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Overview of the Current Status and Prospects of Electrical Energy-Saving Technology

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Abstract:

With the ongoing industrialization and urbanization, China faces an increasingly prominent energy bottleneck. Promoting energy conservation and emission reduction, along with building a resource-saving and environmentally friendly society, are long-term strategic goals for the country. Electrical energy is widely used across various sectors of the national economy due to its relatively straightforward production and conversion, ease of transmission and distribution, and convenient use and control. As a major sector in energy production and consumption, the electricity industry integrates energy-saving efforts across all stages, including power generation, transmission, transformation, distribution, and end-use, each presenting significant opportunities for energy conservation. This paper first describes the current status of electrical energy-saving efforts in China, then discusses the principles of implementing energy-saving technologies and their application prospects through case studies, which have major implications for future research and development of energy-saving technologies in electricity.

Keywords:

Electrical technology
Energy
Energy-saving
Importance
Application

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1. The evolution of electrical energy saving in China

Electrical energy, as a high-quality secondary energy source, has become indispensable to the national economy, people's daily lives, and industrial and agricultural production. Recently, China has faced a persistent demand-supply gap in electric power resources. In 2013, the national total electricity consumption reached 5,322.3 billion kWh, marking a 7.6% increase over the previous year, with an annual growth rate averaging 10.16% from 2006 to 2013 [1,2]. The year 2014 marked a turning point in China's energy-saving efforts, with total electricity consumption reaching 5,563.7 billion kWh, albeit with a growth rate slowdown of 3.18 percentage points. The energy saved through power conservation accounted for 78.9% of social-technical energy savings [3]. From 2015 to 2017, national electricity consumption growth rates were 1.0%, 5%, and 6.6%, respectively, showing a U-shaped trend in the past five years.

In terms of installed capacity for power generation, China relies heavily on coal-fired power, which constitutes over 70% of the installed capacity. In 2011, thermal power plants with capacities of 6,000 kW or more consumed 1.987 billion tons of raw coal, accounting for 53.88% of the national industrial coal usage [4]. With the progressive implementation of energy-saving and emission-reduction measures, the share of thermal power capacity has gradually declined, falling to 58% of the total installed generation capacity by 2017 [5].

2. Major areas of electrical energy saving

In China's overall end-use electricity consumption, general-purpose equipment accounts for more than half of the terminal electricity consumption, making it a primary target for energy-saving initiatives [6]. Major electricity-consuming equipment includes fans, pumps, conveyors, motors, transformers, generators, turbines, hoists, and others. The following sections provide an analysis of energy-saving principles and application methods for pumps, fans, and power transformers.

3. Energy saving for pumps and fans

3.1. Overview of energy saving for pumps and fans

Pumps and fans are widely used across various sectors where fluid and gas transportation is necessary. Pumps and fans account for approximately 30% to 35% of global electricity consumption, with fan power usage constituting 10.4% of national power consumption and pump usage accounting for 20.9%. In China, the average operational efficiency of fans is around 50%, while that of pumps is approximately 41%. Energy-saving potential for fans ranges between 20% and 60% and for pumps between 20% and 40%, making pumps and fans a significant focus area for energy conservation.

3.2. Energy-saving principles and applications for pumps and fans

There are two main approaches to power savings in pump and fan applications: (1) the development of high-efficiency pump and fan equipment and speed-control devices, and (2) the pursuit of quantitative energy-saving design, calculations, and control methods. While the technical development for high-efficiency devices has reached a relatively mature stage, the latter approach remains a focal challenge in both domestic and international industries.

Despite slight variations in operational strategies across different products in the pump and fan domain, the primary control logic generally follows a single closed-loop control model (**Figure 1**).

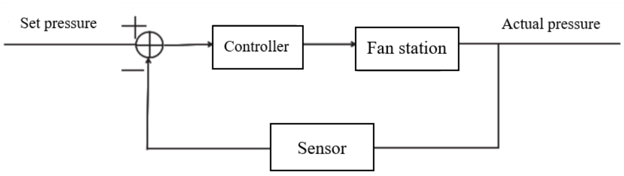

Figure 1. Constant-pressure fan control system

Control principle: When the actual pressure falls below the set pressure, the fan speed increases. If maximum fan speed still fails to meet the pressure requirement, an additional fan is activated. Conversely, if the actual pressure exceeds the set pressure, the fan speed decreases. If the minimum fan speed still fails to lower the pressure sufficiently, a running fan is shut off.

This approach optimizes individual equipment but does not take a comprehensive view of the total electricity consumption across the pump and fan stations. It also lacks consideration for specific environmental conditions or the aging effects on operational parameters. This can lead to increased system power consumption. To address these issues, a systems-engineering optimization mindset and information technology control framework should be applied to this energy-saving field. This would allow for achieving operational efficiency while ensuring process requirements, safety, and reliability. Factors such as the following should be incorporated into an internet-based system for comprehensive energy-saving management:

(1) Optimization of pump and fan design and manufacturing

(2) Selection of appropriate operational modes for pumps and fans
(3) Impact of environmental factors, such as temperature and humidity, on operational parameters
(4) Consideration of line loss across the entire fan and pump stations
(5) Establishing dynamic intervals for inspection, updates, and cleaning
(6) System energy savings benefits and investment payback time

Integrating these factors into a digital energy management system breaks away from the traditional model where operational parameters remain static once power equipment is deployed. Instead, by leveraging internet technology, the system can provide optimal energy-saving operation at any time, achieving the goal of "maximum energy efficiency at all times." This is suggested as a direction for further research.

4. Energy saving of power transformers

4.1. Overview of energy saving in power transformers

Power transformers are widely used in various parts of the electric power system, including power generation, transmission, transformation, and distribution. While the rated efficiency of power transformers exceeds 98%, with some large transformers reaching up to 99.7%, the extensive usage and long operating hours mean significant energy-saving potential remains. Statistics indicate that transformer losses account for over 40% of total grid losses and approximately 3% of total power generation [7]. Reducing transformer losses by just 1% could save billions of kilowatt-hours annually, making energy-saving technology in power transformers an important area for energy conservation.

4.2. Principles and applications of energy saving in power transformers

When a power transformer operates at an excessively low or high load rate, the proportion of total losses within its input energy increases, reducing actual operating efficiency. Therefore, selecting an appropriate load rate for power transformers is crucial.

If a transformer is chosen based on matching load power as closely as possible, the selected capacity will be smaller, and the investment will be lower. However, if the goal is to achieve an optimal load rate and minimize active power loss, the transformer capacity selected will be larger, increasing the investment. The current solution is to consider both approaches and weigh the pros and cons. However, a persistent issue remains that the "optimal energy-saving plan may not be the most economical."

The process of energy saving is also a process of improving management, enhancing management systems, advancing technology, and signifies national modernization. As energy-saving policies continue to be implemented, the future direction will aim to bring the optimal energy-saving plan closer to the most economical one. Researchers should continue to explore the best solutions for power transformer capacity selection and economic operation, while also focusing on innovations in technology and policy regulation to bridge the gap between the most efficient and economical plans for power transformers.

5. Conclusion

Energy conservation is not a temporary measure but a long-term policy, an urgent necessity in today's world, and a responsibility that requires continuous commitment. The energy-saving principles and development directions discussed in this paper for pumps, fans, and power transformers are equally applicable to other general equipment.

Disclosure statement

The authors declare no conflict of interest.

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