BASIC ELEMENTS OF A RELIABLE SUBSTATION CONTROL SYSTEM

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Abstract - The main purpose of energy distribution companies is to optimize the activity using state of the art equipments .This goal is possible only through a technological reengineering applied on equipments used in substations, implemented in intelligent electronic devices using microprocessor technology. Once established the objectives regarding the projected system, the key of success consists on involving qualified human resources, which will lead to achievement of a reliable protection command and control system.

Key words: tasks notebook, human resources, FAT, SAT,IEC 61850, IED, SCADA

1.INTRODUCTION

The technologies used until 1980 in the national energy system proved to be useful and appropriate, but today they constitute an exceeded solution.Thus it is essential to realise a technological reengineering of the equipments, by using technologies based on microprocessors.

These equipments besides the protection functions that they have to make offers the advantage of digital technology-driven facilities. Complex picture of an advanced protection command and control system as part of the management system is shown in figure 1.

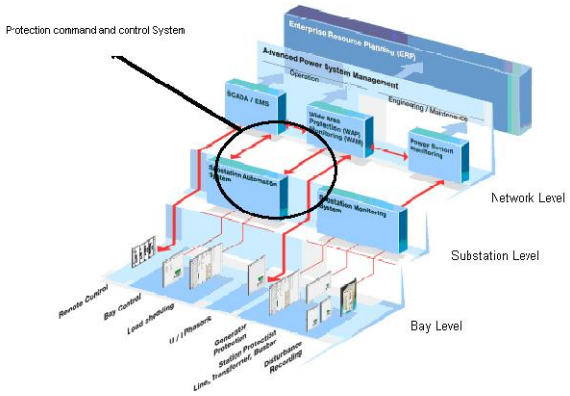

Figure 1. Assignment of protection command and control system in management system

2. ESTABLISHING THE DEVELOPMENT STRATEGIES

Having at disposal the direction which that should be followed in the process of retrofit, the only thing that we need to do now, is to respect IEC 61850 requirements, which have paved the way for obtaining a reliable system.

Keeping a large proportion of classical equipments due to the major financial investments that must be realized, the energy companies are trying to introduce gradually the new technologies, switching in the new digital stage. To achieve this objective, beside the investments in equipments , it is also necessary an important investment regarding the human resource. Just as with the equipments, addition to the requirements of technical nature from energy field, skills are necessary in the IT technology direction.

Like the equipments, the human resources have proved to be essential for the pursuit of activity in the energy field and that's why it is necessary a trained staff combined in the new technologies. Even if this new side is prevalent, is essential the foundation of technical knowledge in the energy domain.

3. DEVELOPMENT OF TASKS NOTEBOOK FOR A HV SUBSTATION

Thus paper tries to present some of the steps needed to be prosecuted in achieving a reliable protection, command and control system . This is done based on the experience of over 10 years in the S.C. Electrica – Transilvania Sud Brasov, in the process of transition from conventional to digital technology, defined as technological reengineering. Also it will be presented issues that have lead to a increased reliability of protection command control system by identification and treatment of weaknesses. This is closely related with the interest shown by the staff involved.

As a starting point were considered the investments made by Electrica, the national distribution company, in new or retrofit of existing HV substations. These investments were made in order to ensure the power supply in conditions of maximum security, based on technical and economic predetermined criteria.

In the absence of special requirements, new HV substations are made on the model of energy requirements associated with conventional equipment

from actual substation. The difference derives from the fact that at the level of protection, command and control systems, has been a real revolution determined by technology based on microprocessors introduced in these systems.

Regarding the structure demands of the new objectives it appeals to the principles set out in the design guidelines, which proved covering, in previous periods, when the electricity consumption recorded a decrease. In the particular case of the romanian national energy system, were not radical changes due to the high demands imposed until now. In these documents are established the main requirements imposed on primary equipments, interlocks and necessary protection and control functions required.

All these requirements are found mostly and in the functional goals in the present moment and even in units built in the years 1970. Innovative aspect is the equipments through these requirements are implemented and also essential in informatics terms of additional facilities, provided by the process control and command functions associated with digital technology, related to Intelligent Electronic Devices.

In the design domain still is available qualified human resources, due to the large volume of equipment carried by an outstanding liability. Experience gained should be filled with innovative aspects relating to digital technologies used. For this reason , a first condition to achieve a reliable protection, command and control system is to create a competent team with qualified human resources for making the tasks notebooks. This is the first stage through which the beneficiary sets his demands, which the system to be built must comply. The success of this phase is to achieve a mixed team composed from specialists who have the necessary energy knowledge and supplemented by information technology specialists.

Because the digital technology is in constant evolution a very important aspect is the interest showed for the new information, regarding the computing process.

If 10 years ago the terms of compatibility was seen as a general requirement without having a reference point, in the present IEC standards are intended to establish of requirements regarding the unification of safety, command and control functions offered by digital equipments.

In this direction the impact accomplished by switching from proprietary communications protocols of the protection, command and control systems at “open” protocols. A new reference point is the time when the major manufacturers of equipments and control systems have join for starting tests of interoperability. This action was carried out in order to establish the requirements for communication between remote equipment and application. The great advantage offered by IEC 61850 is to provide to the designers and manufacturers of equipments the requirements that must satisfy both hardware and software for command and control applications.

The next essential element in achieving an efficient system is the selection of the requirements from the standard, those necessary aspects required in the project, having available all the data of the standard. Of these recall data such as communication network configuration, organizational structure of the command control application based on logical nodes, data and attributes, requirements regarding the communications, compliance tests, etc. If 5 years ago it was presented a certain vision of a “half-open” protection , command and control system action of replacement of the damaged equipment or to expand with a new equipment , store the dependency substrate of the manufacturer of the system. Currently under the new compliance standard, replacing and the previous changes become more accessible. In addition to the standard principles will continue to present specific aspects that should be included in the tasks notebook for achieving a reliable system of protection, command and control:

- The main functions of protection, command and control and the way of its implementation;
- The necessary standards applied (both those regarding the types of equipment used and installation;
- The minimum amount of information for each bay type;
- Required necessary factory acceptance test and site acceptance tests (FAT and SAT);
- The technology records relating to the used equipments requirements;
- Staff training issues involved in the maintenance activity both for hardware and software equipments. These trends have a particularly importance due to the involvements in the maintenance activity of a qualified staff that significantly reduces the occurrence of incidents because of human resources. As noted in different studies above more then 70% of errors are caused by human factors;
- The need for a protection, command and control system with equipment from a single manufacturer which eliminates the shortcomings of the compatibility of equipments;
- The achievement of necessary matrix and tripping signals;
- Establishing the spare parts and software licenses to ensure the independence of the beneficiary regarding the unexpected actions (equipment failures, changes in structure);
- Achieve the log parameter.

4. TECHNICAL PROJECT DEVELOPMENT AND INSTALLATION DETAILS

Making de assumption that the elaborating stage of requirements from tasks notebook was a success on the beneficiary part, it passes to the next stage, namely the analysis of available offers. At this stage the human resources involved must know the principles of how to implement the requirements from tasks notebook. It will be made an objective technique analysis of the offered solutions. After establishing the optimal technical and economical variant, it passes to the next stage which consist in implementation of the technical project and

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execution details. These documentations must be compiled and verified by the recipient through a qualified team, because these is the bridge which allows carrying out the requirements from the tasks notebook. In this documentation it will be recover integral and clear the requirements . A particularly important aspect it is represented by the organization way of technical project , also the need to respect the existing norms of projection.

Starting from the premise that in the tasks notebook is clarified in detail the requirements of the beneficiary , technical project and execution details, according with the selected equipment , transpose the way to achieve the solution. And in this phase, must also be allocated human resources with a rich experience, because of the need to identify possible projection errors.

One of the author's recommendations is to introduce between the execution details the parameterization log of the principles schemes for the protection and automation from substations, and the logical schemes also. This is necessary for the detection from early stage, the human errors occurred in the programming of the equipments.

This is the moment when the programmers, parts of the beneficiary team improve their knowledge on the reliability of the protection, command and control system. After all these checks are made, is resorting to validate the documentation by entering the requested changes.

The next step is to complete the factory acceptance tests. The importance of this stage is to eliminate the possibility of a significant number of failures identified during the commissioning tests. At the factory acceptance tests, is recommended to attend at least one person , preferably the one who will coordinate de testing of commissioning.

It is the time when it can be identified and corrected both the discrepancies regarding the tasks notebook and the existing standard. For this reason the personnel involved must acquire both the requirements from the tasks notebook and the approved version of the technical project. For a significantly reduce of the commissioning times it is necessary an initial analysis for configurations of the protection, command and control equipments.

5 INSTALLATION AND SITE ACCEPTANCE TESTS OF PROTECTION COMMAND AND CONTROL SYSTEM

Upon the factory acceptance test, the next phase is the delivery and the installation of all furniture in accordance with the approved documentation. After installation, the testing equipments of commissioning by the manufacturer followed by the tests reports. In this stage it is recommended to name at least a representative from the digital protection department . Through this representative will be clarified any ambiguous points occurred in the execution process. For reducing the times of commissioning is recommended the participation of all staff involved, from the protection department, in the site acceptance tests.

Because of time needs for corrections, it is recommended that the commissioning tests be conducted after the completion of all errors, by the manufacturer. An important element is the participation at the final tests of a representative from the manufacturer side who know the features of the protection, command and control system, that runs alongside the commissioning tests. This step is considered part of training program.

Note that prior to the commissioning test it is necessary to complete the training program , an opportunity to put the knowledge bases of the equipment involved. The making of commissioning tests should be based on a predetermined routines by developing of test reports.

In fig 1 it is presented a table model of a Test Report

Table 1.Model of Testing report for HV Bay

Transformer 110/20 kV Hărman HVSubstation											
Commands											Notice
Signal/command	Command			Alarm		Event				Signal	
				Pick up	External	Relay	SCADĂ	Interface		Alarm	
	Local	Distance								DSG	
		SCADĂ	Relay					SCADĂ	Relay		
Connecting I 110 kV Q0				-							

These testing reports are specific for each bay type and contain the requirements from the tasks notebook that must be checked and confirmed by the team that realize the necessary tests.

A particularly important aspect for future maintenance is to check the correspondences between the approved implementation schemes and the installation , namely the introduction of all changes for achieving the documentation "As build" .

To achieve efficiency tests , the testing forms will contain both the evidence from the protection, command and control equipments and signaling commands from the SCADA system.

In these tests it will be pointed each protection function , the signaling in SCADA system and at the IED level , also the general signaling panel. Any unfit is necessary to be repaired on the spot, because have been identified various situations when a change generates various anomalies, which in the future can not be then identified.

At this stage a special attention will be given to the protection and automation testing at substation level : Load Shedding, Breaker Failure, Automatic Reclose, Automatic Bus Transfer, because during site acceptance testing, these functions can be fully simulated , aiming each signal through the tripping matrix from

Table 2 . Example of tripping matrix

Tripping matrix Trafo 110 kV													
Relay	Protection function	Trip Breaker 110 kV		Start AR	Breaker failure	Command AR	Block AR	Envent rec	recorder	Alarm	Lockout	Teleprotection	
		Coil 1	Coil 2										
RED670	Pdif												

Regarding the compatibility aspects, we have to mention that is very important the choice of both equipments, the hardware and the software applications, offered by the same manufacturer.

This solves the problem of compatibility because no matter how "open" it is the used protocol, has been proved that are a lot of failures in communication between devices. Having at disposal both the devices and the applications offered by the same supplier , the communication problem and the conflict between the equipments is supposedly resolved. This because the interoperability tests are performed by the supplier. So, the reliability of this system increases significantly, being eliminated the interoperability problems.

In terms of hardware it is necessary to establish strict requirements regarding the hardware of SCADA application. We mention in this direction the immunity to disturbance, high life duration, the condition to work uninterrupted, providing immunity to shock. Having at disposal the requirements of IEC 61850 it is necessary the allocation of qualified human resources, prepared to verify their compliance with these requirements, and also the tools which these requirements are verified.

In this direction, will be allocated both the hardware and software equipments needed for these checks. A significant aspect to achieve portability and integration, is the delivery by the suplier of the protection, command and acontrol system of application, of the ICD, SCL, SCD files with which it can be follow the corespondence with the standard requirements and also facilitates the interventions in the system.

Very important is the availability of these files after the completion of application because these are the key to further integration and changes of the system. Noted that any intervention should be performed by the qualified staff due to the high level of complexity. The checking of information provided by IED can be done by using specialized test tools for this purpose.

Due to the novelty aspect of this equipments, use of this tools also involve complex and advanced knowledge in the field of computer programming. On the other hand a check more handy is the individual test of the information, the signals for each bay with the mention of a low response time .

In the framework of the verification samples must be analyzed the based tools which will run post factum analysis. In this respect, will be checked the oscilo and how to configure the records at trials.

It is particularly useful to create files in commtrade format to stimulate various fault conditions. With these files, also with complex tools, are tested the proper functionality of protection and command equipments, being able to generate reports(very useful regarding the analysis of operational reliability of equipments). Regarding the application of remote, the beneficiary has the task to check detailed each information from database, previously approved in the technical project. The beneficiary also must demonstrate the compliance with IEC 61850 standard and the communication requirements with fiber support to ensure the independence of disturbances. This requirement also applies in the case of hardware structure from the substation. The guarantee of

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obtaining a reliable solution derive from stringent requirements imposed by IEC 61850.

A final step in organizing the data needed for a proper maintenance of the system built is the realization of internal technical instructions by the operating center, based on the documentation provided by the manufacturers, as well as the organization schemes As Build. Thus the inherent changes that occurred in the schemes, configurations that must be made and approved. Noted that protection department's staff should analyze the way of making each protection , automation, for identifying the operating conditions, respective block. All this information will be reflected in the content instruction. After the completion of the commissioning test it is mandatory to carry a back-up for both the remote control application and for all IED configurations.

6. CONCLUSION

Regarding the data presented , the most important element in obtaining a reliable protection command and control system is human resource. The reason is represented by the fact that the experience of staff involved in establishing tasks notebook, technical project, commissioning and exploitation is critical for reliability of system. Through all these stages, the beneficiary should assure qualified staff and maybe most important staff interested by the newest technologies. In this way, we presume that the human resources reengineering started once with introduction of IEDs in protection and control systems. Main request remain for each beneficiary to create its team specialized in new technologies for commissioning and exploitation. The goal of this team should be continuous training based on experience , and high interest for a domain with an exponential evolution. One of the positive aspects of a various types of equipments and applications implemented in distribution of energy domain, is attached by the advantage of creating an complex image of the potential for each supplier. The experience of local distribution system consist of working with high quality systems such as ABB, Siemens, SEL, Telvent. Studying the behavior of each system, possible only after few years of exploration, can be established for each of them the operational reliability. From this reasons, it is necessary a continuous monitoring of their functionality for creating a feed back link through requests of tasks notebook

For the moment, the coordinate on evolution scale of digital protection systems, is pointed on IEC 61850 standardization .

7. REFERENCES

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