STUDY ON RUNNING SIMULATION FOR ELECTROSTATIC PRECIPITATOR

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1. Introduction

With the rapid development of electric power industry in China, ESP had become one of the most necessary equipments for safely power generating and environmental protection in power plants. However, owing to various reasons, many ESP in China is in poor operation and maintenance, and approximately 30 percent of them could not attain the designed dust collection efficiency. The principle training simulator for ESP could supply good conditions for technical training on personnel in operation, maintenance and management on ESP. It was mainly composed of hardware system, software system and mathematical models (Tian, 1994).

Description of training simulator for ESP

The principle training simulator for ESP was made up of one host computer, three I/O interfaces and six pieces of simulating dials.

Host computer. It could accomplish mathematical models calculation, signals and induction information collection, then according to the results that had been worked out, it sent out all kinds of instructions to control the whole training simulator.

Interface. STAR-90 intellectual dispersed interfaces were used in the training simulator, which could transform all sorts of operating signals on the high and low voltage simulating dials to digital signals that could be accepted by the host computer, then send them to mathematical models for carrying out simulating calculations. On the other hand, they could also transform the output data which had been produced from the mathematical models that were stored in the host computer to various visual signals, such as indicator lamps, voltage, current meters, etc.

RS-232 series communication was applied between the interfaces and the host computer, 3 pieces of I/O interface boards were all suspended in the simulating control dials. It did not need other hardware in computer, so the connection between them was very clear, it was considerably convenient to debug and operate. In the training simulator, there were totally 3 kinds of interfaces: a digital input (DI), a digital output (DO) and an analogue output (AO). Each of them was connected with the host computer through an interface board. Relevant driven program could be compiled on the host computer, all the datum (input/output) were carried out by the interruption communication style. Through large amounts of tests, it proved that the designation for the I/O interfaces could satisfy real time requisition of the training simulator. Not only was it highly accurate, but also it could save time for the host computer. So, it is an ideal configuration.

Simulating control dials. The principle training simulator for ESP was designed according to a single chamber horizontal wire-plate ESP with three electric fields, which was equipped with the large generating units in coal-burning power plants. Every electric field was made up of 2 simulating control dials: one for high voltage control, the other for low voltage control. So there were totally 3 pieces of high voltage simulating control dials and 3 pieces of low voltage simulating control dials, separately. For convenience of technical training, either of the high voltage simulating control dials or the low voltage simulating control dials was closely similar in functions and hardware configuration with the real control dials that were widely adopted in coal-fired power plants in China. One difference was that a collection efficiency indicator was added to each of the three high voltage simulating control dials, with which the simulating collection efficiency could be indicated. Not only could it display the collection efficiency of local electric field, but also it could give the comprehensive collection efficiency of several electric fields.

Instruction platform. The host computer of the training simulator also acts as the instruction platform, by which the instructor could select various training items, such as system start-up, normal running, system shut-down, parameters alteration, operation supervision and man-made faults installation, et al. Furthermore, during the whole training process, it could send out various instructions that controlled the operation status of the training simulator, for example, parameters printing, freezing/unfreezing, retrieving, and marking, et al.

The simulating mathematical models of ESP

Approximately 100 simulating mathematical models had been constituted, which were suit for the requirements of the principle training simulator for ESP. They primarily included the following mathematical models and some relevant simulating curves:

Models for high voltage energizing system. The mathematical description of the high voltage energizing system, including those of two types of control patterns, which were spark tracing energizing control and intermittent energizing control. There were models of system start-up, system shut-down, normal operation and adjustment and so on.

Models for low voltage control system. There were system start-up, shut-down, normal operation, adjustment of the low voltage control system and so forth, mainly including that of collecting/discharging electrode rapping control, dust removal control and heating control and so on.

Models for common faults in high voltage system. They were models for common faults generating in high voltage energizing system, such as secondary short circuit, secondary open circuit, primary over current, bias-excitation, non-indication on secondary current display, voltage and current rising sharply, high voltage insulation descending, the pointer of secondary current meter vibrating periodically, breakdown voltage descending, operating current being too small, oil-temperature in T/R being too high and so on.

Models for common faults in low voltage system. Include primary faults on positive/negative electrode rapping control system, fly-ash removal control system, heating control system, etc.

Voltage-current curves under various conditions. There were mainly V-I curves of unloading dust-contained flue gas, loading dust-contained flue gas, V-I curve shifting to right, V-I curve rotating to left or right, V-I curve shifting to left and shortening, V-I curve passing through origin, V-I curve when there were slight back corona and serious back corona.

Models for collection efficiency of ESP. It was the qualitatively simulating mathematical models for collection efficiency of ESP. The collection efficiency was under the influence of many factors, including primarily corona power, dust specific resistivity, gas stream distribution pattern, bunch flow and reentrainment, mean diameter of dust particles, gas flow rate, et al. All of these factors were taken into account in the collection efficiency mathematical models.

Parts of simulating models were listed below (Hu Z.G., et. 1993, Tian H.Z., 1994):

(1) Conducting angle of thyristor:

Voltage ascending segment:

$$\phi_i = \pi(1 - e^{-s_1 i})$$

Voltage descending segment:

$$\phi_i = \pi \cdot e^{s_2 \cdot i}$$

Where s_1 and s_2 denoted voltage ascending and descending rate, and i was its half-wave number during one sparking period.

(2) **Primary voltage after smoothed waveform by reactor:**

$$U_1'(t) = \begin{cases} 0 & (i-1)\pi < \omega t \le i\pi - \phi_i \\ \sqrt{2}U_{1i}' \sin(\omega_i t - \beta_i) & i\pi - \phi < \omega t \le i\pi (i = 1,3,5\cdots) \\ -\sqrt{2}U_{1i}' \sin(\omega_i t - \beta_i) & i\pi - \phi_i < \omega t \le i\pi (i = 2,4,6\cdots) \end{cases}$$

Where:

ω was the angle frequency of power supply, (ω=314 radian/s);

ω_i was the angle frequency of ith half-wave, $\omega_i = \frac{\pi}{\phi_i}\omega$;

β_i was the initial phase angle of ith half-wave, $\beta_i = \frac{\pi}{\phi_i}(i\pi - \omega)$;

U_{1i}' was primary voltage virtual value of ith half-wave during the region of $(i\pi - \omega) \sim i\pi$, $U_{1i}' = \sqrt{\frac{\pi}{\phi_i}} U_{1i}$;

(3) Secondary voltage after rectification:

$$U_2(t) = \begin{cases} 0 & (i-1)\pi < \omega t \le i\pi - \phi_i \\ \sqrt{2}U_{2i}' \sin(\omega t - \beta_i) & (i\pi - \phi_i) < \omega t \le i\pi \end{cases}$$

where: U_{2i}' was the secondary sin value of the ith half-wave during the region of $(i\pi - \omega) \sim i\pi$, $U_{21i}' = \sqrt{\frac{\pi}{\phi_i}} U_{2i}$

(4) Secondary current:

$$I_2(t) = \begin{cases} 0 & U_2(t) < U_0 \\ \frac{A\pi\varepsilon_0 k}{cb^2 \ln(4b/\pi a)} U_2(U_2 - U_0) & U_0 \le U_2(t) < U_p \end{cases}$$

Where: U_2--the second voltage between two electrodes, A--the dust collecting area, U_0--the corona voltage, ε_0--was the vacuum dielectric constant, k--was the ionic mobility of the gas, U_p--was the discharging voltage, c--was the half space between the corona lines, b--was the half space between the collecting boards, α--was the minimum curvature radius of the corona line.

(5) **Program control model for positive electrode rapping:**

$$MR(t) = \begin{cases} 0 & nTR < t < nTR + TR_2 \\ 1 & nTR + TR_2 \le t \le (n+1)TR \end{cases}$$

Where $MR(t)$ was the state of the electric motor for rapping. It is equal to 1, implying the motor was in operation. Otherwise, it was in shut-down. $TR=TR_1+TR_2$ denoted the rapping period for positive electrode rapping system, $TR_1$and TR_2 were rapping time and non-rapping time, respectively.

(6) **Auto ash-removal control model:**

$$MX(t) = \begin{cases} 0 & 0 \le t < TX_0 \\ 1 & TX_0 + nTX \le T \le TX_0 + nTX + TX_1 \\ 0 & TX_0 + nTX + TX_1 < t < TX_0 + (n+1)TX \end{cases}$$

Where $MX(t)$ denoted the state of the electric motor for ash removal. If it was 1, implying that the motor was on operation. Otherwise, it was shut-down. $TX=TX_1+TX_2$ was the ash removal period. TX_1 and TX_2 were the time for ash-removal and ash-accumulation separately, whereas, TX_0 denotes the original time which had passed for the first time ash-removal.

(7) V-I simulating curve for shifting to left or right. Owing to sharp changes for dust concentration of flue gas or other reasons, the equivalent resistivity between two electrodes altered greatly (Tian, 1994). It made the V-I curve shifting to left or right (Figure 1).

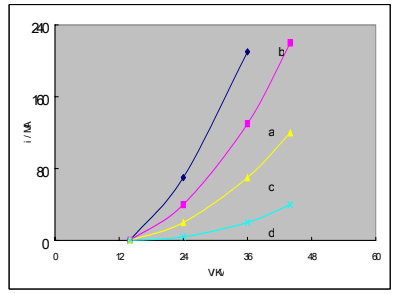

Figure 1 The simulating V-I curve for shifting
a--normal, b--shifting left, c--shifting right, d--shifting right seriously

(8) Simulating curve for back corona. When fly ash resistivity that entraining the electric field exceed about $10^{11}\Omega\cdot$cm, there would happen back corona on the layer adhering on positive electrode (Hu et al. 1995). The simulating curve for back corona was shown in Figure 2.

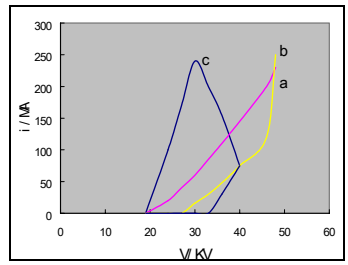

Figure 2 The simulating curve for back corona
a--normal running, b--slight back corona, c--serious back corona

From simulating curves listed above, we would see that they were very closely consistent with those encountered in real ESP.

The Train software for ESP

The training software for ESP was a large comprehensive system with multi-functions. It was established by the way of modularized and structured programming method, developed totally Turbo C. It could be divided into 15 key functional modules, and each was under the administration of the upper management software. Aiming at the main usual faults of electrostatic precipitator, the Fault Diagnosis Expert system was developed. It could judge the faults and provide disposal measures on time.

Conclusions

The configuration of principle training simulator was closely similar to those widely applied ESP in practice, which could accomplish various simulating train functions. By now, Over 1000 workers from coal-fired power plants through China have practiced the relevant operation of ESP on the simulator. It proved that it was an ideal training simulator for technical train of personnel in operation, maintenance and management for ESP. It is very helpful for the safe, efficient and stable operation of ESP in China.

References

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