APPLICATION OF THE AUTOMATIC CONTROL TECHNOLOGY FOR ENERGY CONSERVATION OF THE AIR-CONDITIONING SYSTEM IN SUBSTATIONS IN SHANGHAI

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ABSTRACT
Energy conservation has been the trend around the world. In allusion to the status of the rough management of air-conditionings in substations in Shanghai, an automatic control strategy for energy conservation of air-conditionings is confirmed, after analyzing the distribution of brands of air-conditioning equipments. Then, an automatic control system based on the strategy has been established, which can centrally control the air-conditionings and fans of one or multiple brands to save energy automatically. In this system, “manual control mode” has been designed in view of human nature in the field. After the period of setting time, “manual control mode” will turn to “automatic control mode” automatically. The actual results show that the energy consumption can reduce at least 25 percent, when the control system has been put into operation.

INTRODUCTION
Due to the temperature demand of microcomputer relays, air-conditionings have been widely used in substations in Shanghai to keep the temperature within reasonable bounds. However, the rough management of the air-conditionings has resulted in the massive power consumption at present. The purpose of this paper is to reverse the management status by application of the automatic control technology to reduce the energy consumption in substations.

PRESENT SITUATION AND PROBLEMS
During the summer at present, the air-conditionings often go on around the clock all days continuously once they are turned on, no matter how temperature has changed in the external environment. It always results in a great waste of energy. In addition, the staff in the field often set the temperature of the air-conditionings too low for personal feelings in the summer. The lack of set standards and management also leads to the increase of energy consumption in substations.
In summary, the problems of the operation of air-conditionings are as follows:
- Rough management of the running time
- No standard for setting the operating parameters, and the temperature is often too low
- Low utilization rate of the exhaust systems in substations

For the above, the introduction of automatic control technology has been considered to control the air-conditionings and exhaust fans centrally and regularly, based on a guarantee of the safe and steady operation of the internal equipments in substations, including the microcomputer relay protection devices. In the automatic control system, the temperature of the air-conditionings can be set regularly and properly for a good COP index (Coefficient of Performance), and the potential of the exhaust system has also been excavated to save energy.

AUTOMATIC CONTROL SYSTEM FOR ENERGY CONSERVATION

Survey of Air-conditioning Brands
As of July 2008, there are 221 substations above 35kV in Shinan Power Supply Company, and there are 861 air-conditionings in these substations. After statistics and analysis, we find out that the major air-conditioning brands in decreasing order are Daikin (314 units), Mitsubishi (235 units), Haier (108 units), Panasonic (95 units). The proportion of the above four brands accounts for 87.34 percent, as shown in Figure 1.

![Figure 1 The Statistics of Air-conditioning Brands in Substations](image-url)
If we take the substation as a unit, and analyze the air-conditioning brands in one substation, we find out that the there are 41 substations (19 percent) in which the air-conditionings are all Daikin, 40 substations (18 percent) for Mitsubishi, 12 substations (5 percent) for Panasonic, 9 substations (4 percent) for Haier, 42 substations (19 percent) for the above four brands combination, and the rest 35 percent for other small brands, as shown in Figure 2.

![Figure 2 The Distribution of Air-conditioning Brand Combinations in Substations](image)

From the above statistics and analysis, we find out that the coverage of Daikin, Mitsubishi, Haier, Panasonic brand and their combinations reach 65 percent of the whole substations. Consequently, the four brands become the focus and our main objective to achieve to control automatically for energy conservation. The rest 35 percent substations involving a dozen small brands of air-conditioning are not the focus of this paper.

**Control Strategy Analysis**

**Boundary Conditions**

The automatic control system shall guarantee a safe and steady operation of the microcomputer relays and other devices, and provide a comfortable circumstance for the workers doing some maintenance in substations.

**Control Strategy**

Based on such ideas, we select the indoor temperature $T$ as the first factor to meet the temperature requirements of microcomputer relays, select the temperature difference $\Delta t$ between indoor and outdoor as the second factor, and selected the humidity as the third factor considering the special humidity requirements of the indoor devices, et al. The detailed control strategies are as shown in the appendix Table 1 and Table 2.

**Hardware Structures**

To achieve the above mentioned control functions, it is necessary to choose the appropriate hardware modules for a optimal cost-effective aim. The required hardware modules in the automatic control system include CPU module, LCD touch screen, analog input modules, relay output module, the alarm buzzer and lights, air-conditioning interface, and so on. There are several ways to establish the hardware modules according to a variety of concrete components, we select the economic and reliable one. As follows, we take a typical hardware implementation way as an example to describe the control system.

- CPU module: 16-bit industrial PLC control module.
- Touch screen: LCD touch-screen (20cm).
- Analog input module: 2 analog input modules, single module has 3 roads sensor input.
- Relay output module: a selection of domestic brands relay output module.
- Alarm buzzer and light: giving a local alarm on site, and providing an output interface for remote alarm.
- Air-conditioning interface: selection of a relevant communications board according to air-conditionings brands in the substation.

Based on the above selection of hardware modules, the hardware principle block diagram is as shown in Figure 3.

![Figure 3 The Hardware Principle Block Diagram of the Automatic Control System](image)
Figure 4 The Software Control Process Logic Block Diagram in the Automatic Control System

- **Stand-by**: when the temperature is proper for the micro-computer relays and other devices in the substations, the air-conditionings do not need to run.
- **Heating**: when the temperature is too low for the operation of the devices, at this time, the air-conditionings begin to heating.
- **Ventilation**: when the outdoor temperature is low, and there is a large difference between the indoor and outdoor temperature, the exhaust fans can be used to adjust the indoor temperature by ventilation.
- **Refrigeration**: when the outdoor temperature is too high, and it is no use to reduce the indoor temperature by ventilation, refrigeration becomes necessary. According to the different number of the open air-conditionings, there are two operation modes, refrigeration mode 1 (to open half of the air-conditionings), refrigeration mode 2 (to open all the air-conditionings).
- **Dehumidification**: it is necessary to make full use of the dehumidification function of the air-conditionings for the humidity request of the devices in substations.

### Manual Control
Taking into account the regular inspection and maintenance for the staff in substations, “manual control mode” has been designed in view of human nature in the field. When they are doing some work in substations, the staff can adjust the “automatic control mode” to “manual control mode” in order to create a comfortable working environment. The staff can select a different return time setting according to the workload: they can select “1 hour” return time if they will do some inspection or small equipment repair work; they can select “2 hours” if they will do some equipment overhaul; and they can select “3 hours” if they will maintain the equipments of a large scale or a large circuit. They can readjust to “manual control mode” and reselect the return time, if it has reached the setting time but there are still some things to do. The reason why we set up an automatic return function after the setting time is mainly to remedy that the staff may forget adjusting to “automatic control mode” after they have finished the work. It will result in the continued low-temperature running of the air-conditionings and the significant increasing of energy consumption.

### Other Functions
In addition to the above, the automatic control system also has some other functions as follows.

- **Display**: it can show the indoor temperatures of different area, the average outdoor temperature, the operation mode, the system parameters and faults on the screen, etc.
- **Alarm**: it can alarm in local place if some faults have occurred, and it also offers an interface for remote alarm.
- **Data Record**: it can record the action sequence of the air-conditionings, and the record can be educed out for statistical analysis.
- **Rights Management**: different levels of staff have different rights and corresponding passwords.

### CONCLUSION
In this paper, the automatic control system has changed the traditional management methods and optimized the operation mode of air-conditionings. The results show that the energy consumption can reduce 25 percent averagely after the automatic control system has been installed, according to the actual operation of several substations in Jiading District of Shanghai. So, it can not only save money and energy consumption, but also be helpful to protect the circumstance.

### REFERENCE

### AUTHORS
Weibin Wang (1975-), male, master, senior engineer, majored in the application of new technologies in power system.
Bin Hua (1968-), male, senior engineer, majored in the technology management in power system.
### Table 1 The Detailed Strategy of Automatic Control

<table>
<thead>
<tr>
<th>Indoor Temperature T/°C</th>
<th>Temperature Difference ∆t (indoor-outdoor) / °C</th>
<th>Indoor Humidity</th>
<th>Outdoor Humidity</th>
<th>Operation Mode</th>
<th>Corresponding Action</th>
<th>Start Condition</th>
<th>Stop Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5</td>
<td>&lt; -3</td>
<td>-</td>
<td>&lt;75%</td>
<td>Ventilation</td>
<td>Fans work</td>
<td>T&lt;5</td>
<td>△t&gt;1</td>
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<tr>
<td></td>
<td>≥-3</td>
<td>-</td>
<td>≥75%</td>
<td>Heating</td>
<td>All air-conditionings heating</td>
<td>T≥6</td>
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<tr>
<td>5-30</td>
<td>-</td>
<td>&lt;75%</td>
<td>-</td>
<td>Stand-by</td>
<td>All air-conditionings stand-by</td>
<td>5≤T≤30</td>
<td>T≤4 or T≥31</td>
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<tr>
<td></td>
<td>≥75%</td>
<td>-</td>
<td>Dehumidification</td>
<td>All air-conditionings dehumidifying</td>
<td>Indoor humidity ≥75%</td>
<td>Indoor humidity &lt;70%</td>
<td></td>
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<tr>
<td>30-33</td>
<td>&gt;3</td>
<td>-</td>
<td>&lt;75%</td>
<td>Ventilation</td>
<td>Fans work</td>
<td>30≤T≤33</td>
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<tr>
<td></td>
<td>&gt;3</td>
<td>-</td>
<td>≥75%</td>
<td>Refrigeration 1</td>
<td>Half air-conditionings refrigerating</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0-3</td>
<td>-</td>
<td>Refrigeration 1</td>
<td>Half air-conditionings refrigerating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt;0</td>
<td>-</td>
<td>Refrigeration 2</td>
<td>All air-conditionings refrigerating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>≥75%</td>
<td>-</td>
<td>Dehumidification</td>
<td>All air-conditionings dehumidifying</td>
<td>Indoor humidity ≥75%</td>
<td>Indoor humidity &lt;70%</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2 The Detailed Strategy of Manual Control

<table>
<thead>
<tr>
<th>Indoor Temperature T/°C</th>
<th>Run-time Settings /h</th>
<th>Type of Work</th>
<th>Operation Mode</th>
<th>Corresponding Action</th>
<th>Start Condition</th>
<th>Stop Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;16</td>
<td>1</td>
<td>Inspection, minor repairs</td>
<td>Heating</td>
<td>All air-conditionings heating</td>
<td>Manual adjustment</td>
<td>Reach the set time</td>
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<td></td>
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<td>Major repairs</td>
<td>Heating</td>
<td>All air-conditionings heating</td>
<td>Manual adjustment</td>
<td>Reach the set time</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Circuit overhauling</td>
<td>Heating</td>
<td>All air-conditionings heating</td>
<td>Manual adjustment</td>
<td>Reach the set time</td>
</tr>
<tr>
<td>16-26</td>
<td>-</td>
<td>All types</td>
<td>Stand-by</td>
<td>All air-conditionings stand-by</td>
<td>Restricting manual adjustment</td>
<td>T&lt;16, T&gt;26</td>
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<tr>
<td>&gt;26</td>
<td>1</td>
<td>Inspection, minor repairs</td>
<td>Refrigeration 2</td>
<td>All air-conditionings refrigerating</td>
<td>Manual adjustment</td>
<td>Reach the set time</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Major repairs</td>
<td>Refrigeration 2</td>
<td>All air-conditionings refrigerating</td>
<td>Manual adjustment</td>
<td>Reach the set time</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Circuit overhauling</td>
<td>Refrigeration 2</td>
<td>All air-conditionings refrigerating</td>
<td>Manual adjustment</td>
<td>Reach the set time</td>
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