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Computer Based Control of Operation and Maintenance of SHP Plants

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Abstract

Operation and maintenance (O&M) cost of small hydropower (SHP) contribute substantially in their annual costs. Conventional methods of control of O&M of such plants become totally uneconomical. Hydro generating units have been monitored and controlled by human operators for many years, both locally and remotely. The generating efficiency is hard to be adequately optimized by human operators due to the vast number of variable parameters that can affect unit efficiency and also rapid change in variables. Most of the SHP sites are in remote areas where available manpower is unskilled and has little or no knowledge of operation and maintenance control. The unavailability of relevant manpower adversely affects the efficiency of generating units. Control of operation and maintenance system for SHP should be simple, reliable, cheap and with minimum interference of operating personal. Control system should be such that remote operation can also be performed easily. An automatic computer based system can be useful to control the automatic starting, stopping, safe operation and protection the generating equipment. Computer based automation system have the ability to operate the hydro generating unit in a more efficient, accurate, safe and consistent manner. The present paper is aimed to describe the various computer based control techniques and monitoring which can be able to enhance efficiency of the system at reduced cost.

Keywords: Small hydropower, control system, automation, operation and maintenance.

1. Introduction

Hydropower is one of the most promising available energy sources in the world. However, due to other problems like, high construction cost, environmental concerns due to impounding of river water and long gestation period of large hydro have ceased to be offering any long-term solution for our increasing power demand. On the other hand Small hydropower can be built in less time and create less environmental problems [1]. The control of operation and maintenance system for small hydropower plants have advanced in recent years. Small hydropower plants were using hardwired relays for semi-automatic operation of the turbine auxiliaries, and a mechanical governor for speed control. With the development in computer technology, computers are widely used in hydropower stations for various controls. An automatic computer based system can be useful to control the automatic starting, stopping, safe operation and protection of the generating equipment. Control of operation and maintenance system for SHP should be simple, reliable, cheap and with minimum interference of operating personal. Control system should be such that remote operation can also be performed easily [2]. In the present study, an attempt has been made to present various computer based control and monitoring techniques for efficient operation of SHP plants.

2. Automation of SHP Plants

An automatic control system or automation system is to allow the automatic starting, stopping, safe operation, and protection of any equipment being controlled through computerized control. An additional benefit of an automation system is the ability to operate the hydro generating unit in more efficient manner. Computer-based automation improves hydro power plant operation and maintenance activities. Many activities previously accomplished by plant personnel can be performed more accurately, safely, and consistently by computer-based automation systems. Hydro generating units have been monitored and controlled by human operators for many years, both locally and remotely. The generating efficiency is hard to be adequately optimized by human operators due to the vast number of variable parameters spanning multiple systems that can affect unit efficiency and also due to rapid change in the variables. Computer-based automation systems allow plant owners to operate and maintain their plants in better ways. Control algorithms based on criteria such as efficiency, automatic generation control, and voltage control allow more cost effective and safe operation of plants and interconnected power systems. Maintenance activities are improved by the computer's ability to isolate problems, describe trends, and keep maintenance records [3]. This one-point control has many advantages, including reduced operations staff, consistent operating procedures, and the capability to have all control and data available for reference during normal and abnormal conditions. Figure 1 shows the automation system for SHP station [4].

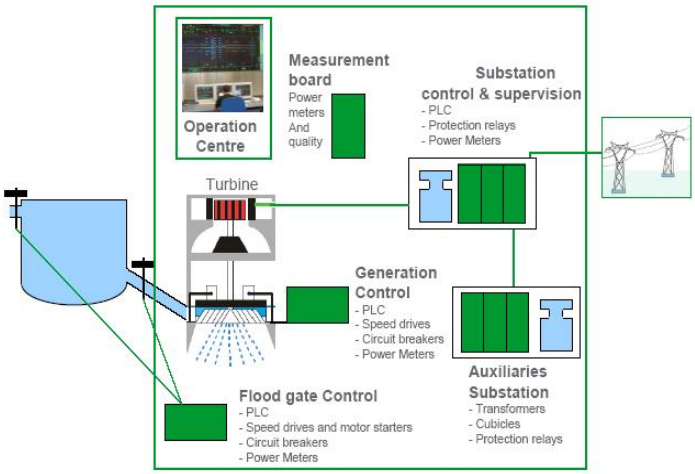

Figure 1: Automation system for SHP station [4]

3. Automation Classification

There are two general classification of system used in hydropower plant automation systems. One class of systems uses proprietary hardware and software, and makes little or no provision for interoperation with other hardware and software. These are termed as closed systems. The other general system class is an integrated system, with all plant control and monitoring components having a common data communication structure supported by common hardware and software structures. The trend in these control systems is towards open systems. For contrast, a traditional supervisory control system is included to illustrate similarities and differences. Practically, it is seen that neither fully closed nor truly open system exist. Rather, spectrums of systems exist, all with some ability to communicate or function with other systems as shown in table 1 [3].

Table 1: Classifications of computer control systems.

System type	Applications examples	Major components
Closed	Stand-alone systems (proprietary, single function controllers)	Proprietary controllers, Proprietary operator console stations.
Open	Hydropower controllers (systems), Large scale energy management systems, SCADA systems (microprocessor-based)	Programmable logic controllers on communications networks, Networked PCs or workstations, End user programmable remote terminal units.
Traditional supervisory control	Hardwired supervisory control systems	Master stations, Nonprogrammable remote terminal units

4. Control Systems for Operation and Maintenance

A general control for hydropower plants is defined in IEEE Std 1010-1987. The combination of computer-based and non computer-based equipment utilized for unit, plant, and system control should be arranged as described in Table 2. The computer-based equipment may handle only automatic unit sequences and data acquisition, with all other functions, such as local manual control, handled by non computer-based equipment. Manual controls are used during testing, and maintenance, and as a backup to the automatic control equipment. Generally, manual controls are installed adjacent to the devices being controlled, such as pumps, compressors, valves, and motor control centers. Often, capability to operate individual items of equipment is also provided at the unit switchboard while in the local-manual mode. During normal operation, the control and supervisory functions are carried out by the computer-based equipment and separate equipment is used for the protective functions [3, 6].

Table 2: Control systems for operation and maintenance.

Control Category	Subcategory	Remarks
Location	Local	Control is local at the controlled equipment or within sight of the equipment.
	Centralized	Control is remote from the controlled equipment, but within the plant.
	Off Site	Control location is remote from the project.
Mode	Manual	Each operation needs a separate and discrete initiation; could be applicable to any of the three locations.
	Automatic	Several operations are precipitated by a single initiation; could be applicable to any of the three locations.
Operation (Supervision)	Attended	Operator is available at all times to initiate control action.
	Unattended	Operation staff is not normally available at the project site.

5. Components of Automation

Performance and reliability related components of a hydropower plant instrument and control system are based on the automation design. The components of automation are given as below [5].

- *PLC (programmable logic controller):* The function of a PLC is the heart of digital control system with programming capability that performs functions similar to a relay logic system. PLC consists of a CPU (central processing

unit), memory, power supply and means of communications to I/O and other devices.

- *RTU (remote terminal unit):* The function of RTU is to collect data and it is similar to PLC. Sometimes, it may be termed as PLC, depending on the vendor terminology. RTU is generally associated with older control systems with minimal control capabilities.
- *HMI (human machine interface):* The function of the HMI is to be the interface for the operator to the control system. The HMI is normally a PC as the client portion of client/server architecture. In some cases, the HMI and the server are the same.
- *Data Server:* The function of a data server is to link the controllers and the network to send data to the HMI and receive operator input from the HMI back to the controllers.
- *Network LAN (local area network):* There are normally two major networks in a hydropower control system.
  - The TCP/IP network (Ethernet) links the server(s) to the HMIs, the controllers, data historians, firewall, and other Ethernet based devices.
  - The I/O network may also be Ethernet, though it is commonly a protocol used by the controls.
- *SCADA (Supervisory Control and Data Acquisition):* Over the decade, SCADA systems, PLC based systems and DCS (distributed control systems) have migrated towards being synonymous.
- *I/O (wired input and output to field devices):* The function of I/O is to send commands to devices or receive information from devices.
- *Local Control (definition):* Controls located at the equipment itself or within sight of the equipment. For a generating station, the controls are located on the unit switchboard-governor control station.
- *Automatic Control (definition):* An arrangement of controls that provide for switching or controlling, or both, of equipment in a specific sequence and under predetermined conditions without operator intervention after initiation.
- *Firewall:* The function of a firewall is to restrict and protect the plant control network from outside unauthorized access.
- *UPS (uninterruptible power supply):* The function of the UPS is to provide temporary power to a system in case of main power failure. The UPS also acts as a power filter to protect control equipment.
- *IDS (intrusion detection system):* This device resides on the process control network to detect and log any intrusion attempts – failed or successful.
- *Historical Archive:* The function of the historical archive is to store historical information from the control system.
- *Reporting:* The function of reporting is for GADS *(*Generating Availability Data System).

- *Engineering Workstation:* The function of the engineering workstation is to configure the software for the control system controllers, servers, HMIs and other controls equipment.
- *Efficiency Optimization:* This is a program that runs on top of the control system to maximize efficiency of the plant.

6. Need and Benefits of Computer Based Control for SHP

Although sophisticated control equipment are being used for the control and protection of large hydropower plants, the same does not apply to SHP due to the following [1].

- High cost of control and protection equipment. In the large plants, the cost of control and protection systems, compared with the total investment is not so significant, while its share is much higher in small hydro plants. Thus comparatively cheaper system which can still provide adequate control and protection requirements is needed in SHP stations.
- SHPs are usually situated in remote areas and are manned by operators without adequate skills. This often leads to a number of problems caused by operational mistake, or remedial actions are not taken in time, etc. The control system should be simple and easy to operate.
- Maintenance and repair of equipment becomes difficult as spare parts, tools, and skilled personnel are usually difficult to obtain in remote places. The system should be reliable and maintenance-free as far as practicable.
- The cost of operation has to be kept low in SHP. Hence the system must be designed to operate with minimum staff. Automatic/semi-automatic control saves operational costs. In view of the above, it is necessary to select simple, reliable and cheap control system for SHP. The conventional control system uses separate equipment for turbine governing, generator excitation control, plant control and protection. They tend to be costly and become complicated to operate and maintain. Control system should be such that remote operation can be performed easily.

An Automation System is more relevant in case of SHP due to following reasons.

- Hydro Plants are started & stop more frequently.
- Hydroelectric units also provide flexibility of changing the mode of operation for example, kW Control, Level Control.
- Provides successful, efficient and smooth operation.
- Plants are situated in remote areas with difficult to access.

Benefits

Normally, an automation system is implemented to improve the efficiency, productivity and the operating management of the system. This automation will be

better to the production needs and services. Followings are the major benefits of Automation System for SHP Station [1, 6].

- To make complete power plant information available at any time online.
- Efficient utilization of Manpower.
- Maintenance is easier and quick.
- Reduction in down time due to online diagnostics.
- Reduction in Manpower.
- Ability to integrate plant control functions in one hardware system.
- Reduced Panel space.
- Improved performance
- Provides security against wrong operations by the operator.
- Automatic starting and stopping of machine sets are faster than manual starting and stopping.
- Efficiency of power plant can be raised through automation to almost practically highest value by
- guide operator to optimize generation.
- Reliable operation
- Lower cost

An additional benefit of an automation system is the ability to operate the hydro generating unit in a more efficient manner.

7. Conclusions

Our energy demand continues to grow, while conventional resources are diminishing. Small hydropower (SHP) is one of the most appropriate options to meet increasing energy demand especially in a country like India. Hydro power generation is a significant renewable energy resource that can be used to cater to the demand. The conventional methods for plant control may be uneconomical, if applied to SHP due to high cost, so integrated automation and control has become the solution for making it efficient and cost effective. Computer based control and automation has a number of advantages over other conventional types being used in SHP such as lower cost, simple operation and maintenance, operators can extend the serviceable life of their equipment while improving the efficiency, reliability, and safety of their systems.

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