Research on the Automatic Fusion Strategy of Fixed Value Boundary Based on the Weak Coupling Condition of Grid Partition

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Abstract. With the continuous strengthening of power grids, the network structure is becoming more and more complicated. An open and regional data modeling is used to complete the calculation of the protection fixed value based on the local region. At the same time, a high precision, quasi real-time boundary fusion technique is needed to seamlessly integrate the various regions so as to constitute an integrated fault computing platform which can conduct transient stability analysis of covering the whole network with high accuracy and multiple modes, deal with the impact results of non-single fault, interlocking fault and build “the first line of defense” of the power grid. The boundary fusion algorithm in this paper is an automatic fusion algorithm based on the boundary accurate coupling of the networking power grid partition, which takes the actual operation mode for qualification, complete the boundary coupling algorithm of various weak coupling partition based on open-loop mode, improving the fusion efficiency, truly reflecting its transient stability level, and effectively solving the problems of too much data, too many difficulties of partition fusion, and no effective fusion due to mutually exclusive conditions. In this paper, the basic principle of fusion process is introduced firstly, and then the method of boundary fusion customization is introduced by scene description. Finally, an example is given to illustrate the specific algorithm on how it effectively implements the boundary fusion after grid partition and to verify the accuracy and efficiency of the algorithm.

1. Introduction
In recent years, the rapid development of UHV AC and DC grid and renewable energy power plants has made great significance to optimize the allocation of resources and promote the efficient use of energy in China, and also makes the connection of regional grid more tight and frequent, and the power grid structure more complicated. For the regional grid, on the one hand, a set of open, regionalized data is needed to complete the calculation of protect set point based on the conservation value of the region; on the other hand, a high-precision, quasi-real-time boundary fusion technique is required to constitute an integrated fault computing platform by stitching each region seamlessly and to accomplish the transient stability analysis with high-precision which can cover whole grid and multiple mode, so as to cope with the hazard for non-single failure and interlocking failure, and to build a strong “first defending line” for the power grid.

During the normal operation and maintenance of the grid, the set point calculation personnel usually maintenance the grid model by incrementing or modifying the local new-built power plant on
it, and receive the latest equivalent boundary figure from the supervisor dispatching center half yearly or yearly. This mode is convenient and fast for the calculation of model of the partition grid, but the tight and frequent connection of the regional power grid highlights the drawback of the modeling method above. And the rapid development of renewable distributed energies and the energy interconnection of China has increased the difficulties of power grid analysis and set point calculation. So how to keep real-time synchronization of the change speed of the grid, while maintaining the original efficiency based on regional calculation is the goal of this paper to be solved.

The research on the boundary set point fusion strategy based on distributed autonomous agent is developed and applied accordingly [1-3]. It implements an open, shared architecture for relay protection setting calculation of power system. The system allows the updating based on the local distributed parameters and protection schemes among the boundaries and the fusion of strategies and the coordination between them. Its main contents are:

- Replace simplified modeling with global parameter modeling to reduce data maintenance difficulty;
- To determine the labeled technical specifications based on relay protection settings to facilitate the standard, transparent management of protection algorithm of the various manufacturers at the bottom layer, in order to achieve the fusion at the bottom layer;
- For each voltage level, a unified rule base is specified for the whole calculation, providing technical support for the setting calculation.

From the above it can be seen that in dealing with the boundary set point fusion strategy, the core two aspects are as follows: one is standardized design, which mainly reflects in the application of the label technology and the unification of the rule base; the other is the realization of complete modeling, whose deep meaning and realization rely on open data platform, the partition accurate modeling, and finally, the boundary fusion technology. Therefore, it can be seen that the labeling, standardization as the foundation, and the boundary fusion as the means, the ultimate goal is to achieve accurate transient calculation of the whole grid with an open platform and quasi-real-time splicing of data of high capacity [4-5]. As there exists real-time grid parameters quasi-synchronous with the development of the grid, the corresponding operation mode can also fully be reflected. When the short-circuit current (i.e., transient stability) reaches the critical point, the engineers can adjust the operation mode. For a districting power supply mode as an example, engineers can adjust the operation mode to one with sufficient margin of stability. And the modeling platform concerning complete-parameter gives most timely warning information by short-circuit current calculation method, which is the most simple and effective.

This complete-parameter real-time calculation platform, due to the usage of minimum parameters (super-transient impedance) of the short-circuit calculation for protection value setting, as well as the maximum possible operation mode, when the global short-circuit current reaches the critical point of transient stability, the system will guide the operator to re-adjust the operation mode, in which the transient stability can be strengthened substantially. Such mechanism is absolutely positive and effective, where early predictive transient stability level information is directly used to adjust operation mode, keeping the grid operating at a safe level.
Initiation & management of boundary splicing

Modeling and data based on local partitions

It can be seen from figure 1 that this algorithm is essentially a distributed method, and adopts splicing and fusion method afterwards [7-8]. In order to realize this method, we adopt the technique of data identification based on the URI partition. According to the scheduling scope of the distributed system, we configure the URI prefix for the data of scheduling unit, guaranteeing the uniqueness of the URI of each data object in the whole grid. In the progress of distribute data modeling, when a data object is to be generated, the URI of the data object is made up of the URI prefix of the scheduling unit stitching on ID of the data object. Such is how the object-based URI-stitched data works, as during the modeling of distributed data, the association between data objects is recorded by their URI. Once the URI of the data object is created, it will never be modified, realizing the seamless stitching of data objects.

2. Decision system of boundary fusion of BDI main objects based on multi-agent technology

There are many concrete implementations of border fusion based decision-making. In this paper, we firstly submitted data of scheduling unit, commit the confidence calculation afterwards, and submit for the manual review finally when the confidence value exceeds the threshold, see in figure 2. The confidence mentioned above is divided into one, two, three levels according to the source of the parameters and the verification situation, so as to measure the reliability of the parameters. The evaluation progress of the confidence of the parameters include the pre-assessment and post-evaluation steps in reality. The pre-assessment corresponds to the evaluation before the parameter by the means of software and artificial comprehensive assessment so as to test the integrity and correctness of the parameters. After the parameters being used, the post-evaluation verify the correctness of the parameters using the actual operation data, and with the state estimation and fault recovery as the main means, being the most important criterion for parameter error prevention. The parameters passing the pre-assessed process are at the premier and secondary level, which are lower, while parameters passing the post-evaluation verification by fault-recovery data are at the third level.

Figure 1 A Scheme of Unique Identification Based on URI Partition
Figure 2 Structure of log tree based on BDI boundary fusion and queue formation method diagram

It can be seen from figure 2, that sometimes it’s necessary to judge whether the scenes are exclusive mutually. When the mutual exclusion of the scenes is distinguished, the border fusion with limited condition will be needed. The specific flow is shown in figure 3.
The realization of the method above is based on the Multi-agent technology, including the manual audit process in the method. According to the assumptions made by the main objects of component...
BDI, the behavior of the Agent is determined entirely by the spirit (belief, desire, goal, and intent) component it possesses. Because of this, the exclusion conditions of the boundary fusion can be reflected proactively. The decision-making and implementation of the Agent's fusion also reflects on the changes in the spiritual components. What is important is that Agent uses its perceptual component to understand the environment. While information provided by the perceptual component of the agent is not static, each agent analyzes the environment by establishing its individual environment model. And whether the relay protection setting calculation is reasonable depends on whether the scene settings are reasonable and the model of Agent meets the actual application on site. As for the protection rules and the relationship between the settings, it is derived from the practical application set by the scene. If the scene changes, the corresponding rules of fault calculation will change accordingly.

3. Boundary Fusion Algorithm Based on Mesh-operation of Power Grid

3.1. The principle of algorithm based on scene setting

![Diagram of Boundary Fusion Algorithm](image)

It can be seen from figure 4 that through the scene setting, the observation point, cyclical mode of the station, operation mode of the line during the fault are set globally, and the boundary fusion must be one that meets the needs of this scene, otherwise it will lose its meaning. Because the final optimization direction of the protection scheme is actually the one that is at a level of the grid health assessment and able to maintain the rationality of the protection action when the multi-level fault occurs, and this scheme is in fact more from the judgment on the safety degree of the grid subjectively as well as the comparison of advantages and disadvantages among various options. So, it can be said that all protection strategies are relatively better ones after trade-off. Similarly, sometimes boundary fusion computing is a specific application of the way in which dispatching partitions are interconnected. As the excellent operation mode are actually such ideal situations as partition management, local balance, sharing of resources. Meanwhile, in the event of cascading accidents, it is best to divide power supply scope of partitions in view of balancing the supply and demand naturally, so as to limit the scope of the failure. Therefore, this paper divides the power supply partition naturally to balance the supply and demand in each partition, while limit the fusion rules on the boundary by the
operation mode, so as to limit the short-circuit current level of the power grid and improve the transient stability. Meanwhile, the boundary fusion set a limited operating conditions, corresponding to limited calculation scenes, so that the calculation is greatly simplified, while at the same time, evaluate the transient stability conforming to the operating conditions, as shown in figure 5.

Figure 5 The transient analysis diagram of grid power grid

3.2. Boundary conditions setting of fusion based on grid meshing

The overall trend of the power flow of the 220kV, 500kV system is from the west to east. With the reinforcement of the grid structure, the incensement of the power generation, and the completion of special high voltage grid, the power transmission capacity and the level of static stability rose dramatically, but also brought about problems such as power grid short circuit current over-limited at 220kV, conformation of electromagnetic loop, and larger power supply area than usual. In order to take into account of the level of power grid transient stability, try the following adjustment of operation mode: take the balance line between the generation and the local load at normal power flow as flow gates, divide the grid into mesh partitions, the tie-line of the grid keeps open-loop operation. Each meshing grid supply the power dependent on its regional generation, while in weak connection situations the open-loop line turn to direct-supply mode in order to realize power support. However, due to the variation of the operation mode of the open-loop lines and the plant at the ends of the lines, and the rejection between the original operation modes, the result of the approach above is that the cyclical combination of simple station mode will result in errors in the coordinative calculation of boundary fusion. To avoid this, in the previous boundary fusion process, integrate the relevant circumstances of the scene, and give the conditions to avoid the mutual exclusion, so as to give a reasonable fusion result to accord with the operation mode.

The setting principle of the plant on both sides of the boundary line of sub-regions is to ensure that the combination of cyclical modes of the plant at the two sides of the line avoid the one that makes the open-loop line operate in ring network mode. Therefore, the boundary fusion is actually one that is defined on the weak interconnection between partitions.

3.3. Condition setting of boundary fusion based on weak coupling connection mode
Take the setting principal of the operation mode of a station connecting two sets of open-circuit lines as the example. In Fig. 6, the red cross mark denotes the intermittent point of the normal operation. The boundary fusion process sets the Xing Han line and Xing Li line as open-loop, and as direct distribution line when the local power supply encounter shortage or at the accident mode. In the latter situation, Xing Han line supply Hancang station (north sub-region) or a main transformer of Xingcun station (south sub-region) directly, while Xing Li line supply Licheng station (north sub-region) or a main transformer of Xingcun station (south sub-region) directly.

Therefore, basing on the considerations above, during the basic mode setting of Xingcun station on boundary fusion, the following should be considered. Normally, the normal open-loop operation should be considered, i.e. Xing Han line switch open, Xing Li line switch open, #1,2 stations operate, #1 station is grounded. When the local power supply encounter shortage or at the accident mode, direct distribution line operation is needed, i.e. Xing Han line switch off, Xing Li line switch open, Xing Han line only take load of #1 main transformer of Xingcun station. At the same time, the high, medium and low voltage side of the bus-coupler of Xingcun station is open, to split the Xingcun station from the original grid, whose load is taken by the lines of adjacent partition in open-loop mode. Similarly, Xing Han line directly takes the load of #2 main transformer of Xingcun station, the high, medium and low voltage side of the bus-coupler of Xingcun station are open. Or Xing Li line only take the load #1 main transformer (or #2 main transformer) of Xingcun station, and the high, medium and low voltage side of the bus-coupler of Xingcun station are open. The specific diagram is shown in figure 7.

![Figure 6](image1.jpg)

**Figure.6** Open-loop operation schematic diagram of Han Xing Line, Xing-Li Line

![Figure 7](image2.jpg)

**Figure.7** Main wiring diagram of Xing Cun Station
4. Conclusions
This paper introduces a boundary fusion algorithm suitable for mesh operation and weak coupling of modern grid. This algorithm takes the actual operation mode for qualification, complete the boundary coupling algorithm of various weak coupling partition based on open-loop mode, improving the fusion efficiency, truly reflecting its transient stability level, and effectively solving the problems of too much data, too many difficulties of partition fusion, and no effective fusion due to mutually exclusive conditions. This article provides an effective method for realizing the integrated modeling and calculation of grid splicing.

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