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ANALYSIS OF EVENTS IN ELECTRIC STATIONS USING FOCUS FOR WINDOWS PROGRAM

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ABSTRACT: *The continuous development of the energetic system and the necessity to increase the safety in operation and the quality of the supplied electric power imposes increasingly severe conditions to the protection and control systems. Among the most important components of SCADA systems used for the electric stations control and protection are the equipments for disturbances recording and analysis, such as the Compact Digital Recorder (CDR). The data stored in the internal CDR memory can be extracted on a PC by CDR Link for Windows program. This paper presents Focus for Windows program, designated for visualization, analysis, interpretation and printing the recordings performed in electric stations with CDR equipments.*
KEYWORDS: *energetic system, safety in operation, Compact Digital Recorder (CDR), SCADA systems*

INTRODUCTION

In Romania, according to TRANSELECTRICA strategy (Romanian Transmission and System Operator), for managing the electric transport and distribution grid is used an EMS/SCADA system (Energy Management and Supervisory Control and Data Acquisition). This system has a hierarchical, decentralized, distributed and redundant architecture.

An EMS/SCADA system contains [1, 2]:

a. *measuring components (for electric grids are measured the voltages, currents, active and reactive powers, frequency, as well as the active and reactive energy);*
b. *drive and automation components (for electric grids: switches, circuit breakers, disconnectors etc.);*
c. *hardware components: computers, printers, plotters, monitors, synoptic displays, process management modules, PLC control modules, storing units (discs and/or magnetic tapes) etc;*
d. *software components: operation systems (in real time, or not), data collecting systems, database management systems, simulation programs, communication programs, archiving/data restoration programs;*
e. *communication components:*

- ☐ *LAN networks (Local Area Network: coaxial cables, UTP, fiber optic cables, network cards);*
- ☐ *telephone lines;*
- ☐ *terrestrial radio communication equipment (emission-reception stations, transmission relays);*
- ☐ *communication equipment.*

The measuring components could be simple transducers connected to an analogue-digital conversion unit, or can be instruments with digital output.

The digital value of measurement is taken by a RTU (Remote Terminal Unit), which evaluates the measurement result (is made a verification to frame within the pre-established measuring limits); for some usual cases RTU initiates the performance of some controls and communicates the measurement results to the processing central system.

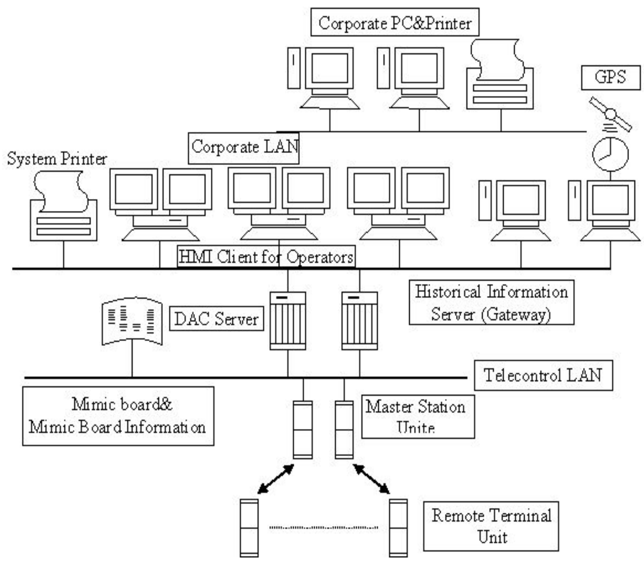

Figure 1. Principle diagram of an EMS/SCADA system

One of the most important components of EMS/SCADA systems is the database management system.

The drive and automation components are connected to the RTU tele-transmission terminal units or to PLCs, which, based on the evaluation results, or based on the controls arrived from the processing central system control the performance of some operations. RTUs are local decisional modules that can initiate some critical or routine operations.

The hardware components offer the processing, storing, enter, display and data printing support.
From safety considerations are used redundant elements to prevent the data loss or operations interruption.
The software components allow the data monitoring, visualizing and processing. Some of these components can initiate physical operations, such as controlling of some drive and automation elements.
The communication programs, beside the electronic communication support, ensure the connections between different system elements. Provided that the communications ensure the system's vital data flux, are used redundant means to prevent the system's partial or total drop.
EMS/SCADA functions within the energetic system are:
- *data acquisitions and exchange;*
- *chronological recording of events;*
- *data automatic processing;*
- *post fault analysis;*
- *real-time database updating; maintaining the database with historical information regarding the system operation;*
- *tele-control; warnings and alarms;*
- *user interface [3-7].*

When a disturbance occurs in electric stations, it takes place a variation of the analogue and binary parameters. This variation is recorded by the acquisition (scanning) equipments, from which category is also the Compact Disturbance Recorder produced by TELECOMM Bucharest [8].

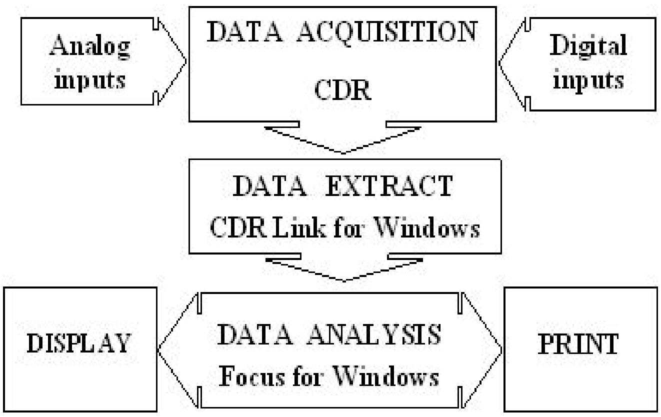

Figure 2. Logic operational diagram of the acquisition, extraction and analysis system of the events from an electric station

CDR records the disturbance data and events during the time period:

$$t_{recording} = t_{Pre} + t_{Fault} + t_{Post}, \quad (1)$$

where: t_{Pre} represents the pre-fault recording time, t_{Fault} is the fault recording time, and t_{Post} is the post-fault recording time.

Focus for Windows [9] is a program designated for visualization, analysis, interpretation and printing the recordings performed in electric stations with equipments of digital perturbograph type.
Each parameter is associated with a logic channel, a set of value segments (pre and post-fault) and auxiliary information. These are components of a focus document. Focus program provides a summary of the fault analysis through a disturbance report.
The quantities (analogue and numerical) acquired by CDR can be graphically visualized with Focus for Windows program.
The program provides, also, the phasor diagrams of voltages and currents, and their harmonic analysis.
There are two types of menus used within the program: static menus and contextual menus. The static menus provide general (global) options regarding the focus documents.
The contextual menu allows the obtaining of information about a channel (about a visible quantity) as well as performing of specific operations on the respective channel (amplification on abscise, on ordinate, color setting, graph line thickness setting etc.).

SUMMARY OF A FAULT REPORT GENERATED BY FOCUS PROGRAM

Further is presented a summary of the fault report generated by Focus program in case of a single-phase short-circuit with ground on the 400 kV overhead transmission line (OTL) Sibiu, in Mintia station.

A. Values of Pre-fault Quantities

The total time allocated to record the pre-fault quantities was 99.96 ms. Figure 3 show the phasor diagrams of voltages and currents at time moment t=-60 ms. The differences betweens the RMS values of phase voltages, respectively phase currents are very small: UL1=239.2 kV, UL2=240.6 kV, UL3=239.5 kV, IL1=365 A, IL2=374.6 A, IL3=369.5 A.

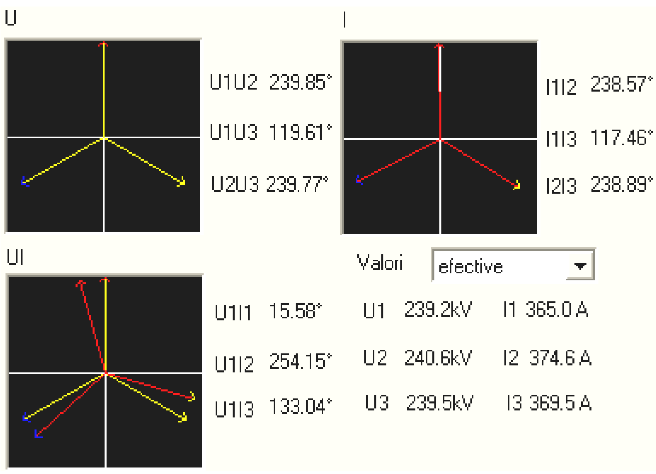

Figure 3. Marker 1: t=-60 ms (pre-fault). Phasor diagrams of voltages and currents

Phase difference between voltages is approximately 120°. Also, the phase currents are shifted symmetrically by approximately 120°. One can notice that the phasors U and I are slightly dephased. The homopolar voltage and the homopolar current have low RMS values: U0=5.159 kV, I0=42.23 A. All these indicate a normal operation of the electric line at the moment t=-60 ms.

In Figure 4, at t=-30 ms, the phase differences between the phase voltages are a little modified against the normal operation.

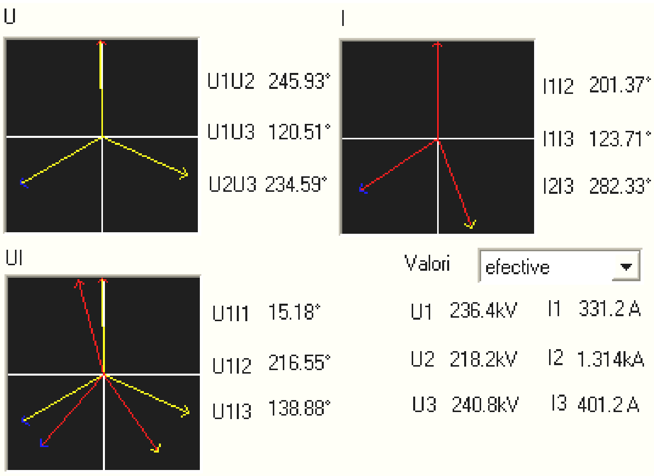

Figure 4. Marker 2: t=-30 ms (pre-fault).
Phasor diagrams of voltages and currents

Is noticed a slight decrease of the voltage on phase 2 (UL2=218.2 kV) compared with the voltages on the other phases (UL1=236.4 kV, UL3=240.8 kV). The current on phase 2 (IL2=1.314 kA) has a higher value (IL1=331.2 A, IL3=401.2 A). The homopolar voltage and the homopolar current have high values (U0=111.8 kV, I0=1.344 kA).

Marker 2 (at t=-30 ms) catches the incipient stage of a phase-to-ground fault on phase 2 (L2).

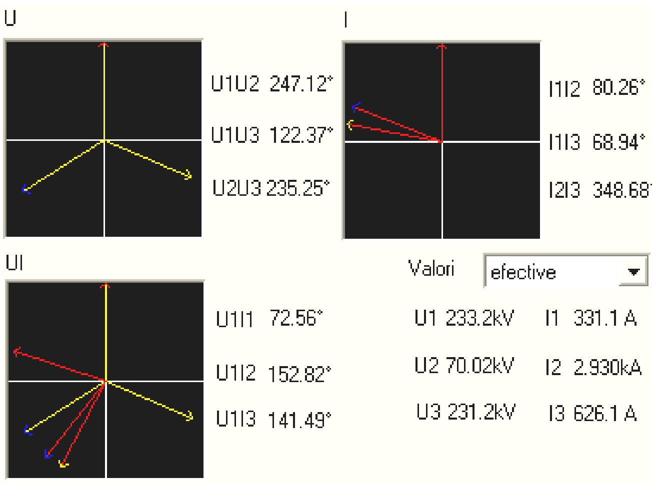

Figure 5. Marker 4: t=17 ms (fault).
Phasor diagrams of voltages and currents

B. Values of Fault Quantities

The values measured at the moment t=17 ms (Figure 5) are framed within the fault period of the recording. At this moment is recorded a maximum value of the current on phase 2 (IL2=2.93 kA) and a voltage decrease on phase 2 (UL2=70.02 kV).

One can notice a significant increase of the homopolar quantities (I0=3.597 kA, U0=294 kV), up to the limit when the high-voltage breaker's protections of OTL Sibiu are triggered.

At t=34 ms (Figure 6) is noticed the disappearance of the phase fault current (IL2=44.49 A) and homopolar current (I0=312.6 A).

Analogue quantities in the time period t= -60 ...34 ms are presented in Figure 7. Numerical quantities in the time period t= -60 ...34 ms are presented in Figure 8.

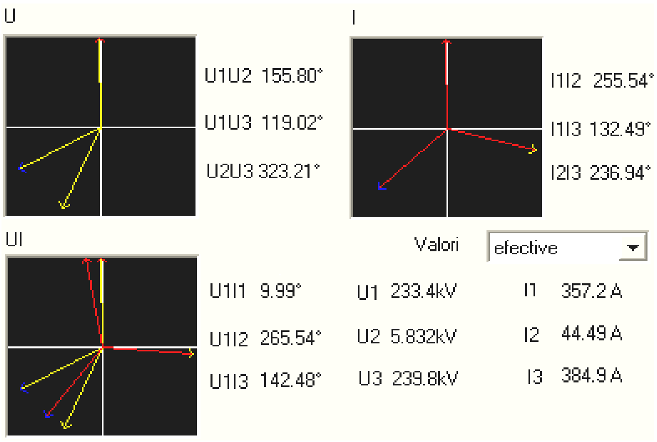

Figure 6. Marker 5: t=34 ms (fault).
Phasor diagrams of voltages and currents

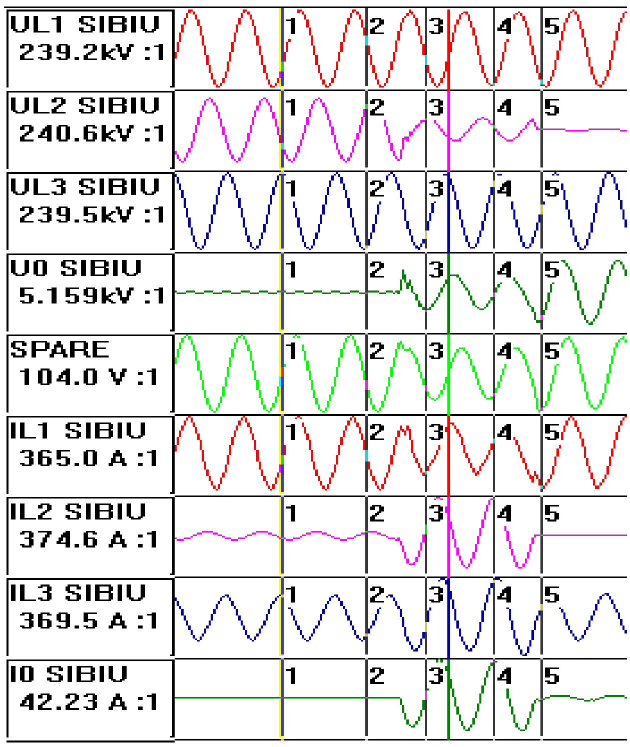

Figure 7. Analogue quantities
in the time period t= -60 ...34 ms

Markers 1 (t=-60 ms) and 2 (t=-30 ms) show that the OTL protections are in stand-by (pre-fault period). Marker 3 (t=-8 ms) is close the trigger limit.

In Figure 8, marker 5 (t=34 ms) indicates: PLC REC CH 0:1 – trigger impulse issued by the distance protection REL 521 of the teleprotection channel that sends a trigger impulse to the high-voltage breaker of Sibiu station.

In Figure 8, marker 4 (t=17 ms) indicates the start of distance protections: START L2 RE 1:1 – start for group 1 of protections through the line distance protection terminal REL 521, phase L2; GEN. START 1:1 – general start of distance protection REL 521; GEN. TRIP R1:1 – trigger impulse sent by the distance protection REL 521 to the high-voltage breaker of OTL Sibiu, in Mintia station; DIST. TRIP 1:1 – trigger of distance protection REL 521; START L2 LZ 1:1 – start for group 2 of protections through the digital relay LZ96a, phase L2; GEN. START 1:1 – general start of digital relay LZ96a; DIST. TRIP 1:1 – trigger of digital relay LZ96a.

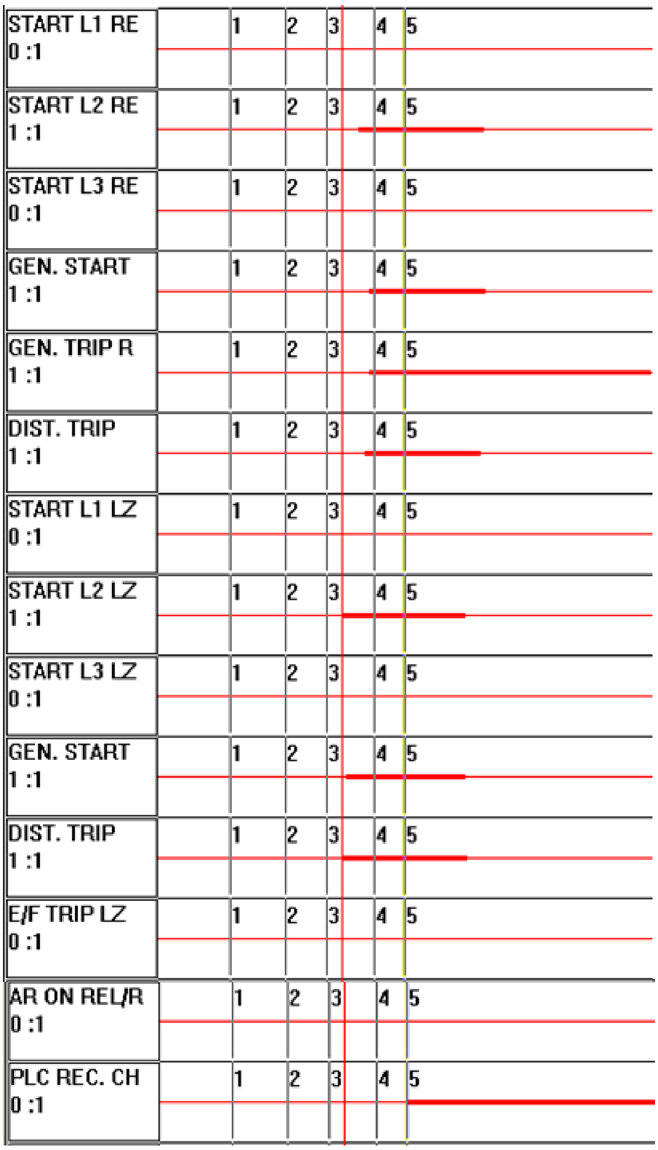

Figure 8. Numerical quantities in the time period t= -60 ...34 ms. Start of distance protections

In Sibiu station the distance protection frames the single-phase-to-ground fault in triggering step two, and the protection from the Sibiu station starts; the two breakers of high-voltage OTL, from Mintia, respectively Sibiu, trigger simultaneously.

In Figure 9, marker 6 (t=165 ms) presents the revert of the distance protection from initial state.

Fault locator of REL 521 terminal use for the distance to fault calculation a line modelling algorithm, that takes into account the sources at both ends of the line. Taking into account the RMS values of the phase currents and voltages, the distance is quantified from the place where the protection is mounted up to the fault place, and is equal by 24.2 km.

In Figure 10, marker 7 (t=1065 ms) indicates AR ON REL/R 1:1, with the following functions:

- *sending of a reclosing impulse to the Sibiu OTL's breaker in Mintia;*
- *sending of a reclosing impulse to the Mintia OTL's breaker in Sibiu, by emitting a high-frequency impulse through teleprotection (this being a common channel).*

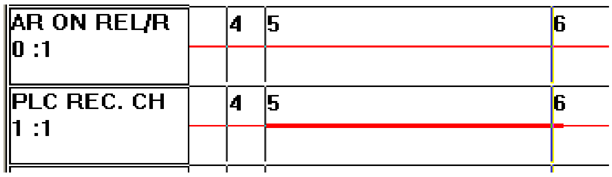

Figure 9. Marker 6 (t=165 ms): revert of distance protection from initial state

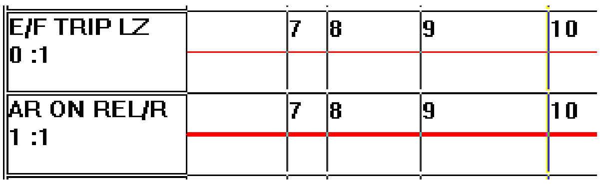

Figure 10. Marker 7 (t=1065 ms): reclosing impulses to the breakers

Marker 8 (in Figure 10) indicates the time moment t=1083 ms, when the Sibiu OTL' breaker is in closing progress.

Marker 9 (in Figure 10) indicates the moment t=1125 ms, when the Sibiu OTL breaker is closed.

C. Values of Post-fault Quantities

At the moment t=1184 ms (Figure 11) small differences between RMS values of the phase voltages (UL1=239.6 kV, UL2=242.5 kV, UL3=239.9 kV) and RMS values of the phase currents (IL1=375.8 A, IL2=394.3 A, IL3= 369.5 A) are noticed. The RMS value of the homopolar quantities are low (U0=37.58 kV, I0=42.23 A).

This figure presents the end of the successful reclosing (+).

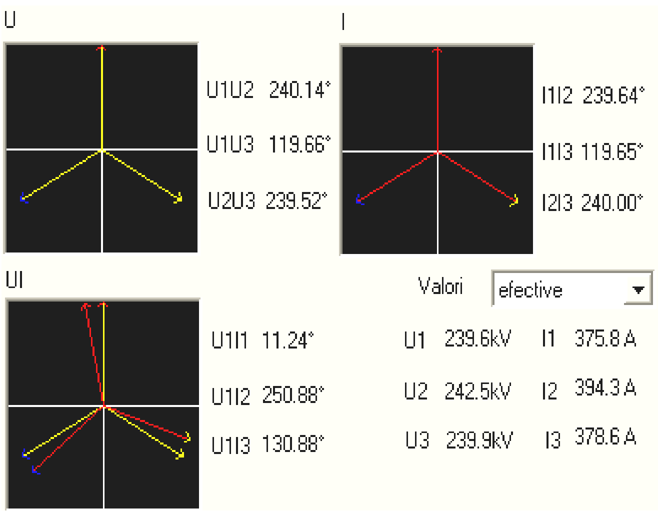

Figure 11. Marker 10: t=1184 ms (post-fault). Phasor diagrams of voltages and currents

CONCLUSIONS

The EMS/SCADA functions within the energetic system are: data acquisitions and exchange; chronologic recording of events; data automatic processing; post-fault analysis; real-time database update; maintenance with historic information regarding the system's operation; tele-control; warnings and alarms; user interface.

The Compact Digital Recorder (CDR) allows the recording of events that appear in electric stations operation.

Focus for Windows is a program designated for visualization, analysis, interpretation and printing the recordings performed in electric stations with equipments of digital perturbograph type. Each parameter is associated with a logic channel, a set of value segments (pre and post-fault) and auxiliary information. These are components of a focus document.

Focus program provides a summary of the fault analysis through a disturbance report. Are noticed especially the facilities offered by Focus program in analyzing the analogue and numerical quantities; the visualization of RMS values, phasor diagrams and harmonic analysis are in real time. Focus program allows the harmonic analysis of the voltages and currents up to 10-th order.

Further the analysis of the disturbance report issued by the Focus program, can be determined the causes, amplitude and consequences of the appeared disturbance.

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