

# The method of a joint intraday security check system based on cloud computing<sup>a</sup>

Wei Dong<sup>1,3</sup>, Changyou Feng<sup>2</sup>, Caiqi Zhou<sup>2</sup>, Zhi Cai<sup>1</sup>, Xu Dan<sup>1</sup>, Sai Dai<sup>1</sup>,  
Chuancheng Zhang<sup>1</sup>

<sup>1</sup> Power Automation Department, China Electric Power Research Institute, Beijing  
100192 China

<sup>2</sup> National Electric Dispatching and Control Center, State Grid Corporation, Beijing  
100192 China

E-mail: dongwei3@epri.sgcc.com.cn

**Abstract.** The intraday security check is the core application in the dispatching control system. The existing security check calculation only uses the dispatch center's local model and data as the functional margin. This paper introduces the design of all-grid intraday joint security check system based on cloud computing and its implementation. To reduce the effect of subarea bad data on the all-grid security check, a new power flow algorithm basing on comparison and adjustment with inter-provincial tie-line plan is presented. And the numerical example illustrated the effectiveness and feasibility of the proposed method.

## 1. Introduction

The intraday security check (ISC) is one of the four core applications for smart grid dispatching control system. It has been widely used in all levels of the State Grid Corporation dispatching center. With the development of UHV interconnected power grid, the contact among inter-provincial power grid operation is increasingly close [1]. The three level of dispatching centers (national, regional, provincial) are urged to join together and accomplish the main grid operation schedule and security check. The existing ISC can only calculate with the local model and data, lack of synchronous function with data and model, and ability of reducing the effect of bad planning data to the power flow in ISC is poor [2-8]. This paper firstly shows a method of joint intraday security check system based on cloud computing. And a new power flow algorithm basing on comparison and adjustment with inter-provincial tie-line plan is presented. It would alleviate the effect of bad planning data coming from subarea on all-grid power flow in the ISC. The numerical example illustrated the effectiveness and feasibility of the proposed method. At last, the paper forecasts the development trend of the key technology in the design and implementation of the ISC system based on cloud technology.

## 2. Cloud Computing in the Intraday Security Check

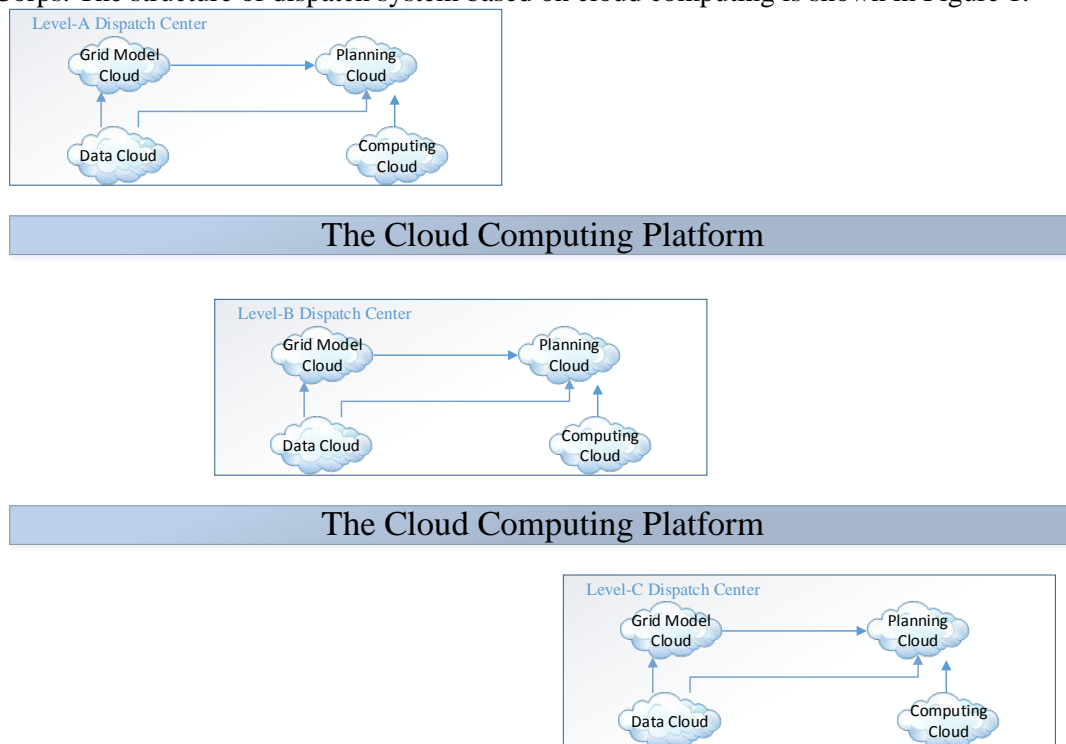
Cloud computing technology is mainly applied on four aspects in the joint intraday security check system.

<sup>a</sup> This paper was supported by Science and Technology Projects of the State Grid Corporation of China



- The Power System Model Cloud: With the virtualization technology, a cloud service of power grid structure and realtime information is supported and managed by the power grid model cloud.
- The Power System Data Cloud: The intraday-plan integrated data is stored in different types of database, such as real-time database, relational database. The integration service is provided by the data cloud.
- The Grid Compute Cloud: The AC power flow and state security analysis using in the Joint ISC system both base on the grid compute cloud service. With the help of its great computational capacity, the all-grid intraday-plan can be handled by the new ISC system much quicker than before.
- The Planning Cloud: The planning cloud proposes the service such as data and parameters preparation, status notification, unified calculation.

The cloud computing platform used in the joint ISC system is composed of the four types of cloud services above. In this paper, three level dispatch center is used to describe the whole power grid manager architecture, which name after Level-A, Level-B, Level-C dispatch center. Level-A generally represents the national dispatch center, Level-B represents the regional dispatch center, and Level-C means the provincial dispatch center. This architecture has been widely established in China power grid Corps. The structure of dispatch system based on cloud computing is shown in Figure 1.



**Figure 1.** Figure with short caption (caption centred).

### 3. The Method of A Joint Intraday Security Check Based on Cloud Computing

Based on the multi-level schedule balance management, the function which can automatically and orderly transfer and balance the intraday schedule will be realized by the method. The multi-level plans are calculated and analysed by the ISC. The alarm information is sent to security-constrained economic dispatch(SCED) system where it will be iteratively adjusted until the results meet the safety requirements of power grid.

The general principles of the joint ISC is "top-down", which means the superior dispatch center release new intraday research unit schedule to the subordinate SCED system. The corresponding plans

will be automatically programmed and synchronized by the Planning Cloud and the power system data cloud service. The all levels of ISC results are shown to all-level dispatcher to determine whether the schedule data meet the safety operation requirements.

The whole joint ISC system should have the intraday-plan integrated data process, the intraday-plan automatic planning, the security check computation, the check result analysis and the intraday-plan adjustment function.

The Intraday-plan integrated data processing function should possess periodic and artificial trigger control, intraday plan collection and the pretreatment of planning data.

According to the requirements of load balance, regulation, the clean energy accommodation principles, the intraday-plan should be automatically made and adjusted. In this paper, a method based on power balance management authority mode is proposed to solve the complicated problem of the multilevel schedule planning.

### 3.1. Balance management rights model

- a) The local system can trigger the new research plan scheme, the subordinate system would receive the research plan triggered by the higher level and prepare the preliminary subordinate plan according to the planning information received from higher level dispatch center.
- b) Using the monitor function, subordinate units can apply recommendations to the higher authorities for changing the data of the preliminary plan.

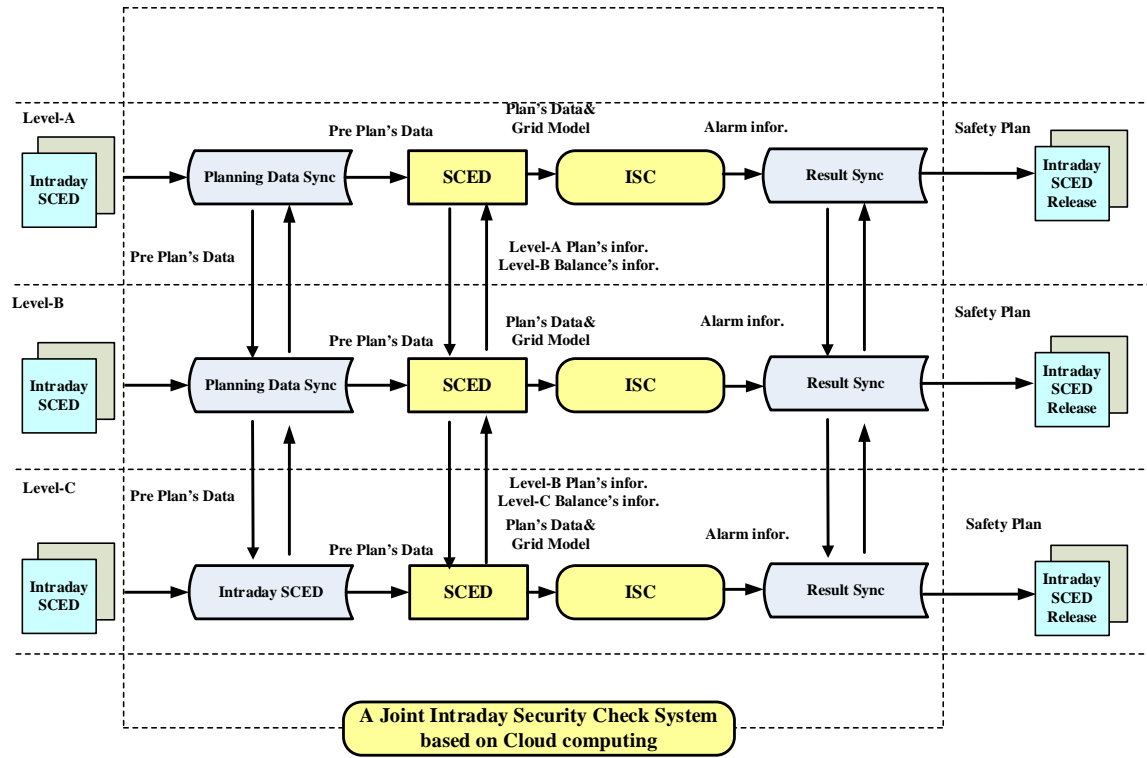
### 3.2. The Method Implement

- a) The rights:
  - Level-A: In accordance with the principle of balance management rights, the Level-A dispatch center has the highest authority for triggering a SCED and joint ISC in the work process. In the meantime, the Level-B, Level-C dispatch center should respond to the workflow initiated by the Level-A.
  - Level-B: the workflow launched by Level-B should be respond by Level-C. If Level-A needs it , the application from Level-B could be sent to Level-A too.
  - Level-C: If Level-C dispatch center finds that the intraday tie-line schedules need to be modified, the application from Level-C could be sent to Level-B, and the workflow will be launched by Level-B dispatch center if needed.
- b) Workflow: Firstly, pre-plan data are created according to the system requirements at the Level A dipatch center, and transferred to the Level-B and Level-C dispatch center. The workflow will trigger their adjustment. Secondly, Level-A dispatch center integrates data collected from local and the Level-B, Level-C dispatch center. Thirdly, SCED and ISC programm will run through all-level dispatch center to make a new schedule synchronized by the data cloud service. The process is shown in Figure 2.

The functions of the security check computation, the check result analysis and the intraday-plan adjustment are mature technologies. Due to space limitations, they are not discussed further in this paper.

## 4. Equations and mathematics Power Flow Adaptive Adjustment Optimization Algorithm Considering Tie-Line Plan

Compared with real-time calculation, the joint ISC calculation based on cloud platform involves a large number of schedules full of the future forecast data with much uncertainty. In order to improve the accuracy of calculation and avoid bad subarea data influence in the section power flow calculation, this paper proposes a algorithm considering the adaptive optimization adjustment of inter-provincial tie-line for planning power flow. The algorithm makes every part digest the internal unbalance flow of their own according to its proportion by controlling the transmission flow the AC power flow calculation strategy, thereby ensures the accuracy and practicality of the large power grid ISC.



**Figure 2.** The process of workflow

#### 4.1. Algorithm Steps

##### 4.1.1. Precheck and revise the plan value of tie-line as follows:

a) Determine the initial plan value of the sum  $\Delta p$  by the following formula:

$$\Delta p = \sum_{i=1}^N p_i^{sch0} \quad (1)$$

b) If  $\Delta p$  is equal to zero, the initial value of the tie-line plan of each con section is pass for precheck:

$$p_i^{sch} = p_i^{sch0} \quad (2)$$

In (1) and (2),  $p_i^{sch}$  is the regional tie-line schedule value for the use of power flow calculation,  $p_i^{sch0}$  is the initial regional tie-line schedule value. The large power grid is divided into  $N (i \in N)$  area.

c) If  $\Delta p$  is not equal to 0, then the region  $i$ 's tie-line power schedule initial value  $p_i^{sch}$  will be corrected, including:

$$p_i^{sch} = p_i^{sch0} - \Delta p * \left| p_i^{sch0} \right| / \sum_{i=1}^N \left| p_i^{sch0} \right| \quad (3)$$

and then

$$\sum_{i=1}^N p_i^{sch} = 0$$

**4.1.2. AC Power flow calculation** AC power flow calculation is carried out to calculate the unbalanced active power of the nodes and the regions; the power flow calculation is carried out by the future generation planning and bus load forecasting, and the total unbalance active power is concentrated on the balance node. A balance of nodes in the region for , the total power imbalance of active power is  $\Delta p_s$ .

In addition to region , other regional imbalance of active power is:

$$\Delta p_i = p_i^{sch} - \sum_{jk \in L_i} P_{jk} \quad (4)$$

$P_{jk}$  for the branch  $jk$  of the active power,  $L_i$  for the area  $i$  of the contact line section of the member branch collection. The unbalanced active power of regional A is

$$\Delta p_a = \Delta p_s - \sum_{i \in G, i \neq a_i} \Delta p_i \quad (5)$$

$G$  is a set of regions.

**4.1.3. The balance of active power** Judging the balance of active power absolute value is less than the convergence criteria: if not active power balance absolute value greater than the convergence criteria, and adjust the active power of generator and load can be adjusted, return to step 2; otherwise flow convergence, calculated using the trend the N-1 and fault set calculation.

- a) According to the equation, whether the absolute value is less than the active power imbalance convergence criteria is judged

$$|\Delta p_i| < \varepsilon \quad (i \in G) \quad (6)$$

- b) Convergence accuracy is represent by  $\varepsilon$ . If the formula (6) is satisfied, the flow convergence is judged, and the result of power flow calculation is used to calculate the N-1 and fault sets;

$$\Delta p_m^{unld} = \frac{p_m^{unld}}{\sum_{j \in R_i} p_j^{unld}} \cdot \Delta p_i \quad (m \in R_i, i \in G) \quad (7)$$

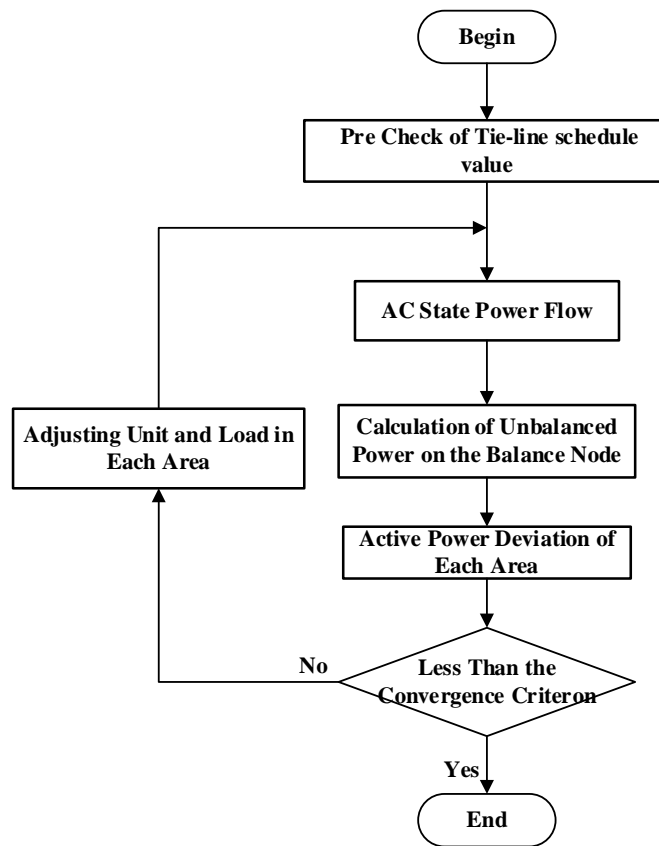
- c)  $\Delta p_m^{unld}$  on behalf of the regulatory unit or load to bear the burden of the adjustment of power;  
 $p_j^{unld}$  on behalf of the adjust[[ unit or load  $j$  to participate in the adjustment of the coefficient;  
 $R_i$  on behalf of the region  $i$  involved in the adjustment of the unit or load set. The process of the algorithm is shown in Figure 3.

## 4.2. Application Examples

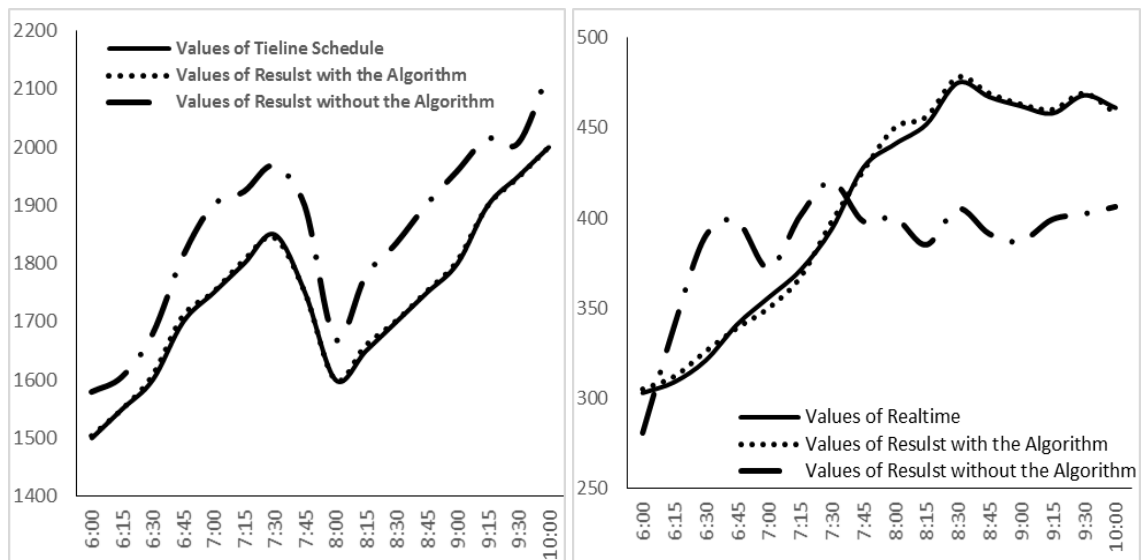
In order to verify the effectiveness of the proposed algorithm, the results are compared with actual power grid calculation of the joint ISC.

We select an existing power grid tie-line section to show the effect of the proposed algorithm. The results are shown in Figure 4. It shows that the calculation results of the optimal control algorithm considering tie-line schedule are consistent with the plan, but the results obtained by the direct calculation are quite different. Using this algorithm, average deviation rate of tie-line calculation values is 0.2%, otherwise it is 6.9%.

A transmission line in the contact line section is selected for showing the algorithm effects. The results are shown in Figure 4. It can be seen from the graph that the difference of calculation results with the algorithm and the actual result is very small, but directly calculation of line flow and the value of actual line flow varies greatly. Using this algorithm, average deviation rate of contact line calculation values is 0.7%, otherwise it is 12%.



**Figure 1.** The process of power flow algorithm considering tie-line schedule



**Figure 4.** The comparison of a tie-line section and transmission line in tie-line section calculation

#### 4.3. The Advantages of the Algorithm

1) The algorithm proposed in this paper according to the plan value control Liaison Section transmission of active power, the partitioned iterated elimination system generation planning and bus load forecast data between mismatch are reasonable recently AC power flow section, on the basis of this section were N-1 and fault set calculation and improve the power system recently static security checking the reliability and practicability.

2) The algorithm can adapt to the different regions reported data quality is inconsistent, the reasonable elimination of active power imbalance.

3) This Algorithm can quickly according to the size of the regional power imbalance, to check the quality of the data reported in each region.

4) It can realize the compatibility of the contact line plan and the power generation plan, and improve the accuracy of the results of static security check before the day.

The algorithm according to the plan value control Liaison Section transmission of active power, the partitioned iterated elimination system generation planning and bus load forecast data between mismatch are reasonable recently AC power flow section, on the basis of this section were N-1 and fault set computing, to improve the reliability and practicality of static security checking.

#### 5. Conclusion

Cloud computing is a research hotspot right now, and it has been researched and developed in both industrial and academic field. This paper proposes the method of a joint intraday security check system based on cloud computing. The power flow algorithm using in joint ISC which considers tie-line plan is proposed to solve the problem occurring on a large scale power system planning section flow calculation. The method described in this paper would be used in multi-level dispatch centers of State Grid Corporation of China. Its application will greatly enhance the ability of all-grid dispatch center to deal with complex large power grid safety operation and the adaptation of power market reform.

#### Acknowledgments

This paper was supported by Science and Technology Projects of the State Grid Corporation

#### References

- [1] Cao Y 2012 *Chn. Ele. Pow.* **45** 14-17
- [2] Popeanga J 2012 *Database Syst.J.* **3** 57-66
- [3] Guo Y, Pan M and Fang Y 2012 *IEEE Trans. Parallel Distrib.Syst.* **23** 1593-1606
- [4] Samaresh B, Sudip M and Joel J 2015 *IEEE Trans. Parallel Distrib.Syst.* **26** 1477-1494
- [5] Ying L, Guangming L 2015 *Auto. Elec. Pow.* **39** 171-176
- [6] Xingzhi W and Sheng Y 2011 *Pow. Sys. Pro.* **39** 90-95
- [7] Chuancheng Z 2016 *Pow. Sys. Tech.* **40** 3342-3347
- [8] Zonghe G and Jian G 2008 *Auto. Elec. Pow* **32** 28-30