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PARTIAL RECONSTRUCTION OF ELECTRIC POWER DISTRIBUTION EQUIPMENT

N. Pažin, "Elektrokrajina", Banja Luka, Republika Srpska
S. Kuzmanović, "Elektrokrajina", Banja Luka, Republika Srpska

ABSTRACT

This paper presents possibilities for instalation and connection of medium voltage switching equipment of various generations are described, along with various construction solutions and respective technical characteristics, taking in concern size of buildings, value of investments and maintenance costs. Also, we have to consider also importance of reconstructed objects. Here described partial reconstruction of the distribution switchgear, with such wide gap between new and existing generation of equipment, which lifetime have not expired, brings significant savings in investments, while increasing operational reliability of the distribution system.

1. INTRODUCTION

Extraordinary conditions, originated from the war conditions in Republika Srpska, caused disturbance in development and exploatation of electric power system (EPS). Severe power delivery reductions, phisical demages of equipment and instalations due to war actions, along with unacceptable electrical stress have caused degradation of EPS.

Need to rapidly revitalize whole EPS in peacetime, including distribution network, have resulted in break in process of introduction of new generation equipment and existent condition.

Modern distribution of electric power, considering its level of technical development, have to satisfy certain characteristics including:

- Quality of delivered power;
- Reliability;
- Economy.

Quality of electric power encompass following parameters, regulated by corresponding standards:

- U_{rms} stability, with allowable deviation;
- frequency stability, with allowable deviation;
- power factor, allowable value;
- allowable voltage asymmetry;
- allowable voltage fluctuation;

Along with mentioned, following is needed to be provided:

- human lives and property protection;
- environmental protection;
- simplicity;
- manageability;
- flexibility, adaption and evolution.

It is very hard to strike balance in cases when certain parts expected life has not expired, but there are needs to upgrade or replace equipment with new generation because of: worn-out equipment, move from 10 kV voltage level to 20 kV voltage network, grounded by a resistor, increase in load, need to improve reliability, need for remote operation, and need for facilitated maintenance and operation.

Connections of installations of various generations, constructions and technical characteristics, confined with site dimensions, make technical solution occasionally more complicated then it is to make new installation. However, gradual equipment replacement with new generation equipment, accompanied with minimal interruptions in power supply, mostly has economical justification. Correct answer to the raised questions can be found following the fact that investment value of installation and maintenance costs should be matched with power supply reliability and importance of consumers.

Full technical documentation is required for complete and high-quality completion of a project, in details:

- correction of location in accordance with adjustments required for new installation;
- installation documentation;
- correction of present wiring in accordance with wiring of new installation;
- verification of system parameters.

In this document we analyze possible, as well as implemented process of total or partial equipment replacement, based on technical-economical analysis.

2. EQUIPMENT IN HV/MV SUBSUBSTATIONS (110/20(10) kV)

In following text we analyze existing indoor circuit breakers for rated voltage level up to 24 kV. Choice of type of the switchgear include following elements, along with technical characteristics of power grid:

- switchgear price;
- land value;
- building value;
- operational safety and reliability;
- achieved level of technical development;
- ease of manipulation of equipment in normal and extraordinary mode of operation;
- compatibility with existing equipment;
- possibility for gradual equipment replacement, accompanied with minimal interruptions in power supply;
- remote operation and monitoring.

Existing switchgear can be divided in following groups:

- Classical, air-insulated switchgear, separated with wall and with fix-mounted circuit breakers;
- Prefabricated, air-insulated, open type, metal switchgear, with fix-mounted circuit breakers;
- Prefabricated, air insulated, metal-clad switchgear, with withdrawable circuit breakers.

3. CLASSICAL SOLUTIONS FOR PROTECTION, REMOTE CONTROL, SIGNALISATION AND MEASUREMENT FUNCTION

Classical solutions assume separated protection, measurement and remote control functions. Classical solution of secondary equipment characteristics in respect to modern integrated solutions are: extensive and complicated wiring, bigger equipment inside of switchgear, complicated implementation of manipulation blockades, limited flexibility in regard to multiple function usage, full self control of relays is complicated for implementation (more expensive relays with decreased reliability), and from those reasons periodical inspections and fitting is necessary, simpler and more robust construction (electromechanical relays), resistance on noise from secondary equipment.

Protection function that is implemented by means of electromechanical or static relays serves its function without problems no matter it is technically obsolete.

Multi-functionality of integrated solutions, global trend of rapid microprocessor technology development, increased reliability, continuous software improvements, as well as acceptable prices are pointing on conclusion that implementation of protection with electromechanical and static relays in new objects is irrational, because it complicate planning and construction, and especially maintenance.

4. DISTRIBUTION SUBSUBSTATIONS FOR POWER SUPPLY

Well-built, fast for construction and increased functionality is what makes concrete transformer subsubstations (CTS) suitable for urban areas. In basic, there are two types of BTS:

- compact CTS;
- prefabricated CTS.

Metal-enclosed transformer subsubstations (MTS) are usually located in urban areas, for their visual appearance is suitable for any location.

For coverage of rural and poorly populated areas load we use pole mounted transformer substations (PTS). Pole, on which TS is fixed can be concrete or steel. Elements of PTS are prefabricated, so they can be assembled very fast at chosen location. These TS are ussualy situated in the center of load, with aim to make connecting lines as shorter and easier to track as possible. Also, we have to take in concern easy access to PTS for construction or replacement of transformer.

5. NEW GENERATION OF PRIMARY AND SECONDARY DISTRIBUTION SWITCHGEAR FOR INDOOR CONSTRUCTION

Metal-clad switchgear, with withdrawable circuit breakers belong to the top of air insulated apparatus and their use along with type selection beside technical characteristics of grid encompass following elements: value of switchgear, land value, building value, operational safety and reliability, ease of manipulation of equipment in normal and extraordinary mode of operation, compatibility with existing equipment, possibility for gradual equipment replacement, accompanied with minimal interruptions in power supply.

All protection, monitoring and control equipment elements are located in LV compartment.

Here we have microprocessor protection, that has several advantages in compare with electremechanical and static protection, including:

- price;
- reliability;
- integration.

Modern trends in MV level switchgear design are focused on achievement of more compact and modular equipment. That help to achieve significant saving in space comparing to classical solutions.

Result of this development are gas insulated switchgear with SF_6 that are airtight with steel metal sheets, with use of advance welding technologies. All parts under voltage are separated in metal compartments, while circuit breaker drive mechanism and auxiliary equipment are accessible from outside, and fully separated from primary equipment.

All external causes of malfunctioning, such as moisture, small animals, dust, are eliminated. Basic characteristics of these switchgear are: modular structure, single bus system, three-position disconnector tah serve as bus disconnector and earthing (in some constructions), reliable earthing through vacuum circuit breakers, significant decrease in width of the switchgear in regard to air insulated installations, installation is airtight sealed with stainless steel metal sheets, they are designed mainly for cable connections (cable connection is possible by means of indoor or outdoor connecting equipment), and safe and reliable manipulation.

Constant progress in development and construction of installations and equipment based on SF_6 technique backed up with affordable price contributed significantly to their broad deployment during last several years. MV level SF_6 systems are very different from conventional solutions and we can consider them as totally new generation of installations and equipment. High insulation characteristics of SF_6 make possible construction of small, compact units. Also, use of gas insulation assume airtight compartments with primary equipment.

Justification for installation of prefabricated compact switchgear, designed in SF_6 technique (Ring Main Unit (RMU)), for distribution TS, are based on following technical characteristics, beside of significant saving in space:

- high reliability;
- unnecessary maintenance;
- maximal personnel safety;
- independence of weather conditions;
- remote control.

Taking in concern previously stated characteristics, one of the main advantages of RMU is opportunity to replace existing classical HV indoor switchgear, with air insulation, and all that with minimal interruptions in power supply and with minimal reconstruction of existing building. Replacement of present equipment can be phased with opportunity for enlargement, based on our needs.

Installation of motor drive, for purposes of remote control, is possible.

Construction of RMU enable simple cable connection in classical way, or by connectors, with preserved easy connection of cable testing equipment.

Problems that we encounter:

- Malfunction at any part of primary equipment require replacement of whole RMU, because users are not, in principle, capable to repair this by themselves
- User usually chose certain producer, because that solution require less spare parts in storage (including cable connectors).

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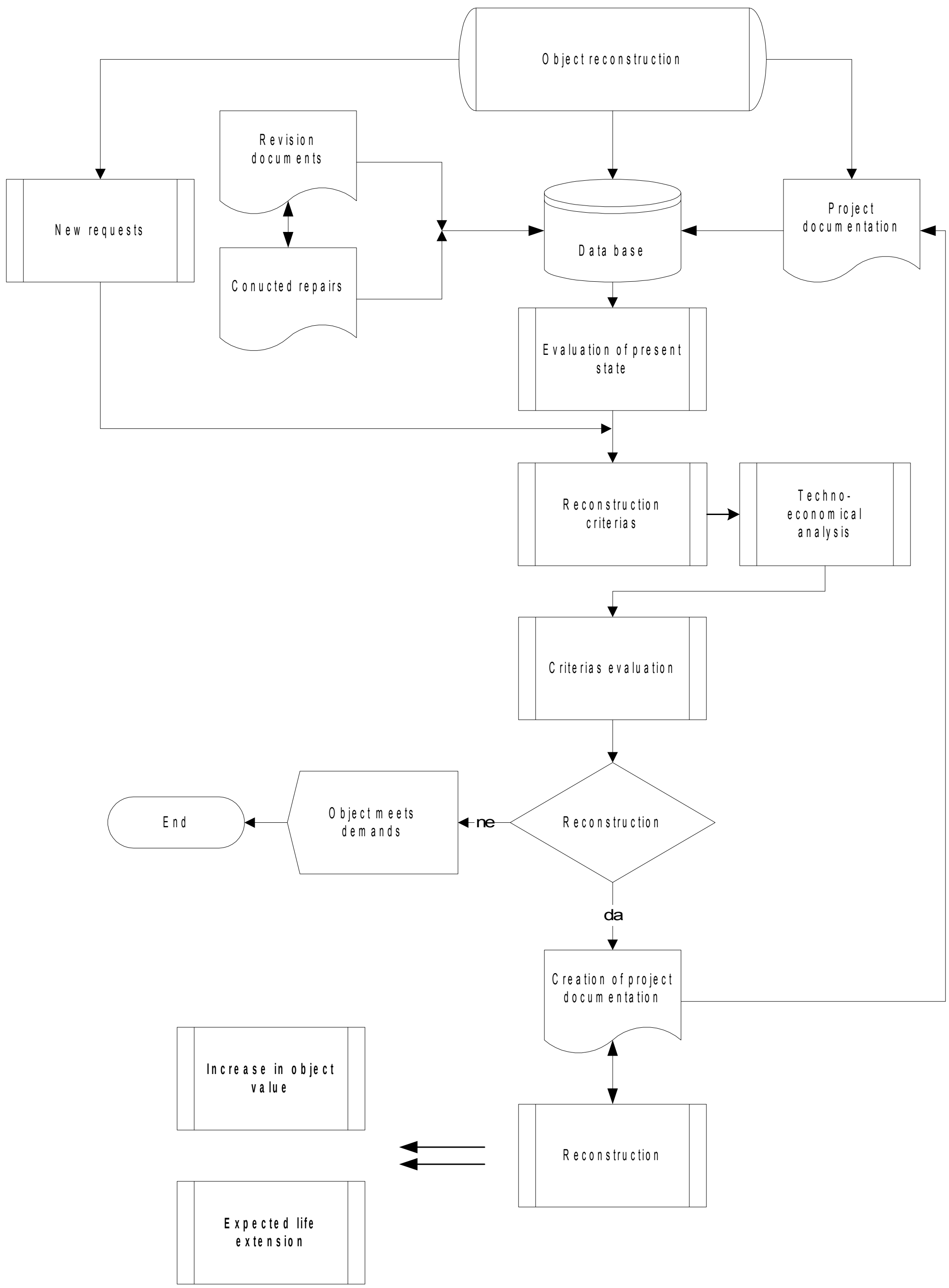
6. GRADUAL REPLACEMENT OF EXISTING EQUIPMENT WITH NEW GENERATION EQUIPMENT

Flowchart 1 present process of reconstruction of distribution substations.



Flowchart 1- process of reconstruction of of distribution substations

Market force usage of strategy where creation of new technical solution or reconstruction of existing distribution substations will be defined with target functions (criteria's) dependant of variables, like investment and operational costs. By finding extremes of target functions (minimum in this case), we come to optimal solution.

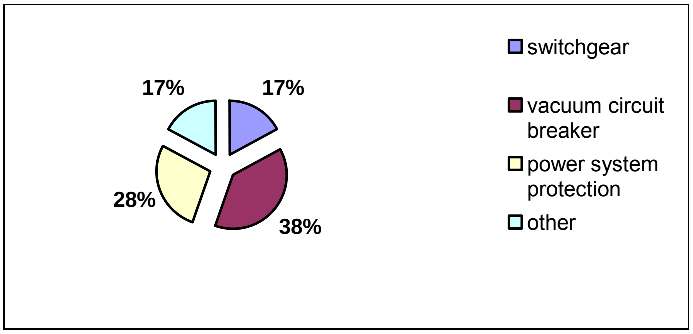
Technical-economical analysis of reconstruction costs usually include:

- Cost of same equipment and spare parts (if present at the market) along with existence of tools and skilled work force;
- Cost of equivalent equipment based on modern technologies, including spare parts, tools and training of work force;
- Cost of additional construction and infrastructure works;
- Cost of installation and adaptation;
- Cost that include undelivered energy;
- Cost of maintenance;
- Cost of disassembly and storage of existing equipment with evaluation of remained value, if equipment's expected life has not expired.

Current trends of costs are as follows:

- Cost of modern equipment is decreasing, same as cost of transfer of "know-how", or training, thanks to modern communications and increased competition between equipment manufacturers;
- Cost of additional construction and infrastructure works are lower (less space needed);
- Cost of installation and adaptation is lower (simpler installation, simpler connection of secondary equipment, simpler pre-usage testing, simpler introduction of modern supervision and control systems);
- Cost of maintenance of modern equipment are generally lower (mostly it is equipment categorized as equipment with maintenance in case of need);
- Cost of maintenance of older generations equipment increases (lack of availability at the market and higher price of spare parts, more complicated (expensive) introduction of modern supervision and control systems);
- Modular structure and multifunctional equipment based on modern technologies, along with opportunity for gradual replacement of existing equipment, significantly decrease cost of undelivered energy.

In aim to compare required investment costs, for various solutions, following picture is shown with parts values for modern cable switchgear (Picture 2a), without other operational and economic parameters, which are considered as input parameters for long-term analysis of distribution network development.



Picture 2a- values of main parts

Dominant value is of circuit breaker so all activities aimed to extend its expected life result in significant savings in investment. Picture 2b shows division of cost in funds needed to convert low oil content circuit breaker in vacuum one, and Picture 2c present same division in case that we replace low oil content circuit breaker with new vacuum circuit breaker.

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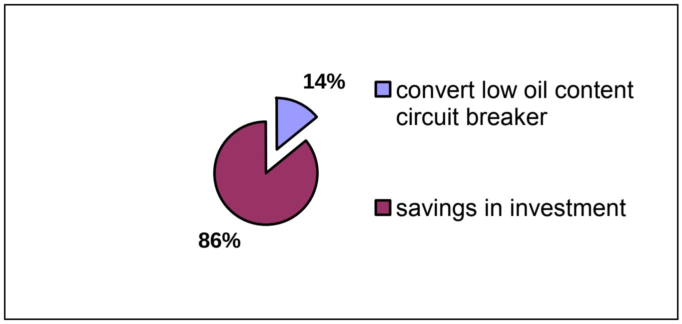
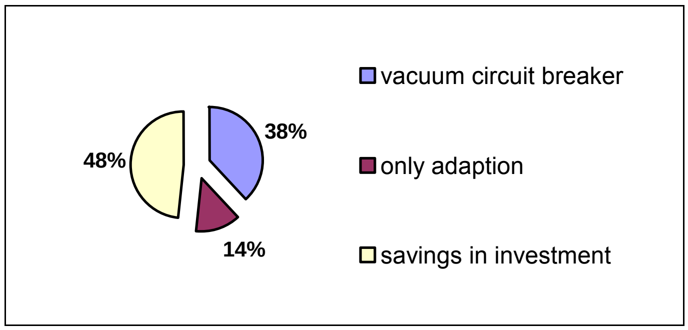


Picture 2b – division of cost to convert low oil content circuit breaker in vacuum circuit breaker



Picture 2c - – division of cost to install new vacuum circuit breaker

Replacement process of existing equipment with new one requires strategic approach where are available solutions with dominant economic criteria over technical and functional criteria.
Major problem that we encounter at distribution TS is mostly linked to damage of a building (metal sheet corrosion, damage on concrete walls) and occasionally we question whether it is justifiable to repair it. Also, there is a problem of space adjustment for new RMU. We have to answer question about manipulation of switching equipment and other equipment inside of TS, i.e. whether to keep outdoor-manipulation or should we replace it with indoor one?
Second direction for solving this problem is linked to use of existing foundations and installation of new prefabricated concrete elements, what is strategically more appropriate, for its resistance on weather conditions and longer expected life.
Mostly, at reconstruction of distribution TS, process itself should be phased. First step should be replacement of HV elements, and after that LV elements should be replaced with minimal interruptions in power supply.

7. CONCLUSION

Optimal maintenance and extension of equipment's expected life by means of evaluation of its present state, accompanied with gradual reconstruction, contribute to decrease in investment costs, because some equipment, despite amortized, is still reliable and in use. This situation is justifiable in long term, if backed up by continuous analysis of following parameters: investment / maintenance ration, cost of undelivered kWh / cost of delivered kWh ration, and investment / cost of kWh of energy ratio.

Modern strategies for maintenance elements of distribution system, in situation when available funds are decreasing, switch from time-programmed maintenance to maintenance based on demand, i.e. conditioned by importance of equipment. In conclusion, along with evaluation of equipment condition, important are consequences of equipment malfunction, and there we base our ranking of distribution system elements in priority for maintenance.

8. LITERATURE

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