Application of transformer heavy load and overload analysis and management system

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Abstract. In recent years, with the development of China's economy and society, the social electricity consumption increases rapidly. As a support for the development of the national economy, the scale of power grid has expanded. The load capacity of oil-immersed power transformer is an important safety and performance index. Limited load capacity or overload may cause a large area of power grid blackout. Therefore, it is necessary to analyze and control the transformer heavy load and overload.

1. Instruction

As the most important equipment in a substation, its safe, reliable and economical operation has vital impact on the whole power grid. Once the transformer in the power system breaks down, it will bring about the serious consequence of large-scale blackout[1-3]. The load increase of transformer will lead to the increase of winding temperature, which will affect the insulation level of transformer and finally shorten its service life. Therefore, it is necessary to take measures to effectively monitor the transformer load to ensure that the transformer load is under control[4-6].

In this paper, the active power and reactive power of the transformer are collected from SCADA of the dispatching operation system and calculated in the load condition of the operating transformer according to the weekly, monthly, semi-annual, annual time period. The operation characteristics and risk of heavy load and overload of transformer are analyzed. And system operation, planning, infrastructure and other departments are formed a linkage mechanism. Operation and maintenance strategies and planning projects are formulated targeted to realize the healthy and stable operation of transformer. The technology structure of transformer heavy load and overload analysis and management is proposed in Fig.1.
2. Transformer heavy load and overload main evaluation index

2.1. Transformer maximum load rate per year (month, week)
The maximum load rate of transformer per year (month, week) is used to reflect the maximum utilization of transformer in a given year (month, week). The calculation formula is that the maximum load rate of transformer per year (month, week) equals the maximum load per year (month, week) divided by the rated capacity of main transformer. The transformer load $S$ is obtained by the following formula:

$$S = \sqrt{P^2 + Q^2} \quad (1)$$

Where, $S$ is the transformer load, $P$ is the active power on the high-voltage side of the transformer, and $Q$ is the reactive power on the high-voltage side of the transformer.

2.2. Transformer annual (month, week) equivalent average load rate
The annual (month, week) equivalent average load rate of transformer is used to reflect the average utilization level of network load of transformer in one year. The calculation formula is that the equivalent average load rate of transformer per year (month, week) equals equivalent average load per year (month, week) divided by rated capacity of transformer.

2.3. Heavy load transformer
The maximum load rate and equivalent average load rate of a transformer meet the following criteria is called a heavy load transformer. The criterion conditions are: maximum load rate $\geq 80\%$ and equivalent average load rate $\geq 40\%$.

Principle of equivalent average load rate is that considering the utilization hours of between 5500 and 6000 hours, the equivalent average load rate of 20% corresponds to the maximum load rate of about 30%. The equivalent average load rate of 15% corresponds to the maximum load rate normally in the range between 20% and 25%. Considering the large difference in power supply load characteristics between 110kV and below stations, the value could be appropriately reduced.

2.4. Overload transformer
The maximum load rate of a transformer meets the following criteria is called an overload transformer. Its criterion condition is that maximum load rate $\geq 100\%$. 
2.5. **Heavy load and overload transformer**

The maximum load rate and equivalent average load rate of a transformer meet the criterion conditions is called heavy load and overload transformer. The criterion conditions are that maximum load rate ≥100% and equivalent average load rate ≥40%.

3. **Heavy load and overload transformer management**

3.1. **Data acquisition**

In principle, the service data should be collected from the operation data, such as the active power and reactive power, and the equipment parameters, such as the rated capacity, of 35-110kV transformers in the SCADA system of each power supply bureau of Guizhou Power grid.

3.2. **Heavy load and overload transformer judgment**

(1) According to the judgment basis of heavy load transformer in 2.3, the judgment of heavy load transformer is carried out to search in transformers of each power supply bureau.

(2) According to the judgment basis of overload transformer in 2.4, the judgment of overload transformer is carried out to search in transformers of each power supply bureau.

(3) According to the judgment basis of heavy load and overload transformer in 2.5, the judgment of heavy load and overload transformer is carried out to search in transformers of each power supply bureau.

3.3. **Transformer heavy load and overload cause analysis**

3.3.1. *The System Operation Department conduct cause analysis in the following aspects:*

(1) Whether it is temporary heavy load and overload caused by scheduled maintenance and fault trip;

(2) Whether it is long-term heavy overload caused by long-term supply of large user loads;

(3) Whether it is long-term heavy overload caused by large power supply range and rapid increase of natural load;

(4) Whether it is seasonal heavy overload caused by the increase of air conditioning load in summer and heating load in winter.

3.3.2. *The Program Development Department conduct a heavy overload cause analysis in the following areas:*

(1) Peripheral planning projects are not in schedule (including the lagged construction of supporting low-voltage power grid);

(2) Load development exceeds the planned expectation;

(3) Planning construction standards are low and (including low planned transformer capacity or low line load flow);

3.4. **Transformer heavy overload risk analysis**

3.4.1. *The System Operations Department conduct a heavy overload system risk analysis in the following areas:*

(1) The power limit risk of overload transformers in normal mode;

(2) The power limit risk and thermal stability after transformer accidents in the transformer N-1 condition in multi-transformers substation;

(3) The power limit risk after transformer accidents in the transformer N-1 condition in a single-transformer substation;

(4) The characteristics of the the load (livelihood or industry load)
3.4.2. **The Production Technology Department conduct equipment risk analysis for heavy overload transformer in the following aspects:**

(1) Whether the substation where the heavy overload transformer is located in the key substation in the annual operation plan;

(2) Whether the heavy overload transformer is the key equipment in the annual operation plan;

(3) Whether the heavy overload transformer is in the annual I-level or II-level control equipment list;

(4) Whether the transformer's annual status evaluation and dynamic status evaluation results of the heavy overload transformer is in serious, abnormal or attention state.

3.5. **Transformer heavy overload risk control and management measures**

3.5.1. **The System Operation Department formulate and implement scheduling risk control measures for heavy overload transformer in the following aspects:**

(1) Whether the heavy overload load rate can be reduced by optimizing the operation mode of the power grid;

(2) Whether there is a controlled section to ensure that it does not exceed the accident overload capacity after accidents in the transformer N-1 condition;

(3) Whether there is a measure to optimize the starting mode of regional power grid to reduce the load rate by the water storage of hydropower stations and coal supply of thermal power stations.

(4) Whether the safety and stability control device is equipped;

(5) Whether the overload transformer deloading device is planned to be added;

(6) Whether there is a heavy overload substation dispatch and disposal plan;

3.5.2. **The Production Technology Department formulate and implement equipment risk control measures for heavy overload transformer in the following aspects:**

(1) Carry out equipment status evaluation and risk analysis, assess the equipment operation and maintenance control level, and make effective record;

(2) Focus on the equipment defect control level during heavy overload period;

3.5.3. **The Program Development Department formulate and implement planning project control measures for heavy overload master changes in the following aspects** (including but not limited to).

(1) Propose solutions for substations existing the heavy overload risk;

(2) Propose solutions for substations without heavy overload risk but in risk warning.

3.5.4. **The Infrastructure Department shall formulate and implement the control measures for the heavy-overload main transformation of the infrastructure projects in the following aspects**:

(1) Propose solutions for infrastructure projects that solve the overload risk;

4. **Construction of transformer heavy load and overload analysis and management system**

The transformer heavy load and overload analysis and management system automatically calculate and analyze transformer load rate by multi-data acquisition. Data acquisition includes the quasi real-time data, the CIM model tripping action event data, equipment, equipment parameter data (including scheduling, production), important equipment data, equipment health degrees geographic information data, equipment, power outages, plan, working ticket, equipment defect data and environmental data, including lightning and ice data, etc. Data fusion and data modeling are developed to research the basic functions of real-time load rate, heavy load, overload, and index characteristics, multidimensional index calculation, statistics, visual display and other basic functions of transformer equipment. The transformer load risk assessment model and the heavy load and overload risk prediction model are applied to realize advanced application functions. The system functional architecture is as follows in Fig.2. The main system surface is shown in Fig.3.
5. Conclusion
In this paper, a comprehensive monitoring and analysis system for the load condition of the main transformer in Guizhou was developed to realize the unified model construction of the load foundation of the transformer. Ledger management, index management, statistical report, alarm management, main variable load risk assessment, main variable load forecast management, main variable load closed-loop management and other application functions are developed. The data application results are visually displayed. The whole process of load risk control from load risk assessment, prediction, decision making and risk reduction/avoidance is systematically carried out.

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References

[1] He Jianzhang, Wang Haibo, Ji Zhixiang, et al. Influence factor Analysis of heavy overload of distribution transformer for smart grid [J]. Power Grid Technology, 2017, 041(001):290-295.

[2] He Jianzhang, Wang Haibo, Ji Zhixiang, et al. Prediction of distribution Transformer heavy overload based on stochastic Forest Theory [J]. Power Grid Technology, 2017(08):2593-2597.

[3] Shi Changkai, Yan Wenqi, Zhang Xiao-hui, et al. Prediction of Spring Festival Allocation weight overload based on BP Network and Gray model [J]. Journal of Electric Power Science and Technology, 2016, 31(003):140-145.

[4] Zhen Cheng, Wang Qi, Zhou Yuan, et al. Research on the Effectivengess of transformer Oil quality on-line Monitoring based on multi-frequency Ultrasound [J]. Electric Measurement and Instrumentation, 2019, 056(013):142-147.

[5] Yang Qiping, Xue Wude, Lan Zhida. Application of sensor Technology in transformer On-line Monitoring [J]. Transformers, 2007(12):50-55.

[6] Sun Ming, Lu Ping, Yan Yang, et al. Research on online Monitoring Scheme of Intelligent Transformer [J]. Hydro-electric Energy Science, 2013(1):193-196.