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Implementation of an Automatic System for the Monitoring of Start-up and Operating Regimes of the Cooling Water Installations of a Hydro Generator

The safe operation of a hydro generator depends on its thermal regime, the basic conditions being that the temperature in the stator winding fall within the limits of the insulation class. As the losses in copper depend on the square current in the stator winding, it is necessary that the cooling water debit should be adapted to the values of these losses, so that the winding temperature falls within the range of the values prescribed in the specifications. This paper presents an efficient solution of commanding and monitoring the water cooling installations of two high-power hydro generators.

***Keywords**: automatic system, monitoring, programmable automaton, frequency converter, asynchronous motor.*

1. Introduction

The water cooling system of two hydro generators in a high-power hydro electric power plant is made of two water cooling pumps driven by synchronous motors.

In order to adjust the cooling water debit, one resorts to the modification of the number of revolutions of an asynchronous motor driving the cooling water pump by their powering from a variable frequency converter in the range (20-50)Hz [1,2].

The value of the cooling water through the air coolers is established depending on the hydro generator load regime.

The debit information is acquired by the analogical output of a programmable automaton equipping the automation installation.

The cooling water is pumped into a basin of adequate size, able to assure the necessary volume of cooling water during the nominal operation of one or two generators.

Through a level transducer one monitors online the level of water in the basin, the level information being transmitted to the programmable automaton through an analogical signal acquired by an analogical input from the programmable automaton [3].

Thus, the monitoring of the cooling installation of the two hydro generators is done through the programmable automaton.

2. Theoretic considerations

The programmable automata must be connected to the external equipment, through cables, but the content of their programme memory may be changed at any moment so that the software programmes could be adapted to diverse control tasks [1-3].

Programmable automata [3] receive data, process them and send the results to the exterior. This process takes place on three levels according to Figure 1:

- input level
- processing level
- output level

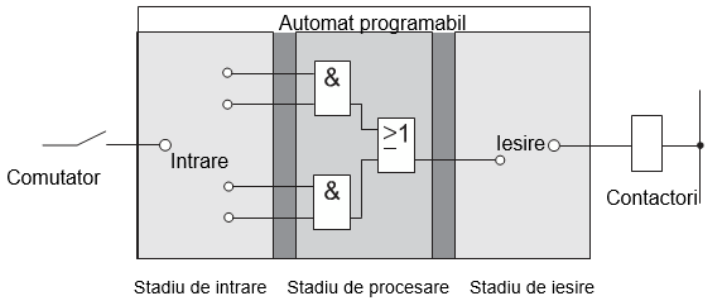

Figure 1. Processing of a programmable automaton

a) Input level

The input stage transmits the control signals from switches, buttons or sensors to the processing stage.

The signals come from these components are generated as parts of the control process and are transmitted to the input devices as logic statuses.

The input stage transmits them to the processing stage in a pre-processed format.

b) Processing stage

In the processing stage, the pre-processed signals originated from the input stage are processed and combined with the help of logic operations and other functions. The programme memory of the processing stage is entirely programmable.

The processing sequence may be changed at any moment by the modification or replacement of the stored programme.

c) Output level

The results of the input signals processing by the programme are conveyed to the output stage, where they control the elements that may be switched, such as: contactors, signalling lights, electromagnetic valves etc.

A programmable automaton performs its tasks by running software usually developed inside the automaton and transferred then to its programme memory. Before starting the programming, it is useful to have basic notions about the way in which the programmes process these programmes.

A programme of a programmable automaton consists in a sequence of instructions controlling the functions of the automaton. The programmable automaton executes these instructions of sequential control, i.e. one after the other.

The entire programme sequence is cyclic, which means it keeps repeating in a continual loop. The duration necessary for a single programme iteration is called the programme cycling duration or period

The process image processing

The programme from the programmable automaton is not directly run from inputs and outputs, but uses a „process image" of these inputs and outputs.

The inputs process image

At the beginning of each programme cycle, the system interrogates the input signals statuses and stores them in a buffer memory, creating an inputs „process image".

2. Implementation of the programmable automaton in the automation installation

Unlike the conventional control whose functions are determined by physical cabling, the functions of programmable automata are decided by a programme [4,5].

Figure 2 shows the diagrams of PLC integration into the cooling water pumps command.

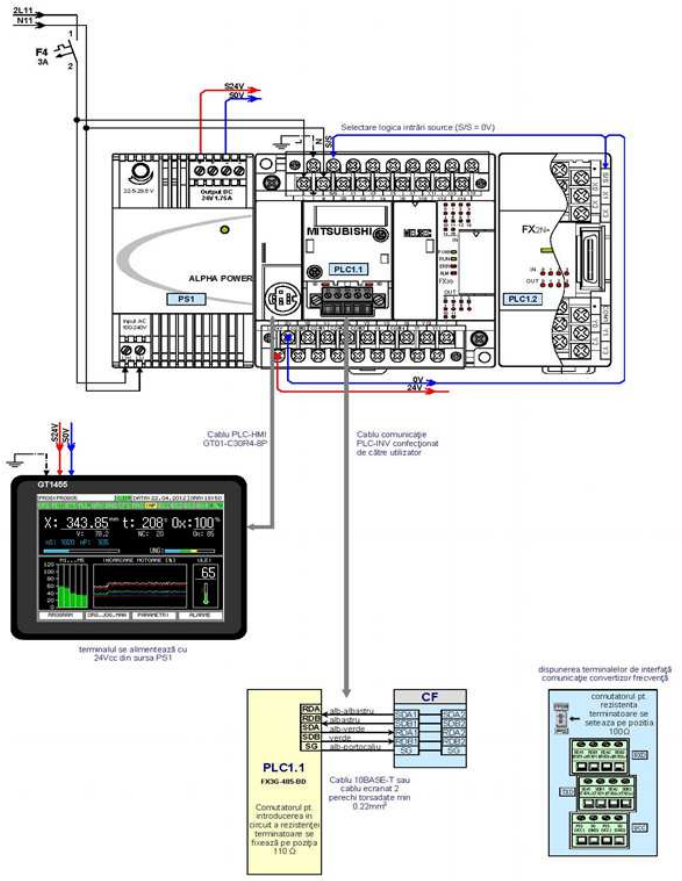

Figure 2. PLC integration into the cooling water pumps command

All FX controllers [3] have the same basic design. One used the FX3G 24M controller manufactured by the Mitsubishi company for digital inputs.

The input circuits use floating inputs. They are electrically insulated from the other circuits of the programmable automaton, by opto -couplers. The output circuits may be on transistors or relays. The transistors outputs are also electrically insulated from the other circuits of the programmable automaton, by opto-couplers.

The switch voltage [2-4] of all digital inputs must be the same (for instance 24 V DC). This voltage may be received from the integrated power unit of the pro-

grammable automaton. If the switch voltage in inputs is lower that the nominal value (for instance lower than 24 V DC), the input will not be processed.

The maximum output current is 2A for the models of relays powering resistive loads, 250 V AC tri phase and 0.5 A for loads powered by 24 V DC.

Furthermore, for the analogical inputs one used a FX3U-4AD analogical model.

The analogical input / output modules convert the analogical input signals into digital values or internal numerical values into analogical signals [5], [6].

There are several modules available for current or variable signals for the monitoring of temperatures, with the direct connection to Pt100 sensors or thermo-elements.

The operating terminal used is GOT1000 manufactured also by Mitsubishi Electric which provided an efficient and intuitive interface with the controller of the MELSEC FX series. The HMI control units make the functions of the controlled application transparent and easy to understand.

All available units may monitor and edit any of the parameters of the programmable automaton, such as actual and reference values of delay swithces, counters, data registries and sequential instructions [5, 7].

The HMI control unit are available in the key or sensor screen variants. The completely programmable functional keys and sensor screens makes these units much easier to use. The programming environment of these terminals is easy to use and intuitive and run under Windows.

The HMI terminals [3] communicate with the FX programmable automata through programming ports and are directly connected to a standard cable, so no additional modules are necessary.

The drive of cooling water pumps is provided to be made both through motor powering with variable frequencies by frequency converter and through direct start-up to the 400V network [2,4].

The dimensioning of the force circuits of the electro power supply was made based on the electric parameters of pumps driving motors.

The force circuits must assure:

- converter start-up of an electric motor;
- direct start of an electric motor.

The command of the electric motors start-up and their control during nominal operation is made through a programmable automaton which must assure both the command of the automatic sequences and the automatic control of operation parameters of motors during their exploitation, both in automatic and in manual regime.[5,6] The force diagram of the start-up installation of cooling water pumps is shown in Figure 3.

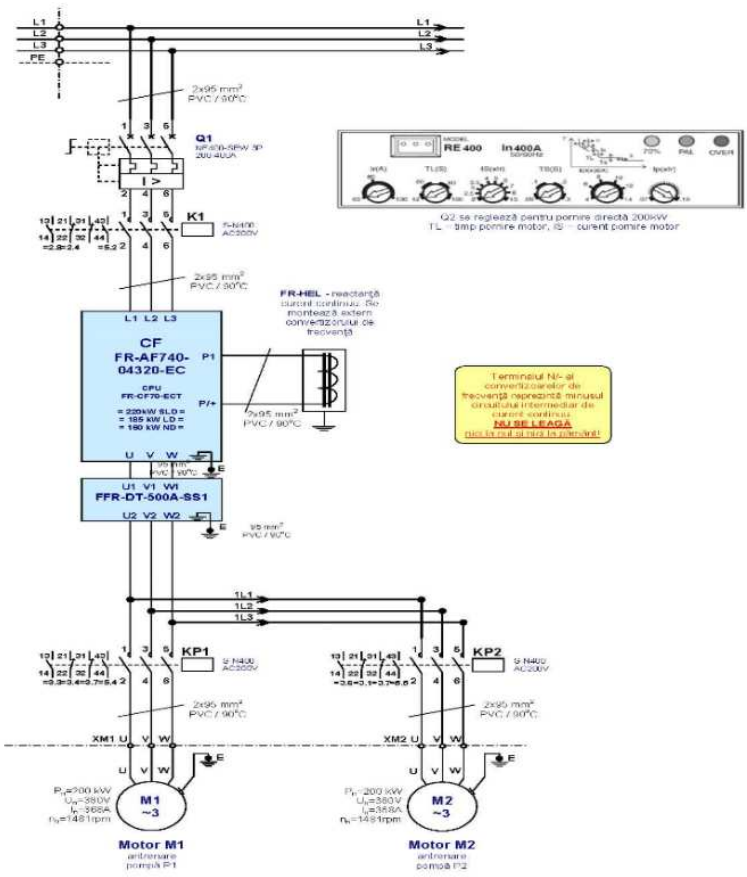

Figure 3. Force diagrams of start-up installations of cooling water pumps

Each of the 2 driving motors of cooling water pumps may be started both through CF frequency converter or directly from the network through the Kr contactor.

The diagram of power supply and emergency stop of the installation is given in Figure 4.

After the implementation of the automatic system, the results obtained met our expectations, the synchronous motors operating in maximum safety regime, eliminating the stresses occurring in the direct start from the network.

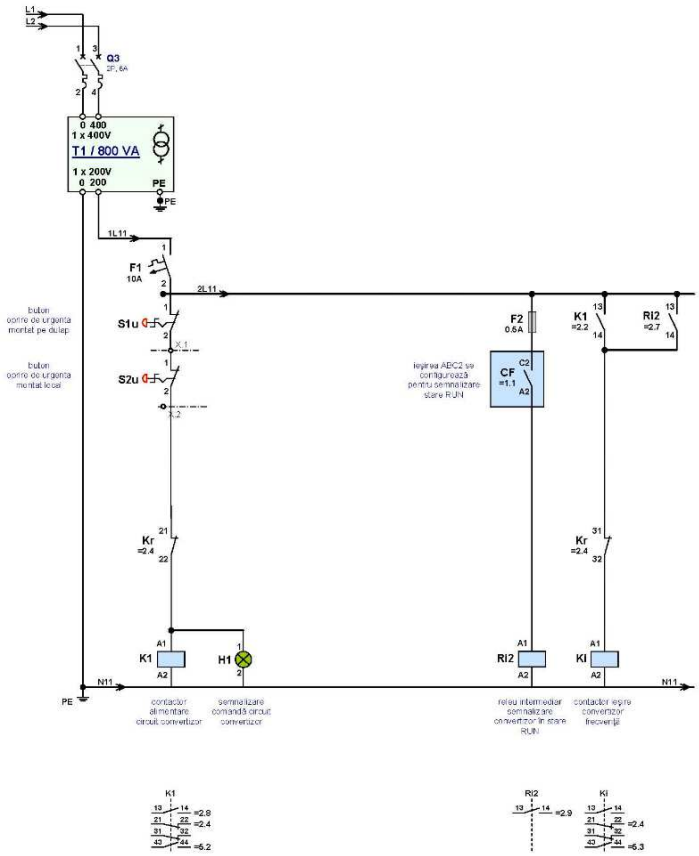

Figure 4. Diagram of supply and emergency stop of the installation

With the help of the automatic system, one modifies the rotating speeds of asynchronous driving motors depending on the necessary cooling water debit.

Figure 5 presents the synoptic diagram for the start-up and monitoring of cooling water pumps, in the presented situation the asynchronous motor 2 for the driving of the pump is in operation [7].

One may monitor online the main parameters characterising the operation regime of the asynchronous motor, the current at nominal operation and the frequency varying depending on the necessary water debit. Furthermore, one may monitor the water level in the basin. [4], [6, [7].

As one may remark, their start-up may be done automatically or manually choosing which of the asynchronous motors should start. In the automatic regime, we implemented in the automaton programme a registry counting the number of operation hours of each motor, and at the next start on the automaton, the pro-

gramme compares the number of hours of each motor and the motor with the lowest number of hours, according to figure 6, will start first.

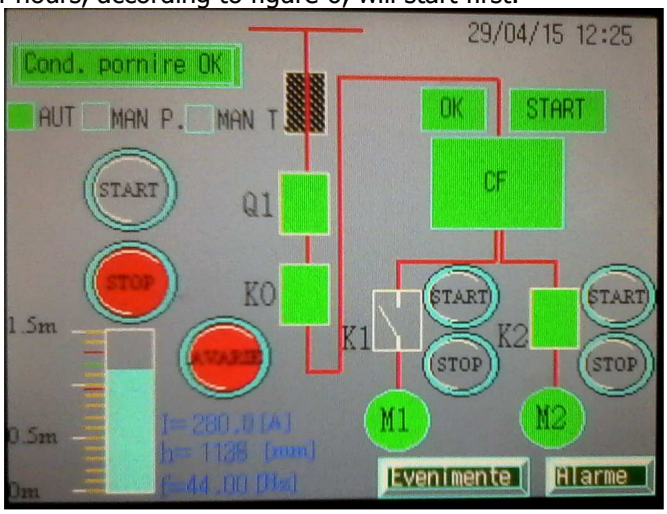

Figure 5 Synoptic scheme for the start and monitoring of cooling water pumps

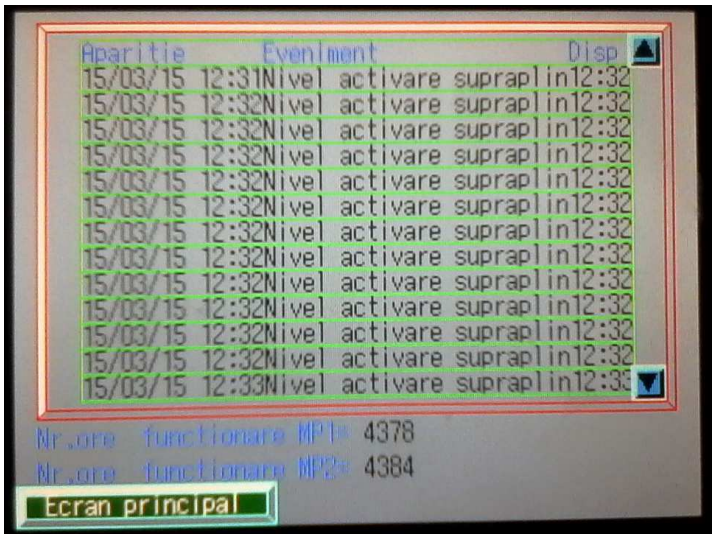

Figure 6. Number of operation hours. List of events.

On the HMI terminal one may also monitor a list of alarms and its apparition and disappearance Figure 7.

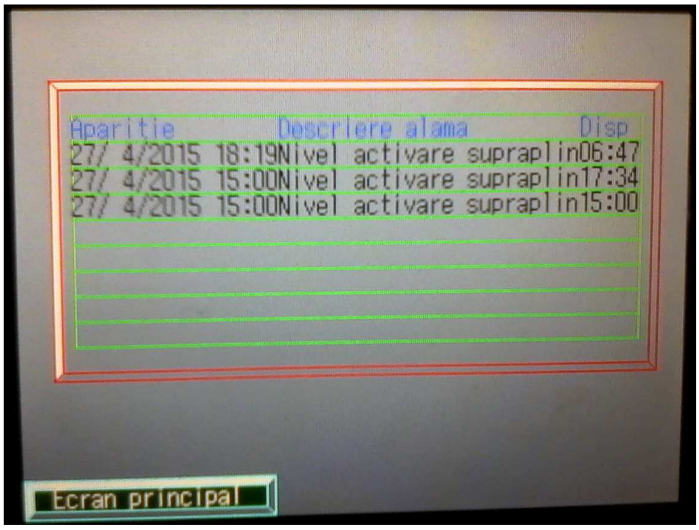

Figure 7. List of alarms

4. Conclusions

As a result of the implementation of the above solution for the driving of the cooling water pumps of hydro units, one eliminated a series of major deficiencies during the exploitation of cooling water pumps.

Among the advantages of the solution adopted, we may list the following:

- reduction of current shock at the start-up of the asynchronous motor;
- reduction of electric power consumption during the start-up regime and during nominal operation ;
- reduction of the start up current of the asynchronous motor by the low-frequency start;
- adaptation of the supply voltage frequency to the concrete conditions of pumps functioning;

When one single hydro unit is in operation, the frequency of the supply voltage is reduced to the value of 44Hz.

During the simultaneous operation of the two hydro units, the frequency of the supply voltage is automatically increased up to the values able to assure the necessary debit of cooling water.

By starting the asynchronous motors at variable frequency one eliminates the couple shocks in couplings and thus one assures the premises for an optimum exploitation of the electro-pumps, reducing the maintenance expenditure by much.

Grace to the use of this automatic installation, one eliminates the intervention of the operational personnel during start-up and exploitation of cooling water pumps.

Acknowledgement

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