Communication technology in the application of the smart grid

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Abstract

By studying the significance of the smart grid, combined with a regional substation point location, line conditions, existing and future business development, existing communications equipment status, etc., the author initially sets the smart grid communications infrastructure deployment and network planning, in order to use the most reasonable communication technologies to support rapid development of smart grid. In a certain city with electric power communication network to the actual construction goal, we should complete the city power system communication network covering the whole deployment. At the same time combined with network energy efficiency project, we should analyse the already formed network, provide effective optimization model of energy efficiency and practical algorithm, and analyse its rationality through the simulation analysis, further improve the overall network in order to make it efficient to run.

Keywords: Smart grid, Data network, Network energy efficiency, Energy efficient routing strategy

1 The meaning of the smart grid communication network construction

The smart grid is the high integration of traditional electric power industry and the information communication. It will become a comprehensive configuration platform of energy and information, makes the grid infrastructure in a larger scope, and serves the society in more ways. Among them, intelligent power grid transformation is supported by information and communication technology, based on intelligent control means, covering all aspects of power grid. We should improve its informatization, automation, interactive level in order to meet the demand for electricity on the basis of economic and social development and people's lives.

Electric power communication network is an important part of strong smart grid. With the continuous development of smart grid technologies, the business application system has been improved gradually, and higher requirements on the network bandwidth and reliability etc. are put forward. Communication network is an important component of the electric power communication network platform and is an extension of the electric power communication network backbone. However, because of its wide coverage, multiple nodes, difficult construction and other reasons, it has been lack of applicable communication technology and construction mode for the electric power communication network, and has become the bottle neck restricting the application and development of electricity business (see, e.g. [1-3]). Power communication network is an important foundation to promote the intelligent power grid construction, protection grid production, operation, management and supply services. Because the units unable to fully grasp the modern communication technology and the development trend, there are many problems in the construction of electric power communication network and in grasping the technical direction in the current and different regional electric power communication network construction mode, the level of equipment, as well as the application effect are different; Companies generally do not pay attention to the choice of communication technology and network, the work way of thinking is not clear, communication network construction is lack of system planning, the cost of construction and operation is high, the input and output does not match, the overall level of communication network lag behind the development requirements; Some companies hire public network channel resources to transport important business information, which will bring risks to the power grid operation and management services. All of these were not adapted to the development of strong smart grid, to strengthen and perfect the construction of electric power communication network is very urgent.

For carrying out the future development of power grid planning and the future development of the communication network planning to China State Grid Corp, to meet the needs of smart grid construction, the ability of supporting construction should be focused and improved, the backbone communication network will be extended to the 66 kV side, and the construction of communication network should be further strengthen. As an important part of communication network, the electric power communication network, need to change the traditional mode of development, accelerating the pace of construction and upgrading, efforts to solve the influence and restriction of power automation communication

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problems, and the intelligent application of management information system, and provide important technical support to improve the power grid safe and economic operation level and the management level of enterprises.

Because the characteristics of the network is flexible, chain network, tree network, star network, ring network, hand in hand net basic network, and the combination of network by any of these basic network structure can be formed. The use of passive optical network can be based entirely on a grid structure for low-voltage networking communications network, and once with the low-voltage grid structure adjustment to achieve rapid adjustment of the communication network. Passive optical network having a multi-node failure characteristic, the passive optical network communication terminal of any one failure will not affect the normal operation of other communication terminals. It is much in line with large communication terminal distribution automation, information collection requirements on the reliability of communication. Passive optical network technology in China Telecom has been running for many years and there are many manufacturers to provide equipment and technical support. Passive Optical Network in Power Line Communication as a relatively new technology in the power system pilot cities have been widely used, and achieved good results.

2 Access network planning and research

Smart grid access network communication network construction is the construction of distribution network, considering the PON access technology has been widely used in the operator access networks, the smart grid access network side (i.e. distribution communication network side) of PON access will be focused research.

In the distribution network, the communication backbone layer distribution master station to the substation used SDH backbone optical transmission network which has been built. In access layer, substation to ring network cabinet, column switch and other automated information collection site selected access scheme in EPON optical fibre network technology. EPON communication is based on the network structure of hand in hand, and it support dual OLT uplink mode and support for 1 + 1 and 1:1 protection way.

1) OLT equipment is installed in the substation, interconnected existing SDH transmission devices via GE or FE, completing the distribution information to the master transfers. OLT support EPON/GPON platform, support 10G GE, STM-1, E1 and other upstream, to facilitate future expansion application and cost savings. It also supports dual master control, dual power supply and the uplink port redundancy backup, to ensure the system security.

2) The ONU equipment is installed in the information collection points to achieve related equipment information uploaded to the substation. ONU devices use double PON port equipment to achieve full protection self-healing, using industrial grade equipment, case closed, aluminium material. It's surface without holes to prevent water leakage accident. It support environment temperature -40 degrees to +85 degrees to meet the operating environment more hostile scene. It also support AC, DC power supply, DC power supply support adaptive 9V~60V. Convenient installation and maintenance, saving the spare parts and saving investment are the main features of ONU equipment.

3) The logical table of telecommunication system in electric is shown in Fig. 1.

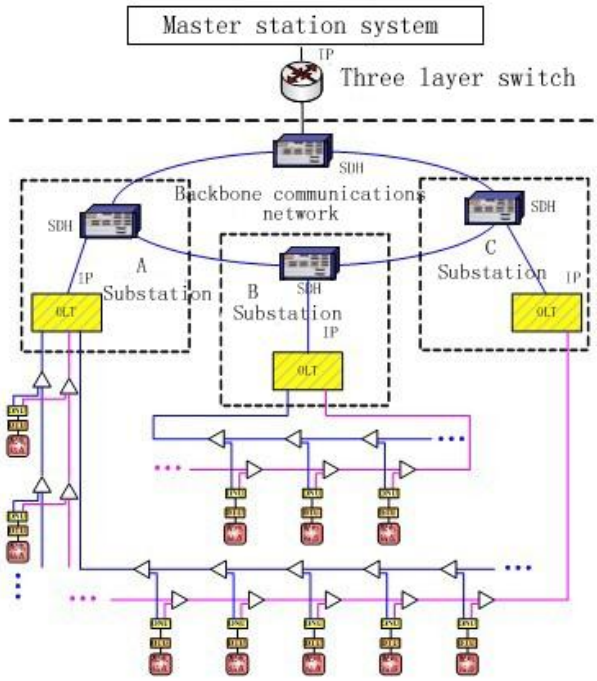

FIGURE 1 Logical table of telecommunication system in electric

Now combined distribution network characteristics and advantages of PON network, EPON network deployment recommendations are summarized as follows:

Suggestions for the development of OLT

1) OLT location and coverage area

According to coverage, select the appropriate room. Urban areas of OLT coverage should be controlled within 5 km, rural area can be properly extended to 10 km.

2) OLT configuration recommendations

In the end, the installation of OLT equipment should be used in large capacity and OLT rack mounted equipment. The OLT equipment deployed in the module Bureau and the access point should be based on the final number of users to select the appropriate capacity equipment and should be appropriate use fixed port OLT devices with small capacity. OLT equipment should have at least two GE port, which with the increase of users. We should increase the port GE as the user speed gradually, and ensure OLT port has at least one backup GE.

Suggestions for the development of ODN [4]

1) How to set the beam splitter position

City area splitter position should mainly adopt the centralized placement, set in the area of optical node,

such as small room, small roadside or corridor in order to improve the trunk fibre utilization rate and try to avoid placing OLT and the splitter in the same end office room. Rural area splitter position can be flexibly placed in the township end office, cable transfer box or optical cable connector box etc. according to the actual situation.

2) How to choose the beam splitter

POS (Passive Optical Splitter) optical branching ratio should be used 1:2, 1:4, 1:8, 1:16, 1:32 the five common types according to the selection, the number of broadband users of one PON port should not be more than 512. The 2: N optical splitter can be used in the case there is a need of protection. The PLC (Planar Light wave Circuit) splitter should be the main choice in current. In the low branching ratio (1:2, 1:4) situation based on the cost we may be appropriate to consider the use of FBT (Fused Bi-conical Tap) type optical splitter.

The total splitting ratio of ODN should be determined according to the users' requirements, the optical link bandwidth attenuation factors and other factors. Single-stage method should be mainly used in the urban area and the rural areas. Multistage method can be used based on the multistage light cable resources and village distribution, but it should be controlled in three stages.

Suggestions for the development of ONU

In the network construction, enterprises should select different types of ONU according to the users' needs, but they should control total types, avoiding excessive ONU models in the access network. Products, which can replace the port of PON module, should be select. The ratio of broadband and narrowband users should be considered, so enterprises should try to choose products that can be flexibly adjusted ratio. For the ONU supported the type of DSL, consideration should be given to the board and the general DSLAM network equipment in order to use network to adjust the DSL card.

Suggestions for the development of network management system

A unified PON network management system should be established while in the PON network. The system should support for OLT and ONU configuration, fault, performance, security and other management functions, and requires an ONU that can support automatic discovery. Through the development of connecting single system, service system and accounting system interface, it can gradually complete the job automatically accepted, business automatic opening function. The PON management should be incorporated into the integrated network management system that already has broadband data integrated network management system.

3 The construction of the access network

Access network construction combined with SDH transmission ring network can provide network load for the automation system of smart grid. The sub regional centre and the 66 kV substation have been built the SDH loop network, so the OLT can through the Ethernet port access SDH transmission equipment in substation. When connected to the FE electrical interface in the same SDH, the OLT can automatic or manually turn its rate to one Mbps.

The network of the telecommunication backbone is shown in Fig. 2.

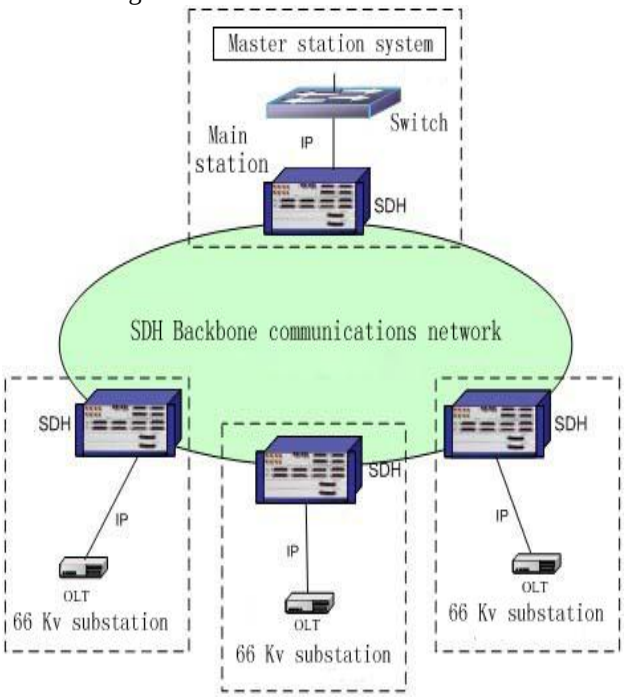

FIGURE 2 The network of telecommunication backbone

A three layer of Ethernet switches was placed in the centre of the network to gather all the data of distribution automation from each substation. Taking into account the future network communication system with numerous communication terminal equipment carried by each substation, isolation and stratification can be achieved through the three layer routing.

Considering the redundancy and other factors, each 10 kV line needs 24 core cables, 16 cores used to transmit distribution information, 8 cores used to transmit electricity information. Fibre optic cable is interrupted and fused in a set of light distribution which installed on each ring network cabinet (or switch on the pillars), and then connect it to the ONU equipment of the distribution station through a splitter pigtail.

All information collection points involve in the project adopt the fibre EPON communications system and use the ONU with double PON ports as information collection terminals. Routings use the "hand in hand" type of protection way combined with the actual trend of distribution lines in the selected area.

The hand-in-hand two-point structure of EPON as shown in Fig. 3, OLT1 and OLT2 were installed in the different substation and the ONU equipment were installed in each information collection point. When the cable break or individual OLT equipment fail to work, the ONU equipment can select different access point to connect the OLT in order to protect the system.

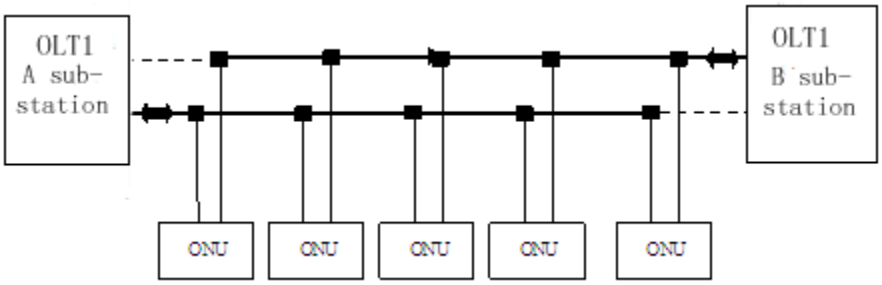

FIGURE 3 Hand-in-hand two-point structure of EPON

According to the OLT to the ONU channel attenuation's range and the experience of the ONU configuration, combined with the actual situation of City Bureau distribution network, and give full consideration to the future network expansion, the transformation and upgrade, the early network should be set aside enough light power capacity. For wiring way hand-in-hand, the number of ONU carried by PON ports of the OLT should be not more than 12 in the early planning, the highest level of optical-splitting is eight stage optical-splitting in the backbone. When the number of nodes exceeds the number that the ONU equipment and the splitters can control, enterprises can take apart the network and add new light core to the network in order to reduce the beam splitter series and the channel attenuation. In the design phase of scale, enterprises should take the above design as the basis and combine with the distribution network connection status and the long-term planning of the specific situation on the channel attenuation to analyse and calculate the channel attenuation in order to determine the ONU of each line and the actual configuration of the beam splitter.

The following is a concrete example, a network structure corresponding to a hand-in-hand line. The architecture of hand-in-hand joint-access is as shown in Fig. 4.

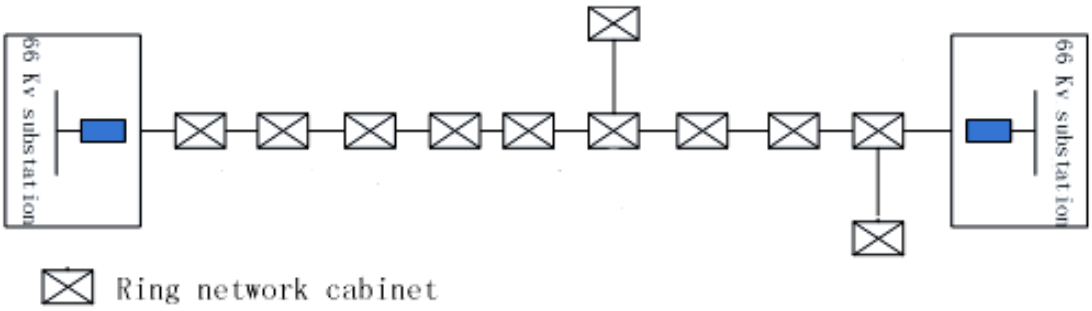

FIGURE 4 The architecture of hand-in-hand joint-access

a. Line's ends were ended in two substations OLT device based on the construction of distribution automation project line information point within the region distribution, respectively, which is similar to the above line grid structure with hand-in-hand network structure.

b. The network topology may change in the future, considering the expansion, transformation and upgrading of network, so enterprises need to reserve space for expansion. Each splitter should reserve at least one expansion port, if the recent expansion of the branch is large, enterprises can use the splitter with large splitting ratio splitter to get more expansion ports.

c. All lines in the network use hand-in-hand type structure, trunk lines use the beam splitter whose spectral ratio is 10:90 to make the network realize five stage optical-splitting modes or six stage optical-splitting modes. ONU access different PON ports of OLT in the different substation point, respectively. The typical circuit occupies two PON ports of each site, four PON ports in the network, and occupies four core optical fibres of the trunk line. The hand-in-hand communication structure is shown in Fig. 5.

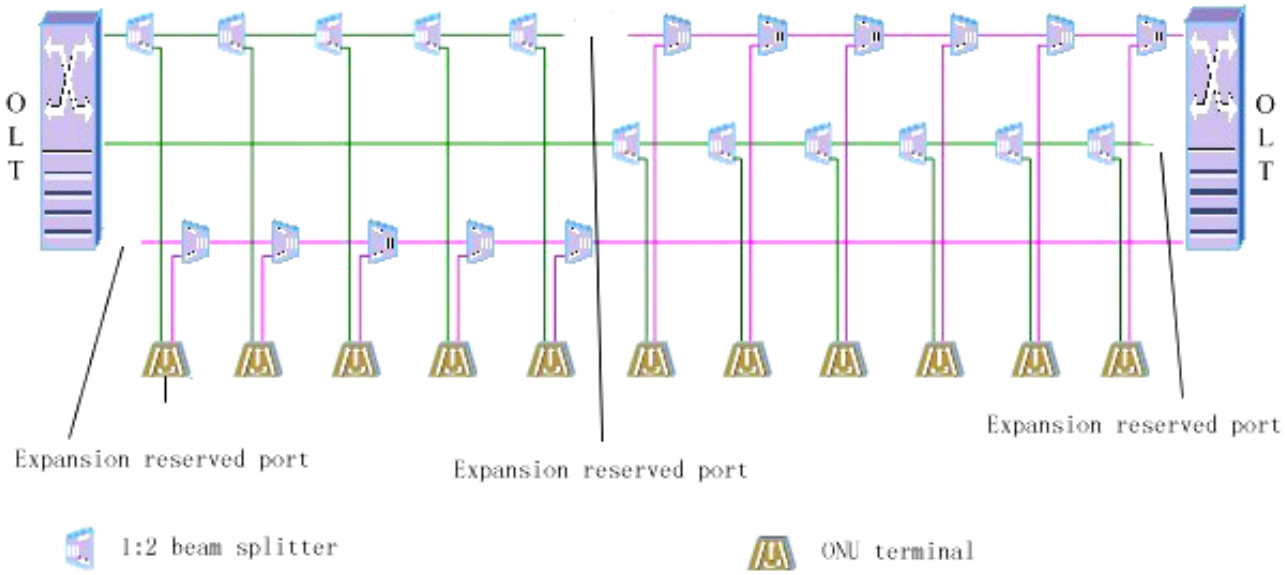

FIGURE 5 The hand-in-hand telecommunication

4 Energy efficiency analysis of the network

4.1 THE INDICATORS OF ENERGY EFFICIENCY EVALUATION

In order to evaluate the energy efficiency performance of the network, this section will introduce a series of performance indicators. They are mainly used to illustrate the superiority of the proposed algorithm in the simulation analysis process.

4.1.1 The link utilization [5]

First, the author defines the link utilization. In this paper, $\overline{u_{ij}}$ indicates the link utilization. The link utilization L_{ij} is the ratio of average flow on the link and the link capacity, the formula is shown as follows:

$$\overline{u_{ij}} = \frac{\overline{f_{ij}}}{C_{ij}}, \tag{1}$$

The link utilization is mainly used to measure the status of the link utilization, for example, if the $\overline{u_{ij}}$ of the link L_{ij} is more than 80%, then the link rate is higher, and the network's risk that other services through this link brings is bigger, which is more easily lead to link congestion and denial of service condition. We should avoid the link utilization rate is too high. However, if the network utilization rate is too low, then the network energy efficiency would decline. So in order to achieve energy efficiency network, the link utilization should be controlled in a safe range by using a reasonable mechanism.

4.1.2 The link utilization variation

U is the matrix of the network link utilization variation within the time T after several users' request, $\overline{u_{0ij}}$ and $\overline{u_{ij}}$ indicates the initial link utilization rate and the request link utilization, respectively. The formula is expressed as:

$$U_{ij} = \overline{u_{ij}} - \overline{u_{0ij}} \quad , L_{ij} \in E \, . \tag{2}$$

Link utilization variation matrix is used to measure the link utilization of the entire network and to constraint the performance indicators of the network. It is mainly used in algorithms (1) and (3).

4.1.3 The average node degree

Due to network node degree is inherent in a network, the average node degree of network is large, the connectivity of the network is strong, and the network can adapt to the negative load state of the business. So the average node degree will also affect the results of the algorithm simulation, the average node degree is defined as follows:

$$D = \frac{\sum_{i \in V} d_i}{\|V\|}, \tag{3}$$

d_i indicates the degrees of node i, $\|V\|$ denotes the number of nodes in the network. The indicator is used in the simulation analysis and mainly embodies that average node degree of different network has different effects on algorithm performance.

4.1.4 The average activation link utilization

The average activation link utilization is similar to the link utilization. This definition is specially used for the network of energy efficiency, because only in the network of energy efficiency it can sleep for the redundant links. In this paper, the average activation link utilization is the ratio of the sum of the average utilization of link utilization and the number of the activation link. The formula is shown as follows:

$$U_l = \frac{\sum_{l \in E} u_l}{\|E\| - S_n}, \tag{4}$$

u_l is the link utilization of l, $\|E\|$ indicates the total number of links in the network, S_n indicates the dormancy link number. The average activation link utilization is used to measure network performance after dormancy.

4.1.5 The denial service rate

The denial service rate is the ratio of the number of refused service and the number of the total requests in network traffic when the network link residual bandwidth is shortage in the case of the network routing is successful. In this paper, the author use the BUG to indicates the denial service rate. The formula is shown as follows:

$$Br = \frac{Nr}{NR}, \tag{5}$$

Br indicates the denial service rate, Nr indicates the number of refused service and NR indicates the number of the total requests in network traffic.

This article defines the above indicators used to measure the performance of network and used in the simulation analysis, deeply describes the network of the energy efficiency performance.

4.2 RESULTS AND ANALYSIS OF THE SIMULATION

The network energy efficiency of A, B, C and D with ring network mode were analysed by using MATLAB in this paper. For dormancy algorithm, we use the EAR algorithm, the traditional dormancy algorithm to compare the energy efficiency of four kinds of networking solutions and network characteristic properties under the different routing algorithms.

The simulation results are shown in Fig. 6, the cumulative number of denial of service distribution in 10 independent times is depicted in the figure. We can find that the two routing algorithms (OSPF and MHA) have little effect on the denial service times under the same network mode. Only in A ring network the routing algorithms have effect on the denial service times.

The simulation results are shown in Fig. 7. The figure shows cumulative distribution of the denial service rate. The x axis represents the different link, the y axis represents the average link usage calculated in the 10 times of the simulation experiments, the curves of different colour in the figure represent the changes of each link usage obtaining by using different routing algorithms. The horizontal line presents the average link usage of the network; we can see the routing algorithms have no effect on link usage from the simulation diagram. In addition, the link order is A, B, C and D on the basis of the average usage from large to small.

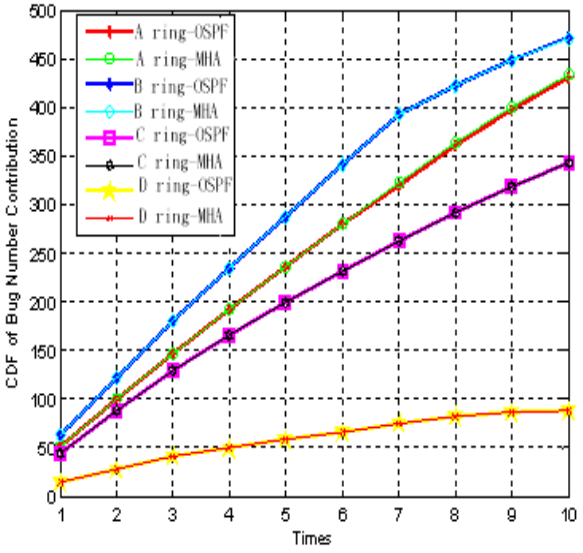

FIGURE 6 The accumulation distribution figure of devotion rate of refusal to service in different route algorithm

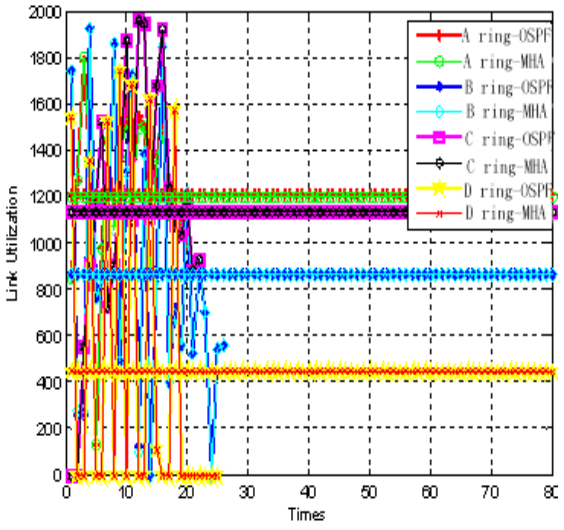

FIGURE 7 The consumption in average link with different route strategies

The values of network power-efficiency with different emulation labs as shown in Figure 8. It can be seen that the difference between OSPF algorithm and MHA

algorithm on A ring network energy efficiency is bigger, but the two algorithms have little influence on other network efficiency.

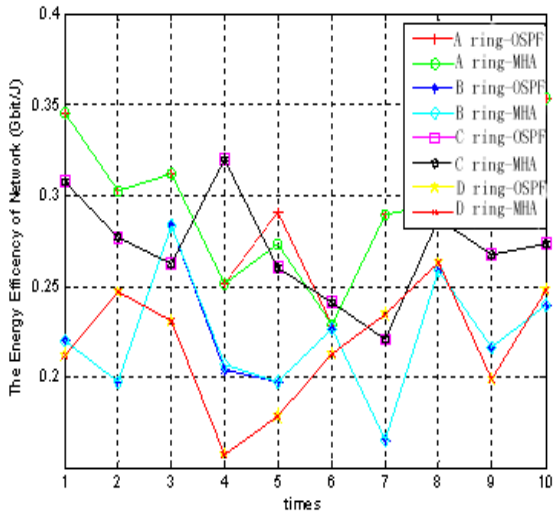

FIGURE 8 The value of network power-efficiency with different emulation labs

5 Conclusions

For example, we can carry out the actual communication network construction in a northern city, including the detailed content of construction and the equipment configuration of cable, transmission, access network and data network. Combining with the classic network performance analysis, we should construct the energy efficiency analysis model, carry out the simulation on the basis of the energy efficiency index set for the simulation, analyse the experimental results deeply and complete network performance optimization for deployment through regional pilot in the process of designing network operations in order to support the development of electric power communication network better.

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