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# MODERN SOLUTIONS FOR PROTECTING THE POWER SYSTEM TRANSFORMERS OF THE TRANSMISSION NETWORKS

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*For several decades, the power system protection relay has experienced many important changes, from purely electromechanical type to the mixture of electronic and electromechanical type, then to fully static and now fully numerical relays based on microprocessors. In the transformer protection area, similar changes can be seen. This new numerical technology had been developed so much that now the protection systems integrates in the same device, besides the protection function also the control functions, this kind of systems also being called as multifunctional protection system (MPS).*

*The paper relieve the main features of the newly developed transformer protection and control systems, the positive impact on the faults clearance times and also the development trends in this domain .*

**Keywords :** numerical technology, protection systems, control systems

## 1. Introduction

A modern transformer protection and control system has many functions reflecting the technical trends of function integration, such as transformer differential protection, restricted earth fault protection, thermal overload protection, overexcitation protection, earth fault protection, directional or non-directional overcurrent protection, overvoltage and undervoltage protection, voltage control function for single transformer and parallel transformers as well as frequency measurement function. The integrated transformer protection and control system also includes adaptive functions such as the adaptive measurement with analogue inputs during the frequency change in power systems, and on load tap changer position compensation for increased sensitivity of the differential protection. The modern transformer differential protection demonstrates more adaptive features that give the possibility to combine high stability for inrush and external faults with a high sensitivity for internal faults. In addition to the features

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described above, the new system can be configured and set in a flexible way for different types of applications with an advanced configuration tool [1], [2].

The paper will present the main features of a multifunctional protection system in general and the typical protection and control functions implemented in such a device in particular along side with communication aspects. For a better highlight of all this it is also present a fault clearance of this kind of protection systems for a autotransformer which is functioning in a transmission network.

## 2. The main features of a multifunctional protection system

Fig. 1 shows the block diagram of a typical multi-function protection system. The system has analog inputs (currents, voltages, temperature etc.), binary inputs, contact inputs for switch status use in the control circuits, and contact outputs for sending trip and alarm signals. An MPS may also have bi-directional communication ports which may use electrical or optical interfaces and protocols, on copper wires, on fiber optic cables or on some other hardware interface for communicating with other devices in the substation and outside the substation. Internal hardware consists of an analog data acquisition system which includes signal scaling, isolating, filtering (anti-aliasing) analog multiplexing, and analog-to-digital converting. The digital subsystem consists of a microprocessor, flash memory for program storage, random-access memory (RAM) for temporary storage of information, and electrically erasable programmable memory (EEPROM) for storage of set points.

The operation and performance of these systems are determined by the hardware of the system and the software programs used to perform the protection functions. Digital signal-processing algorithms are used to filter the voltage and current inputs and calculate the parameters required for the relaying functions. The relay logic program compares the set points to the calculated parameters and implements the required time delay characteristics. The software program also implements other features such as communication, oscillography, event recording, and local interface with the user [2].

The drawback is the need of more skilled protection engineers, more settings to be calculated and transferred to the relay, more detailed system analysis and intensive tests of the relay. Even the large amount of technical documentation to be studied and applied represents more than usually needed for classical relays. The need of numerical relay configuration is perhaps the most difficult task for a protection engineer when dealing with numerical relays. Although this feature gives large possibilities to fit numerical relays to any kind of application, configuration takes a lot of time to be implemented and to be carefully tested [3], [4].

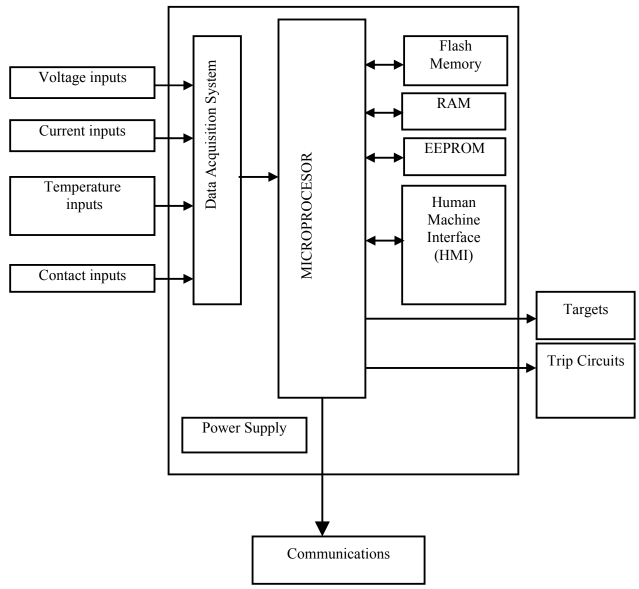


Fig. 1. Block diagram of a typical MPS.

## 3. Typical protection and control functions of the transformers MPS'S

Protective functions integrated into MPS packages include two or more of the following:
- Transformer Differential (87T)
- Restricted earth fault or ground differential protection (87GN)
- Instantaneous and inverse time Overcurrent (50/51)
- Ground instantaneous and inverse time Overcurrent (50G/51G)
- Current Unbalance/Negative Sequence (46)
- Over-excitation (24)
- Under-voltage (27)
- Over-voltage (59)
- Under-frequency (81U)
- Thermal Protection (49)
- Breaker failure (50BF)

The numbers in the parenthesis in the list represent ANSI (American National Standards Institute) device function numbers. Function numbers 27 (Under-voltage) and 81U (Under-frequency) are used for load shedding on distribution transformer applications. Function 46 (Current Unbalance/Negative Sequence) is used to provide sensitive backup for phase to phase faults on a distribution feeder. A one-line diagram showing typical protection functions included in a multifunction transformer protection system is shown in Fig. 2.

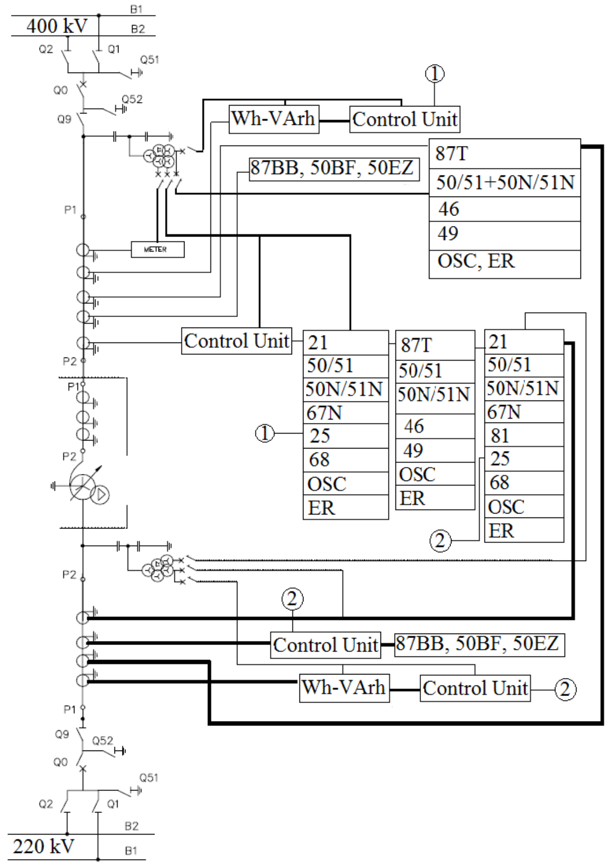


Fig. 2. One-line diagram Block of a typical MPS

Beside this protection functions a MPS contain also control functions as:

- Voltage control for Power Transformers
- Synchro-check, energizing check and synchronizing
- Apparatus control function
- Event Function
- Disturbance Report
- Remote communication etc.

Among protection functions not frequently used we point out the following:

- Over-excitation protection function. The function is based on the Volt/Hertz criterion and usually covers generation transformer protection.

- Residual high resistance differential protection function. The protection is specialized to protect for winding faults to ground in application where CT saturation could affect normal Differential Protection Function.
- Miscellaneous over current protection functions, negative sequence over current protection functions, under voltage protection functions, etc [3].

An example of oscilography registered at a fault inside a autotransformer of 200 MVA 220/110 kV, equipped with a numerical protection system, a SIEMENS technology, 7UT*** type can be seen in fig. 3. From this oscilography coud be observed the fast react of the protection system and the functions which picked up, tripped, the moments of this reacts and other useful information in understanding the incident.

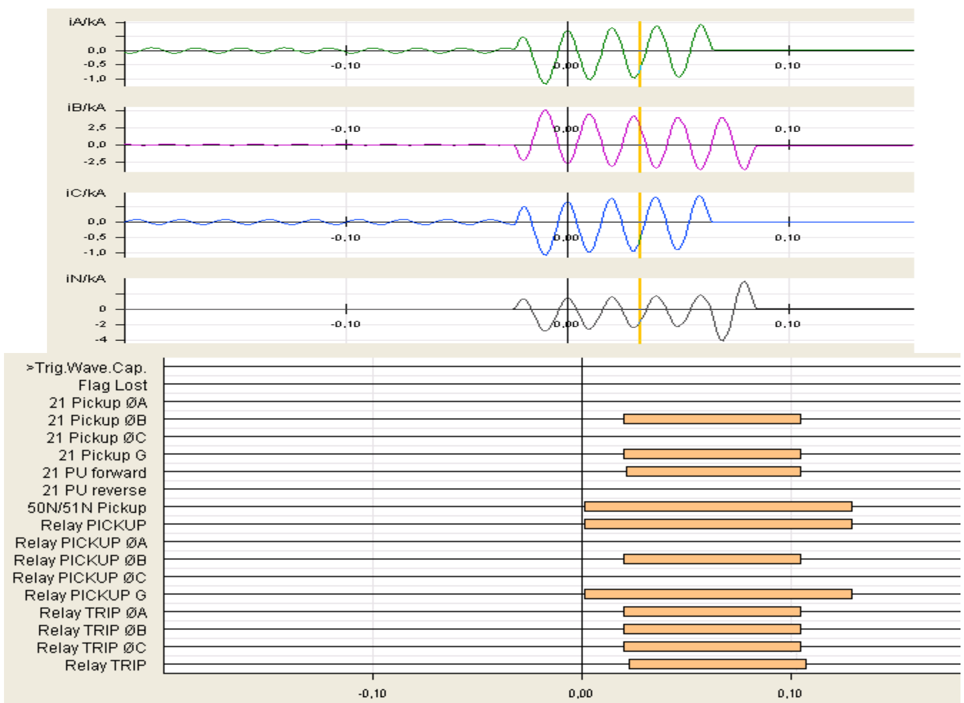


Fig. 3. Oscilography from a 7UT*** numerical protection system [5].

## 4. Communication

The digital electronics technology is naturally suited for use in numerical relays for communicating with other relays and with substation and central control computers. The additional cost is marginal and the benefits of the additional capabilities far exceed the cost. Most numerical relays now include facilities that allow them to exchange information with other relays, measuring instruments and, substation and central control computers [2], [6]. One of the problems with the communication facilities is that different protocols were used previously in different parts of the world. The Utility Communication Architecture (UCA) Group started, in mid 1990s, to work on developing a North American communication standard for use in protection, automation and control applications. IEEE later joined the activity and provided sponsorship. At about the same time, IEC started working on developing a communication standard for use in protection and automation [2], [7].

The two activities were consolidated in 1998 and it was agreed that the standard be developed as an IEC document. This activity finally resulted in the publication of the IEC 61850 Standard that is now being used by relay and IED manufacturers all over the world. The use of this standard has made it possible for devices installed in a substation, but provided by different manufacturers, to communicate with each other without the use of special purpose software for facilitating communications between devices designed by different manufacturers. This is a great feature for facilitating substation automation and control [2], [6].

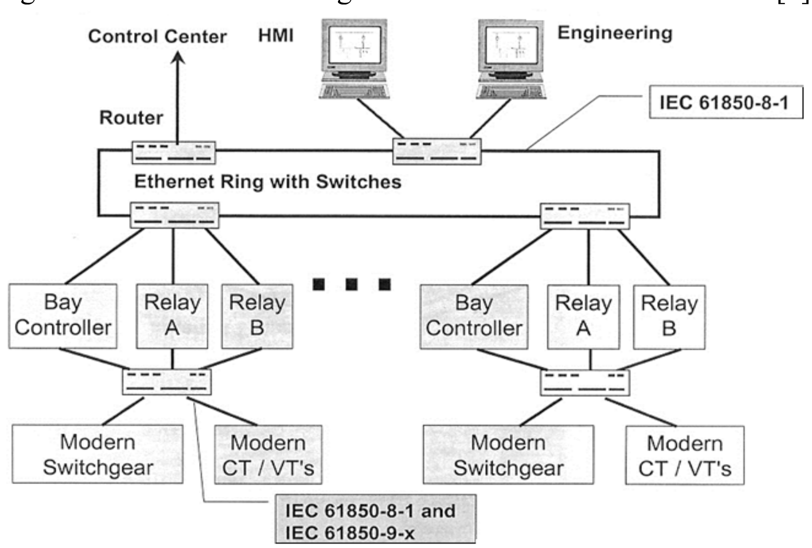


Fig. 3. Example of the communication system architecture of a substation after the IEC61850 standard.

## 5. Future view

A modern transformer protection and control system has many functions reflecting the technical trends of function integration. The integrated transformer protection and control system could also include adaptive functions such as the adaptive measurement with analogue inputs during the frequency change in power systems, on load tap changer position compensation for increased sensitivity of the differential protection and adaptive voltage control function.

The adaptive voltage control function has a feature in which once the voltage control command is issued, the expected change of voltage amplitude is checked and the next operation will be temporarily blocked if the expected change of voltage amplitude cannot be confirmed in the previous action. This feature provides a positive effect in avoiding voltage collapse when the power system is short of reactive power supply [1], [8].

Numerical relays can be designed to include abilities for changing their settings automatically so that they remain attuned to the system operating state as it changes [9]. Some of the functions that can be made adaptive are as follows.

- Using the most appropriate algorithm during a disturbance
- Changing settings of relays of a distribution network as the system loads or configuration change
- Changing the settings of second and third zone distance relays as the system operating state changes
- Compensating for the CT and VT errors
- Changing the circuit auto - reclosers delays to ensure that the circuit is reclosed after the arc is extinguished [2].

## 6. Conclusions

The massive introduction in electric power substations of the modern equipment, especially digital control and protection systems and digital transmission systems had a positive impact synthesized in:

- Increasing safety operation of power systems with fast and safe removal fault and / or avoiding dangerous operating states
- Remote Management of the protection systems
- The software configuration and parameterization;
- Low and easy maintenance because of the real time functions of "self-test" and "self-monitoring"
- Short times of search and clearance fault
- Accessible prices in present because of mass production

Difficulties related to the use of numerical protection systems:, control and transmission systems (not related to their operation itself):

- The staff used has to be highly skilled, multi-disciplinary trained, experienced;
- Inspections and tests (FAT, SAT, Commissioning) are very complex and must take place after appropriate procedures;

The paper aimed to underline the advantages of using a modern numerical protection and control system to protect a power system transformer and also expose the opportunity of implementing the adaptive concept, which represent the future of the numerical protection technology.

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## R E F E R E N C E S

[1] *J. Wang, Z. Gajic, S. Holst*, The multifunctional numerical transformer protection and control system with adaptive and flexible features, ABB Automation Products AB, Sweden, Available on: www.abb.com

[2] *M. S. Sachdev, S. R. Aggarwal, C. Diaconu, H.-J. Hermann, S.-H. Kang, N.N. Misra, W. Offhaus, R. Simon, S. Troedsson, Corresponding Membres: R. Chano, R. Cormack, S. Kim, P. Mysore, B. Sparling, P. Stewart, M. Yalla*, Modern Techniques for Protecting, controlling and monitoring power transformers, Cigré Study Committee B5 Working Group B5.05 Report, CIGRE June 2011

[3] *A. Vasilievici, F. Balasiu, Gh. Moraru*, Protection and control equipment for transformer of electrical substation, The 5th International Power Systems Conference, Romania, Timişoara, 06-07.11.2003, p.525-532.

[4] *I. C. Constantin, S. St. Iliescu*, Automatic Voltage Regulation of the Transformer Units Implemented in Digital Multifunction Protection Systems, 13th International Conference on Optimization of Electrical and Electronic Equipment, 2012

[5] *** *SIEMENS,* EcHoS,Siemens *DIGSI* v4 83 ISO

[6] *M. S. Sachdev* (Coordinator), et al, Advancements in Microprocessor Based Protection and Communication, IEEE Tutorial Course, Institute of Electrical and Electronics Engineers, Piscataway, N.J. U.S.A., Pub No. 97TP120-0, 1997

[7] *Nicoleta Arghira, Daniela Hossu, Ioana Făgărăşan, Sergiu Stelian Iliescu, Daniel Răzvan Costianu* , Modern SCADA philosophy in power system operation – a survey, U.P.B. Sci. Bull., Series C, Vol. 73, Iss. 2, 2011

[8] *I. C. Constantin, S. St. Iliescu*, Master-Follower Method for Controlling Parallel Transformers Implemented in a Numerical Protection System, in Proc. 2012 IEEE International Conference on Automation, Quality and Testing, Robotics , Cluj Napoca, Romania, 2012

[9] *S.H. Horowitz, A.G. Phadke, J.S. Thorp*, Adaptive Transmission System Relaying, IEEE Transactions on Power Delivery, Vol. 3, No. 4, October 1988, pp. 1436-1445