ANNUAL REPLACEMENT DECISION-MAKING OF ELECTRICAL EQUIPMENTS IN DISTRIBUTION NETWORK

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ABSTRACT

As a solution, a new method considering both network reliability and equipment economy is presented in this paper. It consists of two parts: equipment-replacing necessity decision-making, which is used for all electrical equipments to select annual replacing ones in the network with equipment-replacing probability index, aiming at reliable power supply; and equipment-replacing option decision-making, which is used for each replacing equipment to find out the best replacing option among three alternatives with equipment-replacing B/C ratio index, considering its performance improvement. The proposed method is successfully applied to Shanghai Siping Community, and contributes valuable reference to its annual replacement plan of electrical equipments in distribution network.

INTRODUCTION

In the planning and construction of power grids, it needs the annual plan for equipment replacement. With reasonable repair equipment, transformation and updating of the plan, power grids will be safe and economic to provide a solid guarantee. As a result, the decision-making study of equipment replacement methods of the possible distribution will be a practical significance.

Although the current method of distribution for the replacement of the decision-making equipment has provided a very good idea, power is different from other sectors of production. Its power grid integrity, continuity and reliability of electric power, and these special requirements of the decision of the distribution network equipment replacement decision-making need to combine the characteristics of its own power grid. This kind of research has been few in the world [1].

This paper, combined with the reliability of power supply equipment and economic change the annual distribution network equipment decision-making methods, methods with two parts: 1) the whole network equipment replacement needs of decision-making in order to ensure reliable electricity distribution network for the goal and change the use of indicators to determine the percentage of annual turnover of equipment; 2) a single decision-making equipment replacement program, considering the replacement of equipment to improve performance, use the benefits of the use of replacement equipment indexes to determine the replacement program. This method has been applied in Shanghai Siping area successfully and provides a good reference for information.

REPLACEMENT NEED OF DECISION-MAKING FOR NETWORK EQUIPMENT

Power equipment replacement is carried out gradually for each year, from the point of view of the power supply to ensure the reliability of equipment and economic, first of all to determine which network equipment need be replaced.

The exchange percentage concept is proposed in this paper:

$$EP = \frac{Num_r}{Num_e} \times 100\% \quad (1)$$

Num_r - The number of possible replacement of equipment. The basis for the replacement judge is that the device's actual service life of such equipment is more than the average length of replacement;

Num_e - Power in the total number of such devices.

As a judge standard, with an average turnover to determine the number of years, it is necessary to satisfy both requirements: 1) the low cost of use of equipment in the life of the average annual use of can ensure that the business of economic production, more than the number of years after the equipment rapidly rise in the cost of using it will be difficult to maintain the requirements of the input-output; 2) reliable operation of equipment in the life of the equipment failure rate lower, to ensure the reliability of the power grid to meet certain requirements over the years, equipment failure increase will affect the reliability of the electricity grid. Combined with practical experience in the power of workers, part of this paper, electrical equipment, the average length of change (recommended value), as shown in table 1.

Tab.1 Physical life and average replacement life of some electrical equipments (proposed values)

Equipment	Physical service	The average length of

	life	replacement
Cable	25	20
Overhead	12	10
Main transformer	12~18	15
Switchgear	15~20	12
Distribution transformer	10~20	10

Possible exchange percentage of targets is a relative concept. Using these indicators to determine each year planning period (hereinafter referred to as "planning") of the replacement equipment, the value of the benchmark indexes through the year and planning to achieve value. Concrete steps are as follows:

(1) Statistical classification of the status of the equipment has been used in years, according to the average number of years into the possible replacement of the replacement equipment, various types of equipment may be obtained percentage change;

(2) To identify various types of equipment, the benchmark indicator of value, if the reliability of the grid is high, use the value as the base year value, if the the reliability of the grid is not ideal planning or construction of power grids more reliable requirements, it need re-set the benchmark indicators of value;

(3) Planning in all types of computing devices may change the percentage of targets;

(4) For each type of equipment, to determine whether the value in planning to meet the requirements (for example: less than or equal to the value of the base). If it does not meet the requirements of the election, such that may change with age and has the largest equipment as replacement of equipment;

(5) For each type of equipment, equipment replacement may be deducted step (4) to determine the replacement equipment, step back to the (3), re-planning in all types of computing devices may change the percentage of indicators to judge until the index value to satisfy Requirement.

DECISION-MAKING OF A SINGLE EQUIPMENT REPLACEMENT PROGRAM

Planning identified the need for change in the power network equipment, for a single device, it need to further determine how we are going to change in most economical and reasonable way.

In practice, equipment replacement program are the following:

(1) Overhaul of the equipment: for original equipment continues to overhaul its operation in order to extend the service life;

(2) The replacement of equipment: running out of the economy and reliability considerations, the original equipment with models of TM;

(3) To update the device: As the development of the power grid, and other requirements of the existing equipment will be updated to better performance of the equipment.

The equipment replacement will have a certain amount of benefits, such as: the ability to increase the electricity supply grid, and so on. Traditional methods often assume that the same benefits to the level of costs as a judge of the merits of the standard program, which concluded the lack of rationality. Therefore, this paper proposed replacement of equipment indicators from the viewpoint of replacement of equipment to improve the performance:

$$ER = \frac{B}{C} \tag{2}$$

Where: B - efficiency; C - replacement costs.

Here, for the understanding of the benefits after the replacement of equipment than the original to raise the most obvious technical performance, such as: updated 31.5MVA main transformer to 40MVA, the main change is effective capacity. Obviously, the larger the index value, the better economy corresponds to the technical change.

The three programs, and its replacement cost is calculated as follows.

Equipment overhaul

$$C = \left[R + \sum_{t=1}^{N_c} \frac{OC_t}{(1+i)^t} - \frac{S_{N_c}}{(1+i)^{N_c}} \right] \times \frac{i(1+i)^{N_c}}{(1+i)^{N_c} - 1} \tag{3}$$

Where: R - the cost of major repairs; N_c - period calculate overhaul; OC_t - original equipment t year costs of operation and maintenance; S_{N_c} - years after the original equipment residual value; i-discount rate.

N_c can be obtained from (4)

$$N_c = N_p - (N - N^*) + 1 \tag{4}$$

Where: N_p - The average replacement age of equipment; N - the original equipment life; N^* - original equipment after the overhaul of economic life, the value of new equipment for the physical life, to meet the constraints: the replacement cost of the smallest year.

S_{N_c} can be obtained from (5)

$$S_{N_c} = \max\left(I_{old} - (N + N_c) \times I_{old} \times r, I_{old} \times \lambda\right) \tag{5}$$

Where: I_{old} - original equipment initial investment; r - the rate of depreciation of equipment; λ - the rate of residual value of the equipment.

The replacement of equipment

$$C = \left[I_{new} + \sum_{t=1}^{N^*} \frac{OC_t^{'}}{(1+i)^t} - \frac{S_{N^*}^{'}}{(1+i)^{N^*}} - S_0 \right] \times \frac{i(1+i)^{N^*}}{(1+i)^{N^*} - 1} \quad (6)$$

Where: I_{new} - an initial investment of new equipment; N^* - after the new equipment to replace the economic life of the value of new equipment for the physical life, to meet the constraints, the replacement cost of the smallest year; $OC_t^{'}$ - new equipment t years of operation and maintenance costs; $S_{N^*}^{'}$ - After years of the new equipment residual value, calculated with the type (5) similar to that at this time to replace I_{new} for I_{old} and replace N^* for $N + N_c$; S_0 - the original value of existing equipment, and the calculation of its type (5) similar to that at this time to replace N for $N + N_c$;

Update equipment

And the method of calculation to replace a similar program, see-(6). The three programs, equipment replacement benefits than the present value of the indicator is the largest of the best programs, but the program also needs to identify common planning requirements.

Taking into account the completion of the replacement of equipment in more than the average number of years after turnover, it will change the next decision-making. There are certain constraints limits for decision-making equipment replacement program of economic life. The overhaul program, equipment life after the deduction of economic life of its value can not be greater than the average length of replacement; for replacement and update program, equipment economic life can not be greater than the average length of replacement.

Taking into account the continuity of the policy-making of annual replacement of equipment, the completion of the replacement equipment may not participate in the next year or even years after need to change the decision-making. Therefore, it must be based on the final package of equipment which has been updated with age. That the overhaul program years will be deducted from the economic life of equipment has been used as a new age; for replacement and update program has been used for a number of years.

EXAMPLE

Taking 10kV network of Shanghai Siping community for example, we verify the effectiveness of decision-making method of distribution annual replacement of equipment.

The calculation of the EP percentage of network

From Table 1 (the average length of replacement), Siping statistical distribution network (2005) cable, the main transformers, distribution transformers and switchgear equipment, various types of computing devices may be the percentage of replacement indicators, as shown in table 2.

Tab.2 the equipment-replacing EP values of some electrical equipment in Siping distribution network in 2005

Equipment	Num_e	Num_r	*EP*
Cable	464	15	3.23%
Main transformer	6	0	0
Distribution transformer	58	7	12.07%
Switchgear	227	0	0

The benchmark value indicator

Reliability of Siping community of the status quo power grid is high, reaching 99.99 percent, and operating equipment is in good condition with the reliability of power grids to meet the requirements. Therefore, various types of equipment could change in the percentage of the value of the base, planning the replacement of equipment.

Planning in the whole network equipment replacement plan

Take 2006 as an example to show the whole network equipment plans. Through the years to ensure that the various types of equipment may change the percentage of the value is not more than the benchmark indicator of value in 2006, as show in Table 3 and 4.

Tab.3 The general replacement plan of some electrical equipment in Sipng distribution network in 2006

Equipment	*EP*	replacement plan
Cable	3.66%	2 replacement for more than 20 years of cable
Main transformer	0	none
Distribution transformer	20.69%	6 replacement of more than 10 years of distribution transformer
Switchgear	0	none

Tab.4 The detailed replacement plan of some electrical equipment in Siping distribution network in 2006

Cable		Distribution transformer	
name	operation time	name	operation time
Chifen 71-55	1983	Anshan four1#	1995
Chi 15	1978	Anshan four2#	1995
		ICBC 1#	1994
		ICBC 2#	1994
		Lianmi 1#	1988
		Lianmi 2#	1988

A single equipment replacement plan

Take ICBC # 1 for example as how to develop single

equipment replacement plans.

In 2006, ICBC# 1 of life span is 13 years, the average change over the years (10 years), based on the entire network equipment replacement plan, so it need for change. Replacement of three existing programs:
1) Overhaul: overhaul of the original equipment cost of initial investment (119,300 yuan) 30% of the physical life extension of up to 4 years;
2) Replacement: a new type of equipment with an initial investment of 150,000 yuan for the physical life of 15 years;
3) Update: New equipment from 300kVA capacity increased to 400kVA, the new equipment for the initial investment of 200,000 yuan, the physical life of 15 years.

According to the provisions of the power sector, taking the rate of depreciation for equipment 0.0792, and the residual value of the rate of 0.05, the discount rate to 0.1, the calculation of the three equipment replacement program benefits than this, its parameters and results as shown in Table 5 to 7.

Tab.5 The equipment-replacing B/C ratio of the transformer by major repair

Indicators	R(Million)	OC_t(Million)		S_{Nc}(Million)
Value	3.58	0.08		0.60
Indicators	N_c (year)	C (Million)	B (kVA)	ER (kVA/ Million)
Value	2	1.86	300	161.48

Tab.6 The equipment-replacing B/C ratio of the transformer by equivalent substitution

Indicators	S_0 (Million)	I_{new} (Million)	OC_t' (Million)	$S_{N'*}$' (Million)
Value	0.60	15	0.06	3.12
Indicators	N* (year)	C (Million)	B (kVA)	ER(kVA/ Million)
Value	10	2.21	300	135.85

Tab.7 The equipment-replacing B/C ratio of the transformer by advanced substitution

Indicators	S_0 (Million)	I_{new} (Million)	OC_t' (Million)	$S_{N'*}$' (Million)
Value	0.60	20	0.08	4.16
Indicators	N* (year)	C (Million)	B (kVA)	ER(kVA/ Million)
Value	10	2.98	400	134.37

Comparing the three programs, the ICBC # 1 take overhaul of the equipment replacement program benefits the largest ratio, the area of the economy the best technology, equipment repair program in 2006 to take the most economical and reasonable. In addition, the device has been used to update the age of 9 years.

CONCLUSION AND OUTLOOK

Equipment replacement for the traditional method of decision-making does not fully reflect the distribution network reliability and economy of the lack. This paper combined with the reliability of power supply equipment and economic to change the annual distribution network equipment decision-making method of the main advantages is:
(1) In close connection with the method of characteristics power network, to ensure that the entire network for reliable power supply to determine the starting replacement of equipment, from the program to optimize the cost-effective technology to determine the starting replacement program to ensure that the planning of the annual replacement of equipment not only meet the requirements of the reliability of power grids, but also has a good technology economy;
(2) In the whole network equipment replacement needs of decision-making, may be adopted by the percentage change indicators will need to replace equipment and the reliability of the power grid linking the replacement of equipment not only embodies the power grid requirements of economic production, but also reflects the power grid reliable supply of electricity requirements;
(3) In a single decision-making equipment replacement program, through the replacement of equipment than the target of this benefit will be the cost of replacement equipment and technology linked to the benefits, taking into account the cost of replacement at the same time take into account the replacement of the power network equipment to improve the performance of the role;
(4) Methods for the development of distribution network equipment, replacement of the annual plan to provide reference for information, promotion of good practical value.

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BIOGRAPHIES

Saiyi WANG was born in Ningbo, Zhejiang Province of P.R. China, on January 30, 1978. He received his Ph.D. in electrical engineering in Tianjin University. He is the vice-director in Planning & Development Department of the company and his research interest is distribution system planning.