03.05.2006. Novi Sad

RECONSTRUCTION OF SUBSTATION 110/35 kV NOVI SAD 1 INTO 110/35/20 kV

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INTRODUCTION

Substation 110/35 kV Novi Sad 1 was put into service in 1955 and since then it has been one of the most important node in 110kV network because of connections from three different substations, such as: Belgrade substation, S. Mitrovica substation and Novi Sad substation. There are two 110 kV busbars and in normal conditions they operate separately. As mentioned, this 110 kV node is very important to Vojvodina county and its operation function cannot be overtaken by any other substation. In other words, although this substation is very old, it has to be located at the same place.
After this long period of exploatation, almost fifty years, some kind of complete reconstruction had to be done.
Recently some of the equpment was replaced and one more transmission line was constructed in 1993. godine, but it was not enough for further safe and reliable operation.
So, at the first glance, it was concluded that some kind of complete reconstruction had to be done like many other decisions such as: way to do this job, possibilities of long duration power switching off, space for 20 kV equipment, what to do with 35 kV substation and the building in the future… In constructing new substations the limiting factors are financial origin, but it was easy to do in this case.
Because of these reasons, first of all the authors made cost-benefit analysis for all options, chose the best solution and then realized: technical documentation and tender for equipment and workforce.

REASONS FOR RECONSTRUCTION

Several photos show a lot of reasons for reconstruction. Each and every part of this substation was reconstructed because everything was damaged. Concrete poles and foundation of the portals were in very bad condition. Bases of the HV apparatus made of steel were rusty. Also, each electro equipment was out-of-date, especially conductors 150 mm2 made of copper and insulators made of porcelain. Meanwhile, there was a need for more reliability and capacity.

As mentioned, each 110kV equipment was out-of-date, in a very bad condition and without possibility for remote control. Only one of five transmission lines "D -1" was built with a new equipment (1993. god.).
Power transformers had two windings 110/36.75kV, 20MVA and many failures happened under operation such as: failures on automatic voltage control, automatic tap changer and transformers protection.
In some transmission lines 110kV circuit breakers were replaced with little oil type, but others were air compressed type and for their operation, instalation with compressed air was used. There was a lot of failure during operation, but the most significant problem was how to find spare parts because these circuit breakers were no longer in use.
Disconnectors 110kV once had air compressed drive, but meanwhile, one by one drive was demounted. Also, supporting insulators on disconnectors were very old and there was a possibility of crack and injury for the crew.
Measuring transformers were, also, in bad shape with old insulation. In 110kV switchyard there were no instalation housings.
Substation 35kV was located inside the building and it had out-of-date equipment, as well. Circuit breakers 35kV with air compressed drive were produced by “Magrini”, Italy and for their operation, instalation with compressed air located in basement was used.
Production date of the equipment meant "antique value" that was greater than operational.
Just the building was in solid state with no damage and recently the roof was replaced by a new one.

COST-BENEFIT ANALYSIS OF THE POSSIBLE SOLUTIONS

Reconstruction of substation 110/35kV Novi Sad 1 was necessary by all means and it was quite clear that each equipment had to be replaced. The most important job was the complete reconstruction of the switchyard 110kV. On the other hand, this reconstruction was the chance for building the new 20kV substation instead of 35kV, which meant that in the first stage, one of the two power transformers 110/35 kV, 20 MVA would be replaced by 110/20 kV, 31.5 MVA, and in second stage, the other one, as well. Meanwhile, there would be two separated MV substations: 20 kV and 35 kV located side by side in the existing building or substation 20 kV would be located in a new building.
Just this **choice** of location of 20kV substation was the premise of cost-benefit analysis of the possible solutions.

BASIC POSSIBLE SOLUTIONS

As mentioned, the building was in good condition and according to this a new 20kV substation could be located inside. This building was big enough, but there was no possibility to build inside one 20kV section without knocking some parts, so a lot of reconstruction had to be done close to substation under voltage.
Based on data obtained from maitenance Sector, these input data were concerned for further analyze, as follows:
- at first, power transformer ET1had to be replaced,
- one part of metal clad switchgears 35kV had to be removed because substation 20kV had to be placed inside the building at the first stage,
- during the first stage it had to be in operation: one transformer metal clad switchgear, one metal clad switchgear with voltage measuring transformers, one metal clad switchgear for internal cosumers in substation and four metal clad switchgears for distribution lines - total amount of seven metal clad switchgears 35kV.

Placing 20kV substation inside the building represents the variant 1 consisting of two parts:

PART “1a” - remove some of the metal clad switchgears 35kV and place 20kV substation in the existing building.
This substation would operate until the second stage at which the other power transformer ET 110/35kV would be replaced by a new one 110/20kV and then 35 kV substation would be eliminated. This moment was hard to predict at that time, but from many reasons 35kV substation would exist for many years.
Basic lack of such a reconstruction is the way it will be realized. This means that in order to finish the complete 20kV substation two reconstructions of inside building have to be done. Both reconstructions should be done close to substation under voltage. In this case risks are high especially when the work-

ing staff is non-electrical occupation and, also, this happens not once but twice.
Advantage of this part "1a" are savings money for a new building. The other one is its close relation to the part "1b".

PART “1b” - remove the complete 35kV substation and place the new 35kV and 20kV substations inside the existing building.
It can be assumed that 20kV and 35kV substations will operate in the future beyond 2014, so the old building with 35kV substation will fulfill the investments.
The authors intended to energize under 20kV metal clad switchgears 35kV in the second stage with just replacing voltage measuring transformers. Of course, there is always a possibility to use these 35kV metal clad switchgears in any other substation that belongs to our distribution company and in the same way to solve the similar problem of the old 35kV substation.
Further on this paper describes metal clad switchgears 35kV under 20kV voltage in the second stage.
In realizing this part a long period of time (quite a few month) without supplied voltage must be considered. This means that the complete substation 110/35 kV Novi Sad 1 will be switched off. All the substations 35/x kV fed by substation 110/35 kV Novi Sad 1 could be fed by adjacent substations, so in realizing the part "1b" the basic premise was fulfilled.
This part "1b" enables mounting the new protection devices and relays at the first stage even on the unreplaced power transformer ET2 110/35 kV which could be replaced in the second stage by 110/20 kV power transformer.
It is clear that, after the first stage, all aims of the reconstruction will be achieved:
- new transformer 110/20 kV,
- reconstruction of the complete substation 110kV,
- up-to-date substation 35kV with eliminated operating problems and
- up-to-date complete protection of the whole substation.

VARIANT “2” - making a new building with 20kV equipment

This variant would be actual just in case if substation 35kV could not be fed by adjacent substations during reconstruction because of some unexpected reasons. Also, this variant has just one problem - location of the new building with 20 kV equipment and secondary devices. Even 110/35kV Novi Sad 1 substation was located in the large yard (100m lenght and 65m width), in some variants extending measures were considered.
Variant 2 is divided into three parts:
- part “2a” - building will be located in area instead of existing warehouse and garage which have to be removed.
- part “2b” - building will be placed close to southern side of fence which has to be removed about 10m. In this case problem could be existing distribution lines 35kV positioning above a new building.
- part “2c” - building will be placed close to northern side of fence which has to be removed a little near the front gate.
This variant considers equpment mounting in substation 110/35kV under voltage. In this case the way of reconstruction and reconstruction terms do not depend on switching off the substation or its parts except to a replacing of power transformer 110/35kV by a new transformer 110/20kV.

Analysis of all variants

In considering all suggested variants, total expenses must be taken into account, as follows:
- new building (substation 20kV) expenses are 7% (var.”1b” related to var. ”2c”) related to expenses for reconstruction of the first stage. If the total reconstruction expenses are taken into account: expenses for both stages and reconstruction of substation 110kV, this percentage will be less, about 1%.
One may conclude that savings in building a new object will be compensated for the solving of problems during building a new 20kV substation near 35kV substation under voltage.
After a new substation 110/20kV and reconstruction of both stages are finished, the old building could be knocked down or used as a warehouse according to future needs.
Part “1b” solves the problem of the old and out-of-date substation 35kV.
Furthermore, in all cases the best choice could not be the cheapest variant because the effects of each variant are not the same. The right choise means to determine the variant with the best “cost benefit” - variant that gives the greatest value in return for expended money. This financial criterion is not the only one for making decision. There are many other criteria which cannot be evaluated precisely alhough they affect the total expences. In this sense, in order to analyze each variant (lacks and

advantages), the following criteria are determined:
- reconstruction expenses of MV substation
- need for special, additional expenses for crew and premises safety during reconstruction
- electro project of the future substation
- problems with providing SCADA for MV substation
- Reliability of energy supplying during reconstruction
- reconstruction stages
- license for building substation, the law of property and other files
- harmonizing equipment 35kV with up-to-date technologies

Importance and influence of each criterion on making decision may be represented by valuable coefficient. After analysis of each variants using adopted criteria, the best variant was part “1b”.
After that the authors defined all activities for realizing this variant.

PROCUREMENT OF EQUIPMENT AND MATERIAL

At the end of 2003 and beginning of 2004 tender documentation for procurement of electro and protection equipment was finished. During 2004 public tender was held. Also, in the same time all necessary contracts with well-known suppliers were signed. Contracts were signed for delivery of 110 kV circuit breakers isolated with SF6 gas, oil-filled measuring transformers 110 kV with silicon insulators, but surge arresters 110 kV remained the same because they were recently replaced by a new one. Also, the old disconnectors 110 kV were replaced by a new one, but on some of them which were replaced in the last ten years, just drives were changed. The new substation 35 kV and 20 kV were delivered in metal - clad type. Up-to-date protection devices and relays were delivered, as well with parameters setting up for the whole system. After the technical documentation of equipment obtained by suppliers was finished then technical projects had to be completed.

ORGANIZING OF STAGE ACTIVITIES

Reconstruction of substation 110/35 kV Novi sad 1 was planning partly in 2004 and mostly in 2005.
In autumn 2004, before the winter period, it was planning that all disconnectors 110kV as well as busbars and insulator strings needed to be replaced. First, this plan required technical projects of 110 kV substation without secondary wirings to be completed. After that, replacement of disconnectors, busbars and insulator strings was finished. It was planned to finish completely the whole busbar system with connections to circuit breakers and disconnectors.
It was, also, planned that from the spring 2005 till the end of the same year all activities had to be completely finished and the whole substation put in use. The rest of activities had to be done in 3 stages. In order to keep service reliability of the 110 kV network, the first stage in 2005 considered activities in transformer sections 110 kV together with demounting of the complete 35 kV substation. The second stage included activities in 2 transmission sections and sectionalizing section 110 kV before the end of the first stage from 2005. After activities in these 5 sections 110 kV and after finishing the complete new substations 35 kV and 20 kV, activities in the rest 3 transmission sections 110 kV had to be realized.

PREPARING HV AND MV CONSUMERS FOR SWITCHING OFF FOR ACTIVITIES IN 2004

In preparing activities in 2004 the complete substation 10 kV had to be disconnected. Each of 5 transmission sections 110 kV had to be switched off from adjacent substations. As one of these sections 110kV was radially operated (DV 1217) it had to be short circuited with 110kV transmission line no.127/1 in a common transmission pole on the transmission line section located just over the river Danube. Also, the conductors of this transmission line had to be demounted towards substation 110/35 kV Novi Sad 1.
Because of completely disconnected substation 110 kV including transformers 110/35 kV, it should have enabled voltage supply of 35 kV substation during activities.
All substations 35/10 kV which were fed by transformer station 110/35 kV Novi Sad 1 had to be switched on to adjacent substations 35/10 kV except substation 35/10 kV Sremski Karlovci which was fed by substation 35 kV in transformer station Novi Sad 1and voltage 35 kV was supplied from transformer station 110/35/20 kV Novi Sad 7.

ACTIVITIES - SEPTEMBER 2004

Activities in 2004 should begin in september after delivery of equipment and material necessary for this stage. All of preparing activities were done (substation was disconnected from the power) and building started in september 01.2004.
Electricians demounted 110kV old conductors, insulators and connections in order to enable restoration of disconnector and busbar supporters made of concrete.
This restoration might be the most important activity because it had to be done properly. If this restoration had be done with poor quality, any other activity would be useless. This restoration was going on, as follows:
First, damage of steel fortified concrete structure was determined and then some parts of concrete around steel rods were eliminated by using hammers. Then this surface was cleaned by using brushes and the dust was removed with brooms and soft brushes. After that, these structure was coated with layer - chemical two-component coating composed of cement and polymer on this clean surface and after 24 hours a new layer was coated with two-component modified polymeric waterproof mortar. Component mixing was done by machine device according to instructions without adding any water or other substance. After that, these structure was coated with layer - chemical two-component coating composed of cement and polymer on the whole surface and after 24 hours a new layer was coated with two-component modified polymeric composed of cement.
As soon as construction workers were finishing this job, electricians started to mount conductors and insulators.
The existing conductors were made of copper, cross-section 150 mm2 (37x2.25 mm).
In choosing new bus conductors, the following instructions had to be considered: sags of conductors had to remain the same, reliable coefficient of the new conductors had to be higher or equal to coefficient of the existing conductors made of copper (150 mm2), capacity of transmission lines had to be high enough according to future development of HV transmission grid.
In choosing new insulator strings for busbars and related connections instead of existing insulator strings type K-3 and hanging eqiupment "Hofman", the following instructions had to be considered: increase of sags of the new conductors due to the weight of new insulator strings had to be less than increase in the case of existing insulator strings. This means that reliable coefficient of the new insulator strings should be higher than coefficient of the existing insulator strings. In another words service safety should be greater with the new insulator strings.
Composite insulators were chosen for pollution zone II, isolation degree Si 123 (withstand voltage 230 kV, surge voltage 550 kV) and minimal breaking force 120 kN. These insulators were chosen due to less force (its component Vz) to the supporters made of fortified concrete.
All disconnectors 110kV remained on the existing supporters made of concrete “T” shape, as described above (in transmission line section “-1“ the existing supporters made of steel remained). Old disconnectors 110kV were replaced by the new disconnectors, but some of them were left and just motor drives were replaced. But in the meantime, all these motor drives were switched off until activities suggested in 2005.
All of the new equipment were connected to existing grounding system.
Exactly after one month, as previously planned, all of the activities were finished and the whole substation was energized again.

PREPARING HV AND MV CONSUMERS FOR SWITCHING OFF FOR ACTIVITIES IN 2005

As technical documentation was preparing, the other equipment was delivered one by one. Activities should be continued in spring 2005 in order to be finished until the end of 2005 before winter time.
As mentioned, activities in 110 kV switchyard should be done in three stages. In the last stage 110 kV no.1217 and no. 127/1 transmission lines should be connected again. This time it was realized in substation 110kV TS Novi Sad 1 and connections to disconnectors were eliminated.
Because of activities inside the building, the complete substation 35 kV had to be switched off and consumers would be fed by adjacent transformer stations 35/10 kV. The only problem was transformer station 35/10 kV Sremski Karlovci. This transformer station could be energized by transformer 20/35 kV (located in the same station) from substation 110/20/35 kV Novi Sad 6. Beside that, in order to increase service safety, in substation Novi Sad 1 an extra cable 35 kV was connected to 35 kV distribution line Rimski Šančevi which was fed by substation 110/35/20 kV Novi Sad 7 and to 35 kV distribution line Sremski Karlovci fed by substation Novi Sad 1.

ACTIVITIES IN 2005

The new contract was signed and all structure and electro activities were continued. Permission for reconstruction was gained, activities were denounced and they could start all over again.
Reconstruction started in the beginning of april in 2005. First of all, substation 35kV and transformer sections 110 kV were demounted. In switchyard 110 kV foundation and supporters of circuit breakers and measuring transformers were crushed and new ones were built. Then, new grounding system and manholes for each section were built. Every time when activities on structures were finished in some section, electricians continued their work in that section.
After that, equipment 110kV was replaced by new one, new secondary LV cables were laid inside the existing main manhole which had enough space to receive all of them including existing old cables. New power transformer 110/20kV and repaired power transformer 110/35 kV were placed. New 35kV and 20kV cables between power transformers and building were laid.
Electrical instalations inside the building were completely repaired, as well as, walls and floor. Also, old windows were replaced and doors were renewed. In order to bring inside the building metal clad switchgears 20kV and 35kV, the door on the first floor were mounted.
In control room on the first floor, protection devices in housing were located together with remote control units without removing the existing housings because these units had to ensure the operation of nonreconstructed sections in the period from energizing partly reconstructed sections untill complete reconstruction of substation.
The existing battery 220V direct current had to be, also, in function all the time and the new one 110V was placed in another room. In that way, “old” and “new” substations had their own separated uninterrupted power system. When activities on two transformer sections 110kV, two transmission line sections 110kV, sectionalizing section 110kV, substations 20kV and 35kV were over, all secondary wirings were checked, each device and its function was inspected and, finally, this part of substation was energized.
Soon after that reconstruction was continued again on the rest of 110kV transmission line sections. Then, the old control panel and battery 220V DC were removed and rooms were renewed.
The rest of three 110 kV transmission line sections were put under voltage in the beginning of December in 2005 and that was the end of reconstruction. The new up-to-date substation 110/35/20 kV started a new era.

CONCLUSION

Problems that follow reconstruction of out-of-date substations are mostly familiar to many engineers, electricians, operational staff, project engineers and project managers. Probably some of them wished to knock out old substation and build a new one. In the existing distribution system there is a little chance for this. Reconstruction of the existing substations will be often the only possible solution. The authors would like to pay attention to other engineers who attend to reconstruct substations about this complex work. Cooperation of all staff must be at a high pitch, as well as, precise coordination of all activities. During reconstruction transformer station Novi Sad 1, a lot of meetings were held and many particular tasks were assigned to all workers.
It is noteworthy that reconstruction was, also, realized by the following fact: this transformer station was built in the early 1950s and from nowadays point of view it is very large with a lot of space. This fact made reconstruction easier. Also, the main communications were large and this fact enabled the common ”life” of old and new substations during reconstruction. This old fashioned philosophy “for all times” made our task easier. Up-to-date philosophy of building “for one usage” will not enable this to the future times but perhaps it is, also, regular opinion.

Figure 1 - Switchyard 110 kV before reconstruction

Figure 2 - Switchyard 110 kV after reconstruction

Figure 3 - Switchgear 35 kV before reconstruction

Figure 4 - Metal clad switchgear after reconstruction