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Study on quality control method of distribution transformer based on life cycle theory

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ABSTRACT

The government sampling inspection pass rate of Distribution Transformers (DTs) is less than 75% in China, which causes serious impact to the product quality and brings serious security risks. In order to improve the whole quality of DTs, it has important significance to study quality control method. The main quality defects and reasons of the DTs are introduced. The game theory of sampling inspection is analyzed. The method of establishing quality information system of DTs based on life cycle theory is proposed, which includes production, installation, operation and maintenance process. The DT's quality control method based on life cycle information is study on. The effect of the method is verified by the large power transformer sampling example.

INTRODUCTION

In recent years, China distribution equipment enterprises increase investment, expand the throughput, which causes the DT market overcapacity and fierce competition [1]. The enterprises take low price competition strategy, while some hold down cost deliberately, in order to take the market share. A few enterprises use the inferior raw material (such as instead of copper wire with aluminum, used silicon steel sheet) during the production process in order to reduce the costs, which causes the loss, partial discharge and temperature rise of DTs unconformity.

It also causes serious impact to the product quality, and brings serious security risks. The government sampling inspection pass rate of DTs is less than 75% in recent three years. It has important significance to study quality control method to improve the whole quality of DTs.

QUALITY DEFECTS ANALYSIS

The government entrusts the specialty testing institution to inspect the DTs by sampling from 2009 to 2011. The testing items include measurement of winding resistance, voltage ratio and check of phase displacement, short-circuit impedance and load loss, no-load loss and current, separate source AC withstand voltage test, short-duration induced AC withstand voltage test, temperature rise, measurement of partial discharge and insulating oil test. 87 DTs are tested, 22 of them unconformity, where the pass rate is less than 75%. The detail information is shown in table I.

Table I the sampling test pass rate of 2009-2011

Date	Total sample	unconformity	Pass rate
2009	29	7	75.9%
2010	29	6	79.3%
2011	29	9	69.0%
total	87	22	74.7%

The unconformity items mainly include temperature rise, load loss, no-load loss and partial discharge.

Temperature rise
Temperature rise test checks the DT's heat, which is determined by the loss of DT. For the oil-immersed type DT, the influence factors of cooling include product structure, winding up state, oil tank capacity and radiator area, oil circulation. For the dry-type DT, it is related to the air ventilating duct of core and windings, insulation wrapping, resin-casting.

DT temperature rise test belongs to type test, and few enterprise tests the item before its delivery. It is difficult to detect the defect. Due to the irregular market competition, some enterprises reduce the oil tank capacity and radiator amount, decrease the design margin of conductor and core, and even use the inferior materials, in order to reduce the cost. All of that result in excessive temperature rise of the DT, which will accelerate the aging of the insulation materials. It also affects the DT useful life, security, reliability, and even leads to short-circuit, accident, which brings safe hidden trouble to the user.

No-load loss and load loss
The no-load loss of DT mainly comprises hysteresis loss and eddy-current loss. Hysteresis loss depends on the silicon sheet steel materials. Eddy-current loss is related to the flux density, thickness of silicon sheet steel and the frequency. The load loss of DT is mainly consisted of windings and leads resistance loss. The additional losses caused by leakage flux take very small proportion [2]. The unconformity of those items is mainly because of enterprise's dishonest behavior. Some enterprises decrease the design margin, without considering the raw materials and production process deviation, in order to reduce the materials cost.

QUALITY CONTROL THEORY ANALYSIS

Key factors to the product quality
Product quality not only constraints by interior of the enterprise, but is also affected by the external environment [3]. The quality problem is not limited to only enterprise its-self; it is also related to the whole society. The key factors affecting the product quality are from of enterprise interior, including the enterprise lead's cognition, quality organization level, worker's actual ability, high quality raw materials, advanced technique and equipments, reliable inspection.

Game theory of sampling inspection
The selection mode of the rules for the enterprise depends on the total income, including obeying rules income R_1, disobeying rules income R_0, and the probability punishment for disobeying rules F. If $R_1 > (R_0-F)$, the enterprise probably obey the rules; if $R_1 < (R_0-F)$, the enterprise may not obey the rules [4][5].

Hypothesis
①$N=\{1,2\}$ is a set of the two sides in the game. 1 stands for the enterprise. 2 stands for the sampling inspection unit.

②$\Theta=\{\theta_0,\theta_1\}$ is the enterprise type space, which is private information of the enterprise. The sampling inspection unit does not know the value of θ, but can get the probability of θ:

$P\{\theta=\theta_1\}=\alpha$;
$P\{\theta=\theta_0\}=1-\alpha$;
where
θ_1 the enterprise obey the rules
θ_0 the enterprise not obey the rules

③$M=\{S_0,S_1\}$ is a set of enterprise signal space.
where
S_0 the enterprise does not put up production and sales.
S_1 the enterprise still puts up production and sales.

④$A=\{a_0,a_1\}$ is a set of the sampling inspection unit action. a_0 stands for no sampling. a_1 stands for sampling.

Game Sequence and solution
First step: the enterprise select the signal $m(\theta)=S\in M$ based on the private information. It means the enterprise can select to produce and sale the conformity or unconformity product.

Second step: the sampling inspection unit observes the signal S_k, k=0,1, and then form the inference about type θ : $\pi_k=p\{\theta=\theta_1|m=S_k\}$, k=0,1。

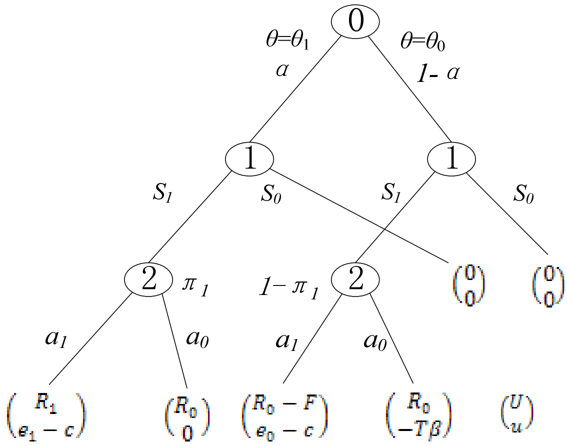
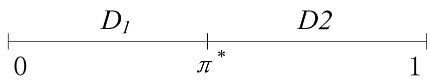


Fig.1 game sequence diagram

It is solved that the sampling inspection unit inference complied with the sub-game refined Bayesian equilibrium, and the enterprise inference complied with the sub-game refined Bayesian equilibrium. The solution is shown in the follow figure.



$$\pi^* = \frac{e_0 - c + T\beta}{e_0 - e_1 + T\beta}$$

where
c the cost of sampling inspection unit.
e_1 the reward sampling inspection unit obtained without finding the quality defects, according to the rules.
e_0 the reward sampling inspection unit obtained, when they find the quality defects.
T the punishment for the sampling inspection unit nonfeasance.
β the probability that sampling inspection unit nonfeasance can be found.

When $\pi \in D_2$, namely $\pi^* < \pi \le 1$, it is pooling equilibrium.
When $\pi \in D_1$, namely $0 < \pi \le \pi^*$, it is pooling equilibrium.
Only π^* close to 1, namely $e_1 = c$, and $R_0 - F < 0$, it is separating equilibrium.

The award sampling inspection unit obtained should not be less than the inspection cost, and the punishment should more than the disobeying rules income.

R_0*, *R_1* and *F

The value of R_0, R_1 depends on the enterprise. It can be regarded as fixed in a period. The value of F is proportional to f_s, p_s, p_c, c_p, namely

$F=f(f_s,\ p_s,\ p_c,\ c_p)$,

Where
f_s the frequency of sampling inspection.
p_s the probability of finding defects by sampling inspection.
p_c the probability of enterprise's problem.
c_p the loss because of the punishment.

The values of f_s, p_s, c_p are related to the sampling inspection. The reasonable value of F can be obtained though scientific setting, which makes $R_1 > (R_0 - F)$.

THE QUALITY CONTROL METHOD

The life cycle quality information system

The life cycle quality information of DTs covers the following stage: purchasing, design, manufacturing, packaging, transportation, installation, debugging and operation. The analytic hierarchy process can be used to classify the quality defects of DTs [6]. The life cycle quality information system can be established, which can provide support to enhance the quality control. The DT quality information should include the enterprise information, product type, technique requirement, project name, the quality defects, classification of defects, weight of defects, date information, detailed analysis, improvement measures, and information source.

The quality control method based on life cycle theory

The ultimate goal of enterprise management is profit. In order to guide the enterprise pay attention to quality, the reasonable profit R_1 should be guaranteed in the purchasing period. Based on the DT life cycle quality information, the sampling inspection method is ordinarily adopted, combination with the manufacturing supervision.

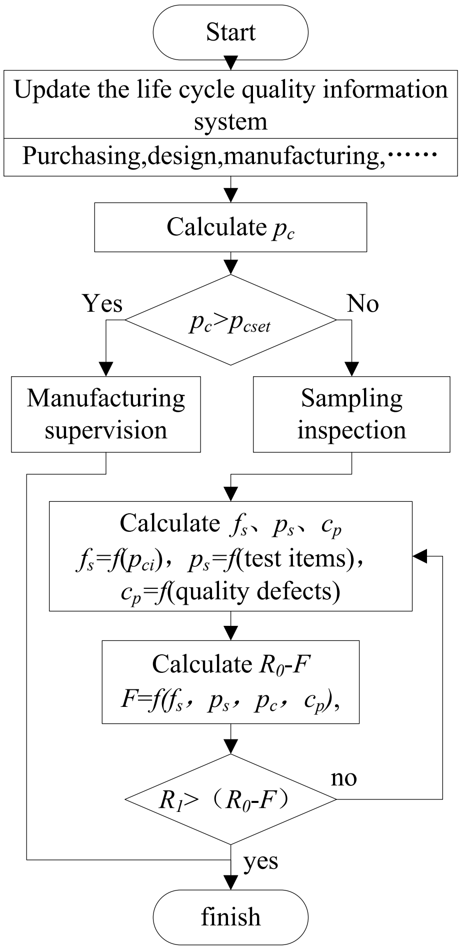


Fig.2 quality control flow based on life cycle information

According to the contract, the manufacturing supervision enterprise constitutes an expert group to supervise and witness the DT manufacturing process and schedule [7]. The whole manufacturing process can be witnessed, but the cost is high. It is applied to the enterprise with more problems. The sampling inspection is to test the sample of product. The items include product performance, parameters, raw materials and components[8]. The quality control flow based on life cycle information is shown in fig. 2.

p_c can be obtained though the DT life cycle quality information system. Compared p_c with p_{cset} in size, the manufacturing supervision method is taken, when the enterprise has more quality problems. Otherwise, the sampling inspection method is adopted. p_c is proportional to f_s, which should be higher to enterprise with more problems.

p_s depends on the scientific sampling inspection method, closely related to the test items. The items should be tested, which are easy to find problem and have serious influence to the security operation, such as the following items: temperature rise test, short-circuit impedance, no-load loss and current, separate source AC withstand voltage test, short-duration induced AC voltage test, measurement of partial discharge. Some time short-circuit withstand test can be taken to check the DT short circuit withstand ability. We also can disassemble the DT to check the materials of conductor and silicon sheet steel.

It is determined by the punishment measures largely, whether sampling inspection plays the role. The punishment measures should consider the DT's quality defects and lost.

EXAMPLE ANALYSIS

State Grid Corporation of China organizes the specialty testing institution to inspect the large power transformer enterprises inner by sampling. Considering the cost and effect, the test items include measurement of no-load loss and current, short-circuit impedance and load loss, long-duration induced AC voltage test, determination of sound level. On basis of the analysis of enterprise product quality defects, the sampling inspection frequency should be increased to the enterprise with more problems. According to the game theory of sampling inspection, the corresponding punishment should be taken to the enterprises for their unconformity product.

81 large power transformers were sampled and tested from 2008 to 2011, and 9 of them were unconformity. The pass rate of the sampling inspection increased from 83% in 2009 to 95% in 2011.

CONCLUSION

The government sampling inspection shows that the sampling inspection cannot solve the problem without the corresponding punishment measures. It only reflects the problems of the DT industry and enterprises.

The game theory of the sampling inspection and example are analyzed. The validity of the quality control method is approved, which is based on life cycle information. Through the reasonable frequency, scientific methods and punishment measures, the risk of breach of contract will be increased and the costs of breach of contract will rise up. The quality supervision effect will be given full play to.

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