



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

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TABLE OF CONTENTS

FOREWORD		7
SECTION A.	Electrical Networks of the Future	
A 102	Enhanced Power System State Estimation with Synchronized Measurements and Pseudo-Measurements V.I. PRESADA, M. EREMIA, L. TOMA	9
A 103	Power Flow Control Using Phase Shifting Transformer or Thyristor Controlled Series Capacitor C. CONSTANTIN, I. CONSTANTIN, M. EREMIA	17
A 104	High Voltage Direct Current, Solution for Power Systems Interconnection E. DRAGAN, G.N.GHEORGHITA	25
A 105	Measurement of OHL Electrical Parameters - Powerful Tool in Protection Settings Gh. MORARU, F. BALASIU	31
A 106	Phase Shifting Transformers Guidance for Planning and Operation H. SCHINNERL	38
A 107	Efficient Operation of the Hydropower Cascade under Active Networks E.D. COMANESCU, Gh. GRIGORAS, R. DUMITRESCU, F. SCARLATAACHE	47
A 108	Use of Real-Time Thermal Ratings to Increase Network Reliability under Faulted Conditions S. BLAKE, P. DAVISON, P:C. TAYLOR, D.C. MILLER, A. WEBSTER	55
A 109	Metering Interoperability for Energy Market Smart Metering Architecture D. APETREI, I. SILVAS, D. FEDERENCIUC	64
A 110	How to Measure the Energy when Voltage and Current Are No Longer Analogue Values? J. WIDMER	70
A 111	The Romanian TSO's Power Quality Monitoring System C. STANESCU, G. MURESAN, P. POSTOLACHE, C. LISMAN., M. SARB	74
A 112	Transelectrica's Experience with a Tool for On-Line Stability Assessment of Electric Power Systems U. KERIN, R. KREBS, F. BALASIU, R. BALAURESCU	82

A 113	Living Master Plans and Smart Engineering Solutions S. GUNALTAY, N.J. BACALAO, B. AKDUMAN, I. SAHIN, B. KARAERIK	89
A 114	Energy Efficiency and Sustainability in the Water Sector A. SPAHIU, P. MARANGO, O. ZAVALANI, L. DHAMO	97
A 115	Power System Oscillation Detection and Mitigation: Are Synchrophasors the Answer ? D.G. DUMITRASCU, C. HOSU, I.V. BARBURAS, T. PETROVAN, H.C. BALAN	105
A 118	Determination of Soil Thermal Properties in the Design and Laying of Underground High Voltage Cables I. BUSER	113
A 119	Cost Benefit Analyses for Smart Grid Projects Gh. INDRE, S.L. SOARE, E.F. TURCAN, N. PANTAZI	119
A 120	After Laying Test and Diagnostic of HV Cable Lines by Using DAC Technique R. EGYED	125
A 121	Solution for impact reduction over safe operation of PS by the integration of a large volume of wind power plants M. UNGUREANU, F. MIHAILESCU, M. SANDULEAC	132
A 122	Standardization Status for Measures in Critical Situations in a Smart Grid I. HAUER, S.A. STYCZYNSKI	139
A 123	SCADA / EMS with Dynamic Stability Assessment for Online Usage C.O. HEYDE, R. KREBS	147
A 124	Real Time Monitoring System Portile de Fier – Anina 400 kV OHTL & Resita – Pancevo 400 kV OHTL P. FILIPESCU, B. CIURUMELEA, V. POPESCU, L. IACOBICI, C. MATEA, L. NICULAE	153
A 125	Evolutions and Developments of the Smart Grid Concept at a National and European Level A. POPESCU, M. COTEANU, A. POANTA	163
A 126	Improving Crisis Management in the Aftermath Situation – Transelectrica’s contributions in CRISYS FP7 European Project S. VORONCA	169
A 127	Design and Implementation SCADA Platform Dedicated for Transelectrica’s Telecontrol Centers S. NICULESCU, I. MERFU	179
A 128	European Grid Code - technical requirements for units grid connection F. BALASIU, D. ILISIU	186

SECTION B. State of the Technology and Future Trends

B 101	Equipment’s life time management based on linear regression“ V. ZAHARESCU, C. PANOIU, L. MIRON, A. ROMANESCU, A. BUCUR	195
B 102	Unconventional Transformers Used in Romanian Power Grid A.C. RUSU, D. BALACI, D. CRISTESCU	201

B 103	Operation Performance of the System Integrity Protection Scheme (SIPS) in the Interconnection Between the Turkish and ENTSO-E Power Systems	209
	F. KOKSAL, S. METIN, J. CARDENAS, O. CASANOVA, A. LOPEZ, F.ILICETO	
B 104	On-line Refurbishment of Aging Power Transformers	217
	J. SABAU, I. FOFANA	
B 105	Objective Decisions for Maintenance in Electricity Transmission Grid, under Equipment Ageing Conditions	227
	C. BARBULESCU, R. MARCIU, C. DIACONU, I.D. HATEGAN, M. FLOREA	
B 106	XLPE 400 kV Cable in Substation Stupina 400 kV – CNTEE Transelectrica – Constanta Branch	235
	I.D. HATEGAN, N. BALTA, R.G. SAVA	
B 109	Some results in the transformer maintenance of Transelectrica applied in 2010-2012 by SC Smart SA	243
	A. MORARU, F. GEORGESCU, Gh. FILIP, P. CIOBANU	
B 110	Assessment of Power Transformers Conditions Based on Health Index	253
	G. TANASESCU, O. DRAGOMIR, L. VOINESCU, B. GORGAN, P. NOTINGHER, T. SURU, M. CORNEL	
B 112	Protection Security Assessment – Innovative Strategies and Methods For Future Grids	261
	J. JAEGER, R. KREBS, T. BOPP, L. SHANG, C. BLUG	
B 113	Chemistry of insulating oil, its effect on service life of the oil and specification	267
	B. PAHLAVANPOUR, P. WIKLUND, C. WETTERHOLM	

SECTION C. Power System Solutions for Renewable Sources (RES)

C 101	Impact of Emerging Distributed Generation Facilities on Distribution Network	274
	D. STANESCU, I. BLAGU	
C 102	Topics on Protection Systems for Renewable Energy Sources Integration	280
	F. BALASIU, Gh. MORARU	
C 103	Battery Utilization in Electric Substations	288
	T. CHIULAN, C.Gh. DIACONU, M. MARCOLT	
C 104	Integration of generation from renewable energy sources in SCADA-EMS systems	293
	M.A. RONCEA, O. CODREANU	
C 105	Use of Battery Storage to Increase Network Reliability under Faulted Conditions	302
	S.R. BLAKE, J. YI, D.C. MILLER, I. LOYD	
C 106	Aspects of Wind Power Plants Effects on the Electrical Power System	310
	C.E. BOAMBA, C. RADOI	
C 108	Power Network Application to Support Management of Power Systems with high share of renewables	316
	U. KERIN, E. LERCH	

C 109	Quantification Method for RES Power Cut Versus Grid Reinforcement	323
	F.C. CIOBANU, M. UNGUREANU, E.A. BUCUR	
C 112	Virtual Power Plant – Opportunity, Necessity, Conditions for achieving	328
	H. ALBERT, G. GUTU. B. MARCU	
C 113	Current Issues Regarding the Connection of Wind Power Plants to the National Power System	334
	H. ALBERT, G. LAVROV, N.E. ROSCA	
C 115	The Influence of Wind Farm Automatic Secondary Voltage Regulations Systems Installed in the Transmission Grid on the Operational Voltage of the Connection Substation and Surrounding Area	344
	M. CONSTANTIN, V. IVAN, M. EREMIA	
C 116	Planning the Electrical Networks in the Context of Renewable Energy Integration	352
	D. BOLBORICI, D. PETRESCU, S. OPREA, O. STANESCU	
C 117	Integration of Renewable Energy in National Energy System Using the Concept of VPP	357
	C. BOGUS, L. BENGHEA, A. ROMANESCU	
C 118	Photovoltaic Power Development and Grid Connection. ISPE – Provider of Complete Engineering & Consulting Solutions for Photovoltaic Power Development and Grid Connection	364
	M. COTEANU, A. STANCIULESCU, I. VASILIU, C. PATRASCU, C. SPATARU	
C 120	Modeling of wind power plants generators in transient stability analysis	377
	O. STANESCU, D. BOLBORICI, S. OPREA	

SECTION D. Challenges in Education of Power System Workforce

D 101	Evaluation of two fault location algorithms using Matlab modeling	387
	M. DRAGOMIR, A. MIRON, M. ISTRATE, I. NEDELICU	
D 102	The Electromagnetic Compatibility Seen into Capability Diagram at One H.P.P.- Storing Energy Facilities, Using Variable Drivings	393
	B. GUZUN, E. ANGHEL, J. BARBOIANU, C. GROFU, V. ZAHARESCU	
D 106	Clustering-based algorithm in power system partitioning	402
	G. GRIGORAS91, C. BARBULESCU	
D 107	Recent Advances on the Magnetic Field Computation in High Voltage Substations	410
	I.T. POP, C. MUNTEANU, C. HANGEA, T. GUTIU	
D 108	Optimal Reactive Power and Voltage Control Using Evolutionary Techniques	416
	C.F. IONESCU, C. BULAC, I. TRISTIU	

INDEX		423
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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
Chairman

Dr. Constantin Moldoveanu
Vice-Chairman

Dr. Dorin Ioan Hategan
Secretary



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SECTION A

Electrical Networks of the Future



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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 $X=[U_1; U_2; \dots; U_n; \theta_1; \theta_2; \dots; \theta_{n-1}]^T$. 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.

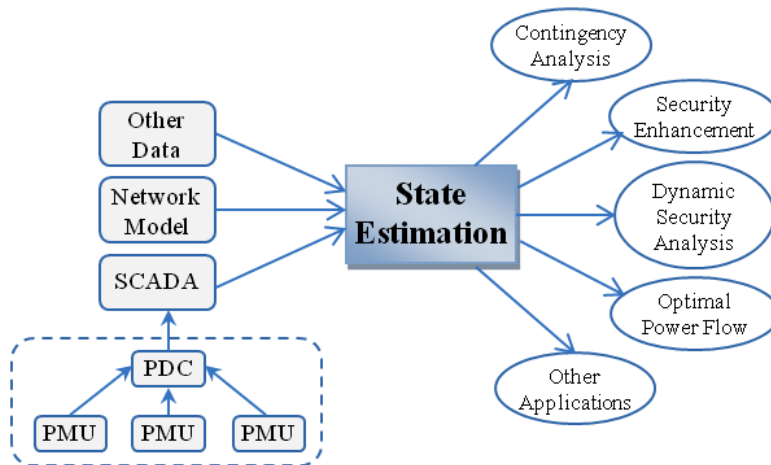


Figure 1. The role of state estimation in power system operations.

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.