Using physical switches on a modern simulator: the experience of SRP Agua Fria Unit 2

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When SRP Agua Fria Generating Station (SRP AFGS) chose to invest in a simulator, they selected an option for a physical emulation of the turbine pistol grip switches and related indicators. This paper reviews the reasons for this selection and the feedback from the operations staff after the simulator was installed.

SRP AFGS Unit 2 is a 100 MW oil and gas fired unit, built in 1956. The steam turbine was supplied by General Electric (GE). At SRP AFGS nearly all of the unit control now utilizes a Foxboro I/A DCS. However, turbine preheating, roll-up, synchronization, and valve transfer operations are carried out using three pistol grip switches on the control room hard panel. There is one switch for the stop valve, one switch for the turbine governor, and one switch for the load limiter. Careful operation of these switches, especially during turbine roll-up and synchronization, is of critical importance for turbine protection. Because the stop valve switch has 5 positions: fast close, slow close, no action, slow open, and fast open, it takes new operators at the plant some time to develop a “feeling” for how much to move the switches to achieve the desired turbine response while keeping the turbine under control at all times. SRP AFGS worked with the simulator supplier to purchase pistol grip switches with same model numbers as those used in the plant today. Surprisingly, during testing of the new pistol grip switches on the simulator, the new load limiter switch was determined to feel like the existing stop valve switch. The switches were swapped and reconfigured. The simulator, with the physical switches, is now an integral part of the SRP AFGS operator training procedures.

Plant Description and Simulator Objectives
Salt River Project (SRP) Agua Fria Generating Station (AFGS) has a capacity of 626 MW from six units, three simple cycle combustion turbines, three Rankin cycle units, and one solar generating unit. Construction began in the late 1950s, with the first steam unit coming on line in April of 1957 and the last steam unit coming online in May of 1975. The solar generation unit came online in 2001. Today the station is used to supplement base-load plants.

Procurement of a dynamic simulator was determined to be one way to meet the training objectives of SRP AFGS, which included shortening the time training time for new operators and maintaining the skills of operations staff during winter months when the units are typically not in operation.

Unit 2 was chosen to be the basis for the simulator. Unit 2 has a capacity 113 MW. The unit may fire either natural gas or oil. The Architect/Engineering firm was Bechtel. The boiler was supplied by Riley Stoker and the steam turbine was supplied by General Electric. Typical of steam turbines of the 1950’s time period, the steam turbine utilizes mechanical-hydraulic control of the steam turbine. Figure 1, below, is a photo of the switches used by the operator to control the AFGS Unit 2 steam turbine. On the left hand panel are analog displays showing the control valve position and the turbine acceleration.
the right hand panel are three black piston grip switches. The left pistol grip switch is the stop-valve bypass switch; the center pistol grip switch is the governor control switch, and the right pistol grip switch is the load limit switch.

**Figure 1: Hard Panel Turbine Control Station for SRP AFGS Unit 2**

**Evaluation of using a Physical Hard Panel**

Simulation vendors offer the ability to replicate a physical panel via software. The figure below shows such a software replication of the AFGS Unit 2 hard panel.

**Figure 2: Software Emulation of the Turbine Control Station for SRP AFGS Unit 2**
Modern graphics allows the software replication to look very similar to the actual equipment. Visual feedbacks such as lights and numeric displays can be accurately represented. Operator actions, such as moving a switch position or pushing a button, are emulated either by moving the mouse or by interacting with a touch screen. Given this fidelity to the actual system, software emulations of a hard panel allow many training objectives to be achieved: the trainee can become familiar with the appearance of the panel under a variety of operation conditions and the trainee can practice performing many required actions.

For the Agua Fria Unit 2 simulator, one example where software emulation was deemed sufficient for simulator training is shown in the figure below, which shows the software emulation of a portion of the AFGS Unit 2 electrical panel. All training objectives could be achieved with a software emulation of the electrical panel. Trainees could be introduced to the various components of the system and practice various operations.

However, a software emulation of the turbine control switches was deemed insufficient to meet the SRP AFGS training objectives. For the turbine control switches, the physical feeling of manipulating the
switches is an important part of the training objectives. Specifically, the power plant operator must learn how much (or how little) force must be used to manipulate the switches. This is of particular importance during the turbine roll-up, turbine synchronization, and valve transfer processes. For this reason SRP AFGS chose to implement a physical hard panel for the simulator. To make the experience more complete, the feedbacks and switches near the three turbine switches were also included in the physical hard panel on the simulator. After some review, it was decided to include 14 lamps, 5 push buttons, 6 digital readouts, two simple switches, and the 3 mechanical switches in the physical hard panel emulation.

![Figure 4: Close-up Photo of the Hard Panel Turbine Control Station for SRP AFGS Unit 2](image)

**Building the Physical Hard Panel**

**Design**

One design consideration was the voltage of the system. The equipment at the plant uses high voltage but 24 volt devices were determined to be satisfactory for the simulator. Also, a single power supply was determined to be sufficient. Another design consideration was the physical construction of the panel. The equipment was mounted on the front face of steel case. The front face is hinged, while the case is bolted to the table. Electrical wires, power supply, and other electrical devices are placed within the case. When fully assembled there are two wires exiting the case: one 120 Volt AC cable for power and one Ethernet cable to send signals to and received signals from the simulation.
Procurement

In order to match the existing turbine switches (Stop Valve Bypass, Governor, and Load Limiter) as closely as possible, the serial numbers and model numbers of the existing switches were obtained from the unit. The original equipment manufacturer confirmed that these switches were still manufactured and the lead time for completing the order was six months.

The lead time for the other equipment on the panel was less than a week. This equipment, including push buttons, lamps, analog numeric displays, and digital numeric displays, was readily available from a number of suppliers. The one exception was the analog numeric displays for the turbine acceleration and control valve position, shown at the right. These analog displays were not available from manufacturers, though used equipment was available on e-Bay. For the analog numeric displays digital numeric displays were used. The fully assembled hard panel is shown below.

![Hardware Emulation of the Hard Panel Turbine Control Station](image)

Hardware to/from Software connections

The switches and lights are connected to 24 Volt DC digital input and output modules. The numeric value displays are connected to a 4-20 ma analog output module. An Ethernet communications module is used to exchange I/O data with the simulation software, and a single power supply is used. Each piece of hardware is modular and fits together on a standard rail inside the case.

Timing considerations

When rolling up the turbine from turning gear speed to 3600 rpm, the operator makes very small adjustments with the stop valve bypass switch. A small touch of the switch to the left or right is all that is required to keep the turbine accelerating at the required rate or to hold the turbine at the required speed. The duration of these operator actions is much less than the 0.25 second time-step of the
process model. To capture the very quick physical actions of the operator, a separate calculation loop with a 0.05 second time-step was used.

**Experienced operator feedback**

Testing of the simulator by an experienced operator revealed one surprise: the new load limit switch felt exactly like the existing stop valve bypass switch on the unit, which has a noticeable click when the switch is moved to the point where the slow lower and slow raise speed signals are triggered. This click was not present with the stop valve bypass switch procured for the simulator. Inspection of the vendor documents confirmed that it was possible to re-configure the switches. The new load limit switch, which was intended to be used as a 3 position switch, was re-configured as a 5 position switch. And, the new stop valve bypass switch, which was intended to be used as a 5 position switch, was re-configured as a 3 position switch. After swapping the switches the simulator was ready for installation at the plant. The figure below shows the installed simulator:
**Training Results**

Feedback from the trainees has been positive. Trainees are able to practice start-ups and shutdowns using the simulator. Trainees and experienced operators report that the feeling of the operating the switches on the simulator is very similar to that of the real unit.

![Figure 8: Training Exercises with the SRP AFGS Simulator](image)

**Acknowledgements**

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**References**