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EDUCATIONAL PLATFORM FOR MONITORING AND RECONFIGURING OF ELECTRIC POWER DISTRIBUTION NETWORKS

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The paper presents the development of an educational platform for monitoring electrical parameters in a distribution network and its reconfiguration in the event of a fault. Automating physical processes reduces restart time. The electrical parameters (the actual phase and line voltages of each source, the frequencies of the networks, the current absorbed in the operation on the backup source) are measured by means of two multi-function power meters. They communicate with the programmable logic controller assembly via the serial port. The Ethernet connection of the machine is used for communication with the human-machine interface. The use of the programmable logic controller, multi-function power meters and user interface allows the creation of an automatic back-up switching system cheaper than dedicated ones. The latter allows, through various applications, the simulation of faults and reconfiguration of electric power distribution networks.

Keywords: the network parameters monitoring, electric power distribution networks, programmable logic controller, multi-function power meter

1. Introduction

The reconfiguration of electrical networks in the event of a fault represents the action of connecting electrical consumers to a backup circuit, in the shortest possible time, when a voltage drop is detected at the normal supply circuit. The voltage drop may be due to a breakdown or disconnection imposed by the protective devices. The backup circuit can be supplied by another electric line or its own generator unit. The back-up electrical networks are dimensioned the same as the main electrical networks and can sustain all the power consumed. In the case of an electro generator, its power is limited and only vital consumers are supplied.

The construction of Automatic Transfer Switch (ATS) systems depends on the degree of safety that is to be achieved and the level of voltage gaps tolerance of the supplied consumers [1].

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The first step in building this type of power source is to define the tasks that have to be fulfilled and set the order of maneuvers to be performed.

The main condition in any type of ATS is that during any of these maneuvers the feeds are not paralleled [2, 3].

There are three types of ATS: *reversible classic* (uses switching between normal source and backup source), with *two sources, generator and coupler* (allows the supply of consumers from two transformers and one generator) and *two sources, one couple and one sacrificial breaker* (the current to be monitored by the consumer is monitored, and if this current exceeds a preset value, the programmable logic controller (PLC) will command the opening of the sacrificial breaker, the opening of the coupler and the supply of the consumers from the backup source).

2. Hardware description of the educational platform

Using the three solutions presented above as a starting point, an educational platform has been developed that ensures the following requirements:

- If the primary voltage source suffers imbalances in voltage or frequency for a period of more than 8 s, an acoustic warning will be given and the switching to the backup source will be commanded;
- The number one source, the low voltage transformer, has priority in normal operations. If the ATS switched to source number two, and the voltage returns to source number one, switching back to source one will be done 3 seconds after the network parameters have stabilized within the required limits;
- The programmable automatic assembly disconnects non-vital consumers in the event of a fault and reconnects them upon the return of the power supply;
- The user interface displays the source that is used for powering and manages the platform in manual mode.

For the practical realization of this platform, the main components were chosen from Schneider: Modicon M221C40R PLC, PM 2120 measuring stations, HMISTO531 touch screen. Communication between HMI and PLC was accomplished via Ethernet connection.

Fig. 1 shows the electrical diagram needed to supply the power stations. The measuring stations have a separate power supply circuit, in order not to be affected by the K1 and K2 contactors switching. The measuring stations voltage references are protected against short-circuit by F6-F11 fuses. As this is an educational platform, the absorbed current is low and the force side has been connected directly to the measuring station terminals. Under electric power distribution networks, current transformers had to be used [4].

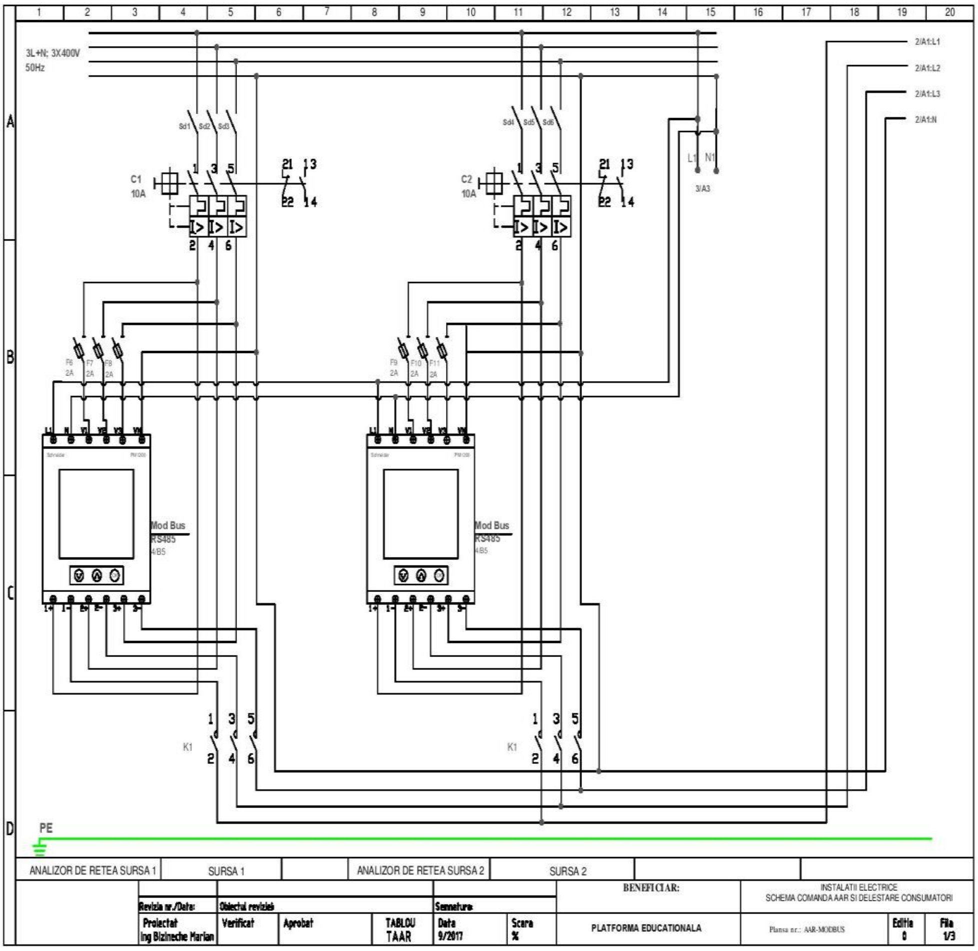

Fig. 1. The electrical scheme required to supply multi-function power meters

In order to achieve the disconnection of a consumer according to the imposed current, we used three single-phase consumers, their distribution was made on the three phases. The three consumers are protected from short circuit and overload by three circuit breakers, C3, C4, C5.

Fig. 2 shows the PLC connections. Its inputs are digital, powered at 24 V_{DC} and short-circuit protected by fuse F5. Outputs are relay type, each four relays have a common supply, they are short-circuit and overload protected by fuses F3, F4.

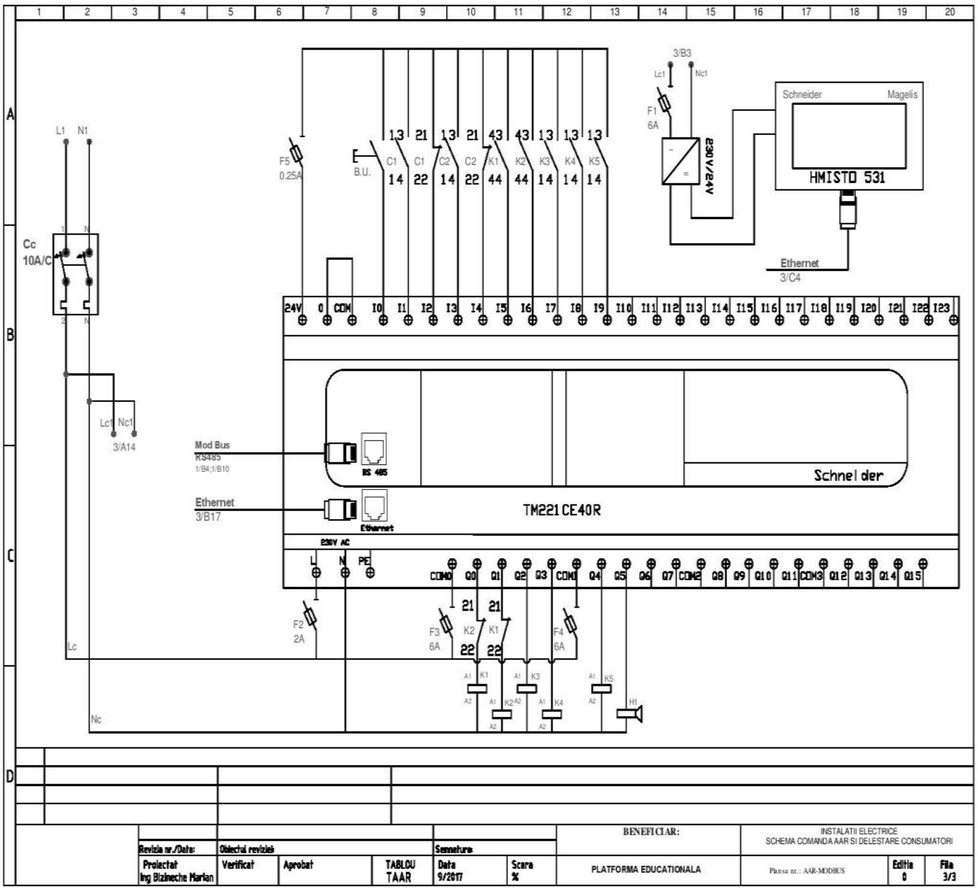

Fig. 2. Electric diagram of the PLC links

3. Software description of the educational platform

PLC programming was performed in the So Machine Basic program [8] using the LADDER DIAGRAM [5] programming language.

The programming of the touch screen was done in Vijeo Designer [9].

The "Modbus Serial IOScanner" function was used to read the parameters from multi-function power meters. In the channel assistant work window, we have set one column for each read parameter, the reading is cyclic at one second. At the offset we entered the desired address, decrementing with a unit.

The PLC is connected via a TCP / IP connection with the HMISTO531 touchscreen to display the ATS system operation status and to command the system manually.

Parameters read from the measurement centers are found in "% IWN (i+x).y.z", then their value is taken up in "% MW - memory words":

- i – serial connection 1, 100 for SL1 and 200 for SL2;
- x – slave unit ID, maximum 16;
- y – channel ID;
- z – depending on the size of the read variable.

Fig. 3. Reading parameters of the measuring multi-function power meters

The I0.2 and I0.4 entries read the state of the C1 and C2 main switches. When one of them is active, the M101 marker is set and the ATS system will display “unavailable”.

In order to reset the system, the operator has to mitigate the fault and reset the ATS system using the touchscreen.

Fig. 4. Checking – triggering

When the Emergency Stop Button is not active, the operating mode is selected from the touch screen and then the phase voltage check stage begins for the main source. If the voltages are within the set range, the timing for the enabling sequence of the K1 contactor begins. In manual mode, it goes over the stress check sequence and activates the timing directly.

The enabling of the K1 contactor is conditioned by the state of the K2 contactor, ensuring the electrical interlock. If the ATS is not "unavailable", output

Q0.0, which supplies the coil of the contactor K1, is activated. Thus, the TM0Q contact activates the check sequence for the engagement command and stops the coil power supply after five seconds. Analogously, we did for the K2 contactor engagement sequence.

Fig. 5. Phase voltages checking of the number one power source

The sacrificial consumer coupling is made using a comparator block, which has the left term consisting of the difference of the input value and the calculated current, and the right-hand term represented by the normal value of the sacrificial consumer current.

The consumer is disconnected using a comparator block, which compares the calculated current and the value entered on the screen.

The graphical interface consists of the six screens shown in Fig. 6.

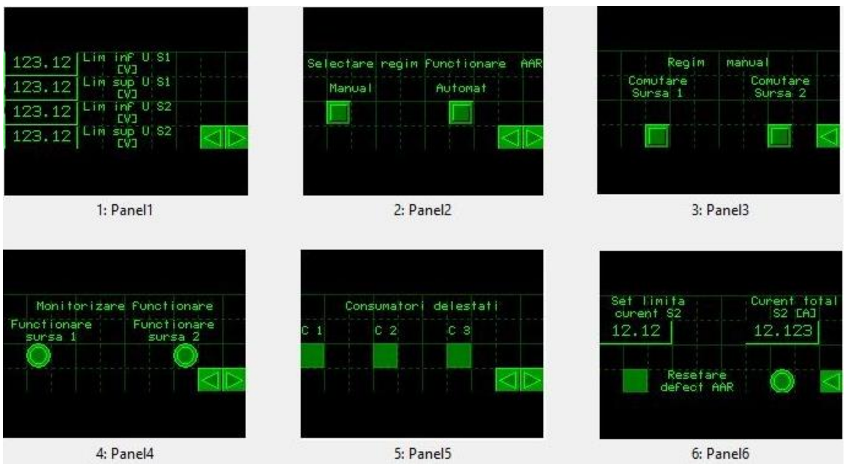

Fig. 6. Graphical User Interface

The control of the coupling and the decoupling of the consumers is made from the screen five (Fig. 6) for both ATS system operating modes. Disconnection is only performed when running on a backup source. To make the correlation between graphical and PLC buttons, "memory bits" imported to Vijeo Designer from SoMachine Basic have been used. The buttons used are on-off. Setting the limit for the absorbed current when operating on the backup source is done by means of a numeric display. The number entered on the keyboard is tens and has two decimal places. And for setting the voltage range for the two sources, the same display model was used.

4. System verification

With the help of a Arnoux Chavin network analyzer, the functionality of the educational platform was checked. The voltage probes were mounted at the common point between the contactors K1 and K2 in the distribution area to the consumers. In the 0-29 s interval, the system was switched off, the coupling on source 1 was made at time index 29 s. At time index 53 s, a fault was detected on phase 2 from source 1 and the system switched to the backup source. When the voltage returned, at time index 97, the system switched to source 1. At time index 137 s, the system was switched to manual mode and voltage drops were simulated in different phases, they no longer had any influence on the ATS system. The above can be seen in Fig. 7.

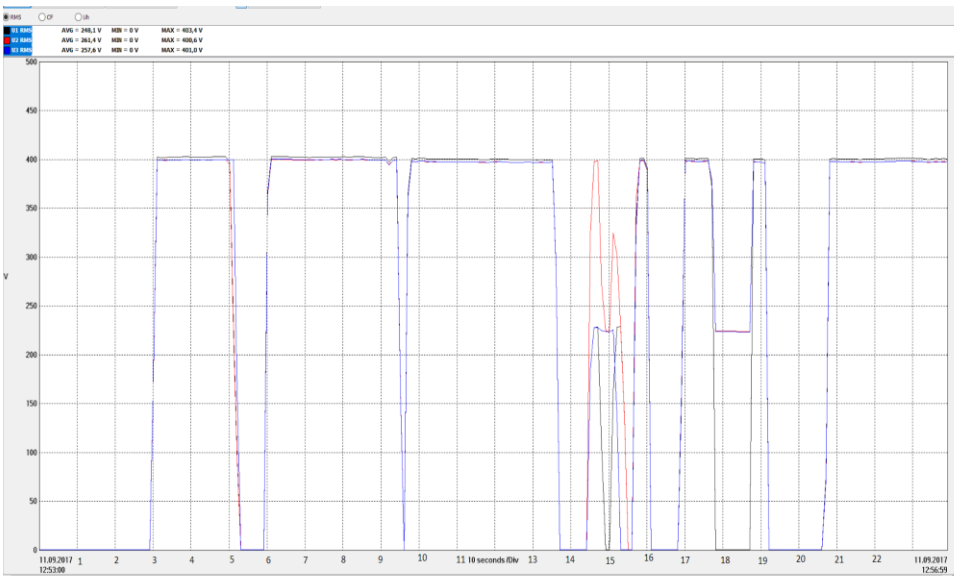

Fig. 7. Functioning checking of the educational platform

5. Conclusions

The diagram does not represent the only way to design an ATS, as PLCs also offer remote control alternatives. One of these alternatives is to monitor and control remotely using the Internet or using a local network [7]. In order to be able to connect to the Internet, a "switch" is required, because in the current installation, the touch screen occupies the PLC's Ethernet port. The ATS system can be implemented in applications with two different voltage sources, regardless of the power required. For applications where power is more than 100 kW, it is recommended to use motorized circuit breakers, the control of which is still carried out via contactors K1 and K2. Compared to a conventional ATS system [10], ATS with PLC provides real-time monitoring and modification of parameters. The price of such a system is approximately 30% lower than an ATS control module, offering the possibility of reconfiguration according to the customer's requirements, without changing the electrical wiring. In order to avoid voltage drops, the AUFASD device (Automatic Ultra-Fast Automatic Switching Device) can be used to permanently supply the consumers, switching from one source to another within 4 milliseconds.

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