Dynamic Reconfiguration of EPCM Network Based on Minimum Connected Dominated Set

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ABSTRACT

Due to the inherent complexity of electric power systems, power plants and electrical equipment require more and more complex electric power management strategy to ensure adequate system performance and reliability. But traditional Electric Power Communication Management Network (EPCM Network) uses static, fixed network management model, resulting in a number of difficulties in practice. For example, bandwidth, distance, network security and scalability are key issues. The paper uses minimum connected dominated set to extract out key node from EPCM Network, dynamic forming "backbone network", then according to specific network structure of EPCM Network, optimal routing in EPCM Network is adjusted and deployed by shortest path algorithm. When it comes to irresistible natural disasters, "backbone network" can be reconstructed to achieve efficient and reliable management.

INTRODUCTION

Electric power systems is the modern basis for the development of the national economy, while Electric Power Communications Management Network (EPCM Network) is the guarantee of electric power systems, is intelligent core in electric power systems, therefore is an extremely important part of electric power systems. Management of electric power systems is done by hand in the past, and quality service is relying on expert. But along with a complex network structure, power companies are obliged to boost control over electric power systems. Therefore, it is necessary to take full advantage of EPCM Network, which is a convenient, fast and accurate network system, thus improving quality service and production efficiency of electric power systems. EPCM Network should have the following basic functions: a high reliability, real-time, and automatic response to emergencies in a timely manner. And, EPCM Network is dispersed, such as the substation is located...
in a remote area. Due to historical reasons, EPCM Network have to use complex interface specification and different communications protocols to connect separately, resulting in the complexity of the network structure. When some unexpected reasons for electric power plants, electric power equipment, and electric power monitoring, EPCM Network should be able to withstand these risks accidents and withstand external shocks. When there is a natural disasters which cannot be resisted by human resources, EPCM Network should be capable of supporting the use of emergency stand-by means [1].

The paper proposes a distributed hierarchical EPCM Network, which use minimum connected dominated set to extraction out key nodes from EPCM Network, and then shortest path algorithm is used to deploy optimal routing in EPCM Network, thus reaching efficient and reliable management.

HIERARCHICAL EPCM NETWORK BASED ON THE "BACKBONE NETWORK"

With ideology represented by the cellular phone system with wireless network infrastructure, the concept of "backbone network" is introduced in EPCM Network, which can effectively solve technical challenges in EPCM Network, and improve network performance.

Using the concept in graph theory, dominating set acts as key nodes in EPCM Network. Dominating set has the following properties: either all nodes in the network are belonging to the dominating set, or at least with a node of dominant set is connected by edges (that is, within the communication range of each other). If all the nodes in a dominating set are connected, which is called a connected dominating set [2]. Usually evaluation indices are size of connected dominating set, network diameter of connected dominating set, average number of hops of connected dominating sets and complexities [3]. Because only routing information of nodes in the connected dominating set need to be maintained, routing entries are reduced. So from the point of view, smaller connected dominating set is, the "backbone" is the higher efficiency.

Figure 1 shows a "backbone network" of EPCM Network with 6 nodes. \{1,2,3,6\} and \{4,5\} was dominating set, and \{4,5\} is a connected dominating set. Because \{4,5\} includes a minimum of nodes, it is also the minimum connected dominating set.

OPTIMAL ROUTING IN "BACKBONE NETWORK"

Various types of data in EPCM Network have different QOS performance requirements, [4] noted that data in smart electric power communications can be divided into: real-time operational communication data, management communication data. Specification of China electric power industry [5,6] divides data into remote control data, remote adjustment data, remote data, and telemetry data. It can be seen that data transmission in real-time is key in EPCM Network.
As shown in Figure 2, due to the nature of the dominating set, all nodes in the network either are belonging to dominating set, or at least with a node in dominant set is connected by edges, therefore nodes in EPCM Network is directly connected with dominating set. In consequence routing problem of "backbone network" just needs to be optimized.

Under normal circumstances, connected dominating set of size is smaller, meaning less number of nodes involved in network management, with greater network efficiency. So a minimum connected dominating set is expected as "backbone network". Secondly, the routing protocol is responsible for data packets forwarded through the network from the source node to the destination node, as shown in Figure 3. According to the characteristics of real-time network, an undirected graph G(\(v, e\)) is used as a description of "backbone network". \(v\) and \(e\) represent a set of nodes and a set of links in "backbone network". 1,2,3,4,5 nodes form the "backbone network". \(L(e)\) is hop count of relays for the link \(e\) (node \(x\) to node \(y\)). Path \((a, b)\) is the path from the source node to the destination node. In this way, route optimization of “backbone network” is to find a routing tree in the network, which meets:

\[
J = \min \sum_{e \in \text{path}(a,b)} L(e)
\]

Optimization objective is to achieve minimized hop count of relays between the source node \(a\) and target \(b\) effective when communication. Due to the structure of "backbone network" in a hierarchical EPCM Network, all the collected information should be summarized into a management centre and all SNMP or TMN management commands are issued from the management centre, so a network infrastructure with multiple source nodes and a destination node is used. Dijkstra has proposed a classical algorithm for solving the shortest path for the network structures [7].

Figure 1. EPCM Network based on "backbone network".

Figure 2. Routing based on "backbone network".
OPTIMAL ROUTING IN EPCM NETWORK

The paper proposes an algorithm on hierarchical EPCM Network based on "backbone network", which can guarantee the service quality of EPCM Network. Therefore it is of great significance for the practical application of the intelligent EPCM Network.

Algorithm is as follows:
Step 1: Use an undirected graph $G(v, e)$ to describe the existing EPCM Network. $v$ and $e$ represent the nodes in the network set and link set.
Step 2: Based on a algorithm on minimum connected dominating set in graph theory presented by Wang Lingmin in 2016[8], extract key nodes in EPCM Network to form a "backbone network". The algorithm is reasonable narrow the scope of the search to improve search efficiency, thus reducing the computation time.
Step 3: Use Dijkstra algorithm to calculate the shortest path as the optimal route.
Step 4: Due to some unexpected reason, when manipulated structure of EPCM Network changes, start from step 1 again, forming a new optimized structure of EPCM Network.

TYPICAL APPLICATIONS

Beginning of July 2015, the China State Council issued a circular on promoting "Internet +" action guidelines with 11 actions. "Internet +" and smart energy is one of it[9]. Firstly, "Internet +" is infrastructure. On its basis, by the use of information and communication technology to connect all nodes, various Internet applications come to being. At present, EPCM Network in China has developed various communication technologies, and optical communication has become the main way of communication. With continuous improvement of optical communications, optical communication technology has been widely used in EPCM Network, and effectively solves the problem of network interconnection of EPCM Network, therefore the infrastructure is completed, as shown in Figure 4. Now, EPCM Network usually has a wealth of Internet resources, so "backbone network" can be quickly found by this algorithm, achieving the optimal routing. larger networks is, the more complex network structures is, its advantages is more obvious, which can effectively solves the problem of large-scale EPCM Network.
CONCLUSIONS

Large-scale complex EPCM Network is hot spot nowadays. Clearly, hierarchical network management is the only choice for optimization, but how layered to better satisfy the real-time network performance, reliability and scalability and dynamic reconfiguration of network with an unexpected failure is a huge challenge. This paper uses minimum dominating set algorithm to form "backbone network" for dynamic layers of EPCM Network. And the optimal routing of the network is achieved by Dijkstra algorithms, ultimately ensuring the timeliness and reliability of the network. When EPCM Network changes due to unexpected failures, the algorithm can be iterated to find new "backbone network", to find a new optimal routing.

REFERENCES