EKC²+ACCESS *Smart Grids* Workshop

An InnoEnergy CC Sweden Initiative

Control and Pricing for Smart Transmission Systems

May 24, 2011
0800-1800

Place:
E2, Third Floor
Lindstedtsvägen 3
KTH Royal Institute of Technology,
Stockholm, Sweden

Organized by:

EKC² Swedish Center of Excellence in Electric Power Engineering — ACCESS the future — KTH VETENSKAP OCH KONST — eit Knowledge & Innovation Community KIC InnoEnergy

The Swedish Center of Excellence in Electrical Power engineering, EKC2, in collaboration with the ACCESS Linnaeus Center, invites you to the "EKC²+ACCESS *Smart Grids* Workshop" to take place at KTH, in Stockholm on May 24th, 2011.

The aim of this workshop is to bring to KTH, to our competence centers, and to the EIT InnoEnergy Colocation Center Sweden, different point of views of what "smart grids" may accomplish at the transmission level, particularly considering aspects related to pricing and control.

The workshop will feature both national experts, as well as distinguished international guests. To register please fill out the on-line form:

http://tinyurl.com/ekc2-access-sg-workshop

List of speakers:

Karl Henrik Johansson, KTH Royal Institute of Technology, Sweden
Kameshwar Poolla, University of California, Berkeley, USA
Jan Ove Gjerde, Statnett, Norway
Joe H. Chow, Rensselaer Polytechnic Institute, USA
Lars Nordström, KTH Royal Institute of Technology, Sweden
Aranya Chakrabortty, North Carolina State University, USA
Stephan Hutterer, Upper Austria University of Applied Sciences, Austria
Romeo Ortega, SUPELEC, France
Yuri Makarov, Pacific Northwest National Laboratory, USA
Lennart Söder, KTH Royal Institute of Technology, Sweden

Program

08:00-08:30	REGISTRATION AND COFFEE
08:30-09:00	Welcome and Opening Presentation Title: On Cyber-Security of State Estimators and Fault Analysis of the Transmission Grid Karl Henrik Johansson, KTH, Sweden
09:00-09:40	Title: Smart Grid Data Integrity Kameshwar Poolla, University of California, Berkeley, USA
09:40-10:20	Title: WAMS and WACS Enabling the Smart Grid at Statnett Jan Ove Gjerde, Statnett, Norway
10:20-10:40	COFFEE BREAK
10:50-11:30	Title: Wide-Area Power System Damping Control using Synchrophasor Data Joe H. Chow, Rensselaer Polytechnic Institute, USA
11:30-12:00	Title: Experimental ICT Systems for Wide-Area Measurement and Control Systems Lars Nordström, KTH, Sweden
12:00-13:30	LUNCH
13:30-14:10	Title: Optimal Sensor Placement for Parametric Model Identification of Electrical Networks Using Mixed Phasor Measurements Aranya Chakrabortty, North Carolina State University, USA
14:10-14:50	Title: Metaheuristic Open Source Power System Optimization and Analysis using HeuristicLab Stephan Hutterer, Upper Austria University of Applied Sciences
14:50-15:10	COFFEE BREAK
15:20-16:00	Title: Some Control Teory Problems in Modern Energy Systems Romeo Ortega, SUPELEC, France
16:00-16:40	Title: New Phenomena in Bulk Power System Control Yuri Makarov, Pacific Northwest National Laboratory, USA
16:40-17:10	Closing Presentation Title: Pricing in Markets with Large Amounts of Variable Power Production Lennart Söder, KTH, Sweden
17:10-17:30	Panel with the Speakers – Moderator Lennart Söder, KTH, Sweden

For more information about the topics and organization of the workshop, please contact the Workshop

Organizers

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Presentation Abstracts

On Cyber-Security of State Estimators and Fault Analysis of the Transmission Grid

Karl Henrik Johansson, KTH, Sweden

Abstract: Not available at time of publication.

Smart Grid Data Integrity

Kameshwar Poolla, University of California, Berkeley, USA

Abstract: Real power injections at loads and generators, and real power flows on selected lines in a transmission

network are monitored, transmitted over a SCADA network to the system operator, and used in state estimation algorithms to make dispatch, re-balance and other Energy Management System decisions. Coordinated cyber-attacks of power meter readings can be arranged to be undetectable by any bad data detection algorithm. These unobservable attacks present a serious threat to grid operations. Of particular interest are sparse attacks that involve the compromise of a modest number of meter readings.

We present an efficient algorithm to find all unobservable attacks [under standard DC load flow approximations] involving the compromise of exactly two power injection meters and an arbitrary number of power meters on lines. This requires $O(n^2m)$ flops for a power system with n buses and m line meters. If all lines are metered, there exist canonical forms that characterize all 3, 4, and 5- sparse unobservable attacks. These can be quickly detected in power systems using standard graph algorithms. Known-secure phase measurement units [PMUs] can be used as countermeasures against an arbitrary collection of cyber-attacks. Finding the minimum number of necessary PMUs is NP-hard. We show that (p + 1) PMUs at carefully chosen buses are sufficient to neutralize a collection of p cyber-attacks. We conclude with a discuss of open problems and opportunities in cyber-security of electricity grids.

WAMS and WACS Enabling the Smart Grid at Statnett

Jan Over Gjerde, Statnett, Norway

Abstract: It will require considerable R&D efforts to develop the concepts and software tools to be able to implement all applications to cope with the Smart Grid ideas. On the other hand Statnett has been working within these technical areas for years and have internal and external resources available, which have the necessary skills and motivation to fulfill the vision of this R&D Program.

This presentation will present the R&D work at Statnett, with focus on:

- *Statnetts vision with in Smart Grid*
- *How to utilize the WAP platform (WAMS, WACS and WAPS applications) in order to strengthen Statnett ability to cope with the challenges connected to operational planning, on-line operation, protection and balancing of production and demand in elucidation with the EU 20/20/20 goals, i.e., with significantly increased renewable power connected to the main power grid.*
- *Oresent applications and ideas which cope with the Smart Grid concept and ideas*
- *Highlight results from the R&D activities with respect to will create new methodology, competence and software tools to in a more cost-effective way solve Statnett's main tasks and daily processes connected to extension planning, operational planning, on-line operation, protection and balancing of production and demand connected to a power system that is more challenging to operate*

Wide-Area Power System Damping Control using Synchrophasor Data

Joe H. Chow, Rensselaer Polytechnic Institute, USA

Abstract: This talk presents an interarea mode damping control strategy for power systems using synchrophasor data. A key consideration is the time delay in computing the phasor quantities and the variable communication network latency for controllers to use remote synchrophasor data. Based on the statistical estimate of the synchrophasor arrival time, a control strategy is developed assuming a fixed delay time that would accommodate most of the data. An adaptive component is used to augment the control design for data arriving beyond the selected delay time. The design is illustrated with a 2-area power system. Applications to large power systems will be discussed.

Experimental ICT Systems for Wide-Area Measurement and Control Systems

Lars Nordström, KTH, Sweden

Abstract: Wide-Area Measurement and Control Systems are completely dependent on interoperable, robust, high-performing and secure ICT systems. The requirements on the ICT system by WAMC applications vary with the applications scope and the type of control being implemented, and the design of the ICT system needs to cater to several concurrent sources of requirements. To facilitate design of these types of ICT systems, research is being done in the area of system modeling involving representation of key interoperability and security techniques and their impact on the performance on the ICT system. To validate the system models, an experimental WAMC system has been developed utilising the openPDC opensource platform as a base. This presentation is focused on the development of this platform, its present capabilities and planned development.

Optimal Sensor Placement for Parametric Model Identification of Electrical Networks Using Mixed Phasor Measurements

Aranya Chakrabortty, North Carolina State University, USA

Abstract: This talk will present algorithms for placing sensors optimally along the edges of a large network of electrical oscillators to identify a parametric model for the network using a linear combination of three fundamental electrical signals - namely, the magnitude, the phase angle and the frequency of the voltage phasors along each edge, corrupted with Gaussian noise. We will pose the identification problem as estimation of four essential parameters for each edge, namely the real and imaginary components of the edge-weight (or, equivalently the resistance and reactance along the transmission line), and the inertias of the two machines connected by this edge. We will then formulate the Cramer-Rao bounds for the estimates of these four unknown parameters, and show that the bounds are functions of the sensor locations as well as of the contribution of each variable in the combined output. We will finally state the condition for finding the optimal sensor location and the optimal signal combination to achieve the tightest Cramer-Rao bound. A brief note on convexity and the associated numerical costs of these optimization algorithms will also be discussed.

Metaheuristic Open Source Power System Optimization and Analysis using HeuristicLab

Stephan Hutterer, Upper Austria University of Applied Sciences

Abstract: Since the introduction of smart grids causes new challenges to electric power system optimization, new algorithms have to be investigated that are capable of handling high- dimensional problems, partly in a multiobjective manner. Metaheuristic algorithms like genetic algorithms have been proven to being able of handling such problems in the last couple of years and seem to be a promising choice. Therefore, a simulation-based optimization approach is being introduced as sophisticated framework to investigating accurate optimization strategies for future smart grid technologies. The main idea is the application of simulation for computing the fitness- values subject to the solution generated by a metaheuristic optimization algorithm. Considering the software architecture of this framework, two independent software packages are being aggregated, namely HeuristicLab being a generic and extensible environment for heuristic optimization, and an appropriate power system simulation software.

The advantages of the simulation based framework are presented. On the one hand, it enables easy formulation and computation of polymorphic optimization problems. Thus, known optimization problems, no matter if coming from the transmission or distribution level, can be solved easily by various metaheuristic algorithms that are already implemented in HeuristicLab. On the other hand, the usage of simulation for optimization allows modelling of stochastic behaviour in

the power grid. The framework is shown using the exemplary concept of optimal integration of e-mobility together with power plants with stochastic delivery (like wind power) into the power grid. The extensive optimization and data analysis capabilities of HeuristicLab are presented with respect to applications in electric power system research.

Some Control Theory Problems in Modern Energy Systems

Romeo Ortega, LSS-SUPELEC, France

Abstract: In this talk we discuss the following challenging problems in control theory that arise in recent applications of energy systems and propose some potential solutions.
1. A dynamic router for energy management. A new strategy to achieve efficient regulation of the energy transfer between generating, storage and load subsystems is proposed. In contrast with current practice, the direction and rate of change of the power flow is determined without relying on steady - state considerations and filtering.
2. Transient stability of power systems revisited. New control strategies based on the ideas of energy shaping and damping injection have emerged recently. Classical field excitation, as well as, modern flexible AC transmission systems have been considered. Departing from standard stabilization objectives a synchronization viewpoint, where a suitable pendulum dynamics is immersed into the system, is adopted.
3. Wind speed estimation of a windmill system. Wind speed enters into the generator dynamics through a highly nonlinear function; hence we are confronted with a difficult problem of estimation of a nonlinearly parameterized system, which is solved using Immersion and Invariance techniques.

New Phenomena in Bulk Power System Control

Yuri Makarov, Chief Scientist – Power Systems, Pacific Northwest national Laboratory, USA

Abstract: With the increasing penetration of renewable variable generation resources, many new system impacts have been observed, whereas well-known power system control tasks require significant rethinking and revisions. This short presentation attempts to review some of these phenomena and briefly analyze their possible solutions. Particular attention is paid to increasing interconnection balancing needs, overgeneration problem, tail events, frequency control, control of interchanges and congestion management, generation reserves and their flexibility, energy storage, incorporation of uncertainty information into system dispatch and coordination among Transmission System Operators (TSOs). The presentation outlines several new approaches to mitigate the impacts of renewable generation, including the concept of performance envelopes, wide-area energy management systems, security region concept, and others.

This presentation will describe the advances made by Statnett for more than over 10 years, and describe how WAMS and WACS provide the building blocks for constructing a Smart Grid at the transmission level.

Pricing in Markets with Large Amounts of Variable Power Production

Lennart Söder, KTH, Sweden

Abstract: he amount of variable power sources is continuously increasing, and the share of this type of sources can be expected to grow significantly in many systems. The balance between production and consumption has to be kept continuously in any power system. In this type of system the controllable power plants (and the controllable load) have to follow the net load, i.e. fixed load minus production in variable power plants. The variation of the net load can be significant and the forecasts can be rather bad. This has and will have a large impact on the pricing since the production in the controllable power plants depends on the prices which thereby will be more volatile. These volatile prices (changes over time, node and forecast horizon) have a significant impact on the operation and also design on the future power system. It is important that the prices in the system both leads to efficient operation and incentives for correct investments in the system. Of specific interest is the challenge to obtain enough power plants in systems with low utilization time of peak units, especially in competitive markets where investments depend on expected market prices.