EFFICIENCY MEASUREMENT WITH UNCERTAINTY ESTIMATES FOR A PELTON TURBINE GENERATING UNIT

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Abstract— **The estimation of efficiency for a hydraulic electricity generating plant requires the measuring of the inlet water flow. This measurement is rarely available in most small and medium-sized hydraulic power plants, and was not available at the plant investigated. This paper discusses the solution developed to measure the inlet flow and therefore the efficiency of the generating unit. Confidence bands were estimated for the measurand (efficiency) based on Monte-Carlo simulations. The tuned algorithm has been tested using independent data collected at the hydroelectric power plant and agrees quite well with a validation set of measurements.**

Keywords— **Efficiency, turbine-generators, power plants instrumentation, power plant monitoring.**

I. INTRODUCTION

The efficiency of hydraulic turbine-generators is of great practical importance. For instance, if a certain turbine-generator is known to have a low efficiency at certain load levels, operating at such points should be avoided in order to optimize water consumption, which is a growing concern nowadays. For instance, "for a small (i.e., 15 MW low-head unit, a 1% error in the definition of the best gate can result in a loss of tens of thousands of dollars in generation revenues per year for each unit" (Doering and Gawne, 1998). In recent works, turbine-generator efficiency has been used in defining a methodology for the optimal dispatch of generating units in a large hydroelectric plant (Arce *et al.*, 2002) and in specifying a way of assessing economic performance and maintenance of hydraulic generating units (Liu *et al.*, 2003). Important though as it is, very often electricity producing companies only have a rough estimate of the efficiency at nominal load.

In some cases, manufacturers provide a curve that shows how efficiency varies with the operating point (load). However, more often than not, such a curve is estimated based on reduced-scale models (in labs) or simply mathematically (Arce *et al.*, 2002). For such reasons it is of practical interest to have a more realistic estimate of the efficiency of turbine-generators units in working conditions at power stations. Moreover, if such an estimate is available online, such information could be used in monitoring and fault detection schemes (Liu *et al.*, 2003). It is believed that the last statement will be especially true if besides an estimate of efficiency an estimate of the its uncertainty is also available.

The practical estimation of efficiency in hydraulic turbine-generators is a task far from trivial. The main reason for this is that such an estimate strongly depends on plant variables, some of which are difficult to measure— such as the inlet water flow, or discharge (Doering and Gawne, 1998)— and some of which are obtained by data-fitted models— such as the pressure loss along the piping. This means that the estimated efficiency is uncertain. But how uncertain? This paper will describe the procedure followed to answer the above question in the context of a specific case study at a power station to be described briefly in section II. A key point in the procedure is the measurement of the inlet water flow, that will be described in section III. The procedure for calculating the efficiency is described in section IVand the Monte Carlo approach used to determine the uncertainty associated to the estimated efficiency is described briefly in section V.. Finally, the main conclusions are given in section VI.

II. THE POWER STATION

The power station under consideration consists of a rather small natural water reservoir located over 360 m above the turbine-generator unit. The water flows from the reservoir to the turbine-generator through a long pipe with diameter equal to 1 m. The water volumetric flow is measured by means of a Cole (1935) type Pitot tube (more on this later) installed close to the reservoir— this results in relatively low absolute pressures— and far from any corners— this reduces