Asia-Pacific
Economic Cooperation

APEC

Distribution Transformer Survey: Estimate of energy saving potential from mandatory efficiency standards (MEPS)

Volume 2 (China Work)

APEC Energy Working Group

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Introduction

About a third of transmission and distribution losses took place in distribution transformers (DTs), thus DTs represent a considerable potential for energy, carbon and cost savings through policy and standard intervention within APEC.

The Asia-Pacific Economic Cooperation (APEC) secretariat divides the project Distribution Transformer Survey: Estimate of energy saving potential from mandatory efficiency standards (MEPS) (EWG 15 12A) into two parts, one is the distribution transformer survey (international work), and the other is the distribution transformer survey (China work).

Furthermore, APEC secretariat awarded Zhong Biao Standard Technology Research Institute Co. Ltd (ZBSTRI) the distribution transformer survey (China work) project in line with the APEC Regulatory Cooperation Process Mechanism on Trade-Related Standards and Technical Regulations, and the project overseer is the China National Institute of Standardization. The project aims at assessing the potential of energy savings and GreenHouse Gas (GHG) emission reduction related to increases of Minimum Energy Performance Standard (MEPS) for Distribution Transformers (DTs), sharing Chinese successful Energy Efficiency Standards and Labeling (EES&L) programs' experiences with APEC economies.

Two reports have been separately accomplished. The international work report (Volume 1) was carried out by Econoler Canda, which presented experience analysis, strategic national roadmaps of other APEC economies for DTs on introducing or raising mandatory MEPS. The China work report (Volume 2) consists of four parts, the first part is enterprise questionnaire, the second part is policies and standards collection related to energy efficient DTs' promotion and application, the third part is current market status and energy efficiency data collection, and the fourth part is energy saving potential's estimation & market analysis from energy efficiency standards and policies.

Therefore, the reports of Volume 1 and Volume 2 should all be consulted to have a complete picture of the APEC distribution transformer survey project.

Part Ⅰ Enterprise questionnaire

Chapter 1 Warming Up and Introduction (5 minutes)

Enterprise questionnaire

Basic information about the interviewed enterprise

Name of the interviewed company:___________

Address of the interviewed company:_________ Province:____________________________________

Name of the interviewee: __________________ Department which the interviewee belongs to: _____

Post of the interviewee: ___________________ Telephone (with area code):______________________

Name of the interviewer: __________________ Name of the assistant interviewer: ________________

Interview time:__(MM)__(DD), 2013, at__(time) Interview duration: ____________________

1 Greetings and interviewer's self-introduction

2 Introduce basic information about Huatong Company to the interviewee

3 Introduce the background of this project and the subject and purpose of this interview

4 Clarify the roles that the interviewer and the interviewee are playing

 4.1 The interviewer is neutral;

 4.2 Any answers are acceptable;

 4.3 Try to express the thoughts on your mind

5 Confidentiality of information

 5.1 The name and contact information of the interviewee will not be present in the report or disclosed to others

 5.2 Information provided by the interviewee is for internal analysis only

6 Interviewee's self-introduction for further confirmation of his/her qualification for the interview.

Chapter 2 Interview Questionnaire (60 minutes)

Section 1: Screening of basic information

S1. In which year was your company founded? _______(YY). In which year did your company start to manufacture distribution transformers? ________(YY)

S2. Through the previous preliminary communication, we know that distribution transformer is one of the main products of your company. So what is the total sales volume of your company in 2012?______yuan. What is the proportion of distribution transformer in the sales volume of your company? _____%.

S3. Are you in charge of business regarding distribution transformer of your company? (Yes/No). What kind of business are you in charge of?

By function: (single choice)		**By product:** (single choice)	
Production	1.	Oil-immersed distribution transformer	1.
Technology	2.	Dry-type distribution transformer	2.
Marketing/sales	3.	Integrated	3.
Integrated	4.	Other classification standard	4. (Please specify)
Others	5. (Please specify)		

(If the interviewee is not in charge of distribution transformer business, ask him/her to recommend a proper person in charge. Write down the contact information of the recommended person and contact him/her for making an appointment on interview).

Section 2: Production information on the enterprise

Q1. What kinds of distribution transformers is your company manufacturing? (Multiple choices)

Insulating medium	**Voltag e class**	**Voltage regulation mode**	**Loss series**	**Phase number**	**Capacity (KVA)**		**Core material**	**Core structure**
□Oil-immersed □Drv-type	□6kV □10kV □35kV	□non-excitation □on-load voltage	□8 □9 □10 □11 □12 □13 □15	□Single-phase □Three-phase	□30 □50 □63 □80 □100 □125 □160 □250 □160 □250 □315 □400 □500 □630 □800	□1000 □1250 □1600 □2000 □2500 □other s	□Silicon □Amorphous alloy □Others **Remarks:** Sometimes manufacturers also refer silicon steel as electrical steel.	□Laminated □Wound core □Three dimensional □Others

Q2. How many distribution transformers as described above does your company manufacture in 2012? Sets. What is the total capacity?_____KVA

Now we would like to ask you some information about distribution transformer production by different classification standards. As the classification is in detail, you probably do not have complete statistical data, but we only need you to tell us those data you already know. Thanks!

By insulating medium: Oil-immersed and dry-type

Q3. What are the outputs (or proportions) of oil-immersed and dry-type distribution transformers of your company in 2012? (*By numbers and capacities*)

By type of cooling	**By number**		**By capacity**	
	Output (set)	Proportion (%)	Capacity (kVA)	Proportion (%)
Oil-immersed distribution transformer				
Dry-type distribution transformer				
Total	**Number in Q2**	**100%**	**Capacity in Q2**	**100%**

Note: 1. *This question is based on the data known by the interviewee at that time. It's better if the interviewee can give specific output data. But if the interviewee does not remember clearly, proportion is also acceptable. Similarly hereinafter.*

2. *If the interviewed enterprise only manufactures one type of these distribution transformers, skip this question.*

Q4-1. What are the main loss series of your **oil-immersed** distribution transformers manufactured in 2012? What are the outputs (or proportions) of each series? (*By numbers and capacities*)

Q4-2. What are the main loss series of your **dry-type** distribution transformers manufactured in 2012? What are the outputs (or proportions) of each series? (*By numbers and capacities*)

If the interviewed enterprise only manufactures one type of these distribution transformers, just ask about that type.

Oil-immersed distribution transformer					Dry-type distribution transformer				
Loss series	By number		By capacity		Loss series	By number		By capacity	
	Output (set)	Proportion (%)	Capacity (kVA)	Proportion (%)		Output (set)	Proportion (%)	Capacity (kVA)	Proportion (%)
□8					□8				
□9					□9				
□10					□10				
□11					□11				
□12					□12				
□13					□13				
□15					□15				
Total	**Number in Q3**	**100%**	**Capacity in Q3**	**100%**		**Numb er in Q3**	**100%**	**Capacity in Q3**	**100%**

Remarks: If the interviewed enterprise manufactures series 11 dry-type distribution transformer, ask about the specific loss so as to confirm whether it's compliant with the standards for series 11.

By voltage: 6KV, 10KV and 35KV

Q5. What are the outputs (or proportions) of distribution transformers with different voltage classes of your company in 2012? (*By numbers and capacities*)

By voltage	**By number**		**By capacity**	
	Output (set)	Proportion (%)	Capacity (kVA)	Proportion (%)
6KV				
10KV				
35KV				
Total	**Number in Q2**	**100%**	**Capacity in Q2**	**100%**

Note: 1. This question is based on the data known by the interviewee at that time. It's better if the interviewee can give specific output data. But if the interviewee does not remember clearly, proportion is also acceptable. Similarly hereinafter.

2. If the interviewed enterprise only manufactures one type of these distribution transformers, skip this question.

Q6-1. What are the main loss series of your **6KV** distribution transformers manufactured in 2012? What are the outputs (or proportions) of each series? (*By numbers and capacities*)

Q6-2. What are the main loss series of your **10KV** distribution transformers manufactured in 2012? What are the outputs (or proportions) of each series? (*By numbers and capacities*)

Q6-3. What are the main loss series of your **35KV** distribution transformers manufactured in 2012? What are the outputs (or proportions) of each series? (*By numbers and capacities*)

6KV distribution transformer					10KV distribution transformer				
Loss series	By number		By capacity		Loss series	By number		By capacity	
	Output (set)	Proportion (%)	Capacity (kVA)	Proportion (%)		Output (set)	Proportion (%)	Capacity (kVA)	Proportion (%)
□8					□8				
□9					□9				
□10					□10				
□11					□11				
□12					□12				
□13					□13				
□15					□15				
Total	**Number in Q5**	**100%**	**Capacity in Q5**	**100%**		**Number in Q5**	**100%**	**Capacity in Q5**	**100%**

35KV distribution transformer				
Loss series	By number		By capacity	
	Output (set)	Proportion (%)	Capacity (KVA)	Proportion (%)
□8				
□9				
□10				
□11				
□12				
□13				
□15				
Total	**Number in Q5**	**100%**	**Capacity in Q5**	**100%**

By voltage regulation mode: Non-excitation and on-load voltage regulation

Q7. What are the outputs (or proportions) of non-excitation and on-load voltage regulation distribution transformers of your company in 2012? (*By numbers and capacities*)

By voltage regulation mode	By number		By capacity	
	Output (set)	Proportion (%)	Capacity (KVA)	Proportion (%)
Non-excitation distribution transformer				
On-load voltage regulation distribution transformer				
Total	**Number in Q2**	**100%**	**Capacity in Q2**	**100%**

Note: 1. *This question is based on the data known by the interviewee at that time. It's better if the interviewee can give specific output data. But if the interviewee does not remember clearly, proportion is also acceptable. Similarly hereinafter.*

2. *If the interviewed enterprise only manufactures one type of these distribution transformers, skip this question.*

Q8-1. What are the main loss series of your **non-excitation voltage regulation** distribution transformers manufactured in 2012? What are the outputs (or proportions) of each series? (*By numbers and capacities*)

Q8-2. What are the main loss series of your **on-load voltage regulation** distribution transformers manufactured in 2012? What are the outputs (or proportions) of each series? (*By numbers and capacities*)

If the interviewed enterprise only manufactures one type of these distribution transformers, just ask about that type.

Non-excitation voltage regulation distribution transformer					**On-load voltage regulation distribution transformer**				
Loss series	By number		By capacity		Loss series	By number		By capacity	
	Output (set)	Proportion (%)	Capacity (KVA)	Proportion (%)		Output (set)	Proportion (%)	Capacity (KVA)	Proportion (%)
□8					□8				
□9					□9				
□10					□10				
□11					□11				
□12					□12				
□13					□13				
□15					□15				
Total	**Number in Q7**	**100%**	**Capacity in Q7**	**100%**		**Number in Q7**	**100%**	**Capacity in Q7**	**100%**

Other classification methods

Q9. What is the output (or proportion) of single-phase distribution transformers of your company in 2012? (*By numbers and capacities*)

With specific value: Number:_______, Capacity:_______KVA

Without specific value: by number:_______%, By capacity:________%

(If the interviewed enterprise doesn't manufacture single-phase distribution transformers in Q2, skip this question.)

Q10-1. What is the output (or proportion) of **amorphous alloy** distribution transformers of your company in 2012? (*By numbers and capacities*)

With specific value: Number:_______, Capacity:_______KVA

Without specific value: by number:_______%, By capacity:________%

Q10-2. What are the main series of **amorphous alloy** distribution transformer manufactured by your company? Are all these loss series of **amorphous alloy type**? If not, what is the proportion of **amorphous alloy** products in this loss series?

(If the interviewed enterprise doesn't manufacture amorphous alloy distribution transformers in Q2, skip this question.)

Loss series	8	9	10	11	12	13	15
Amorphous alloy distribution transformer	**0%**	**0%**	**0%**	**0%**			
Other distribution transformers	**100%**	**100%**	**100%**	**100%**			
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Q11-1. What is the output (or proportion) of distribution transformers with **three dimensional wound core** manufactured by your company in 2012? (*By numbers and capacities*)

With specific value: Number:_______, Capacity:_______KVA

Without specific value: by number:_______%, By capacity:________%

Q11-2. What are the main series of distribution transformers with **three dimensional wound core** manufactured by your company? Are all these loss series of **three dimensional wound core type**? If not, what is the proportion of products with **three dimensional wound core** in this loss series?

(If the interviewed enterprise doesn't manufacture distribution transformer with three dimensional wound core in Q2, skip this question.)

Loss series	8	9	10	11	12	13	15
Distribution transformer with three dimensional wound core	**0%**	**0%**	**0%**				
Other distribution transformers	**100%**	**100%**	**100%**				
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Q12. As we know, there are only a few enterprises which manufacture distribution transformers with **three dimensional wound core**. What factors do you think hinder the promotion of such products?

(Open-ended question. The interviewee may answer the question according to his/her own knowledge. The interviewer may discuss with the interviewee in terms of technological barrier, patent limitation, cost of production, market demand, etc.)

Section 3: Product export information

Q13. Was your distribution transformer exported in last four years? (Single choice)

Yes………………1. *(Q14 continued)*

NO………………2. *(Skip to Q17)*

Q14. What was the export volume of your distribution transformers in recent years? (By numbers and capacities)

Year	By number (set)	By capacity (kVA)
2012		
2011		
2010		
2009		
Total		

Q15. What are the main types of your distribution transformers exported in 2012? What are the proportions respectively? (By numbers and capacities)

2012	Type	Proportion (%)	
		By number	By capacity
By insulating medium	Oil-immersed type		
	Dry-type		
	Subtotal	100%	100%
By voltage regulation mode	Non-excitation voltage regulation		
	On-load voltage regulation		
	Subtotal	100%	100%
By voltage range	6KV		
	10KV		
	35KV		
	Subtotal	100%	100%

(If the interviewee was able to remember data of several years before 2012 at the moment, made a detailed inquiry about those data)

Q16. What are the main loss series of your distribution transformers exported in 2012? What are the proportions respectively? (By numbers and capacities)

Loss series	Proportion (%)	
	By number	By capacity
□8		
□9		
□10		
□11		
□12		
□13		
□15		
Total	**100%**	**100%**

Section 4: Raw material consumption

Q17. At present, raw materials of distribution transformer mainly consist of silicon steel/steel, copper, transformer oil, etc., and as far as you know, what are the proportions of those raw materials in one distribution transformer (either by cost or by weight, please specify)? Is there any difference between different types of distribution transformer?

Statistical caliber:______________*(Cost/weight)*

Material / Type	Copper	Silicon steel	Steel	Amorphous alloy	Transformer oil	Epoxy resin	Other materials	Total
Dry-type								100%
Oil-immersed type								100%
Amorphous alloy								100%
Three dimensional wound core								100%

Note: Amorphous alloy transformer and three dimensional wound core shall be calculated separately and will not be included in the common oil-immersed/dry-type transformer.

Copper consumption

Q18. What is the kind of copper mainly used for the current distribution transformer, and what is the copper density in general? __________(kg/dm^3).

Q19. Is there any difference between copper types used for distribution transformers with different **voltage classes?** What is the average copper consumption of distribution transformers of various voltage classes?

Yes………………1 *(Ask about copper type and consumption)*

No………………2 *(Ask about copper consumption of various voltage classes)*

Voltage class	Copper type	Copper density (kg/dm^3)	Average copper consumption (kg)
6KV			
10KV			
35KV			

Q20. Is there any difference between copper types used for distribution transformers of different **loss series?** What is the average copper consumption of distribution transformers of various **loss series?**

Yes………………1 *(Ask about copper type and consumption)*

No………………2 *(Ask about cooper consumption of various loss series)*

Loss series	Copper type	Copper density (kg/dm^3)	Average copper consumption (kg)
8			
9			
10			
11			

Loss series	Copper type	Copper density (kg/dm^3)	Average copper consumption (kg)
13			
13			
15			

Q21. Is there any difference between copper types used for distribution transformers of different **capacities**? What is the average copper consumption of distribution transformers of various **capacities**?

Yes………………1 *(Ask about copper type and consumption)*

No………………2 *(Ask about copper consumption of various voltage classes)*

Capacity (KVA)	Copper type	Copper density (kg/dm^3)	Average copper consumption (kg)
30			
50			
63			
80			
100			
125			
160			
250			
315			
400			
500			
630			
800			
1000			
1250			
1600			
2000			
2500			

Q22. As far as you know, what are the main factors influencing the market price of copper for distribution transformer? What is the change trend in recent years (2009-2012)? How do the prices of the several kinds of coppers you mentioned above change?

Influencing factors:____

____

____

Changing trends in 2006-2012:____

____

____

Copper type	Copper density (kg/dm^3)	Average price (yuan/ton)			
		2009	2010	2011	2012

Note: *Conduct the interview according to several types that the interviewee mentioned in Q19, Q20 and Q21.*

Steel and silicon steel sheet consumption

Q23. What are the main grades of your silicon steel sheets in the distribution transformers? Is there any imported product? Which countries or APEC economies are the imported products imported from and what are the grades of these products?

____

____

____

Q24. Is there any difference between silicon steel sheet grades of distribution transformers of different **loss series**? What is the average silicon steel sheet consumption of distribution transformers of various **loss series**?

Yes………………1 *(Ask about the grade and the consumption)*

No………………2 *(Ask about the consumption)*

Loss series	Main grade	Silicon steel sheet consumption (kg)
8		
9		
10		
11		
13		
13		
15		

Q25. As far as you know, what are the main factors influencing the market price of silicon steel sheet? What are the change trends in recent years (2006-2012)? How do the prices of the several kinds of coppers you mentioned above change?

Influencing factors:____

Changing trends in 2006-2012:____

Silicon steel grade	**Average price (yuan/ton)**			
	2009	**2010**	**2011**	**2002**

Note: *Conduct the interview according to several types that the interviewee mentioned in Q23 and, Q24.*

Consumption of other materials

Q26. You mentioned just now that raw materials of the distribution transformer, besides copper and silicon steel, include <u>*transformer oil, epoxy resin, amorphous alloy and other materials (listed out according to materials that the interviewee mentioned in Q17 herein)*</u>*, what is the approximate proportion of these materials in the raw materials of the distribution transformer? Would you please give several typical product examples?*

Section 5: Industry and technology development information

Q27. As far as you know, how many distribution transformers are produced each year throughout the APEC economy? (By numbers and capacities)

Number:_______Sets, **Capacity:**_______KVA

Q28. What do you think about the proportion of different types of distribution transformers in the output of the whole APEC economy? (By numbers and capacities).

	Transformer type	**Proportion (%)**	
		By number	**By capacity**
By insulating medium	Oil-immersed type		
	Dry-type		
	Subtotal	100%	100%
By voltage regulation mode	Non-excitation voltage regulation		
	On-load voltage regulation		
	Subtotal	100%	100%
By voltage range	6KV		
	10KV		
	35KV		
	Subtotal	100%	100%
By loss series	8		
	9		
	10		
	11		
	12		
	13		
	15		
	Subtotal	100%	100%

Q29. If the distribution transformer manufacturers across the APEC economy are divided into 10 classes according to production scale, what class do you think your company belongs to (only distribution transformer output scale in consideration)? For output, what do you think about the contribution of your annual output to the total output of the APEC economy?

Q30. After new energy saving materials (silicon steel sheet, copper, amorphous alloy core, etc.) are adopted, the loss is reduced while the cost is increased, so what do you think about the relationship between material costs and saving effects during use? What measures are taken by enterprises at present to balance the cost rising as far as you know? From what aspects do you think cost can be better controlled (design optimization, copper-iron ratio adjustment, material replacement and enterprise's awareness of full life cycle design, etc.)?

Q31. As the method to save energy used by distribution transformers is to reduce iron loss and copper loss, technically speaking, which do you think has a larger reduction potential, the iron loss or copper loss? What are the main methods (optimization design, new materials, etc.)? Which of these methods are the more practical in actual production?

Q32. As far as you know, is there any new energy saving distribution transformer that is under development or trial-manufacturing currently? If there is, could you please briefly introduce the energy saving principle, merits and demerits of the new energy saving distribution transformer?

Q33. As far as you know, are there any other well-known representative enterprises at home currently in the distribution transformer filed? What are their places in the industry? (Proportion of annual output in total output of the industry, technical fields, etc.)

Q34. What's your opinion and suggestion on current *Efficiency Standards for Distribution Transformers*? What expectations and advices do you have for this revision? (The project manager needs to tell the interviewee the main objective of and relevant adjustment to this revision)

Chapter 3 Presentation and Explanation of Data Form, Ending of Interview and Acknowledgements (10 minutes)

The project manager expresses thanks to the interviewee and provides data acquisition form, explains various items in the form to the interviewee, and asks the interviewee to offer views and advices. He/she shall leave the data form after both sides reach an agreement on the contents and formats, and ask the interviewee to assist in completing it. Then the interview is ended and the project manager expresses thanks.

Part Ⅱ　Policies and Standards Collection Related to Energy Efficient DTs' Promotion and Application

Chapter 4 Policies

4.1 Law of the People's Republic of China on Energy Conservation [1]

The 30th session on October 28th, 2007 held by the 10th Standing Committee of National People's Congress made some amendments to *the Law of the People's Republic of China on Energy Conservation* (No. 90 Decree of PRC Chairman) implemented from January 1st,1998 and adopted the *new Law of the People's Republic of China on Energy Conservation* (No. 77 Decree of PRC Chairman, hereinafter referred to as "this law") implemented since April 1st, 2008 in order to promote energy conservation by the whole society, improve efficiency of energy utilization, protect and improve the environment and stimulate comprehensive, harmonious and sustainable economic and social growth.

This law specifies the obligations of government bodies on energy conservation, such as implementation of energy saving responsibility system and energy consumption quota management by government bodies, enhancement of supervision for key authorities and addition of incentive policies for energy saving measures. Such law lays a legal basis for energy conservation in China. Article 17 of this law specifies that energy consuming products and equipment that the State eliminates or fails to comply with the mandatory standard of energy efficiency are prohibited for production, import and sale in China; energy consuming equipment and production technologies that the State eliminates are prohibited to use; Article 18 specifies that energy efficiency identification management is implemented for domestic appliances and energy consuming products with wide application and high energy consumption.

This law constitutes the basic Chinese national policy, which provides a legal safeguard for promotion and application of energy-efficient distribution transformer in China. As stipulated by this law, the Ministry of Finance of the PRC and provincial-level local finance department shall arrange special fund for energy conservation, support R&D of energy-saving technologies, demonstration and promotion of energy-saving technologies and products, implementation of key energy conservation projects, as well as dissemination and training, information service and reward on energy conservation. This law lays a foundation for the formulation of all incentive policies on the promotion of energy-efficient transformer.

4.2 Financial incentive for transformation of energy-saving technologies[2]

On the basis of the *Decision of the State Council on Strengthening Energy Conservation* (Guo Fa [2006] No. 28) and the *Notice of the State Council on Issuing Comprehensive Work Program for Energy Conservation and Emission Reduction* (Guo Fa [2007] No. 15), the Ministry of Finance of the PRC offers necessary guide fund, by means of substituting subsidies with rewards, provides appropriate supports and rewards for top 10 key energy-saving projects and gives the support for enterprises to conduct transformation of energy-saving technologies. For this purpose, the Ministry of Finance and National Development and Reform Commission issued *Provisional Regulations for Financial Rewarding Fund Management on Transformation of Energy-Saving Technologies* on August 10th, 2007 (Cai Jian [2007] No. 371).

To guarantee actual energy saving effects of energy-saving technological transformation project, the fund for energy conservation is granted by means of award, and the amount of fund is linked up with the amount of energy conservation. Rewards are given to those enterprises that undertake energy saving projects and the amount of reward is based on the amount of the actual energy conservation after the completion of technological transformation.

The amount of energy saving shall be verified based on corporate report, third party's review and governmental confirmation. Enterprises shall submit energy usage before transformation, energy saving measures, amount of energy conservation and methods for measurement and inspection. Then, a third party entrusted by the

[1] http://www.gov.cn/flfg/2007-10/28/content_788493.htm

[2] http://jjs.mof.gov.cn/zhengwuxinxi/zhengcefagui/201106/t20110623_566086.html

government shall review the mentioned matters and be responsible for the audit report issued by itself. *Provisional Regulations for Financial Rewarding Fund Management on Transformation of Energy-Saving Technologies* suggests that projects on energy saving technological transformation in the eastern region shall be rewarded with 200 yuan/per ton standard coal based on actual energy saving amount and similar projects in central and western regions shall be rewarded with 250 yuan/per ton standard coal.

4.3 The government forces the governmental bodies to procure energy saving products[3]

To pertinently enhance energy conservation of governmental bodies, give play to the guiding role of governmental purchasing policy and establish the system forcing the governmental bodies to procure energy saving products, General Office of the State Council of the People's Republic of China issued *Notice of Establishing the System Regarding Procurement of Energy Saving Products Forced by the Government* on July 30th, 2007 (No. 51 GBF [2007]). According to the notice, governments at all levels, when spending financial fund to make governmental purchases, providing such indicators as their technology and service meet the demand, shall give priority to purchases of energy saving products and shall be forced to purchase those that meet the requirements in terms of energy-saving effect and performance, so as to promote energy conservation and environmental protection and reduce energy cost and expenditure of governmental bodies. China has established a management system for governmental energy saving products purchasing list to determine the classification of energy saving products preferentially procured by the government and compulsorily procured by the government and guide governmental bodies to procure energy saving products.

The governmental energy saving products purchasing list is formulated by the Ministry of Finance and National Development and Reform Commission. Products listed in this list are determined among energy saving products certified by energy saving products certification authority with national admission based on energy saving performance, technological level and maturity degree in the market, and those products are published regularly on www.ccgp.gov,cn, www.sdpc.gov.cn and http://agripollute.nstl.gov.cn. The State implements dynamic management and regular adjustment for the governmental energy saving products purchasing list. Purchasing list and adjustment scheme will be released on the media designated by www.ccgp.gov.cn for more than 15 working days. Released products that do not meet the requirements will not be listed in the purchasing list. The offence reporting system and reward & punishment system are established, in which the reporting method, receiving agency and methods of reward & punishment are clarified and subject to social supervision.

General Office of the State Council of the People's Republic of China also stipulates, the financial authorities at all levels shall strengthen supervision and inspection for energy saving products purchased by the government and intensify the punishment for illegal procurement. As for the units that do not purchase energy saving products in accordance with the regulations on compulsory procurement, the financial authorities shall take immediate and effective measures to order such units to make corrections. If the units refuse to take corrective actions, financial authorities shall circulate a notice of criticism and shall not grant procurement fund. If purchasing agencies are responsible for the procurements, the financial authorities shall investigate the legal responsibility of units and individuals concerned.

4.4 Preferential policy for corporate income tax related to energy saving products[4]

To speed up the construction of resource saving and environment-friendly society and give support to the development of energy saving product enterprises, it is a measure with practical significance to promote environmental protection with the tax policy. The 197th State Council Executive Meeting adopted *Regulation on the Implementation of Corporate Income Tax Law of the PRC* on Nov 28th, 2007 and this regulation took effect in January 1st, 2008.

Environmental protection and energy & water saving projects that can enjoy favorable corporate income tax include public sewage treatment, public garbage treatment, comprehensive development and exploitation of

[3] http://www.gov.cn/zwgk/2007-08/06/content_707549.htm
[4] http://www.gov.cn/zwgk/2007-12/11/content_830645.htm

biogas, transformation of energy saving and emission reduction technologies and sea water desalination project. The enterprises are exempted from corporate income tax in the 1st, 2nd and 3rd year since tax year of the first revenue arising from production or operation and will pay half the income taxes in the 4th, 5th and 6th year; where an enterprise utilizes the resources as listed in the *Catalogue of Resources for Comprehensive Utilization Entitling Enterprises to Income Tax Preferences* as its major raw materials to make products which are not restricted or prohibited by the State and comply with the relevant national or industrial standards, the income derived therefrom shall be calculated into the total income of such enterprise in the year at the reduced rate of 90%. Amount of investment in dedicated device for environmental protection, energy and water conservation and safe production is based on tax credit in proportion. *Regulation on the Implementation of Corporate Income Tax Law of the PRC* provides that enterprises incur the expenditure on special equipment that protects the environment, conserves energy and water, offers work safety, can get tax exemption on a certain percentage. The Implementation Regulations provide that where the enterprise incurs actual expenditure on special equipment that is on the list of *Catalogue of Equipment for the Exclusive Use in Environmental Protection that Receives Tax Preferences*, *Catalogue of Equipment for the Exclusive Use in Energy and Water Conservation*, and *Catalogue of Equipment for the Exclusive Use in Work safety that Receives Tax Preferences*, 10% of the actual expenditure can be credited against the tax payable for the current year. If the tax payable is not enough, the credits can be carried over for use in the next five tax years.

In regard to enterprises for manufacturing energy efficient distribution transformer, they can apply for corresponding corporate income tax preferences according to *Regulation on the Implementation of the Income Tax Law of the People's Republic of China* in order to boost their initiatives to produce energy efficient equipment (products).

4.5 Energy saving assessment for fixed asset investment[5]

To strengthen energy saving management for investment projects of fixed assets, promote energy utilization in a scientific and rational way, wipe out energy waste from the source and improve efficiency of energy utilization, the National Development and Reform Commission *issued Interim Regulation on Energy Efficiency Assessment and Examination with Respect to Fixed Asset Investment Projects* (No.6 Decree of NDRC) on September 17th, 2010 pursuant to the *Law of the PRC on Conserving Energy* and the *Decision of the State Council on Strengthening Energy Conservation*, which took effect since November 1st, 2010 and shall apply to any fixed asset investment projects that are constructed within China under the management of the development and reform authorities of the people's governments at various levels.

This regulation provides that the energy efficiency assessment documents for fixed asset investment projects and the opinions based on the examination, energy efficiency registration forms and opinions about registration and filing in relation thereto shall constitute preconditions for project review, approval or construction commencement and a major basis for project design, construction and acceptance of completed construction. With respect to those fixed asset projects that have failed to receive energy efficiency examination or have failed to be accepted upon energy efficiency examination pursuant to this regulation, the project examination or approval authorities shall not grant approval to the same; the construction unit shall not commence construction, and any completed construction shall not be put into production or operation. *Interim Regulation on Energy Efficiency Assessment and Examination with Respect to Fixed Asset Investment Projects* highlights energy efficiency assessment and examination shall conform to relevant laws and regulations, planning, industrial entry conditions, industrial policies and relevant engineering data and technical contract. This regulation also provides energy consuming products, equipment and production process that the State eliminates are prohibited to put in use, thereby creating favorable conditions for marketization application of energy efficient distribution transformer.

4.6 High energy consuming and obsolete equipment (products) elimination system[6-7]

It is one of the energy conservation and emission reduction measures to accelerate eliminating obsolete capacity in high energy consuming industry taken by the Chinese government, which has great significance on

5 http://www.sdpc.gov.cn/zcfb/zcfbl/2010ling/t20100921_372517.htm
6 http://www.miit.gov.cn/n11293472/n11293832/n12768545/12903291.html
7 http://www.miit.gov.cn/n11293472/n11293832/n12845605/n13916898/14560365.html

deepening industrial energy saving and emission reduction efforts, promotes industrial transformation and upgrading, optimizes industrial structure, improves the overall industrial level, achieves transformation of economic growth pattern and enhances economic benefits. Based on the development of high energy consuming industry in China and in combination with practical situations of energy conservation and emission reduction in the industry and communication industry, the Ministry of Industry and Information Technology of the PRC issued the first and second batches of *Catalogue of Obsolete Mechanical and Electrical Equipment (Products) Eliminated due to High Energy Consumption* respectively in December, 2009 and April, 2012. According to the lists, all units producing and using high energy consuming equipment (products) shall make great efforts to eliminate the equipment (products) listed in the above catalogue. The production units should stop producing such equipment and the customers shall replace them with energy efficient equipment (products) as soon as possible. The first batch of elimination catalogue issued SJ, SJ 1, SJ 2, SJ 3, SJ 4, SJ 5, SJL, SJL1, S, S 1, SZ, SL, SLZ, SL 1 and SLZ 1 series of small and medium size distribution transformers, DJMB series of dry type transformer for lighting and DBK series of dry type transformer for control, SL7-30/10~SL7-1600/10 and S7-30/10~S7-1600/10 distribution transformer with high energy consumption and loss. The first batch of elimination catalogue issued SCB8 (SCB8-30~2500/10) dry type transformer whose no-load loss and load loss cannot meet with the requirements of GB20052-2006, HJ/T224-2005 and GB/T10228-2008.

China is dedicated to creating institutional, policy and market environment which are conducive to eliminating high energy consuming and obsolete mechanical and electrical equipment (products), promoting wide application of energy efficient mechanical and electrical equipment (products), speeding up eliminating high energy consuming distribution transformer and positively spreading the usage of energy efficient distribution transformer.

4.7 Project to promote energy efficient products for the benefit of the people[8-9]

To promote wide application of energy efficient distribution transformer, the Ministry of Finance, National Development and Reform Commission and Ministry of Industry and Information Technology of the PRC jointly issued *Implementation Rule on Promotion of Energy Efficient Distribution Transformer regarding Project to Promote Energy Efficient* Products for the Benefit of the People (Cai Jian (2012) No. 854) on November 6th, 2012. This rule takes effect in the period of November 1st, 2012 to October 31st, 2013. Its main contents include:

I. Range and conditions of promoted products

(I) Promoted products are oil-immersed transformers (three-phase; voltage grade: 10 kV; non-exciting regulation; rated capacity: 30 kVA~1600 kVA) and dry type distribution transformers (rated capacity: 30 kVA~2500 kVA).

(II) Products that are applied for promotion of energy efficient distribution transformers (hereinafter referred to as energy efficient distribution transformer) must meet the following requirements:

1．Their energy efficiency is over Level 2;

2．They are certified by the state-recognized third party and energy saving product certification authorities (Products that are listed in the first batch of promoted products catalogue shall get energy saving certification within 3 months after the release of the catalogue);

3．They are produced and used in mainland China;

4．All products of this brand are qualified during product quality supervision in recent three years.

II. Standards of financial subsidies for promotion of energy efficient transformer are shown in Table 4.1:

Table 4.1 Standards of financial subsidies for promotion of energy efficient transformer

Product type	Level of energy efficiency	Material of iron core	Standard of subsidies (yuan/**kVA**）
Oil-immersed type	Level 1	Amorphous alloy	30
		Electrical steel sheet	20
	Level 2	Amorphous alloy	4

8 http://jjs.mof.gov.cn/zhengwuxinxi/tongzhigonggao/201211/t20121119_698704.html

9 http://www.sdpc.gov.cn/zcfb/zcfbgg/2013gg/t20130117_523220.htm

Product type	Level of energy efficiency	Material of iron core	Standard of subsidies (yuan/**kVA**）
		Electrical steel sheet	10
Dry type	Level 1	Amorphous alloy	40
		Electrical steel sheet	25
	Level 2	Amorphous alloy	6
		Electrical steel sheet	15

On January 11th, 2013, the, National Development and Reform Commission, Ministry of Finance and Ministry of Industry and Information Technology of the PRC jointly organized the examination for promotion and application report on energy efficient distribution transformer and relevant documents submitted by local governments and issued *Catalogue of Enterprises for Promotion of Energy Efficient Distribution Transformer and Product Catalogue with Respect to Project to Promote Energy Efficient Products for the Benefit of the People* (the first batch) (No. 5, 2013) in order to carry out financial subsidies for energy efficient distribution transformer. Catalogue of enterprises for promotion of energy efficient distribution transformer and product catalogue herein are shown in the table 4.2 and Table 4.3:

Table 4.2 Catalogue of Enterprises for Promotion of Energy Efficient Distribution Transformer (the first batch)

Serial No.	Enterprise name	Number of oil-immersed type	Number of dry type
1	Changzhou Special Transformer Co., Ltd.	1	—
2	Guangzhou Haihong Electric Co., Ltd.	18	2
3	Guangxi Xianhe Electrical Co., Ltd.	6	—
4	Hainan Weite Electric Group Co., Ltd.	30	10
5	Hangzhou Qiantang River Electric Group Co., Ltd.	17	—
6	Henan Zhongjing Electric Co., Ltd.	6	—
7	Henan Zhulu Electric Co., Ltd.	—	7
8	Jiangsu Hongyuan Electric Co., Ltd.	2	1
9	Jiangsu Huapeng Transformer Co., Ltd.	4	3
10	Jiangxi Han's Power Technology Co., Ltd.	10	—
11	Jiangxi No.2 Power Equipment Co., Ltd.	1	—
12	Quzhou Hangyong Transformer Co., Ltd.	11	—
13	Sanbian Sci-Tech Co., Ltd.	33	2
14	Shandong Dachi Electric Co., Ltd.	24	—
15	Shanghai Lianneng Zhixin Amorphous Alloy Transformer Co., Ltd.	11	—
16	Shanghai Wangwei Electric Co., Ltd.	3	3
17	Shanghai Superconductor Energy Equipment Co., Ltd.	6	—
18	Shanghai Zhixin Electric and Amorphous Transformer Co., Ltd.	22	13
19	Shanghai Zhixin Electric Co., Ltd.	22	13
20	Wolong Electric Yinchuan Transformer Co., Ltd.	6	—
21	Wujiang Transformer Co., Ltd.	8	1
22	Xuji Transformer Co., Ltd.	—	21
23	Zhejiang Golden Triangle Transformer Co., Ltd.	11	12
24	Zhong'an (Changzhou) Electric Co., Ltd.	1	—
25	Zhongzhao Peiji (Beijing) Electric Co., Ltd.	7	—

Note: Names of enterprises are in the order of their initials of pinyin.

Table 4. 3 Catalogue of Energy Efficient Distribution Transformers Promoted (the first batch)

Serial No.	Type	Brand	Material of iron core	Rated capacity (kVA）	Level of energy efficiency	Standard of subsidies (yuan/kVA）
I. Oil-immersed type						
1. Changzhou Special Transformer Co., Ltd.						
1	SBH15-M-800/10	Wenfu	Amorphous alloy	800	1	30
2. Guangzhou Haihong Co., Ltd.						
1	SH15-M-100/10(SH-M-100/10-NX2）	Haihongsheng	Amorphous alloy	100	2	4
2	SH15-M-315/10(SH-M-315/10-NX2）	Haihongsheng	Amorphous alloy	315	2	4
3	SH15-M-400/10(SH-M-400/10-NX2）	Haihongsheng	Amorphous alloy	400	2	4
4	SH15-M-50/10(SH-M-50/10-NX2）	Haihongsheng	Amorphous alloy	50	2	4
5	SH15-M-630/10(SH-M-630/10-NX2）	Haihongsheng	Amorphous alloy	630	2	4
6	S13-M·RL-100/10(S-M·RL-100/10-NX2）	Haihongsheng	Electrical steel sheet	100	2	10
7	S13-M·RL-1000/10(S-M·RL-1000/10-NX2）	Haihongsheng	Electrical steel sheet	1000	2	10
8	S13-M·RL-160/10(S-M·RL-160/10-NX2）	Haihongsheng	Electrical steel sheet	160	2	10
9	S13-M·RL-200/10(S-M·RL-200/10-NX2）	Haihongsheng	Electrical steel sheet	200	2	10
10	S13-M·RL-30/10(S-M·RL-30/10-NX2）	Haihongsheng	Electrical steel sheet	30	2	10
11	S13-M·RL-315/10(S-M·RL-315/10-NX2）	Haihongsheng	Electrical steel sheet	315	2	10
12	S13-M·RL-50/10(S-M·RL-50/10-NX2）	Haihongsheng	Electrical steel sheet	50	2	10
13	S13-M·RL-500/10(S-M·RL-500/10-NX2）	Haihongsheng	Electrical steel sheet	500	2	10
14	S13-M·RL-800/10(S-M·RL-800/10-NX2）	Haihongsheng	Electrical steel sheet	800	2	10
15	S16-M·RL-200/10(S-M·RL-200/10-NX1）	Haihongsheng	Electrical steel sheet	200	1	20
16	S16-M·RL-315/10(S-M·RL-315/10-NX1）	Haihongsheng	Electrical steel sheet	315	1	20
17	S16-M·RL-630/10(S-M·RL-630/10-NX1）	Haihongsheng	Electrical steel sheet	630	1	20
18	S16-M·RL-800/10(S-M·RL-800/10-NX1）	Haihongsheng	Electrical steel sheet	800	1	20
3. Guangxi Xianhe Electrical Co., Ltd.						
1	SBH15-160/10	Luanshan	Amorphous alloy	160	2	4
2	SBH15-200/10	Luanshan	Amorphous alloy	200	2	4
3	SBH15-250/10	Luanshan	Amorphous alloy	250	2	4
4	SBH15-315/10	Luanshan	Amorphous alloy	315	2	4
5	SBH15-400/10	Luanshan	Amorphous alloy	400	2	4
6	SBH15-500/10	Luanshan	Amorphous alloy	500	2	4
4. Hainan Weite Electric Group Co., Ltd.						
1	S(B) 13-M-100/10	Weite	Electrical steel sheet	100	2	10
2	S(B) 13-M-1000/10	Weite	Electrical steel sheet	1000	2	10
3	S(B) 13-M-125/10	Weite	Electrical steel sheet	125	2	10

Serial No.	Type	Brand	Material of iron core	Rated capacity (kVA）	Level of energy efficiency	Standard of subsidies (yuan/kVA）
4	S(B) 13-M-160/10	Weite	Electrical steel sheet	160	2	10
5	S(B) 13-M-200/10	Weite	Electrical steel sheet	200	2	10
6	S(B) 13-M-250/10	Weite	Electrical steel sheet	250	2	10
7	S(B) 13-M-30/10	Weite	Electrical steel sheet	30	2	10
8	S(B) 13-M-315/10	Weite	Electrical steel sheet	315	2	10
9	S(B) 13-M-400/10	Weite	Electrical steel sheet	400	2	10
10	S(B) 13-M-50/10	Weite	Electrical steel sheet	50	2	10
11	S(B) 13-M-500/10	Weite	Electrical steel sheet	500	2	10
12	S(B) 13-M-63/10	Weite	Electrical steel sheet	63	2	10
13	S(B) 13-M-630/10	Weite	Electrical steel sheet	630	2	10
14	S(B) 13-M-80/10	Weite	Electrical steel sheet	80	2	10
15	S(B) 13-M-800/10	Weite	Electrical steel sheet	800	2	10
16	S(B) H15-M-100/10	Weite	Amorphous alloy	100	1	30
17	S(B) H15-M-1000/10	Weite	Amorphous alloy	1000	1	30
18	S(B) H15-M-125/10	Weite	Amorphous alloy	125	1	30
19	S(B) H15-M-160/10	Weite	Amorphous alloy	160	1	30
20	S(B) H15-M-200/10	Weite	Amorphous alloy	200	1	30
21	S(B) H15-M-250/10	Weite	Amorphous alloy	250	1	30
22	S(B) H15-M-30/10	Weite	Amorphous alloy	30	1	30
23	S(B) H15-M-315/10	Weite	Amorphous alloy	315	1	30
24	S(B) H15-M-400/10	Weite	Amorphous alloy	400	1	30
25	S(B) H15-M-50/10	Weite	Amorphous alloy	50	1	30
26	S(B) H15-M-500/10	Weite	Amorphous alloy	500	1	30
27	S(B) H15-M-63/10	Weite	Amorphous alloy	63	1	30
28	S(B) H15-M-630/10	Weite	Amorphous alloy	630	1	30
29	S(B) H15-M-80/10	Weite	Amorphous alloy	80	1	30
30	S(B) H15-M-800/10	Weite	Amorphous alloy	800	1	30
5. Hangzhou Qiantang River Electric Group Co., Ltd.						
1	SH15-M-1000/10	Qianchao	Amorphous alloy	1000	2	4
2	SH15-M-1250/10	Qianchao	Amorphous alloy	1250	2	4
3	SH15-M-160/10	Qianchao	Amorphous alloy	160	2	4
4	SH15-M-1600/10	Qianchao	Amorphous alloy	1600	2	4
5	SH15-M-200/10	Qianchao	Amorphous alloy	200	2	4
6	SH15-M-250/10	Qianchao	Amorphous alloy	250	2	4
7	SH15-M-315/10	Qianchao	Amorphous alloy	315	2	4
8	SH15-M-400/10	Qianchao	Amorphous alloy	400	2	4
9	SH15-M-500/10	Qianchao	Amorphous alloy	500	2	4
10	SH15-M-630/10	Qianchao	Amorphous alloy	630	2	4
11	SH15-M-800/10	Qianchao	Amorphous alloy	800	2	4
12	S13-M-160/10	Qianchao	Electrical steel sheet	160	2	10
13	S13-M-200/10	Qianchao	Electrical steel sheet	200	2	10
14	S13-M-250/10	Qianchao	Electrical steel sheet	250	2	10
15	S13-M-315/10	Qianchao	Electrical steel sheet	315	2	10

Serial No.	Type	Brand	Material of iron core	Rated capacity (kVA）	Level of energy efficiency	Standard of subsidies (yuan/kVA）
16	S13-M-400/10	Qianchao	Electrical steel sheet	400	2	10
17	S13-M-500/10	Qianchao	Electrical steel sheet	500	2	10
6. Henan Zhongjing Electric Co., Ltd.						
1	SBH15-M-160/10	Zhongjing	Amorphous alloy	160	2	4
2	SBH15M-200/10	Zhongjing	Amorphous alloy	200	2	4
3	SBH15-M-250/10	Zhongjing	Amorphous alloy	250	2	4
4	SBH15-M-315/10	Zhongjing	Amorphous alloy	315	2	4
5	SBH15-M-400/10	Zhongjing	Amorphous alloy	400	2	4
6	SBH15-M-500/10	Zhongjing	Amorphous alloy	500	2	4
7. Jingsu Hongyuan Electric Co., Ltd.						
1	S13-M-630/10	Baonaide	Electrical steel sheet	630	2	10
2	SBH15-M-630/10	Baonaide	Amorphous alloy	630	1	30
8. Jiangsu Huapeng Transformer Co., Ltd.						
1	S13-M-1600/10	Huapeng	Electrical steel sheet	1600	2	10
2	S13-M-200/10	Huapeng	Electrical steel sheet	200	2	10
3	S13-M-500/10	Huapeng	Electrical steel sheet	500	2	10
4	S13-M-800/10	Huapeng	Electrical steel sheet	800	2	10
9. Jiangxi Han's Power Technology Co., Ltd.						
1	SB13-M.RL(315)	Han's power (oil 10)	Electrical steel sheet	315	2	10
2	SB13-M.RL(500)	Han's power (oil 12)	Electrical steel sheet	500	2	10
3	SB13-M.RL(630)	Han's power (oil 13)	Electrical steel sheet	630	2	10
4	SB13-M.RL(800)	Han's power (oil 14)	Electrical steel sheet	800	2	10
5	SB13-M.RL(1000)	Han's power (oil 15)	Electrical steel sheet	1000	2	10
6	SB13-M.RL(1250)	Han's power (oil 16)	Electrical steel sheet	1250	2	10
7	SB13-M.RL(1600)	Han's power (oil 17)	Electrical steel sheet	1600	2	10
8	SB13-M.RL(160)	Han's power (oil7)	Electrical steel sheet	160	2	10
9	SB13-M.RL(200)	Han's power (oil8)	Electrical steel sheet	200	2	10
10	SB13-M.RL(250)	Han's power (oil9)	Electrical steel sheet	250	2	10
10. Jiangxi No.2 Power Equipment Co., Ltd.						
1	S13	JXED	Electrical steel sheet	800	2	10
11. Quzhou Hangyong Transfomer Co., Ltd.						
1	SBH15-M-1000/10	QBE	Amorphous alloy	1000	2	4
2	SBH15-M-1250/10	QBE	Amorphous alloy	1250	2	4
3	SBH15-M-160/10	QBE	Amorphous alloy	160	2	4
4	SBH15-M-1600/10	QBE	Amorphous alloy	1600	2	4
5	SBH15-M-200/10	QBE	Amorphous alloy	200	2	4
6	SBH15-M-250/10	QBE	Amorphous alloy	250	2	4
7	SBH15-M-315/10	QBE	Amorphous alloy	315	2	4
8	SBH15-M-400/10	QBE	Amorphous alloy	400	2	4
9	SBH15-M-500/10	QBE	Amorphous alloy	500	2	4
10	SBH15-M-630/10	QBE	Amorphous alloy	630	2	4
11	SBH15-M-800/10	QBE	Amorphous alloy	800	2	4
12. Sanbian Sci-Tech Co., Ltd.						

Serial No.	Type	Brand	Material of iron core	Rated capacity (kVA）	Level of energy efficiency	Standard of subsidies (yuan/kVA）
1	SBH15-M-1000/10	Sanmen	Amorphous alloy	1000	2	4
2	SBH15-M-1250/10	Sanmen	Amorphous alloy	1250	2	4
3	SBH15-M-160/10	Sanmen	Amorphous alloy	160	2	4
4	SBH15-M-1600/10	Sanmen	Amorphous alloy	1600	2	4
5	SBH15-M-200/10	Sanmen	Amorphous alloy	200	2	4
6	SBH15-M-250/10	Sanmen	Amorphous alloy	250	2	4
7	SBH15-M-315/10	Sanmen	Amorphous alloy	315	2	4
8	SBH15-M-400/10	Sanmen	Amorphous alloy	400	2	4
9	SBH15-M-500/10	Sanmen	Amorphous alloy	500	2	4
10	SBH15-M-630/10	Sanmen	Amorphous alloy	630	2	4
11	SBH15-M-800/10	Sanmen	Amorphous alloy	800	2	4
12	S13-M·RL-1000/10	Sanmen	Electrical steel sheet	1000	2	10
13	S13-M·RL-1250/10	Sanmen	Electrical steel sheet	1250	2	10
14	S13-M·RL-160/10	Sanmen	Electrical steel sheet	160	2	10
15	S13-M·RL-1600/10	Sanmen	Electrical steel sheet	1600	2	10
16	S13-M·RL-200/10	Sanmen	Electrical steel sheet	200	2	10
17	S13-M·RL-250/10	Sanmen	Electrical steel sheet	250	2	10
18	S13-M·RL-315/10	Sanmen	Electrical steel sheet	315	2	10
19	S13-M·RL-400/10	Sanmen	Electrical steel sheet	400	2	10
20	S13-M·RL-500/10	Sanmen	Electrical steel sheet	500	2	10
21	S13-M·RL-630/10	Sanmen	Electrical steel sheet	630	2	10
22	S13-M·RL-800/10	Sanmen	Electrical steel sheet	800	2	10
23	S13-M-1000/10	Sanmen	Electrical steel sheet	1000	2	10
24	S13-M-1250/10	Sanmen	Electrical steel sheet	1250	2	10
25	S13-M-160/10	Sanmen	Electrical steel sheet	160	2	10
26	S13-M-1600/10	Sanmen	Electrical steel sheet	1600	2	10
27	S13-M-200/10	Sanmen	Electrical steel sheet	200	2	10
28	S13-M-250/10	Sanmen	Electrical steel sheet	250	2	10
29	S13-M-315/10	Sanmen	Electrical steel sheet	315	2	10
30	S13-M-400/10	Sanmen	Electrical steel sheet	400	2	10
31	S13-M-500/10	Sanmen	Electrical steel sheet	500	2	10
32	S13-M-630/10	Sanmen	Electrical steel sheet	630	2	10
33	S13-M-800/10	Sanmen	Electrical steel sheet	800	2	10
13. Shandong Dachi Electric Co., Ltd.						
1	SBH-315/10-2	Dachi	Amorphous alloy	315	2	4
2	SBH-400/10-2	Dachi	Amorphous alloy	400	2	4
3	SBH-500/10-2	Dachi	Amorphous alloy	500	2	4
4	SH-100/10-2	Dachi	Amorphous alloy	100	2	4
5	SH-125/10-2	Dachi	Amorphous alloy	125	2	4
6	SH-160/10-2	Dachi	Amorphous alloy	160	2	4
7	SH-200/10-2	Dachi	Amorphous alloy	200	2	4
8	SH-250/10-2	Dachi	Amorphous alloy	250	2	4
9	SH-30/10-2	Dachi	Amorphous alloy	30	2	4

Serial No.	Type	Brand	Material of iron core	Rated capacity (kVA）	Level of energy efficiency	Standard of subsidies (yuan/kVA）
10	SH-50/10-2	Dachi	Amorphous alloy	50	2	4
11	SH-63/10-2	Dachi	Amorphous alloy	63	2	4
12	SH-80/10-2	Dachi	Amorphous alloy	80	2	4
13	S-100/10-2	Dachi	Electrical steel sheet	100	2	10
14	S-125/10-2	Dachi	Electrical steel sheet	125	2	10
15	S-160/10-2	Dachi	Electrical steel sheet	160	2	10
16	S-200/10-2	Dachi	Electrical steel sheet	200	2	10
17	S-250/10-2	Dachi	Electrical steel sheet	250	2	10
18	S-30/10-2	Dachi	Electrical steel sheet	30	2	10
19	S-315/10-2	Dachi	Electrical steel sheet	315	2	10
20	S-400/10-2	Dachi	Electrical steel sheet	400	2	10
21	S-50/10-2	Dachi	Electrical steel sheet	50	2	10
22	S-500/10-2	Dachi	Electrical steel sheet	500	2	10
23	S-63/10-2	Dachi	Electrical steel sheet	63	2	10
24	S-80/10-2	Dachi	Electrical steel sheet	80	2	10
14. Shanghai Lianneng Zhixin Amorphous Alloy Transformer Co., Ltd.						
1	SBH-M-160/10-NX2(SBH15-M-160/10)	Lianneng Zhixin	Amorphous alloy	160	2	4
2	SBH-M-200/10-NX2(SBH15-M-200/10)	Lianneng Zhixin	Amorphous alloy	200	2	4
3	SBH-M-250/10-NX2(SBH15-M-250/10)	Lianneng Zhixin	Amorphous alloy	250	2	4
4	SBH-M-315/10-NX2(SBH15-M-315/10)	Lianneng Zhixin	Amorphous alloy	315	2	4
5	SBH-M-400/10-NX2(SBH15-M-400/10)	Lianneng Zhixin	Amorphous alloy	400	2	4
6	SBH-M-500/10-NX2(SBH15-M-500/10)	Lianneng Zhixin	Amorphous alloy	500	2	4
7	SBH-M-1000/10-NX1(SBH15-M-1000/10)	Lianneng Zhixin	Amorphous alloy	1000	1	30
8	SBH-M-1250/10-NX1(SBH15-M-1250/10)	Lianneng Zhixin	Amorphous alloy	1250	1	30
9	SBH-M-1600/10-NX1(SBH15-M-1600/10)	Lianneng Zhixin	Amorphous alloy	1600	1	30
10	SBH-M-630/10-NX1(SBH15-M-630/10)	Lianneng Zhixin	Amorphous alloy	630	1	30
11	SBH-M-800/10-NX1(SBH15-M-800/10	Lianneng Zhixin	Amorphous alloy	800	1	30
15. Shanghai Wangwei Electric Co., Ltd.						
1	SBH15-1000/10	Wangwei	Amorphous alloy	1000	1	30
2	SBH15-315/10	Wangwei	Amorphous alloy	315	1	30
3	SBH15-630/10	Wangwei	Amorphous alloy	630	1	30
16. Shanghai Superconductor Energy Equipment Co., Ltd.						
1	SBH15-M-160/10	Ensav	Amorphous alloy	160	1	30
2	SBH15-M-200/10	Ensav	Amorphous alloy	200	1	30
3	SBH15-M-250/10	Ensav	Amorphous alloy	250	1	30
4	SBH15-M-315/10	Ensav	Amorphous alloy	315	1	30
5	SBH15-M-400/10	Ensav	Amorphous alloy	400	1	30
6	SBH15-M-500/10	Ensav	Amorphous alloy	500	1	30
17. Shanghai Zhixin Electric and Amorphous Transformer Co., Ltd.						
1	S((B) H-M-100/10-NX2(S((B) H15-M-100/10）	Zhixin	Amorphous alloy	100	2	4

Serial No.	Type	Brand	Material of iron core	Rated capacity (kVA）	Level of energy efficiency	Standard of subsidies (yuan/kVA）
2	SBH-M-1000/10-NX2(SBH15-M-1000/10)	Zhixin	Amorphous alloy	1000	2	4
3	SBH-M-125/10-NX2(SBH15-M-125/10)	Zhixin	Amorphous alloy	125	2	4
4	SBH-M-1250/10-NX2(SBH15-M-1250/10)	Zhixin	Amorphous alloy	1250	2	4
5	SBH-M-160/10-NX2(SBH15-M-160/10)	Zhixin	Amorphous alloy	160	2	4
6	SBH-M-1600/10-NX2(SBH15-M-1600/10)	Zhixin	Amorphous alloy	1600	2	4
7	SBH-M-200/10-NX2(SBH15-M-200/10)	Zhixin	Amorphous alloy	200	2	4
8	SBH-M-250/10-NX2(SBH15-M-250/10)	Zhixin	Amorphous alloy	250	2	4
9	SBH-M-315/10-NX2(SBH15-M-315/10)	Zhixin	Amorphous alloy	315	2	4
10	SBH-M-400/10-NX2(SBH15-M-400/10)	Zhixin	Amorphous alloy	400	2	4
11	SBH-M-500/10-NX2(SBH15-M-500/10)	Zhixin	Amorphous alloy	500	2	4
12	SBH-M-630/10-NX2(SBH15-M-630/10)	Zhixin	Amorphous alloy	630	2	4
13	SBH-M-800/10-NX2(SBH15-M-800/10)	Zhixin	Amorphous alloy	800	2	4
14	SH-M-30/10-NX2(SH15-M-30/10)	Zhixin	Amorphous alloy	30	2	4
15	SH-M-50/10-NX2(SH15-M-50/10)	Zhixin	Amorphous alloy	50	2	4
16	SH-M-63/10-NX2(SH15-M-63/10)	Zhixin	Amorphous alloy	63	2	4
17	SH-M-80/10-NX2(SH15-M-80/10)	Zhixin	Amorphous alloy	80	2	4
18	SBH-M-1000/10-NX1(SBH15-M-1000/10)	Zhixin	Amorphous alloy	1000	1	30
19	SBH-M-1250/10-NX1(SBH15-M-1250/10)	Zhixin	Amorphous alloy	1250	1	30
20	SBH-M-1600/10-NX1(SBH15-M-1600/10)	Zhixin	Amorphous alloy	1600	1	30
21	SBH-M-630/10-NX1(SBH15-M-630/10)	Zhixin	Amorphous alloy	630	1	30
22	SBH-M-800/10-NX1(SBH15-M-800/10)	Zhixin	Amorphous alloy	800	1	30
18. **Shanghai Zhixin Electric Co., Ltd.**						
1	S((B) H-M-100/10-NX2(S((B) H15-M-100/10)	Zhixin	Amorphous alloy	100	2	4
2	SBH-M-1000/10-NX2(SBH15-M-1000/10)	Zhixin	Amorphous alloy	1000	2	4
3	SBH-M-125/10-NX2(SBH15-M-125/10)	Zhixin	Amorphous alloy	125	2	4
4	SBH-M-1250/10-NX2(SBH15-M-1250/10)	Zhixin	Amorphous alloy	1250	2	4
5	SBH-M-160/10-NX2(SBH15-M-160/10)	Zhixin	Amorphous alloy	160	2	4
6	SBH-M-1600/10-NX2(SBH15-M-1600/10)	Zhixin	Amorphous alloy	1600	2	4
7	SBH-M-200/10-NX2(SBH15-M-200/10)	Zhixin	Amorphous alloy	200	2	4
8	SBH-M-250/10-NX2(SBH15-M-250/10)	Zhixin	Amorphous alloy	250	2	4
9	SBH-M-315/10-NX2(SBH15-M-315/10)	Zhixin	Amorphous alloy	315	2	4
10	SBH-M-400/10-NX2(SBH15-M-400/10)	Zhixin	Amorphous alloy	400	2	4
11	SBH-M-500/10-NX2(SBH15-M-500/10)	Zhixin	Amorphous alloy	500	2	4
12	SBH-M-630/10-NX2(SBH15-M-630/10)	Zhixin	Amorphous alloy	630	2	4
13	SBH-M-800/10-NX2(SBH15-M-800/10	Zhixin	Amorphous alloy	800	2	4
14	SH-M-30/10-NX2(SH15-M-30/10)	Zhixin	Amorphous alloy	30	2	4

Serial No.	Type	Brand	Material of iron core	Rated capacity (kVA）	Level of energy efficiency	Standard of subsidies (yuan/kVA）
15	SH-M-50/10-NX2(SH15-M-50/10)	Zhixin	Amorphous alloy	50	2	4
16	SH-M-63/10-NX2(SH15-M-63/10)	Zhixin	Amorphous alloy	63	2	4
17	SH-M-80/10-NX2(SH15-M-80/10)	Zhixin	Amorphous alloy	80	2	4
18	SBH-M-1000/10-NX1(SBH15-M-1000/10)	Zhixin	Amorphous alloy	1000	1	30
19	SBH-M-1250/10-NX1(SBH15-M-1250/10)	Zhixin	Amorphous alloy	1250	1	30
20	SBH-M-1600/10-NX1(SBH15-M-1600/10)	Zhixin	Amorphous alloy	1600	1	30
21	SBH-M-630/10-NX1(SBH15-M-630/10)	Zhixin	Amorphous alloy	630	1	30
22	SBH-M-800/10-NX1(SBH15-M-800/10	Zhixin	Amorphous alloy	800	1	30
19. Wolong Electric Yinchuan Transformer Co., Ltd.						
1	S13-M·RL-160/10	YCB	Electrical steel sheet	160	2	10
2	S13-M·RL-200/10	YCB	Electrical steel sheet	200	2	10
3	S13-M·RL-250/10	YCB	Electrical steel sheet	250	2	10
4	S13-M·RL-315/10	YCB	Electrical steel sheet	315	2	10
5	S13-M·RL-400/10	YCB	Electrical steel sheet	400	2	10
6	S13-M·RL-500/10	YCB	Electrical steel sheet	500	2	10
20. Wujiang Transformer Co., Ltd.						
1	SBH15-M-100/10	WS	Amorphous alloy	100	2	4
2	SBH15-M-315/10	WS	Amorphous alloy	315	2	4
3	SBH15-M-400/10	WS	Amorphous alloy	400	2	4
4	SBH15-M-500/10	WS	Amorphous alloy	500	2	4
5	S13-MR-400/10	WS	Electrical steel sheet	400	2	10
6	SB13-M-1000/10	WS	Electrical steel sheet	1000	2	10
7	SB13-M-315/10	WS	Electrical steel sheet	315	2	10
8	SBH15-M-250/10	WS	Amorphous alloy	250	1	30
21. Zhejiang Golden Triangle Transformer Co., Ltd.						
1	S13-M.RL-1000/10	Golden Triangle	Electrical steel sheet	1000	1	20
2	S13-M.RL-1250/10	Golden Triangle	Electrical steel sheet	1250	1	20
3	S13-M.RL-160/10	Golden Triangle	Electrical steel sheet	160	1	20
4	S13-M.RL-1600/10	Golden Triangle	Electrical steel sheet	1600	1	20
5	S13-M.RL-200/10	Golden Triangle	Electrical steel sheet	200	1	20
6	S13-M.RL-250/10	Golden Triangle	Electrical steel sheet	250	1	20
7	S13-M.RL-315/10	Golden Triangle	Electrical steel sheet	315	1	20
8	S13-M.RL-400/10	Golden Triangle	Electrical steel sheet	400	1	20
9	S13-M.RL-500/10	Golden Triangle	Electrical steel sheet	500	1	20
10	S13-M.RL-630/10	Golden Triangle	Electrical steel sheet	630	1	20
11	S13-M.RL-800/10	Golden Triangle	Electrical steel sheet	800	1	20
22. Zhong’an (Changzhou) Electric Co., Ltd.						
1	SBH15-M-630/10-NX2	Shenke	Amorphous alloy	630	2	4
23. Zhongzhao Peiji (Beijing) Electric Co., Ltd.						
1	SBH15-1000	Feijinyuan	Amorphous alloy	1000	2	4
2	SBH15-1250	Feijinyuan	Amorphous alloy	1250	2	4

Serial No.	Type	Brand	Material of iron core	Rated capacity (kVA）	Level of energy efficiency	Standard of subsidies (yuan/kVA）
3	SBH15-160	Feijinyuan	Amorphous alloy	160	2	4
4	SBH15-1600	Feijinyuan	Amorphous alloy	1600	2	4
5	SBH15-200	Feijinyuan	Amorphous alloy	200	2	4
6	SBH15-630	Feijinyuan	Amorphous alloy	630	2	4
7	SBH15-800	Feijinyuan	Amorphous alloy	800	2	4

4.8 The 12th Five-Year Planning for Energy Conservation and Emission Reduction[10]

To achieve the obligatory goal of energy conservation and emission reduction during the 12th Five-Year Plan, relieve environmental and resource restriction and enhance sustainable development capacity, the State Council issued the *12th Five-Year Plan for Energy Conservation and Emission Reduction* on December 8th, 2012 (Guo Fa [2012] No. 40). The Chinese government has set specific goals of energy conservation and emission reduction in 2015, that is the energy consumption per unit industrial added value (for industrial enterprises above designated size) will fall about 21% over 2010; The proportion of unit energy consumption index of major products (workload) that will reach advanced energy saving standard will greatly increase; energy efficiency index of new key energy consuming equipment, such as fan, water pump, air compressor and transformer will reach domestic or international advanced level. Thereinto, as for no-load loss and load loss of power transformer, the Chinese government has set a specific goal of consumption reduction, which is shown in Table 4.4.

Table 4.4 Specific goal of consumption reduction of Chinese government

Index	2010	2015	Range of variation
No-load loss	43 kW	30 kW~33 kW	-10 kW~-13 kW
Load loss	170 kW	151 kW~153 kW	-17 kW~-19 kW

To achieve the goal of the *12th Five-Year Plan for Energy Conservation and Emission Reduction*, the Chinese government has proposed to improve the laws, regulations and standard systems related to energy conservation and environmental protection, speed up the construction of energy conservation and environmental protection standard system, expand the coverage of standard and increase admittance threshold. The Chinese government has also made amendments to mandatory energy consumption limit standard for over 50 high energy consuming products, such as crude steel, iron alloy, coke, polycrystalline silicon and sodium carbonate and mandatory energy efficiency standard for over 40 terminal energy consuming products, such as high voltage three-phase asynchronous motor and panel TV set. In addition, it formulated energy management system standard in the steel and cement industries.

4.9 Promotion of national key energy saving technologies (the 5th batch)[11]

To speed up the promotion of key energy saving technologies, guide energy consuming enterprises to adopt new advanced energy saving technologies, process and equipment and improve efficiency of energy utilization, the National Development and Reform Commission prepared *Catalogue of National Key Energy Saving Technologies Promoted* (the 5th batch) on December 13th , 2012 (No. 42 (2012)) involving 12 industries, such as power, steel, non-ferrous metal, chemical, building material, machinery, transportation, communication, etc. totaling 49 key energy saving technologies. The National Development and Reform Commission will plan to invest 5.2 billion yuan for promotion of controllable automatic capacity and voltage regulation distribution transformer technologies in 10 kV distribution network of power industry in 2015, thus the amount of energy conservation per unit is expected to reach 8.4 tce/set per year.

The controllable automatic capacity and voltage regulation distribution transformer technology achieves

[10] http://www.gov.cn/zwgk/2012-08/21/content_2207867.htm
[11] http://www.ndrc.gov.cn/zcfb/zcfbgg/2012gg/t20121225_520026.htm

automatic capacity and voltage regulation, remote load control, three-phase active power unbalanced regulation, low voltage fine reactive power compensation and energy saving operation of transformer by using combined voltage and capacity switch to change the connection method and status of load switch of all taps of the transformer coils. See Figure 4.1 and 4.2 for specific principle and inner structure of the transformer.

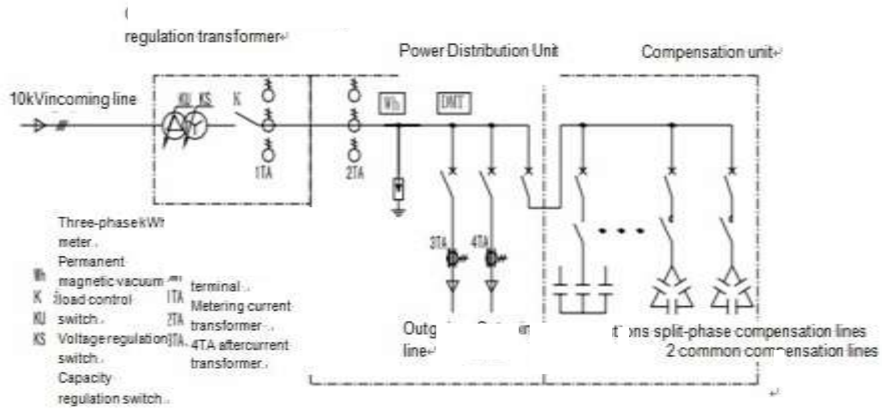


Figure 4.1 Primary schematic diagram of combined automatic capacity and voltage regulation transformer

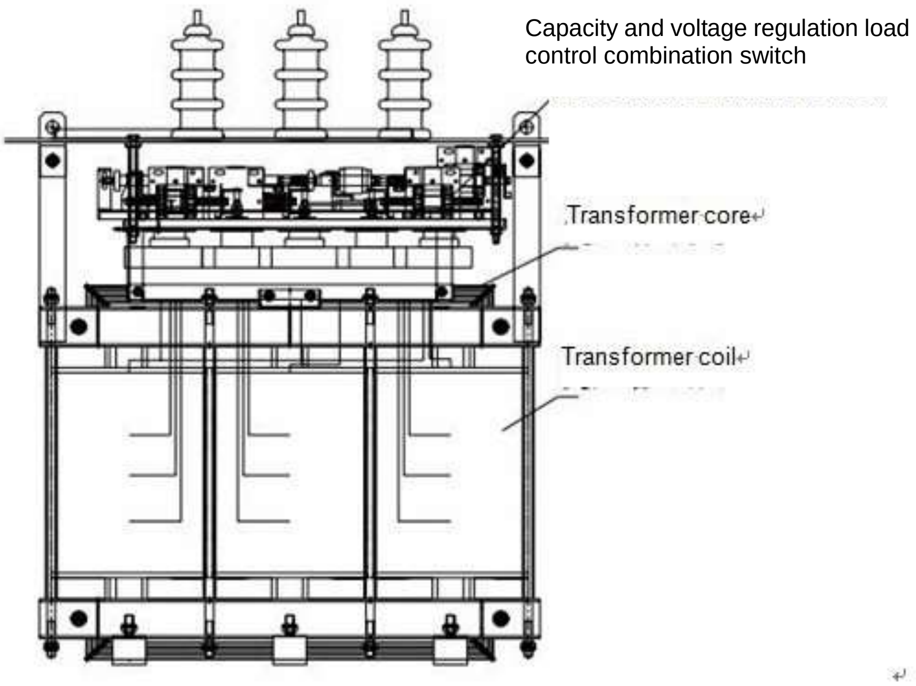


Figure 4.2 Inner structure of combined capacity and voltage regulation and load control transformer

Compared with S11 transformer, total losses of operation will reduce 48% with the controllable automatic capacity and voltage regulation distribution transformer technology; compared with S9 transformer, total losses of operation will reduce 53% with the same technology; the 36-step fine compensation technology can save 10,000kWh each year. The promotion and application of this technology can not only deal with prevalent voltage instability among consumers of power distribution network, low power factor, large on-load loss and unbalanced three-phase load of distribution transformer in rural power distribution network, but this technology can achieve intelligent controllable operation to ensure the economical and reliable operation, automatic control and comprehensive monitoring and management for energy consumption in power distribution network. It is estimated that the proportion of this technology applied in national distribution network will increase to 5% in 2015 from less than 1%, achieving about 670,000 tce of annual energy saving capacity.

4.10 Energy conservation certification for three-phase distribution transformer[12]

China Quality Certification Center issued *Energy Conservation Certification Rules for Three-Phase Distribution Transformers* on January 10th, 2013. In lieu of the *Limit Values of Energy Efficiency and the Evaluating Values of Energy Conservation for Three-Phase Distribution Transformers* (GB20052-2006), *Energy Conservation Certification Technical Specification for Three-phase Distribution Transformer*s (CQC3137-2012) is deemed as the basis of inspection, which is applicable to energy certification for three-phase distribution transformers and improves the requirements of the evaluating values of energy conservation for transformers.

Energy Conservation Certification Rules for Three-Phase Distribution Transformers are applicable to the following products: oil-immersed distribution transformers (three-phase, voltage grade:10 kV; non-exciting regulation; rated capacity: 30 kVA~1600 kVA) and dry type distribution transformers (rated capacity: 30 kVA~2500 kVA), but not applicable to gas-filled *transformers.*

The energy conservation for three-phase distribution transformer is certified as follows: product inspection + initial factory inspection + post supervision. The basic links of certification include: application, product inspection, initial factory inspection, assessment and approval for certification results, post supervision and reexamination. As for the certified products, they may use energy saving certification mark of three-phase distribution transformers as shown in Figure 4.3.

Figure 4.3 Energy Saving Certification Mark of Three-phase Distribution Transformers

4.11 China energy efficiency labels of three-phase distribution transformers[13]

According to *Measures for the Administration of China Energy Efficiency Labels*, China will implement energy efficiency labeling system for oil-immersed distribution transformers applicable to three-phase, voltage grade: 10 kV; non-exciting regulation; rated capacity: 30 kVA~1600 kVA specified by current effective version of GB20052 and dry type distribution transformer (rated capacity: 30 kVA~2500 kVA). No-load loss and load loss of three-phase distribution transformer shall be tested in accordance with the requirements of GB1094.1 and GB1094.11. Energy efficiency shall be divided into three levels, i.e., Level 1-high efficiency and energy conservation and Level 3-high consuming energy. See Figure 4.4 for the pattern and specification of energy labels.

[12] http://www.cqc.com.cn/chinese/rootfiles/2013/02/28/1312218401492865-1361779858481204.pdf

[13] http://energylabel.gov.cn/UserFiles/files/%E4%B8%89%E7%9B%B8%E9%85%8D%E7%94%B5%E5%8F%98%E5%8E%8B%E5%99%A8%E8%83%BD%E6%BA%90%E6%95%88%E7%8E%87%E6%A0%87%E8%AF%86%E5%AE%9E%E6%96%BD%E8%A7%84%E5%88%99-%E5%BE%81%E8%AF%A2%E6%84%8F%E8%A7%81%E7%A8%BF.pdf

Figure 4.4　Pattern of China energy label of three-phase distribution transformer

China energy label of three-phase distribution transformer shall be hung, pasted and fixed in conspicuous positions of three-phase distribution transformer. Each distribution transformer to be delivered or exported shall be attached with the label and provide its details in the product description. Manufacturer or importer shall keep product specification and type on record in authorized agency and on www.energylabel.gov.cn respectively. As for the enterprise that has kept it on record and verified, an authorized agency shall release label information of the recorded product on www.energylabel.gov.cn and shall regularly announce the same information on relevant media. If the manufacturer or importer changes their recorded information, such manufacturer or importer shall keep such change on record again in the authorized agency. By referring to China energy label attached on three-phase distribution transformer, consumers and customers are aware of energy efficiency levels and other performance indexes of three-phase distribution transformer provided. In addition, these labels can guide customers and consumers to select energy efficient three-phase distribution transformer.

Chapter 5 Standards

In recent years, China has made continuous improvements in relevant energy efficiency standards and economical operation standards of the distribution transformer, as well as given full play to the national and industrial standards on restructuring and acceleration for the industrial development. These standards provide a technical support for the market-oriented popularization and application of the energy-efficient power distribution. The major standards involved include the guidelines for determining energy efficiency and techno-economic appraisal for distribution transformers (DL/T985-2012), economical operation for power transformers (GB/T13462-2008) and the limit values of energy efficiency and the evaluating values of energy conservation for three-phase distribution transformers (GB20052-2013) (a draft for approval). The main contents of each standard are as follows:

5.1 Guidelines for determining energy efficiency and techno-economic appraisal for distribution transformers (DL/T985-2012)

5.1.1 General rules

By calculating the integrated energy efficiency cost of the distribution transformers during the economical lifetime, and making analysis and comparison of the technically feasible alternative schemes, the energy efficiency and techno-economic appraisal for distribution transformers aims at picking out a scheme which is technically feasible and of optimal economy, namely selecting the distribution transformer with the minimum integrated energy efficiency cost during the economical lifetime.

5.1.2 Basic calculation (non-power supply enterprise)

5.1.2.1 Calculation of integrated energy efficiency cost of the distribution transformers

The integrated energy efficiency cost of the distribution transformers from non-power supply enterprise during the economical lifetime includes: first cost of the distribution transformer, equivalent first cost of no-load loss and equivalent first cost of load loss. Calculation of the cost is related to the way the basic electric charge of non-power supply enterprise is calculated.

When the basic electric charge is calculated according to maximum demand, the following formula is applicable to its integrated energy efficiency:

$$TOC = CI + AP_0 + BP_k \tag{5.1}$$

When the basic electric charge is calculated on the basis of transformer capacity, the formula below shall apply to its integrated energy efficiency:

$$TOC = CI + AP_0 + BP_k + 12k_{pv}E_cS_e \tag{5.2}$$

Where:

k_{pv}——present value factor of the cost for several continuous years n, at the discount rate i;

E_c——electric charge of unit capacity paid by enterprises, that is the monthly basic electric charge collected according to transformer capacity in the two-part price, yuan/kVA;

S_e——rated capacity of transformers, kVA.

5.1.2.2 Calculation of factor A of the equivalent first cost of no-load loss

When the basic electric charge is calculated according to maximum demand, the following formula is applicable:

$$A = k_{pv}(E_eH_{Py} + 12E_d) \tag{5.3}$$

When the basic electric charge is calculated on the basis of transformer capacity, the formula below shall apply:

$$A = k_{pv} E_e H_{Py} \tag{5.4}$$

$$k_{pv} = \frac{1 - \left[1/\left(1+i\right)\right]^n}{i} \tag{5.5}$$

Where:

k_{pv}——present value factor, calculated according to formula (5);

E_e——electric charge of unit capacity paid by enterprises, yuan/kWh;

E_d——electric charge of unit capacity paid by enterprises, that is the monthly basic electric charge collected according to maximum demand in the two-part price, yuan/kW;

H_{py}——annual charged hours of transformers, h.

5.1.2.3 Calculation of factor B of the equivalent first cost of load loss

When the basic electric charge is calculated according to maximum demand, the following formula is applicable:

$$B = \left(E_e \tau + 12E_d\right) PL^2 k_t \tag{5.6}$$

When the basic electric charge is calculated on the basis of transformer capacity, the formula below shall apply:

$$B = E_e \tau PL^2 k_t \tag{5.7}$$

$$PL^2 = \sum_{j=1}^{n} \{[\beta_0 \times (1+g)^{(j-1)}]^2 \times [1/(1+i)^j]\} = \frac{{\beta_0}^2}{(1+i)^n} \times \frac{(1+i)^n - (1+g)^{2n}}{(1+i) - (1+g)^2} \tag{5.8}$$

Where:

τ——hours of annual maximum load loss, h.

PL——annual load equivalent factor of transformers during the economical lifetime, calculated according to formula (8);

k_t——temperature correction factor of transformers, generally 1.0.

5.2 Economical operation for power transformers (GB/T13462-2008)

5.2.1 Basic requirements

5.2.1.1 Transformer selected or replaced shall be in line with the requirements of GB1094, GB/T6451 and GB/T10228, and both its no-load loss and load loss shall conform to GB20052 and other relevant energy efficiency standards.

5.2.1.2 Capacity and quantity of transformer banks shall be rationally chosen.

5.2.1.3 Economical operation mode with the lowest integrated power loss of transformers shall be optimally chosen.

5.2.1.4 Transformer load shall be reasonably adjusted and be in operation within the range of lowest integrated power loss.

5.2.2 Calculation of economical load factor and division of economical operation range of the two-winding transformers

5.2.2.1 Calculation of economical load factorIntegrated power loss rate of two-winding transformers shows a non-linear variation along with the load factor when in operation. The lowest point in the non-linear curve is the economical load factor of integrated power, whose calculation formula is:

$$\beta_{JZ} = \sqrt{\frac{P_{0Z}}{K_T P_{KZ}}} \tag{5.9}$$

Where:

β_{JZ}——economical load factor of transformer's integrated power;

P_{0Z}——no-load loss of transformer's integrated power, unit: kW;

P_{KZ}——power loss of rated load of transformer's integrated power, unit: kW;

K_T——loss factor of load fluctuation.

5.2.2.2 Division of the economical operation range

A transformer operating at its rated load falls into the upper limit of the economical operation range, and the other point equal to loss rate of rated integrated power of the upper limit falls into the lower limit. Load factor of the upper limit of the economical operation range is 1, while that of its lower limit is β^2_{JZ}, see Figure 5.

5.2.2.3 Division of the optimum economical operation range

A transformer operating at 75% of its load falls into the upper limit of the optimum economical operation range, and the other point equal to loss rate of integrated power of the upper limit falls into its lower limit. Load factor of the upper limit of the optimum economical operation range is 0.75, while that of its lower limit is 1.332, see Figure 5.

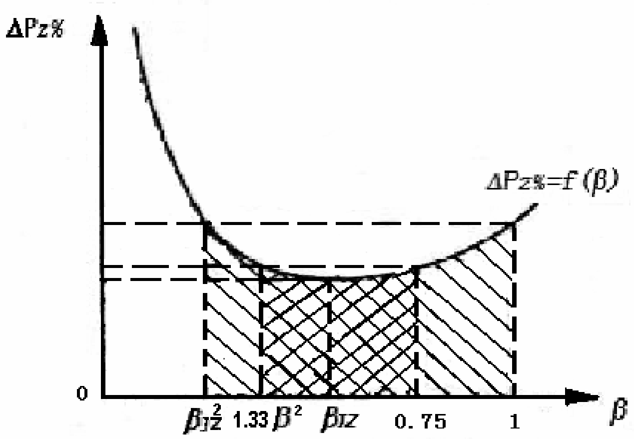


Figure 5.1 Division of operation range of integrated power of two-winding transformers

Notes: $\Delta P_{Z\%}=f(\beta)$ is a function characteristic curve between the integrated power loss rate of transformer and average load factor β. In terms of division of operation range of transformer's integrated power, the economical operation range is $\beta^2_{JZ} \le \beta \le 1$, the optimum economical operation range is $1.33\beta^2_{JZ} \le \beta \le 0.75$, and the non-economical operation range is $0 \le \beta \le \beta^2_{JZ}$.

5.2.3 Calculation of economical load factor and optimum economical load factor, division of economical operation range of the three-winding transformer

5.2.3.1 Economical load factor

When the loads of windings at the secondary- and tertiary-terminals of a three-winding transformer are distributed randomly, the lowest point of loss rate of such transformer's integrated power is the economical load factor of its integrated power, and the economical load factor of its integrated power at its mains terminal shall be calculated according to formula 5.10.

$$\beta_{JZ1} = \sqrt{\frac{P_{0Z}}{K_{T1}P_{K1Z} + K_{T2}C_2^2\left(\frac{S_{1N}}{S_{2N}}\right)^2 P_{K2Z} + K_{T3}C_3^2\left(\frac{S_{1N}}{S_{3N}}\right)^2 P_{K3Z}}} \tag{5.10}$$

5.2.3.2 Optimum economical load factor

When the loads of windings at the secondary- and tertiary-terminals of a three-winding transformer are distributed economically, the lowest point of loss rate of such transformer's integrated power is the optimum economical load factor of its integrated power. For calculation of economical distribution factor of loads of windings at the secondary- and tertiary-terminals, see formula 5.11 and 5.12 respectively.

$$C_{J2}=\frac{K_{T3}\frac{P_{K3Z}}{S_{3N}^{2}}}{K_{T2}\frac{P_{K2Z}}{S_{2N}^{2}}+K_{T3}\frac{P_{K3Z}}{S_{3N}^{2}}} \tag{5.11}$$

$$C_{J3}=\frac{K_{T2}\frac{P_{K2Z}}{S_{2N}^{2}}}{K_{T2}\frac{P_{K2Z}}{S_{2N}^{2}}+K_{T3}\frac{P_{K3Z}}{S_{3N}^{2}}} \tag{5.12}$$

Optimum economical load factor of integrated power at the mains terminal of the three-winding transformer shall be calculated in accordance with formula 5.13.

$$\beta_{JJZ1}=\sqrt{\frac{P_{0Z}}{K_{T1}P_{K1Z}+\frac{K_{T2}K_{T3}S_{1N}^{2}P_{K2Z}P_{K3Z}}{K_{T2}S_{3N}^{2}P_{K2Z}+K_{T3}S_{2N}^{2}P_{K3Z}}}} \tag{5.13}$$

5.2.3.3 Division of the economical operation range

A transformer operating at its rated load falls into the upper limit of the economical operation range, and the point equal to the loss rate of rated integrated power of the upper limit falls into its lower limit. Load factor of the upper limit of economical operation range at the mains terminal is 1, while that of its lower limit is β^{2}_{JZ1}.

5.2.3.4 Division of the optimum economical operation range

The operation range in which the loss rate of three-winding transformer's integrated power is less than 1.2% is the optimum economical operation range. Load factor of the upper limit of economical operation range at the mains terminal is 1.865β_{JZ1}, while that of its lower limit is 0.537β_{JZ1}.

5.2.4 Economical operation management of transformers

5.2.4.1 The unit shall be equipped with electric energy metering device for transformers and improve the measuring means.

5.2.4.2 The unit shall record daily operation data and typical daily load of the transformer and provide data for its economical operation.

5.2.4.3 The unit shall improve the management of documents in respect of transformer's economical operation and keep its original data; the test data after overhaul and upgrading of the transformer shall be kept in the archive of the transformer.

5.2.4.4 Analysis on transformer's economical operation shall be regularly carried out; on the basis of guaranteeing its safe operation and quality of power supply, some improvements shall be proposed. Relevant data shall be kept in the files.

5.2.4.5 The unit shall make an analysis and summary on transformer's economical operation on a monthly, quarterly and yearly basis, and prepare a statistical table and summary sheet about the energy-saving effect and economic benefit of the transformer.

5.2.5 Judgment and evaluation of economical operation

5.2.5.1 If the no-load loss and load loss of transformer reach the evaluating values of energy conservation specified in the energy efficiency standard, the transformer operates in the optimum economical operation range, and the economical operation management complies with the requirements in Section 2.2.4, the transformer is recognized as operating economically.

5.2.5.2 If the no-load loss and load loss of transformer reach the limit value of energy efficiency specified in the energy efficiency standard, the transformer operates in the economical operation range, and the economical operation management meets the requirements in Section 2.2.4, the transformer is recognized as operating rationally.

5.2.5.3 If the no-load loss and load loss of transformer cannot reach the limit value of energy efficiency specified in the energy efficiency standard, or the transformer operates in the non-economical operation range, the transformer is recognized as operating uneconomically.

5.3 Limit value of energy efficiency and the evaluating values of energy conservation for three-phase distribution transformers (GB20052-2013)

5.3.1 Basic requirements

Other technical parameters and requirements of distribution transformers shall comply with GB1094.1 and GB/T6451, that of oil-immersed amorphous alloy core transformer shall also conform to GB/T25446, and that of tridimensional wound-core distribution transformer shall also conform to GB/T25438. Other technical parameter and requirements of the dry type distribution transformer shall be in line with GB1094.11 and GB/T10228, and that of the dry type amorphous alloy core transformer shall also conform to GB/T22072.

5.3.2 Energy efficiency levels of the distribution transformer

The energy efficiency of the distribution transformer can be divided into three levels, among which Level 1 means the lowest loss. No-load loss value and load loss value of the oil immersed distribution transformer in each level shall not exceed as specified in Table 5.1, while the dry type distribution transformer in each level shall not exceed as specified in Table 5.2.

Table 5.1 Energy efficiency levels of oil-immersed distribution transformer

Rated capacity kVA	Level 1						Level 2				Level 3			Short-circuit impedance %
	Electrical steel strip			Amorphous alloy			No-load loss (W)		Load loss (W)		No-load loss (W)	Load loss (W)		
	No-load loss (W)	Load loss (W)		No-load loss (W)	Load loss (W)									
		$D_{yn}11/Y_{zn}11$	$Y_{yn}0$			$D_{yn}11/Y_{zn}11$		Amorphous alloy	$D_{yn}11/Y_{zn}11$	$Y_{yn}0$		$D_{yn}11/Y_{zn}11$	$Y_{yn}0$	
30	80	505	480	33	565	540	80	33	630	600	100	630	600	4.0
50	100	730	695	43	820	785	100	43	910	870	130	910	870	
63	110	870	830	50	980	935	110	50	1090	1040	150	1090	1040	
80	130	1050	1000	60	1180	1125	130	60	1310	1250	180	1310	1250	
100	150	1265	1200	75	1420	1350	150	75	1580	1500	200	1580	1500	
125	170	1510	1440	85	1700	1620	170	85	1890	1800	240	1890	1800	
160	200	1850	1760	100	2080	1980	200	100	2310	2200	280	2310	2200	
200	240	2185	2080	120	2455	2340	240	120	2730	2600	340	2730	2600	
250	290	2560	2440	140	2880	2745	290	140	3200	3050	400	3200	3050	
315	340	3065	2920	170	3445	3285	340	170	3830	3650	480	3830	3650	
400	410	3615	3440	200	4070	3870	410	200	4520	4300	570	4520	4300	
500	480	4330	4120	240	4870	4635	480	240	5410	5150	680	5410	5150	
630	570	4960		320	5580		570	320	6200		810	6200		4.5
800	700	6000		380	6750		700	380	7500		980	7500		
1000	830	8240		450	9270		830	450	10300		1150	10300		
1250	970	9600		530	10800		970	530	12000		1360	12000		
1600	1170	11600		630	13050		1170	630	14500		1640	14500		

Table 5.2 Energy efficiency levels of dry type distribution transformer

Rated capacity kVA	Level 1								Level 2					Level 3				Short-circuit impedance %
	Electrical steel strip				Amorphous alloy				No-load loss (W)		Load loss (W)			No-load loss (W)	Load loss (W)			
	No-load loss (W)	Load loss (W)			No-load loss (W)	Load loss (W)												
		B (100℃)	F (120℃)	H (145℃)		B (100℃)	F (120℃)	H (145℃)	Electrical steel strip	Amorphous alloy	B (100℃)	F (120℃)	H (145℃)		B (100℃)	F (120℃)	H (145℃)	
30	135	605	640	685	70	635	675	720	150	70	670	710	760	190	670	710	760	
50	195	845	900	965	90	895	950	1015	215	90	940	1000	1070	270	940	1000	1070	
80	265	1160	1240	1330	120	1225	1310	1405	295	120	1290	1380	1480	370	1290	1380	1480	
100	290	1330	1415	1520	130	1405	1490	1605	320	130	1480	1570	1690	400	1480	1570	1690	
125	340	1565	1665	1780	150	1655	1760	1880	375	150	1740	1850	1980	470	1740	1850	1980	
160	385	1800	1915	2050	170	1900	2025	2165	430	170	2000	2130	2280	540	2000	2130	2280	4.
200	445	2135	2275	2440	200	2250	2405	2575	495	200	2370	2530	2710	620	2370	2530	2710	
250	515	2330	2485	2665	230	2460	2620	2810	575	230	2590	2760	2960	720	2590	2760	2960	
315	635	2945	3125	3355	280	3105	3295	3545	705	280	3270	3470	3730	880	3270	3470	3730	
400	705	3375	3590	3850	310	3560	3790	4065	785	310	3750	3990	4280	980	3750	3990	4280	
500	835	4130	4390	4705	360	4360	4635	4970	930	360	4590	4880	5230	1160	4590	4880	5230	
630	965	4975	5290	5660	420	5255	5585	5975	1070	420	5530	5880	6290	1340	5530	5880	6290	
630	935	5050	5365	5760	410	5330	5660	6080	1040	410	5610	5960	6400	1300	5610	5960	6400	6.
800	1095	5895	6265	6715	480	6220	6610	7085	1215	480	6550	6960	7460	1520	6550	6960	7460	
1000	1275	6885	7315	7885	550	7265	7725	8320	1415	550	7650	8130	8760	1770	7650	8130	8760	
50	1505	8190	8720	9335	650	8645	9205	9850	1670	650	9100	9690	10370	2090	9100	9690	10370	
00	1765	9945	10555	11320	760	10495	11145	11950	1960	760	11050	11730	12580	2450	11050	11730	12580	
00	2195	12240	13005	14005	1000	12920	13725	14780	2440	1000	13600	14450	15560	3050	13600	14450	15560	
00	2590	14535	15455	16605	1200	15340	16310	17525	2880	1200	16150	17170	18450	3600	16150	17170	18450	

5.3.3 The limit value of energy efficiency of the distribution transformer

No-load loss value and load loss value of the oil-immersed distribution transformer shall not exceed as specified under Level 3 in Table 5.1, while that of the dry type distribution transformer shall not exceed as specified under Level 3 in Table 5.2.

5.3.4 The evaluating values of energy conservation of the distribution transformer

No-load loss value and load loss value of the oil-immersed distribution transformer shall not exceed as specified under Level 2 in Table 5.1, while that of the dry type distribution transformer shall not exceed as specified under Level 2 in Table 5.2.

Part Ⅲ Current Market Status and Energy Efficiency Data Collection

Chapter 6 Introduction

6.1 Background

For elabrately implement the EWG 15 12 A project, Zhong Biao Standard Technology Research Institute Co. Ltd (ZBSTRI) has invesitigated Chinese distribution transformer market, collected current market status and energy efficiency data such as yield, yield growthrate, energy efficiency grade mix, etc. The main data collection purposes are as follows:

- Classify the all distribution transformers per insulation types and core materials in 2012 to know the prices of various types of distribution transformers.
- To know market information and material consumption information of the distribution transformers of different energy efficiency grades especially energy efficiency grade 1.
- To know the recovery costs and prices of the distribution transformers.

6.2 Contents

The following information is available by the research:

6.2.1 Yields of three-phase non-excited distribution transformers in China in 2012

- As insulating media: oil-immersed distribution transformers and dry-type distribution transformers;
- As core materials: silicon steel distribution transformers and amorphous alloy distribution transformers;
- As different loss series: by energy efficiency grade 1, 2 and 3 of oil-immersed type distribution transformer and by energy efficiency grade 1, 2 and 3 of dry-type distribution transformers.

6.2.2. Prices of three-phase non-excited distribution transformers in China in 2012

- As capacities: distribution transformers with capacities from 30 to 2500.

6.2.3 Costs information of distribution transformers.

6.2.4 Material consumption of three-phase non-excited distribution transformers of energy efficiency grade 1.

6.2.5 Stock of distribution transformers.

6.3 Samples and implementation

6.3.1 Sample performance

The main samples of the research are from the catalog of key manufacturing enterprises previously researched and Enterprises Promoting the "Energy-saving Products to Benefit Customers" Program, with 50 enterprises has been successfully visited.

6.3.2 Research Scope

Time range: 2012

Area coverage: China

6.3.3 Research time:

From June 1, 2013 to June 30, 2013

6.4 Yield derivation method

6.4.1 Step1: Determine the total yields of distribution transformers of enterprises in 2012

As some enterprises were sensitive to the yields and sales volume in the research, the researchers can at least obtain the growth rate of the annual yields in 2012. The yields of 2012 are derived from the yields results in 2011 previously searched and the growth rate in 2012.

6.4.2 Step 2: Determination of the yields and ratios for different types of distribution transformers of the enterprises

The data is based on the enterprise data obtained from the actual research while adjusting in accordance with the referring to production ratio of the industry to determine finally the yield ratios of various types of distribution transformers of all enterprises.

6.4.3 Step 3: Determine yields of various types of distribution transformers of the enterprises

The yields of various types of distribution transformers are calculated as per the following formula after determined the ratio between the total yields of distribution transformers of various enterprises and the yields of various types of distribution transformers:

$$E_{Total} = \sum E_i \times \varphi_i \tag{6.1}$$

$$E_i = E_{Total} \times \varphi_i \tag{6.2}$$

Where, E_{Total} – Total yields of distribution transformers of the such enterprises

E_i – yields of type i distribution transformers of the such enterprises

Φ_i – Ratio of type i distribution transformers of the such enterprises

6.4.4 Step 4: Calculate the total yields of various types of distribution transformers

The total yields of various types of distribution transformers are obtained by summing the determined yields of various types of distribution transformers of the enterprises.

6.5 Research limitations

The research results have certain limitations described as follows:

6.5.1 Sample coverage

To ensure continuity of samples, the original samples of the research are from the list of key manufacturing enterprises previously researched and Enterprises Promoting the "Energy-saving Products to Benefit the People" Program. These enterprises are determined by ACMR by telephone screening based on the economic census data of the National Bureau of Statistics of China. The list is the most complete sample frame available at present. However, statistical errors and screening errors will cause that some enterprises are excluded from the total sample frame, and the national statistical data are based on classification of enterprises by main businesses, some enterprises that produce distribution transformers but have the main businesses in other industries may be omitted. Since the Catalogue of Enterprises Promoting the “Energy-saving Products to Benefit the People” Program covers some manufacturing enterprises of distribution transformers of energy efficiency grade 1 and energy efficiency grade 2, certain enterprises are still not covered.

6.5.2 Data Availability

In the actual research, the research data are too specific, many enterprises are unwilling to disclose their detailed data about businesses or provide some data only. Especially, the enterprises have strong vigilance and are unwilling to easily make data involved in enterprises businesses available, so it is more difficult to obtain data and effective data can be obtained by contact with a great lot of samples.

6.5.3 Data Integrity

The classification of the distribution transformers is very particular in the research. Distribution transformers are classified in a cross manner by insulating media, core materials, energy efficiency grades, rated capacities, etc. Mass data need to be collected from every enterprise. Data may be insufficient because of statistical differences of enterprises and other factors in the actual research.

Chapter 7 Research results

7.1 GB20052 *Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Three-phase Non-excited Distribution Transformers* (for approval)

According to the technical and market development of the distribution transformer industry, China National Institute of Standardization, China Electric Power Research Institute, State Grid Electric Power Research Institute and International Copper Association (China) updated and modified GB20052-2006 *Minimum Allowable Values of Energy Efficiency and Evaluating Values of Energy Conservation for Three-phase Distribution Transformers*, i.e. GB20052 *Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Three-phase Distribution Transformers* (draft for approval), with the specific energy efficiency evaluation methods and indicators as follows:

7.1.1 Technical requirements

1) Basic requirements

Other technical parameters and technical requirements of distribution transformers shall conform to GB 1094.1 and GB/T 6451, and oil-immersed amorphous alloy iron core transformers shall conform to GB/T 25446, as well as tridimensional toroidal-core distribution transformers shall conform to GB/T 25438. In addition, other technical parameters and technical requirements of dry-type distribution transformers shall conform to GB 1094.11 and GB/T 10228, and dry-type amorphous alloy iron core transformers shall conform to GB/T 22072.

2) Energy efficiency grades

According to the *Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Three-phase Distribution Transformers* (for approval), 10 KV three-phase non-excited distribution transformers are divided into energy efficiency grade 1, energy efficiency grade 2 and energy efficiency grade 3 by no-load loss rate and load loss rate. The no-load loss values and load loss values of oil-immersed distribution transformers of different energy efficiency grades shall be not higher than the values specified in Table 7.1, and the no-load loss values and load loss values of dry-type distribution transformers of different energy efficiency grades shall be not higher than the values specified in Table 7.2. Energy efficiency grade 1 has the best energy-saving effect.

Table 7.1 Energy efficiency grades of oil-immersed three-phase non-excited distribution transformers

Rated capacity, kVA	Grade 1						Grade 2				Grade 3			Short circuit impedance, %
	Electrical steel band			Amorphous alloy			No-load loss (W)		Load loss (W)		No-load loss (W)	Load loss (W)		
	No-load loss (W)	Load loss (W)		No-load loss (W)	Load loss (W)									
		Dyn11/Yzn11	Yyn0			Dyn11/Yzn11		Amorphous alloy	Dyn11/Yzn11	Yyn0		Dyn11/Yzn11	Yyn0	
30	80	505	480	33	565	540	80	33	630	600	100	630	600	
50	100	730	695	43	820	785	100	43	910	870	130	910	870	

Rated capacity, kVA	Grade 1						Grade 2				Grade 3			Short circuit impedance, %
	Electrical steel band			Amorphous alloy			No-load loss (W)		Load loss (W)		No-load loss (W)	Load loss (W)		
	No-load loss (W)	Load loss (W)		No-load loss (W)	Load loss (W)									
		Dyn11/Yzn11	Yyn0			Dyn11/Yzn11		Amorphous alloy	Dyn11/Yzn11	Yyn0		Dyn11/Yzn11	Yyn0	
63	110	870	830	50	980	935	110	50	1090	1040	150	1090	1040	
80	130	1050	1000	60	1180	1125	130	60	1310	1250	180	1310	1250	
100	150	1265	1200	75	1420	1350	150	75	1580	1500	200	1580	1500	
125	170	1510	1440	85	1700	1620	170	85	1890	1800	240	1890	1800	
160	200	1850	1760	100	2080	1980	200	100	2310	2200	280	2310	2200	4.0
200	240	2185	2080	120	2455	2340	240	120	2730	2600	340	2730	2600	
250	290	2560	2440	140	2880	2745	290	140	3200	3050	400	3200	3050	
315	340	3065	2920	170	3445	3285	340	170	3830	3650	480	3830	3650	
400	410	3615	3440	200	4070	3870	410	200	4520	4300	570	4520	4300	
500	480	4330	4120	240	4870	4635	480	240	5410	5150	680	5410	5150	
630	570	4960		320	5580		570	320	6200		810	6200		
800	700	6000		380	6750		700	380	7500		980	7500		
1000	830	8240		450	9270		830	450	10300		1 150	10300		4.5
1250	970	9600		530	10800		970	530	12000		1 360	12000		
1600	1170	11600		630	13050		1170	630	14500		1 640	14500		

Table 7.2 Energy efficiency grades of dry-type three-phase non-excited distribution transformers

Rated capacity, kVA	Grade 1								Grade 2					Grade 3				Short circuit impedance, %
	Electrical steel band				Amorphous alloy				No-load loss (W)		Load loss (W)			No-load loss (W)	Load loss (W)			
	No-load loss (W)	Load loss (W)			No-load loss (W)	Load loss (W)												
		B (100 ℃)	F (120 ℃)	H (145 ℃)		B (100 ℃)	F (120 ℃)	H (145 ℃)	Electrical steel band	Amorphous alloy	B (100 ℃)	F (120 ℃)	H (145 ℃)		B (100 ℃)	F (120 ℃)	H (145 ℃)	
30	135	605	640	685	70	635	675	720	150	70	670	710	760	190	670	710	760	
50	195	845	900	965	90	895	950	1015	215	90	940	1000	1070	270	940	1000	1070	
80	265	1160	1240	1330	120	1225	1310	1405	295	120	1290	1380	1480	370	1290	1380	1480	
100	290	1330	1415	1520	130	1405	1490	1605	320	130	1480	1570	1690	400	1480	1570	1690	
125	340	1565	1665	1780	150	1655	1760	1880	375	150	1740	1850	1980	470	1740	1850	1980	
160	385	1800	1915	2050	170	1900	2025	2165	430	170	2000	2130	2280	540	2000	2130	2280	
200	445	2135	2275	2440	200	2250	2405	2575	495	200	2370	2530	2710	620	2370	2530	2710	4.0
250	515	2330	2485	2665	230	2460	2620	2810	575	230	2590	2760	2960	720	2590	2760	2960	
315	635	2945	3125	3355	280	3105	3295	3545	705	280	3270	3470	3730	880	3270	3470	3730	
400	705	3375	3590	3850	310	3560	3790	4065	785	310	3750	3990	4280	980	3750	3990	4280	
500	1160	4590	4880	5230	930	360	4590	4880	5230	835	4130	4390	4705	360	4360	4635	4970	
630	1340	5530	5880	6290	1070	420	5530	5880	6290	965	4975	5290	5660	420	5255	5585	5975	
630	1300	5610	5960	6400	1040	410	5610	5960	6400	935	5050	5365	5760	410	5330	5660	6080	

Rated capacity, kVA	Grade 1								Grade 2					Grade 3				Short circuit impedance, %
	Electrical steel band				Amorphous alloy				No-load loss (W)		Load loss (W)			No-load loss (W)	Load loss (W)			
	No-load loss (W)	Load loss (W)			No-load loss (W)	Load loss (W)												
		B (100 ℃)	F (120 ℃)	H (145 ℃)		B (100 ℃)	F (120 ℃)	H (145 ℃)	Electrical steel band	Amorphous alloy	B (100 ℃)	F (120 ℃)	H (145 ℃)		B (100 ℃)	F (120 ℃)	H (145 ℃)	
800	1520	6550	6960	7460	1215	480	6550	6960	7460	1095	5895	6265	6715	480	6220	6610	7085	
1000	1770	7650	8130	8760	1415	550	7650	8130	8760	1275	6885	7315	7885	550	7265	7725	8320	
1250	2090	9100	9690	10370	1670	650	9100	9690	10370	1505	8190	8720	9335	650	8645	9205	9850	
1600	2450	11050	11730	12580	1960	760	11050	11730	12580	1765	9945	10555	11320	760	10495	11145	11950	
2000	3050	13600	14450	15560	2440	1000	13600	14450	15560	2195	12240	13005	14005	1000	12920	13725	14780	
2500	3600	16150	17170	18450	2880	1200	16150	17170	18450	2590	14535	15455	16605	1200	15340	16310	17525	

3) Evaluating values of energy conservation

The no-load loss values and load loss values of oil-immersed distribution transformers shall be not higher than those for grade 2 specified in Table 7.2. The no-load loss values and load loss values of dry-type distribution transformers shall be not higher than those for grade 2 specified in Table 7.3.

7.1.2 Energy efficiency standards and loss series

For the occupancy of various loss series distribution transformers in the market, GB20052 *Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Three-phase Distribution Transformers* (draft for approval) is established according to performance indicators of oil-immersed S11 distribution transformers and dry-type SC10 distribution transformers.

The oil-immersed three-phase distribution transformers with energy efficiency grade 3 correspond to S11 loss series, and the oil-immersed three-phase distribution transformers of energy efficiency grade 2 correspond to S13 and S15 loss series, and the oil-immersed three-phase distribution transformers of energy efficiency grade 1 correspond to S13 loss series (with the load loss rate reduced by 20%) and S15 (with the load loss rate reduced by 10%). (See Table 7.3 for details)

Table 7.3 Corresponding energy efficiency grades of oil-immersed three-phase non-excit distribution transformers

Energy efficiency grade 3	Energy efficiency grade 2		Energy efficiency grade 1	
	Silicon steel	Amorphous alloy	Silicon steel	Amorphous alloy
S11	**S13**	**S15**	The load loss rate of S13 series is reduced by 20%.	The load loss rate of S15 series is reduced by 10%.

The dry-type three-phase distribution transformers of energy efficiency grade 3 correspond to SC10 loss series, the dry-type three-phase distribution transformers of energy efficiency grade 2 correspond to SC 13 and SC 15 loss series, and the dry-type three-phase distribution transformers of energy efficiency grade 1 correspond to SC13 loss series (with the load loss rate reduced by 10%) and SC15 (with the load loss rate reduced by 5%). (See Table 7.4 for details)

Table 7.4 Corresponding energy efficiency grades of dry-type three-phase non-excited distribution transformers

Energy efficiency grade 3	Energy efficiency grade 2		Energy efficiency grade 1	
	Silicon	Amorphous	Silicon steel	Amorphous alloy

	steel	alloy		
SC10	**SC13**	**SC15**	The load loss rate of SC13 series is reduced by 10%.	**The load loss rate of SC15 series** is reduced by **5%.**

7.2 Production conditions of three-phase non-excited distribution transformers in 2012

The total yields of three-phase non-excited distribution transformers were about 980,715 sets in 2012, with the total capacity of 406.70 million KVA. The yield is increased by 6% as compared to 2011. Compared with **11.1% growth rate at the same period historically, the yields of distribution transforms in 2012 increased slightly, with slow growth rate,which is shown in Figure 7.1.**

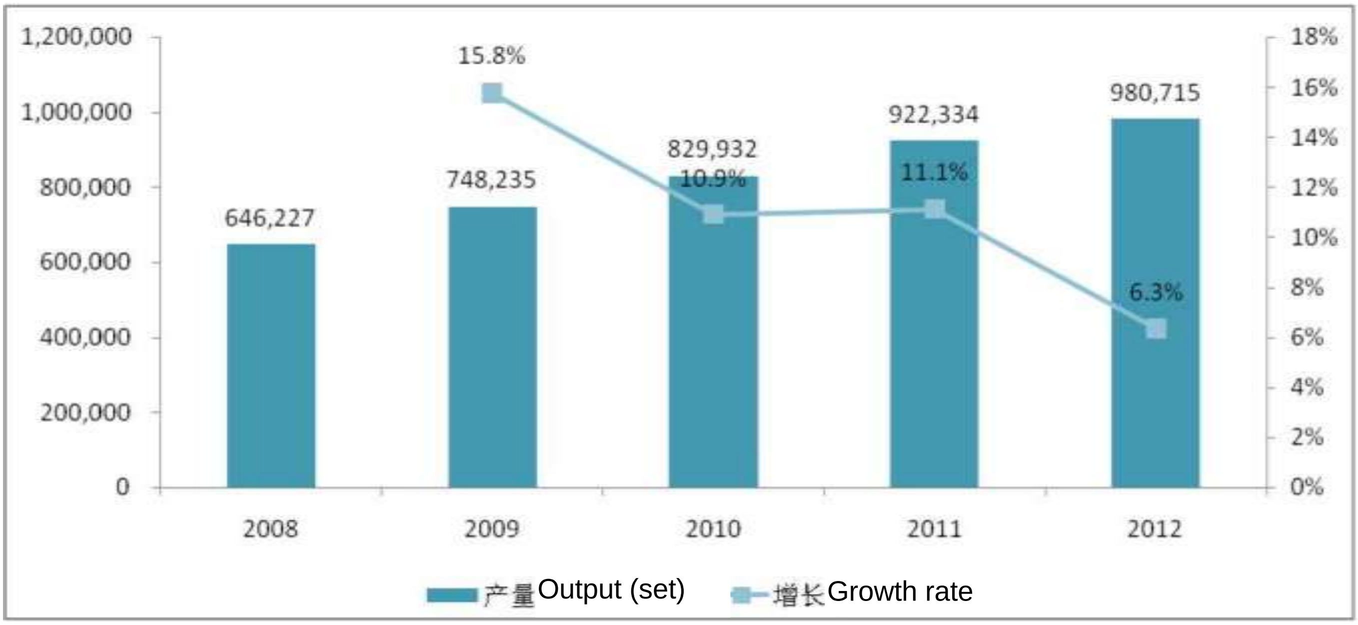


Figure 7.1 Yields and annual yields growth rate of three-phase non-excited distribution transformers in 2008 to 2012 (unit: set) （Data source: ACMR research）

7.2.1 Yields of three-phase non-excited distribution transformers in 2012

The yield of national three-phase non-excited distribution transformers in 2012 is accounted by different voltage classes, insulation types, core materials and energy efficiency grades, which showed in the table 7.5.

Table 7.5 Yields of three-phase non-excited distribution transformers in 2012

Classification		**Yields**	
		(set)	**(10000 KVA)**
Voltage classes	6 KV	33,344	13
	10 KV	869,894	37,420
	35 KV	70,611	3,030
	Other voltage classes	6,866	207
Insulation types	Oil-immersed	755,151	22,466
	Dry-type	225,564	18,204
Core materials	Silicon steel	895,001	37,132
	Amorphous alloy	85,714	3,538
Energy efficiency grades	Energy efficiency grade 1	67,393	2,676

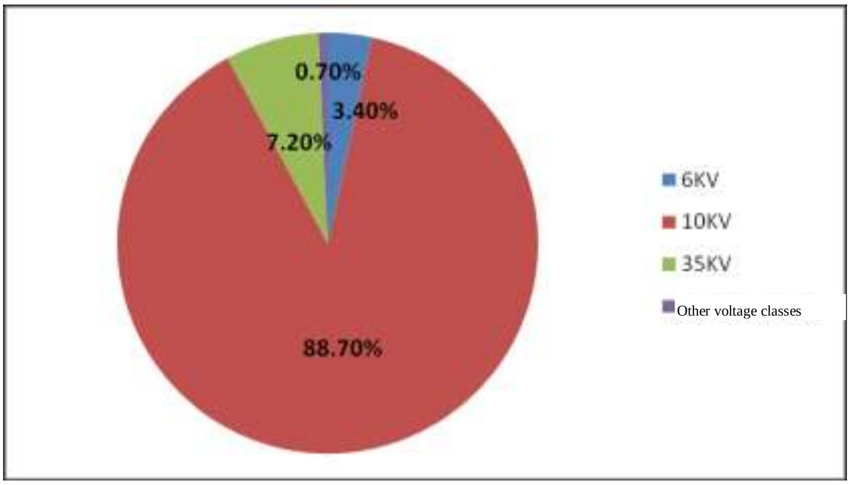
Classification		Yields (set)	Yields (10000 KVA)
	Energy efficiency grade 2	137,917	5,917
	Energy efficiency grade 3	775,405	32,077
Total		980,715	40,670

Data source: ACMR research, the number of samples: N = 50

7.2.2 Yields of three-phase non-excited distribution transformers with different voltage classes in 2012

In 2012, **Yield ratios of three-phase non-excited distribution transformers of different voltage classes in 2012 are shown in Figure 7.2. We can see that** the total yields of three-phase non-excited distribution transformers of different voltage classes were 980,000 sets in China, with the total capacity of 406.70 million KVA,

At present, 10 KV distribution transformers have the maximum yields in the domestic market, the yields of 10 KV three-phase non-excited distribution transformers were 869,894 sets in 2012, with the total capacity of 374.20 million KVA, accounting for 88.7% of the domestic market, followed by 35 KV distribution transformers, the yields of 35 KV three-phase non-excited distribution transformers were 70,611 sets in 2012, with the total capacity of 30.30 million KVA, accounting for 7.2% of the domestic market. However, the market share of 6 KV distribution transformers is less, the yields of 6 KV three-phase non-excited distribution transformers was 33,344 sets in 2012, with the total capacity of 130,000 KVA, only accounting for about 3.4%. In addition, the yields of three-phase non-excited distribution transformers of other voltage classes were 6,866 sets, with the total capacity of 2.07 million KVA, accounting for about 0.7% of the total yields.



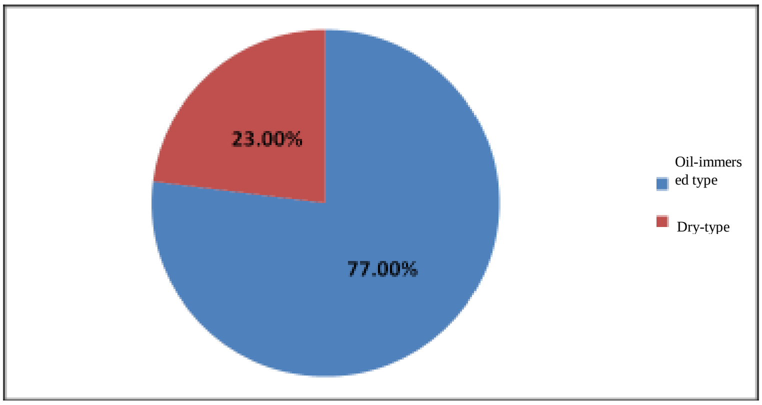
Data source: ACMR research, the number of samples: N = 50

Figure 7.2 Yield ratios of three-phase non-excited distribution transformers of different voltage classes in 2012

7.2.3 Yields of three-phase non-excited distribution transformers of different insulation types in 2012

The main three-phase non-excited distribution transformers currently available in the market are oil-immersed transformers, which is shown in Figure 7.3.

The yields of oil-immersed three-phase non-excited distribution transformers was 755,151 sets in 2012, with the total capacity of 224.66 million KVA, accounting for about 77% of the total yields; and the yields of dry-type transformers were 225,564 sets in 2012, with the total capacity of 182.04 million KVA, accounting for 23% of the total yields.

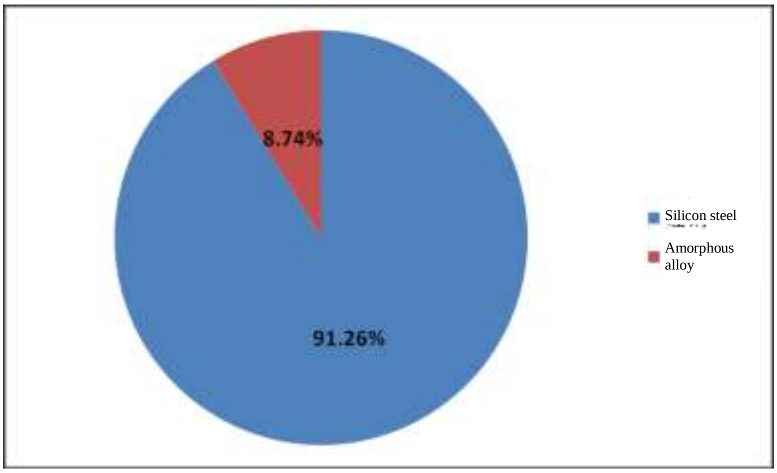


Data source: ACMR research, the number of samples: N = 50

Figure 7. 3 Yield ratios of three-phase non-excited distribution transformers of different insulation types in 2012

7.2.4 Yields of three-phase non-excited distribution transformers of different core materials in 2012

At present, the main core material of distribution transformers is silicon steel in China, the situation is shown in Figure 7.4. The yields of silicon steel three-phase non-excited distribution transformers were 895,001 sets in 2012, with the total capacity of 371.32 million KVA, accounting for 91.26% of the total yields. The remaining is amorphous alloy transformers, and the yields of amorphous alloy transformers were 85,714 sets in 2012, with the total capacity of 35.38 million KVA, accounting for 8.74% of the total yields.



Data source: ACMR research, the number of samples: N = 50

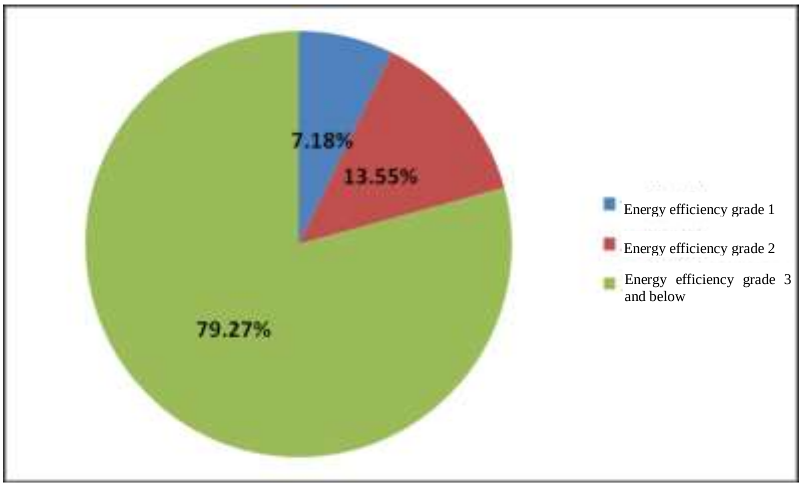
Figure 7. 4 Yield ratios of three-phase non-excited distribution transformers of different core materials in 2012

7.2.5 Yields of three-phase non-excited distribution transformers of different energy efficiency grades in 2012

1) **Yields of oil-immersed three-phase non-excited distribution transformers of different energy efficiency grades in 2012**

According to new energy efficiency grades (GB20052 draft for approval), oil-immersed three-phase non-excited distribution transformers are divided into energy efficiency grade 1, energy efficiency grade 2 and energy efficiency grade 3 by different no-load losses and load losses, corresponding to S13 loss series (with load loss reduced by 20%), S15 loss series (with load loss reduced by 10%), S13 loss series, S15 loss series and S11 loss series respectively.

In this research, the yields of oil-immersed distribution transformers of energy efficiency grade 1 were 54,220 sets in 2012, with the total capacity of 16.13 million KVA, accounting for 7.18% of the yields of oil-immersed distribution transformers in 2012. The yields of oil-immersed distribution transformers of energy efficiency grade 2 were 102,323 sets in 2012, with the total capacity of 30.44 million KVA, accounting for 13.55% of the total yields. The yields of oil-immersed distribution transformers of energy efficiency grade 3 and below were 598,608 in 2012, with the total capacity of 178.09 million KVA, accounting for 79.27% of the total yields.



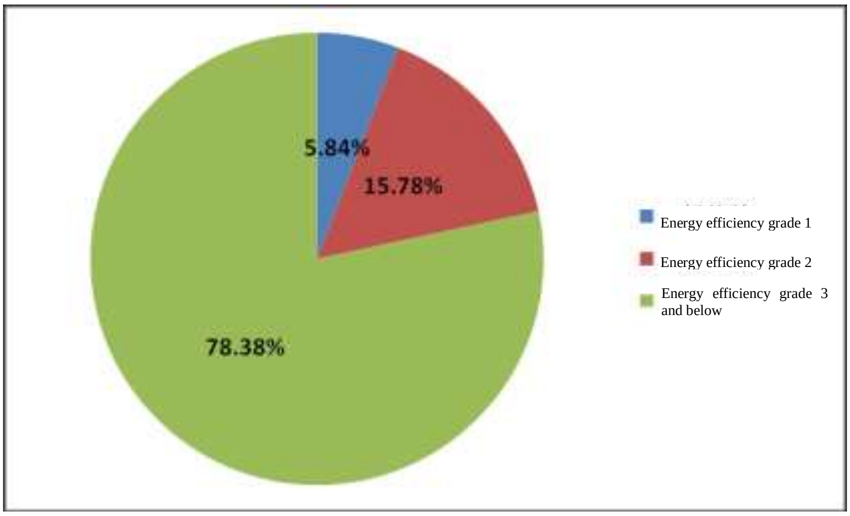
Data source: ACMR research, the number of samples: N = 50

Figure 7.5 Yield ratios of oil-immersed three-phase non-excited distribution transformers of different energy efficiency grades in 2012

2) **Yields of dry-type three-phase non-excited distribution transformers of different energy efficiency grades in 2012**

According to new energy efficiency grades (GB20052 draft for approval), dry-type three-phase non-excited distribution transformers are divided into energy efficiency grade 1, energy efficiency grade 2 and energy efficiency grade 3 by different no-load losses and load losses, corresponding to SC13 loss series (with load loss reduced by 10%), SC15 loss series (with load loss reduced by 5%), SC13 loss series, SC15 loss series and SC10 loss series respectively.

In this research, the yields of dry-type distribution transformers of energy efficiency grade 1 were 13,173 sets in 2012, with the total capacity of 10.63 million KVA, accounting for 5.84% of the yields of dry-type distribution transformers in 2012. The yields of dry-type distribution transformers of energy efficiency grade 2 were 35,594 sets in 2012, with the total capacity of 28.73 million KVA, accounting for 15.78% of the total yields. The yields of dry-type distribution transformers of energy efficiency grade 3 and below were 176,797 sets in 2012, with the total capacity of 142.68 million KVA, accounting for 78.38% of the total yields.



Data source: ACMR research, the number of samples: N = 50

Figure 7.6 Yield ratios of dry-type three-phase non-excited distribution transformers of different energy efficiency grades in 2012

At present, distribution transformers of energy efficiency grade 3 are mainly used and sold in the domestic market. Distribution transformers of energy efficiency grade 2 are also produced and used, but their quantity is not too large, and distribution transformers of energy efficiency grade 1 are fewer. Some qualified manufacturers do not manufacture distribution transformers of energy efficiency grade 1 due to no market orders.

7.3 Changes in raw material costs of transformers

From the materials of transformers, the cost of the three-phase distribution transformer is mainly affected by 1) price of copper and 2) price of silicon steel. The prices of copper and silicon steel are both affected by the prices in the international market.

In 2010, the prices of copper and silicon steel in the international market increased, which increased the transformer costs, but since 2011, their prices reduced to some degree. In 2012, the prices of copper and silicon steel went down consistently, and their prices in the international market also had downtrend. The decrease in copper price and silicon steel price in the international market directly reduces the production cost of transformers.

7.3.1 Changes in copper price

At present, the copper price in the domestic market is highly affected by the international market price, so the change in copper material price in the international market has direct effect on the transformer cost.

From 2004 to 2008, the fluctuation range of copper price was 30,000 yuan/ton to 70,000 yuan/ton.

Since 2009, the fluctuation range of copper price became small compared with that from 2004 to 2008, and remained at the level of 50,000 yuan/ton to 60,000 yuan/ton till 2011.

Copper price increased to 70,000 yuan/ton from the end of 2010 to the beginning of 2011, and then fluctuated from 60,000 yuan /ton to 70,000 yuan/ton. Copper price went down after falling to 60,000 yuan/ton in September 2011, and fell to 55,000 yuan/ton at the end of 2011.

In 2012, copper price had a narrow fluctuation range and keeps at about 50,000 yuan/ton at present.

7.3.2 Changes in silicon steel price

Since the change in international price of iron ores has great effect on the market price of silicon steel sheets, the international price change of silicon steel directly affects the silicon steel price, thus affecting the transformer cost.

Silicon steel price was relatively high from 2006 to 2007.

After 2008, as the steel yields in the international market increased gradually, the silicon steel price reduced slowly.

Since 2011, silicon steel price showed a slight decline, and reduced to 6,000 yuan/ton gradually after increasing to 8,000 yuan/ton in March from 7,000 yuan/ton at the beginning of the year.

In 2012, silicon steel price had a downtrend after minor increase at the beginning of the year, and the current silicon steel price is about 5,800 yuan/ton.

7.4 Material consumption of transformers

All enterprises visited reflected that copper and steel consumptions lacked industrial standard in the production of distribution transformers, and manufacturers determined the copper and steel consumptions as per drawing design, so they have difference in copper and steel consumptions. In actual production, the consumptions of materials for each type of distribution transformers are different also.

In general,:

① the copper and steel consumptions of the dry-type distribution transformers are more than those of the oil-immersed distribution transformers;

② in the transformers of the same capacity type, the steel consumption is more than the copper consumption;

and ③ the larger the capacity of the distribution transformers is, the less the copper and steel consumptions are.

7.4.1 Material consumption of distribution transformers of energy efficiency grade 3

The research reveals that for oil-immersed distribution transformers of energy efficiency grade 3, the copper consumption per KVA is about 0.82 kg, and the steel consumption per KVA is about 1.40 kg. For dry-type distribution transformers of energy efficiency grade 3, the copper consumption per KVA is about 1.06 kg, and the steel consumption per KVA is about 2.51 kg. The enterprises have different material consumptions for the transformers of the same capacity due to difference in technological level and process.

The research shows that for oil-immersed three-phase non-excited distribution transformers of different capacities, the copper and steel consumptions per KVA are shown in Table 7.6:

Table 7.6 Material consumption per KVA of oil-immersed non-excited distribution transformers of energy efficiency grade 3 with different capacities (unit: kg)

	Copper consumption	Steel consumption
30 KVA	1.67	3.49
100 KVA	0.98	1.15
315 KVA	0.96	1.00
500 KVA	0.60	1.30
1600 KVA	0.39	0.90
3000KVA	0.27	0.58

Data source: ASMR research

For dry-type three-phase non-excited distribution transformers with different capacities, the copper and steel consumptions per KVA are shown in Table 7.7:

Table 7.7 Material consumption per KVA of dry-type non-excited distribution transformers of energy efficiency grade 3 with different capacities (unit: kg)

	Copper consumption	Steel consumption
30 KVA	2.16	4.48
100 KVA	1.37	2.87
315 KVA	1.13	2.46
500 KVA	0.83	2.20
1600 KVA	0.64	1.88
3000 KVA	0.50	1.20

Data source: ASMR research

7.4.2 Material consumption of distribution transformers of energy efficiency grade 1

The research shows that the consumption of copper and steel required for amorphous alloy distribution transformers of energy efficiency grade 1 is lower than those required for silicon steel distribution transformers of energy efficiency grade 1; oil-immersed distribution transformers require less materials than dry-type distribution transformers; and for transformers with the same capacity, steel consumption is larger than copper consumption.

Because the enterprises actually manufacturing transformers of energy efficiency grade 1 are a few, it is difficult to obtain complete material consumptions for all capacities. Therefore, only the material consumption of all capacities of oil-immersed amorphous alloy distribution transformers of energy efficiency grade 1 and 100 kVA distribution transformers of energy efficiency grade 1 are listed.

Table 7.8 Material consumption per KVA of oil-immersed amorphous alloy distribution transformers of energy efficiency grade 1 with different capacities (UNIT: KG)

	Copper consumption	Steel consumption
30 KVA	1.69	3.00
50 KVA	1.05	2.50
100 KVA	1.03	1.65
500 KVA	0.63	0.60
800 KVA	0.42	1.25
3000 KVA	0.28	0.58

Data source: **ACMR research**

For example, for 100 KVA distribution transformers of energy efficiency grade 1, the copper consumption and steel consumption are as follows.

Table 7.9 Material consumption per KVA of 100 KVA distribution transformers of energy efficiency grade 1 (unit: kg)

	Copper consumption				Steel consumption			
	Oil-immersed		Dry		Oil-immersed		Dry	
	Silicon steel	Amorphous alloy	Silicon steel	Amorphous alloy	Silicon steel	Amorphous alloy	Silicon steel	Amorphous alloy
100 KVA	1.10	1.03	2.50	2.00	3.20	1.65	4.00	2.80

Parts Ⅳ Energy Saving Potential's Estimation & Market Analysis from Energy Efficiency Standards and Policies

Chapter 8 Overview

As the foremost fundamental energy industry in the development of China's economy, electric power industry is not only the vital foundation to national prosperity and the people's livelihood, but also the priority in the economic development strategy. Electric power has been playing an important role in the development of economy and society. It has a crucial bearing on major strategic issues regarding our economic security beyond ensuring people's daily life and stable social climate. China's demand on electric power is increasing as its economy grows and the expansion of power sales market in turn drives generation of electric power.

Distribution transformers are essential electrical equipment for electric power transmission. In recent years, nearly 6.4% of the power generated in China has been lost in transmission and distribution, wasting about 150 TWh every year. In view of their widespread service and long operating time, there is a great energy-saving potential in selection and use of the distribution transformers, especially the 10kV distribution transformers widely used in the power distribution grid. Therefore, energy saving has always been a major task of Chinese government and some achievements are seen in improving energy efficiency of transformer. The energy efficiency standard is formulated to guide transformer manufacturers in terms of development and production of energy-efficient distribution transformers and elimination of outdated inefficient ones, and to implement such a system among transformer manufacturers to certify energy-saving products and wash out high-energy-consumption products, making a significant contribution to saving energy resources, protecting ecological environment and boosting sustainable economic development.

8.1 Brief description of distribution transformer

8.1.1 Type of distribution transformer

Over the century or more since its invention, production process and manufacturing technology of transformers have been upgraded better and better, and their application widened as well. That is why a variety of transformers are available nowadays, including distribution transformers for electric energy transmission, industrial transformers used in the industrial production, dedicated transformers for special circumstances, as well as instrument transformers and voltage regulators. In addition, these transformers may also be classified by the number of phases, iron-core structure, voltage regulation mode, cooling medium, cooling type, quantity of windings, iron-core or winding material and so on. Transformers are classified and described by some attributes as follows:

1. By transformer capacity

The transformers are generally divided into small- and medium-capacity ones, high-capacity ones and ultra-high-capacity ones.

1) Small- and medium-capacity transformers

The small- and medium-capacity transformers with the voltage not more than 35kV, and the capacity within 5–6300kVA (5–500kVA for the small-capacity, and 630–6300kVA for the medium-capacity) are widely used, generally for power distribution, and produced by many manufactures.

2) High-capacity transformer

Its capacity is not more than 110kV, and the capacity is within 8000–63000kVA.

3) Ultra-high-capacity transformer

Its voltage is above 220kV, and the capacity is above 31500kVA.

2. By function of transformer

The transformers may be classified by usage of transformer into two major types:

1) Distribution transformer

It is a transformer used for electric energy transmission by means of converting the AC voltage and current of an electric power system into different voltages and currents of another electric power system.

2) Industrial transformer

It is a transformer dedicated for industrial production process, including the electric furnace transformer for power supply for electric furnaces, rectifier transformer used for rectifying device, mining transformer for electric drive and lighting in mines, explosion-proof transformer used in production environment with explosive hazards, moisture- and smoke-proof marine transformer used on ships, testing transformer for electrical insulation tests of electrical equipment and insulating materials, etc.

3. By number of phases

By number of phases, single-phase transformers and 3-phase transformers are involved, the former is generally used for single-phase loading, and the later for 3-phase loading.

4. By iron-core structure and material

In this category, transformers may be divided into the core-type, shell-type and rolled iron-core transformers. In a core-type transformer, the iron core is surrounded by the winding. One side of winding is provided only with inner core, and the other side with the iron core. At present, most manufacturers are engaged in production of core-type transformers. For the shell-type transformer, its winding is surrounded by iron core, which is at both sides of winding. Transformers of this type, featuring transport in small pieces and field assembly, are mainly used for small radio transformers and ultra-high-voltage distribution transformers. By iron-core material, transformers may be classified into the silicon-steel and iron-core ones and the amorphous alloy ones.

5. By voltage regulation mode

By voltage regulation mode, the non-excitation regulating transformer and the on-load regulating transformer are included. The former is the one which is equipped with non-excitation tap-changer and only enables voltage regulation with no excitation. The later is the transformer which is equipped with on-load tap-changer and only enables voltage regulation on load.

6. By cooling medium

By cooling medium, transformers may be divided into the oil-immersed transformer, dry-type transformer and gas insulated transformer. The oil-immersed transformer is the one with its iron core and winding immersed into insulating oil. The dry-type transformer is the one with its iron core and winding wrapped in the non-insulating oil, and transformers of this type may be divided into the impregnated insulation ones, resin-casting insulation ones and filament winding insulation ones. Nowadays, the oil-immersed and dry-type transformers are most frequently used.

7. By cooling type

By cooling type, oil-immersed self-cooled, oil-immersed air-cooled, forced oil-circulation air-cooled, forced oil-circulation water-cooled and transpiration-cooled transformers are included.

8. By quantity of windings

By quantity of windings, transformers may be classified into the two-winding transformer, three-winding transformer, autotransformer and split-type transformer.

The two-winding type, used frequently, consists of primary winding and secondary winding (also called HV winding and LV winding). The HV winding is marked with A, B and C at the head, and X, Y and Z at the tail; the LV winding is marked with a, b and c at the head, and x, y and z at the tail, and o stands for the neutral point.

The three-winding transformer, mostly used for high- and ultra-high-voltage transformers, employs windings at three voltages per phase. If the electric power system or consumer is powered at two voltages, or the hub substation is connected with electric power systems at several voltages, a set of three-winding transformer is recommended. The three windings refer to primary, secondary and tertiary windings (also called HV, MV and LV windings). For the three-winding transformer, the primary (HV) winding is marked with A, B and C at the head, and X, Y and Z at the tail; the secondary (MV) winding is marked with A_m, B_m and C_m at the head, and X_m, Y_m and Z_m at the tail; the tertiary (LV) winding is marked with a, b and c at the head, and x, y and z at the tail. The neutral points are marked with 0, 0_m and 0.

The autotransformer is the one having at least two windings with common part. For the autotransformer, its windings are interrelated electromagnetically and even on the circuit. Moreover, some windings are shared.

For the last one, its LV windings are split into two parts, which may run separately or simultaneously. If one generator is out of service due to failure, the other still runs normally. The impedance voltage between two parts of LV windings is the sum of impedance voltages of HV windings to two parts of LV windings.

8.1.2 Main parameters of a transformer

1. Rated capacity

Rated capacity refers to the nominal apparent power of a transformer winding. Specified in the nameplate of transformer, it is the product of the rated no-load voltage, rated current and corresponding phase factor. For the 3-phase transformer, its rated capacity (unit: kVA) is the product of the rated no-load line voltage and the rated line current. The rated capacity refers to the maximum capacity continuously output throughout the specified normal service life. The rated capacity of 3-phase transformer is given as follows:

$$S_e = \sqrt{3} U_e I_e \times 10^{-3} \tag{8.1}$$

Where: S_e——Rated capacity of transformer (kVA);

U_e——Rated voltage at the secondary side of transformer (V);

I_e——Rated current at the secondary side of transformer (A).

At present, the transformer capacity in China is determined as per R10 series and type spectrum, in other words, it is multiplied by a factor of 1.26 (i.e. approximate value of $\sqrt[10]{10}$). According to the *Technical Specifications and Requirements for Oil-immersed Distribution Transformers* (GB/T 6451), the capacity of oil-immersed non-excitation regulating transformer is rated as 30kVA, 50kVA, 63kVA, …, 12500kVA and 1600kVA, totaling 17 ratings.

2. Rated voltage

It refers to the voltage applied between line terminals of 3-phase transformer or induced at no load, and its unit is kV. The voltage levels of distribution transformers in China mainly include 6kV, 6.3kV, 10kV, 10.5kV and 11kV.

3. Short-circuit impedance (short-circuit voltage)

In a pair of windings, the equivalent series impedance Z between terminals of a winding can be $Z=R+jX$ (at rated frequency and reference temperature); in such case, terminals of the other winding is short-circuited, and other windings opened. In a 3-phase transformer, the secondary impedance is for single-phase winding.

In general, the impedance voltage (U_k) is represented by the percentage of rated voltage ratio (U_k%). The short-circuit impedance value of distribution transformer in China varies, with rated capacity, between 4% and 14%.

4. Transformer loss

The electric energy conversion efficiency of transformer is in inverse relationship with its loss, thus the loss is reduced by an increase in its efficiency. During operation of the transformer, most of electric energy is converted, and the remaining, consumed by itself, is called transformer loss. The transformer loss mainly consists of no-load loss and load loss, and the sum of them is the total loss.

5. No-load loss

Where the rated voltage at the rated frequency is applied to a winding terminal, other windings are open-circuit. Meanwhile, the active power is absorbed by the transformer. The no-load loss is given as follows:

$$P_0 = P_h + P_b + P_s = K_h f B_m^n V + K_e f^2 B_m^2 + P_s$$

Where:

P_0——No-load loss (kw);

P_h——Hysteresis loss;

P_s——Additional iron loss;

B_m——Maximum flux density, T;

f——Frequency (Hz);

n——Hysteresis coefficient;

V——Core volume (m^2);

K_h, K_c——Constant;

Most of no-load loss is from the iron core of transformer, so it is also called iron loss, including hysteresis loss, eddy current loss and additional loss. The iron loss is generated due to the flux in the iron core changing at AC frequency of power grid, and finally delivered as heat out of the transformer. The no-load loss is directly dependent on the property and thickness of iron-core material, the iron-core lamination form and its workmanship.

6. Load loss

It refers to the loss from windings when the primary and secondary windings are provided with current during operation of the transformer. Most of load loss in windings of the transformer is also called loss on copper, mainly including the loss from the conductor resistance when the windings are provided with load current as well as the additional loss on copper, both of which are finally delivered as heat out of the transformer. The load loss is mainly affected by load current and conductor resistance. The conductor resistance of winding is affected by temperature, so the transformer temperature has an impact on the load loss. The additional loss includes eddy current loss in the winding conductor, circular current loss in the parallel conductor of winding, additional loss in the iron core and clamps, additional loss of fuel tank, etc.

The load loss of transformer is given as follows:

$$P_k = P_\tau + P_s = I_{IN}^2 r_1 + I_{2N}^2 r_2 + P_s$$

Where:

P_r——Basic loss on copper;

P_s——Additional loss on copper;

r_1—Resistance of the primary winding in the transformer.

8.2 Development of energy-saving technology of distribution transformers in China

8.2.1 Evolution of transformer type

Before 1990s, the design of transformer in China was under centralized control, the government would fund the design and stipulate unified standards. Enterprises involved could use relevant drawings for free, and the designation of the same series was applicable across the APEC economy. Therefore, viewed from the development history of transformer energy-saving technology, our transformers have undergone the replacement of Sj, S7, S9, S11, S13, S15 and other series. This evolution indicates distribution transformers in China become more and more efficient with ever-decreasing loss.

Since the late 1940s, the distribution transformer manufacturers in China had introduced BS and US standards. From 1950s, they adopted standards of the former Soviet Union. Till 1964, *Distribution Transformer* (JB500-64), the first technical standard for distribution transformer in China, was issued. This standard is equivalent to Γ0CT401－41, and its product performance data is also based on it. The standard was abolished in the early 1970s, and major series included SJ, SJ1, SJ2, SJ3, SJ4, SJ5, SJL and SJL1. In the industry, the transformer series in such period are also collectively referred to as 1964-standard-compliant transformers.

This standard was revised by our departments concerned in 1971 and 1979, and the corresponding product performance standard is the *Basic Specifications and Technical Requirements for Three-phase Oil-immersed Distribution Transformers* (JB1300–1301 — 73) issued in 1973. The major series included S, S1, S2, S5, SL, SL1 and SL3, in which, SL, SL1 and SL3 are aluminum-coil products. In the industry, the transformer series in such period are also collectively referred to as 1973-standard-compliant transformers.

The *Distribution Transformer* (GB1094.1) and *Technical Specifications and Requirements for Three-phase Oil-immersed Distribution Transformers* (GB6451.1–2) were revised again in 1985 and in 1986. The GB1094.1–5—1985 is equivalent to the IEC76.1–5—1976. The GB6451.1–2—1986 is prepared in accordance with loss values specified in DIN42500, DIN42503, DIN42511 and other standards of Siemens Corporation, and these loss values stated are greatly lowered. The major series include SL7, S7, S8 and SL8.

China launched three activities aiming at eliminating high-energy-consumption transformers from 1984 to 1998. In 1984, the original Ministry of Machinery Industry of China along with associated ministries and commissions issued the *Catalog for High-energy-consumption, Mechanical, and Electrical Products to Be Eliminated in the Machinery Industry of China* to forcedly replace SJ, SJL, S, SZ, SL and other series of transformers by S7 series. With the promotion of energy-saving technology, the annual power consumption per kVA is reduced by 15kWh. In 1998, China issued the *Catalog for Mechanical and Electronic Products to Be Eliminated in the Seventeenth Installment in the Machinery Industry of China* to officially eliminate transformers of SL7 and S7 series. SL7 series are aluminum-coil transformers, and S7 series are copper-coil transformers based on SL 7 series. The loss indices of such two series are similar. With continuous technological progress and enhancement in reliability, SL7 and S7 series have some shortcomings. Especially the average no-load loss and load loss are respectively 11% and 28% higher, and the annual consumption is about 100MkWh higher than that of S9. Compared with S7, the annual average operating cost of S9 is 17.8% lower.

With constantly deepening and improvement of our market economic system, continuous growth of private enterprises and foreign-funded enterprises energizes our transformer industry, and these enterprises not only attach importance to market development trend and internal management, but also focus on development and application of new energy-saving technologies. With self-dependent innovation, some enterprises make sustained efforts to develop more efficient transformers with less loss, so as to make the transformer efficiency approach the international level in a short period. After all-round promotion of S9, some enterprises soon launched S10, S11 and other series of energy-saving distribution transformers.

In 2006, China issued and implemented *The Minimum Allowable Values of Energy Efficiency and the Evaluating Values of Energy Conservation for Three-phase Distribution Transformers* (GB20052-2006), which specifies three indices concerning energy efficiency, namely the minimum allowable values of energy efficiency (MAVEE), the target minimum allowable value of energy efficiency and the evaluating values of energy conservation. The MAVEE is prepared for implementation of elimination system for high energy-consumption products, the target MAVEE for implementation of advancing energy efficiency standards, and the evaluating values of energy conservation for implementation of certification system for energy-saving products. Our issuance and implementation of energy efficiency standards again motivate manufacturers to develop highly efficient distribution transformers, and to launch the three-dimensional rolled iron-core distribution transformer (S13) and amorphous-alloy and iron-core distribution transformer (S15), continuously lowering the no-load loss and load loss of distribution transformer.

On June 9, 2013, China issued the newly revised *Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Three-phase Distribution Transformers* (GB 20052-2013), which specifies the energy efficiency grades of distribution transformers. The no-load loss values for S13 and S15 are incorporated as the grade-2 energy efficiency index; the load loss for S13 oil-immersed transformer lowered by 20% and the load loss for amorphous transformer lowered by 10% are considered as the grade-1 energy efficiency index, further lowering the no-load loss and load loss of distribution transformer.

8.2.2 Variation trend of distribution transformer loss

With the evolution of distribution transformer type, distribution transformers in China become more and more efficient with ever-decreasing loss. Figure 8.1 and Figure 8.2 show that the no-load loss and load loss of distribution transformers are continuously decreasing with preparation and revision of relevant standards.

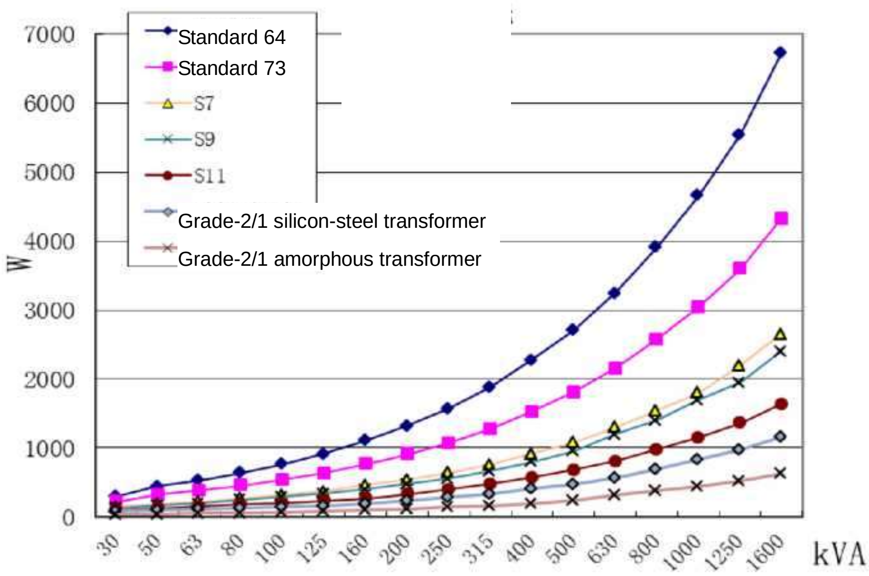


Figure 8.1 No-load loss of various series of distribution transformers

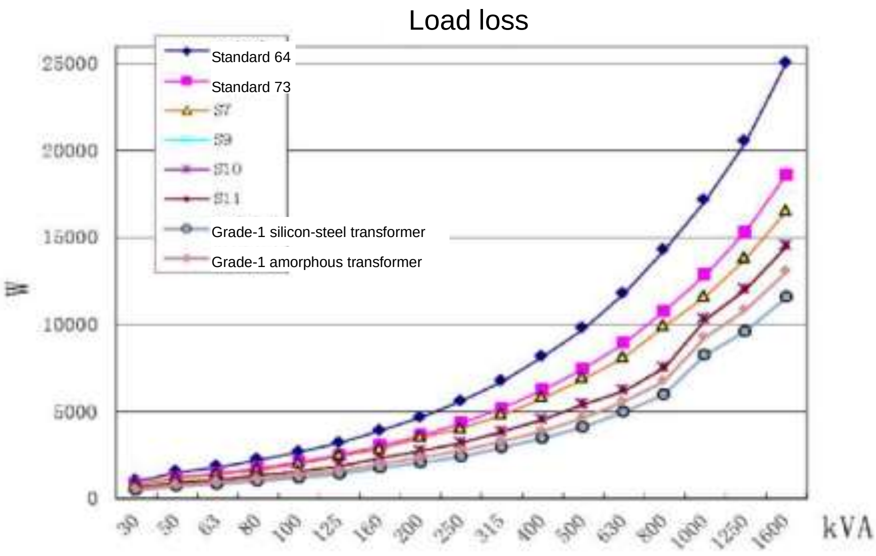


Figure 8.2 Load loss of various series of distribution transformers

Chapter 9 Production and Market Analysis of Distribution Transformers

9.1 Overview of China's electric power industry

9.1.1 Power supply in China

As the foremost fundamental energy industry in the development of China's economy, electric power industry is not only the vital foundation to national prosperity and the people's livelihood, but also the priority in the economic development strategy. Electric power has been playing an important role in the development of economy and society. It has a crucial bearing on major strategic issues regarding our economic security beyond ensuring people's daily life and stable social climate. China's demand on electric power is increasing as its economy grows and the expansion of power sales market in turn drives generation of electric power.

1) Power supply

Along with both rapid and slow development of its economy, China once saw power shortage and surplus on large scale. Power supply and demand was balanced in 1950s. However, the APEC economy had suffered a long-term power shortage since 1960s, and the gap even exceeded 20% of total generating capacity by 1986. The power supply and demand was balanced again in 1997, and there was a 10% surplus in 1999. From the second half of 2002, regional power shortage began to occur, and spread to most grids throughout China rapidly within two years. By 2004, 26 provinces (municipalities and autonomous regions) in China had experienced power shortage.

To deal with power shortages, governments took various measures in terms of power supply expansion and power consumption reduction, such as increasing power investment, cancelling preferential electrovalency for big power consumers, restricting fast expansion of some high energy-consumption projects, etc. These short-term measures relieved the tension in power supply effectively, but seasonal power shortages still lasted until 2007.

To safeguard China's economic development, China's government increased the investments in construction of electrical infrastructures and the capacity of power supply was improved in a continuous manner.

2) Installed capacity of generator sets

The installed capacity of generators in China was 1,062.53GW in 2011, increased by 10.2% over 2010. From 2005 to 2011, the installed capacity of generator sets enjoyed an increase of 105.3% YoY. In 2011, the capacity of hydropower generators was 232.98GW, increased by 98.5% YoY; the total installed capacity of thermal power plants was 768.34GW, increased by 96.3% YoY, and nuclear power plants 12.57GW, increased by 83.8.2% YoY. To boost the supply of clean energies, wind-power generator units tended to develop rapidly after 2008. By 2011, the installed capacity of wind-power generator units in China had reached 46.23GW, with the annual growth rate being 83.7% by average.

3) Power generation

In 2011, the national generating capacity reached 4,700.1TWh, increased by 89.9% over 2005. The generating capacity of hydropower was 694TWh, increased by 73.1% YoY, which mainly benefited from successive going into operation and power generation of large hydropower units such as the Three Gorges; the generating capacity of thermal power was 3,843.9TWh, increased by 90.5% YoY. With steady increase, the annual generating capacity of nuclear power was 87.2TWh, increased by 66.7% YoY.

9.1.2 China's power transmission and distribution industry

In 2011, China had 474,688km electric transmission lines at or above 220kV, among which 1,000kV lines were 1,006km, 750kV lines were 3,334km, 750kV lines were 10,005km, 500kV lines were 140,263km, 330kV lines were 22,267km, and 220kV lines were 297,813km. Figure 9.1 shows the length of transmission lines at different voltage levels.

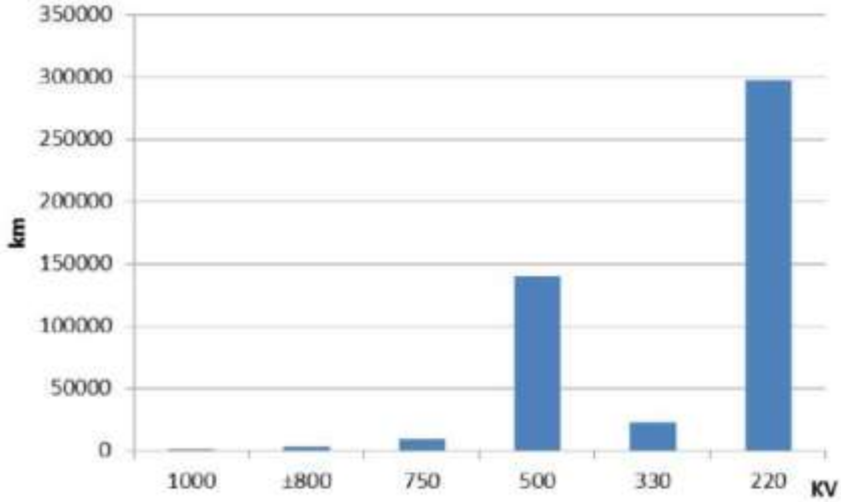


Figure 9.1 Length of transmission lines at different voltage levels

As the generating capacity increases, the loss also increases during power transmission and distribution. The power transmission and distribution loss was 93.67TWh in 2000, and 256.82TWh in 2010, increased by 174.2% YoY. However, the percentage of transmission and distribution loss in the generating capacity tended to decrease in recent years, decreased from 7.39% in 1995 to 6.12% in 2010. This shows the energy-saving effect is very obvious after energy-saving measures are taken by power supply sectors. Figure 9.2 shows the change in transmission and distribution loss and its percentage in generating capacity from 2000 to 2010.

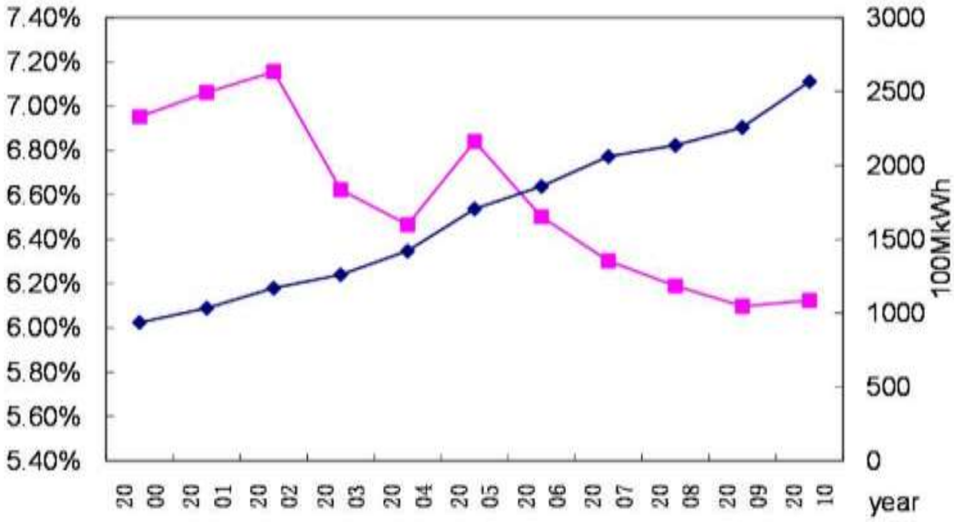


Figure 9.2 Transmission and distribution loss and its percentage in generating capacity

9.2 China's distribution transformer industry

From the perspective of economic scale of enterprises, China's distribution transformer production enterprises as a whole are characterized by small number of large-sized enterprises and large number of small- and medium-sized enterprises, as shown in Figure 9.3. With regard to the number of enterprises, currently 95.5% distribution transformer production enterprises in China are small- and medium-sized ones with annual turnover less than 300 million yuan, and small-sized enterprises with annual turnover less than 10 million yuan account for 62.5% of all these enterprises. The number of large leading enterprises with annual turnover more than 1.5 billion yuan is only 10.

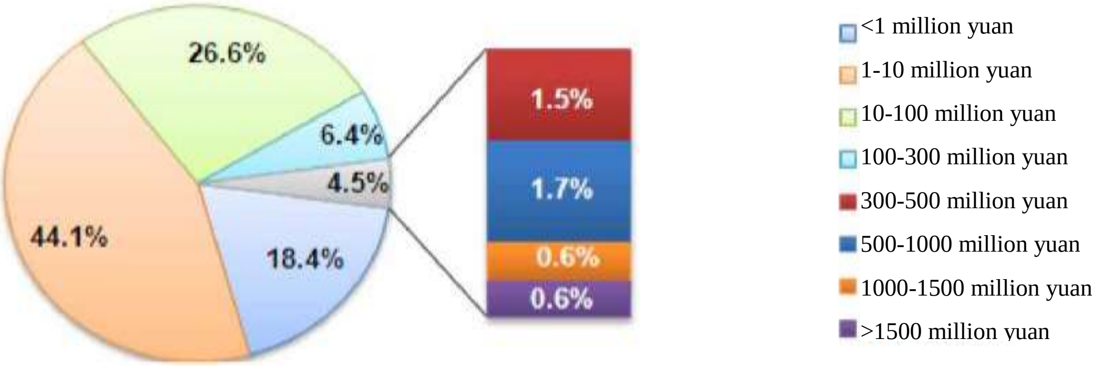


Figure 9.3 Distribution of economic scale of China's distribution transformer production enterprises

The distribution of number of China's distribution transformer production enterprises in different provinces (cities) is shown in Figure 9.4. It can be seen that China's distribution transformer production enterprises are centralized in Liaoning, Jiangsu, Zhejiang, Shandong, Guangdong, Hebei, Shanghai. The total number of distribution transformer production enterprises in these seven provinces (cities) reaches 1,119, accounting for 65.6% of total number.

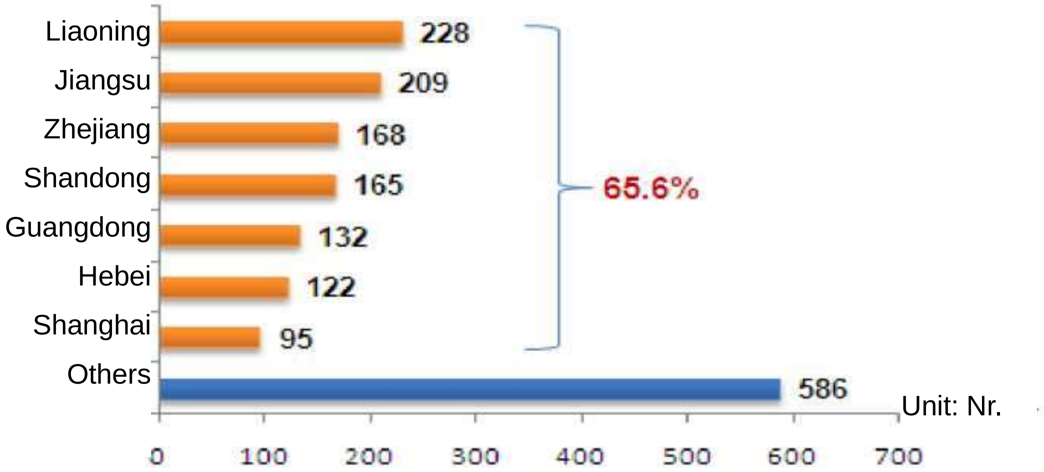


Figure 9.4 Distribution of number of China's distribution transformer production enterprises in different provinces (cities)

From 2006 to 2009, annual output of distribution transformers in China increased from 639,000 sets/year in 2006 to 878,000 sets/year in 2009, with an average annual growth rate of 11.2% in these four years; the total capacity increased from 268,960,000 KVA/year in 2006 to 372,720,000 KVA/year in 2009, with an average annual growth rate of 11.5% in these four years.

9.2.1 Overview of distribution transformer market in China

The sales volume of distribution transformers was 633,000 sets in 2006 in China's markets, and increased to approximate 861,000 sets in 2009, with an average growth rate of approximate 10.8%; the total sales capacity was 266,160,000KVA in 2006 in China's markets, and increased to 363,660,000KVA in 2009, with an average growth rate of 10.9%. From 2006 to 2009, production of distribution transformers in China was developed at rapid speed as a whole. Both total number and total capacity reached an annual growth rate of about 10%, and total salves volume in China's markets also reached a growth rate of about 10%.

From 2006 to 2009, in terms of sales volume, the ratio of oil-immersed distribution transformers (ODTs) to dry-type distribution transformers (DDTs) was kept at about 4:1. The ratio of DDTs sees a slight increase in recent years, but the increase is not significant. Figure 9.5 shows the proportion of sales volume of ODTs and DDTs in China's markets in 2006-2012.

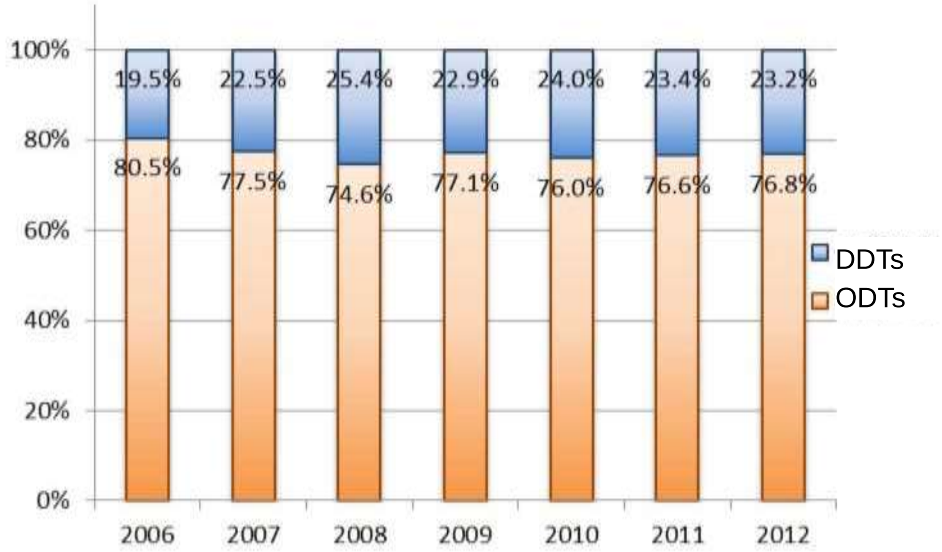


Figure 9.5 Comparison between sales volume of ODTs and DDTs in China's markets in 2006-2012 (by set number)

See Figure 9.6 for the production proportion of distribution transformers at different voltage levels in Chinese markets in 2012. The 10KV distribution transformers had the largest volume sales, accounting for 88.6% of output in China. They were followed by 35KV distribution transformers which accounted for 7.1% in Chinese markets. However, 6KV distribution transformers had small market shares, only about 3.4%.

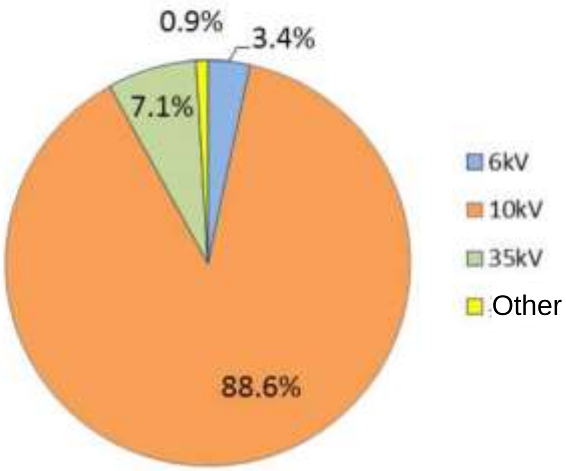


Figure 9.6 Production proportion of distribution transformers at different voltage levels in Chinese markets in 2012 (by set number)

Among the 861,000 distribution transformers sold in Chinese markets in 2009, there were about 15,000 on-load regulating distribution transformers, which accounted for about 1.7%. Hence, non-excitation regulating distribution transformers accounted for 98.3% and are major products in markets, as shown in Figure 9.7.

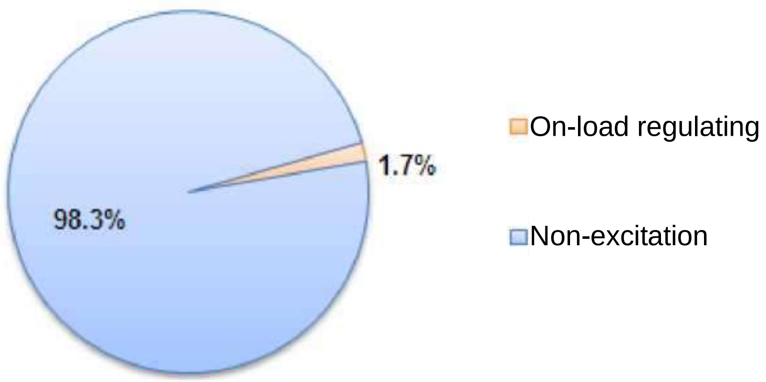


Figure 9.7 Proportion of distribution transformers of different tap changing sold in China

In recent years, the proportion of energy-efficient distribution transformers tends to increase in Chinese markets. See Figure 9.8 for sales proportion of distribution transformers with different loss in Chinese market in 2008 and 2012. S9 series ODTs still had a market share of 25.7% in 2008, but S9 transformers disappeared in markets in 2012. S13 and S15 energy-efficient distribution transformers appeared on markets gradually. For ODTs, S13 series increased from 0% in 2008 to 1.91%, and S15 increased from 2.4% in 2008 to 9.98% in 2012. The original market share of S9 was basically replaced by S11 series transformers.

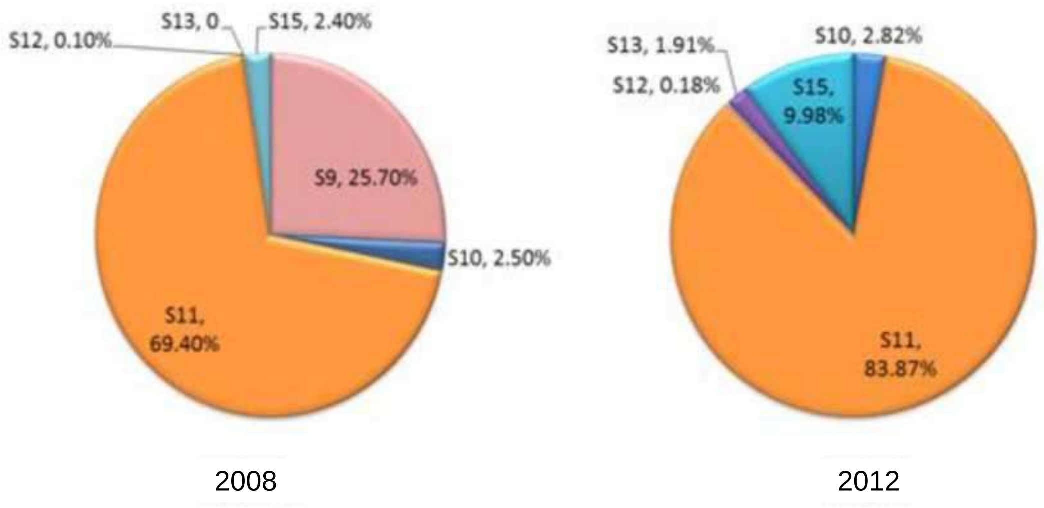


Figure 9.8 Sales proportion of distribution transformers with different loss in Chinese market

9.2.2 Actual situation on load rate for distribution transformer operation

1. Load rate of substation transformer

We surveyed 183 transformer substations, and selected 308 transformers randomly. The proportion of transformers of different load rate ranges is shown in Figure 9.9. Among these transformers, 105 ones (accounting for 34.1% of all transformers) had load rate below 50%, 47 ones (15.3%) had load rate between 50% and 60% (including 50% and 60%), 38 ones (12.3%) had load rate between 60% and 70%, 42 ones (13.6%) had load rate between 70% and 80% (including 70%), 38 ones (12.3%) had load rate between 80% and 90% (including 80%), 25 ones (8.1%) had load rate between 90% and 100% (including 90%), and 13 ones (4.2%) had load rate at or above 100%. Transformers give the peak efficiency when the load rate is 50-60%, but transformers of such load rate range in fact are not obviously more than transformers of other load rate ranges.

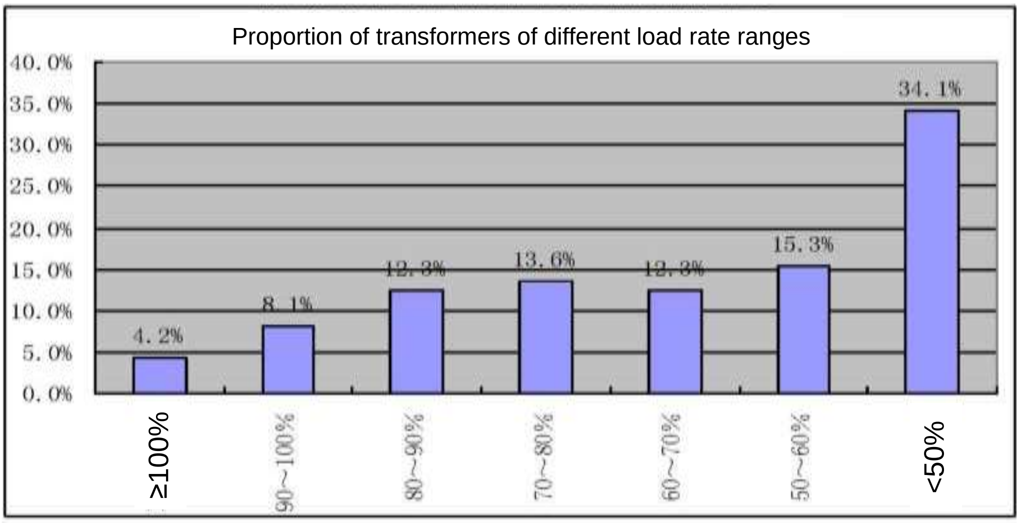


Figure 9.9 Proportion of transformers of different load rate ranges

Throughout a year, the maximum load rate occurs in summer in South China because of the use of air conditioners, and in winter in North China because heating is required. Moreover, the load is large at 18-21 p.m. in both South and North China. Some transformer substations will approach to or even exceed full load during the Spring Festival and in case of failures of other substations.

2. Load rate of transformers for industrial customers

The power consumption of large manufacturing enterprises is large. For some special industries, 50%-60% load rate is required, and the design is based on such load rate. However, as time goes on, the load rate is increased to up to about 80% because the production scales of some enterprises are expanded day by day after technical transformation.

9.2.3 Production, import and export of distribution transformers

1. Output of 10kV distribution transformers in 2006-2012

In 2006-2012, 10kV distribution transformers tended to increase steadily as a whole in China. Their change in output is shown in Figure 9.10. With industrial and urban construction in China, power transmission and distribution grids obtain long-term development. With the demand increase of distribution transformers, their output increased at an average rate of 11.3%. In 2012, the output of 10kV distribution transformers was about 1,210,000, with the growth rate being 12.21%. The total number of DDTs was less than ODTs. The total output of DDTs was about 933,000 in 2012, but their average growth rate, 14.96%, was a slightly higher than ODTs. The total output of ODTs was about 281,000 in 2012, with an average growth rate of 10.53%.

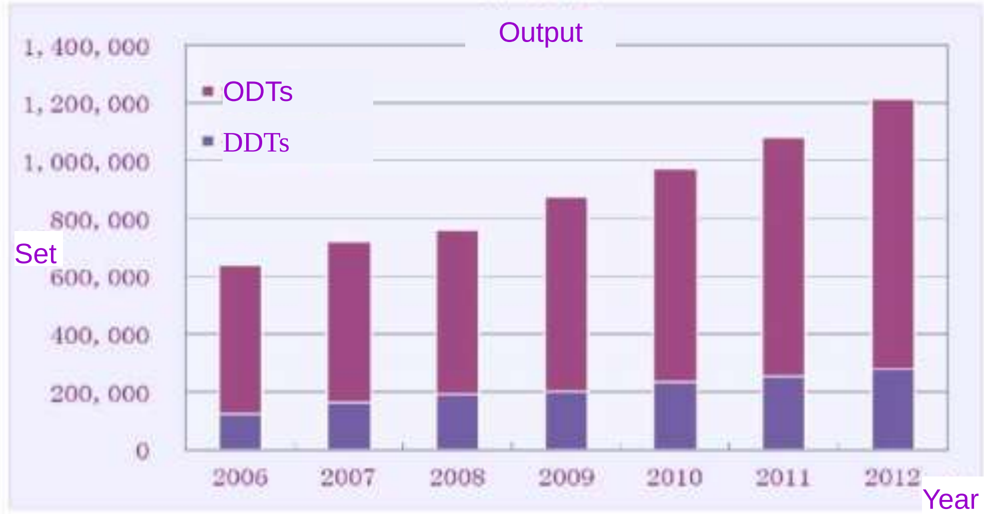


Figure 9.10 Change in output of distribution transformers in China

2. Export volume of 10KV distribution transformers in 2006-2012

Due to the price factor, distribution transformers used in China are generally made in China except some special-purpose ones. For reasons of quality and technical levels, China exported few distribution transformers in the past. However, with the improvement in transformer production technology levels in recent years in China, the export of distribution transformers is changed fundamentally, especially after innovative technologies of proprietary intellectual property rights emerge. According the survey data, the number of exported distribution transformers tended to increase in China in 2006-2012. And the annual average export growth rate reached about 26.3%, with growth rate of ODTs and DDTs being 21.4% and 61.7% respectively, which are shown in Figure 9.11.

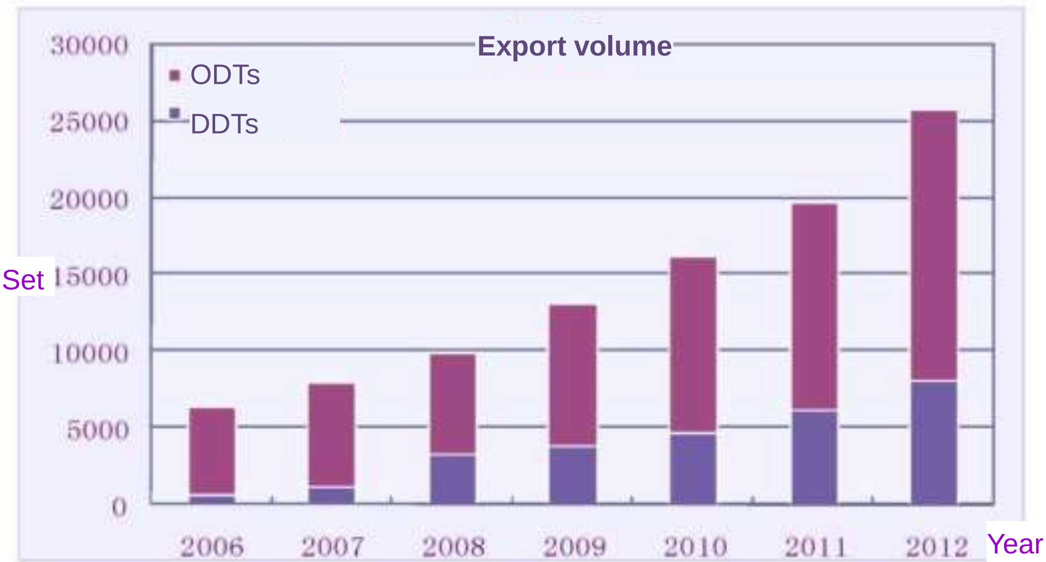


Figure 9.11 Change in export volume of distribution transformers in China

Chapter 10 Engineering Analysis for Distribution Transformer Energy Efficiency Standards

10.1 Applicable national and industrial standards on distribution transformers

In China, *Power Transformers—Part 1: General* (GB 1094.1) and *Specification and Technical Requirements for Oil-immersed Power Transformers* (GB/T6451) are related to the quality of 3-phase oil-immersed distribution transformers and must be referred to accordingly; the standard related to terminology is *Electrotechnical Terminology—Transformer, Instrument Transformer, Voltage Regulator and Reactor* (GB/T2900.15).

10.1.1 Power Transformers - Part 1: General (GB 10941.1)

Power Transformers - Part 1: General (GB 10941.1-1996) is the most basic standard for distribution transformer manufacturing and also a mandatory national standard which provides service conditions, related terminology, ratings, technical requirements for transformers with tap windings, as well as connection and connection symbol, nameplate, test and other requirements for 3-phase transformers. A qualified transformer shall meet requirements of this standard at first. As the product quality is emphasized in energy efficiency standard, the standard is referenced in Chapter 3 (Terms and Definitions) and Section 4.1 (General Requirements) of *Distribution Transformer Energy Efficiency Standard*.

10.1.2 Specification and Technical Requirements for Oil-immersed Power Transformer (GB/T6451-2008)

Specification and Technical Requirements for Oil-immersed Power Transformer (GB/T6451-2008) provides specific technical parameters and requirements for 3-phase oil-immersed distribution transformer, including performance parameters, technical requirements and test items. As it is also a technical standard for the product quality of distribution transformer, the standard is referenced in Section 4.1 (General Requirements) of *Distribution Transformer Energy Efficiency Standard*.

10.1.3 Electrotechnical Terminology - Transformer, Instrument Transformer, Voltage Regulator and Reactor (GB/T2900.15)

*Electrotechnical Terminology - Transformer, Instrument Transformer, Voltage Regulator and Reactor (*GB/T2900.15*)* is the standard for terminology in transformer industry. Many terms used in *Distribution Transformer Energy Efficiency Standard* are all defined in GB/T2900.15, such as rated capacity, rated voltage, load loss, no-load loss, and short circuit impedance. Therefore, the standard is referenced directly in *Distribution Transformer Energy Efficiency Standard* so that terms need not to be defined again.

10.1.4 Economical Operation for Power Transformers (GB/T13462)

Economical Operation for Power Transformers (GB/T13462) is the energy-saving standard established for improving efficiency during transformer operation. As power transformer is widely used in all fields from power generation, supply, distribution to utilization, the standard is applicable for economical operation management of power transformers used by enterprises engaged in power generation, supply, and utilization and power transformer configuration in construction and reconstruction. The standard provides methods for selecting capacity and number of transformers reasonably, optimizing and selecting the economical operation mode with the lowest integrated power loss, adjusting transformer load reasonably, and operating in the economic operation range with the lowest integrated power loss.

10.1.5 Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Three-phase Distribution Transformers (GB20052)

The Minimum Allowable Values of Energy Efficiency and the Evaluating Values of Energy Conservation for Three-phase Distribution Transformers (GB20052-2006) is the first edition of *Distribution Transformer Energy*

Efficiency Standard, and *Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Three-phase Distribution Transformers* (GB20052-2013) is the revised second edition of *Distribution Transformer Energy Efficiency Standard*. This is a mandatory standard with equal effect of technical regulations in China. According to Article 16 of *Energy Conservation Law of the People's Republic of China*, if energy efficiency index of the distribution transformer cannot meet allowable values specified in GB20052, the distribution transformer is not allowed to be manufactured, imported and sold in China.

Energy efficiency grades and evaluating values of energy conservation are also specified in GB20052. Energy efficiency grades are divided into 3 grades. The loss of grade-1 is the lowest and the energy efficiency is the highest; grade-2 can be regarded as an advanced level in China; grade-3 is a qualified level and also a mandatory index. At the same time, GB20052 is also the basis for the implementation of energy saving policies such as high energy consumption distribution transformer product selection, energy-saving product certification and energy efficiency label.

10.2 Main content of energy efficiency standard for distribution transformers in China

10.2.1 Energy efficiency parameters of energy efficiency standard for distribution transformers in China

Different parameters are adopted to evaluate the energy efficiency of transformers in different APEC economies. Some APEC economies such as Australia and America adopt efficiency (%) as the parameter to evaluate the energy efficiency, some EU countries adopt no-load loss (W) and load loss (W), and Japan adopts total loss (W) as the parameter.

IEC standard is generally adopted as the product standard for transformers in China. As a result, no-load loss and load loss are usually used for evaluating energy efficiency in the transformer industry in China. During the development of transformer technology in China, the energy efficiency performance of transformers has also gone through several processes of S7, S9, S11, S13, and S15. Therefore, on-load loss and load loss are still adopted for evaluating energy efficiency in *Distribution Transformer Energy Efficiency Standard*. Considering the development trend of energy-saving technology, reducing the on-load loss will be an important measure for transformer energy-saving in the future. The adopting of no-load loss and load loss is beneficial for guiding enterprises to improve energy efficiency grade when standards are revised in the future.

In recent years, electricity consumption of industry, commerce, and residents is increasing rapidly and that of other industries is also keep the trend of increasing. The maximum power load of all major power grids in China continues to rise at the increase rate up to 22.5%, which lead to the increasing of distribution transformer load. This is different from the low distribution transformer load in developed APEC economies such as America and Canada. As a result, load loss shall also be controlled strictly in China besides reducing no-load loss. If not, once distribution transformers with high load loss enter the market, huge electric energy will be consumed in the process of electric power transmission and cause huge loss of electric power.

In addition, the actual service load of distribution transformers is changing constantly with different rules in different industries, which make it impossible to determine a load applicable for all distribution transformers. Adopting no-load loss and load loss to evaluate energy efficiency of distribution transformers can avoid the problem of the actual service load of transformers.

Chinese energy efficiency standard defines energy utilization characteristics of products to set the market access threshold or certification index for energy saving. Whether products operate under economical conditions is defined by the economical operation standard. Energy efficiency standard and economical operation standard are all energy-saving standards but defined from different angles, with different nature and purposes. Therefore, economical operation index of products are not defined in energy efficiency standard.

10.2.2 Energy efficiency grade index for distribution transformers

At present, S7 distribution transformers have already been eliminated by the market in China. According to GB20052-2006, S9 distribution transformers shall also withdraw from the market on July 1, 2010 while the market scale of S11 and SC10 distribution transformers has become predominant. As a result, the minimum allowable value of energy efficiency for oil-immersed distribution transformer is based on performance index of S11 and that of dry-type distribution transformer is based on performance index of SC10; the energy efficiency index of grade-2 oil immersed distribution transformer are no-load loss and load loss index of silicon-steel triangle three dimensional rolled iron-core (S13) and amorphous alloy iron-core (S15) and that of Grade-2 dry-type are no-load loss and load loss index of silicon-steel SC13 and SC15. No-load loss of a grade-1 oil immersed & silicon steel distribution transformer is the same with that of a grade-2 oil immersed & silicon steel distribution transformer but the load loss is 20% lowered than that of S13; no-load loss of a grade-1 oil-immersed & amorphous distribution transformer is the same with that of a grade-2 oil immersed & amorphous distribution transformer but the load loss is 10% lowered than that of S15. Efficiency of a grade-1 dry-type & silicon-steel distribution transformer is based on the no-load loss of SC13, but the load loss is 10% lower than that of SC13; energy efficiency of a grade-1 dry-type & amorphous distribution transformer is based on the no-load loss of SC15, but the load loss is 5% lower than that of SC15. Table 10.1 shows the relationship between energy efficiency grades and transformer models.

Table 10.1 Relationship between energy efficiency grades and transformer models

Energy efficiency grade-3		Energy efficiency grade-2				Energy efficiency grade-1			
Oil-immersed	Dry-type	Oil-immersed		Dry-type		Oil-immersed		Dry-type	
S11	SC10	Silicon-steel	Amorphous	Silicon-steel	Amorphous	Silicon-steel	Amorphous	Silicon-steel	Amorphous
		S13	S15	SC13	SC15	S13 20% lower load	S15 10% lower load	SC13 10% lower load	SC15 5% lower load

10.2.3 Comparison of distribution transformer no-load loss and load loss in China with EU standards

Figure 10.1 shows the comparison of new distribution transformer energy efficiency standard with EU energy efficiency values. It can be seen from the figure that the no-load loss is divided into 5 grades of E0, D0, C0, B0 and A0 in EU, among which the no-load loss of A0 is the lowest. The grade-3 energy efficiency in China is basically the same with C0 in EU; no-load loss of grade-1 and grade-2 silicon-steel transformer is basically the same with A0 in EU; no-load loss of grade-1 and grade-2 amorphous transformer is much lower than A0 in EU.

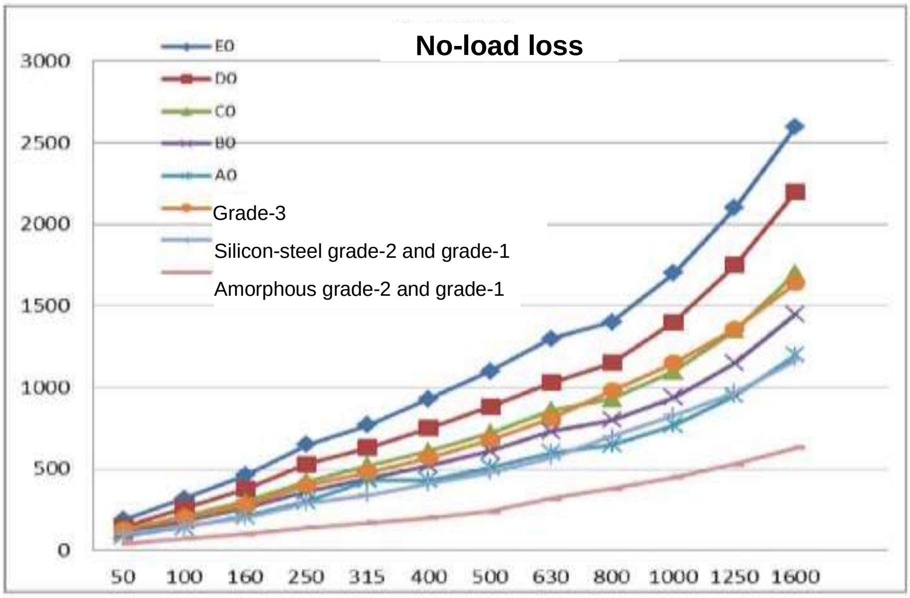


Figure 10.1 Comparison of distribution transformer no-load loss in China with EU standards

Figure 10.2 shows the comparison of new distribution transformer load loss of different energy efficiency grades with that of EU. It can be seen from the figure that the load loss is divided into 4 grades of DK, CK, BK, and AK in EU, among which the load loss of AK is the lowest. The grade-3 and grade-2 load loss in China is basically the same with CK in EU; load loss of grade-1 amorphous transformer is basically the same with BK in EU; load loss of grade-1 silicon-steel transformer is basically the same with AK in EU.

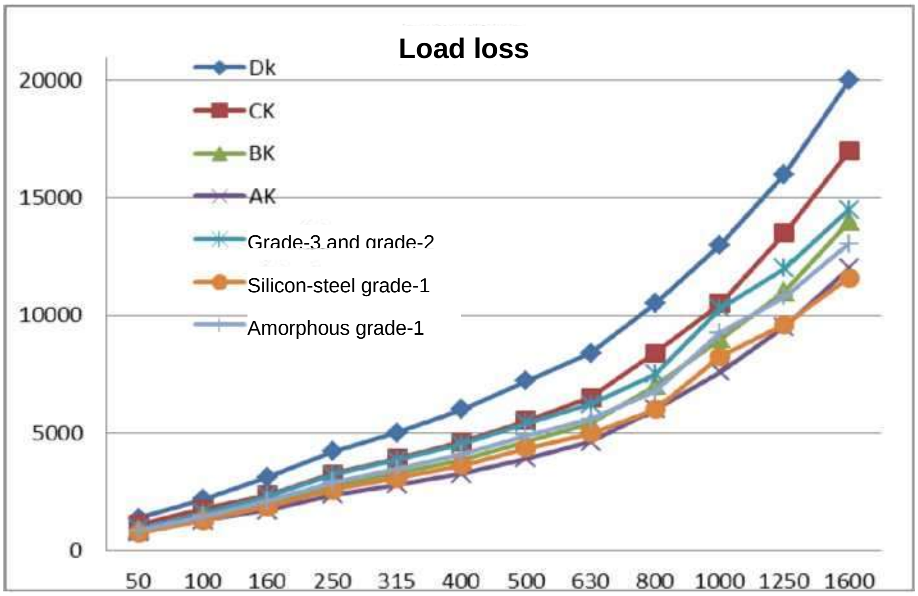


Figure 10.2 Comparison of distribution transformer load loss in China with EU standards

Chapter 11 Analysis of Life Cycle Costs

Purchasing energy-efficient distribution transformers affects a customer in two aspects: reducing the operation cost and increasing the purchase cost, which are closely related with the economic benefits of the customer. Generally, energy-saving products are manufactured with higher cost due to new processes, technologies and material adopted. Can electrovalency converted from energy saved during operation make up for the increased manufacture cost? Can an energy-efficient transformer bring economic benefits to the customer? These questions are answered through the analysis of life cycle cost of the product.

There are some worries in the China’s transformer industry concerning the reduction of transformer loss. Given that the severe competition in the industry focuses on price and reducing loss means increasing cost, manufacturers are careful to increase the cost. The goal of analyzing the life cycle cost and payback period in this chapter, therefore, is to comprehensively demonstrate the scenarios for operations of transformers of different types and energy efficiency grades and analyze the effects of CECP-certified products on customer’s economic benefits.

11.1 Calculation and analysis method of life cycle cost and payback period

11.1.1 Life cycle of a product

Life cycle cost (LCC) of a product refers to the fund consumed due to operation of the product within a given period. The fund includes all cost rising from purchasing, installation, and operation of the equipment till the end of the period and is dependent upon many factors.

Three options are available for a customer to purchase a transformer: investing more fund in purchasing an energy-efficient transformer, investing less fund in purchasing a common transformer, or not purchasing a transformer. When opting to purchase a common transformer or not to purchase a transformer, a customer saves some money which can be deposited into a bank or put into the stock market or invested in other profitable businesses and will in whichever way increase in value. Given the time value of money, the money of the same par value at the time of purchasing a transformer is different from one or a couple of years later, which means that less money is to be spent in the future than what is spent now in terms of nominal value. Therefore, the discount rate shall be considered for expenses during operation. In other words, the money to be spent for each year in the future must be converted to its present value.

According to the definition of LCC, the LCC analysis of a common transformer involves two parts: purchase cost (PC) and operation cost (OC), of which the discount rate shall be calculated for the latter. The LCC is calculated in the following equation:

$$LCC = PC + \sum_{t=1}^{N} \frac{OC_t}{(1+r)^t} \tag{11.1}$$

Where:

LCC - life cycle cost;

PC - purchase cost of the transformer;

OC_t - operation cost of the t^{th} year;

R - discount rate;

t=1, 2, 3, ……N;

N - number of years in the statistics.

However, a transformer is a special product whose materials contain much copper, silicon steel, and steel with high residual values when the transformer is scrapped. The residual values should be considered for calculating the LCC and payback period of a transformer. Specifically, these values should be deducted from the original life cycle cost. As a result, the preceding equation is changed into:

$$LCC = PC + \sum_{t=1}^{N} \frac{OC_t}{(1+r)^t} - V_C \qquad (11.2)$$

Where:

V_c - residual value of the transformer.

The LCC is subject to “yuan”, the unit for RMB of Chinese currency. A lower LCC is preferred, because it indicates that the transformer is cost-effective. A high LCC indicates that the transformer is not cost-effective, because the overall cost will increase after being purchased.

11.1.2 Payback period

Payback period (PAY) is the time required for counteracting the excessive cost on purchasing an energy-efficient transformer by lowering the operation cost. It is an important indicator for measuring the economic effect of energy-saving. The shorter the payback period, the better the economic effect, and vice versa. The payback period can be calculated in the following the equation:

$$\Delta PC + \sum_{t=1}^{PAY} \Delta OC_t = 0 \qquad (11.3)$$

Normally, the payback period can be calculated from the time value between two consecutive years, i.e. calculating with the end or beginning of each year as the clearing date. Assuming the operation cost as a constant, we can simplify the equation into:

$$PAY = -\frac{\Delta PC}{\Delta OC} \qquad (11.4)$$

Where:

PAY - payback period

ΔPC - difference in the purchase cost of the transformer

ΔOC - difference in annual operation cost

Since a distribution transformer has a long service life, its payback period is longer than other products. The life expectancy can be decades long if no capacity expansion is required. This means that the energy saved will be the economic benefit if the difference in the initial investment is recovered.

11.1.3 Analysis program

On account of various data involved in the life cycle cost analysis of distribution transformers, a computer must be used to carry out the analysis and calculation to achieve efficient analysis, for which we have written an application program. The purpose of the analysis is to compare the economic efficiency of distribution transformers of different grades under the same operating condition. To facilitate comparison, we need to select a reference line. Here, we select the minimum allowable value of energy efficiency (S9) in the energy efficiency standard for distribution transformers (GB20052-2006) as the reference line and compare the service life of Grade-3, 2 and 1 distribution transformers in the revised standard with the transformer in question.

Table 11.1 Data input sub-area of the life cycle analysis software

	A	B	C	D	E	F	G	H	
1		Input sub-area of analysis data							
2	Type	Dry-type	Capacity	630/4.0					
3	Voltage level	10 KV							
4	Winding connection	YynO							
5	Thermal class for electric insulation of a dry-type transformer		F(120℃)				Before subsidy		
6	Load rate	53%							
7	Operating	No-load	364	d	8736	h/y			
8	time	Load	300	d	7200	h/y			
9	Program-based computing for price								

	A	B	C	D	E	F	G	H	
10	Price	SC9	SC10	SC11	SC12	SC13	SC15		
11								Yuan	
12	Service life		28	Year(s)					
13	Price of copper scrap	55	Price of steel scrap	3	yuan\kg				
14	Current price of electrovalency		0.6	yuan/kWh					
15	Annual growth rate of electrovalency		3.0%	%					
16	Cash discount rate		3.0%	%					
17									

Using EXCEL as the computing tool, we divide the EXCEL worksheet into two sections. The first section is for data input and conversion, and it is further divided into the input sub-area and data conversion sub-area. In the input sub-area, input the no-load operating time, load operating time, load rate, voltage level, winding mode, capacity, and service life of a transformer and current electrovalency, annual growth rate of electrovalency, cash discount rate, etc. Table 4.1 shows the interface for the data input sub-area.

The analysis software can analyze only the transformers specified in the national standard *Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Three-phase Distribution Transformers*. Consequently, capacity values within the specified range shall be input in the prompt bar for the minimum and maximum values next to the input bar for capacity. Besides, the input box for pre- and post-subsidies is available for the ongoing subsidy program for energy-efficient distribution transformers in China. By clicking the program, the life cycle costs with and without the subsidy are calculated.

After all the preceding data is input, the reference price, residual value, no-load loss, load loss, total loss, and power consumption of transformers of various energy efficiency grades and of various classes will be automatically displayed in the data conversion sub-area and imported into the analysis program for life cycle cost and payback period.

The second section is for computing results. It displays the life cycle cost and payback period for energy-saving investment of transformers of various grades after relevant data is input in the data input section. Two methods are available for comparing the payback period of energy-saving investment: with S9 (an outdated product) and with Grade-3 energy efficiency (minimum allowable value of energy efficiency).Meanwhile, a histogram is displayed below this section for the life cycle cost of and electrovalency saved by transformers of different energy efficiency grades.

11.2 Setting of basic parameters for analysis

Before analyzing, we need to set a reference value for all parameters affecting the life cycle cost.

11.2.1 Load operating time and load rate

Assume that a transformer operates for 364 days for each year and 24 hours for each day, the no-load operating time is then set to 8736 hours, the load operating time set to 5500 hours and load rate set to 59.5% (calculated and checked according to the substation data).

11.2.2 Service life of a transformer

A distribution transformer has a long service life, which generally ranges from 20 to 30 years. In calculating life cycle cost of transformers, we see that the longer a transformer operates, the more electric energy it consumes, and the greater the economic benefit it brings. Therefore, we take a service life of 20 years in the analysis.

11.2.3 Electrovalency by the grid and discount rate

Electrovalency differs from place to place in China and it has a tendency of continual growth. Assume 0.5 yuan/kWh as the base price and 3% as the annual growth rate. Given severe completion in the transformer industry, we set the discount rate to 5%.

11.2.4 Price of a transformer

Transformers provided by different manufacturers are priced differently even if they are of the same type and specifications due to the price of copper, silicon steel, and other materials. The price of a transformer is important for calculating the life cycle cost, and therefore two input modes are adopted in the analysis program. The first mode is to provide a price input box to enable a customer to input the actual price of a distribution transformer, and the other mode is to adopt the built-in price information originating from many domestic distribution transformer manufacturers. Average prices of distribution transformers of various capacities produced by such manufacturers are taken to generate a price regression curve so that the program determines the calculated price of the transformer after the basic parameters of a transformer are input.

11.2.5 Residual value of a transformer

The value of copper, silicon steel, and steel is mainly considered for the residual value of a transformer after being scrapped. Based on the survey data, we calculate the average weight of copper, silicon steel, and steel respectively of transformers of different voltage levels, capacities and energy efficiency grades. Then, we calculate the average ratio of the residual value of transformers of various specifications on the selling price of transformers of various energy efficiency grades according to the present recycling price of scrapped copper, silicon steel and steel, which is the average residual value ratio of a transformer. After inputting the market prices of scrapped copper and steel in the corresponding input sub-area, we run the program to finally calculate the residual value of transformers of different energy efficiency grades.

11.2.6 No-load loss and load loss

The no-load loss and load loss of distribution transformers are taken from the national standard *Minimum Allowable Values of Energy Efficiency and Energy Efficiency Grades for Three-phase Distribution Transformers* (GB20052-2013). They are also input in the analysis program. After the voltage level, winding mode and capacity are input in the data input sub-area, the no-load loss and load loss of transformer will be called out automatically for calculation.

11.3 Computing results of life cycle cost and payback period of distribution transformers

11.3.1 Analysis of oil-immersed distribution transformers

When oil-immersed distribution transformers have a capacity of 315kVA, an annual no-load operating time of 8,736h, an annual load operating time of 7,200h and a load rate of 60%, their life cycles at various energy efficiency grades calculated based on the analysis model for life cycle costs of distribution transformers are as shown in Figure 11.1.

315kVA	Computing results of life cycle cost			Ten thousand yuan	
S9	Grade 3	Silicon steel (SS) Grade 2	Amorphous metal (AM) Grade 2	SS Grade 1	AM Grade 1
24.43	22.21	21.51	20.23	19.63	19.94

		Payback period		Year(s)	
	Grade 3	SS Grade 2	AM Grade 2	SS Grade 1	AM Grade 1
Compared with type 9	2.36	8.83	9.91	9.02	12.23
Compared with grade 3		7.47	9.01	8.20	11.49

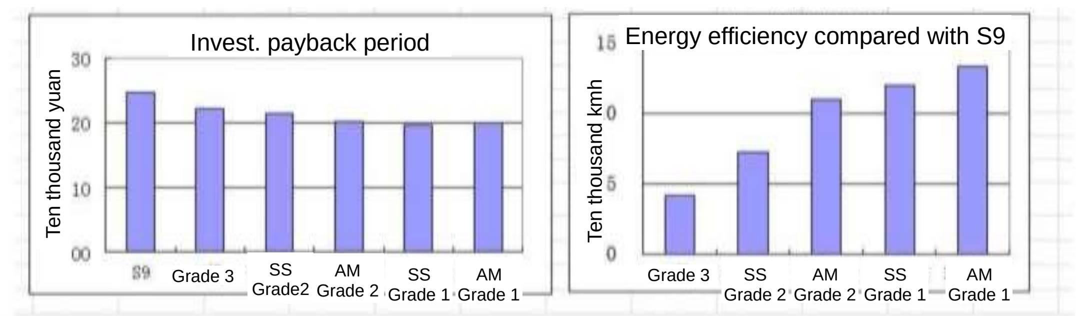


Figure 11.1 Analysis result section of the life cycle analysis software

As shown in Figure 11.1, we see that the life cycle cost decreases in steps with the increase of energy efficiency grade, indicating that the standard energy efficiency index is correctly selected. Selection of energy-efficient distribution transformer by a customer based on the above settings is economically suitable, and also brings good energy-saving effects. Moreover, in the energy-saving effect diagram, we see that a transformer of a higher energy efficiency grade saves more energy. The payback period for investment in energy-saving of energy-efficient transformer is 7 - 11 years or in other words, one third of the service life (assume the service life is 30 years). Electrovalency saved for the rest two thirds of its service life is therefore the benefit of energy-saving.

11.3.2 Analysis of dry-type transformers

Click **Type** to enable the software to analyze the life cycle cost of dry-type distribution transformers. Assume the capacity is 1,000kVA, annual no-load operating time is 8,736h, annual load operating time is 7,200h and load rate is 53%, and select the option of getting subsidized. Figure 11.2 shows the life cycle of transformer at various energy efficiency grades calculated with the analysis model for life cycle costs of distribution transformers.

1600/6.0kVA	Computing results of life cycle cost			Ten thousand yuan	
S9	Grade 3	SS Grade 2	AM Grade 2	SS Grade 1	AM Grade 1
83.23	78.55	74.33	68.12	70.77	64.45

		Payback period		Year(s)	
	Grade 3	SS Grade 2	AM Grade 2	SS Grade 1	AM Grade 1
Compared with type 9	6.35	7.91	13.12	9.15	10.40
Compared with Grade 3		4.81	11.73	7.06	9.10

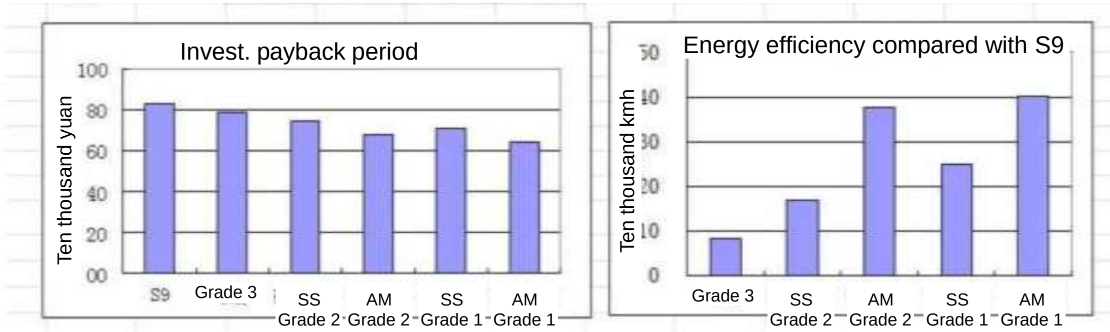


Figure 11.2 Life cycle cost and energy-saving analysis of different dry-type distribution transformers

We can see that the life cycle costs of AM Grade-2 and 1 are lower than that of Grade 3, and that thanks to their energy-saving effects, their life cycle costs are low under such operation conditions and lower than that of SS Grade 1. Moreover, the energy-saving effect of AM Grade-2 and 1 is obvious.

11.4 Analysis of the life cycle cost sensitivity of distribution transformers

The purpose of analyzing the life cycle cost of transformers of different energy efficiency grades is to know whether transformers of low loss and high energy efficiency are acceptable by a customer in terms of overall economic performance and whether they are money-saving as much as energy-saving. The life cycle cost is affected by factors such as load rate, electrovalency, discount rate, transformer price. Will the life cycle cost of a low-loss transformer be lower than that of a common transformer when such factors have changed? This question needs to be answered through analysis of the life cycle cost sensitivity.

11.4.1 Analysis of the sensitivity to electrovalency change

Assume that an oil-immersed distribution transformer with a service life of 30 years and capacity of 315kVA is used at a discount rate of 3% and load rate of 53%.The changes of its life cycle cost at various energy efficiency grades when electrovalency changes from 0.4 yuan/kWh to 2 yuan/kWh are as shown in Figure 11.3.

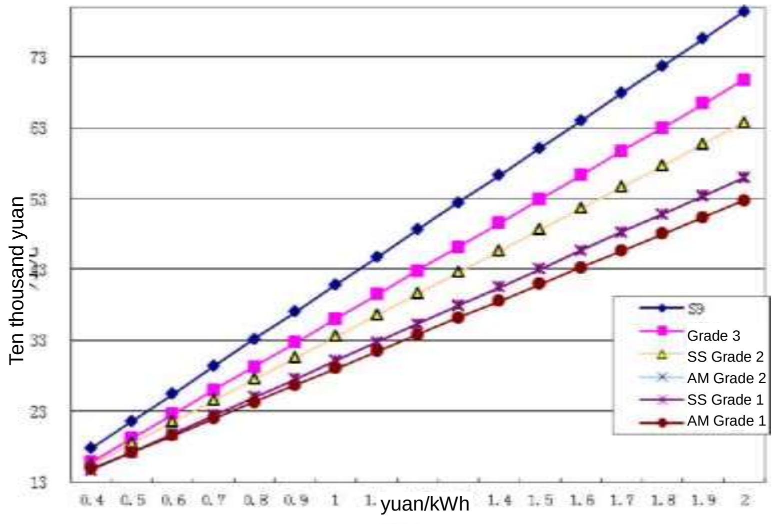


Figure 11.3 Life cycle cost sensitivity of an oil-immersed transformer upon change of electrovalency

With the change in price, the life cycle cost of transformers differs at different energy efficiency grades. Specifically, the more energy-efficient, the lower the life cycle cost. Life cycle costs of SS Grade 1 and AM Grade 1 are basically the same when the electrovalency is low. However, as the electrovalency rises, the life cycle cost of transformer of AM Grade 1 becomes lower than that of SS Grade 1.

Assume that a dry-type distribution transformer with a service life of 28 years, capacity of 360kVA, discount rate of 0.5% and load rate of 53% is used. The changes of its life cycle cost at various energy efficiency grades when electrovalency changes from 0.4 yuan/kWh to 2 yuan/kWh are as shown in Figure 11.4.

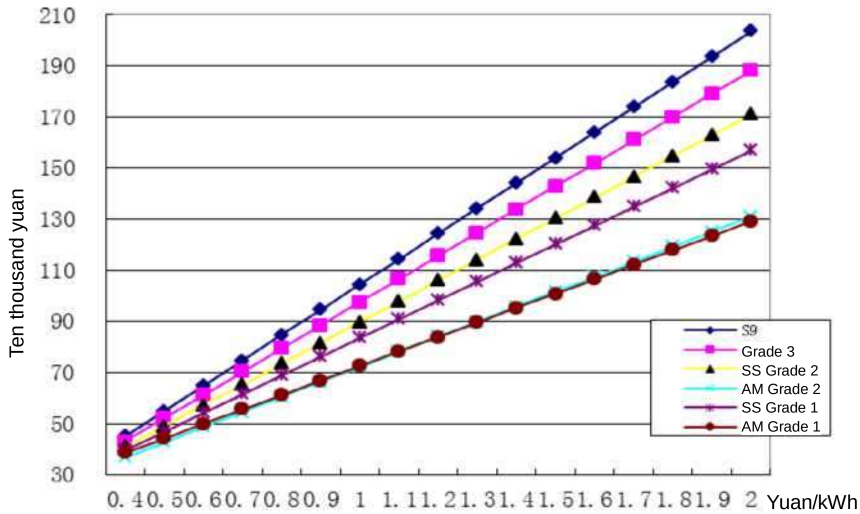


Figure 11.4 Life cycle cost sensitivity of a dry-type transformer upon change of electrovalency

With the change in price, the life cycle cost of transformers differs at different energy efficiency grades. Specifically, the more energy-efficient, the lower the life cycle cost, which is the same with oil-immersed transformer. When the electrovalency is high, the life cycle costs of both AM Grade 1 and Grade 2 are much lower than those of transformers of other energy efficiency grades. They almost have the same life cycle cost within the range of change of electrovalency.

11.4.2 Analysis of sensitivity to the load rate change

Assume that an oil-immersed distribution transformer with a service life of 30 years and the capacity of 315kVA is used at a discount rate of 3% and electrovalency of 0.6 yuan/kWh, changes of its life cycle cost at various energy efficiency grades when load rate changes from 30% to 102% are as shown in Figure 11.5.

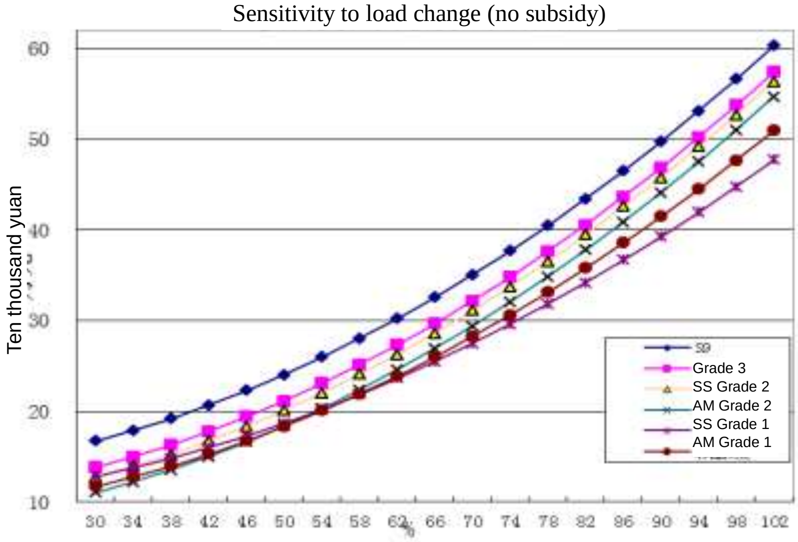


Figure 11.5 Sensitivity of life cycle cost to load rate change

With the increase of load rate, the life cycle cost of transformers at different energy efficiency grades increases with little change in the difference of life cycle cost among energy efficiency grades. When the load rate is lower than 54%, the life cycle cost of AM Grade 2 is lower than that of AM Grade 1; when it is higher than 54%, the life cycle cost of SS Grade 1 is the lowest.

Assume that a subsidized dry-type distribution transformer with a service life of 28 years and the capacity of 360kVA is used at a discount rate of 0.5% and electrovalency of 0.6 yuan/kWh. The changes of its life cycle cost at various energy efficiency grades when load rate changes are as shown in Figure 11.6.

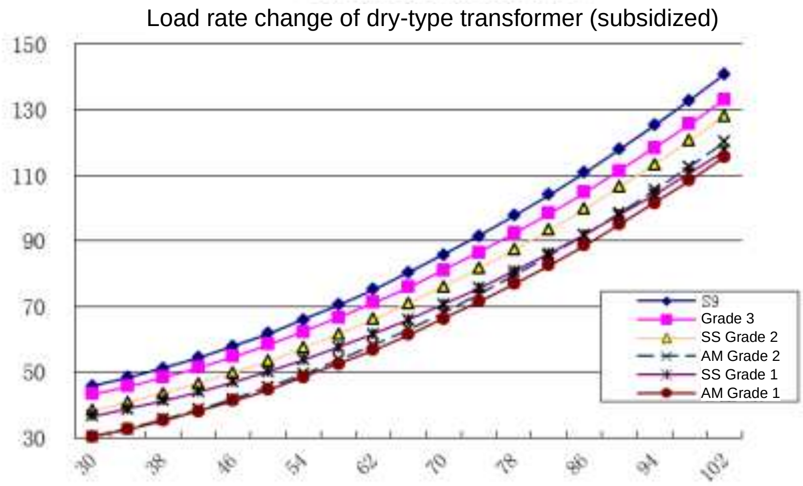


Figure 11.6 Sensitivity of the life cycle cost of a dry-type transformer (subsidized) to load rate change

With the increase of load rate, the life cycle cost of transformers at different energy efficiency grades increases with that of subsidized AM Grade 1 always lower than other energy efficiency grades.

Chapter 12 Analysis of Potential Energy Saving and Environmental Effect upon Implementation of Energy Efficiency Standards

12.1 Overview of the analysis method

Energy efficiency standards are the basis for implementing energy-saving policies. After issuance and implementation of these standards, the energy efficiency of distribution transformers in China will be improved by executing mandatory energy-saving policies (for example eliminating high energy-consumption products and implementing the energy efficiency label system) and energy-saving encouragement policies (such as certification of energy-saving products, projects of benefiting people with energy-saving products) and developing energy-efficient products. This chapter analyzes the effects of energy efficiency standards on the reduction in power consumption, electrovalency and environmental pollution in China.

The potential energy saving brought by the implementation of energy efficiency standards is analyzed based on some forecasted parameters such as annual growth rate and inventory of distribution transformers, proportion of distribution transformers of various energy efficiency grades (EEG) in the power grid system and growth rate of electrovalency. In virtue of a number of data involved, a computer-based analysis program is also used for analysis. We have proposed two scenarios: scenario 1, where China has not issued or implemented any energy efficiency standard and the forecast is based on the development of existing distribution transformer market fully led by market mechanism; and scenario 2, where China has issued and implemented energy efficiency standards on distribution transformers and the forecast is based on the development of distribution transformer market under the intervention of energy-saving policies. The reduction in power consumption and environmental pollution and the increase in economic benefits brought by implementing energy efficiency standards on distribution transformers are calculated by comparing and analyzing these two scenarios.

The analysis on the LCC is conducted subject to the micro calculation of economic effect brought by energy-efficient distribution transformers, whereas what described herein is subject to the macro calculation of economic effect brought by energy-efficient distribution transformers.

12.2 Forecast of annual production of distribution transformers

According to the preceding description, the service life of a transformer is set to 30 years, but GB20052-2013 (an energy efficiency standard on distribution transformer) will be constantly revised in future, and no-load loss and loss load specified will also decrease with the development of energy-saving technologies for transformers in China. Therefore, the analysis is only carried out for the effects of energy saving and emission reduction after the implementation of energy efficiency standards.

12.2.1 Forecast mechanism

A professional survey company provides us with the production of distribution transformers in China from 2006 to 2012, and the production of power transformers in future is a forecasted value. The forecasted production is based on historical data. We collected relevant data and obtained the amount of power consumption and annual GDP in the years from 2000 to 2011 from *China Statistical Yearbook*. We all know that the transformer production is closely related to the demand for transformers and there is certain relationship between the installed capacity of power generation equipment and the demand for transformers. The economic development and city expansion increase the power consumption. To meet the power demand, the installed capacity of power generation equipment must be enhanced, and the power generated by newly-added power generation equipment must be transmitted from new power transmission and distribution grid to new enterprises and expanded cities, so the construction of new power transmission and distribution grid requires new distribution transformers. The power consumption by 2023 is forecasted to estimate the effects of energy saving and emission reduction in ten years after the execution of energy efficiency standards.

The demand for transformers depend on the amount of power supply, whereas the power demand is determined by the economic development. Therefore, we first forecast China's national economic development by 2023 (i.e. annual gross domestic product (GDP) by 2023) to estimate the total production of distribution transformer by 2023; then the annual amount of power consumption is calculated according to the contribution of power to the economic development, and the production of distribution transformer each year is calculated based on the amount of power consumption.

12.2.2 Forecast of GDP and power consumption

The amount of power consumption is related to GDP growth. In the years from 2000 to 2012, China enjoyed a rapid GDP growth, as shown in Figure 12.1. The average growth rate of China's GDP was 14.87% in the years from 2000 to 2012; however, the global economic growth was slow, the growth rate of China's GDP dropped to 9.7% in 2012, and since then China has experienced slower economic development.

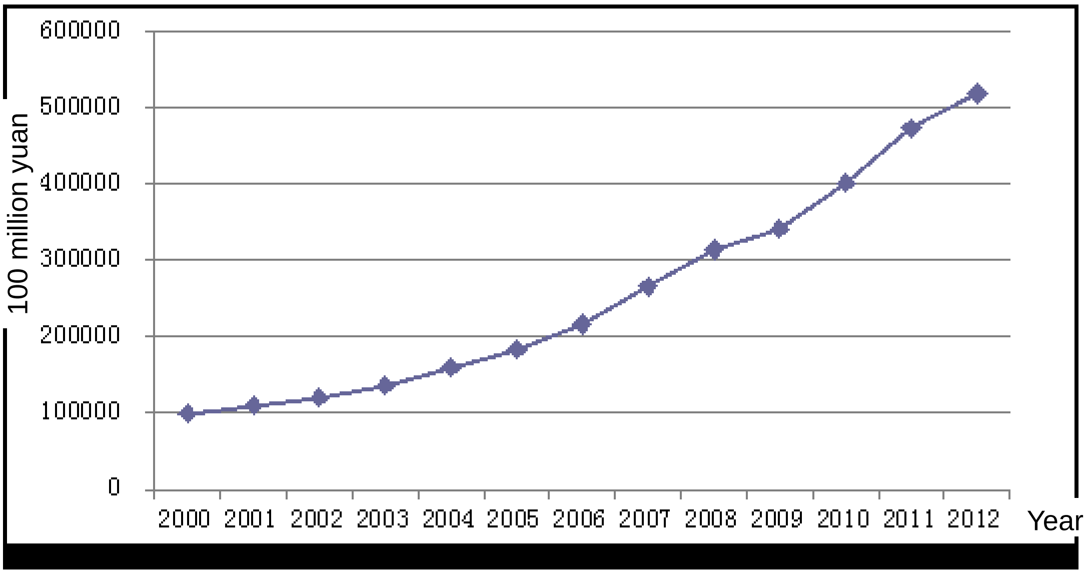


Figure 12.1 Growth of China's GDP in the years from 2000 to 2012

China saw continuous increase in power consumption in the years from **2000** to **2012**, and there was a secondary rapid growth in **2003** and **2010**, with the growth rate of **16.5%** and **13.2%** respectively. In future, China will experience slow growth of power consumption within a period due to the decrease in **GDP** growth.

The power consumption closely relates to GDP in China. The statistical data collected over a long period shows that the power consumption increases with the GDP growth. If the total capacity of power generation fails to keep up with the growth of power consumption, China will experience power shortage. As a result, China will increase the investment in construction of electrical infrastructure and expand the total capacity of power generation to make the power supply keep pace with the economic development.

Figure 12.2 shows the change in GDP and total power consumption in China in the years from 2000 to 2012. For comparing GDP and total amount of power consumption in each year, the unit of GDP shown in the figure is changed into one billion yuan, and the unit of total power consumption is taken as 100 MkWh. We can see that the amount of power consumption increases fast with the rapid growth of GDP; the growth rate of power consumption drops when the GDP growth is slow, and the only difference is in the growth and drop rate.

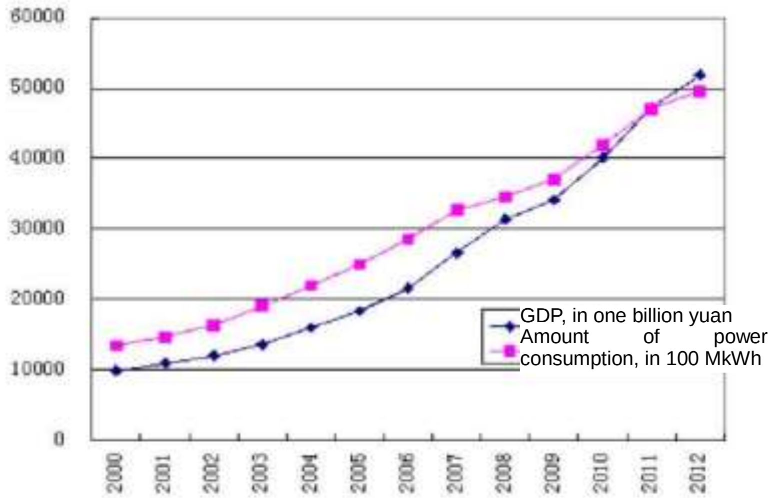


Figure 12.2 Change in GDP and total amount of power consumption in China

We conservatively assume that in the years from 2013 to 2023, the growth rate of China's GDP changes between 7% and 5% and the increase in total amount of power consumption varies from 8.5% to 5%. Therefore, we can estimate GDP and total power consumption in each year by 2023, as shown in Figure 12.3.

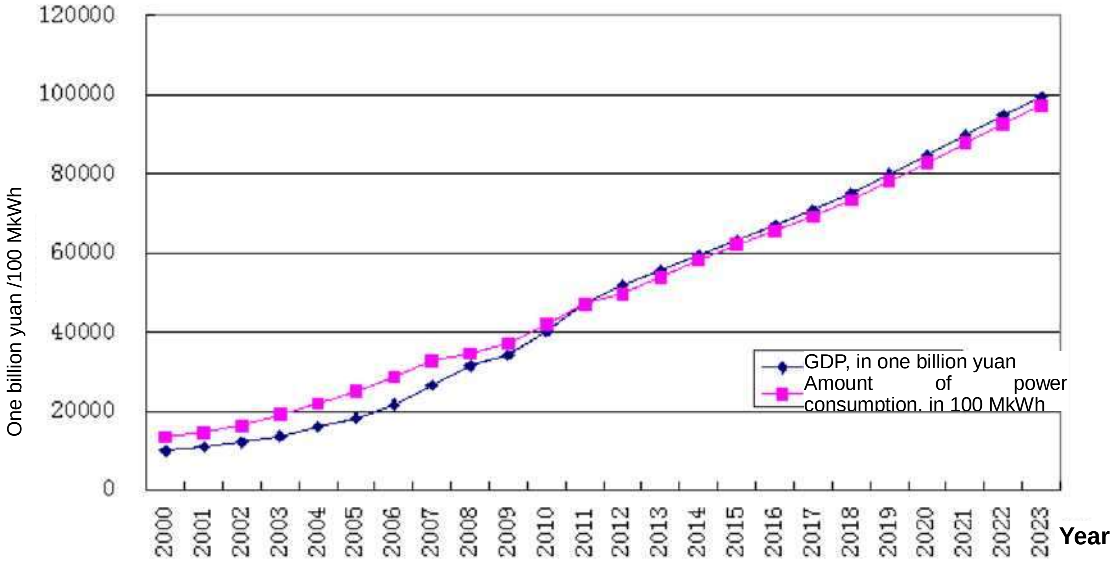


Figure 12.3 Forecast of GDP and amount of power consumption in China

12.2.3 Forecast of production of distribution transformers

The ratio of the amount of power consumption to the production of distribution transformers in the years from 2006 to 2012 is calculated and varies from 0.04217 to 0.0554, as shown in Table 12.1; and the average ratio is 0.04358. The annual production of distribution transformers after 2012 is estimated based on the forecasted amount of power consumption, as shown in Figure 12.4.

Table 12.1 Amount of power consumption and production of distribution transformers in the years from 2006 to 2012 and their ratio

Year	2006	2007	2008	2009	2010	2011	2012
Amount of power consumption	28588	32712	34541	37032	41934	47026	49600
Production of distribution transformers	639678	721453	758478	878210	974154	1082552	1214756
Ratio	0.04469	0.04534	0.04554	0.04217	0.04305	0.04344	0.04083

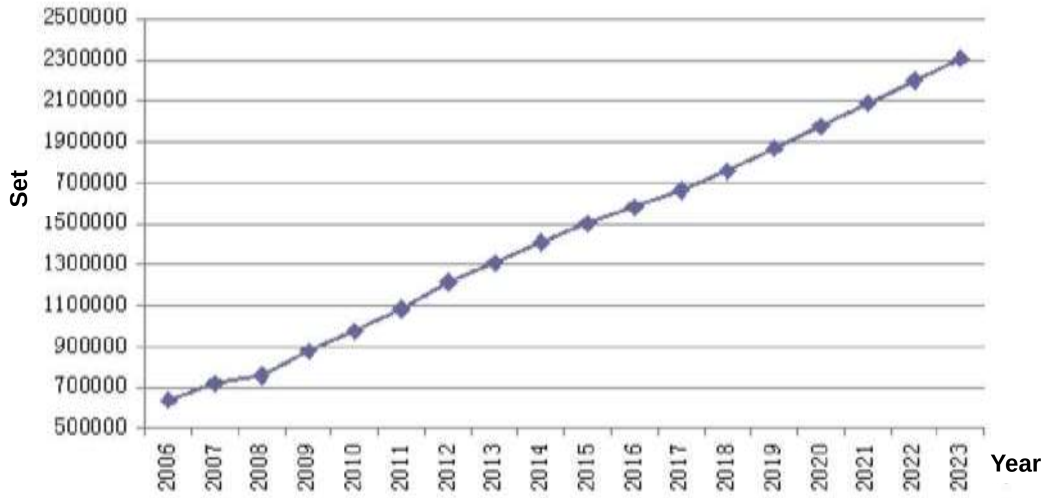


Figure 12.4 Forecast on production of distribution transformers

12.2.4 Forecast on the proportion of production of oil-immersed distribution transformers and dry-type distribution transformers

The proportion of annual production of oil-immersed distribution transformers (ODTs) and dry-type distribution transformers (DDTs) is calculated respectively according to the annual production of ODTs and DDTs in the years from 2006 to 2012. Figure 12.5 shows the change in proportion of production of ODTs and DDTs.

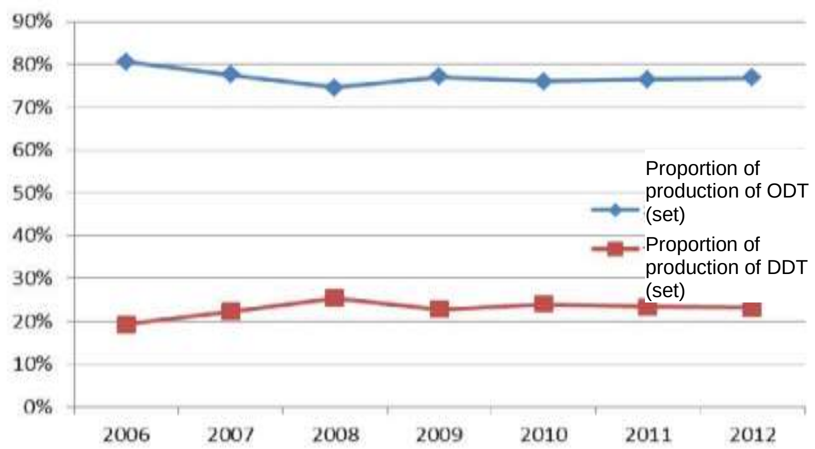


Figure 12.5 Change in proportion of production of ODTs and DDTs

The proportion of production of ODTs and DDTs is stable and the average proportion is 0.77% for ODTs and 23% for DDTs. The production of ODTs and DDTs can be estimated based on these two values, and estimated results are shown in Figure 12.6.

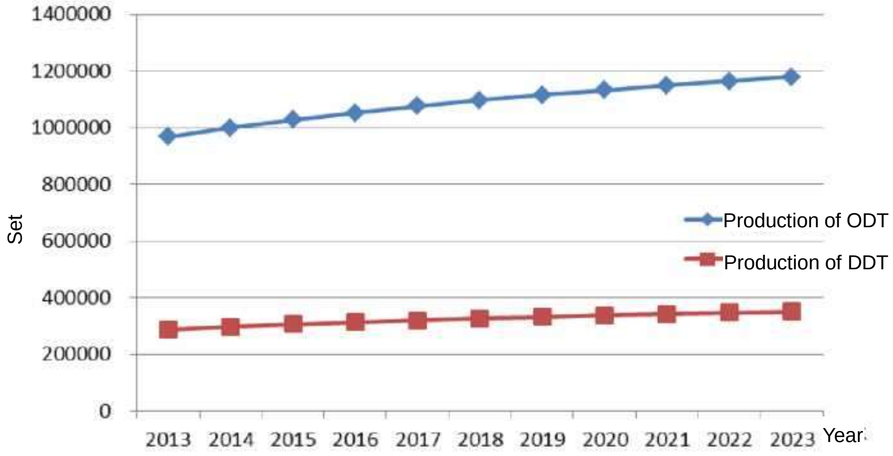


Figure 12.6 Forecast on production of ODTs and DDTs in the years from 2013 to 2023

12.3 Analysis on weighted values of distribution transformers

The calculation of weighted value makes the analysis of the total production of distribution transformer more scientific; various parameters are grouped into several weighted values and each of them includes different factors with different specifications, and the complex calculation based on weighted values can be done via simple methods. The forecast and analysis of the amount of energy saving require weighted capacity of ODTs, no-load loss and load loss of transformers with weighted capacities at different EEGs. With different quantities of various models and various capacities of transformers, the calculation of weighted value is necessary. The weighted values for various capacities of transformers are calculated after the weighted values for various models are figured out, and then the weighted capacities of ODTs and DDTs are computed.

12.3.1 Weighted values for various models

Before implementation of the GB18613-2013 standard, the models of ODTs and DDTs on the Chinese market were S9, S10, S11, S13, S15 and SC9, SC10, SC11, SC13, SC15. Since quantities of various types and models of transformers are different, the statistical analysis is carried out for the quantities of each model of transformer according to the survey on the market situation and production of distribution transformers, and the weighted values for various models are calculated through dividing total production by quantities of each model. The results are listed in Table 12.2.

Table 12.2 Weighted value for various models of ODTs and DDTs

ODT	Model	S9	S10	S11	S13	S15
	Qty.	17186	2739	69030	1864	7655
	Weight	0.1745	0.0278	0.7010	0.0189	0.0777
DDT	Model	SC9	SC10	SC11	SC13	SC15
	Qty.	2804	17846	1731	355	1950
	Weight	0.1136	0.7229	0.0701	0.0144	0.0790

12.3.2 Weighted values for various capacities of transformers

We first count quantities of various capacities of ODTs and DDTs according to the survey data and figure out the weighted values for various capacities of transformers. Then, the weighted capacities for various models are calculated through multiplying the weighted values for various capacities of transformers by capacity. The composite weighted capacities for various models are computed through multiplying the weighted capacity for each model by the weighted values listed in Table 12.2, as shown in Table 12.3.

Table 12.3 Composite weighted capacities for various models

ODT	Model	S9	S10	S11	S13	S15
	Model weighted capacity	255.880	443.349	298.818	333.974	278.745
	Composite weighted capacity	44.657	12.332	209.470	6.322	21.669
DDT	Model	SC9	SC10	SC11	SC13	SC15
	Model weighted capacity	732.422	687.701	351.179	384.425	292.800
	Composite weighted capacity	83.193	497.152	24.625	5.528	23.129

Finally, the weighted capacity of ODTs and DDTs is calculated respectively through summing its composite weighted capacity and equals to 294kVA for ODTs and 634kVA for DDTs.

a) No-load loss and load loss of transformers with weighted capacity at different EEGs

No weighted capacity is provided in any energy efficiency standard. For this reason, we need to calculate the no-load loss and load loss of transformers with weighted capacity. There are two methods to calculate no-load loss and load loss of transformers with weighted capacity: one is to use no-load loss and load loss regression curve, and figure out the no-load loss and load loss of transformers with weighted capacity by substituting the weighted capacity into the regression curve equation calculated; The other is to adopt the interpolation method, which is featured by simple calculation, and no more accurate value is required in the forecasting analysis; therefore, Table 12.4 lists the no-load loss and load loss of ODTs and DDTs with weighted capacity at different EEGs calculated by using the interpolation method.

Table 12.4 No-load loss and load loss of transformers with weighted capacity at different EEGs

EEG		S9	Grade 3 transformer	Grade-2 silicon-steel transformer	Grade-2 amorphous transformer	Grade-1 silicon-steel transformer	Grade-1 amorphous transformer
ODT	No-load loss	641	459	327	162	327	162
	Load loss	3490	3490	3490	3490	2792	3141
DDT	No-load loss	1466	1305	1044	412	939	412
	Load loss	6321	5984	5984	5984	5384	5682

12.4 Analysis of predicted market scenarios for distribution transformers

12.4.1 Principle for scenario setting

The market size and product structure of distribution transformers are determined by customers and manufacturers because of the current market economy in China. If no government guidance is available, the product structure of distribution transformers mainly depends on prices. However, distribution transformers of different energy efficiency grades (EEGs) are priced differently. The higher the grade is, the higher the price will be, and vice versa. If only the market mechanism works, the product structure of distribution transformers will not change. Low-price distribution transformers occupy a larger market share, whereas energy-efficient and high-price distribution transformers take a small market share.

In order to promote the production and application of energy-efficient distribution transformers, Chinese government adopts some policies to lead the development of market for energy-efficient distribution transformers and reduce the market share of low-efficient distribution transformers. These policies include: implementing energy efficiency standards, eliminating high energy-consumption products, adopting certification of energy-efficient products and energy grade labels, purchasing energy-saving products and subsidizing consumers to promote energy-saving products.

Due to the changes in product structure, a large number of energy-efficient distribution transformers are put into use. This not only helps customers to cut electricity bills but also reduces the power wastage in the state grid and saves a lot of power at the supply end. The saved power quantity can be estimated through scenario analysis. First, set a market without government guidance and fully led by market mechanism for distribution transformers. In this market, only the sales volume changes but not the structure of energy efficiency. Second, set a market with government guidance to change the sales volume and energy efficiency structure.

12.4.2 Setting of scenario 1

If China does not develop the energy efficiency standard and not implement relevant energy-saving policies, the current trend of market shares for transformers of different EEGs will continue. The biggest customer for distribution transformers is the State Grid Corporation of China (SGCC). Its annual purchase amount accounts for 70%–80% of the total and its bidding requirement is above S11. At the same time, 20%–30% of customers for distribution transformers are large energy companies and real estate developers. They may also purchase distribution transformers below energy efficiency grade 3. From the survey data in 2009, we learn the shares of ODTs and DDTs of different efficiency grades under the condition that no energy efficiency standard and energy-saving policy is implemented, as shown in Table 12.5.

Table 12.5 Shares of ODTs and DDTs of different EEGs (before implementation of energy-saving policies)

Energy efficiency grade	Below grade 3	Grade 3	Grade 2	Grade-2 silicon-steel transformer	Grade-2 amorphous transformer	Grade 1	Grade-1 silicon-steel transformer	Grade-1 amorphous transformer
ODT	3.00%	76.27%	13.55%	3.39%	10.16%	7.18%	7.11%	0.07%
DDT	0	76.70%	22.30%	6.69%	15.61%	1.00%	0.50%	0.50%

12.4.3 Setting of scenario 2

After adopting the energy efficiency standards and energy-saving policies, Chinese government also formulates an elimination policy to prohibit the production and sale of distribution transformers below grade 3, thus forcing low-efficient transformers out of the market soon. Owing to the encouragement policies, the market shares of grade-2 silicon-steel ODTs, grade-2 amorphous ODTs, grade-1 silicon-steel ODTs and grade-1 amorphous ODTs are expected to reach 47%, 28%, 10.5% and 4.48% respectively in 2023. Meanwhile, distribution transformers of energy efficiency grade 3 will have their sales volume decreased and market share reduced to 10%, because the market share of energy-efficient transformers expands. Figure 12.7 shows the changes of market share for ODTs of different EEGs.

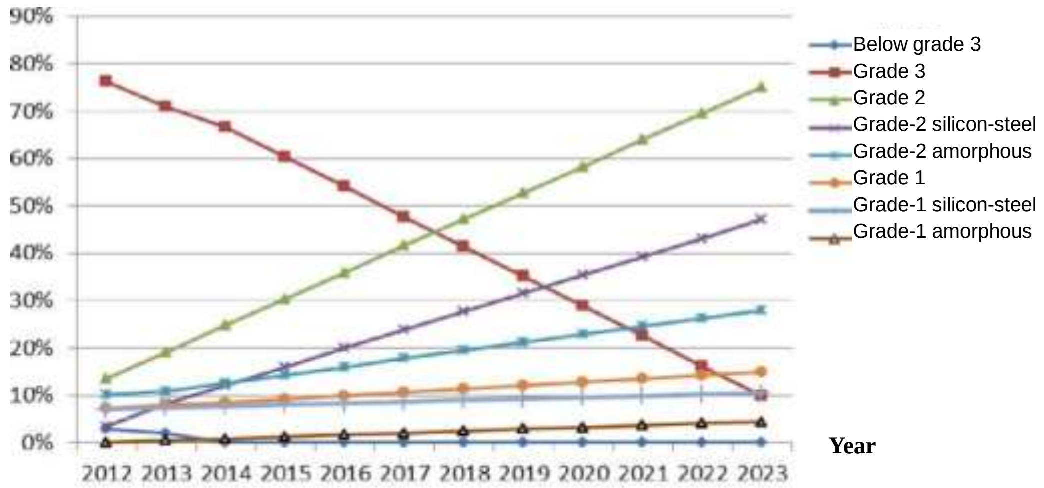


Figure 12.7 Changes of the market share for ODTs of different EEGs (after implementation of energy-saving policies)

Dry-type transformers were withdrawn from the market because their energy efficiency grades were below 3. The market shares for grade-2 silicon-steel DDTs, grade-2 amorphous DDTs, grade-1 silicon-steel DDTs and grade-1 amorphous DDTs will be increased respectively to 26%, 39%, 6.5% and 1.6% by 2023.Figure 12.8 shows the changes of the market share for DDTs of different EEGs.

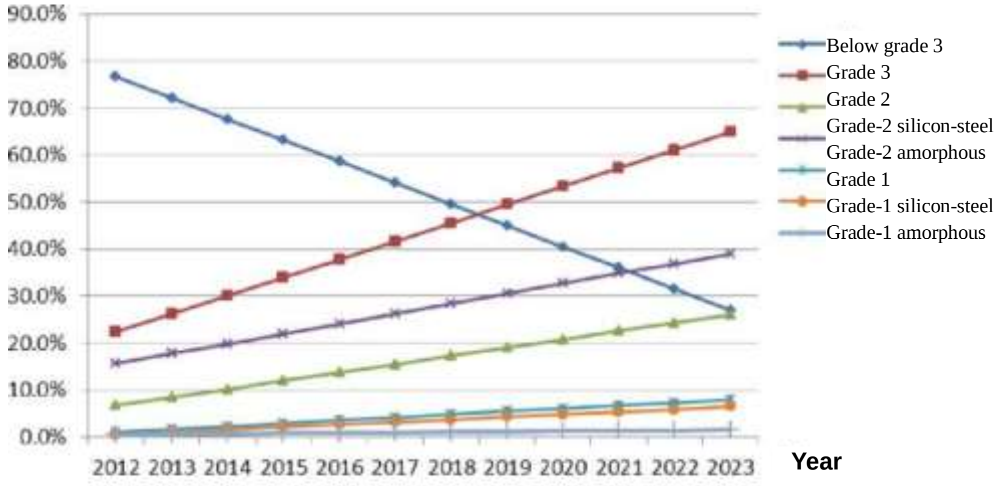


Figure 12.8 Changes of the market share for DDTs of different EEGs (after implementation of energy-saving policies)

12.4.4 Inventory of transformers with different EEGs under different scenarios

Based on the yield prediction, the inventory structure of transformers of different EEGs from 2013 to 2023 is shown in Figures 12.9 and 12.10.

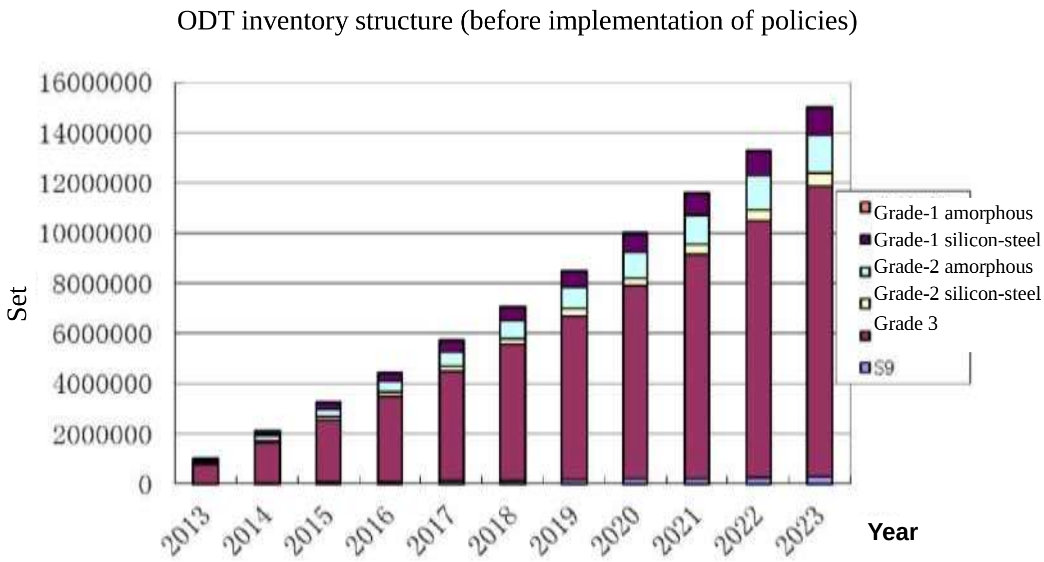


Figure 12.9 Inventory structure of ODTs in scenario 1

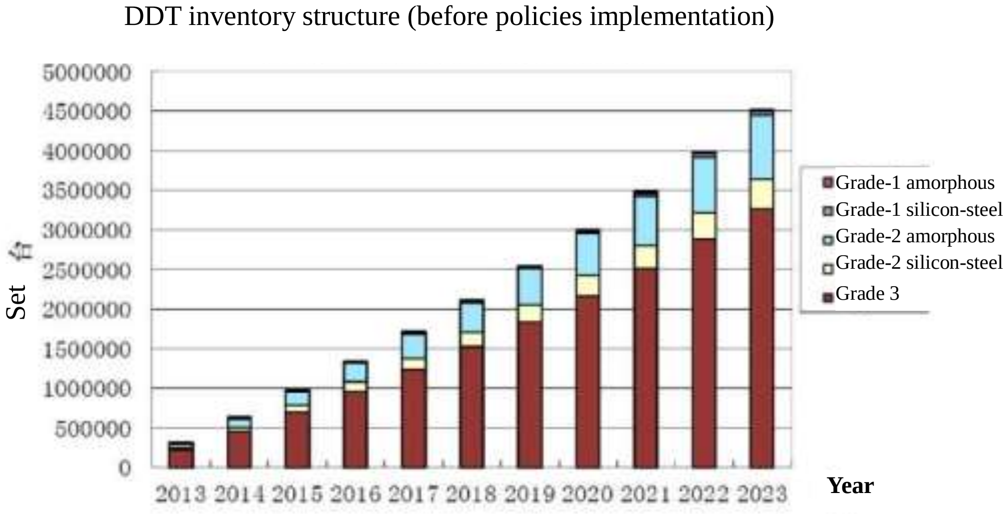


Figure 12.10 Inventory structure of ODTs in scenario 1

In scenario 1, the inventory structure of distribution transformers is shown in Figure 5.9 and 5.10. We can learn from the figures that the inventory of grade-3 transformers still keeps a large share, whereas the inventory of energy-efficient transformers occupies a small share After the energy efficiency standard and energy-saving policy are implemented, the share of energy-efficient transformers has significantly increased and the share of grade-3 transformers has significantly reduced. For details, see Fig 12.11 and 12.12.

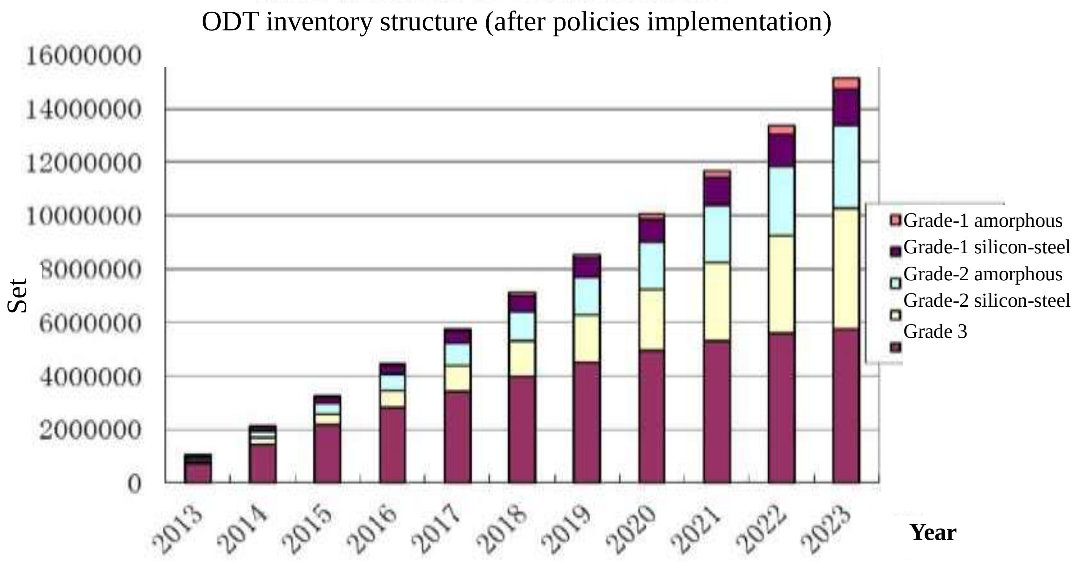


Figure 12.11 Inventory structure of ODTs in scenario 2

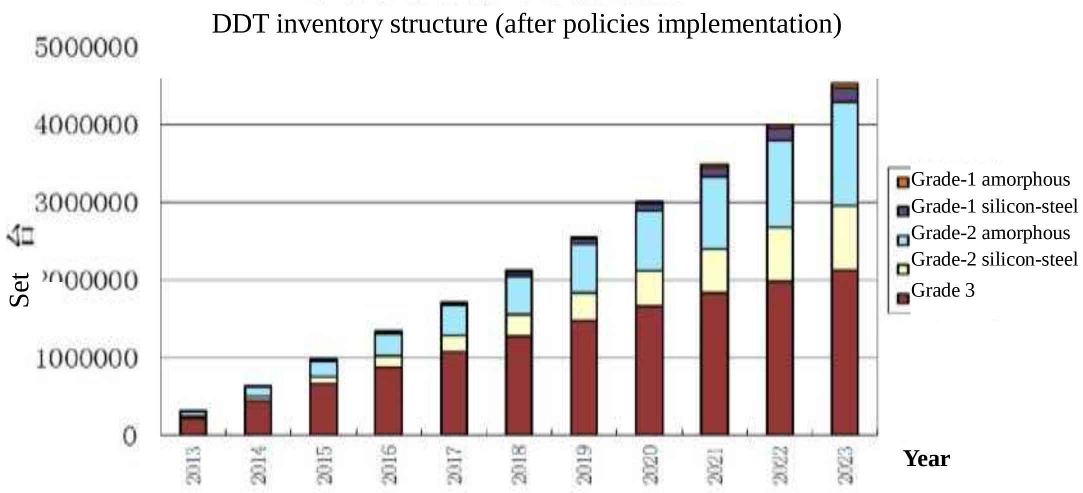


Figure 12.12 Inventory structure of DDTs in scenario 2

The implementation of energy efficiency standard has promoted the production of energy-efficient and low-loss transformers. After putting these new energy-efficient transformers into use, a lot of power has been saved, reflecting the true effect of the efficiency standard. As more and more energy-efficient transformers are put into use every year, the inventory of energy-efficient transformers keeps increasing and the amount of energy-saving increases too.

12.5 Calculations of energy saving and emission reduction

12.5.1 Calculation of power consumption of a transformer with weighted capacity

In the life cycle cost analysis, we have already confirmed the no-load working time is 8,736h/year and load working time is 7,968h/year. The load rate is 75%. According to the no-load loss and load loss of weighted-capacity transformers of different EEGs, we can calculate their annual power consumption, as shown in Table 12.6.

Table 12.6 Annual power consumption of transformers with weighted capacity

	S9	Grade 3	Grade-2 silicon-steel transformer	Grade-2 amorphous transformer	Grade-1 silicon-steel transformer	Grade-1 amorphous transformer
ODT	21257.34	19663.02	18506.7	17061.3	15378.26	15497.08
DDT		38252.09	35965.73	30429.41	32356.73	29075.84

12.5.2 Annual power consumption of ODTs and DDTs in scenarios 1 and 2

The power consumption of each transformer with weighted capacity is multiplied respectively by the inventory of scenarios 1 and 2 in each year to obtain the total power consumption of distribution transformers in scenario 1 and that of distribution transformers in scenario 2. The annual power consumption of ODTs and DDTs in scenarios 1 and 2 are respectively shown in Figure 12.13 and Figure 12.14.

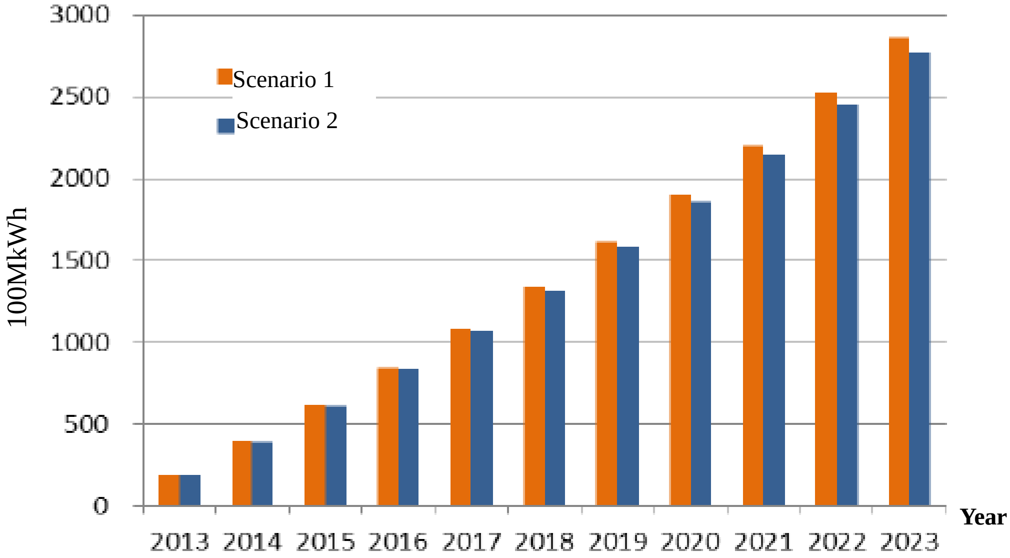


Figure 12.13 Annual power consumption of ODTs in different scenarios

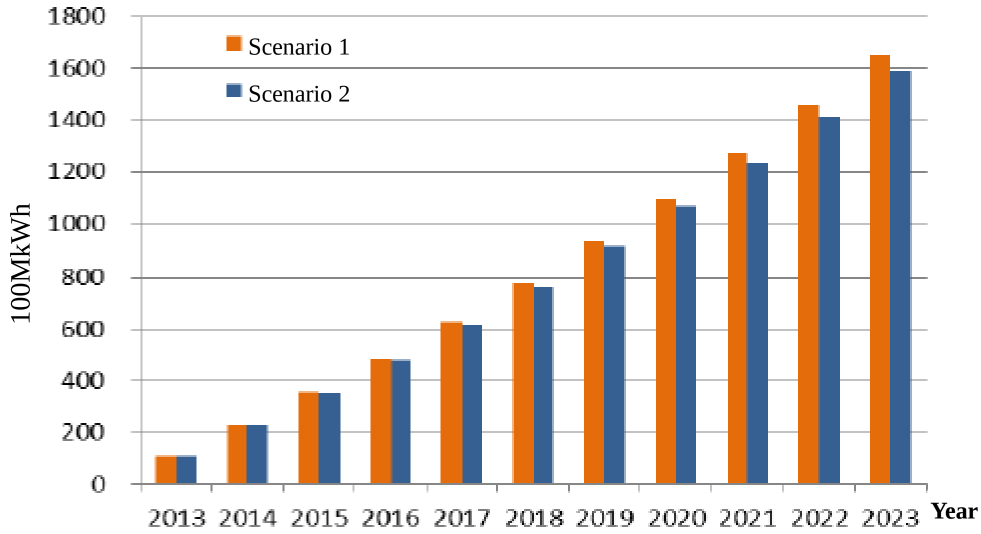


Figure 12.14 Annual power consumption of DDTs in different scenarios

12.5.3 Annual amount of power saving and saved power cost of ODTs and DDTs

The annual amount of power saving of ODTs and DDTs can be obtained respectively by subtracting the power consumption of ODTs and DDTs in scenario 1 from the power consumption in scenario 2. Figure 12.15 and Figure 12.16 show the energy-saving effect of promoting energy-efficient ODTs and DDTs after energy efficiency standards and relevant policies are implemented. More than 60TWh of power can be saved in ten years. If power costs 0.5 yuan/kWh, more than 30 billion Yuan can be saved in ten years.

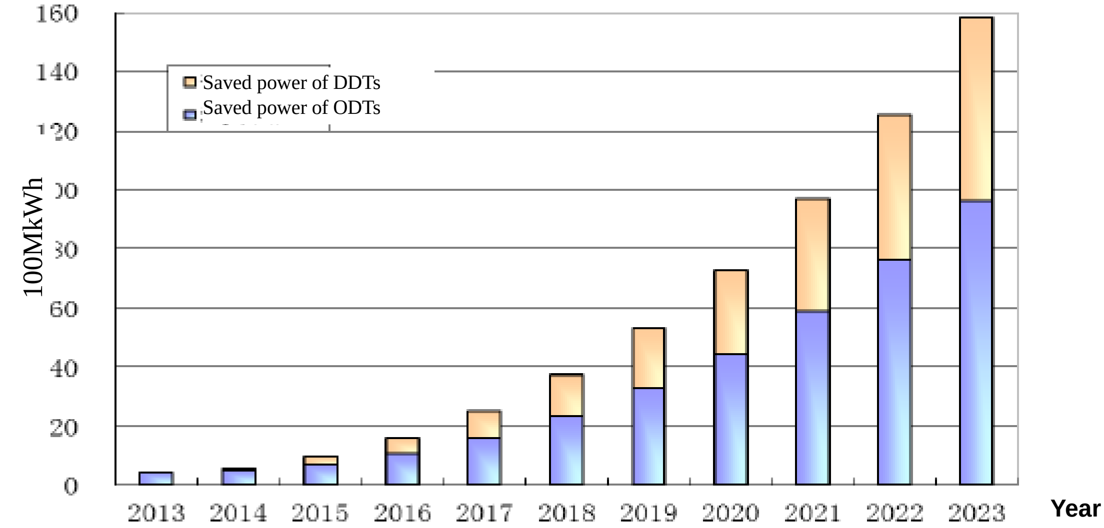


Figure 12.15 Amount of power saving of ODTs and DDTs after implementation of energy efficiency standards

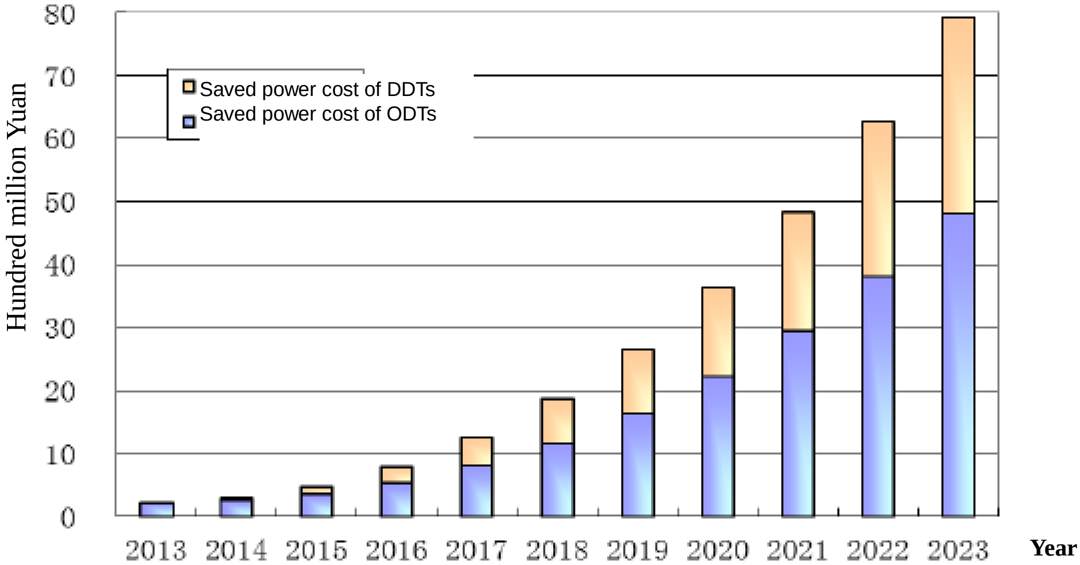


Figure 12.16 Amount of power saving of ODTs and DDTs after implementation of energy efficiency standards

12.5.4 Emission reduction from promotion of energy-efficient ODTs and DDTs

Emission reduction indicates the reduction of CO_2, SO_2 and NO generated from power consumption. China gives priority to coal-fired power generation. Producing one kilowatt hour of power is equivalent to burning a certain amount of coal, so a power plant always emits a certain amount of CO_2, SO_2 and NO. In other words, saving one kilowatt hour of power is equivalent to saving a certain amount of coal, which is also equivalent to reducing the emission of CO_2, SO_2 and NO. Figures 12.17, 12.18 and 12.19 respectively shows the annual emission of CO_2, SO_2 and NO after the energy efficiency standard is implemented and power consumption of each distribution transformer is reduced. According to these figures, 60.2 million tons of CO_2, 1.81 million tons of SO_2 and 0.9 million tons of NO will be reduced in the year from 2013 to 2023.

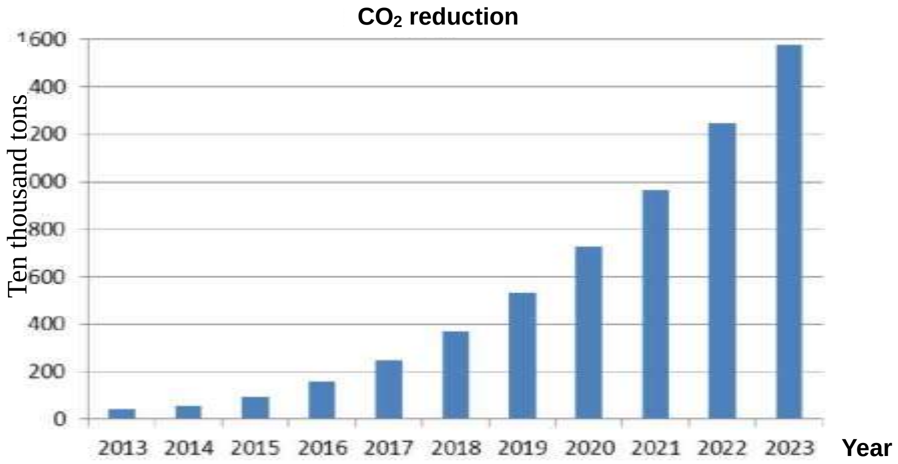


Figure 12.17 Amount of CO_2 reduction after implementation of energy efficiency standards

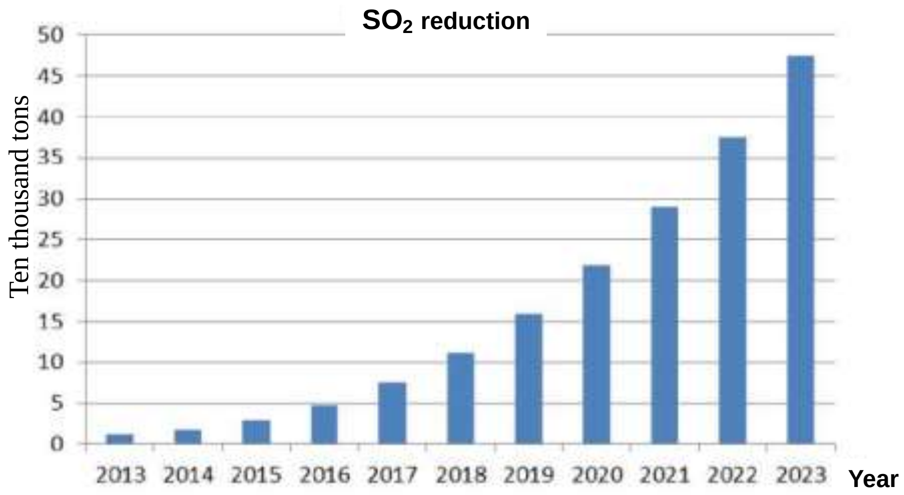


Figure 12.18 Amount of SO_2 reduction after implementation of energy efficiency standards

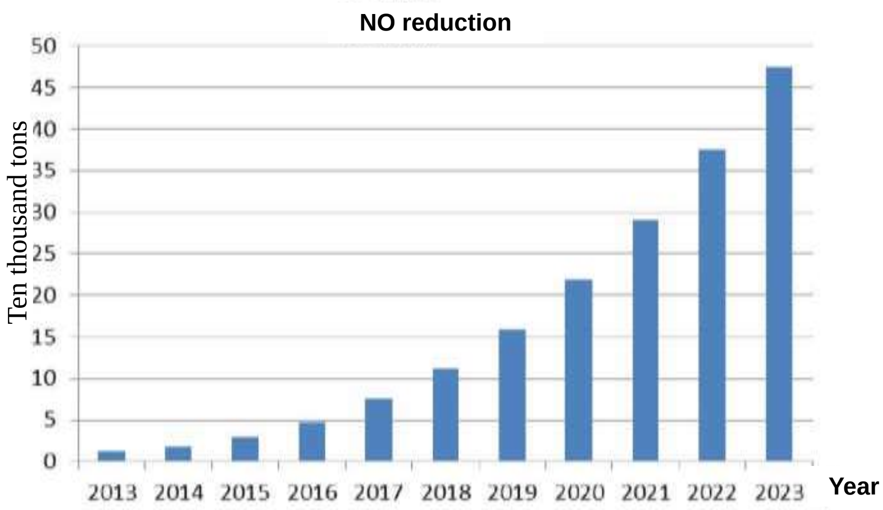


Figure 12.19 Amount of NO reduction after implementation of energy efficiency standards

As shown in Figure 12.18, the potential in energy saving is not substantial after the energy efficiency standard just become into effect. With more and more new transformers being put into use every year, however, the amount of energy saving and amount of emission reduction are significantly increased. This has obtained better effects in energy saving, economic profit and environmental protection.

Appendix

A.1 All 35 KV and above transformers of China in 2011[14]

Region	Ordinary transformers			Ordinary common transformers			Enterprise-owned transformers			Converter transformers		
	Total			Total			Total			Total		
	Set	Bank	Nameplate capacity (10,000 KVA)	Set	Bank	Nameplate capacity (10,000 KVA)	Set	Bank	Nameplate capacity (10,000 KVA)	Converter station (set)	Converter transformer bank (bank)	Nameplate capacity (10,000 KVA)
China	57,834	111,660	397,811	40,889	74,280	348,222	16,945	37,380	49,589	35	234	10,377
Beijing	630	1,413	9,371	435	1,035	8,796	195	378	575			
Tianjin	1,062	2,424	7,155	444	954	5,808	618	1,470	1,347			
Hebei	3,637	7,296	24,968	2,701	5,364	21,307	936	1,932	3,661			
Shanxi	2,221	4,457	14,123	1,137	2,177	10,742	1,084	2,280	3,381			
Inner Mongolia	1,526	2,521	11,301	1,213	1,890	9,230	313	631	2,071	1	12	357
Liaoning	2,289	4,292	17,062	1,530	2,838	14,003	759	1,454	3,059	2	6	701
Jilin	1,165	1,886	5,187	901	1,476	4,564	264	410	623			
Heilongjiang	1,765	2,964	6,581	1,154	1,794	5,140	611	1,170	1,441	1	2	60
Shanghai	1,494	3,195	12,998	836	1,820	10,981	658	1,375	2,017	7	36	1,515
Jiangsu	4,749	9,891	37,237	2,668	4,865	32,849	2,081	5,026	4,388	1	12	340
Zhejiang	2,764	5,288	27,519	1,954	3,668	25,644	810	1,620	1,875	1	2	7
Anhui	2,498	4,819	11,464	1,525	2,737	9,756	973	2,082	1,708			
Fujian	1,352	2,346	10,772	1,132	1,910	10,050	220	436	722			
Jiangxi	1,415	2,457	7,156	1,234	2,119	6,560	181	338	596			
Shandong	5,353	10,873	29,066	2,915	5,608	24,084	2,438	5,265	4,982	1	12	464
Henan	2,830	5,393	20,176	2,237	3,981	17,227	593	1,412	2,949	2	12	266
Hubei	2,115	3,840	13,034	1,592	2,758	11,248	523	1,082	1,786	5	54	1,574
Hunan	2,250	3,970	10,782	1,828	3,072	9,411	422	898	1,371			
Guangdong	2,700	5,474	39,672	2,318	4,686	38,467	382	788	1,205			
Guangxi	2,294	4,529	8,890	1,576	2,530	7,146	718	1,999	1,744			
Hainan	268	441	1,135	237	387	976	31	54	159			
Chongqing	785	1,526	7,456	645	1,267	7,083	140	259	373			
Sichuan	2,134	3,621	15,133	1,814	2,925	13,810	320	696	1,323	2	36	1,127
Guizhou	1,166	2,016	7,433	1,066	1,611	6,528	100	405	905			
Yunnan	2,428	5,275	10,742	1,853	3,869	9,453	575	1,406	1,289			
Tibet	146	184	234	142	184	233	4		1	1	6	71
Shaanxi	1,054	1,902	7,605	1,054	1,902	7,605				1	2	357

[14] Data source: Compilation of Statistical Material of Electric Power Industry, 2011

Region	Ordinary transformers			Ordinary common transformers			Enterprise-owned transformers			Converter transformers		
	Total			Total			Total			Total		
	Set	Bank	Nameplate capacity (10,000 KVA)	Set	Bank	Nameplate capacity (10,000 KVA)	Set	Bank	Nameplate capacity (10,000 KVA)	Converter station (set)	Converter transformer bank (bank)	Nameplate capacity (10,000 KVA)
Gansu	1,378	2,766	7,661	1,100	2,089	6,060	278	677	1,601			
Qinghai	426	1,022	4,323	231	404	3,083	195	618	1,240	1	2	71
Ningxia	477	1,110	4,148	263	485	3,495	214	625	653	1	12	482
Xinjiang	1,445	2,437	4,977	1,136	1,843	4,433	309	594	544			
Cross-region	18	32	2,450	18	32	2,450				8	28	2,985

A.2 Research findings of price of three-phase non-excited distribution transformers[15]

1 Research findings of price of oil-immersed three-phase non-excited distribution transformers

No.	Oil-immersed							
	Minimum capacity		Median 1		Median 2		Maximum capacity	
	Capacity type (KVA)	Price (RMB/set)	Capacity type (KVA)	Price (RMB/set)	CAPACITY TYPE (KVA)	Price (RMB/set)	Capacity type (KVA)	Price (RMB/set)
1	30	9,000	1000	95,000	--	--	12500	600,000
2	50	20,000	1000	90,000	2000	155,000	25000	900,000
4	50	10,000	100	15,000	200	20,000	31500	1,000, 000
6	50	15,000	1000	100,000	1250	150,000	63000	2,000, 000
7	50	10,000	100	17,500	315	35,500	1250	110,000
8	20	5,000	315	30,000	500	45,000	2500	95,000
9	50	10,000	500	50,000	1000	100,000	63000	2,000, 000
10	30	10,500	800	84,000	1250	119,000	4000	280,000
11	10	10,000	125	30,000	800	100,000	31500	2,000, 000
12	50	12,100	160	26,000	630	69,000	35000	720,000
13	30	9,000	1000	80,000	--	--	3150	330,000
15	50	11,500	500	43,000	800	65,000	12500	500,000
16	30	8,000	315	30,400	2500	150,000	3150	190,000
17	30	9,000	160	20,000	800	70,000	20000	1,100, 000
18	10	7,200	500	66,000	1000	105,000	2500	238,900
19	6.3	6,200	315	40,000	1000	120,000	6300	650,000
20	20	15,000	30	185,000	--	--	--	--
21	20	6,500	400	50,000	1600	120,000	40000	2,000,000
22	30	9,000	315	37,500	2000	145,000	7000	425,000
23	30	8, 500	315	20,000	1000	90,000	25000	1,100,000
24	30	9,000	250	35,000	1000	85,000	1600	150,000
25	50	9,000	125	16,000	1000	65,000	1600	100,000
26	30	8, 100	400	39,000	1600	98, 000	2500	140.000
27	30	8, 500	400	41,000	1250	95,000	2500	150.000
28	10	3,500	100	15,000	1600	85,000	20000	1,000,000
29	50	15,000	160	30,000	315	40,000	800	90,000
30	20	6,000	315	30,000	1250	110,000	1600	150,000
31	160	16,500	800	40,000	1600	150,000	3000	245,000
32	30	7, 500	400	36,000	2500	165,000	35000	Rejected
33	5	3,000	315	40,000	1600	145,000	2000	165,000
34	30	9,000	315	32,500	500	45,000	12500	540,000
35	10	5,000	500	50,000	1000	90,000	2500	150,000
36	10	4,800	315	29,000	400	36,500	2500	152,000
39	10	4,000	100	15,000	2000	160,000	25000	1,000,000

[15] Some enterprises do not produce oil-immersed type distribution transformers or dry-type distribution transformers, but such case is not included in the table.

No.	Oil-immersed							
	Minimum capacity		Median 1		Median 2		Maximum capacity	
	Capacity type (KVA)	Price (RMB/set)	Capacity type (KVA)	Price (RMB/set)	CAPACITY TYPE (KVA)	Price (RMB/set)	Capacity type (KVA)	Price (RMB/set)
41	50	20,000	160	35,000	500	70,000	2500	265,000
42	30	8,800	400	40,000	1250	100,000	3150	210,000
43	10	5,500	400	40,000	800	110,000	2500	170, 000
44	10	9,000	1000	100,000	2500	230,000	180000	7, 000,000
45	30	10,000	315	30,000	800	80, 000	3150	190,000
46	50	8, 000	400	45,000	2500	150,000	63000	1,000,000
47	30	9,500	315	26,000	630	46,000	1250	82,000
48	30	10,000	125	20,000	--	--	2500	200,000
49	30	8,000	1600	132,000	2000	162,000	2500	204,000

2 Research findings of price of dry-type three-phase non-excited distribution transformers

No.	Dry-type							
	Minimum capacity		Median 1		Median 2		Maximum capacity	
	Capacity type (KVA)	Price (RMB/set)	Capacity type (KVA)	Price (RMB/set)	Capacity type (KVA)	Price (RMB/set)	Capacity type (KVA)	Price (RMB/set)
1	200	30,000	1000	120,000			2500	255,000
2	50	20,000	1000	100,000	2000	170,000	2500	200,000
3	400	60,000	800	110,000	1600	185,000	12500	1,000, 000
5	10	10,000	400	60,000	1000	120,000	4000	360,000
6	300	55,000	613	100,000	800	120,000	2000	200,000
9	50	30,000	1000	100,000	1600	165,000	2500	200,000
10	30	27,500	800	125,000	1250	170,000	4000	450,000
11	30	15,000	125	50,000	800	120,000	6300	1,000, 000
12	30	11,000	400	60,000	800	110,000	2500	200,000
13	30	15,000	800	110,000	2500	275,000	12500	2,000, 000
14	50	30,000	1600	195,000	2500	315,000	16000	1,650, 000
16	30	13,000	400	55,000	800	78,500	3150	265,000
17	30	12,000	100	23,000	800	90,000	2500	250,000
18	30	27,000	500	90,000	1000	157,000	2500	316,000
22	100	20,000	--	--	--	--	2500	235,000
25	315	50,000	1000	Rejected	1600	155,000	2500	200,000
26	30	17,000	315	52,500	800	99,000	2500	200,000
28	80	23,000	400	58,000	1250	85,000	2500	200,000

No.	Dry-type							
	Minimum capacity		Median 1		Median 2		Maximum capacity	
	Capacity type (KVA)	Price (RMB/set)	Capacity type (KVA)	Price (RMB/set)	Capacity type (KVA)	Price (RMB/set)	Capacity type (KVA)	Price (RMB/set)
31	160	36,500	800	110,000	1600	180,000	3000	420,000
32	50	Rejected	1000	120,000	800	110,000	2500	245,000
33	50	18,500	400	60,000	800	110,000	2500	245,000
34	50	20,000	315	Rejected	1000	Rejected	2500	175, 000
35	10	10,000	500	100,000	1000	180, 000	2500	300,000
36	400	65,000	--	--	1250	130,000	1600	165,000
37	50	30,000	630	90,000	1600	185, 000	3150	265,000
38	30	12,000	125	40,000	1000	130,000	2500	260,000
39	30	14,000	400	63,000	2000	200,000	2500	260,000
40	50	45,000	1000	140,000	1600	180, 000	20000	1,900,000
41	100	40,000	160	65,000	500	125,000	2500	455,000
42	50	19,000	400	60,000	1250	120,000	2500	210,000
43	50	20,000	315	60,000	2500	240,000	3750	300,000
44	30	13,000	1000	125,000	1600	185, 000	2500	260,000
45	30	12,500	400	59,000	800	100,000	3150	210,000
46	50	17, 500	400	67, 000	2500	240,000	6300	590,000
47	30	22,000	315	45,000	630	67, 000	1250	106,000
48	30	12,500	125	23,000			2500	230,000





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