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LIFE CYCLE COST OF DISTRIBUTION SWITCHGEAR EQUIPMENT

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SUMMARY

As in many power distribution and transmission utilities the process of asset management instead of a classical approach comes, some economical and organizational aspects of asset management are highlighted. Examples of cost breakdowns are given. There are many approaches for evaluation of customer’s benefit. While in the past the investment cost were considered as a most important evaluation criteria for comparing different solutions, nowadays the all life cycle cost becomes more important. The goal of any user to minimize the life cycle cost can be achieved by detailed knowledge about the specific parameters and their influence on the life cycle cost.

One of the most important factors, which influence on the life cycle cost, is interruption of energy flow due to major failures. The second factor is life extension of high voltage equipment. This factor can influence on the great saving of money and postponement of investments. In this paper some aspects of the extension of the circuit breaker life is presented.

At the end of the paper an experience about cost breakdowns in one important utility (distribution of power energy) is outlined as guideline for the future work on asset evaluation.

Keywords

Life cycle cost, Asset management, Risk management, Value based comparison, Life management, High voltage switchgear,

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1. INTRODUCTION

Planning new installations is looking for the best solution. Usually this means having the choice between various technologies and suppliers and the procedure to evaluate them. Of course, technical specifications have to be met as well as economical considerations. The price of equipment plays an important role, but is not alone. The other criteria influence decision making as well, and are increasingly gaining importance.

Life cycle cost analysis focuses on the economic impact of an investment, taking into account its entire lifetime. The life cycle costs are the sum of investment costs, failure interruption costs, operational and maintenance costs. For the initial investment costs the price for the switchgear components is a substantial part. Additionally we can take into account land cost, witch vary too much depending on the country and specific location. The other costs are engineering design, civil work on site, permissions, purchase of equipment, installation, training of staff, and price of commissioning of the substations. Operation and maintenance include costs of operation, maintenance and costs of planned service interruptions. At the end are failure interruption costs, that is penalties on power interruption and repair costs.

Before liberalization, the main driving force for the network development was the increase of demand, the connections of new power plants and high reliability of the network. But, with liberalization, the management focus shifted from extending the network capacities to life extension and further utilization of the existing plant. The liberalization is knocking at our door, too. The emphasis is put on the economic performance of the networks and there is a tendency to consider the short term rather than longer term view in decision making. The social and ecological requirements become very important.

There exists a certain discrepancy between the way of thinking of technical experts (long term solutions, less technical risk, large efforts for optimal results) and the way of thinking of economists (short term profit, less financial risk, etc.). The decision making process performed by asset management is first of all a process of ranking priorities and alternative solutions. Far more then in the past, ranking is ruled by economic and financial considerations rather than technical aspects. In the past the management focus was towards the technical infrastructure. Today, the focus is shifted towards the cost and quality of supply to the customers. The technical experts prefer to solve capacity and quality problems by state of the art solutions, which are also sound from a strategic point of view. The complete solutions would be essentially applicable to the whole network and for the long term. The truth is that the existing and solid solutions chosen some decades ago still performing sufficiently, thus avoiding extra costs for refurbishment, replacement or extension of capacity.

On the other side, financial experts prefer solutions with short-term profitability. A postponement of investments is also an advantage from the point of view of economic risk control of the uncertainty related with future developments. The policy is to look for the solution that gives the lowest costs for the short term. Financially oriented people looking for the solution that gives maximum profit for minimum costs.

The third approach to the technical and the financial approach is the risk management approach. Risk management can be defined by technical items like reliability, availability, maintainability, or by financial risk items. The examples are reliability-centered maintenance, end of life estimation, spare parts policy, optimization of substation topology, protection schemes, and degree of telecontrol.

It is important that many economic issues need to be solved by the help of electrical engineers. Of course, coordination between engineers and economists is essential and indispensable because their problems are interleaved.

2. LIFE CYCLE COST BREAKDOWNS

The main goal is the optimization of investment and ownership cost under the aspect of life cycle considerations. There are two main issues:

- How a buyer of high voltage substation can optimize his investment to minimize the overall life cycle cost, and

- How the owner of high voltage equipment has to operate and maintain the substation for the same goal.

The life cycle cost can be evaluated in accordance to IEC 60300-3-3 [2]. That international standard proposes a general cost breakdown structure for high voltage applications.

The cost breakdown structure for this evaluation consists of three portions:

- Cost of acquisition,
- Cost of ownership, and
- Cost of disposal.

2.1 Cost of acquisition

The acquisition costs comprise all cost to the hand over of the installation to the user. The two main components are the cost of the equipment (system cost) and the cost of installation. It is naturally to distinguish system cost from installation cost because the installation cost can be influenced by the supplier or by buyer of equipment. In the case of compact solutions the installation cost is normally an integral part of the system cost. In other words, in that case supplier should to install equipment.

The cost of acquisition consists of:

- System cost is cost of supplied system:
  - Switchgear, control and protection systems,
  - Engineering of system supplier.
- Installation cost
  - Transportation,
  - Land acquisition,
  - Civil works,
  - Installation,
  - Commissioning, and
  - Earthing, fences, gantries.

2.2 Cost of ownership

This cost portion contains all cost of the service period during the lifetime of the equipment. The time of occurrence of these costs is very long and they mast be capitalized. The cost of ownership consist of three major cost elements:

- Operating cost,
- Maintenance cost, and
- Unavailability cost.

Operating cost can be very diverse. First of all, these costs are the costs that are required for regular maintenance except the switchgear. For example, these costs are costs for GIS (Gas Insulated System) building or site maintenance in the case of air insulated systems (AIS).

The maintenance cost comprises material, labor and travel expenses to maintain the switchgear. Labor and travel expenses can differ extremely from country to country.

The planned maintenance cost depends closely on the applied maintenance strategies. Naturally, these are costs for planned maintenance.

The unplanned maintenance costs are all unexpected costs due to unexpected failures, which need repair or other maintenance activity.

The unavailability costs are all costs of potential outages. Due to fact that maintenance can be planned or unplanned, these costs also can be named as planned unavailability cost and unplanned unavailability cost.

The planned unavailability occurs during scheduled maintenance or extension work. The redundancy of the substation layout enables to avoid this unavailability cost.

The interruption of energy flow due to major failure is not a result of planned activity. There is the damage due to unavailable energy, characterized by unavailability cost.

2.3 Cost of disposal

Cost of disposal have to comprise all costs of decommissioning and disposal after use, subtracted by revenue which can be received by selling the reusable materials like spare parts, aluminum, copper etc. These costs must be capitalized.

Calculations of life cycle cost of a substation cover period, which is longer than the individual lifetime expectation of parts of the equipment. Some devices have to be replaced on individual intervals. Reinvestment cost of such equipment has to be taken into account until the end of the calculation period is reached. Life cycle costs for high voltage substations are 30 – 50 years. Due to this very long time, changes of the value of the money have to be respected by, for example, net present value. The effects of inflation should be taken into account.

3. SOME INFLUENTIAL FACTORS REDUCING THE LIFE CYCLE COST

3.1 Reliability and availability of the switchgear

The life cycle cost is influenced by many factors. Only three of them will be mentioned.

The first factor that greatly reduces maintenance costs is reliability and availability of the switchgear. While scheduled maintenance is based on the product recommendations, the unscheduled maintenance is mainly influenced by the reliability of the substation equipment. The deregulation increases demand on reducing the forced outages caused by equipment failures. There is a great interest to reduce the frequency and duration of outages. The high quality of switching and other equipment and condition monitoring provides a powerful tool to achieve this goal.

High power electrical equipment requires careful attention on production and testing as well as adequate training of personnel and appropriate handling during the service period. Both manufacturers and user have an influence on the availability of the switchgear. We can say that nowadays reached level of availability is normally influenced by the next several measures:

- Design and testing in accordance to relevant international switchgear standards,
- Interlocking systems to avoid human errors,
- Safe operation of the switchgear according to the instruction manuals,
- Qualified personnel,
- Adequate switchgear maintenance, and
- Limited access to the installation,

In any case, the average mean time between failures is increased over the years to impressive value. The modern high equipment is mature and reliable. The results of sensitivity analysis presented in [1] show the big importance of that factor. The essence of sensitivity analysis in [1] is in increasing of one factor by 10 % when the others are constant. How much is changed total life cycle cost in that case? The authors analysed three variants of one 145 kV H-scheme substations. The installation cost has a relative small influence on life cycle cost. That means that a high-qualified installation work can save later on money in terms of life cycle cost by reducing the number of failures. The influence of the cost of the amount of energy flow is much higher and consequently very important.

To conclude, the reliability and safety of equipment can save a great amount of money. But, the main question is: is it valid in Serbia and Montenegro due to absence of penalties which distribution company has to pay to utilities?

3.2 Technical progress in switching equipment design

The different technologies for high voltage substations can be classified into three groups:

- Conventional air insulated substations (AIS),
- Encapsulated gas insulated substations (GIS), and
- Compact switchgear solutions.

The first two groups are well known to our engineers. But, the third group of equipment is relatively new. Compact switchgear solutions are either hybrid solutions with a combination of AIS and GIS modules or special arrangements of AIS and GIS modules, mainly for outdoor usage. These are very compact design, which integrate the advantages of the GIS technology with the flexible approach of the AIS substations.

The AIS are optimized with SF6 circuit breakers. New switchgear technologies are hybrid modules with integrated control and monitoring functions. For example, dead (metallic) tank circuit breaker with integrated current transformer at the bushing is combined with classical AIS equipment. New are optimized GIS solutions for different station layouts with combined-functions such as circuit breaker/disconnector. Very interesting are mobile substations (on trailer), which are factory built and tested. Some switchgear is in a container or on a platform.

These solutions save the area for equipment and enhance reliability because they are factory built and tested.

3.3 Life management of circuit breakers

Another way to save money is life management of equipment. In this part of the paper we deal with circuit breakers because it is very important part of switching equipment. But, all is also valid for other equipment.

Circuit breaker life management covers all periods of the life of a group of circuit breakers (specifications, development, testing, erection, on-site commissioning, inspection, maintenance, diagnostics, monitoring, refurbishment, dismantling and disposal). Specifically, the term “life management” is related to the decision-making process with respect to circuit breaker life. That term refers to the circuit breaker’s remaining technical life. Other aspects such as economic, legal, organizational and environmental may also play a decisive role in the choice between refurbishment, replacement or continuing service without any action.

The residual life of a circuit breaker depends on the aging and wears phenomena and on the defects caused by improper design, production, erection, application or maintenance. Cumulating the stresses in service and comparing the results with the allowable level of accumulated stresses could monitor the aging and wear phenomena. The defects may develop into a minor or major failure, reducing the breaker’s performance and reliability. They are detected by inspection, diagnostic testing, monitoring, and maintenance and through malfunction. A data archiving system is required to discover which defects are systematic and which ones will influence the residual life of the circuit breaker group. Stresses, especially accumulated ones, are archived by monitoring systems, protection systems, SCADA systems and maintenance management systems.

The life extension of circuit breakers may be very important for cost reducing. This is in some sense the risky decision. Risk management covers such decisions because those actions can influence the major failure beginning. If there exist no problem with respect to the switchgear’s problem, the network extensions, the legal and environmental requirements, life extension will be normally a good option.

A well-known example of a life extension is the interval between major overhauls (dismantling) as given in the manufacturer’s manuals for single pressure SF6 gas circuit breakers. Initially it was roughly 10 years. These days' intervals of at least 20 years are given, with the manufacturers expressing a preference to extending that period and not dismantling the circuit breaker unnecessarily.

The most important components are the purchasing plus installation cost and the maintenance costs. The last component ordinary is the least known. Certain trends are:

- The purchasing cost of new circuit breakers is decreasing,
- The costs of installation are far less than those necessary for the older technologies (less civil works, less space, simpler secondary connections, simpler erection and commissioning),
- The maintenance costs of new breakers are lower,
- The costs of spare parts for the older technology breakers is increasing rapidly, and
- The know-how is decreasing.

Another saving of money is possible by extension of circuit breaker life. The technical life of circuit breaker can be equal to financial life. But, when the technical life of the equipment outreach the financial life by far, for number of years no depreciation costs will be charged and the department will get used to lower cost level. There is considerable profit from a number of years without the charge of the investment costs.

4. STATE OF THE BREAKDOWN COSTS TREATMENT IN SERBIA

In power utility "Elektrodistribucija Beograd" most of the above-mentioned costs are known. Some costs are known directly because they must be known in advance. The examples are system and installation costs.

One transformer station 110/10 kV in gas insulated switchgear technology is built in the center of a town. That is well-known H-scheme. Two transformers 40 MVA are applied. Some of the prices are:

Two transformers 40 MVA:	40 millions,
Switching equipment 110 kV:	40 millions,
Switching equipment 10 kV:	30 millions,
Protection, MTK and control equipment:	67 millions,
Transport of equipment:	2 millions,
Land cost:	86 millions,
Civil works:	275 millions,
Installation of HV equipment:	7,5 millions,
Installation of MV equipment:	4,5 millions,
Installation of LV equipment:	5 millions.

Operating and maintenance costs may be known, but a posteriori (analyzed for last period). It is known how many people work in maintenance and how many in control. The staff is divided in two groups – one for 35 kV and 110 kV, and the second for 0,4 kV and 10 kV. It is to be noted that a little effort is needed to collect and analyze these data.

Disposal costs are not known. Also, failure interruption costs for power utility and for consumers are not known.

5. CONCLUSIONS

Some conclusions can be done.

With liberalization of the electrical energy market, the management focus shifted from extending the network capacities to life extension and further utilization of the existing plants. The emphasis is put on the economic performance rather then technical one.

Due to the optimization of investment and ownership cost under the aspect of life cycle consideration, there is a need that cost breakdown structure be very well known.

In many power distribution and transmission utilities the process of asset management instead of a classical approach comes. In the paper the examples of cost breakdown are given. It is very important to know all of these costs if we want to minimize the life cycle cost.

Interruption of energy flow due to major failures is the most important factor.

In the distribution power utility "Elektrodistribucija Beograd" practically all of the costs except failure interruption costs are known or may be known with a little additional effort. There is a need to investigate the failure interruption costs more carefully because of their great importance.

Using risk management approach and technical progress in switching equipment design enables us the saving a great amount of money. Life extension of equipment is also very important in cost reducing and postponement of investments.

6. REFERENCES

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