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Study on the energy-saving effect of the energy-saving transformer in the power system under the double-carbon background

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Abstract: *In the context of dual carbon, countries have taken measures to reduce energy consumption and carbon emissions. As one of the important power equipment in the power system, transformer has great potential in energy saving and emission reduction. Traditional transformers have high losses in the waste of energy and the increase of carbon emissions. Therefore, the research and the application of energy saving transformer has become one of the important ways of energy conservation and emission reduction in power system.*

Keywords: *double-carbon background; energy-saving transformer; power system; energy-saving effect*

1. Selection and use of energy-saving transformers

Energy-saving transformer is a transformer with low loss and high efficiency. By optimizing the design and material selection, it effectively reduces the no-load loss and short-circuit loss of the transformer, so as to achieve the goal of energy saving and emission reduction. The application of energy-saving transformers is important in the two-carbon background. Through the extensive promotion and use of energy-saving transformers, the energy consumption and carbon emission of power system can be greatly reduced, and the operation efficiency and environmental sustainability of power system can be improved. Although energy-saving transformers have great potential in energy saving and emission reduction, there are still some problems in practical application. For example, the cost of energy-saving transformers is high and requires full consideration of the economy and return cycle.[1]In addition, the promotion and popularization of energy-saving transformers also needs to solve the problems of technical standards, policy support and market recognition. Therefore, it is of great significance to study and evaluate the energy saving effect of energy-saving transformers in the power system, and to explore the promotion strategies and methods in the practical application to realize the sustainable development of the power system.

The selection and use of energy-saving transformers need to comprehensively consider the energy efficiency performance, compliance with standards and specifications, and reasonable operation and maintenance management. Through the reasonable selection and use of energy-saving transformers, the energy consumption and carbon emission of the power system can be significantly reduced, and the development of the power system can be promoted to a sustainable and efficient direction.

The selection of energy-saving transformers should consider their energy efficiency performance. Effective energy-saving transformer should have high operation efficiency and low loss to reduce energy waste. This can be evaluated by the transformer rated efficiency, load loss, no-load loss and short-circuit loss indicators. Rated efficiency is a measure of the energy efficiency performance of transformers under the rated load. Higher rated efficiency means lower energy loss. In addition, the load loss is the load-related loss generated in the actual operation process of the transformer, while the no-load loss is the loss in the load-free state. Short circuit loss is the loss generated in the short circuit conditions. Choosing energy-saving transformers with lower load loss, no-load loss and short-circuit loss can effectively reduce energy consumption.

The design and manufacture of energy-saving transformers shall conform to the relevant national and industrial standards and norms. When selecting energy-saving transformers, it should be ensured that they meet the national energy efficiency certification standards and technical specifications. The GB20052-2020 Energy Efficiency Limited Value and Energy Efficiency Grade of Power Transformer issued by the State Administration for Market Regulation and the Standardization Administration put forward specific requirements on the design and energy efficiency performance of energy-saving

ISSN 2522-3488 Vol. 7, Issue 7: 74-79, DOI: 10.25236/IJNDES.2023.070710

transformers.[2]Considering the safe and reliable operation of the power system, the energy-saving transformers should also meet the stability and electrical performance requirements of the power system. The use of energy-saving transformers needs reasonable operation and dimensional management. The installation and use of the proper cooling system and cooling device can also effectively improve the operation efficiency of the transformer. In addition, reasonable load planning and load balancing can reduce the loss of transformers and improve their operating efficiency.

2. Energy saving effect analysis of energy saving transformer in power system

2.1 Comparison of no-load and short-circuit loss between energy-saving transformers and non-energy-saving transformers

To evaluate the energy-saving effect of energy-saving transformers in the power system, we conducted a comparative analysis of no-load and short-circuit losses between energy-saving transformers and non-energy-saving transformers. Table 1 provides the comparison data of no-load loss and short-circuit loss of the 10 kV energy-immersed GB / T6451-2015 non-energy-saving transformer in GB20052-2020.

Table 1: Comparison of no-load and short-circuit loss between 10 kV oil-immersed non-energy-saving transformer and energy-saving transformer

Transformer capacity (kVA)	10 kV oil-immersed non-energy-saving transformer in GB / T 6451-2015		GB 20052-202010 kV energy efficiency class 1 energy saving transformer	
	No-load loss (kW)	Short-circuit loss (kW)	No-load loss (kW)	Short-circuit loss (kW)
500	0.68	5.41	0.385	3.90
630	0.81	6.20	0.46	4.46
800	0.98	7.50	0.56	5.40

For no-load loss: in GB / T6451-2015 standard, the no-load loss of 500 kVA capacity of 10 kV oil V is 0.68 kW, 630 kVA capacity is 0.81 kW, and the no-load loss of 800 kVA capacity is 0.98 kW. In the GB20052-2020 standard, the no-load loss of the 10 kV energy efficiency class 1 energy saving transformer with the corresponding capacity is 0.385 kW (500 kVA), 0.46 kW (630 kVA) and 0.56 kW (800 kVA) respectively. Through comparison, it can be seen that the loss of energy-saving transformer in the no-load state is significantly lower than that of non-energy-saving transformer. The design and technology of energy-saving transformers enable it to reduce energy loss when there is no load, thus improving energy efficiency.

For short circuit loss: in GB / T6451-2015 standard, the short circuit loss of 500 kVA capacity of 10 kV oil-immersed non-energy saving transformer is 5.41 kW, the short circuit loss of 630 kVA capacity is 6.20 kW, and the short circuit loss of 800 kVA capacity is 7.50 kW. In the GB20052-2020 standard, the short circuit loss of the 10 kV energy efficiency class 1 energy saving transformer with the corresponding capacity is 3.90 kW (500 kVA), 4.46 kW (630 kVA) and 5.40 kW (800 kVA) respectively. Similarly, it can be observed that the loss of energy-saving transformers in the short-circuit state is also significantly lower than that of non-energy-saving transformers. Energy-saving transformer can reduce the energy loss and improve the energy efficiency of the power system under short-circuit conditions.

Considering the above points, we can draw the following conclusions:

(1) Energy-saving transformer has lower loss than non-energy-saving transformer in the no-load and short-circuit state;

(2) The design and technical improvement of energy-saving transformers enable them to improve the energy efficiency of the power system and reduce the waste of energy;

(3) In the power system, the use of energy-saving transformers can effectively reduce the loss of electric energy and improve the overall energy-saving effect of the power system.

2.2 Analysis of energy-saving transformer loss reduction rate

To evaluate the energy saving effect of energy-saving transformers in power systems, we further analyzed the loss reduction rate of energy-saving and non-energy-saving transformers. We first calculated the no-load loss reduction rate of energy-saving transformers. For transformers with 500 kVA capacity, the no-load loss of non-energy-saving transformer is 0k W, while the no-load loss of energy-saving

ISSN 2522-3488 Vol. 7, Issue 7: 74-79, DOI: 10.25236/IJNDES.2023.070710

transformer is only 0.385 kW. Therefore, the no-load loss reduction rate of the energy-saving transformer with this capacity is: 680

No-load loss reduction rate = (no-load loss of non-energy-saving transformer-no-load loss of energy-saving transformer) / No-load loss of non-energy-saving transformer 100%

= (0.680 – 0.385) / 0.680 ×100%

= 43.4%

Similarly, we calculated the no-load loss reduction rate for transformers with other capacities and obtained the following results:

For the 630 kVA transformer, the no-load loss reduction rate of the energy-saving transformer is 43.2%.

For the 800 kVA transformer, the no-load loss reduction rate of the energy-saving transformer is 42.9%.

Next, we calculated the short-circuit loss reduction rate of energy-saving transformers. Taking the transformer with 500 kVA capacity as an example, the short circuit loss of non-energy-saving transformer is 5.41 k W, while the short circuit loss of energy-saving transformer is 3.90 kW. Therefore, the short-circuit loss reduction rate of the energy-saving transformer with this capacity is:

Short-circuit loss reduction rate = (short-circuit loss of non-energy-saving transformer-short-circuit loss of energy-saving transformer) / short-circuit loss of non-energy-saving transformer 100%

= (5.41 – 3.90) / 5.41 ×100%

= 27.9%

Similarly, we calculated the short-circuit loss reduction rate of other capacity transformers and obtained the following results:

For the 630 kVA transformer, the short-circuit loss reduction rate of the energy-saving transformer is 28.0%.

For the 800 kVA transformer, the short-circuit loss reduction rate of the energy-saving transformer is 28.0%.

Based on the above data analysis, we can clearly see that compared with non-energy-saving transformers, they have a significant reduction effect in no-load and short-circuit loss. The no-load loss reduction rate of energy-saving transformers is between 42.9% and 43.4%, while the short-circuit loss reduction rate is between 27.9% and 28.0%. These results further validate the energy-saving effect of the energy-saving transformer in the power system, and provide a strong data support for its popularization and application.

2.3 Analysis of energy consumption reduction

In order to more comprehensively evaluate the energy saving effect of energy-saving transformers in the power system, we conducted a detailed analysis of the energy consumption reduction. Based on the data presented in Table 1, we compared the energy consumption between energy efficient and non-energy efficient transformers. The reduction in energy consumption can be measured by calculating the difference in energy consumption between the two transformers in the no-load and short-circuit conditions. The energy consumption difference is calculated as follows:

Energy consumption difference = energy consumption of non-energy saving transformer-energy consumption of energy saving transformer

The energy consumption can be expressed by the sum of no-load loss and short-circuit loss. We take the transformer with 500 kVA capacity as an example to analyze the energy consumption reduction situation. The energy consumption of non-energy-saving transformer is 0.68 k W (no-load loss) + 5.41 kW (short-circuit loss) = 6.09 kW. The energy consumption of the energy-saving transformer is 0.385 kW (no-load loss) + 3.90 kW (short-circuit loss) = 4.285 kW. Therefore, the energy consumption reduction situation is follows:

Energy consumption reduction = energy consumption of non-energy saving transformer-energy consumption of energy saving transformer

ISSN 2522-3488 Vol. 7, Issue 7: 74-79, DOI: 10.25236/IJNDES.2023.070710

= 6.09 kW – 4.285 kW

= 1.805 kW

Similarly, we calculated the energy consumption reduction for other transformers with capacities and obtained the following results:

For the 630 kVA transformer, the energy consumption reduction is 2.09 kW.

For the 800 kVA transformer, the energy consumption reduction is 2.52 kW.

From the above data, it can be clearly seen that the energy-saving transformers have a significant effect in reducing energy consumption. The reduction of energy consumption ranges from 1.805 kW to 2.52 kW, which further confirms the significant energy saving advantages of energy-saving transformer and provides a practical basis for its application and promotion in the power system.

3. Promotion and application of energy-saving transformers in the power system

3.1 Energy-saving potential analysis

The promotion and application of energy-saving transformer is of great significance to the energy saving of the power system. In order to deeply explore the popularization potential of energy-saving transformers, we conduct a detailed analysis and calculate the quantitative index of energy-saving potential. First, the number and capacity distribution of transformers used in the power system. The capacity of each transformer is P (kVA), the no-load loss is NL (kW), and the short-circuit loss is SL (kW). The energy consumption of non-energy-saving transformer is ENL (kW), and the energy consumption of energy-saving transformer is EEL (kW). According to the definition of energy consumption reduction rate, the calculation formula of energy consumption reduction rate CR can be obtained is as follows:

$$CR = (ENL — EEL) / ENL \times 100\%$$

Then, according to the actual situation of the power system, the total annual power consumption of the power system can be estimated to be T (kWh). The number of energy-saving transformers is Np, the number of non-energy-saving transformers is N-Np, and the capacity of energy-saving transformers is Cp. The total energy consumption of non-energy-saving transformer is ENL (kW), and the total energy consumption of energy-saving transformer is EEL (kW). We can calculate the annual energy consumption reduction DS (kWh), the calculation formula is:ΣΣ

$$DS = (\Sigma ENL - \Sigma EEL) \times T / 1000$$

Through the above calculation process, we can accurately quantify the energy saving potential in the power system. This can provide specific data support for the promotion of energy-saving transformers in the power system.[3]

3.2 Economic benefit analysis

In addition to the quantitative indicators of energy-saving potential, we also conducted a detailed analysis of the economic benefits of energy-saving transformers in the power system. Economic benefits mainly include energy cost saving and investment recovery period and other indicators. First, methods to calculate energy costs need to be determined. Suppose that the average electricity price in the power system is (yuan / kWh), and the annual electricity consumption is E (kWh). The energy consumption cost of non-energy saving transformer is CENL (yuan), and the energy consumption cost of energy saving transformer is CEEL (yuan).$\bar{P}$ The calculation formula for the energy cost savings (ECS) can be obtained:

$$ECS = (CENL — CEEL) \times E \times \bar{P}$$

Then, consider the investment payback period of energy-saving transformers. The cost of energy-saving transformer is I (yuan), and the annual energy cost saving is ECS (yuan). Then the calculation formula of investment payback period (PP) can be simply expressed as follows:

$$PP = I / ECS$$

Through the analysis of economic benefits, the economic feasibility of energy-saving transformer can be evaluated in the power system and provide decision-making basis for enterprises and decision makers.

ISSN 2522-3488 Vol. 7, Issue 7: 74-79, DOI: 10.25236/IJNDES.2023.070710

3.3 Promotion strategy and policy support

In order to promote the wide application of energy-saving transformers in the power system, it is necessary to develop corresponding promotion strategies and provide policy support. The government may formulate relevant energy conservation policies and standards, encourage the use of energy-saving transformers in the power system, and give corresponding subsidies and rewards. Power enterprises can actively promote the application of energy-saving transformers, and provide relevant technical support and training.[4]In addition, it can also strengthen the development and innovation of energy-saving transformers, improve their performance and efficiency, and meet the demand of the power system for energy saving.

To sum up, energy-saving transformers have great energy-saving potential and economic benefits in the power system. Through the quantitative energy consumption reduction rate and economic benefit analysis, we can accurately evaluate the promotion effect of energy-saving transformer, and formulate the corresponding promotion strategy and policy support. This will provide strong support for the sustainable development of the power system and the energy transition.

4. Future development direction

With the advancement of energy transformation and dual-carbon target, the application prospect of energy-saving transformer in the power system is very broad. In the future, the application of energy-saving transformers in the power system will continue to expand and deepen. Through technological innovation, the development of integrated energy systems, intelligent management and international cooperation, energy-saving transformers will play an increasingly important role in the energy transformation and make positive contributions to the realization of sustainable development and low-carbon economy. We can look forward to the future development of energy-saving transformers in the following directions:

(1) Technological innovation and performance improvement: With the continuous progress of science and technology, the design and manufacturing technology of energy-saving transformers will continue to innovate and improve. Future energy-saving transformers may adopt more advanced materials and design concepts to improve energy efficiency and performance. For example, using high-temperature superconducting materials or magnetic materials, you can reduce loss and improve efficiency. In addition, the application of intelligent and adaptive control technology will also make energy-saving transformers more intelligent and sustainable.[5][6]

(2) Multi-energy complementarity and comprehensive energy system: the future power system will pay more attention to multi-energy complementarity and the optimal utilization of comprehensive energy. Energy-saving transformers can be combined with renewable energy systems, energy storage technologies and smart grids to achieve efficient energy utilization and flexible scheduling. Through the coordinated management of the integrated energy system, the energy-saving transformers can better deal with the changes of energy fluctuations and load demand, and further improve the energy-saving effect.[5]

(3) Intelligent management and data analysis: With the development of the Internet of Things and big data technology, energy-saving transformers can realize remote monitoring, fault diagnosis and prediction and maintenance. Through the real-time collection and analysis of the operation data of the energy-saving transformers, the problems can be found in time and the corresponding measures can be taken to improve the reliability and efficiency of the system. Intelligent management can also optimize the operation strategy of transformers and further improve the energy utilization efficiency and energy saving effect.

(4) International cooperation and policy support: Globally, all countries are promoting energy transformation, energy conservation and emission reduction. In the future, there is expected to be more international cooperation and policy support to promote the global promotion and application of energy-saving transformers. International organizations, governments and enterprises can strengthen cooperation, share experience and technology to jointly promote the development of energy-efficient transformers and contribute to the goal of sustainable energy and carbon neutrality.

5. Conclusion

Through the detailed analysis and calculation of the relevant data, we draw the important conclusions

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about the comparison of no-load, short-circuit loss and energy consumption reduction of energy-saving transformer, and discuss the popularization and application of energy-saving transformer in the power system in depth[7]. In the future, we can look forward to the energy-saving transformers to achieve the goal of sustainable development and low carbon economy under the promotion of technological innovation, the development of comprehensive energy system, intelligent management and international cooperation. To this end, the government, industry organizations and enterprises should strengthen cooperation to jointly promote the research and development, promotion and application of energy-saving transformers, make positive contributions to the energy transformation and carbon emission reduction, build a clean and efficient power system, and promote the development of sustainable energy.

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