CIGRÉ Regional South-East European Conference
October 10th - 12th 2012
Hotel Hilton, Sibiu, Romania
(RSEEC 2012)

Proceedings of

RSEEC 2012

Innovation for future!

Sections A, B, C, D

Organized by:

Romanian National Committee "CIGRÉ"
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Descrierea CIP a Bibliotecii Naţionale a României

ISBN 978-606-8371-73-3

Published by: The Academy of Romanian Scientists Publishing House
54 Splaiul Independentei, District 5th, code 050094, Bucharest, Romania

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FOREWORD

On behalf of the Romanian National Committee of CIGRÉ, it is our great pleasure to welcome our distinguished guests of the first CIGRÉ Regional South-East European Conference (RSEEC 2012), taking place in Sibiu, Romania, on October 10th - 12th 2012.

RSEEC 2012 is organized by the CIGRÉ's Romanian National Committee, as organizer, CNTEE Transelectrica S.A. and ALSTR, as co-organizers.

It is a major event in power systems which will provide an exceptional venue to CIGRÉ members and interested parties for presenting: ***Innovation for efficiency and effective management, solutions for power systems of the future!***

The conference will bring together power systems engineers, decision makers, academics and others with interest in the domain. The conference also promotes CIGRÉ as a strong technical organization, capable of contributing to the technical expertise and know-how database, through its study committees, conference proceedings and technical documents.

Main Topics include: 1) Electrical networks of the future; 2) State of the Technology and Future Trends; 3) Power system solutions for renewable sources (RES); 4. Challenges in education of power system workforce; 5. Live working ("Live Working" section is organized by ALSTR - Live Working Association, Romania).

We would like to extend our warm welcome to all the participants at RSEEC 2012 conference and to wish a successful and enjoyable meeting. We hope that everyone will find the RSEEC 2012, both technically interesting and with stimulating subjects and that your journey in Sibiu - Romania will be an unforgettable and pleasant time.

The Romanian National Committee of CIGRÉ,

Dr. Ciprian Diaconu	Dr. Constantin Moldoveanu	Dr. Dorin Ioan Hategan
Chairman	Vice-Chairman	Secretary

ISBN 978-606-8371-73-3

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SECTION A

Electrical Networks of the Future

ISBN 978-606-8371-73-3

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A 102

Enhanced Power System State Estimation with Synchronized Measurements and Pseudo-Measurements

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SUMMARY

State estimation provides the platform for advanced security monitoring applications in control centers. It determines a best estimate of the current actual power system based on available SCADA measurements and power system model data. Traditional power system state estimation has been undergoing an essential change because of the extensive application of Phasor Measurement Unit (PMU). PMU data provides the direct measurement of state which can significantly simplify the traditional state estimator and does not require any major changes of the existing state estimator.

It is anticipated a gradual migration towards full PMU implementation for utility power systems. The logical direction is towards full observability with PMUs. Due to cost considerations, it is expected that utilities will execute a phased installation of PMUs, that is, batches of PMUs being installed through time. An algorithm of including pseudo-measurements along with traditional measurements and PMU measurements was developed and implemented in MATLAB. Tests and simulations were done on NORDIC 32 bus system. It has been shown that when synchronized phasor measurements are added to the other SCADA measurements in sufficient numbers, the efficiency/precision of the state estimate is improved.

The enhanced state estimator is formulated in such a way that it can be easily modified in case of changes in the measurement configuration.

It should be highlighted that this paper handles only one specific aspect of PMU applications in state estimation, the inclusion of synchronized phasor measurements data in the state estimation process. The traditional state estimator is considered to be functioning normally in the absence of PMU data, it is considered that the existing SCADA system provides measurements in sufficient numbers with proper placement so that the state estimator is able to handle bad data and provide complete observability based on those measurements.

KEYWORDS

Power systems, State estimation, Phasor measurement unit, PMU,

INTRODUCTION

Static or steady state operation of a power system can be fully determined with a minimal set of physical values called state variables which are the components of the state vector *X*. For a *n* bus power system the state vector is defined as a *2n-1* dimension real vector. Its component consists of voltage magnitudes from all buses and voltage phase angles from *n-1* buses. Assuming that bus *n* is the reference bus then $\theta_n=0$, and $X=[U_1;U_2;\ldots U_n;\theta_1;\theta_2;\ldots\theta_{n-1}]^T$. The problem of determining the power system steady state from measurements affected by noise errors is known as static state estimation.

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State estimation in power system is used to build realistic and reliable real-time model of the power network. It is the backbone of online security analysis in energy control centers. It acts like a filter between the raw information received from the system and all application functions that need the reliable data of the current state of the system.

In power systems, the measurements are collected using Supervisory Control and Data Acquisition (SCADA) system. These measurements are not always complete and accurate. Sometimes, there is also a possibility of bad measurement and hence the real-time AC power flow cannot be extracted from these measurements. The state estimation uses the available measurements from SCADA as well as the circuit breaker status, tap positions of transformers, parameters of transmission lines, transformers, shunt reactors and capacitors to estimate the best state of the system. The state variables in this process are the voltage magnitudes and relative phase angles at each bus of the power system. The commonly SCADA used measurements for state estimation is as follows [1]:

1. Power flows: real and reactive power flow through the transmission line;
2. Power injections: real and reactive power injected at the buses;
3. Voltage magnitude: voltage magnitude measurements at the buses;
4. Current magnitude: current magnitude flowing through the transmission lines.

State estimator is the algorithm that based on available SCADA measurements, network model and other data (pseudo-measurements) leads to a maximum reliable power system steady state - voltages, angles, active and reactive power flows, circuit breakers status, transformers taps, etc. These results are the basis for further studies such as contingency analysis, security enhancement, dynamic security analysis and other applications.

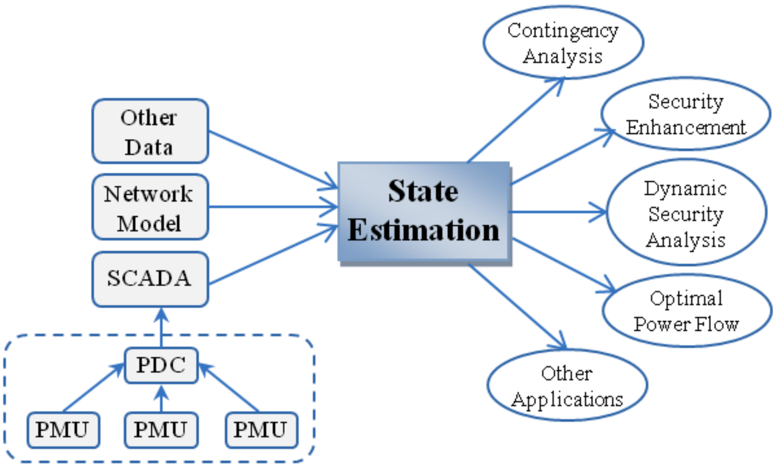

Figure 1. The role of state estimation in power system operations.

The development of electricity markets and the greater emphasis on improved grid safety and security power system state estimation has become a critical, must-run successfully' management and control center function. Figure 1 describes the role of state estimation in power system operation.

However, before the real-time phase measurement unit (PMU) based on GPS was introduced; power system state estimation had been only relying on the measurements provided from SCADA system. Due to the introduction of the PMU, the power system state, which means the voltage magnitude and angle value, can be measured directly, and has high precision and short measurement periodic time. These advantages which affect and contribute on the traditional methods of power system state estimation are the research focus in the power system state estimation field. Synchronized Phasor Measurements can be in form of voltage phasors and current phasors [1].

Each measurement from a PMU contains a GPS-synchronized time-stamp. The conventional measurements used by the SCADA system carry the local time-stamps. Using the two time-stamps, the synchronous PMU measurements can be combined with the asynchronous conventional measurements.

For the power system state estimation, time-synchronized phasor measurements from PMU may be included by a slightly different formulation of the traditional non-linear weighted least squares or they may be taken into consideration after a preliminary system state has already been determined. Even a small number of these precise measurements can weigh heavily on the accuracy of the overall state of the system.