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Using Smart System to Improve Electric Power Grid

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Abstract. Currently, the electricity infrastructure has remained for a long time, while the demand of electricity is increasing. Smart systems could be employed to improve the performance of electric power grid and reduce the . Especially, the communication technology and optimization technology of smart systems are able to enhance the reliability, stabilization and efficiency of the grid. In this paper, several different communication and optimization technologies are compared and analysed. Finally, the summary is obtained of the utilization of smart systems in order to improve the electric power grid.

Introduction

The current electricity infrastructure has remained unchanged for a long time. According to the U.S. Department of Energy report, the demand and consumption for electricity in U.S. have increased by 2.5% annually over last 20 years [1]. China, as a biggest developing county in the world, is developing rapidly with the large demand of electricity. At the same time, the China government proposed a new concept called *Beautiful China* [2], which means China government will continually develop environment protection and renewable energy. For the diversified electricity generations, transmissions and gird-connected, the smart systems are suitable to be employed in the electric power grid.

Smart systems are defined as intelligence devices that incorporate functions of communication, sensing, actuation, control and optimization [3].Among these functions, communication technology and the optimization technology could play an important role for improve the reliability and stabilization of electric power grid, while the optimization technology can help the grid improve the efficiency and reduce the cost of grid [4].

This paper analyses different kinds of communication technology and different optimization algorithms. Through the analysis of each technology,. The communication technologies and the scenarios are described as important part and the optimization technologies and the applications are investigated as a way for fast and economic operating way.

Communication technologies used in electric power grid

In general smart system, communication technology might be the most fundamental component. Communications exist in almost every smart process, which can be used for signal transmission and data exchange. In a small-scale and simplex smart system, the central processor should utilize the parallel and serial interfaces to access the data with memory, sensors, I/O devices and other components [5]. On the other hand, in a synthetical and complex smart system with numbers of simplex distributed parts, bus and network technologies are widely used for intersystem communications and control signal transmission.

Electric power grid is a typical synthetical system. Currently, in China the power grid system is stepping into the stage of smart grid [6]. Through using communications, the smart grid could be more efficiency, more reliability and more safety. For instance, the suppliers tend to adjust the distribution and quantity of electricity by referring to the feedbacks of customers and loads with the information received from the customer and load nodes. In addition, this feedbacks sometimes created by the smart systems located in the customer and load nodes automatically without operating of people.

When classified by the media, the communication used in smart grid could be roughly divided into three different methods, which are wired communication, wireless communication and powerline communication [7]. In the following sub-section, these three methods would be discussed:

A. Wired communication

Wired communication technologies are widely in the field bus, internet and local area network (LAN). The media materials are usually optics fiber and copper-wires. Wired bus technology could be utilized in the mid-distance communication. Without using the switchers and routers, the real-time performance of field bus technology is usually better than the network technology [8]. However, bus technology is not suitable for large number of data transmission. For example, the typical transmissions speed of CAN bus is 5 kbps at the 10km distance, while the LAN speed is typically 100Mbps with using the switchers [9].

No matter what kinds of wired communication technologies, there are many command advantages, such as stability, anti-interference, high communication rate, long-distance etc. Therefore, the backbone networks are built with wired communication, especially optics-fiber communication.

The disadvantages of wired communication are also obvious. The cost of copper-wires is very high. Moreover the network structures are limited by the geography and position. Therefore the structure sand topologies are usually inflexible.

In grid systems, the utilizations of wired communication would increase the stability and reliability, while the construction cost of grid will rise up due to the wires, fiber and the communication devices.

B. Wireless communication

With the recent developing of wireless communication, it could supply the standardized methods for wide area, metropolitan area, local area and personal area networks [10]. In the last two decades, a number of standardize wireless technologies are developed, such as IEEE 802.11 based wireless LAN , IEEE 802.16 based WiMAX, IEEE 802.15 base ZigBee etc. [10]. Each of the wireless communication is suitable in different application scenario.

Wireless LAN (WLAN) based on the IEEE 802.11 is popular currently, which can support robust and high-speed node-to-node and node-to-multipoint communication. Based on the spread spectrum technology, a quantity of users could occupy the same frequency with a smallest interference to each other. IEEE 802.11 b/g/n works on the 2.4GHz frequency band, while 5.8GHz frequency band is adopted with IEEE 802.11g. The data rate of these four standards range from 11Mbps up to 600Mbps. In recent years, many new schemes are presented and the WLAN technologies are more mature. Due to the high frequency band and the low transmit power, the communication distance is limited without using repeater [11]. Therefore, according to the feature of WLAN, it is much suitable for the scenario which needs to transmit a great deal of data in a near distance. In the applications of smart grid, the WLAN could be used for system protections and controlling and monitoring.

WiMAX technology based on IEEE 802.16 is another wireless communication technology, which support much longer distance and higher transmit power. The frequency bands of WiMAX are usually 2.3GHz, 2.5GHz, 3.5GHz and 5.8GHz.WiMAX is suitable for smart meter technologies.

There are several problems in these two technologies used in grid systems. First, the current and the voltage of power line are especially high. So the wireless systems could be probably affected by the electro-magnetic. Second, as WLAN devices are very popular, the security of data could be hardly guaranteed. Moreover, the frequency bands of these two technologies are public frequency bands. It is probably affected by other wireless devices.

To solve these two problem, the advanced encode and encrypt technologies should be used in the WLAN communication [12].

ZigBee is a low power, low-cost and reliable home area wireless network technology based on IEEE 802.15.4. The frequency bands are 868MHz, 915MHz and 2.4GHz [13]. The data rate is from 20 to 200 Kbps, while the communication distance could be 100m. ZigBee devices are able to organize the network topology with different forms by using the protocol stack technology. For security aspect, the 128-bit AES encryption is employed in ZigBee. Currently, ZigBee technology is widely used in the area of Network of Things, which is developed rapidly in China. In smart grid systems, the ZigBee technology could be utilized into the application of home power or devices control.

From the above, due to the flexibility and the easy arrangement, the wireless communication could be diffusely employed in the smart grid systems. Some new encode, encrypt and fault-tolerant would be used to improve the performance of wireless technology to make it better in utilization of power grid.

C. Powerline communication

Powerline communication (PLC) transmits the data and signal with the original powerline. Therefore, there is no cost of new cables or wireless devices. It is seemed that the powerline based communication is a good solution of grid communication. However, it is difficult to guarantee the reliability of the PLC. In this area, new methods are presented recently. In the reference [14], a combination of Narrowband PLC and Broadband PLC is proposed to be used as communication infrastructure for smart grid system, in which the OFDM modulation is applied to make this method possible for stable communication.

With the advanced modulation-demodulation technologies, the PLC might become a suitable method for communication of each node in grid systems though PLC is not a new technology, which was presented in approximately 1920s [15].

From the analysis of above wired, wireless and PLC technologies, each technology has the relevant scenario. When the scenario, geography and cost are considered, the best method could be selected from comparing each method and technology. For improving performance of each technology used in smart grid, some new mathematics methods and advanced electronic devices could be used into this area.

Optimizations used in electric power grid

In electric grid system, there are a great number of generators, transmission line and loads. In each part of them, the parameters such as active power, reactive power, voltage and current need to be monitored [16]. Optimization technology, an important part of smart systems, plays a significant role in reducing the number of measurement devices and improving the efficiency in electric grid.

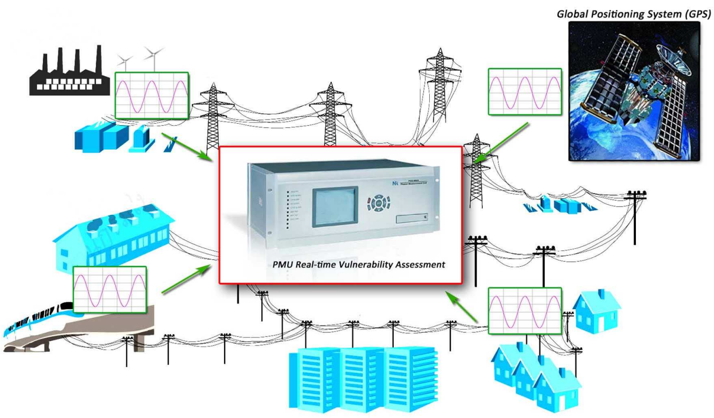

Fig 1. The description of PMU function

Phasor Measurement Unit (PMU) is a digital device which can measure the magnitude and phase angles of currents and voltages in a power grid [17]. By using the for clock synchronization, it is possible to measure the phase between corresponding phasors in different positions in the grid, shown in Fig.1. Therefore, PMU is a powerful tool for monitoring and analyzing power system dynamics. Because of the reason of the cost of PMU devices and cost of manufacturing, it is necessary to the optimize numbers and locations of PMUs in the grid.

The purpose of minimum PMU locations is to minimize the number of PMUs and at the same time, to guarantee the topologically observability of the system during the normal operation and following any single-line contingency. This objective is described by following mathematical module:

$$\begin{cases} \min\limits_{x \in R} \{N, -S\} \\ \text{Subject to } M = 0 \end{cases} \quad (1),$$

where the N is the total number of PMU, the S is the number of observable bus following and single-line outage and the M is the number of unobservable buses. Due to the two optimization objectives, this is a typical multi-criteria problem. Therefore, it is impossible to find the exact solution by using the polynomial algorithm.

Meta heuristics technologies could be applied to solve this multi-criteria problem. There are several kinds of Meta heuristics technologies, such as simulated annealing, genetic algorithm, tabu search, adaptive clonal algorithm and ant colony algorithm [18]. The genetic algorithm uses the techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover. This algorithm is robust and can deal successfully with a large range of problems, including some problems which are difficult for other methods to solve. Tabu search is superior to other Meta heuristics methods such as simulated annealing, genetic algorithm.

Tabu search is developed in the 1980s by Fred Glover [19], which is an improved method of local search. Tabu search enhances the performance of local search technologies by using memory structures that describe the visited solutions or user-provided sets of rules. In tabu search, there are five key concepts to guarantee the performance of optimization, which are neighborhood, tabu list, tabu length, candidate and aspiration criterion. Neighborhood is a set that is associated by each solution, where each improved solution comes from. For generating the neighborhood set, the regular called neighborhood map should be considered. With this neighborhood map, the neighborhood could be obtained from the current solution. Tabu list marks the visited solutions to avoid the repeat calculation, which is the most significant factor of tabu search. Tabu length is the length of tabu list and the candidate is the located best candidate. With the mechanism of aspiration criterion, the visited best solution could be considered again for search new best solution.

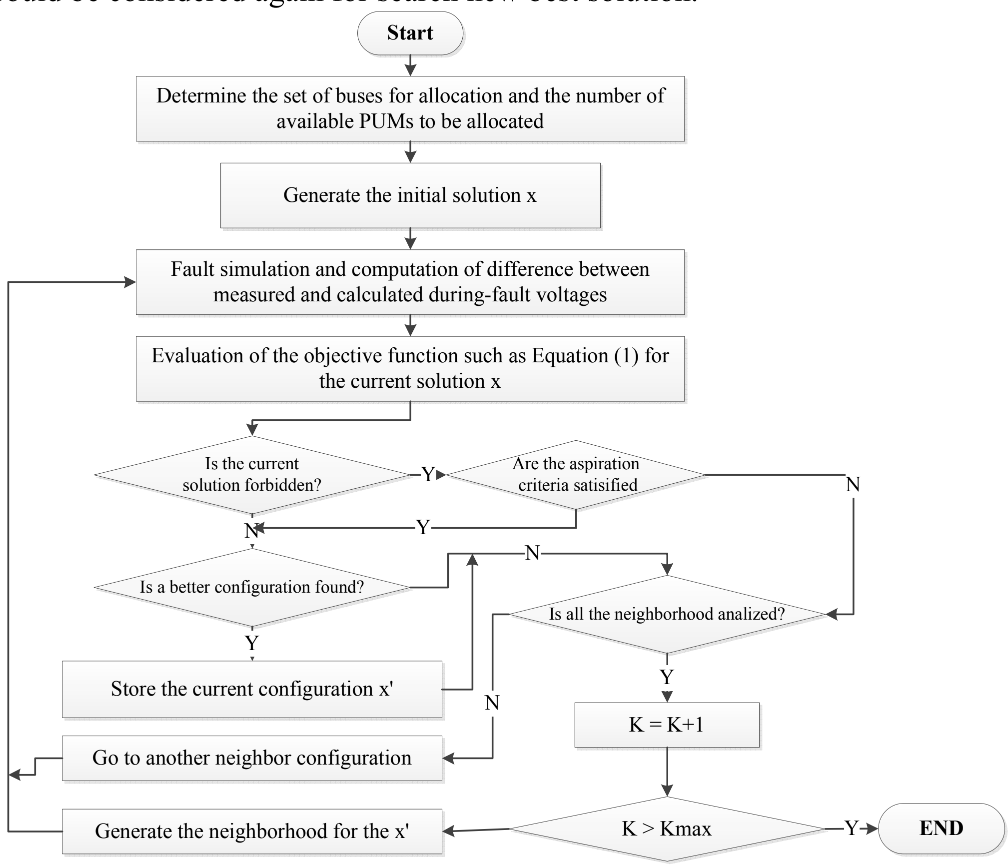

Fig 2. The flow chart of the tabu algorithm used in optimization of PMU location

With this program processing showed in Fig.2, the reference [20] gives us the optimization result in Table 1.

Table 1 The result of optimization of PMU location [20]

PMU available number	Bus number where should be allocated the PMUs				Fault
1	139				6.0
2	140	141			4.0
3	43	107	140		2.0
4	21	31	43	107	0.0

The above example describes the function of optimization used in the electric grid. With the optimization, the number of PMU decrease and the location of PMU are also reasonable.

Conclusion

With the developing of economic and society, the electric grid system is playing an increasingly vital role. In China, the distribution of energy resource is not reasonable, which means the efficiency and stability of electric grid system is more important than that of other countries. In recent years, the smart systems are springing up based on advanced electronic technologies. Among the technologies of smart systems, the communication technology and smart optimization technology are more useful to solve the fundamental problems. In this paper, the different technologies of communication are compared with each other when considering the application scenario, while a typical optimization technology named tabu search prove that the optimization could reduce the cost and improve the efficiency. When we use these technologies, the application scenario should be considered first. After that, the cost and the Construction difficulty should also be thought over. In the further ten years, with the concept of *Beautiful China* which proposed in the 18th congress of the communist party of China, the renewable energy must have a great development in China. As a consequence, the smart systems would be used to resolve many problems of smart grid systems.

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