# Power System Security Assessment and Remedial Measures based on the on-line Dynamic Security Assessment System

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**Keywords:** on-line analyse, dynamic security assessment, intelligent scheduling system, remedial measures

**Abstract:** The on-line dynamic security assessment system introduced in this paper calculates and assesses power system using high performance parallel cluster and the real time on-line data obtained by intelligent scheduling system, achieving a leap from the off-line analysis to the on-line analysis of the power grid. The main structure, function and calculation process of the dynamic security assessment system are briefly introduced, the safety and stability analysis of power grid after serious failures is taken as example, the calculation results show that the dynamic security assessment system can calculate the power grid and propose the corresponding auxiliary decision-making measures timely and effectively, enhancing the emergency handling capacity of power dispatchers in emergency situations, it plays an important role in ensuring the security and stability of power system.

## 1. Introduction

With the increasing demand for power in the world due to rapid social and economic development, the scale of modern interconnected power system is increasing and the structure is more stronger, with the improvement on economy and reliability of the system operation, however, at the same time, it faces various challenges from new problems[1,2]. Several blackouts that have been experienced throughout all over the world during recent few years show that local power disturbance may lead to large-area cascading failures once again[3,4]. Therefore, improving the security and stability analysis level has become one of the important means of ensuring the operation of the power system.

The off-line calculation manner is used for the traditional security analysis of power system, but there is difference between the selected typical mode and actual operation condition, which makes the results tended to conservation in most cases; thus, the on-line security analysis method gains extensive attention both domestic and abroad [5-11]. Aiming at the new demand for the

development of power grid, on-line security and stability analysis technology is need urgently to overcome the insufficiency of traditional off-line calculation, adopting on-line dynamic security assessment to power grid and finding problems in all operation modes, putting forward prevention decision measures, thus to enhance the efficiency of the dispatchers, and effectively improve the capacity of reining operation of bulk power system.

Therefore, implementation of the dynamic security assessment (DSA) based on smart dispatching system and the calculation analysis based on the real-time data collected by the energy management system is of important significance. In this paper, the structure and function module of DSA is briefly introduced first, the stability analysis calculation process of DSA is analysed then, and the security and stability analysis of a certain area power system after fault is carried out as example. The results show that the DSA system plays an important role in assisting scientific decision-making for the dispatchers.

## 2. Introduction to DSA

Based on smart dispatching D5000 system, the DSA responsible for security and stability analysis of power grid within the dispatching management scope, and the overall structure, basic function and calculation flow of DSA will be briefly introduced.

### 2.1. Data source

The data source is the basis for on-line analysis and calculation. The DSA system based on D5000 system first automatically acquires the on-line calculation data issued uniformly by higher dispatching centre through the interface with the dispatching support system, including static model and parameters , real-time flow data, and forms a complete data set that can reflect the real-time operation condition of the power grid through data integration of local dynamic model and parameter for loads and units, to provide complete data source for on-line security and stability assessment.

### 2.2. The structure and basic function of DSA

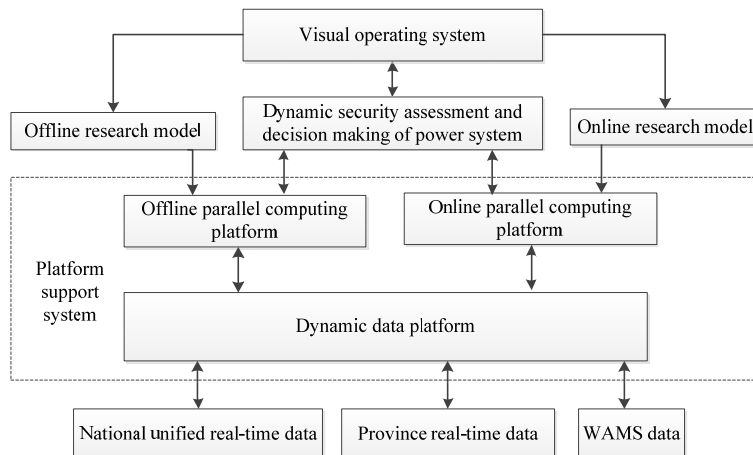The main structure of DSA system is shown in Figure 1.



Figure 1 The main structure of DSA.

Main hardware configurations constituting the system in Figure 1 include compute node cluster, dispatching management server, data interface server, network connection switch, and engineer's

workstation, etc., and each part coordinates with each other for working, completing various calculation and analysis needed or allocated by the system, and returning the results to the human-machine interface.

## 2.3. The analysis flow of DSA

The DSA system gets the calculation data needed through integration of relevant data such as equipment parameters, fault set, and real-time information of power grid, forming the reasonable on-line power flow data conforming to actual operation condition of power grid. Then, six types of calculations are carried out, including basic state flow scanning, static security analysis, transient stability analysis, dynamic stability analysis, voltage stability analysis, and short-circuit current analysis. At the same time, the stability margin of the key section of the power grid is calculated, and the operation mode with low margin is warned, the auxiliary decision measures are proposed. The overall calculation and analysis flow is shown in Figure 2[12].
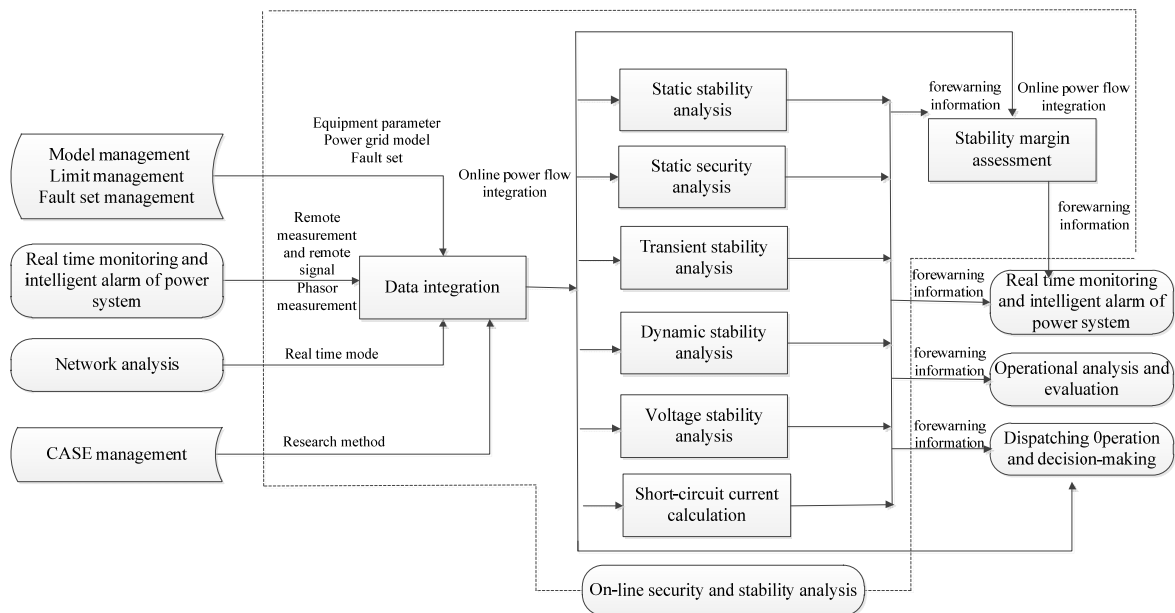


Figure 2   The calculation and analysis flow of DSA.

## 2.4. Calculation mode of real-time state and research state

The calculation modes of DSA system include two modes: real-time calculation module and research calculation module. The real-time module is to realize on-line tracking of actual operation of power grid, whose calculation is started periodically. Six types of calculation analysis and prevention control decision-making measures are carried out for the power grid every 15min regularly, to realize the visualized monitoring and on-line auxiliary decision-making ,providing the dispatcher with the prevention control measures for the power grid under the current operation mode, and giving the stability limit and dispatching strategy.

The research calculation module is started by events, in which the data concerned by dispatchers is selected, to study static, transient and dynamic problems existing in the system in details, search the cause of security and stability problems of the system, and propose the fundamental method of solving these problems, thus to achieve the purpose of optimizing the operation, and improving the stable and economic operation under the current operation mode of power system. The difference

between the two calculation modes is the different start-up period, and the remaining functions are same.

## 3. Application of DSA to power system

From 1 p.m. to 3 p.m. on June 23, 2016, strong rainfall, heavy wind happened in the northern part area of Jiangsu province, with severe convective weather such as strong thunder, short-time heavy rainfall, hail, and thunderstorms. The power grid was severely affected, including tripping of two 500kV lines, multiple 220kV lines and 110kV lines.

As a result, multiple substations in this area operated by single-line feeding, in which 220kV YN-DY double lines, DY-HX line, and HX-XY line were tripped. After tripping of the lines, the power grid was weakened with operation risk, and part of the power grid after the fault is shown in Figure 3.
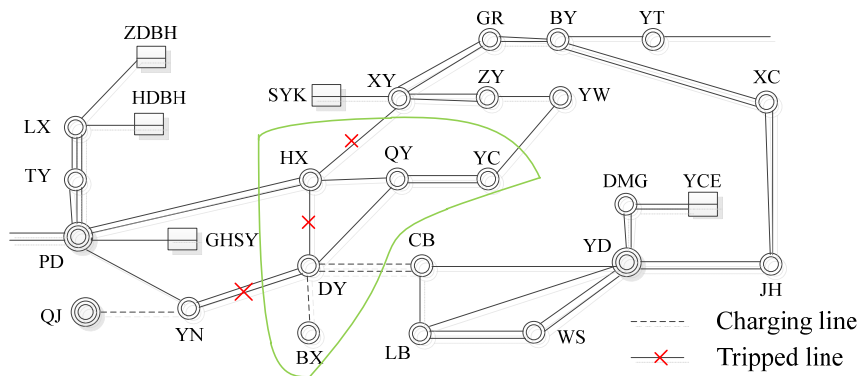


Figure 3   The part of the power grid after fault.

It can been seen that multistage feeding mode is formed in the power grid, five 220kV substations including HX, QY, DY, BX and YC were connected with the other part of power system by PD-HX double lines and YC-YW line, as shown in the green solid line part in Figure 3. The security analysis engineer immediately selected the data issued by the superior dispatching centre at 3 p.m. on June 23, 2016 as the basic analysis data for the DSA system, and six types of calculations were automatically carried out.

After the security analysis of DSA system, it was found that there was static security problems, without problems such as transient stability, dynamic stability, or short-circuit current exceeding limit. The calculation results are shown in Table 1, and detailed static security calculation results are shown in Table 2 and Table 3:

Table 1   Results of dynamic security assessment.

| Overload safety analysis of equipment | | Static voltage security analysis | |
|---|---|---|---|
| Safety margin | -15.92% | Safety margin | -2.51% |
| Overload equipment | YC-YW line | Bus | DY substation /220kV.bus |
| The worst fault | PD-HX double lines tripping | The worst fault | PD-HX double lines tripping |

Table 2   Equipment overload results of static security assessment.

| Fault components | Equipment exceeding limit | Current after fault (A) | Rated current (A) | Safety margin (%) |
|---|---|---|---|---|
| PD-HX double lines tripping | YC-YW line | 1787.46 | 1542.00 | -15.92 |
| PD-HX double lines tripping | TW-YL line | 1866.72 | 2390.00 | 21.89 |
| PD-HX double lines tripping | YF line | 600.83 | 857.00 | 29.89 |
| PD-HX double lines tripping | XY line | 1077.54 | 1542.00 | 30.12 |

Table 3   Static voltage security assessment results.

| Fault components | Bus | Voltage after fault (kV) | Low-limited voltage (kV) | Safety margin (%) |
|---|---|---|---|---|
| PD-HX double lines tripping | DY substation /220kV.bus | 203.76 | 209.00 | -2.51 |
| PD-HX double lines tripping | HX substation /220kV.bus | 205.05 | 209.00 | -1.89 |
| PD-HX double lines tripping | QY substation /220kV.bus | 205.59 | 209.00 | -1.63 |
| PD-HX double lines tripping | YC substation /220kV.bus | 209.31 | 209.00 | 1.87 |

The above calculation results show that the power grid after the disaster has static security problems, and after tripping of PD-HX double lines, YC-YW line will exceeds the limit, and 220kV bus voltage of three stations including DY, HX and QY will exceeds the lower limit.

The auxiliary decision-making measures given by DSA are to reduce active load of YC substation by 99.5MW, and reactive load by 16.73MVar; active load of QY substation by 17.97MW and reactive load by 5.22MVar. The stability calculation results after the auxiliary decision-making measure are adopted are shown in Table 4.

Table 4   Results of after comprehensive assistant decision.

| | | Before adjustment | After adjustment |
|---|---|---|---|
| Overload safety analysis of equipment | Safety margin | -15.92% | 7.75% |
| | The worst fault | PD-HX double lines tripping | PD-HX double lines tripping |
| | Overload equipment | YC-YW line | YC-YW line |
| Static voltage security analysis | Safety margin | -2.51% | 0.3% |
| | The worst fault | PD-HX double lines tripping | PD-HX double lines tripping |
| | Bus | DY substation /220kV.bus | DY substation /220kV.bus |

Under the circumstance that the power grid was seriously damaged and a large of loads were lost, power resources are extremely important for after-disaster emergency rescue as well as production and living, and the operation of load shedding is certainly not appropriate. Due to the area connection lines including DY-CB double lines and YN-QJ line were in charged state for reserve, thus it is decided that these three lines are putted into operation after discussion, in order to strengthen the power grid, and the grid after mode adjustment is shown in Figure 4.
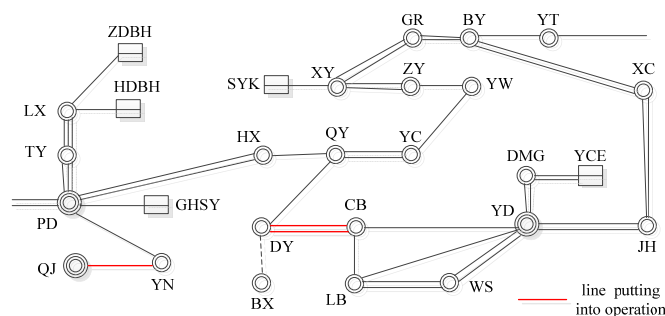
Figure 4   The part of the power grid after operation mode adjustment.

After the operation mode adjustment, the power grid structure was strengthened. After tripping of PD-HX double lines, security margin of YC-YW line is 5.63%, security margin of bus voltage in DY, HX, QY are 3.25%, 4.62%, 5.12%, respectively. Thus the operation risk after tripping of PD-HX double lines is eliminated.

## 4.   Conclusions

In this paper, the DSA system based on D5000 smart dispatching system is introduced, and then the security and stability calculation of power grid in a certain area after mega-disaster is taken as an example. The results show that the DSA system can rapidly and effectively realize on-line security analysis, find the weaknesses in real-time operation of the power grid, and provide the dispatchers with the effective technical support and auxiliary decision making measures for regulating the power grid, which plays an important role in actual operation of power system. However, the auxiliary decision making measures given by DSA is inadequate at present, the regulation measures only includes the starting and shutdown of units, adjustment and control of loads. In most cases, some measures are only feasible in theory, but the operation of reserve connection lines, load transfer and other operation mode adjustment, are not feasible by the DSA now, which needs further optimization and improvement in future.

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