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COMPARATIVE ANALYSIS OF 35/10 kV/kV HIGH VOLTAGE SUBSTATION RECONSTRUCTION ALTERNATIVES

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ABSTRACT
In power system planning it is very often necessary to make a decision based on evaluating different project alternatives. When dealing with the problem of high voltage substation reconstructions where part of the substation equipment is old and in bad shape, the question, which arises, is whether it is better to make a partial reconstruction of a substation, or to make total reconstruction, completely with all protection, station and communication computer and all signal cables. The trade-off is between the amount of investment and the upgraded value of the substation in the long run, assuming the same relative value of substation availability for all analyzed alternatives. The paper presents some details of the five different reconstruction scenarios (case studies) with the accompanying analysis of the actuated cost.

KEY WORDS
Power distribution systems, power system planning

1. Introduction

Most existing substations in public utility service in Serbia are old, built in sixties (1960. to 1970), and their lifetime is theoretically expiring.

Typical urban substation 35/10 kV/kV has indoor type 35kV switchgear, indoor type 10kV switchgear, auxiliary equipment, auxiliary transformer, battery and control table for local signalization and control. Cubicles are draw-out type, air insulated, with circuit breaker filled with oil. Usually, part of switchgear has been reconstructed ten or more years ago. Protection is mechanical, typified with same types of relays in most stations. Circuit breakers are remotely controlled from the one control centre. There is a narrowed set of remote signalization and remote control, according to possibilities of that kind of relays, and according to possibilities of old type remote stations for the connection with the centre.

Each time when reconstruction has to be planned, investment group in cooperation with service department has to decide what will be the size of reconstruction, considering the frequency of occurrence of implausible events and gravity of damage on equipment during the previous period of substation operation.

In this paper the method of present value analysis of costs for the high voltage substation reconstruction will be presented. The real life study cases are given as an example, with the matching expenditure for the equipment approved by the planners.

2. Present state of equipment

Reviewed transformer station is a ttypical urban substation 35/10 kV/kV, situated in central part of the city. It has four power transformers, 4x8 MVA, switchgear 35kV consisting of sixteen cubicles, switchgear 10 kV consisting of twenty eight 10 kV cubicles, AC plumb batteries 110 V, auxiliary transformer 100 kVA, auxiliary equipment and a control table. Cubicles are the draw-out type, air insulated, with the circuit breaker filled with oil. Station was reconstructed ten years ago: 10 kV switchgear was substituted with the same type of air isolated draw-out cubicles, batteries were changed, and remaining equipment was regularly repaired. Electro-mechanical protection is located in the low voltage compartments of cubicles, with classical signal cables connected to concentration relay cubicle. Circuit breakers are remotely controlled from one control center. The whole station is remotely controlled. The signaled indication comprises the circuit breakers positions (44 double indications), the signalization of protection activation (40 single indications), and 15 control measurements. The station occupies four floors in the building situating the following equipment: 10 kV switchgear and the control table on the forth floor, cable 10 kV level on the third floor, switchgear 35kV on the second floor, cable 35kV level on the first floor, and transformers in transformer-boxes.

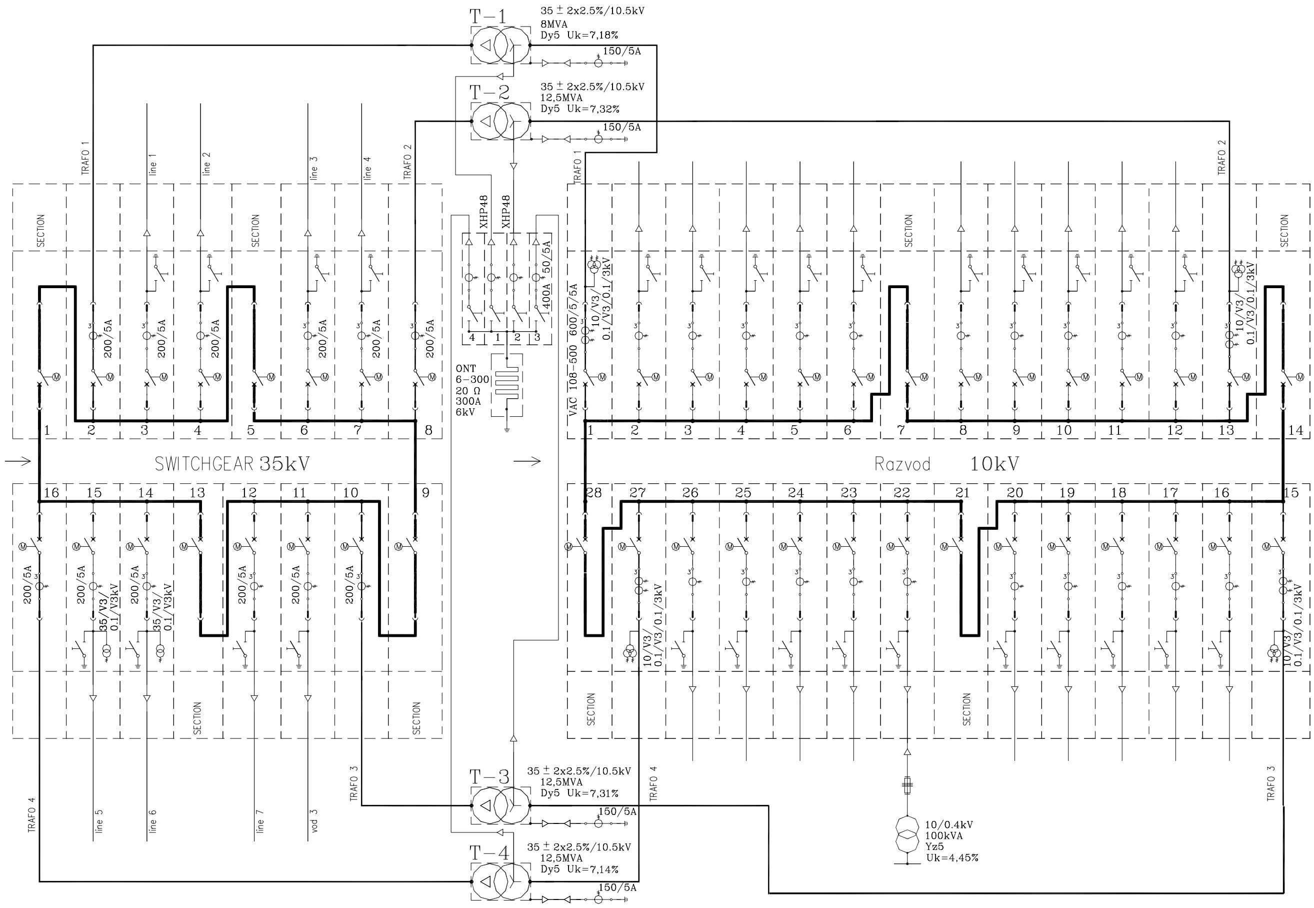

Figure 1: Single line diagram of a rewied transformer station 35/10 kV/kV

Figure 2: The 35 kV switchgear

Figure 3: The 10 kV switchgear

3. Cases Studies

In order to decide what will be the best decission for the substation reconstruction, the five possible alternative plans will be considered.

I. Substitution of all the equipment, 35 kV cubicles, gas insulated - SF6 type, 10 kV cubicles SF6, including microprocessor based protection and the station computer
II. Substitution of all the equipment, 35 kV cubicles, gas insulated - SF6 type, 10 kV cubicles air insulated, including microprocessor based protection and the station computer
III. Substitution of 35 kV cubicles, gas insulated - SF6 type, with new microproprocessor based protection for the whole substation, completely with the station computer
IV. Substitution of 35 kV cubicles, air insulated type, with new microproprocessor based protection for the whole substation, completely with the station computer
V. Substitution of 35 kV cubicles, air insulated type, without changing any protection.

3.1 Case Study 1

1. Space that is ocuppied with switchgear can be reduced, but with some adittional works and extra difficulties during the work. Usually, it is not convinient to reorganize space for some other activity, except for the switchgear.

2. Floors, escpecially in the old buildings, are designed for the certain cubicle width. That means that erecting SF6 isolated cubicles needs reinforcement of the floor, and new openings for the outgoing cables.

3. Cable routes, that are usualy occupied, have to be changed and replaced. Energy cables have to be extended, with new parts of cables, together with new joints to be justified for the the new type of cubicles.

4. Cubicles with SF6 isolation are 1,7 times more expencive than the domestic air insulated cubicles, Table 1.

5. New type of cubicles (SF6) are not used in any substation, workers are not used to them, and have some kind of resistance to the new technology.

6. All equipement is new, with similar life warranty.

7. All cubicles are without maintanance, which has to be reflected in the price of reconstruction.

8. Fault protection and remote signalization is very improved.

9. The availibility of the new substations is significantly reduced by retaining very old energy connecting cables, used over 40 years, in quantity that is not negligible.

3.2 Case Study 2

1. Space that is ocuppied with the switchgear can be reduced, same as above. The same goes for the floors, openings and strenghtenings, cables and cable routes.

2. Cubicles with SF6 isolation are 1,7 times more expencive than the domestic air insulated cubicles.

3. New type of cubicles (SF6) are not used in any substation.

4. All equipement new, with similar life waranty.

5. Fault protection and remote signalization very much improved.

6. Maintanance of 10kV cubicles still remains.

7. Very old energy cables.

3.3 Case Study 3

1. Space that is occupied with switchgear can be reduced, same as above. Same goes for the floors, openings and strenghtenings, cables and cable routes.

2. Price of the cubicles, same as above.

3. New type of cubicles (SF6) are not used in any substation.

4. Part of equipement is new, part of it is old, with huge difference in life - time waranty.

5. Because of the instalation of the new protection relays in old cubicles, time neccessary for reconstruction is much longer than in a previous case study.

6. Very improved fault protection and remote signalization.

3.4 Case Study 4

1. It is not necessary to do any floor reinforcement, nor huge civil building reconstruction.

2. Cables can remain, with no changes in routes and with no extension.

3. Domestic air insulated cubicles are very cheap.

4. Workers are used to air insulated cubicles.

5. Part of equipement is new, part of it is old, with difference in life – time warranty.

6. Because of instalation of new protection relays in old cubicles, on both levels, time neccessary for reconstruction is much longer, than in a previous case study.

7. Fault protection and remote signalization is very improved.

3.5 Case Study 5

1. It is not neccessary to do any floor reinforcement, nor huge civil building reconstruction.

2. Cables can remain, with no changes in routes and with no extension.

3. Domestic air insulated cubicles, which are relatively cheap.

4. Workers are used to air insulated cubicles.

5. Part of equipement new, part of it old, with minor difference in life – time warranty.

6. Because of the instalation of the new protection relays in old cubicles on both levels, time neccessary for the reconstruction is much longer than in the previous case study, and much more than in case study I.

7. Very old protection with no improvement in local and remote signalization, retaining all previously registered mallfunctions.

Table 1 below shows the costs of all reconstructions under study.

Table 1:The case study comparative analysis of cost

No	Description	Case I Euro	Case II Euro	Case III Euro	Case IV Euro	Case V Euro
1	35 kV switchgear, with protection	500.000	500.000	500.000	400.000	
2	35 kV switchgear, with old protection					330.000
3	10 kV switchgear, with protection	1.000.000	500.000			
4	Micropocesor based protection of 10 kV switchgear, with accessories			110.000	110.000	
5	Station computer and SCADA software	30.000	30.000	30.000	30.000	
6	Construction, cables and connections	150.000	150.000	150.000	120.000	200.000
7	Additional expences for maintanance in next 20 years		50.000	100.000	100.000	150.000
8	Changing 10 kV cubicles, life - time n=10 years, present worth of investment, i = 5%, $Pp = P/(1+i)^n$			306.950	306.950	306.950
8	**TOTAL**	**1.680.000**	**1.230.000**	**1.196.950**	**1.116.950**	**986.950**

According to [1, 2] the best time for investing is when expenses are at their minimum, and it can be estimated by

$$[1 - R(T)]C_f = C_m \quad (1)$$

where $R(T)$ is a probability that element will have no damage until time T, C_f and C_m are costs of the damage and prevent expenses, respectively, T is the optimal time for maintenance.

Optimal time between two repairs results in the minimum of the expenses found between the maintenance and the damage expenses.

In most cases, the duration of the reliable work after repair is found according to the Weibull formula

$$R(t) = \exp\left(-\left(\frac{t-\mu}{\alpha}\right)^{\beta}\right)\exp(-\lambda t) \quad (2)$$

where coefficients α, β and μ are factors of ratio, profile and situation of Weibull distribution, and λ is the frequency of malfunctioning in exponential distribution, respectively.

For most cases the best time for maintenance of the substation equipment is 12 months. If that time is shorter, maintenance expenses will exceed expenses caused by the damage.

4. Conclusion

Considering all what is specified, very small savings are achieved in the case study V (the main feature is the change of the 35 kV switchgear, retaining the old protection relays) respective to the case study IV (featuring the changing the 35 kV switchgear, with introducing the new protection). If alternative V had been applied, that certainly would not have been the best of all possible decisions.

However, not all of the benefits of protection substitution could be evaluated in such a study. Benefits of introducing the new technology could be enormous, making the case study V an obsolete alternative.

Comparing other four case studies, it is obvious that the difference between cases II, III and IV is somewhere less than 10%. For all of the cases the theories of the time value of money and opportunity costs have been applied [3].

Concerning all preparation jobs for the reconstruction, especially if the reconstruction is done in two parts (one now, and another in 10 years), the time needed for the reconstruction, the losses for the energy not served (when the substation is left without the energy, not studied here) the final suggested decision for the reconstruction will be the case study II.

Decision is motivated by following reasons:

The best decision from the point of view of the maintenance department would be the case study I. That case is unfortunately 35% more expensive than the case study IV, which gives us the new equipment (no SF6) but with less working on the building. Sometimes, it is very good to introduce the new equipment in reasonably smaller steps.

This particular study can be small in some wider point of view, but can be useful for everyday decisions for the similar medium – sized power transformer substations.

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