Simulator for operator training in the Sudurnes Regional Heating Corporation 30 MW_{el} combined heat and power (CHP) plant

Geir Þórólfsson
Sudurnes Regional Heating Corporation, Iceland
Email: geir@hs.is

Jóhann Þór Magnússon, Jón Vilberg Guðgeirsson and Þórður Runólfsson
Rafhönnun Consulting Engineers
Email: johann@rafhonnun.is, jvg@rafhonnun.is, thordrun@attbi.com

Ágúst Bjarnason
RT Ltd-Rafagnatækni
Email: agust@rt.is

Abstract

Good operator training is one of the key factors in ensuring high availability of a geothermal power plant. Since the plant can run for extended periods, as long as a whole year, without a shutdown and start-up, the operators rarely get a chance to train for dealing with critical tasks on the real plant. Operator Training Simulators (OTS) are common in nuclear and large fossil fuel power plants, but the use of an OTS for geothermal power plants is novel. Using the simulator the operators are trained in start-up and shut down procedures as well as normal operation and process disturbance handling, including faultfinding. Through regular retraining using the OTS, the location of all controls and their functions become second nature to the operators and they gain a thorough understanding of the connections between sub-processes and the operation of the total plant. The CHP (Combined Heat and Power) geothermal plant is briefly described in the paper and complexities due to the co-generation of hot water are illustrated. The OTS configuration includes a Process Controller and a Man-Machine-Interface that is identical to the one used in the real power plant. The training program and an example of a training scenario are described. An overview of the education required for geothermal power plant operators in Iceland is also given. Simulator training reduces the risk of costly mistakes, excessive unit stress and equipment damage. The simulator can also be used for design, evaluation and tuning of the control system, analysis of process design alternatives and preventive maintenance by comparing real and simulated data.

Keywords: *simulator, training, geothermal, CHP, power plant.*

1 Introduction

The use of operator training simulators has been common in nuclear power plants and large fossil power plants for several decades. With the advent of PC computer based simulators, it has become feasible to build training simulators for smaller power plants including geothermal power plants. In Iceland the development of simulators for geothermal power plants started at Rafhönnun in 1987 with the development of a simulator for the Nesjavellir geothermal plant for hot water production. Since then various teaching and training simulators for geothermal plants and district heating systems have been developed at Rafhönnun for the United Nations University

Geothermal Training Programme in Iceland and Danfoss heating controls in Denmark amongst others.
The development of the power plant simulator for Sudurnes Regional Heating Corporation (SRHC) started in 1998 and the first version was completed in 2000. This simulator is one of the first simulators to be specially developed for CHP geothermal power plants. In the first version the Human Machine Interface (HMI) was a copy of the SCADA system VDU displays. The operators, however, mainly use the hardwired control panel, which came with the turbine-generator, to start and stop the turbine. In the second version of the simulator, completed in 2001, a VDU replica of the control panel was therefore added.
The power plant no. 5 (in Icelandic; Orkuver 5, OV-5) simulator has mainly been used for training of SRHC plant operators. Some control and protection system studies concerning load shedding have included the use of the simulator. The simulator has been used at the United Nations University Geothermal Training Programme in a course about simulation and simulators in geothermal projects. In the future it is planned to invite operators from other geothermal power companies in Iceland and abroad and students in schools such as The Marine Engineering College of Iceland to use the simulator for training.

2 Brief description of the Svartsengi geothermal power plant

SRHC operates the Svartsengi geothermal power plant in Iceland. The plant produces hot water for district heating as well as electricity in several turbines of different size and type. There is one 6 MW backpressure turbine unit, seven ORMAT-binary units, each generating 1.2 MW and in OV-5 a 30 MW surface condenser turbine that was commissioned in 1999. OV-5 also produces 240 l/s of hot water. For maximum efficiency the hot water production utilizes steam extracted from the turbine at two points. This concept is well known in fossil fired plants, but is novel in geothermal plants and adds complexity in the operation of the plant. The OTS models the OV-5 turbine-generator and associated equipment.

3 Education and training of power plant operators in Iceland

Most geothermal power plant operators in Iceland are trained marine engineers with several years experience as marine engineers in the fishing and cargo fleet in Iceland. In the harsh winter climate in the North Atlantic, the demands on the marine engineers are often severe. The safety of their ship critically depends on the reliable operation of the ship’s machinery. Today’s ships are also loaded with electrical and computer controlled equipment that the marine engineer must know how to operate and in some cases even repair. Marine engineers that have gained experience in the harsh North Atlantic are therefore resourceful and have an excellent background for work as operators in geothermal power plants.
Marine engineering education in Iceland has mainly been obtained in The Marine Engineering College of Iceland. Most of the plant operators have attended the school for 3 or 4 years full time, depending on the level of certification sought. The training comprises a mixture of theoretical and practical subjects including physics, chemistry, electricity, electronics, first aid, fire and hazard protection, control and automation techniques, computers, practical engineering, refrigeration, and simulator training in diesel ship’s engine operation. For over 15 years simulator based training has

constituted an important part of the Marine Engineering College training and consequently recent graduates are quick to adopt the use of the geothermal power plant operator-training simulator.

4 The Operator Training Simulator

A dynamic simulation model of the 30 MW turbine generator unit and associated equipment runs on a PC computer. In addition to the simulation computer the training simulator consists of a Siemens Simatic S7 programmable controller (PLC) and local operator consoles running P-CIM SCADA software from Afcon Inc. running on PC computers. The operator consoles are exact replicas of the ones used in the power plant and consequently, the operating personnel view and interact with the process just as if they were operating the real plant. A separate program, the Instructor Station, is used to interact with the simulation process to select and configure training scenarios and initial conditions, initiate failures such as malfunction of control valves and sensors etc. Rafhönnun programmed the plant model, and Framatom and Rafhönnun cooperated in writing the software for communication between the model and the PLC, whereas Rafagnatækni programmed the PLC and the operator consoles.

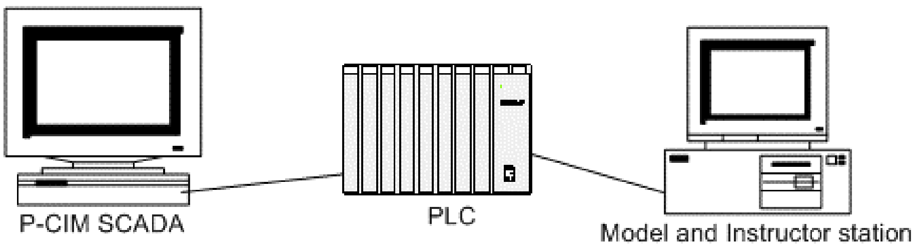

Figure 1: Simulator configuration.

The real time simulation model is programmed in the Modular Modelling System (MMS) environment from Framatom that was initially developed for nuclear and large fossil power plant simulators. The simulation model calculates the process measurements and other state information based on plant response to operator interactions. The main reason for selecting the MMS modelling environment for this project is the wide range of accurate and thoroughly tested simulation modules, which cover most equipment to be found in a geothermal power plant. Without these modules the model programming and debugging task would have been overwhelming and the uncertainty about the accuracy of the model much greater. Another important reason for selecting MMS was the advanced simulator tools included, such as the Instructor station software package and driver software for the communication between the model and the PLC.

The simulator’s user interface includes over 20 SCADA process displays. In addition there are displays that mimic the hard wired control panel normally used for start-up and shut-down of the turbine-generator unit. From this display, it is possible to perform all the same operations as from the real panel and all meters, status lamps and controllers show plant status dynamically. To facilitate the use of the replica panel, all parts of the panel display can be enlarged in separate windows. This makes label and meter reading much easier. The main equipment, which can be controlled and monitored from the panel, are the oil system, vacuum system, turbine governor and steam pressure and power controllers, excitation system, synchronization, vibration and temperature monitoring and an alarm panel. The operation of the PID controllers is modelled in detail and training in their use is therefore included. For each controlled object, such as pumps and valves, there is a selection switch on the panel for LOCAL – REMOTE control. REMOTE control here means control from the normal P-CIM process displays.

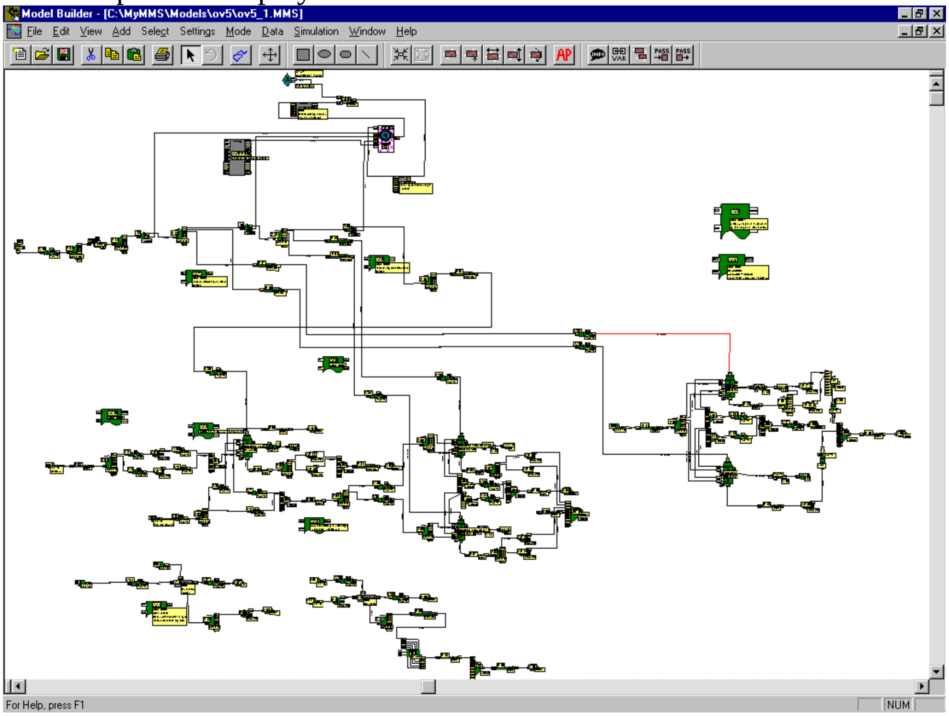

Figure 2: Screen display from the "Modular Modelling System" modelling environment.

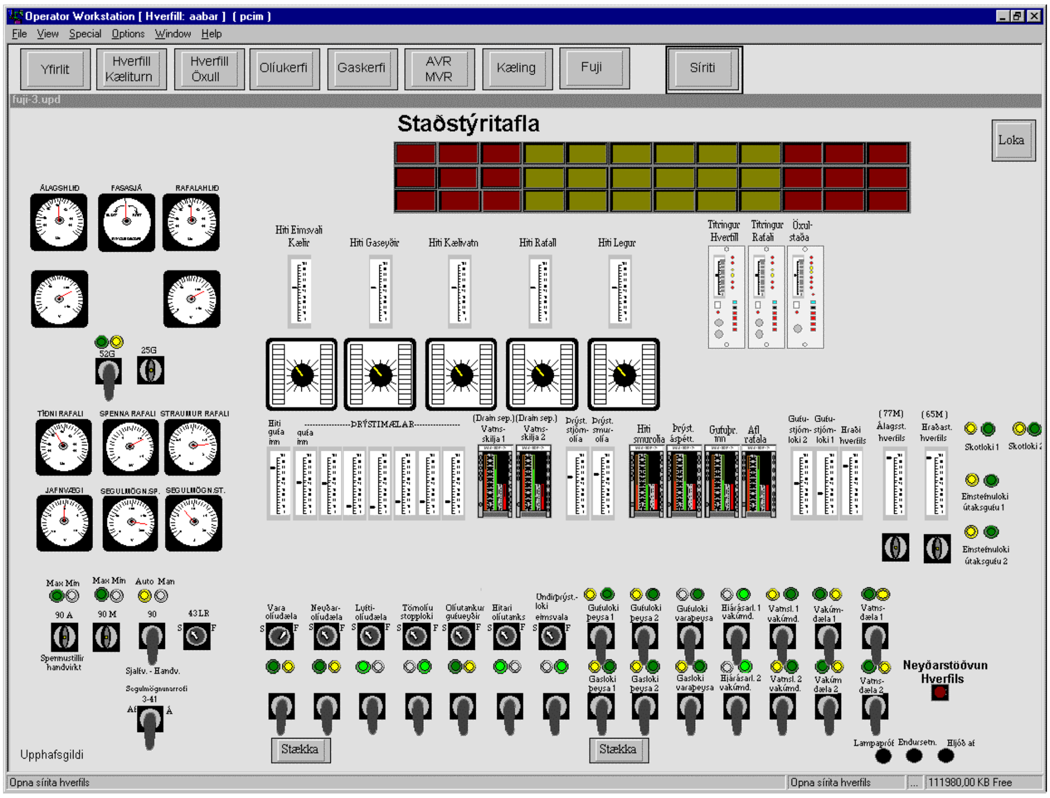

Figure 3: Screen display of a replica of a control panel from Fuji for the 30 MW turbine-generator unit. The display looks almost like a photograph of the actual control panel.

5 The training program and OTS training scenarios

An important part of any training simulator project is the planning of operator training. The simulator is located in the main control room of the Svartsengi power plant. From this location all the turbine-generator units in Svartsengi and the heating station are monitored through a P-CIM SCADA system. Initially the idea was that the simulator training should be rather informal, and the operators would train on the simulator on their own initiative when there was little workload in the control room. However, it turned out some of the operators were well motivated for this type of procedure whereas others were not, principally because the start-up of the simulator requires some effort and experience and also because self-organized learning is not everyone's cup of tea. Based on this experience it was decided to prepare some basic training scenarios for cold start, hot start, normal shutdown and emergency shutdown. These training scenarios are based on different initial conditions that are stored as snapshots from other simulator runs. The operators use the same manuals for operating the simulated plant as for operating the real plant. An instructor from Rafhönnun led the operators, two and two at a time, through the exercises. Also one SRHC electrical engineer was trained as a simulator instructor who will assist the operators with the simulator. Currently the plan is for new operators to go through a thorough training on the simulator. Experienced operators will take shorter refresher training on the simulator, lasting ca 2-3 hours, typically after the summer holidays or longer breaks from control room work (approximately once per month). Once or twice a year it is planned that all operators will receive a more thorough simulator training in one or two 3-4 hour sessions. A system for the documentation (certification) and verification of the operators' training has been discussed but not implemented yet.

It is planned to use the SRHC simulator in the IGC 2003 pre-congress course on simulation and automation in geothermal systems. The participants will get an opportunity to start up the plant in the simulator.

6 Analysis of process design alternatives

In addition to operator training, the simulator has been used for some control system testing and design studies. For instance the simulator was successfully used for a load shedding study, with different levels of local load remaining (see Figure 4). The aim of the study was to analyse and compare different modifications to turbine control and protective relaying to avoid over-speed trip upon load shedding.

7 Conclusions - Further development of the simulator

The training simulator has already proven that it is an excellent tool for training operators in start-up and shutdown procedures as well as normal operation and process disturbance handling. The operators gain thorough knowledge of the location of all controls on SCADA displays and the hard-wired control panel and their functions become second nature to the operators. Furthermore, through training in the simulator they gain a thorough understanding of the connections between sub-processes and the operation of the total plant. After the simulator has been in operation for some time it will be decided if any additions to the simulation model are needed. Based on the experience with the simulator so far, it seems that a model of the steam-field dynamics would add a considerable value. During start-up operators have to be careful not to make sudden load changes and thereby risk getting water into the turbine. Modelling of the steam-field dynamics is rather difficult, but would be an important addition to the simulator. Another useful addition that would be a more detailed model of the heating plant and also some parts of the other power plants located in Svartsengi.

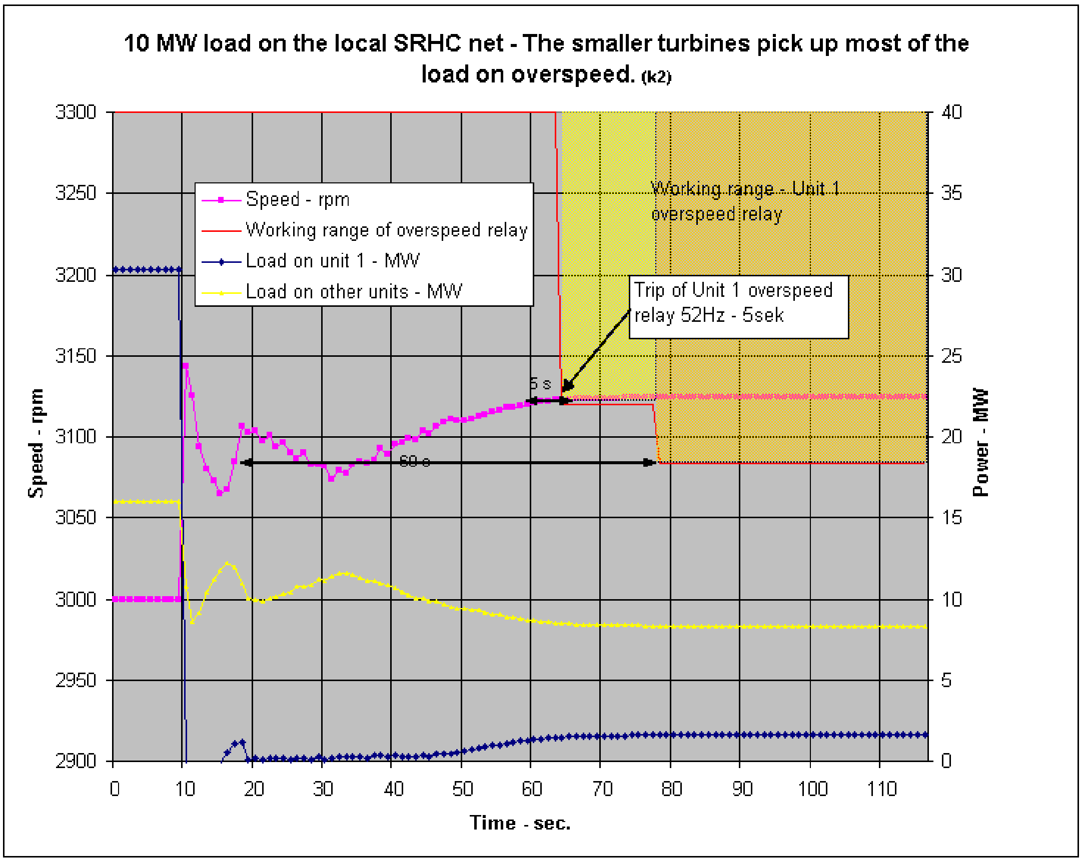

Figure 4: Diagram from a transient study of plant reaction to disconnection from the national grid at full load.

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