Modeling and Analysis of Industrial Power Load Based on Measured Data

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Abstract: With the rapid development of electronic technology, the construction of smart grids has been accelerated. Establishing an accurate load model is of great significance to the stability of distribution network system. Some large-capacity installations with more harmonics and impact, such as electric arc furnaces and wind farm are connected to the grid, which has a serious impact on the power quality of the distribution network. This paper adopts a method of industrial load modeling based on the fitting of measured data, selects electric arc furnace and aluminum rolling mill as typical industrial loads, establishes its model through fitting the measured data, which proves the reliability and accuracy of the load model.

1. Introduction

In recent years, with the rapid development of electronic technology, the construction of smart grids has been accelerated [1]. The distribution system bears the function of supplying power to users. With the continuous growth of the power supply load and the expansion of the scale of the distribution system [2], establishing an accurate load model is of great significance to the stability of the distribution network system. Now with the development and general application of high-power power electronic technology, the proportion of DC transmission, new energy grid connection and new type electric load is increasing. On the basis of traditional energy and AC/DC transmission network, some large-capacity equipment with harmonic and shock effects such as electric arc furnaces and wind farm. It has a serious impact on power quality problems in distribution networks.

As users continue to increase the reliability requirements for power supply [3], modern industrial, commercial, and residential users' electrical equipment is more sensitive to power quality problems, and higher requirements for power quality in distribution networks require the use of power electronic equipment. It is necessary to introduce power conversion technology by power electronic equipment to control the flow of high-power electronic equipment on and off to meet the requirements of users for voltage, frequency, current, waveform and phase. As people gradually understand the load modeling, it is found that changes in the load model have varying degrees of impact on the system transient stability and power flow calculation results. In its critical state, essential changes will occur [4].

In the 1960s, based on field tests conducted by the United States and the former Soviet Union, some load field data was collected. At this time, the most commonly used load models such as constant impedance, constant current, and constant power were proposed, which can converge the power flow calculation[5]. In the 1980s, International Council on Large Electric Systems (CIGRE), the load modeling working group proposed a dynamic model and a static model of the power system load. With
the development of computer data collection technology, based on field measured data, the overall defense method was put forward. This is the development of load modeling work.

Reference [6] used a portable power quality analyzer and online long-term monitoring to collect load data for a substation. After analyzing its harmonic currents, the current harmonic pollution status was obtained, but it did not build a specific load model. Based on this, this paper analyzes the mechanism of a typical industrial disturbance load with shock and harmonic problems, builds its mathematical model through field measured data, and verifies the correctness of its model by comparing the simulation results with the measured data.

2. Typical industrial load model based on measured data

At present, there are few industrial load modeling studies on measured data, and the harmonic problems of industrial loads have not been solved, and the power quality of the power grid is seriously threatened. This paper adopts an industrial load modeling method based on measured data fitting and selects electric arc furnace and aluminum rolling mill as typical industrial loads. Through the measured voltage, current and power data, the model is established by fitting, and the measured results are compared with the measured results. Comparison of simulation results.

2.1. Model analysis of electric arc furnace

Electric arc furnace is a kind of equipment for melting furnace charge by high temperature generated by electric arc [7]. The effect of the electric arc furnace on power quality is mainly reflected in two aspects: the voltage flashover caused by the impact change of the electric arc furnace load and the harmonics caused by its nonlinear resistance. Secondly, the highly non-linear electric arc furnace load is a strong harmonic current source, which will cause distortion of the grid voltage and seriously affect the power quality of the grid. Since the load of the electric arc furnace shows a high degree of time-varying, non-periodic and unpredictable, if the fluctuation of the load of the electric arc furnace is ignored, the influence of the voltage fluctuation and flicker on the power quality cannot be analyzed.

In order to analyze the load characteristics of the electric arc furnace, the researchers conducted on-site voltage, current and power data collection for an electric arc furnace. Fig.1 and Fig.2 are actual measured waveform.

![Fig.1 10KV phase-to-phase voltage waveform measured by electric arc furnace](image1)

![Fig.2 Three-phase current waveform measured by electric arc furnace](image2)

From the measured waveforms, it can be seen that the voltage and current waveforms of the arc furnace are not standard sinusoidal waveforms, and their distortion is very serious, and each phase has obvious distortion. In addition, during the operation of the electric arc furnace, the amplitude of current change is relatively large, and the rate is relatively fast.

The simulation analysis of the electric arc furnace load in MATLAB, according to the characteristics of the electric arc furnace, the equivalent model was built in the simulation as shown in Fig.3.
Fig. 3 Electric arc furnace load simulation model

The current of a certain phase on the grid side of the arc furnace model is shown in Fig. 4, and its frequency spectrum analysis is shown in Fig. 5. The harmonic current order is consistent with the analysis.

Comparing Fig. 2 and Fig. 3, it can be found that the current waveform simulated by the electric arc furnace load model is consistent with the measured waveform, and they all have serious distortion. According to the frequency spectrum, the harmonic component of the electric arc furnace load current is mainly the third harmonic.

2.2. Modeling and analysis of rolling mill

The rolling mill reduces the voltage through the rectifier transformer, the secondary side is connected to the AC-DC converter, and the inverter is connected to the electric excitation AC. The researchers used the power quality analyzer to record the on-site measured waveforms. According to the on-site equipment and the measured current waveforms, the rolling mill is a 6-pulse AC-DC-AC frequency conversion AC synchronous motor. The actual measured waveforms of the rolling mill site are shown in Fig. 6 and Fig. 7.
According to the measured waveforms, the rectifier circuit of the rolling mill is half-wave symmetrical, so there are no even harmonics, mainly odd harmonics, and the harmonic order is $6k \pm 1$. The effective value of each harmonic current is inversely proportional to the harmonic order. The higher the harmonic order, the smaller the harmonic amplitude.

The rolling mill model built in the simulation software is shown in Fig.8.

According to its simulation analysis, the current of a certain phase of the rolling mill is shown in Fig.9, and its frequency spectrum is shown in Fig.10.
Comparing Fig. 7 and Fig. 9, it can be seen that the current in the simulation model of the rolling mill is consistent with the measured current waveform and has a distortion phenomenon. After analyzing its frequency spectrum, it is found that the harmonic current is mainly 5, 7, 11, 13 harmonics, which conforms to the above mechanism analysis, this model is correct and effective.

3. Conclusion
In this paper, combined with the actual measured voltage and current waveforms, a typical industrial load represented by an electric arc furnace and a rolling mill is analyzed for load model construction and mechanism analysis. The simulation model results are compared with the measured waveforms and the harmonic content of the model current is analyzed, which proves the reliability and accuracy of the model.

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