Distributed Control System Used in the Remote Control of Transformer Substations

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***Abstract* — This article presents a distributed control system used in the remote supervision of transformer substations. The system uses a series of devices with digital control of the type SIPROTEC 4, with open communication interface for the control and set up of the remote parameters.**

I. INTRODUCTION

In the modern transformer substations it has been tried to eliminate as much as possible the intervention of the operational personnel as well as the manoeuvre of the primary equipment (breakers, dis-connectors), as well as interpreting some protections and their remote centralised transmission to the dispatcher. In order to achieve the following techniques:

-digital measurement;
-digital filtering and dynamic stabilisation of the measured values;
-signals digital processing;
-protocol communication;

II. THE BASIC STRUCTURE OF A TRANSFORMER SUBSTATION

A transformer substation is the ensemble of electric installations and annexed constructions in which is evacuated the power produced in the power plants or the connection of electricity lines or distribution of electricity to the consumers. Basically, a transformer station is composed of a bus-bars system, simple and double bars and the connection between the bars is made by means of coupling and diameters. Choosing one model or another is done based on a technical-economic analysis. The primary equipment in a substation is composed of: bus-bars, switches, disconnectors, transformers, autotransformer, compensation coils, condenser batteries etc

Fig. 1 The picture of a high voltage transformer substation

Fig.1 presents a 400/220/110kV transformer substation in the activity area of DET Bacau.

It is reduced to a one-pole scheme presented in Fig. 2. The one-pole scheme is used by the operational personnel and dispatcher in the current operations.

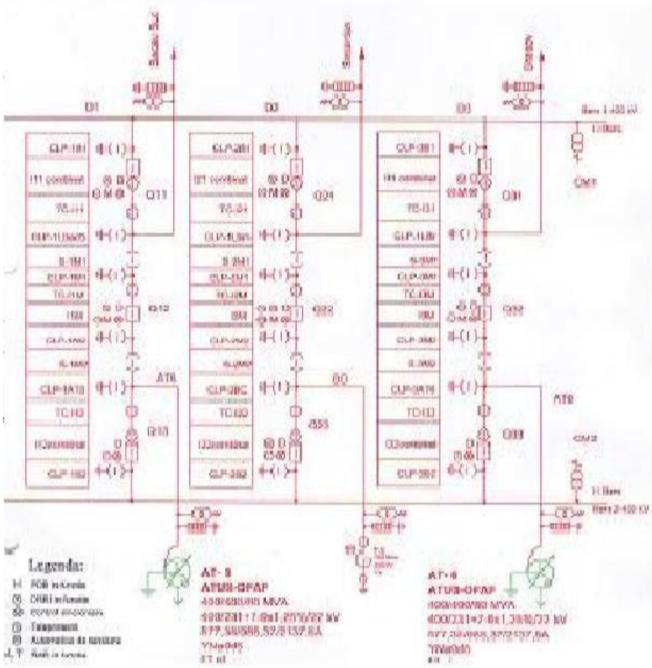

Fig. 2 The main scheme of a high-voltage transformer substation

III. THE FUNCTIONS OF A COMMAND AND REMOTE CONTROL INFORMATION SYSTEM

The main functions of the command and remote control information systems are:

- remote supervision and control of the installations (installation parts) and of the electric power networks;
- alarming; the system is able to recognize the functioning states which are not corresponding of the controlled equipments and networks;
- post-failure analysis. The system keeps a record of the events in the controlled process, offering the dispatcher complete information for a relevant analysis of the events;
-the graphic interface of the user (HMI – *Human Machine Interface*). It allows informing thoroughly the operator about the topology and state of the systems driven by means of the Human Machine Interfaces (HMI);
- self-diagnose. In order to optimise the technical processes functioning, the remote command and control systems were

implemented self-diagnose functions which allow continuous supervision of their running in order to plan as well as possible its own hardware and software resources;
-planning and follow-up of the maintenance process in order to avoid unexpected falls (unavailability);

IV. THE STRUCTURE OF A REMOTE COMMAND AND CONTROL INFORMATION SYSTEM

The remote command and control information system needs to meet the ISO demands (Open System Interconnection –International Standard Organisation). An open system disposes of possibilities to implement applications so that they may:
-be implemented on systems which come from several equipment suppliers;
-be able to work together with other applications on open systems;
-present a consistent style of interaction with the user;

The greatest advantage which the open-system concept brings in designing the remote control and command systems is the possibility to distribute functions in various processing knots. Each functional knot is independent as hardware resource. The work stations constitute such knots which release the Human Machine Interface system.

The dependence degree between knots is variable; still, by means of the hardware a higher level of independence has to be ensured because this is how the extension or replacement are possible. At the same time, the dependence of the processing knots serves to minimizing the messages and overcharging the data transmission network. The redundancy within the knot increases the degree of availability and decreases the risk of losses and of distributing the lost functions in other knots. A characteristic of the open systems is the fact that the knots can be situated at any distance; the distributed architecture becomes a necessity and uses as a support of communication the local data area networks (LAN – *Local Area Network*) and the remote ones (WAN – *Wide Area Network*) which are carried out based on standard procedures and interfaces.

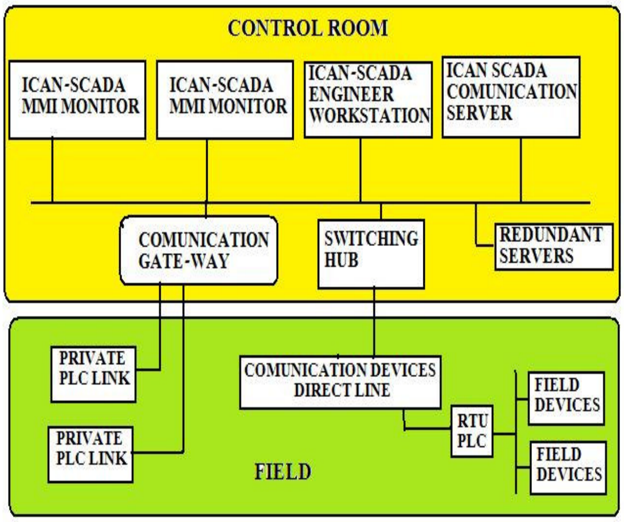

Fig. 3 The general architecture of a remote control and command information system

Fig. 3 presents the general architecture of a distributed remote control and command system, in which the key element is represented by the connection of different components by means of communication networks. At the level of the connection with the technical process (the equipment in the transformer substation), we find the equipment of data acquisition and command (EAC) meant to be an interface to the electric power installations distributed in the interest points. This system ensures taking over the process information as well as transmitting the commands to the process. The modern systems ensure a high degree of local processing at EAC level.

IV.1. COMMUNICATION

The EAC equipment is interconnected through local networks (LAN) with the computers with the role of data processing for the entire process (for example for the transformer substation). The data connection between the transformer substations and the command and control point is performed through data networks which are specific to the remote transmission (WAN): The data transfer between the WANs and LANs which are situated at the control-command points is ensured by the computers with the role of data concentrator (FEP – *Front End Processor*).

DIGSI is very well-known software today. In the beginning it was launched as software for MS-DOS then developed to become a very convenient tool to set up the digital protections in WINDOWS. DIGSI 4 is a very friendly software which is now at the third generation and which easily ensures the set up of any kind of digital Siprotec .

DIGSI4 ensures several communication possibilities like:
- direct communication connection;
- modem line communication through specialized software;
-communication through the network PROFIBUS FMS;

An important role in ensuring a safe and no error communication is held by the addresses. For the communications between the DIGSI and Siprotec devices the DIGSIR4VD addresses are used. These are used for the unique identification of a computer which runs DIGSI4. These addresses can be preset and used as default or need to be modified when there are simultaneous inputs for the two interfaces of the SIPROTEC devices. The addresses once set on the device and computer; one can go on with the device configuration. Generally, the command and control devices have preset functions (differential and longitudinal protection functions, remote protection functions, maximal protection functions of acyclic current) are activated and configured both locally by means of the serial port COM as well as remotely by means of remote software.

IV.2. ESTABLISHING A CONNECTION - PERFORMING A DIGSI 4 DESIGN

Plug & Play is used to establish a direct connection to a device SIPROTEC for which the parameters are not saved in the computer. Therefore, a DIGSI 4 project is necessary.
The procedure is the following:
- A direct connection is established between the computer and the SIPROTEC 4 device in accordance with IEC 60870-5. For this are used a COM serial port from the computer and operator or the service interface from the device.
- Click on the visualizing plan of the DIGSI®4 project on the right button on the directory (**folder**) and the dialog box **Plug & Play** is open through the menu **Device -> Create a device via Plug & Play,** Fig. 4.

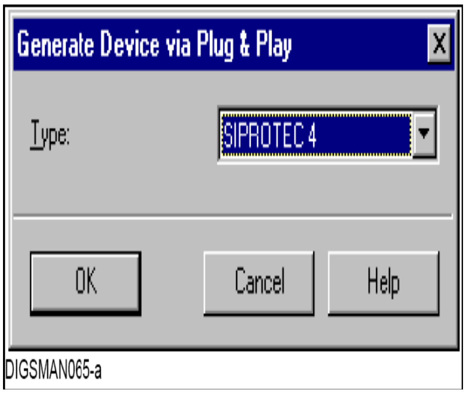

Fig. 4 Generating the device plug&play

The device type is selected and it is clicked OK. The dialogue box Plug & Play is open, Fig. 5.

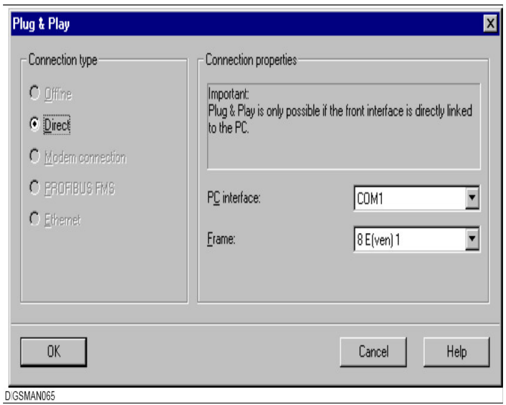

Fig. 5 Selection of the communication port

- From the PC interface, it is selected from the drop-down list the name of the serial port from the computer the device is connected to.
- From the frame of the drop-down list, the DIGSI®4 determines the device type, reads the parameters settings of the SIPROTEC 4 device and recombines with the initial parameters of the device. It generates a variant **SIPROTEC 4** and assigns it the parameters set.

In order to establish a Plug and Play connection, the initial set parameters of the type of device need to be installed on the computer. If these set initial parameters are not installed, an error message occurs.

The established connection is cancelled. The set standard parameters are installed, using the step-by-step installation and the process is repeated.

Not all information of the device is available after the connection Plug and Play is established (for example, there are no long texts defined by the user).

V. THE EQUIPMENT PROTECTION IN A TRANSFORMER SUBSTATION

Every primary equipment (transformer, breaker, bucking coil) usually has a corresponding digital device with control and command functions. The equipment control is done with specialised modules with functions of differential protection, remote protection, and acyclic current maximal protection.

All protections need to meet the following requirements: to be selective, secure, sensible, rapid, independent from the operational conditions, to be economically efficient and small-sized.

Fig. 6 SIPROTEC Siemens digital protection

Fig. 6 presents the Siemens digital module. This module has several functions (remote protection, acyclic current maximal protection etc) which can be activated according to the primary equipment which needs to be protected.

The main advantage of these digital modules of control and protection is that they may eliminate the permanent or temporary faults in a very short time, in µsec according to the settings. These modules can be set from one din µsecond to the next µsecond differently from the analogical ones which could be set from 0.5 sec to 0.5sec. Another advantage of these control and protection digital modules is that they can record a great number of events. Recording each event starts with 30µsec since it took place, when an abnormal activity of the monitored values can be perceived (current, voltage) and it ends when the disturbance is eliminated. These modules have self-control routines which run ON LINE. When minor errors occur in the activity, they intervene.

For all protected equipment, there are two protection and control modules mainly named the first and second protection groups. These perform independently from each other and in case a fault occurs they send a break impulse at the same time. In case the first group does not perform due to various reasons, the second protection group need to act. The action time between the two protection groups is of one.

All command and control modules can be activated by means of touch-screen, either from the distance (remote) or by means of process computers in the command room of the transformer substations or dispatcher. The command level of these modules is in hierarchy. The moment the command key is at a local level, every remote command, of connection or disconnection (from the command room or dispatcher) is not taken into consideration by the equipment. The hierarchy continues in the command room of the substation or dispatcher. If the command is in the substation and the dispatcher wishes to perform a connection-disconnection command that would not be successful without taking over the command.

The information regarding the state of the equipment, alarms and signalling are remotely transmitted by means of a BCU (Bloc Control Unit) which centralises and transmits these data ON LINE. Therefore, it is eliminated the operational personnel intervention from the substation which can lead to failure. There are certain filters which are installed by means of specialised programmes which can deal with the great volume of information which can remotely occur at a failure , namely in the case of the dispatcher.

Taking over, for the post-failure analysis, of the information which can be realized locally by means of the COM port of the module or remotely by means of modem communication through a specialized software or communication by means of the network PROFIBUS FMS by means of the RJ45 port.

In any transformer substation there is basis BCU and a spare one. The late can take over the functions of the former any time by means of two ways:

-manually, by means of the intervention of the operational personnel from the substation if an error alarm occurs. This operates on command keys moving from the basic BCU to the backup BCU;

-automatically with self-diagnosis routines which monitor the basic BCU and if that cannot remedy the error, it handles over the functions to the back-up BCU;

At a central level (dispatcher), we deal with two reception servers, a basic and a reception one. As compared to the ones in the transformer substation, the reception server cannot be moved from the basic one to the backup one, only with the intervention of the human factor, namely the dispatcher. At this level, a great number of stations are monitored, which can eliminate the unnecessary information. Information regarding parameter variations, self-diagnosis information would solicit a greater attention from the decision factor, namely the dispatcher, and would make his actions more difficult to perform.

VI. CONCLUSION

Using the distributed systems in the transformer substations, using digital modules of control and protection led to an increased improvement of the primary equipment, to a better safety in supplying the customers with electricity, to a lower number of programmed technical revisions in the installations and a diminished human intervention in processing certain information.

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