Research on the 2M ASON technology in power communication network

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Abstract. Firstly, this paper analyzes the advantages of the traditional ASON technology in the network operation, and introduces a new 2M ASON technology to solve the problems of the traditional ASON application. Secondly, this paper explains the progressiveness of the 2M ASON from the network survivability and bandwidth utilization through the introduction of the principle of 2M ASON channel establishment, the anti-node failure technology, and the "demolition before reconstruction" channel recovery mechanism. Finally, this paper analyzes the properties of the production services in the power system, and proposes a scheme of the power differential protection service based on the characteristic of the 2M ASON.

1. Introduction
With the increasing demand of power system services, the optical communication bearing technology has been developed rapidly, the real-time interaction and reliability of power supply and demand become an important indicator to influence the safe and stable operation of the grid, which brings higher requirements for the safety and self-healing ability of power communication network. The main requirement for bearing network has been upgraded from performance to survivability. In order to satisfy the construction demand of power transmission network and future intelligent grid, a new generation of optical communication network which can support flexible configuration, intelligent algorithm and high reliability is essential. In recent years, ASON technology has been fully developed [1-3]. ASON device inherits all the functions of the SDH device, also introduces the control plane, and fully utilizes the double-layer linkage effect of SDH+IP. Comparing to the past SDH technology, ASON technology makes great innovation in anti-repeated fiber break ability, as well as in protection and recovery mechanism. ASON technology has also been widely used in practical applications. It can effectively solve the problem of unreasonable configuration of transmission network resources and redundant investment in the current power system communication.

ASON is a dynamic and automatic switched transport network. It is also a new generation of optical network integrating switch and transmission as one, whose service request dynamically initiated by user, net element automatically calculate and choose the path, connection establishment, recovery and demolition through signaling control. At the same time, it has the functions of MESH network [4] flexible group, network link load automatic balancing and optimization, network topology automatic discovery, new service providing, easy network expansion and other functions. The traditional ASON protection can realize multiple fiber break protection, intuitively complete 2M service protection, but essentially is realized by forming multiple VC4 bandwidth tunnels, which brings huge waste to the network bandwidth resources. Moreover, when the convergence node is
dealing with VC4 tunnel joint problem, the service cannot resist the convergence node failure. In order to solve these two problems, 2M ASON technology has come into being.

2. The problems of traditional ASON Technology

2.1. Network survivability risks
Traditional ASON intelligent pipe is based on the VC4 particle level, 2M service with the same source and destination can only be beared in the proprietary VC4 ASON pipe, VC4 pipe utilization will be very low. In order to improve the bandwidth utilization, we often build VC4 pipe in sections to bear 2M services, which means jointing multiple VC4 path to bear 2M services. As shown in Figure 1, the A-D and A-C 2M services carry out VC12 channel multiplexing in node B, bearing together on a VC4 channel between A and B, and node B is the joint node of VC4 channel. To a certain extent, this approach can make the network release more VC4 channel resources, and improve the utilization of network bandwidth, but if node B fails, then all the 2M services through node B will be interrupted and unable to recover, which brings great risks to ASON network survivability.

![Figure 1 sectionally jointed VC4 channel](image)

2.2. Low network bandwidth utilization
In order to improve the survivability of ASON network, the traditional method is to make the 2M services with the same source and destination occupy a VC4 ASON pipe in network, and bear independently. In Figure 2, A-C 2M service transmits through A-B-C route, while A-D 2M service transmits through A-E-D route, the two service routes in the whole network paths have no overlapping portions, and respectively use isolated VC4 channel to bear. The improvement of network survivability is based on the mass consumption of network VC4 channel resources, and is also the essential reason for the low utilization rate of network bandwidth.

![Figure 2 dedicated VC4 channel](image)

In summary, the traditional ASON technology can not satisfy both network survivability and bandwidth utilization at the same time, because the core idea of this technology has mixed these two together. Over satisfaction on one aspect will lead to the performance loss of the other aspect. On the other hand, there will always be care for this and lose that phenomenon, and we cannot satisfy both. The network survivability and network bandwidth utilization are two extremely important factors in evaluation indexes for bearing network reliability. In order to fully and parallel develop the
performance of the two aspects, 2M ASON technology makes innovation.

3. ASON technology based on 2M channel
The development of ASON is the result of the integration of traditional telecommunication and computer network technology, transmission and IP technology. The core technology of ASON includes signaling, routing, link resource management, network management technology, interface technology and others. Routing technology innovation has always been the widely discussed focus of ASON technology. For the routing algorithm and rerouting strategies of different manufacturers are representative, it cannot form a common in the mass deployment. Traditional ASON and power service scenes have a lot of mismatch, and the establishing process of emerging 2M ASON channel can completely meet the needs of power system manufacturing 2M service, coupled with the use of anti-node failure technology and the "demolition before reconstruction" channel recovery technology, and innovatively evolved the 2M ASON solution.

3.1. Establishment of 2M ASON channel
The advantages of 2M ASON technology in network link resources application reflect in “existed preferred” and “hierarchy” comparing to the traditional ASON technology. It has the function of setting up hierarchical service, obtaining the network topology information of different levels and flooding it, and the function of the correct route calculation according to the flood information. The final carrier of the 2M service channel is the VC4 pipe. Comparing to VC12 pipe, VC4 pipe is the lower link, and VC12 is the upper link. Every upper link optimizes and selects from existing lower links before establishment, which can ensure the full use and configuration of existing network resources. When the upper link has no lower link resources or failed to configure lower link resource, there will be hierarchical and purposeful route flooding, and the flooding mechanism compared to the past the mechanism will be more efficient, which submits lower link topology information in virtual form to the upper link, and will eventually establish a new lower link. This rule will be followed when each jump point establishing the virtual link. Finally, a complete end-to-end virtual link will be established, which is the final 2M ASON service channel routing, and the channel has the rerouting trigger function when detecting the low order VC12 alarm. The whole process of virtual link establishment uses new ASON routing optimization algorithm and new OSPF packet simplified compression mechanism, which makes the establishment of 2M ASON channel more efficient in efficiency, more flexibility in scheduling and more reliable in performance than the traditional ASON channel.

3.2. Anti-node failure Technology
2M ASON is based on 2M services to achieve end to end ASON, which uses low order alarm trigger rerouting mechanism, and builds end to end circuit protection. Because 2M ASON does not build VC4 pipe in sections like the traditional ASON technology, instead, it directly builds the 2M pipe, therefore, when the 2M service is dealing with anti-node failure, it can intelligently select a new VC12 channel through preset protection path, and successfully solve the problem of multi service anti-node failure as shown in Figure 3. During transmission process, the multipath 2M service shares one or several VC4 channels through VC12 reusing type, and the utilization of network bandwidth gets the greatest improvement. There is a qualitative change compared with the previous ASON bandwidth utilization technology.
3.3. The "demolition before reconstruction" channel recovery mechanism

Recovery mechanism is a mechanism that establish new connections instead of failed connections by rerouting mechanism. These new connections will occupy the redundant capacity in the network. The recovery mechanism of ASON technology can be divided into two categories: one is manual preset type, the other is intelligent dynamic type [5]. The manual preset type is mainly reflected in the human will. It is a mechanism which can preset reroute new connection instead of failed connection before failure happens based on the deep understanding of the existing network operation and combined with the subjective experience. It can recover fast, but the overall resource utilization is not high. The intelligent dynamic type is mainly reflected in the network intelligent execution of a series of algorithms and protocols when failure happens. Considering the overall network resource mobilization, the recovery of outputting a new routing recovery is slow, but the overall resource utilization is high.

The traditional ASON technology usually uses "construction before deletion" method to reroute or change path, which means retain the original path, and delete the original path after the new path complete set up cross selection. In this way, the new and old paths will coexist for a period of time, and during the coexistence period, the new and old paths are in a cross selection relationship, the collection and distribution of the path may be inconsistent. This will cause misjudgment to the services which has higher requirement on receive and send delays symmetry in power system, and affects service operation. The 2M ASON technology usually uses "demolition before reconstruction" method. As shown in Figure 4, it first directly remove the original fault working path, and then simultaneously switch receive and send ends to consistent preset recovery path, which ensures the simultaneous switch of receive and send ends when service failure happens, so that the consistence of the path can be ensured.

4. Demand analysis of 2M service in power system

At present, the 2M services of power system are mainly located in mass power production area. These services have some common attributes, such as circuit based exchange, strict circuit delay requirement in the transmission process: 5ms delay of communication channel can be used as the basis of special power service excellent performance; 7~8ms delay can be used as available indicators for relay...
protection services; within 10ms delay channels can be used for safe and stable services, and is not conducive to protection services; over 20ms delay communication channel is completely unavailable for relay protection and safe and stable services. So for the one-way service channel delay, the general requirement is less than 8ms. On the basis of this, the differential protection service [6] has strict requirement on the symmetry of receive and send path, so this type of service has particularly high demands in real time. This type of service is the main support to the normal operation of power grid production, so its importance level is the highest of all services, and the protection requirements for this type of service is more comprehensive, usually through the 1+1 dedicated protection or ring protection. Judging from the present technologies, we only can use the SDH 2M rigid pipe to bear these services. With the continuous maturity of ASON technology, 2M ASON technology can improve the network survivability of service bearing to a grade based on the SDH technology.

5. 2M ASON bearing power differential protection service
The innovative advantages of 2M ASON can customize a bearing solution to the 2M service of power system production, and optimize the reasonable bearing to the 2M service. The principle of current differential protection is to compare the current phase and amplitude at both ends of the line at the same time for equivalence, and if the sampling time of both sides are inconsistent, it will cause the inconsistency of current sampling, and may cause malfunction of protection device. Therefore, the power differential protection device requires the "receive" and "send" path of the adjacent site service to be completely consistent, the "demolition before reconstruction" mechanism of 2M ASON is customized for it.

In the power grid system, the service communication channels of the main protection one and main protection two in 220kV line can meet the requirements of the independent dual channel, and there is no risk of line operation with no main protection caused by single point failure [7]. Therefore, two sets of differential protection devices are equipped between the adjacent sites, most of the main protection one communicates through bare fiber, and the main protection two communicates through the SDH 2M signal multiplexing. Now we maintain the communication mode of main protection one, and use 2M ASON technology as communication mode on the main protection two.

In order to verify the adaptability of 2M ASON technology bearing power differential protection service, the state grid Xuzhou electric power company selected A, B, C, D, E, F, G, H, a total of eight 220kV sites, configured a 2M ASON device in each site, and installed differential protection service device and 2M error code testor in A and G sites. The specific network topology and distance between sites as shown in Figure 5.

![Figure 5 differential protection service beared by 2M ASON](image-url)
5.1. Test target
To verify that during bearing process of new built ASON network, the differential protection service between A and G sites cannot be affected by repeated fiber break incident, besides, in every fiber break and recovery process, the time delay of new established communication channel can meet the requirements of differential protection service, and the bearing service can have consistent receive and send path.

5.2. Test method
Achieve fiber break through three times interruption of laser emitting, and each interruption is through A to G single direction. First time, interrupt the direct connection between A and G. Second, interrupt the direct connection between H and F. Third, interrupt the direct connection between A and H. Record the relevant data and alarm of each fiber break.

5.3. Test result and analysis
After the first fiber break, through starting rerouting, calculating the path delay, bidirectional path consistency and other steps, forms an A-H-F-G routing, and successfully recover the service between A and G. Then after the second fiber break, the system will repeat the steps of first time fiber breaking, and forms an A-H-D-E-F-G routing. At last, after the third fiber break, it can also form an A-B-C-D-E-F-G routing to ensure the service recovery between A and G. These three 2M ASON recovery routings are preset selected, so that the network can have the fastest response to the failure and guarantee the timeliness. This result can explain that in the situation of repeated link failures, the 2M ASON network can optical route reconstruct automatically, and carry out anti multi-point failure recovery, resist N-X communication network failure, and improve the network survivability.

Record relevant data in every fiber break process, as shown in table 1. From the table, the difference between occurring time and returning time of channel switch alarm after every fiber break is about 10ms, which can meet the requirements of differential service, but frame lost quantity is increasing. After the first time fiber break, manually set the channel routing for G receiving A as A-B-C-D-E-F-G, and the distance achieves 160km. Due to the distance increase, the time delay of A and G receive and send path will have a big gap. But the test result shows that the optical interface board on receive port of A-G direct path has LOS alarm, and the sampling current values are exactly the same, differential current is zero, which indicates that 2M ASON recovery technology uses "demolition before reconstruction" mechanism to ensure the consistency of the receive and send path.

| No. | Test parameters                  | A Site                  |              |              | G Site                  |              |              |
|-----|---------------------------------|-------------------------|--------------|--------------|-------------------------|--------------|--------------|
|     |                                 | 1st Break               | 2nd Break    | 3rd Break    | 1st Break               | 2nd Break    | 3rd Break    |
| 1   | Channel switch alarm occurring time/returning time | 14:10:01:102 ms | 14:18:22:045 ms | 14:32:41:384 ms | 14:10:01:289 ms | 14:18:22:308 ms | 14:32:41:671 ms |
|     |                                 | 14:10:11:268 ms         | 14:18:31:557 ms | 14:32:51:113 ms | 14:10:11:472 ms | 14:18:31:719 ms | 14:32:51:474 ms |
| 2   | Sampling current value          | 0.05                    | 0.05         | 0.05         | 0.05                    | 0.05         | 0.05         |
| 3   | Frame error No.                 | 0                       | 1            | 1            | 0                       | 1            | 2            |
| 4   | Abnormal packet No.             | 0                       | 1            | 1            | 0                       | 1            | 2            |
| 5   | Frame lost No.                  | 5739                    | 11742        | 17096        | 5791                    | 11895        | 17183        |
| 6   | Miss synchronization No.        | 13                      | 25           | 39           | 12                      | 23           | 35           |

Table 1 Data record from differential protection device
From the tests above, we need to explain that in order to meet the fast action requirement of protection device, the communication protection channel delay should be less than 12ms. The traditional ASON design does not consider the cache limitation of differential device, the one-way transmission delay may be more than 12ms, and the transmission delay constraint cannot be configured. While the 2M ASON differential protection uses the constraint routing algorithm technology [8], which can ensure the one-way transmission delay constraint can be configured. To meet the cache requirements of different differential devices, the one-way transmission delay constraint defaults to 10ms.

In order to obtain the most secure transmission channel, the interrupt delay of service path change must be more than 100ms. This is because the differential protection device of some domestic big manufacturers can detect abnormal channel in 20ms, and will lock communicate channel by not using the channel data, and if the spare channel is normal, it will switch to the spare channel. Although the differential protection device re-synchronizes time every 8 frames (0.833 x 8 = 6.67ms), it cannot detect path changes, this is because the optimization and return of the current ordinary ASON is completed through SNCP switching, the transient breaking time is 4ms ~ 20ms, the device samples according to the cycle that determined by previous delay, the time synchronization sampling data will have deviation. Judged by 24 frames (0.833 x 24 = 20ms) sampling data, the over limit of difference may trigger circuit protection of differential protection device. When the 2M differential ASON protection has actions such as service rerouting, return optimization, it can have delay constraint first, and ensure both ends switch and strict path consistency.

6. Conclusion
2M ASON technology has made substantial innovation based on the original ASON technology, through OSPF packet simplification and compression, ASON routing algorithm optimization, and anti-node failure technology, the ASON recovery process obtained a technical breakthrough, and the network survivability has been obviously improved. At the same time, the scheduling based on VC12 channel has been greatly improved in the network bandwidth utilization compared with the original VC4 channel scheduling. The 2M ASON technology combines the special needs of power industry, customizes a "demolition before reconstruction" recovery mechanism with completely consistent receive and send path to the differential protection service which has the strictest property requirement in power system services, and ensures the ability of automatic multi routing protection and multi point failure response of power grid control services. Southern Power Grid Company clearly stated in the communication procedures that the optical fiber differential protection channel cannot use the SDH protection self-healing function, but through theoretical advantage analysis of 2M ASON technology, the 2M ASON technology in bearing differential protection service becomes possible. As the technology becoming more and more mature and stable, based on bearing differential protection service, the 2M ASON technology can bear other 2M power production services adroitly, such as secure service, scheduling service, automation service, etc. The future power transmission network is no longer a simple bearing network. It is a multi-service bearing platform which provides guarantees of transmission efficiency, security and stability to various services. In the long term, the 2M ASON technology is the reflection of the transmission network reliability upgrade, and is also the innovative and deep reform of power production service bearing.

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