Electrical Power and Energy Systems 58 (2014) 226–241

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Agile numerical modelling of real electric power plants

Vassilios A. Tsachouridis *

School of Engineering and Mathematical Sciences, City University, Northampton Square, London EC1V 0HB, UK

ARTICLE INFO

Article history:
Received 17 April 2013
Received in revised form 17 January 2014
Accepted 19 January 2014

Keywords:
Electric power plants
Numerical modelling
Filter algorithms

ABSTRACT

Novel research results subject to the generation of agile numerical models for a real electric power plant are presented in this paper. Using only instrument measurements of various variables located in different parts of the power station, filtering algorithms are programmed for the computation of numerical models that describe system operation and are agile to adapt between different operational regimes. The contents of the paper constitute original industrial research conducted to a real electric power generation facility. The presented results were validated on site by the power plant's chief engineers.

1. Introduction

Electric power plants are by structure complex multivariable systems for which the construction of analytic formulae-based mathematical models derived from engineering principles is an extremely laborious task. Considering different system operational points relevant analytic formulae exist for a variety of subsystems and components, but summing up all these equations result in complicated theoretical system models of large dimensions. Moreover, the modelling difficulty above is amplified to a certain degree by the unavailability of several model parameter data of subsystems/components due to contractual constraints imposed by the subsystem/component suppliers in disclosing this kind of data. From the system's theory viewpoint, the problem described so far can be identified as incomplete system's parameter space information. For that reason it is apparent that any attempt to build formulae-based analytic models, covering the entire envelope of operation, becomes a futile task for many real-life practical situations in electric power industry. This is more evident when considering aged electric power plants that have been built several years ago, for which parameter information of old and perhaps obsolete machinery is absent.

The need of accurate models is even more crucial today where the posed limits in electrical energy generation in combination with society's increased demand on electrical power, require better understanding of system behaviour through individual power plant simulations to ensure proper policy for continuous operation at maximum capacity. Each power plant system could affect the security of a large power network. Obviously, this has a huge impact on the economy and quality of life. In addition, the availability of single unified models describing the entire system operation is essential for ad hoc optimization designs as well. The later designs are vital for adapting the electric power plant operation accordingly to policy regulations posed by government bodies and industrial standards. For example financial penalties could be posed by the regulator/government on individual power plants when they do not satisfy grid requested power demands in specified time intervals. Furthermore, optimal retuning of control systems in order to adapt to new power plant operation regimes requires accurate models. In this respect the approximate formulae-based models of subsystems and components are problematic since many of their parameters are at best known for specific operational points but not necessarily known for other new operational scenarios.

In order to overcome the problem of constructing detailed formulae-based mathematical models, accurate numerical models can be effectively formed from available measurement data in electric power plants, and this is the major contribution of the present paper. It will be shown that it is possible to build discrete time agile models which describe accurately the whole envelope of system operation, and are capable to simulate/forecast future system events. More specifically, it will be illustrated how filtering algorithms could be adapted for the state space system parameter estimation and modelling of a real power facility, namely: the 330 MW steam electric power plant of Meliti, located at northwest Greece in the municipality of Florina. The algorithms under consideration in this paper are the Kalman Filter [4] and the H_∞ Optimal Filter [5]. These algorithms are mostly used in system state identification problems for reconstructing missing measurement

* Present address: University of Western Macedonia, Department of Informatics & Telecommunications Engineering, Karamanli and Lygeris, Kozani 50100, Greece. Tel.: +30 6946027919.

E-mail address: vassilios.tsachouridis@ieee.org

http://dx.doi.org/10.1016/j.ijepes.2014.01.037
0142-0615/

information of a system as well as in control system design [14,8]. However their use as numerical system model generators in industry is sporadic to the author's knowledge. Particularly real case studies, subject to the generation of unified numerical models for real electric power plants, are limited if not absent from the literature. It should be noted at this point that the algorithms of this research have been tested and validated on cite by chief engineers of the power facility at Meliti. To that respect, the material presented herein is novel and constitutes original research towards the application of systems theory methods into real-life problems in electrical power industry.

The structure of this paper is presented as follows. Section 2 presents briefly the electric power plant under study and the considered variables for modelling. In Section 3 the structure of the agile numerical models are reported along with the proposed filtering methods for their evaluation. The respective model computations are given in Section 4 together with the respective analysis of results, including comparisons between model simulations and real measurements. Finally, overall commends are stated in Section 5.

2. System under study

The steam electric power plant of Meliti, shown in Fig. 1, is the latest investment of its kind by the Greek public company of electricity. It produces electricity by exploiting domestic lignite (xylite with average calorific value 1900 kcal/kg) and antifouling technology. It is located between the villages and hills of Meliti at Municipality of Florina prefecture in western Macedonia and it is located 18 km east of Florina and 75 km north of Kozani. The station currently has one unit of 330 MW total capacity. The total efficiency of the plant is 35.6%, and therefore the unit produces less CO_2 emissions per KW h from other lignite power plants in Greece. The station helping to meet the electricity needs of the country at a rate of 3.2%, showing in some periods an average availability equal to 84.32%.

Four important systems of this power plant are briefed next.

(a) *Boiler*. BENSON penstocks type of tangential combustion of pulverized xylite with the combustion chamber operating in a vacuum (sub-pressure). The maximum continuous steam supply is 1016.6 t/h and the steam supply on 330 MW is 967.9 t/h. Steam pressure, temperature figures are as follows: superheated steam 235.4 bar, 543 °C, cold reignited steam 42.4 bar, 298 °C, hot reignited steam 38.2 bar, 542 °C.

(b) *Turbine*. Russian made by LENINGRAD METAL WORKS (LMZ) (see Figs. 2 and 3). It is a three unit turbine system high, intermediate, low pressure (HP, IP, LP) with double shell on the HP and IP units. The operational values are is 330 MW electrical or 317.9 MW electrical plus 70 MW heat power. Rotation speed is 3000 rpm and low pressure output is 56 mbar.

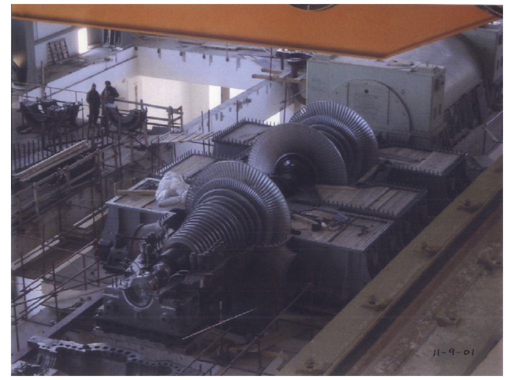

Fig. 2. Turbine.

Fig. 3. Turbine and electric generator.

(c) *Electric generator*. Russian made LENINGRAD METAL WORKS (LMZ) (see Figs. 4 and 3) with rated values of apparent power 330 MW, power factor 0.9, current 10,081 A, voltage 21 kV ± 5% and rotation speed 3000 rpm.

(d) *Control room computer system*. For supervision, measurement, recording and control made by ABB (see Fig. 5).

In order to build a model for a predetermined set of variables, respective measurement data have been gathered digitally from the computer system in the station's control room shown in

Fig. 1. Electric power plant of Meliti.

Fig. 4. Electric generator.