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Automated Control Technique for a Hybrid Hydropower Plant

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Abstract

Power generation is a fundamental social comfort for every running activity. The demand place on electric power is increasing daily while generation may not be able to meet up with demand requirements. One of the aspects of power plant systems where an improvement can be instituted is the installation of efficient plant control. This will be able to minimize waste as well as enable smooth running of the plant ensuring availability of power when needed. The work presented in this paper is an intelligent hybrid hydropower plant control technique successfully applied to a 300kW capacity hydropower plant. The plant combines both conventional hydropower plant and a pumped storage plant. A generic model designed for this work was used in simulating for optimised outcomes. The control design operates effectively using three parameters; generated power, time of operation and the volume of water in the reservoir for generation. Flowcode and Proteus ISIS were used in the design of the control system, which allow plant operation change using the parameter stated. The two tools allow graphic display of plant operation per time. The result proved efficient plant operation and better plant maintenance which are relevant in the management of the plant control.

Keywords: Flowcode, Pumped storage technique, Hydropower plant, renewable energy.

INTRODUCTION

Power plant optimisation is always at peak when suitable control systems are put in place. Due to the availability of small hydropower potentials, many plant operators do not consider a productive use of the resource through components control.An intelligent power generation control architecture was designed and proposed for 300kW hybrid hydropower plant. The control design operates effectively using three parameters; generated power, time of operation and the volume of water in the reservoir for generation. The plant combines both runoff hydropower plant and a pumped storage hydropower (PSH) plant. Therefore control techniques will be used to further enhance both hydro generation and pumping modes of the designed hybrid hydro plant. This will ensure the system is automatically controlled for both base load and peak load management respectively. The control system is introduced to manage power generation, optimize economic performance of the plant and maintain good water resource management so minimize environmental impact on the river. On the part of the economic and technical aspects, a control system takes care of many problems associated with parameters related to variation in hydro plant operations. Such parameters include water flow, water head, efficiency coefficients (generator, pump, turbines etc.). Proper and accurate interaction of these parameters is actually a big challenge and that is why control is a big issue in maximizing system performance.

An auto-control system in a hydropower plant is necessary because when properly implemented will reduce maintenance costs thereby enhancing system reliability which will definitely result in efficient plant operations and invariably increase energy generation processes in the hydro plant. The automation is needed to minimise input waste, excessive pumping and PSH generation, which if not properly managed may result in experiencing operational challenges. It is also important to swiftly detect malfunctioning processes, ensuring that the faulty process is stopped so as to return to normal efficient operation.

Plant Control Review

Control can be a load control[1], generation control[2], transmission or distribution control[3]. In fact, every aspect of electricity can be controlled. In homes with multiple generation sources, it is better to have distributed energy control. The control emphasis is more on the hybrid plant generation control. In renewable energy technology, every energy quantity counts because the conversion process is not as efficient as others like fossil and nuclear sources. As a result of the intermittent pattern of renewable energy (RE)sources and their dependence on climatic conditions, control of generation is vital so that only needed energy is converted to electricity[4]. This has been achieved by engaging different techniques even though excess energy are sometimes stored for consumption hereafter. In a plant where combined energy sources are integrated, appropriate control scheme has to be put in place[4].

As a result of high volume of disturbances with a huge impact on power plants, it is of good interest introducing an auto control mechanism. [5]used a feed forward-plus feedback control scheme in controlling the field temperature of the installed collector. The feed forward-plus-feedback controller recorded a great result as the temperature of the collector is kept constant. The control system was able to increase power plant output by as much as 47% on a sunny day.

[6]developed a coordinated strategy control for a boiler-turbine combining fuzzy reasoning with auto tuning applications. The technique has both basic control level as well as high supervision level. The basic level control operates with proportional-integral derivative (PID) controllers. The Gaussian partition with evenly was used to auto tune the PID controller while decoupling was used between control loops for high level control[6]. The control technique was able to achieve better economic and operational performance result when implemented in a power plant. Operation of hybrid generation system could involve complex process [7];[8]which need more precise and displaying control system.

[8]developed and applied a real-coded genetic algorithm in controlling a power plant which yielding a very good performance on PID controller.[9]used neural network modelling technology to identify dynamic interaction of plant variables with the objective of controlling certain variables such as temperature, pressure, etc in a thermal power plant.

A scheme was introduced [10]to reduce the size of dump load using 'on' and 'off' controls to operate opening and closing of input valves in a HPP. This 'on' and 'off' directly increase or reduce generation input [11]; [12]; [13].[6] also used a fuzzy reasoning and auto-tuning techniques to automatically control a multivariable, nonlinear and a plant with slow time varying having big settling time coupled with many uncertainties. The developed techniques proved to promote adaptability and robustness of the plant as well as displaying improved economic advantages. The designed a control system operating on intelligent decoupling technology and was successfully used in managing Yuanbaoshan Power Plant[6]. The intelligent control system was designed by integrating three basic independent techniques to develop an enhanced and high performing unit for maximum plant management. The techniques, Fuzzy reasoning, adaptive control and auto-tuning techniques all show that the performance of the control was satisfactory. The proposed intelligent decoupling control strategy was successfully applied to a 300MW boiler–turbine unit[6].The predictive control algorithm described in the paper uses the innovation representation of a Markov–Laguerre model[14]. A Monte Carlo study and an experiment show that good models and stable control are obtained.

METHOD

In this paper, an intelligent hybrid hydropower plant control strategy is proposed. This was also successfully applied to a 300kW capacity hydropower plant. A generic model designed for this work was used in simulating for optimised outcomes. Generated power, volume and time are the day are the three parameters used in finding the most suitable specifications.

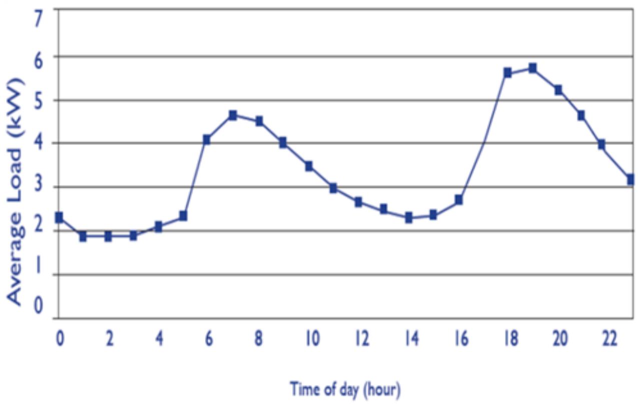

Figure 1: The pattern of consumption of electricity in a typical South African home[15].

Automatic Control System

The automated control system introduced to optimise plant efficiency is designed with two pieces of software: Flowcode version 5 and Proteus ISIS. Flowcode is a graphical programming tool developed to design complex electronic systems. It is chosen as a control tool for this work because of its user friendly ability to develop electromechanical systems quickly with graphical icons. Flowcode is used in this work to develop systems for control and measurement based on microcontrollers. The second software engaged in this control programme is the Proteus Virtual System Modelling (VSM). The choice is because it integrates perfectly microprocessor models and animated components which helps to facilitate simulation of whole microcontroller related designs. The other reason for this choice is that the interaction can be displayed with animated buttons and switches using LED and LCD indicators. It also works with codes and high level languages. For this work, C-codes and hexadecimal codes were used to analyse results.

The control system is designed to govern three parameters which determine plant operation and these parameters are time of specific operations, volume available and power available to support pump activity. The first parameter is time. Time controls the three systems together; which time of operation each has been allocated based on the consumption pattern in Figure 1. At low consumption, the pump begins to work and at peak consumption, PSH is switched on automatically. All these are expressed in Figure 3.

The second parameter of control is the volume. The lower reservoir will not experience difficulty of adequate water supply; in fact, there will be excess that will need to be discharged to flow and join the river course. The major concern is the water level in the upper reservoir III which can be full or inadequate by the set time for PSH operation to start. This now leads to the third parameter, which is the available power for pump operation. Effective pump operation is a function of the power consumption quantity per time. If available power is unable to lift enough water to III, PSH operation will be thwarted and if there is no control measure to manage this, continuous occurrence will bring about plant breakdown. To manage this effectively, this design introduces two floaters to handle that aspect.

In this research, the flow chart inputs are the three major systems that constitute the hydroplant hybrid, which are the pump, the pumped storage hydropower and the river run-off hydropower plant. Flowcode V5 AVR is used to develop a program on the microchip as shown in Figure 2. Figure 2 does not represent the full flowchart as it would take many pages for a full chart.

Writing the flowchart describes step by step the procedure of the program written to control activities of the three system inputs. For example, the program checks if the time is between 00:00 and 05:00, if yes, pump is switched on, but if no it is delayed to wait until the time for the next command. The same time is the set time at which only one-third of the generated power is consumed. This will automatically switch on the pump for water to fill reservoir III. Figure 3 describes in diagrammatic form the allocation of time between the three inputs. The same process is repeated for plant operation between 06:00 to 10:00.

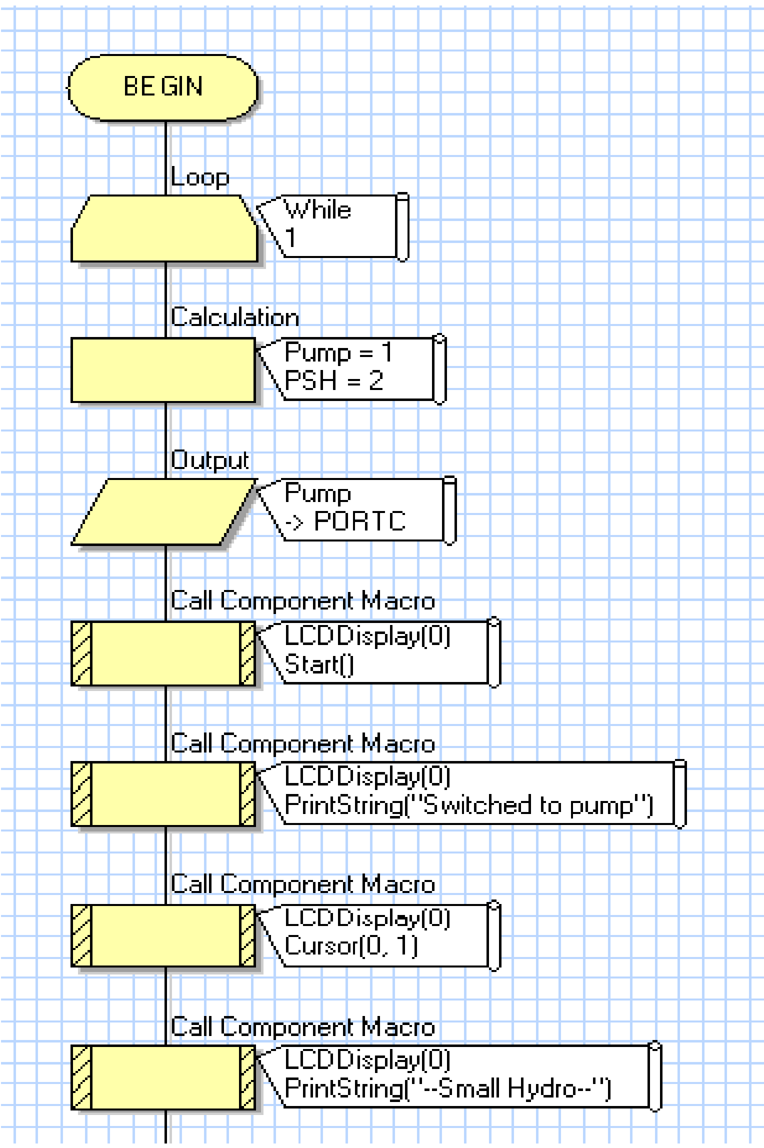

Figure 2: Flow chart showing some of the icons used in the Flowcode model

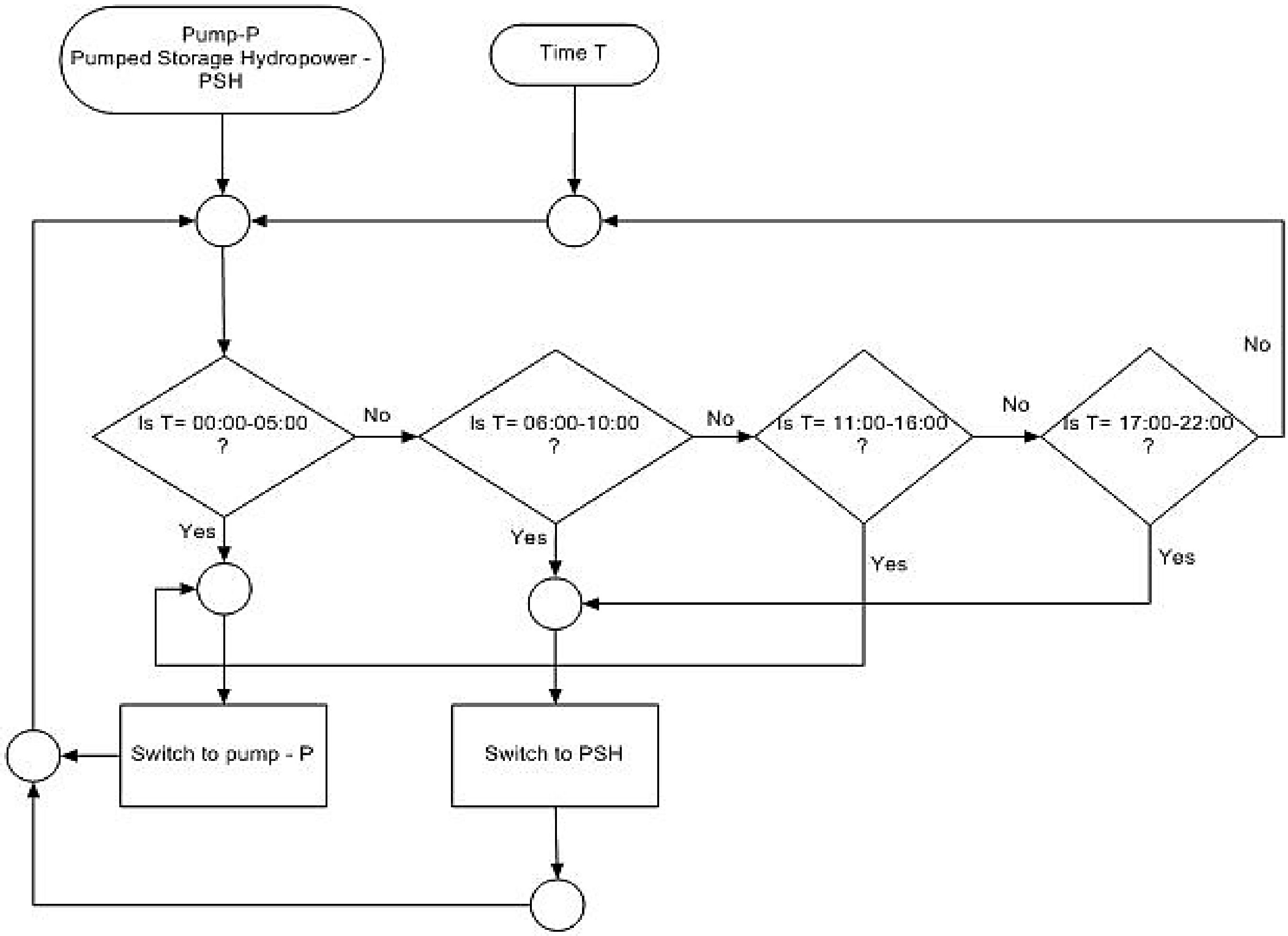

Figure 3: Time allocation chart to the three plant system

Automatic Control System Display

The Flowcode results display the performance of the plant in the Figures 4 to 6. Figure 4 indicates the period when only the primary hydropower is working, which means both the pump and the PSH are off.

The display provides an accurate result for every command that is yielded; this is displayed in the form given in Figure 4. From the figure, one can conveniently monitor the plant operations, Figure 5 displayed that, the pump is switched on, from Figure 1, this is expected between the period of 00:00 to 05:00 and 11:00 to 16:00 while Figure 6 displays the operation of the PSH system.

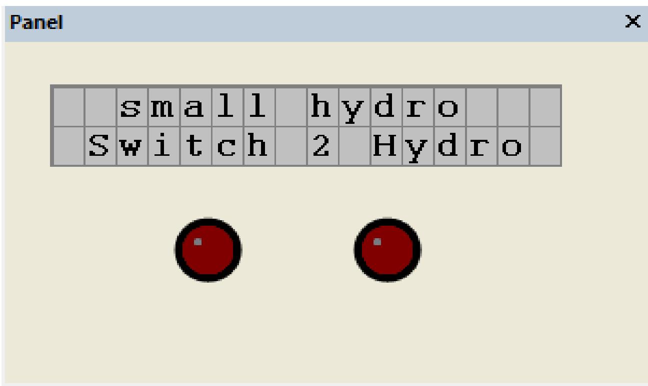

Figure 4: Display when both the pump and the PSH are off

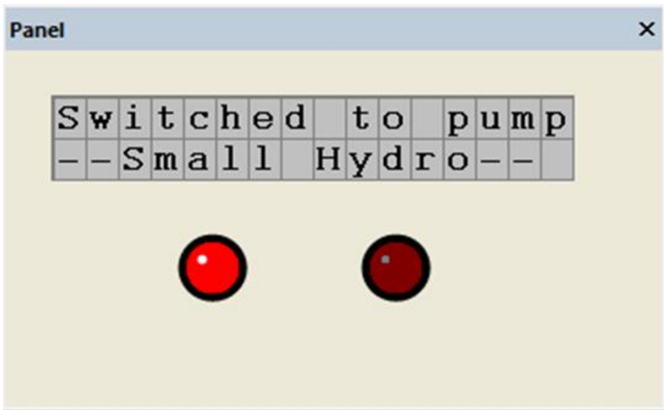

Figure 5: Display when the pump is on and the PSH off

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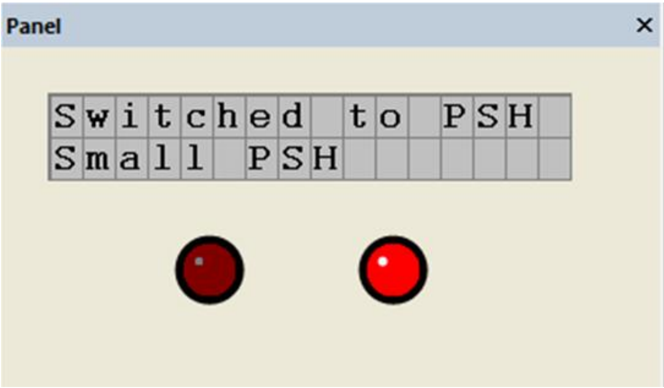

Figure 6: Display when the pump is off and the PSH on

Results generated from the Proteus are presented in Figures 7 to 11. In Figure 7, there is no display on the LCD screen, which reveals that both the pump and the PSH are not working. This means at that time only the hydropower plant is working. The system as described earlier has two floaters, namely, a top floater and a bottom floater, as is evident from Figure 7. The job of these floaters is to control the volume of water in reservoir III at all times. This is necessary for the PSH turbine to work effectively. The Flowcode programme controls the time of either pump or PSH. If at a time PSH is to be switched on but the level of water in the reservoir is low, it may cause major damage to the system but even though it is PSH time immediately the water level reaches the minimum design level, the bottom floater switch will be off putting an end to PSH until there is enough water in III to generate.

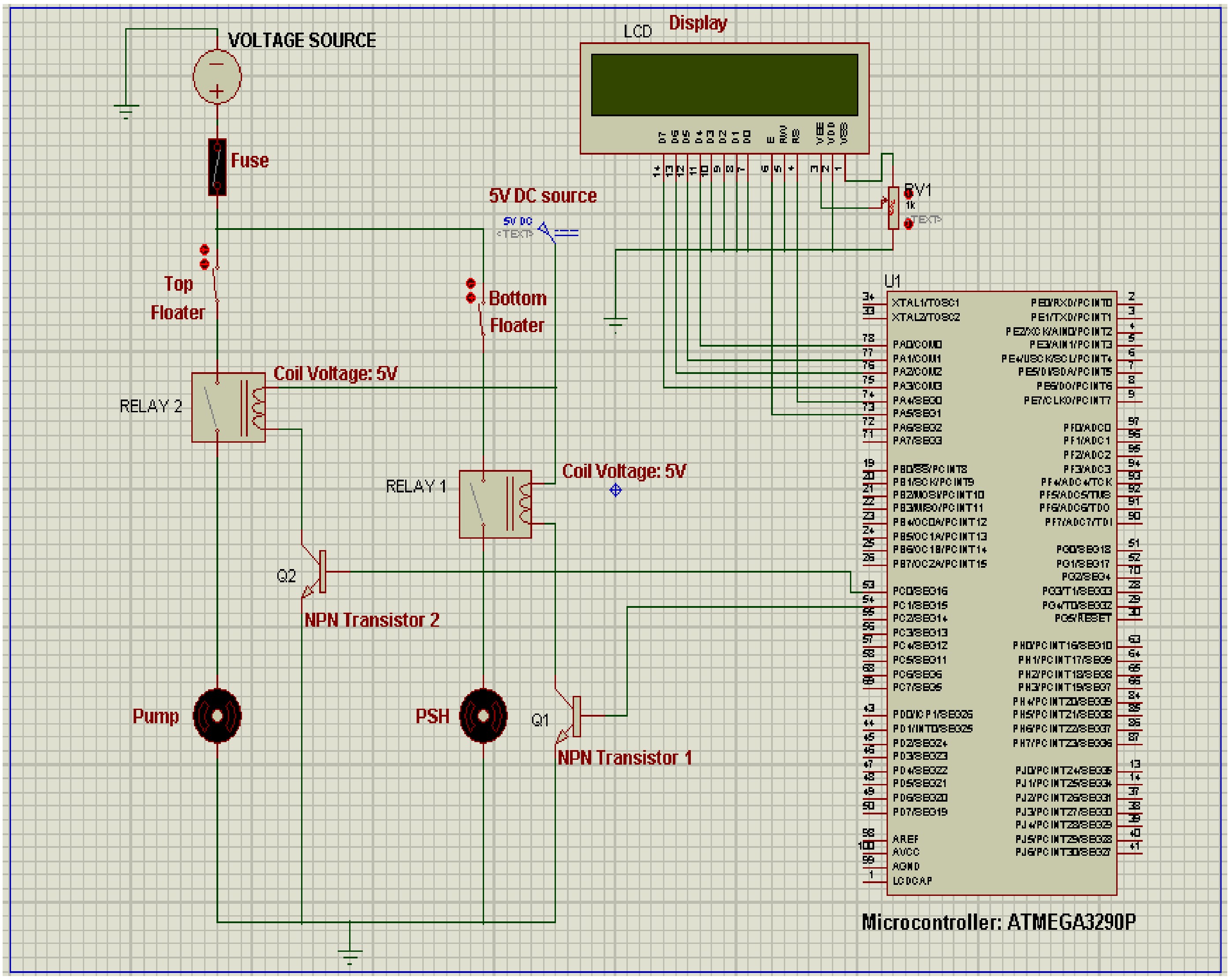

Figure 7: Basic layout of the energy control system without load

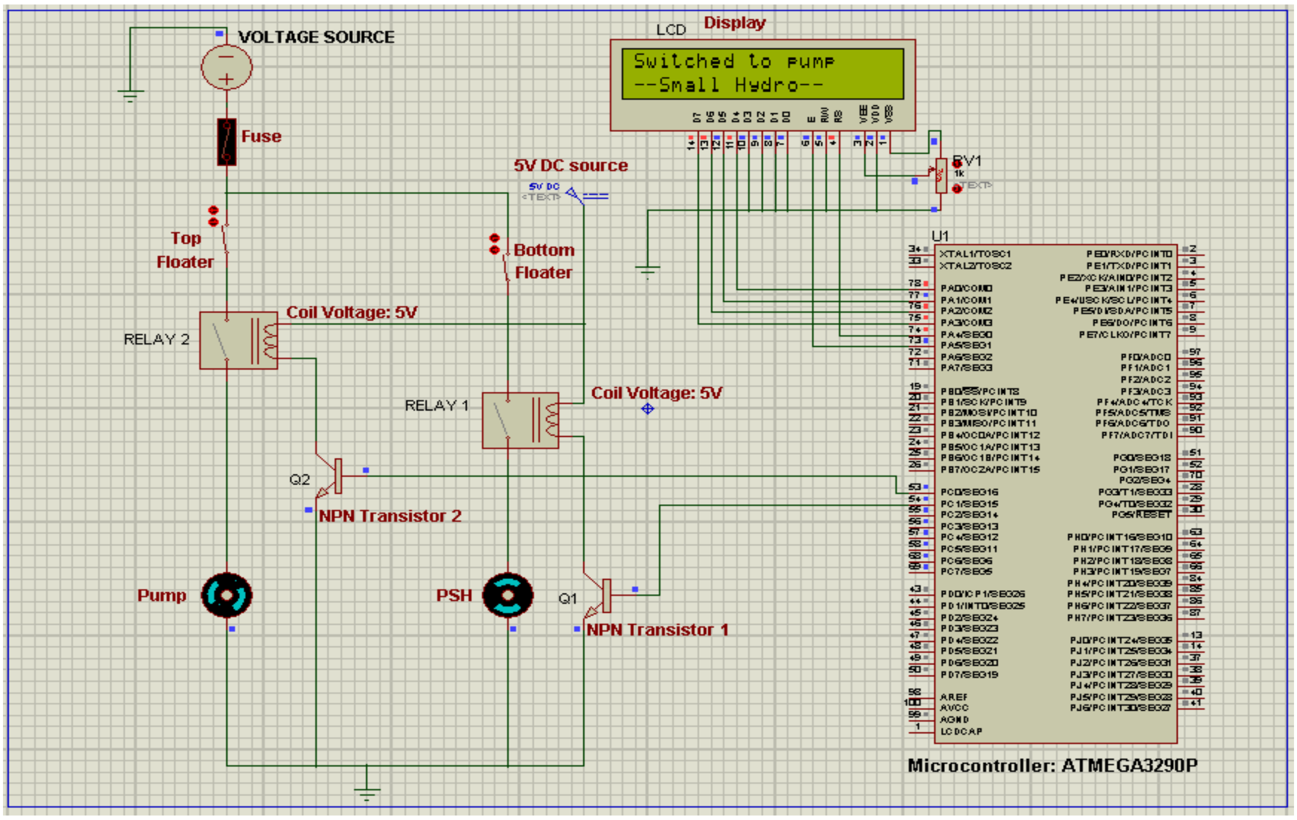

Figure 8: Energy control system when pump is switched on

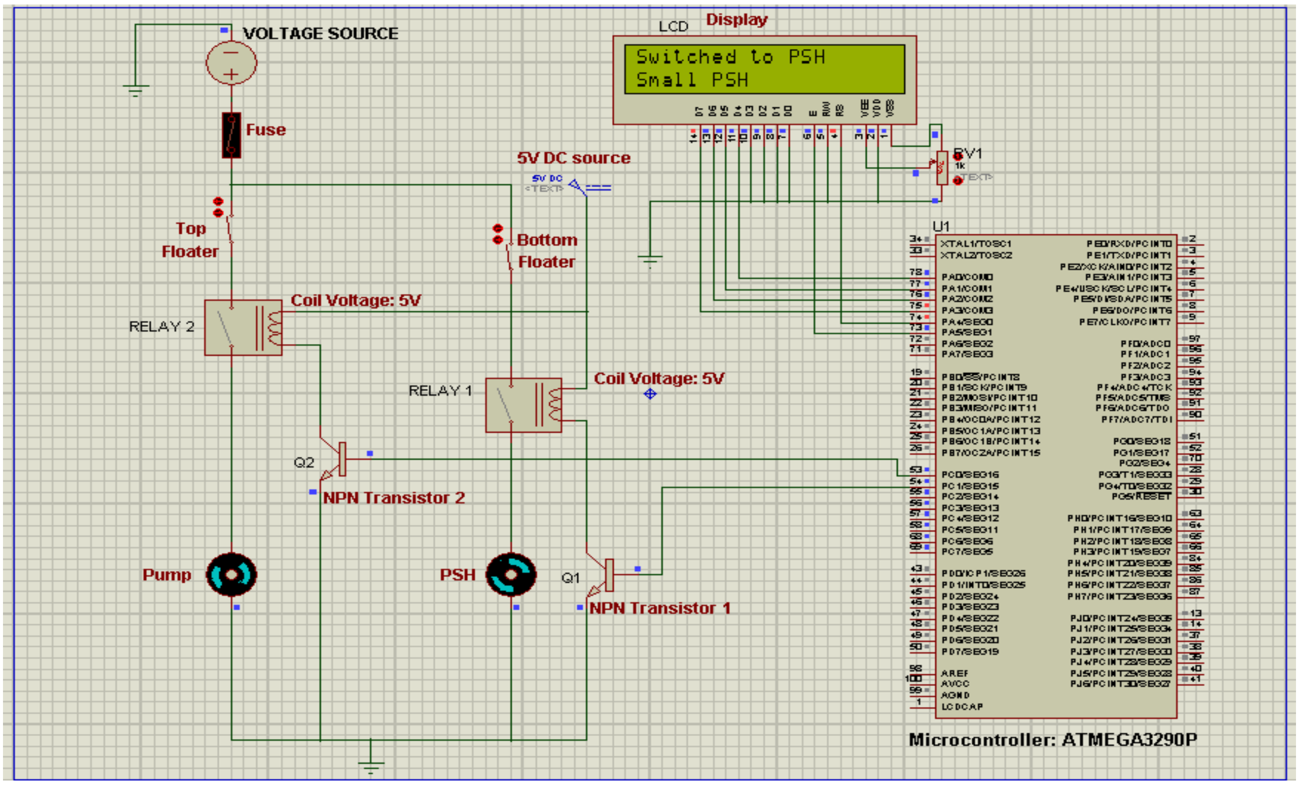

Figure Error! No text of specified style in document.**:** Energy control system when PSH is switched on

The same applies to the top floater which controls the water level during pumping mode. Reservoir II is larger than III and the flow from I is greater than that of II and III, which means there will always be more water to pump up each time. To avoid over filling of the upper reservoir III, immediately the water level reaches the position of the top floater, the pump will automatically switch off even if the system is in pumping allocation time. These floaters will help in controlling the volume of water available in III and to manage the plant for efficient outcome.

For example, in Figure 10, pump activity will be allowed, because the bottom floater is switched off which is an indication that the water level in III is low. At this period PSH activity will be on hold as described in Figure 11 though the display reads PSH.

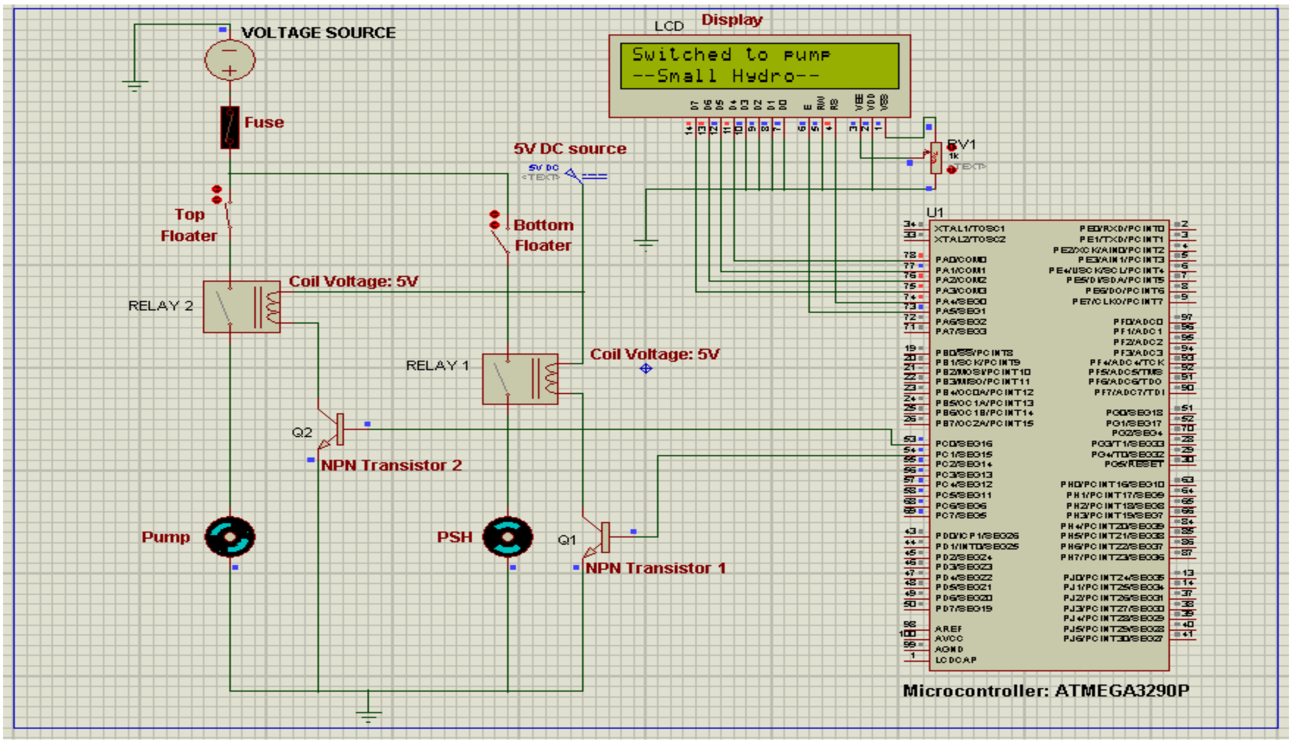

Figure 10: Energy control system when only top floater is switched on

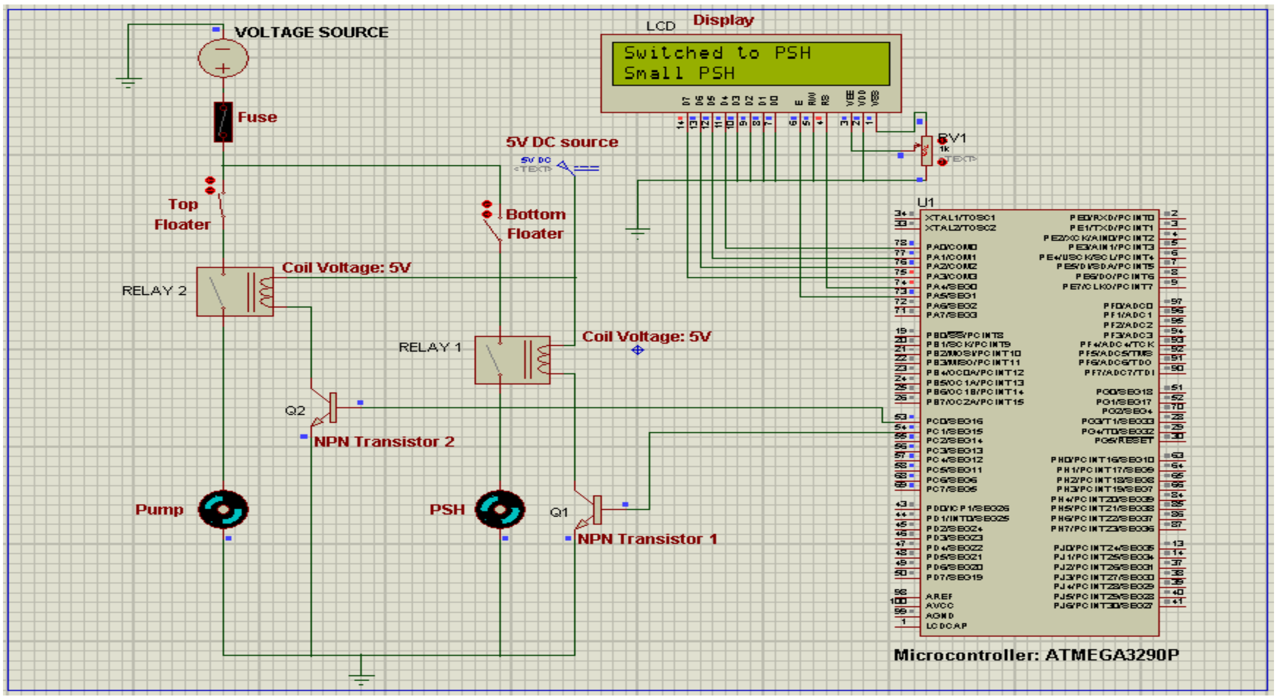

Figure 11: Energy control system when only bottom floater is switched on

CONCLUSION

The floaters provide an accurate result for balanced operation of the hybrid plant. The governing control strategy worked for the proposed plant with quick response at any given time any excess power was available from the primary hydropower plant. Flowcode and Proteus proved to be relevant in the management of the plant control. The display aspect provided ease of identifying which of the plant system was working at a particular time and which was not working. It would also reveal the reason why the expected one to be working is not working especially when it has to do with floater control.

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