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Case Study: A hardware-in-the-loop simulator for a pumped storage hydroelectric station

This work was performed for First Hydro Company, part of a joint venture between International Power plc and Mitsui & Co Ltd.

The Problem

First Hydro Company owns and operates the Dinorwig hydroelectric station, situated in North West Wales. The station has six 300MW rated pump/turbines and is one of the world's largest pumped-hydro schemes. Revenue is generated by pumping water from a lower to an upper lake at night, using cheap base-load electricity, and then releasing the water to generate electricity at times of peak demand when the wholesale price is high. In addition to this 'peak-lopping' mode they can rapidly supply power to the national grid to meet "TV pickups". These are large domestic demand surges created by the concerted activity of the TV watching public at the end of popular programmes and live events. The station also uses its fast-response capability to provide automatic regulation of the grid frequency. How well the station performs in this function depends critically on the electronic governors which modulate the water flow to the turbines. Dinorwig has been in operation since 1982 and it is periodically necessary to upgrade the governor hardware and software. The problem is how to minimise the time for which a pump/turbine is out of operation while this is done and yet ensure that the new hardware and software are fully ready to take over the plant control function.

The Solution

The solution is to first commission the new governor on a real-time computer model of the plant – this is known as a 'hardware-in-the-loop' simulation because the real governor hardware is used to close the feedback loop. Any software bugs or hardware faults in the new governor can be found before it is attached to the real plant – and this can be done while the old governor is still operational! So this approach both saves time and decreases the risk associated with the commissioning process.

GWEFR adopted a model-based design procedure combined with a rigorous software engineering methodology for software validation and verification and project documentation. Dynamic models of the hydraulics, pump/turbines, motor/generators, guide vanes, governors and other components of the plant were developed in Simulink®. The logical sequences for changing operational mode (e.g. transferring the plant from 'Shutdown' to 'Generate' mode) were represented as state machines embedded within the Simulink model. The model response was verified by comparison with measured plant data provided by First Hydro engineers. The simulation was then implemented in real-time on a dSpace® prototyping system with a specially designed electronic interface to the governor PLC hardware. As well as succeeding in its primary objective, the simulator provides improved understanding of the plant characteristics and may in future provide the basis of an Operator training facility.

GWEFR is an engineering consultancy which specialises in mathematical modelling of dynamic systems, computer simulation (including real-time and hardware-in-the-loop), feedback control, instrumentation and servomechanisms.

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