SCADA Network System for the Monitoring and Control of an Electrical Installation Supplied by a Hydro-Generator

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Abstract. The energy industry is one of the domains that need control and monitoring at several levels. This article presents a SCADA monitoring system targeting a large scale process which is in need of immediate and frequent interventions: the monitoring and control of an electrical installation supplied by a hydro-generator. Citect SCADA was used to design a flexible solution and can be used for small or large hydro-generators. The SCADA solution created will be used for the functioning optimization, transmission and supervising of functioning programs execution.

Keywords: SCADA · Human machine interface (HMI) · Hydro-generator · Reserve circuit (AR) · Citect SCADA · Mysql

1 Introduction

Today's energy industry is characterized by large structural conversions. Electricity generating companies aim to improve the efficiency and quality of service. Computerization is one of the premises for the basis of the increase in the efficiency and safety in the exploitation of the energy system.

Supervisory Control and Data Acquisition (SCADA) is computer software which monitors and controls a process that is used for industrial processes. The SCADA system has a multi-layered structure composed from basic functions and graphical user interfaces which are hardware and software supervised in real-time [1].

The functions of the SCADA system are the following [2–4]: it acquires data collected from the process; manages alarms; allows the needed actions for automation; stores and archives data; generates reports; allows the dispatcher to control the process via the HMI; allows the communication with user interface via the HMI using libraries with symbols, a connection between process and graphic elements, a collection of command's operators and multimedia features.

SCADA systems may be extended to a Large Scale System by architecture, maintenance, post-processing, decision support systems, and economic planning [5].

The paper presents the creation of an HMI interface for tracking and command of a hydro-generator. Chapter 2 presents the creation of interface accompanied by Citect SCADA connection between SCADA and database of MySQL. Hydro generator

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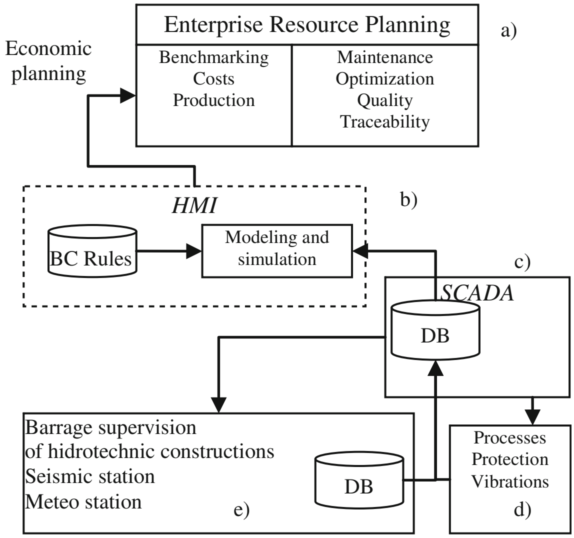

Fig. 1. Extended SCADA architecture with application in hydro energy has the components of (a) Enterprise planning, (b) HMI, (c) SCADA, (d) process and (e) access control

parameter values can be used both in this database and the values read from virtual devices presented interface. The following hydro-energy monitoring architecture is proposed, as shown in Fig. 1.

The components are the following: the physical components of process and access control; the interfacing made in SCADA with data captured from the process and stored in databases; the modeling a process simulation based on rules; the Human Machine Interface – HMI; managerial and operational decisions based on the gathered and interpreted data. Without the SCADA and the HMI interface, the economic planning would be based directly on data gathered from the lower (physical) components and would be slower to gather and analyze.

By using the Citect SCADA software we designed a wiring diagram for the services of a group hydro-generator (HG), capable of producing a power of 1100 kW. In the electrical diagram of the block generator transformer (TA) there are lines of 6 kV, which have a basic power supply and a reserve one and in between the two supplies there is a relation of Reserve Actuation (AR). The Reserve Actuation (AR) is necessary in the case of all groups used for the production of electricity, because when it is in operation the units block their dependents must be supplied with voltage at all times. The diagram includes a large number of motors (M1-M4 presented, but their number can be larger) that drive the fueling pumps, the circulation pumps, the air ventilation and other devices that are necessary in the technological process. In the case of hydro generators, their power consumption can actually reach 12 % of their nominal power. The HMI interface implemented is presented in Fig. 2. The data presented is real data (nominal power, current, power factor) and relates to the energy production of a hydro generator in Ramnicu Valcea, Valcea County, Romania.

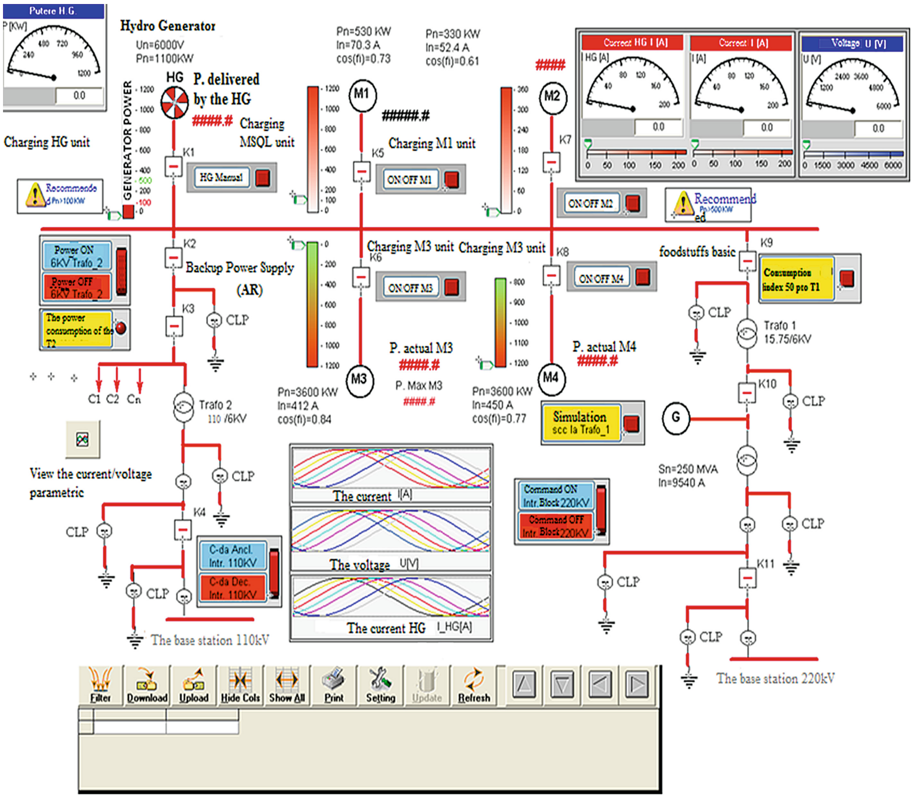

Fig. 2. Advanced HMI interface

2 Description of the Operating Mode of HMI Interface for Electrical Operation Wiring Diagram

A Citect SCADA project includes the following items: graphics, databases, Cicode programs. Graphics represents a graphic page which allows the monitor to display the graphical interface with control buttons. Databases allow the storage of process information collected for monitoring and controlling the system. These may be linked to the graphics page if desired. Cicode programs allow functionality and contain a number of useful functions stored. In order to design the application the following steps were made: identifying the elements used for data acquisition and those necessary for command and control; creating a project; defining the tags; creating the graphical data flow that will mimic the physical process flow that is connected to the data acquisition and control process; writing functions for the graphical elements; establishing the application users and their rights and finally testing and running the application.

The schematic of a Citect SCADA project looks like in the Fig. 3.

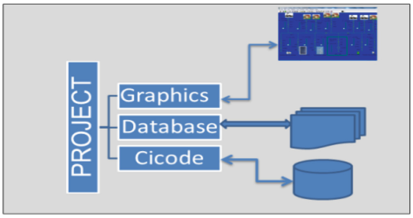

Fig. 3. Scheme of the *Citect SCADA* project

2.1 HMI Operation

For the HMI interface designed it is considered that the rated power of the block is of maximum of 120 MW. At the start of such a group, all units must be operated at nominal parameters and have the role of electricity transmission by the 4 engines of the installation.

The central element is the Hydro-Generator (HG) which was set up to provide electrical power only if reaches about 10 % of maximum power, i.e. 100 kW. If this power is not achieved (for example in the case when there is not enough water flow) a button, called "The power consumption of the T2", should be used to engage the AR. This will switch K1 in the closed position and K2 in the open position if Pn HG > 100 kW and if the power is below the threshold Pn HG < 100 kW then it will set K1 in the open position and K2 in the closed position. The powering of both the AR and the hydro generator is not allowed at the same time. (Figure 4) If the hydro generator needs to be disconnected there is a manual button "HG Manual" that allows this. The AR power is given via an 110 kW line.

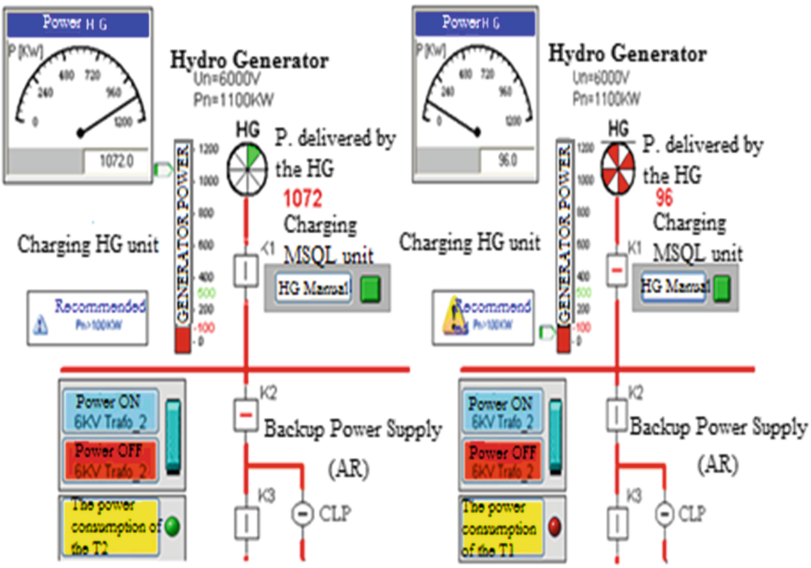

Fig. 4. Command HG/AR

2.2 Interface for Monitoring and Motors Control

The engines (M1-M4) are connected to various power sources according to their roles. The value of the power taken from the grid is set individually for each motor. As SCADA Citect applications can use databases to store the data, in this case the MySQL DB was used to store the input parameters for the engine (Fig. 5).

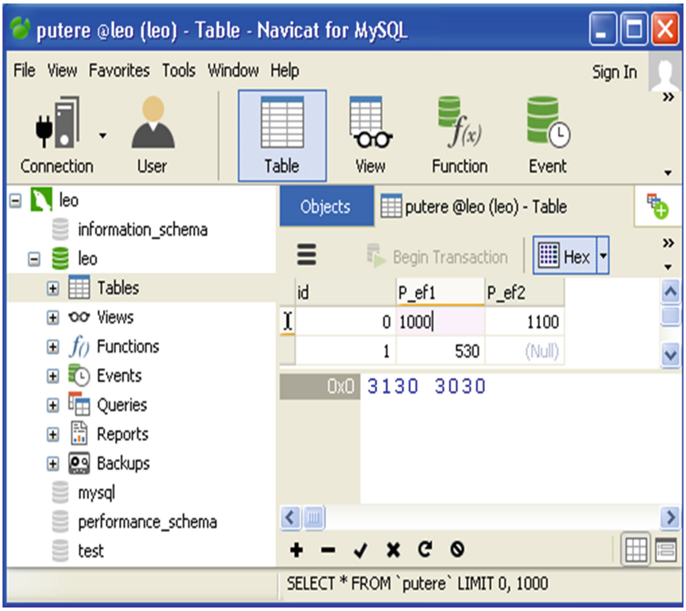

Fig. 5. Table Power MySQL that shows the input parameters for PM1

Citect SCADA does not natively use MySQL. The connection to a MySQL data base was made by using the Open Database Connectivity (ODBC) technology. ODBC provides a standard for the methods and procedures Application Programming Interface (API) software. The using of the ODBC ensures independence from the programming language, which is the basis for the data or the operating system. Most of the producers of databases offer drivers for ODBC connections.

The engine M1 can be powered from both the redundant network of the AR as well as from the supply line of hydro-generator. The amount of power absorbed (Fig. 6) is retrieved from the table of power, and can be set with different values in that table (Fig. 5). Power engine M1 does not depend on the power hydro-generator, being established at 530 kW [1, 6]. Switching off the engine M1 can be done manually with the button “n/Off M1” (Fig. 6).

The M2 can be powered only from the supply line of hydro-generator. The absorbed power is a function of the actual power value hydro-generator, maximum value (1200/3.33 = 360 (kW)) being established at (Fig. 7):

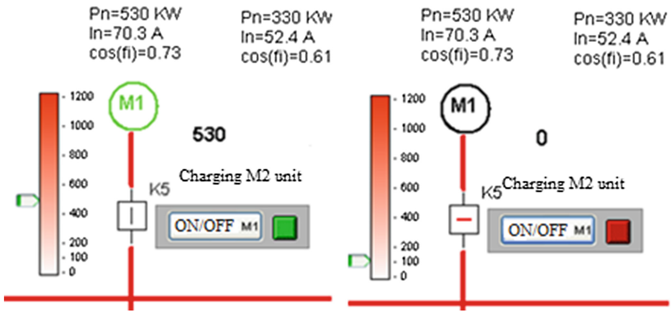

Fig. 6. The value PM1 /Disconnection M1

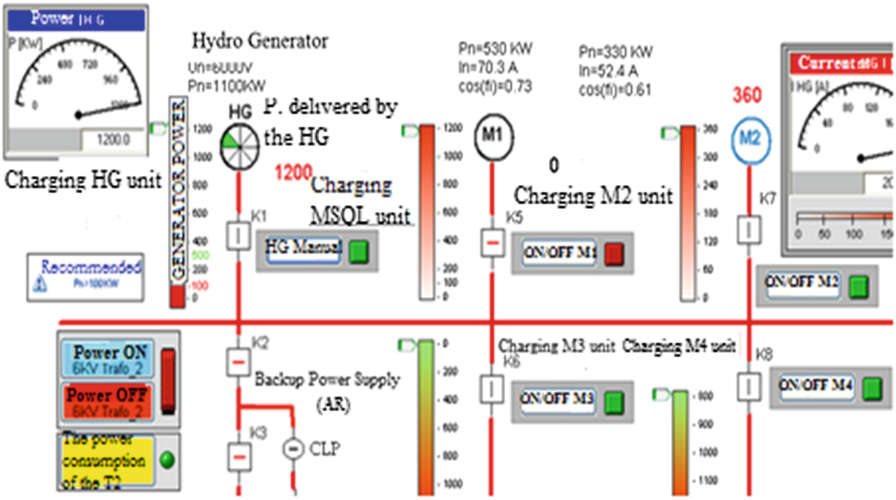

Fig. 7. Power M2 f(PnHG)

$$PM2 = \text{Pn} \; /3.33 = \text{P\_ef1}/3.33(\text{kW}) \tag{1}$$

As seen in Fig. 8, when switching on AR spare power, even if k7 is in the closed position, PM2 power value is zero.

The M3 (Fig. 9) can be powered only from the supply line of AR. So this is only possible if K2, K3, and K4 are closed. Control motor M3 is given by the on/off M3 that closes or opens the switch K6. The absorbed power is a function of the actual power value hydro-generator being established as the difference between maximum power of hydro-generator and its power to:

$$PM2 = Pmax - \text{P\_ef1}(\text{kW}) \tag{2}$$

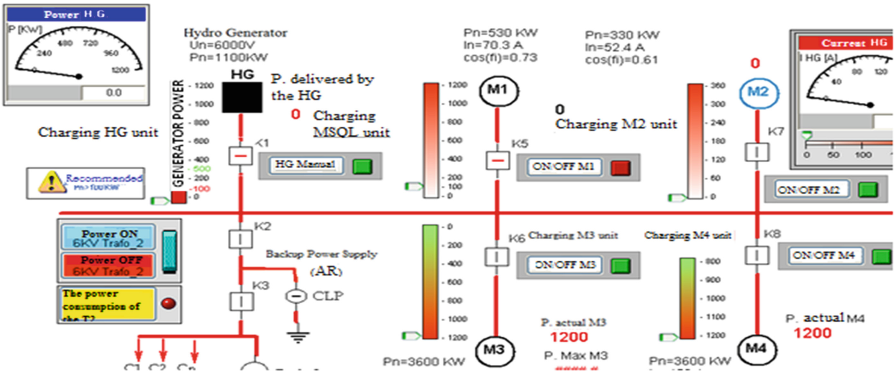

Fig. 8. M2 = 0 for AR

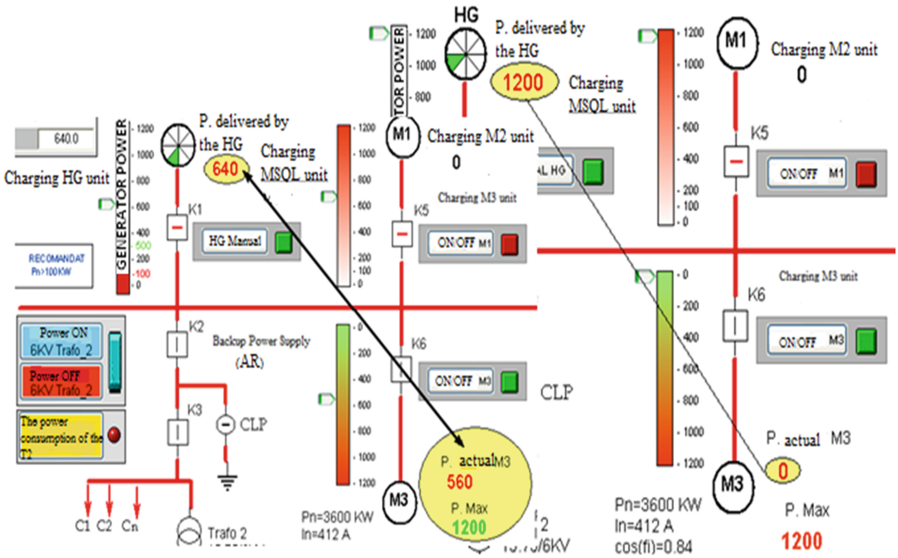

Fig. 9. Actual power M3 /PM3 at maximum PnHG

The power delivered by hydro-generator is at a maximum like is shown in the diagram below (Fig. 9 PM3 at maximum PnHG) (Fig. 11).

The M4 (Fig. 10), similar to M3 can be powered only from the supply line of AR. So this is only possible if K2, K3, and K4 are closed. The control of the engine M4 is given by the on/off M4 that closes or opens the switch K7. The absorbed power is established as the difference between maximum power of hydro-generator and a part of its effective power to:

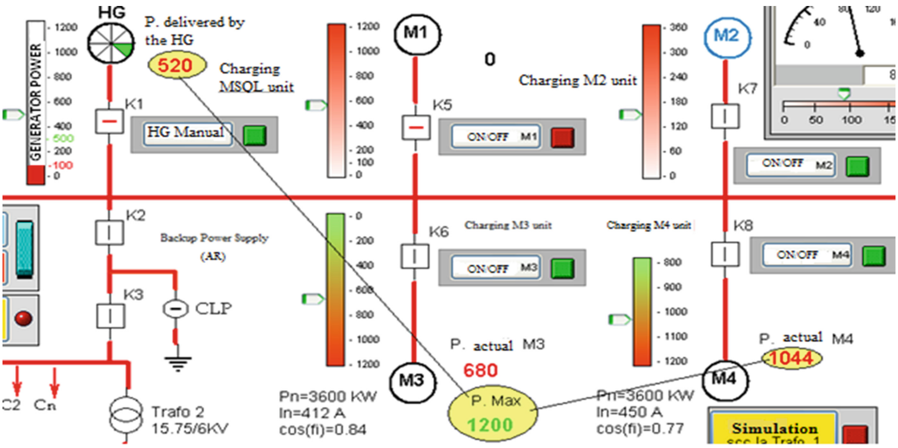

Fig. 10. Actual power M4

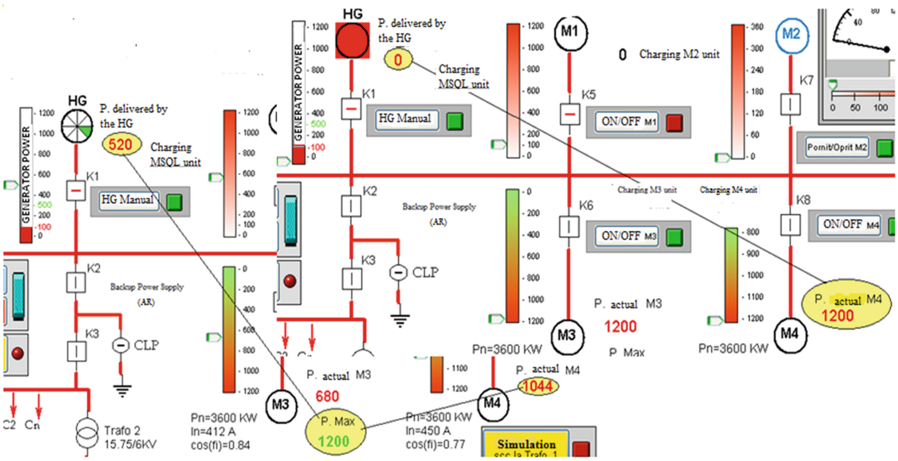

Fig. 11. PM PnHG$ to maximum /PM$ to PnHG = 0

$$PM2 = \mathrm{Pmax} - \mathrm{P\_ef1}/3.33(\mathrm{kW}) \tag{3}$$

There were situations in which the conditions implemented by a simple IF are not sufficient; therefore it was necessary to implement our own functions. An example is presented below, necessary for the M4 engine operation. To add a new function the step presented in Fig. 12 were necessary.

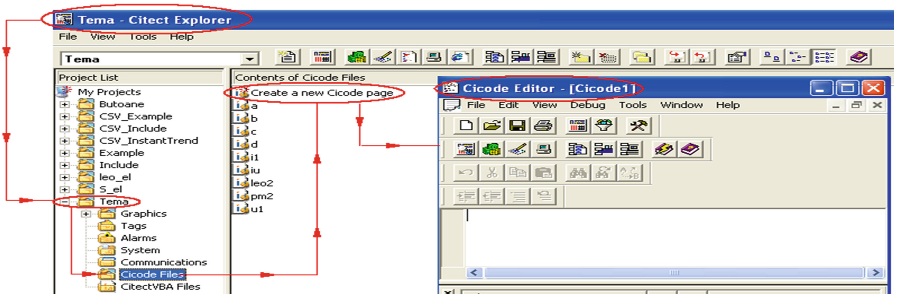

Fig. 12. Function implementation

The function implementation is as follows:

```
INT FUNCTION p_4()
IF I_T1=0 AND S_T1=1 AND C_daA=1 AND M_4=1 THEN
p4=1200-(P_ef1/3.33);
ELSE
p4=0;
END
RETURN p4;
END
REAL FUNCTION simul_i_1()
rad=rad+0.01;
i_alim=(55*(1+Sin(rad)))+90;
RETURN i_alim
END
```

3 Testing and Results

The testing scenarious will focus on the situation where the hydro-generator operates at Pn < 500 (kW) and supplies motors M1 and M2 are started when K1 is closed and k2 is open, as it is displayed in Fig. 13.

1. Supply motors M1 and M2 retrieved values from the table "power" that was made in MySQL. The acquired and stored values for these motors are 530 kW for M1 and 149 kW for M2. The power value for M2 motor will be computed using Eq. (4).

$$p2 = \text{P\_ef1}/3.33 \tag{4}$$

2. If Pn > 100 kW it is to be noted that the hydro-generator is disabled, but it remains on alert for tube current, for which Pn > 500 kW;

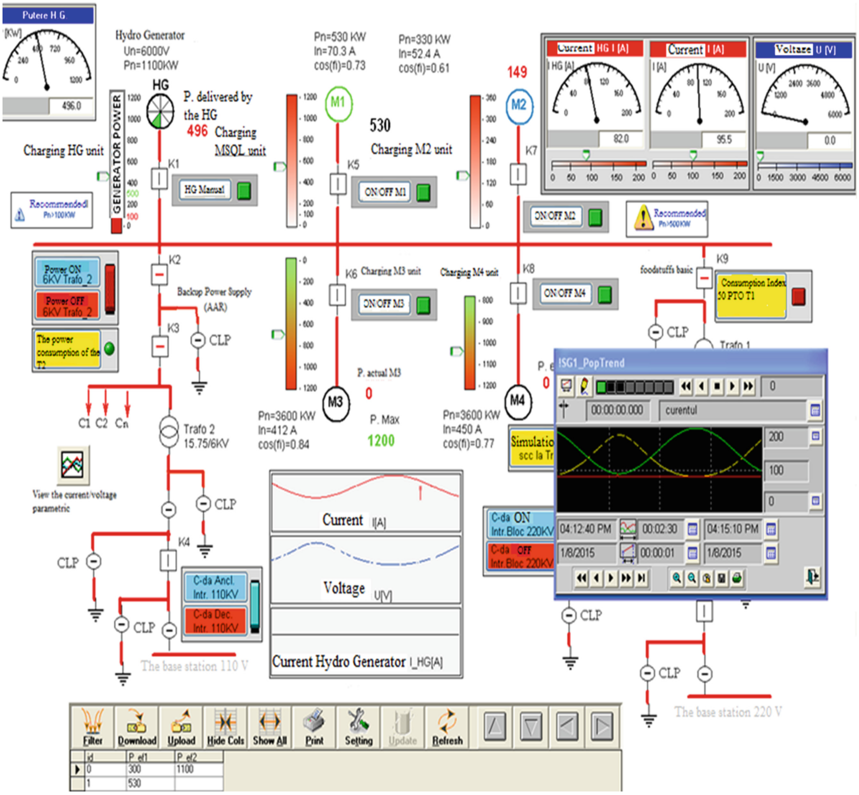

Fig. 13. Results HMI interface

3. The form and the value of the current i_alim debited from the reserve circuit AR, has the form sine, the amount of which shall be between 90 A and 200 A, which complies with the requirement design. In Eq. (5) it is presented the computed formula used for i_alim.

$$i\_alim = (55 * (1 + \sin(rad))) + 90 \qquad (5)$$

4. The current i_alim_HG debited by hydro-generator HG has a linear form (so it is a direct current) and its amount it is determined by the ratio of power hydro-generator and voltage;
5. The supply voltage has a sinusoidal form (in the mirror with that of the intensity i_alim) and its value it is situated between 600 V for Pn < 500 kW and 6 kV for 1200 < Pn > 500.

The particulars entered in each of the motor wiring diagram, represents the characteristics of the various motors which are to be found in the context of such installations (nominal power, voltage, nominal current and power factor).

4 Conclusions

This paper presents the HMI implementation of the tracking and command functions of a hydro-generator. The data presented is real data from the energy production facility of a hydro generator in Ramnicu Valcea, Valcea County, Romania. The implementation of such an interface can limit the damage and help the human operator in the management of the process by implementing functions that will warn the user and act correctly in various system conditions. Using the HMI interface a full automation of the technological process can be achieved. The graphical user interface has a high flexibility and it can be implemented at a central heating located near a course of water. In the near future the user interface will be extended to the diagrams of operation with an increased number of operations.

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