# A MEASUREMENT-BASED PROCEDURE FOR DYNAMIC DATA IDENTIFICATION OF SYNCHRONOUS GENERATORS

K. W. K Priyadarshana

168528U

Degree of Master of Science

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

February 2022

# A MEASUREMENT-BASED PROCEDURE FOR DYNAMIC DATA IDENTIFICATION OF SYNCHRONOUS GENERATORS

K. W. K Priyadarshana

168528U

Degree of Master of Science

Thesis/Dissertation submitted in partial fulfillment of the requirements for the degree Master of Science in Electrical Engineering

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

February 2022

# DECLARATION

I declare that this is my own work and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis/dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

2022/02/12

Signature of the Author: Date:

K.W.K Priyadarshana

The above candidate has carried out research for the Masters Dissertation under my supervision.

Signature of the supervisor: Date: 13 - 02 - 2022

Dr. W.D. Prasad

Senior Lecturer Gr I,

Department of Electrical Engineering,

University of Moratuwa,

Signature of the supervisor: Date: 13-02-2022

Prof. W.D.A.S. Wijayapala

Professor,

Department of Electrical Engineering,

University of Moratuwa,

# ACKNOWLEDGMENT

I owe my sincere gratitude to my supervisors, Dr. W.D. Prasad (Department of Electrical Engineering, University of Moratuwa) and Prof. W.D.A.S. Wijayapala (Department of Electrical Engineering, University of Moratuwa) for their encouragement, support, and expert advice to make this research thesis a success.

I would also like to thank all review panel staff of Department of the Electrical Engineering, University of Moratuwa for their guidance and knowledge gave to make this study a success and for the time they have invested in from their busy schedules to evaluate my research work.

This research would not be possible if the guidance and knowledge rendered by Eng. A.I Madawala, Chief Engineer, CEB for this research work. This research would not be completed if the information and test data obtained from the Staff of Kelanitissa Combined Cycle Power Plant (KCCP). Hence, I thank to Eng Janidu Hemachanra for providing me the all requested data for testing conducted at KCCP.

The valuable support given by the superiors and the subordinates at my workplace, Asset Management branch – Generation division of Ceylon Electricity Board is highly appreciated.

I am grateful to my wife and two children for all the sacrifices they have made along the way and also, I would like to thank my parents for all the support given to me during various endeavors in my life.

K.W.K Priyadarshana

February 2022

# ABSTRACT

Identification of synchronous generator parameters is a vast area in research topics. In order to model an existing power system network, these parameters are very crucial in identifying the behavior of the system during steady state or dynamic state conditions. When considering the Sri Lankan grid network there exists number of power plant which does not have some design parameters of the synchronous generators and for the older machines the existing value of the parameters might be differ from the design value due to several reasons.

This thesis report is based on the identification of synchronous generator parameters using on line measurement data while giving small step response of around 2%-5% to AVR voltage reference set point. The proposed testing procedure does not create any stress to the machine and can be conducted several times without any special preparation or machine outage.

The proposed methodology to identify the synchronous generator dynamic parameters is developed using the 3rd order SG model defined in the IEEE Standards. Two new system functions have derived to estimate the generator parameter which shows the relationship between the steady state and dynamic state parameters in d-q-0 domain and time domain. The Levenberg Marquart method is used as the Nonlinear least square algorithm to extract the parameters from the measured data. Proposed methodology has applied in MATLAB SIMULINK Simulation environment and in the real environment which test conducted at Kelanitissa Combined Cycle Power Plant, Sri Lanka. The Proposed method results have validated over the results with conventional test results conducted based IEEE Standards on two power plants in Sri Lanka and from the literature of similar tests.

The results of the proposed method have showed good accuracy over the design values and the standard method results. It has showed that the output of the synchronous generator, using the estimated parameters is having a very closer behavior to same with the actual generator parameters. Therefore, this method can use to estimate synchronous generator parameters where the parameters are completely unknown or the machine is too old which may need to identify the existing parameter values.

This study further discusses the reasons for any difference between the design parameter value and the estimated parameter value comparing with the standard IEEE based test results.

This research concludes that the results of the estimated dynamic parameters obtained by the proposed method can be recommended in applying for modelling of the synchronous generators and power systems networks which will give a very close response to the actual response.


Keyword: Parameter estimation, synchronous generators, Levenberg Marquart Method, Online Measurements, Small Disturbance.

# Table of Content

## List of Figures

## List of Tables

## List of Abbreviation

| | |
|---|---|
| $\delta$ | Angle of rotor with respect to terminal voltage /load angle |
| $T_m$ | Mechanical input torque |
| $T_e$ | Electrical torque |
| $K_D$ | Damping factor |
| $\omega$, $\omega_0$ | Rotor speed and nominal speed |
| $e'_q$ | Internal of stator at transient |
| $E_{FD}$ | Internal voltage of stator |
| $X_{d\,,}X_q$ | d and q axis reactance |
| $L_{d\,,}L_q$ | d and q axis inductances |
| $L'_d$, $L'_q$ | d and q axis transient inductances |
| $L_{ad\,,}L_{aq}$ | Mutual inductance in d and q axis windings |
| $L_l$ | Leakage inductance |
| $X_{ad\,,}$ | Mutual reactance between the d-axis windings |
| $X'_d$, $X'_q$ | d and q axis transient reactance |
| $X''_d$, $X''_q$ | d and q axis sub transient reactance |
| $i_d$, $i_q$ | d and q axis currents |
| $i_{fd}$ | Field Current |
| $T'_{d0}, T''_{d0}$ | Direct-axis transient and sub open-circuit time constant at transient |
| $\emptyset_f$ | Field flux linkage |
| $R_f$ | Field Resistance |
| $L_{ffd}$ | Self-inductance of field winding |
| $L_{fd}$ | Field wingding inductance |
| $L_{afd}$ | Mutual inductance between stator and rotor windings |
| $L_{f1d}$ | Mutual inductance between field winding and 1st damper winding |
| $R_f$ | Field Reactance |
| $X_e$, $R_E$ | Line reactance and resistance |
| $v_d, v_q$ | d and q axis generator terminal voltage |
| $v_{bd}, v_{bq}$ | d and q axis bus voltage |
| P | Active power |
| Q | Reactive Power |
| I | Generator Current |
| J | Jacobian matrix |
| $\Theta_k$ | Set of updated parameters at kth iteration |
| $\eta$ | Step size |
| $H_{k-1}^{-1}$ | Inverse of the Hessian matrix. |
| n | Number of iterations |
| e | Error vector |
| N | Number of data points |
| I | Cost function in NLS algorithm |
| SG | Synchronous Generator |
| KCCP | Kelanitissa Combined Cycle Power Plant |
| AVR | Automatic Voltage Regulator |