Evaluating Hydraulic Transient Analysis Techniques in Pumped-Storage Hydropower Systems

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**Declaration**

This dissertation contains no material which has been accepted for the award of any other degree or diploma in any tertiary institution, and to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference is made in the text of the dissertation.

Signed

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May 20\textsuperscript{th}, 2011
Abstract

Hydropower is the most widely adopted form of renewable energy in the world today, accounting for approximately 16% of global energy production [1]. With increasing demand for electricity, and concern about reducing fossil fuel consumption, hydropower is likely to continue to play a key role in global energy production. The interest in pumped-storage systems is increasing, due to their ability to regulate power grids, increase the efficiency of thermal power (coal and nuclear), and maximise the penetration of renewable energy such as wind and solar. Since pumped-storage systems must respond quickly to load variations, transient flow phenomena are frequent.

In the design of hydropower systems, transient effects are an important consideration, as rapid flow variations can lead to potentially catastrophic increases in pressure (water-hammer). Numerical techniques for hydraulic transient analysis appear to be well understood, but the hydraulic characteristics of reversible pump-turbines can create difficulties depending on the software used for the analysis. The “S” shape of the machine characteristic in the turbine runaway region is a cause of instability in real machines and a potential cause of numerical instability in incorrectly designed or unsuitable software packages.

The commercial hydraulic analysis software package SIMSEN-Hydro was used to evaluate hydraulic transients in two systems. Project A is a 25.5 MW run of river system utilising three Francis turbines. Hydraulic transients in the system were successfully modelled, and the results showed good agreement with load rejection data measured on site during commissioning of the project.

Project B is a 1333 MW pumped-storage system utilising four reversible Francis pump-turbines. The machine curves include the characteristic “S” shape in the runaway region of the turbine zone. Using SIMSEN-Hydro, the transients in the system were modelled, utilising the machine characteristics. Results were similar to those obtained during preliminary design of the system.

By undertaking a sensitivity analysis for Project B, the effect of modifying input parameters on the simulation results was highlighted. The choice of pipe friction factor, surge tank throttling coefficient and generator inertia all had a notable effect on the results of the analysis. While the range of pressure wave-speeds that were examined did not have a significant effect on the results, this may differ for other systems. Based on these results, it seems important that sensitivity analysis be included on all transient analysis projects, unless the modelling inputs are all known with a reasonable level of accuracy.
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