Real Time Digital Simulator for Small Hydropower Plants

Sharma JD [1] , Arun Kumar[2] and Singhal MK [3]

1) Department of Electrical Engineering, Indian Institute of Technology Roorkee, Roorkee– 247667, India
2) Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, Roorkee – 247667, India

Email: *jaydsfee@iitr.ernet.in, jaydsfee@gmail.com*

ABSTRACT

This paper describes a real time digital simulator (RTDS) for small hydropower plants established at Alternate Hydro Energy Centre (AHEC), IIT Roorkee, India with the aim of providing efficient initial and advanced training to operators and engineering staff of different types of small hydroelectric plants, by creating training conditions very close to real operating conditions. This will meet the large requirement of trained personnel for operation and maintenance of small hydropower plants, reduce O&M costs, reduce damage to plant, increase plant life and reduce training time. The hydraulic part, the generator, the transformers as well as auxiliary electricity systems are taken care in the simulation.

1 INTRODUCTION

The conventional and mostly practiced form of training of operators is on the job training given with 'normal' system conditions under the supervision of an experienced (senior) operator. Procedures dealing with 'abnormal' system conditions have mainly to be studied by the operators themselves and are trained as paper exercises. Real time simulator based training bridges the gap between the theoretical background and the required practically performed actions. Embedded in training courses, the use of RTDS can provide an efficient and realistic environment to replicate SHP's performance. Hydropower plant simulator provides a realistic simulation of the hydropower plant and control centre environments. Beside operator training, they can be used in equipment design and their tuning, hardwire-in-loop testing and to evaluate operator performance and his responsiveness, which eventually will contribute to saving in electric power costs.

With the estimated potential of SHP of about 15,000 MW in India, there are about 500 shp plants in operation and due to government incentives and private sector involvement about 40-50 plants are expected to be commissioned annually.

The simulator developed is able to simulate wide varieties of operating conditions such as: turbine start-up, normal and emergency shut down, synchronization, parallel operation, short-circuit condition, load rejection and line faults. Several types of equipment faults can be simulated and operator is supposed to take necessary action for system restoration. These are summarised below:

- Conduct interactive, multimedia based training on small hydro plant operation
- Selection and sizing of sub systems
- "On-the-job" training environment set up for variety of small hydro plants
- Impart extensive training by simulation
- Accord in depth training to power system operators / engineers on use of PLC/SCADA, electronic Governors etc
- Evaluate operator performance to contingencies and their responsiveness etc
- Capture knowledge of experienced operators and play back as guidance to beginners
- Accord in depth training to Electronic / Control system engineers on System configuration / programming / system maintenance

- Design review
- Commissioning test
- Preliminary assessment and final tuning of control systems

2 GENERAL FEATURES OF SIMULATOR

The SHP Simulator has three main subsystems: (Fig 1)

- SHP Model
- Instructional System and
- Control room Model.

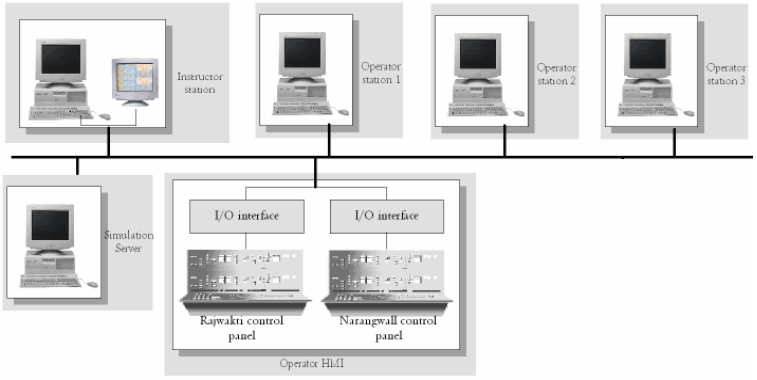

Fig 1. Layout of hardware of simulator

The main features have been provided as below:

- It is a modular system and updating of the simulator is possible.
- It is an open system so that new tools and third party or external models and codes can easily be added
- Supports various training configuration, from a single operating console to a complete replica of a control centre
- Responds in real time just as the small hydropower plant
- Uses long-term dynamic models to simulate the actions of prime movers, generators, governors, excitation system and relays, so that the system is represented under a wide range of frequency and voltage conditions
- Uses training consoles and controls identical to those used for day-to-day operations, so the simulated environment and the actual system share the same look and feel
- Can be quickly initialised from current real-time conditions

The simulation covers the following operations from start up mode to normal operating as well as abnormal and emergency conditions with proper response to failures

- Start/stop of unit
- Synchronisation of unit with the grid
- Load variation
- Turbine and generator protection
- Loss of generators, motors, due to internal problems,
- Breakers failures
- Operation log and trend chart
- Power channel , forebay and penstock draining
- Loss of auxiliary supply
- Valve blocking in position,
- Sensors defects.
- All other malfunctions
- Inflow variations in river / canal

3 REFERENCE PLANTS AND SIMULATION

Two shp plants are simulated on the same hardware architecture. One set of hard panels are correspond to low head Narangwal small hydropower plant (below 3 meters Semi Kaplan turbine based in Punjab), the other to medium head Rajwakti small hydropower plant with (52 m Francis turbine) based in Uttarkhand. The simulator can also be operated through a high fidelity screen-operated human-machine interface (HMI), including a replica of the SCADA system in operation at Narangwal. The Control Room model is an almost exact replica of the control room of these Plants.

Low Head Canal Based SCADA Operated Plant with Semi-KAPLAN Turbine and Induction Generator (Fig 2)
2 x 750 kW, Siphon Intake , Design Discharge = 28.4 m3/s, Head = 2.82 m.
Semi-Kaplan Turbine: Vertical-Axis

Medium Head, Run of the River (R-O-R) plant with Francis Turbine and Synchronous Generator (Fig 3)
2 x 1800 kW, Design Discharge = 10 m3/s, Head = 52 m.,
Francis Turbine: Horizontal Axis

The Francis turbine is simulated by an object which computes flow and power according to the total water level difference, the rotation speed and guide vanes position. The semi Kaplan turbine is simulated by an object which computes flow and power according to the total water level difference, the rotation speed and runner blades position.

Abnormal or emergency operating conditions can be created in the simulator by boundary conditions or in adapted system configuration or equipment malfunctions which are initiated by the instructor.

The simulated elements of the hydro power plant which needed to be simulated were determined from the measures displayed and from monitored parameters and from actions taken during operation. The non simulated elements of the hydro power plant are those elements which are used only in maintenance procedures and have no impact in the operators training. Simulated malfunctions are determined from failure occurring on the process and from generic disturbance concerning sensors and actuators. Care was also taken to replicate the power plant hard panels and plant overview displays included in the soft MMI Operator's station.

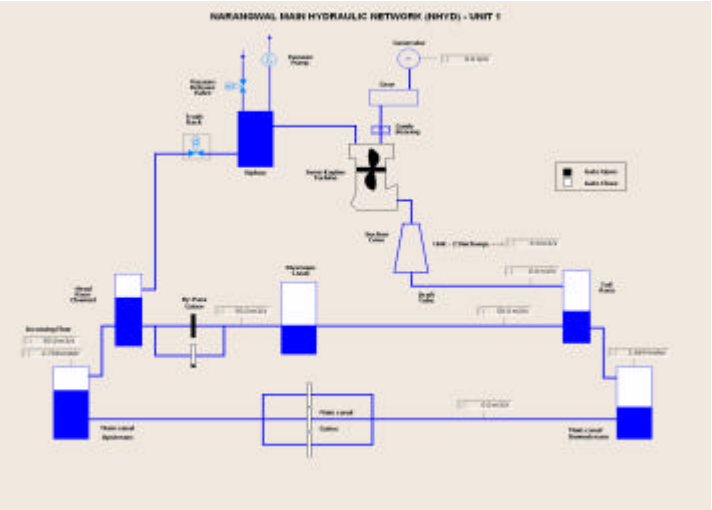

Fig 2. Hydraulic model of Narangwal Low Head SHP

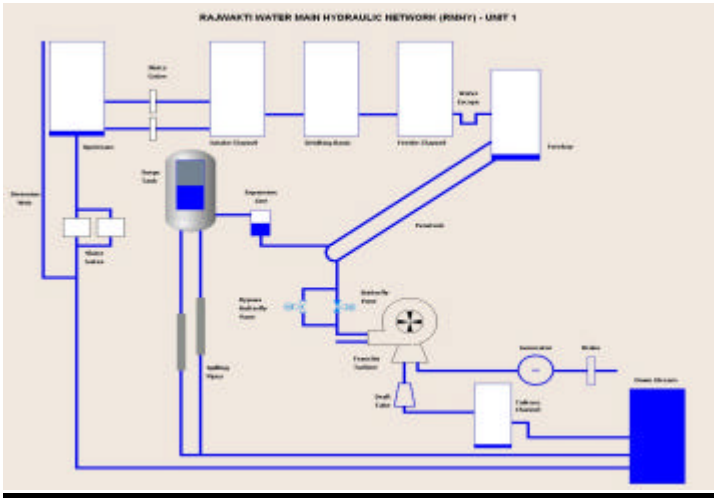

Fig 3. Hydraulic model of Rajwakti Medium Head SHP

4 TRAINING MODULES

It is expected that the simulator shall play a vital role in acquiring skill by plant operators for SHP plant operation improvement through a deep knowledge of the behaviour of plant systems and their dynamics, acquired from training. Training programme for the small hydropower station staff (new as well as existing) ,both in public and private sector, will be conducted regularly by AHEC IIT Roorkee. About 6-8 persons shall be taken for the training in one batch, which shall be depending on the level and experience of the trainee personnel (fig 4):

1 For plant engineers/operators- in service (6 days)
2 For plant engineers/operators- new (15 days)
3 For technicians- in service- (15 days)
4 For plant owners-(1 day)

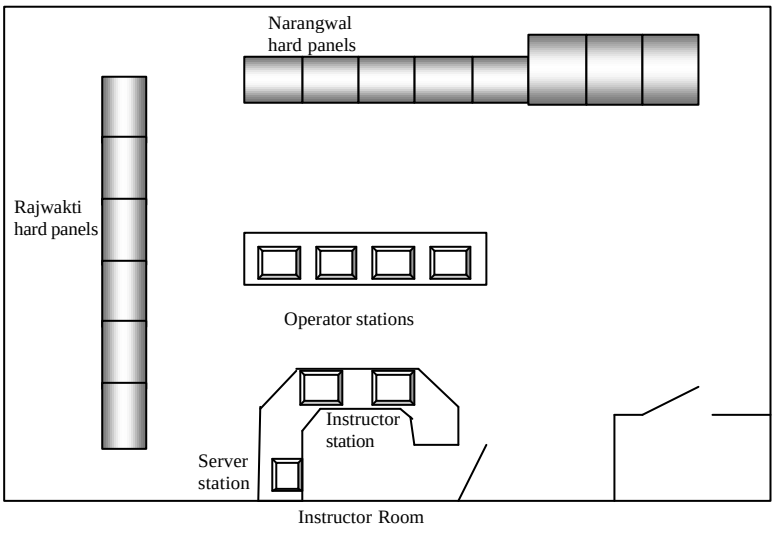

Fig 4. LAYOUT OF Simulator Training Centre

The contents of these training programme are summarized in table 1.

Training modules with duration	**Training contents**			**Target participants**
	General	**Operation**	**Other**	
In-service SHP Plant Engineer / Operator (6 Days)	• introduction to Real Time Digital Simulator • overview of small hydropower plants • small hydropower plant layout	• Start up, Shutdown, Emergency shutdown • Load rejection • Black start • SCADA operation • Trouble shooting	• Gate operation • Switchyard and power evacuation • Plant outages and safety tagging system • Plant safety and fire fighting • Monthly and annual reports and log books • Routing and special maintenance • New Developments in SHP equipment.	Plant Operators, Maintenance Engineers/ Operators of SHP Plants
Fresh SHP Plant Engineer/ Operator (15 Days)	• Introduction to Real Time Digital Simulator. • Overview of Small hydropower plants. • Small Hydropower plant layouts. • Water conductor system overview. • Hydraulic Turbine and auxiliary systems. • Generator and accessories. • Gate operation.	• Governing. • Automatic voltage regulation. • Auxiliary Power supply operation. • Plant start up and synchronizing. • Plant load pick up and drop out. • Shutdown, Emergency shutdown. • Trouble shooting and load rejection	• Hydraulic layout. • Plant panel metering, indicating, operating switches. • Plant equipment condition monitoring and taking readings. • Routine maintenance. • Plant safety and fire fighting. • Plant outages and safety tagging system. • Switch yard and power evacuation. • Monthly and annual reports and log books. • Oil pressure unit simulation. • Reading of station single line diagram. • Bearing cooling water simulation.	Fresh Engineer / Operator of small hydro power plants

Table 1. Details of Real time SHP Simulator based training modules (Continued)

SHP Plant Technician (15 Days)	• Types of hydro power plant and their layout. • Oil pressure unit working. • Generator bearing working / monitoring. • Speed increaser working • Turbine bearing cooling water arrangement. • Butter fly valves, turbine oiling greasing. • Plant day today shift work. • Plant safety and fire fighting.	• Plant panel metering, indicating, operating switches and annunciator. • Plant start up and synchronizing procedure. • Plant load pick up and drop out. • Plant normal and emergency shutdown. • Plant equipment condition monitoring.	Visit to SHP Plant	SHP Plant technicians
SHP Plant Owner/Promotor (1 Day)	• Introduction to Real Time Digital Simulator. • Over view of Small hydropower plants. • Grid and Hydropower Plant.	• Synchronizing and Loading of Generator on Simulator. • Operation of Hydropower Plant under Various Operating conditions. • Trouble shooting in Small Hydropower Plant. eg. High Temperature, Line Tripping etc. • Benefits of Simulator Training of Operators and Technicians.		Plant Owner/ Promotor for Hydro Projects

Table 1. Details of Real time SHP Simulator based training modules (Continues to next page..)

5 TARGETED BENEFICIARIES

While we have a good manufacturing base for small hydro sector in India, training and research are required to improve performance parameters, meet international standards and reduce the cost of equipment. Simplification and optimization of system design and engineering practices is also needed . Real Time Digital Simulator for SHP projects will be useful for providing training to technical staff working on SHP plants and also designing new projects

Real Time Digital SHP simulator at AHEC, IIT Roorkee

- State utilities involved in Small Hydropower generation
- Private Sector-independent power producers
- Captive users
- NGOs/Cooperatives
- Training Institute
- Manufacturers
- State utilities of neighboring and other developing countries
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6 ACKNOWLEDGMENTS

AHEC, IIT Roorkee acknowledge with deep appreciation and gratitude the financial support and timely monitoring provided by Ministry of New and Renewable Energy, Govt. of India under its CCF-II project & UNDP. For developing and establishing the simulator the necessary hardware and software provided by M/s Tractable Engineers and Constructors Pvt. Ltd., New Delhi (TECL) & Corys Training & Engineering support system Grenoble, France (Corys) is also acknowledged.