PLC Based SCADA for Micro Hydroelectric Power Plants

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***Abstract*—The demand for electrical energy in the world is increasing every year. Hydroelectric Power Plants (HPP) in electricity generation are method is very commonly used. Hydroelectric power plants are huge facilities and occupy large areas. Hydroelectric power plants have a lot of special control and commination systems. Along with the increasing number of hydroelectric power plants applications, the need for the education of those systems has been unavoidable in engineering education. Training hydroelectric power plants, especially theoretically continue in the field of engineering. This is a problem. In this study, a prototype has been developed. Improved Micro Hydroelectric Power Plants (MHPP) by analyzing the performance of the prototype, the model are validated.**

***Index Terms*—hydroelectric power plant, engineering education, PLC, SCADA**

I. INTRODUCTION

The increasing demand for electrical energy is one of the vital problems in the world. People use any kind of energy sources for fulfilling their energy demand. One of these energy sources is the hydro power. Total amount of water in the world is about 1.4 billion miles. Main sources of water are; 97.5% as salt water in the oceans and seas, 2.5% is available as fresh water in the rivers and lakes [1]. Electricity production from water sources is also an important field of study for engineering.

An uneducated engineer theoretically is bad a practitioner applicators. Practicing hydroelectric power plants training, which is an expensive investment, in the laboratory is very difficult. İnterest of engineers with insufficient training reduces in this field. Therefore these problems cause to misuse or not using water resources for power generation properly.

In this application, a very small powerful MHPP prototype is designed and developed as a closed loop. Thus, for training in HPP, an actual experiment prototype was developed. In addition, with minor revisions, this system can be used as a real application. In this designed closed-loop flow HPP prototype, rate control method is used. The main reason for choosing this method is to gain a similar system like a large type HPP's control structure. Designed Closed Loop HPP Prototype consists of four parts which are Hydraulic parts, electromechanical parts, controller parts and SCADA controller. Closed-loop block diagram of the prototype including MHPP is shown In Fig. 1. In our prototype, a Pelton turbine with an asynchronous generator which can provide 500W electrical power, portable 300lt horizontal water tank, a 1.5kW centrifugal pump to achieve enough flow rate and head differential and an inverter which controls the pump speed have been used.

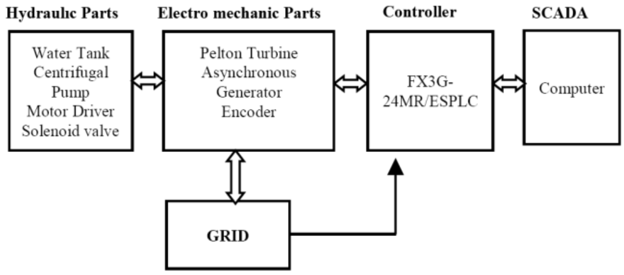

Figure 1. Closed-Loop block diagram of the prototype including MHPP.

A. Hydraulic Parts

The hydraulic section in this application consists of 300 liter water tank, 1.5kW centrifugal pump, Mitsubishi FR-D720S-070-EC Motor drive (inverter) and solenoid valves. In the preliminary design phase, 300 liter water tank was considered in a rectangular type but in practice, considering the portability of the prototype and the mind to occupy less space, horizontal type rectangular water tank was used.

In actual practice, water running HPP has a specific pressure and flow. In our prototype, in order to obtain the pressure and flow rate, a centrifugal pump and controlling the pump FR-D720S-070-EC motor drive (inverter) is used. In the prototype, Pelton turbines are used for production of electricity at 500 W.

Turbine speed control apparatus is not used; turbine speed control is achieved by changing the flow rate directly to the turbine applied [2]. For changing the flow

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rate applied to the turbine engine and the pump drive is provided by changing the frequency.

Solenoid valves which were used in the hydraulic section, butterfly valve and bypass valve, which exist in HPP, were used in order to provide near real valve control in the simulation settings [3]. In the system to simulate penstock 2 inch PVC pipe and as Bypass pipe 1 inch PVC pipe were used in order to provide the flow rate needed by Pelton turbine. Depending on the size of the pipe, instead of butterfly valve, 2-inch solenoid valve was also instead of bypass valve; 1 inch solenoid valve was used. These valves can be controlled both manual and automatically via SCADA (they are also suitable for HPP Commissioning according to ranking). In Fig. 2 the valve arrangement for Closed Loop MHPP prototype is shown.

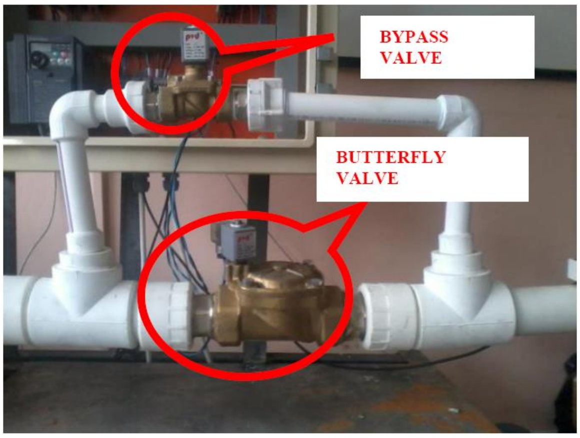

Figure 2. The valve arrangement for closed loop MHPP prototype.

B. *Electromechanical Parts*

Electromechanical parts consist of Pelton turbine, asynchronous generator and encoder [3]. These structural parts are substantially the same as conventional hydroelectric power plants [2].

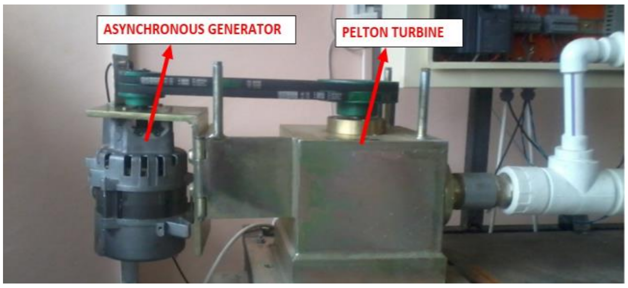

Figure 3. Main elements of electromechanical parts for the closed loop MHPP prototype.

Water drawn from the reservoir by centrifugal pump is transferred to Pelton turbine. Kinetic energy of water is converted to mechanic energy by Pelton turbine [3]. Water coming from the turbine is returns to the water tank again. Thus, a closed loop water cycle is obtained. This mechanical energy, which is connected to the turbine shaft belt pulley, drives the asynchronous generator. The frequency of the asynchronous generator output voltage is proportional to the rotational speed [4]. Therefore, for controlling the frequency generator, the flow rate should also be controllable. For classic flow control in hydroelectric power plants pressure hydraulic systems are used. So water entering the turbine is controlled by using the nozzle or wicket gate. Pelton turbine in this developed prototype doesn't have stage pin hence centrifugal pump rotation was inverted for controlling flow rate. Electromechanical parts for the Closed Loop MHPP main elements of the prototype are given in Fig. 3.

In our prototype, frequency of generator is calculated by two different units. It can be computed firstly by using the information of the speed meter (encoder) received by the PLC FX3G-24MR/ES and secondly by using ME96NS-MBA Energy Analyzer. Encoder used for measuring the speed of the asynchronous generator consists of inductive sensor. The sensor location observed on the belt pulley is shown at Fig. 4.

Figure 4. Measurement system of asynchronous generator speed.

C. *Controller*

The system control parts are given in Fig. 5. PLC is used for controlling MHPP, monitoring security and failure signal. In this application, many of the possible fault signals have been simulated by buttons and position switches.

This prototype has two purposes. The first is for educational purposes for students hence they can learn HPP in the school environment in practice by using this prototype. Second, R & D work is to provide a real opportunity to make over simulation. Therefore, the PID parameters is designed to be interchangeable by using persistent data address (D1000-D1026) via the SCADA screen. The reason for using Persistent Data addresses is to ensure parameter values, which was entered to the system, not to be deleted during the opening and closing of the system.

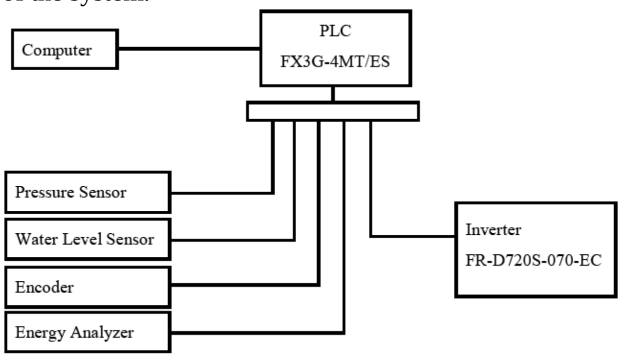

Figure 5. The part of the system of control commands.

II. The Working Methods of the Prototype

Classic HPP can be activated by two different methods which are automatic and manual method. PLC provides automatic or manual startup according to user mode selection screen of SCADA [5].

A. Manual Operation Mode

All control is provided by the operator. PLC does not interfere with anything except for the critical fault signal and the operator's commands. PLC only reflects the signals received from SCADA screen. Operator executes processes like Speed and frequency settings, control of butterfly valve and bypass valve, pump motor control of and so on by himself/herself.

B. Automatic Start/Stop Mode

PLC gets activated system by pressing operator's "Start Unit" button on SCADA screen according to the startup sequence. PLC also closes the simulated contactor and transfers generated energy to load as a disjoncteur when the generated voltage and frequency reaches the set value.

The prototype made some steps in the startup sequence was simulated with buttons and sensors.

C. Maintenance Mode

Maintenance mode prevents to control system both automatic and manually for executing security purposes when there is any malfunction or maintenance of the system. In this mode, the entire system can be selected when the system is static and the system cannot be operated in any way.

In Fig. 6 Closed Loop MHPP general appearance of the prototype is given.

Figure 6. Closed loop MHPP general appearance of the prototype.

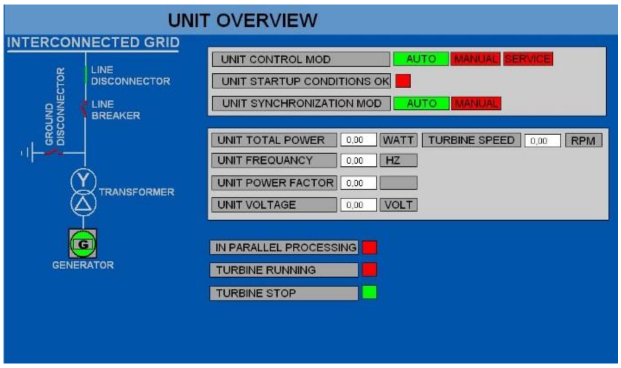

Figure 7. General status screen.

III. SCADA

In this screen, the system single-line diagram of Interconnected Grid connection, the system's operation mode, the power generated by the generator contains general information such as information [6]-[8]. The separator used in single-line diagram, cutting devices such as relays and switches are simulated. Fig. 7 has the general status screen.

A. Start-Stop Screen

In this screen, the system's automatic start and stop operation of the system is in progress and the process steps to be followed in arresting are grouped into sections. Operator can follow processing steps of automatic start-stop system and information about in which section processes are done by using this screen. Starting and Stopping the screen is given in Fig. 8.

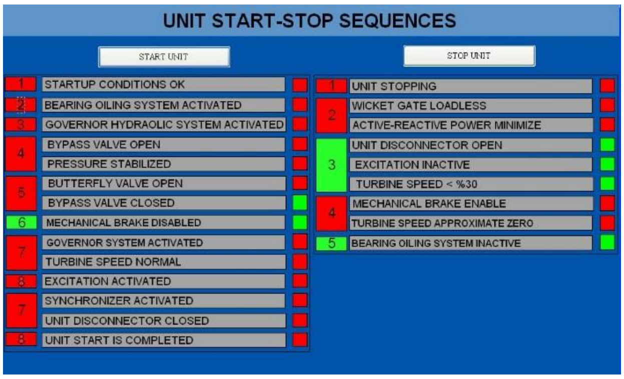

Figure 8. Start-Stop screen.

B. Generator & Turbine Screen

On this screen, the turbine-generator assembly, butterfly valve and bypass valve assembly of the simulated solenoid valves, pump motor assembly and the speed on this device, location, and fault information is displayed. The generator and turbine screen is provided in Fig. 9.

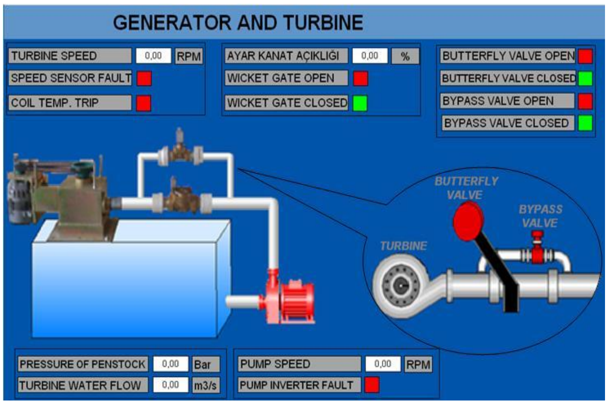

Figure 9. Generator and turbine screen.

C. PID Parameters

This screen includes numeric input address in which PID parameters is entered for fixing turbine speed at the set rate in automatic operation mode of the system. PID parameter screen is provided in Fig. 10.

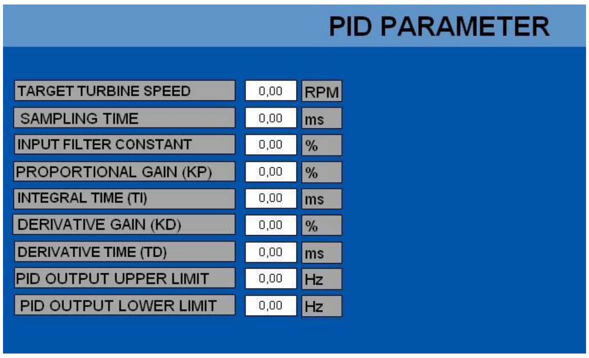

Figure 10. PID parameters screen.

D. Alarms

This screen is a kind of SCADA page that analogue signals, which are above or below the identified critical value, are shown and stored with fault definition described at SCADA. Critical or serious digital signals which are came from fields and generated at PLC are also shown and stored in this page.

IV. Conclusions and Recommendations

In this study, micro-scale hydroelectric power plant, which works separately from the network and its automation, was achieved so as to evaluate hydroelectric energy which is renewable energy sources and an abundant potential in our country. Voltage and frequency regulation is aimed to achieve in our developed prototype. PLC (Programmable Logic Control), which is used widely for controlling hydroelectric plants and for automating power systems on the market, was used in order to develop this prototype. Providing PLC and PID control on the prototype, inductive and resistive load cases were investigated in the frequency and voltage values. Generator speed-voltage curves are shown in Fig. 11.

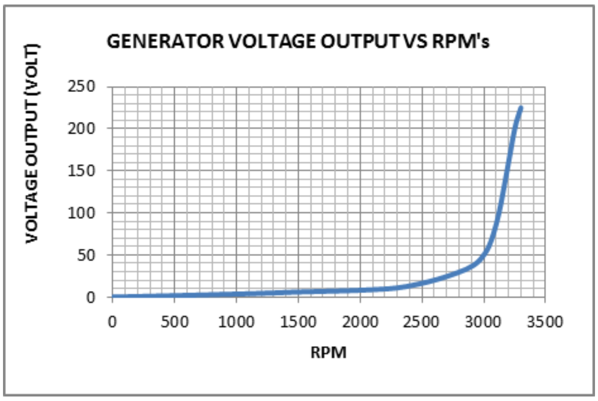

Figure 11. Speed-Voltage curve of the generator.

The design of hydro power plants is an important issue. In addition, training of personnel to operate these power plants is also an important issue. For these purpose hydro-electric power plants at the stage of prototype development was considered in the training topic. The developed prototype, vocational and technical education institutions in the exercise of the power generation benefit has been observed in the laboratory.

References

[1] (2012). Web: Anadolurisk. [Online]. Available: https://www.anadolurisk.com

[2] O. Paish, "Small hydro power: Technology and current status," *Renewable & Sustainable Energy Reviews*, vol. 6, pp. 537-556, 2002.

[3] I. Salhi, M. Chennani, S. Doubabi, and N. Ezziani, "Modeling and regulation of a micro hydroelectric power plant," in *Proc. IEEE International Symposium on Industrial Electronics*, Cambridge, UK, 2008, pp. 1639-1644.

[4] E. Özbay and M. T. Gençoğlu, "Hidroelektrik santrallerin modellenmesi," in *Proc. V. Yenilenebilir Enerji Kaynakları Sempozyumu*, Diyarbakır, 2009, pp. 108-115.

[5] M. Chennani, I. Salhi, and S. Doubabi, "Study of the regulation of a micro hydroelectric power plant prototype," *The International Scientific Journal for Alternative Energy and Ecology*, vol. 5, no. 6, pp. 79-84, 2008.

[6] K. Natarajan, "Robust PID controller design for hydroturbines," *IEEE Transactions on Energy Conversion*, vol. 20, no. 3, pp. 661-667, 2005.

[7] M. B. Djukanovic, M. S. Calovic, B. V. Vesovic, and D. J. Sobajic, "Neuro-Fuzzy controller of low head hydropower plants using adaptive-network based fuzzy inference system," *IEEE Transactions on Energy Conversion*, vol. 12, no. 4, pp. 375-381, 1997.

[8] O. P. Malik, "Amalgamation of adaptive control and AI techniques applications to generator excitation control," *Annual Reviews in Control*, vol. 28, pp. 97-106, 2004.

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