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PLC – HMI Automation based Cascaded Fuzzy PID for Efficient Energy Management and Storage in Real Time Performance of a Hydro Electric Pumped Storage Power Plant

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Abstract

Usually in order to balance the load demand at high peak hours, hydro electric pumped storage power plant is utilized. In this project a novel design, (CFPID) Cascaded Fuzzy PID (Proportional - Integral - Derivative) controller scheme using B&R (Bernecker & Rainer) Industrial Automation PLC - HMI (Programmable Logic Control - Human Machine Interface) for Efficient Energy management and storage in real time performance of a hydro electric pumped storage power plant is proposed. In this scheme, Fuzzy Level is cascaded with PID Flow for improvement in performance. A prototype model of a hydro electric pumped storage power plant with 22 digital inputs and 14 potential free outputs is fabricated with an objective of controlling the process variables, flow and level is done by using conventional PLC and the proposed CFPID control. There are two tanks in the prototype, lower tank with 2 stages of level and upper tank with 5 stages of level. HMI is used to monitor and operate the process in online - real time, for easy control of the operations. In this paper, the proposed PLC- HMI automation based CFPID control scheme is performed and finally compared with the conventional PLC by experimental results and validated by using real time statistics obtained from the hydro electric pumped storage power plant.

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1. Introduction

For generating power, hydro electric power is the most widely used renewable sources of energy. Hydro power generation depends on the available flow and altitude from which it falls. Rajeshwari et al [1] emphasize on controlling the process variable parameters such as level and flow with real time implementation of gate control of hydroelectric power plant using PLC. King et al [2] discusses the development of a fuzzy inference system (FIS) based governor control for a pumped storage hydroelectric plant. Kerning Xie et al [4] proposed a new fuzzy-immune PID cascade control system in superheated steam temperature control System. Tunyasrirut [5] et al described the Fuzzy-PID cascade controller to control the level of horizontal tank. Gagan Singh et al [3] described that a suitable signal is necessary in hydro power plant to operate the gate, need to be identified which may satisfy the requirement of sudden large change in the loads, well as to maintain the constant speed.

To overcome the difficulties such as inherent time delay, nonlinearity due to uncertainty of the process and frequent load changes in the existing control schemes and thereby to enhance the performance of the hydroelectric power plant, the PLC-HMI based CFPID control scheme is developed. This paper is structured as follows: Section 2 deals with the hydro power plant and prototype model. Section 3 deals conventional scheme for hydroelectric power plant. Section 4 describes the proposed CFPID, fuzzy level cascaded with PID flow control scheme. Section 5 describes the PLC-HMI Visualization. Section 6 deals with Experimental results of the conventional and the proposed scheme. Section 7 gives the summary & conclusions.

2. Hydro Electric Pumped Storage Power Plant and Prototype Model

In Pumped storage power plant, Energy is stored by pumping water from lower reservoir to upper reservoir at the time of low power demand and at the time of peak load period's, stored water is utilized to generate and manage load demand. The sequences followed in Hydro electric pumped storage power plant that is put into operation in the prototype model are illustrated as follows: When the water level in the lower tank reaches the low level, the pump 1 is actuated and the water is taken to the upper tank from the lower tank. In upper tank, when the water level reaches the low level, pump 1 is, again switched on and water level raises upto average level. When water level exceeding average level, Gate1 is allowed to open.

Similarly when the level attains medium level, the pump 1 actuated and the water raises upto high level. When water is mounting beyond medium level, Gate 1 and Gate 2 is opened and when water level is reached the high level, Gate 1, Gate 2 and Gate 3 is opened. When the level increases beyond the high level, the pump2 is actuated and water is taken back to lower tank. If the water level reaches high level in lower tank and exceeding danger level in the upper tank, Gate 1, Gate 2 and Gate 3 will be closed and also the pumps 1 and 2 will be switched off.

The Lab scale Experimental Set up operation is shown in Fig.1. Prototype model is provided with lower tank of two levels and upper tank of five levels [1]. The upper five levels are Low level, Average level, Medium level, High level and Danger level. Whereas the two levels of the lower tank are Low level and High level. The Block diagram of Hardware set up is shown in Fig.2 which consists of the hardware components Programmable Logic Controller, FT - Flow transmitters, LT - Capacitive level transmitter, Pumps and Valves. Based on the level transmitter (LT) output, the ladder logic is programmed and as per the programmed ladder logic, the pumps and also the opening of gates of the dam are actuated at their respective levels. The Lab scale Experimental set up is operated based on the sequences demonstrated. The Lab scale Experimental set up is shown in Fig. 3.

3. Conventional Scheme for Hydro Electric Pumped Storage Power Plant

The Hardware components of B&R PLC system is shown in Fig. 4. It has Processor unit (CPU), Memory section, Input/output sections, Power supply unit, Programming device and System buses. The overall B&R Hardware with Power supply, PLC, Input/ Output modules is shown in the Fig. 5.

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