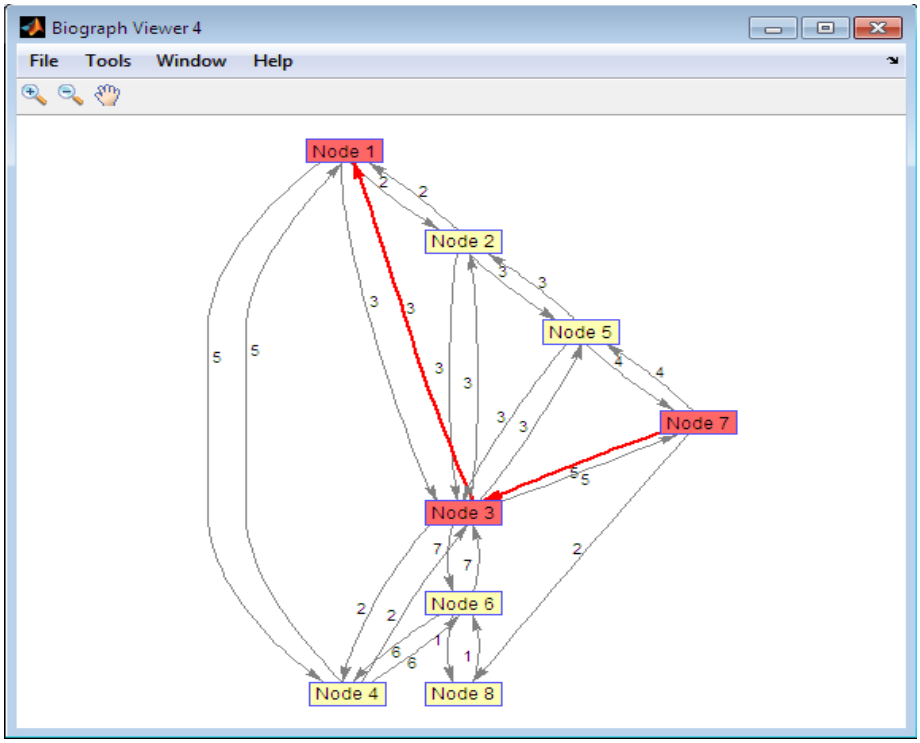


Fig.12 simulated shorest path between 7 to 1

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```
ans =

     0     2     3     5     5    10     8    11
     2     0     3     5     3    10     7    11
     3     3     0     2     3     7     5     8
     5     5     2     0     5     6     7     7
     5     3     3     5     0    10     4    11
    10    10     7     6    10     0    12     1
     8     7     5     7     4    12     0    13
    11    11     8     7    11     1    13     0

dist =

     8

path =

     7     3     1
```

Fig.13 line weight matirx, distance & path

Table.1. Simulation Results

Nodes	Power flow Paths	Distance between nodes
1to 8	1-2-7-8	10
8 to 1	8-6-3-1	11
2to 6	2-3-6	10
6to 2	6-3-2	10
2 to 7	2-5-7-8	9
7to 2	8-6-3-2	11
….	…	…

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CONCLUSION

This paper presents tie set graph theory and Johnson's algorithm applied to bi connected mesh network with autonomous operated grid with distributed generation. The power flow in the network which is generated by the IPP's should flow through the shortest path. This proposed method provides all the possible shortest paths between the nodes. The simulation is carried out on bi connected graph of 8 node and 13 vertices. The power flow will be in either direction with same path of shortest alternative path with their lines weights and path. The Johnson's algorithm gives the shortest paths between all the nodes in graph in the form of matrix.

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