Available online at www.sciencedirect.com

SCIENCE DIRECT®

Computers and Electrical Engineering 31 (2005) 56–68

Computers and Electrical Engineering

www.elsevier.com/locate/compeleceng

# A tool for extracting synchronous machines parameters from the dc flux decay test

F.S. Sellschopp, M.A. Arjona L. *

*Departamento de Ingeniería Eléctrica, Instituto Tecnológico de la Laguna, Carrara 371, Col. Torreón Residencial, 27250 Torreón, Coah., Mexico*

Received 5 September 2003; received in revised form 5 July 2004; accepted 28 October 2004

**Abstract**

A novel computer system tool for the parameter estimation of mathematical synchronous-machine models is presented. It uses state-of-the-art information technology software. The tool allows the electrical power engineers to obtain the electrical parameters of a synchronous machine model. The practical usefulness of the developed system is demonstrated by obtaining the parameter set for conventional and high order *d* and *q* axis models from the dc flux decay test. The two-axis model parameters are estimated with the well-known maximum likelihood algorithm. The user can also validate its set of estimated parameters against experimental data. Consequently, a better behavior prediction of synchronous generators within a power system can be achieved. The tool was developed using LabVIEW as a software environment and a low cost data acquisition card, which has a user friendly interface. A solid salient-pole synchronous generator of 7 kVA was used to illustrate its practical impact of the proposed system, where acceptable accuracy in the set of estimated parameters was achieved.


*Keywords:* Synchronous machines; Parameter estimation; Flux decay test; Computer; Data acquisition; User interface

* Corresponding author. Tel.: +52 871 7051331x115; fax: +52 871 7051326.
*E-mail addresses:* sellschopp@hotmail.com (F.S. Sellschopp), marjona@ieee.org (M.A. Arjona L.).

0045-7906/$ - see front matter 
doi:10.1016/j.compeleceng.2004.10.001

## 1. Introduction

Synchronous generators are the main devices in the production of electric energy all over the world, and they are operated in parallel, interconnected by transmission lines to supply electric energy to industrial and domestic loads. As a consequence, an understanding of their electromechanical behavior is usually required by electric utilities and manufacturers. A practical and economical way to gain the understanding of the synchronous machine behavior is usually carried out throughout digital simulations of mathematical models. Engineers concerned with the planning of power systems also require machine models, but their requirements differ from those of designers. Power system engineers are usually concerned with the behavior of the system as a whole, and not just with the performance of a single generator. For these reasons, power system analysts have preferred lumped-parameter equivalent circuit models, based on the two-axis theory [1]. There are well-established model structures that are recommended in the literature, however, a power analyst also requires a set of electrical parameters of the synchronous machine to be able to predict its behavior under normal or abnormal conditions. Many research centers have invested a lot of effort in developing test procedures that can lead to a reliable set of machine parameters, some of the research results are found in standards [2,3]. Synchronous machine manufacturers normally provide a set of electrical parameters to their customers, such parameters are usually derived from standard electric tests i.e. sudden short-circuit at low terminal voltage and frequency response tests [3]. Traditionally, the parameters are derived for a model with one damper winding along each axis because most commercial power system simulators use this model order. Nowadays, economic issues have led the electric utilities to drive its generators close to their operating limits. Hence, more accurate mathematical models of generators must be used; when a higher order model, i.e. multiple damper windings, is needed, a different set of parameters are required. The electric utility can buy the new parameters from the machine manufacturer, but this is usually prohibitive because of their high cost. Alternatively, the parameters can be obtained with simple experiments, which can be carried out by the utility engineers. There are several procedures to determine machine quantities; they range from standardized to non-confirmed test methods [2,3]. The tests can be classified as those carried out when the machine is at standstill, i.e. step voltage, frequency response and direct current (dc) flux decay, and when the machine is running at its rated speed, i.e. sudden short-circuit, load rejections, etc. Obviously, the standstill-based tests are easier to carry out, and they provide information for the $d$ and $q$-axis machine models. However, the standstill tests have been criticized because: (a) they do not take into account the rotational effects, i.e. variation of contact resistance from standstill to full speed, and (b) the machine does not represent its rated saturation conditions [4]. The machine parameters can also be derived from finite element calculations of the electromagnetic machine model, but this approach is more difficult because machine design characteristics are required [5,6].

The dc decay test has the advantage that it can be done with the machine stationary, and only requires a dc supply that can be passed through one or two phases of the stator [7]. While the standstill frequency test requires expensive power signal generator equipment, and it is a time consuming at low frequencies. In addition, higher excitation currents can be applied to the machine in the dc decay test when compared with the standstill frequency response method. Although the procedure is considered an unconfirmed test by [2], there has been some research interest in the analysis and $d$–$q$ axis parameter extraction from the dc flux decay test [7–11]. However, the main