Recent Trends in Power Grid Monitoring

Wide-area mode and damping estimation in AC transmission
November 29th 2013, at Imperial College London

REPORT OF SYMPOSIUM

Introduction

Members of the EU FP7 Real-Smart project and other guests met in November 2013 for a symposium at Imperial College London. The aim was to discuss the state of the art and to disseminate recent research findings in the area of Wide Area Monitoring Systems (WAMS) with a special focus on wide area mode and damping estimation. The symposium brought together researchers, practising engineers and international experts to discuss these matters. Speakers and discussions covered the following topics:

- Long term industry needs
- Plans for future deployments of WAMS technology in the UK and Europe
- Algorithms for mode and damping estimation using WAMS data and models

Attendees were invited to present their own relevant work as a poster.

The symposium also included a tour on November 28th to the National Grid Control Centre in Wokingham.

Talks

Phasor Measurement Unit Deployment on the GB Transmission System: Phillip Ashton and Alex Carter, National Grid, UK:

Phil presented the talk in which he discussed the deployment by National Grid of Phasor Measurement Units (PMUs) in their Wide Area Measurement system.

He started by discussing the changing energy landscape including more wind generation and closures of fossil fuel power stations, and the investment plans of National Grid in the UK including offshore HVDC and series capacitor compensation. He also looked further ahead to the impact on the UK of a European Supergrid with additional HVDC links in the North Sea. His survey shows that National Grid wants to get more information from PMUs both for planning and for operations.

To this end, Phil surveyed the installed base of PMUs. There are 40 PMUs on 20 buses connected to a Psymetrix Phasor Data Concentrator. Some PMUs are purpose built and others have been upgraded from digital fault recorders that were already in place. Future plans include a more complex hierarchy for handling the PMU data. There are also university PMU networks monitoring local frequency on the low voltage distribution grid and giving good visibility of the system. He showed an example of a 1000MW interconnector trip that was monitored and localized by the university PMU network.

Phil went on the explain National Grid's concerns about lack of visibility of the system inertia. In the summer, up to 50% of generation can be from non-synchronous generators where the inertia is hidden behind power electronics interfaces. This makes it difficult to model the system behaviour, particularly the wide area modes which are affected by the system inertia. He described his work towards inertia estimation using time-varying frequency measurements from PMUs. He is finding good correlations between mode frequency during ambient operation and total system inertia as estimated during transient events.

Phil ended his talk on an optimistic note that network visibility is improving with the growing volume of PMUs. He recommends a detailed analysis of every system event because of the valuable information to be extracted, and he sees a future challenges in handling the huge amounts of data, where data visualization methods are going to be valuable.

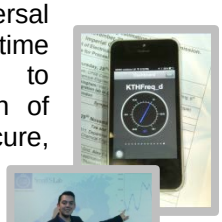
Signal analysis methods for damping estimation: Emilio Barocio Espejo, Biksh Pal, Nina Thornhill, Davide Fabozzi. Imperial College London.

Nina Thornhill started by giving an overview of the Marie Curie IAPP Real-Smart project. The project concerns the use of real-time measurements for monitoring and management of power transmission dynamics, and is now in its last year. She explained the work of the project has been done by recruited researchers and by staff and students undertaking secondment placements. She highlighted a special conference session at the Grenoble 2013 PowerTech conference, and several journal papers as outcomes of the project. One of these was a comparison of the random decrement, wavelet and sub-space identification methods for determination of transmission system damping using ambient data.

Emilio Barocio Espejo continued with ideas for visualization tools for PMU measurements based on multivariate statistical analysis. He showed how adaptive principal component analysis correctly detects system disturbances, determines their locations and gives information about fault propagation.

Monitoring and control of renewable energy sources using PMUs, Luigi Vanfretti, KTH and Statnett.

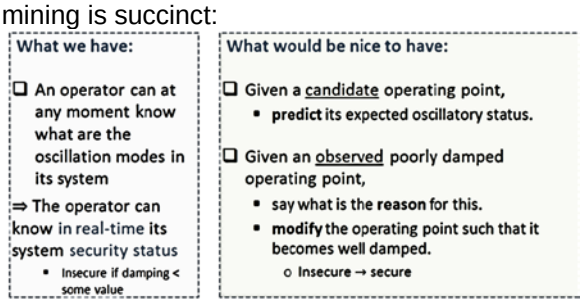
Luigi started by demonstrating real-time monitoring of the frequency in the Scandinavian grid on his phone and tablet. His message was that such easy and universal availability of real-time measurements will lead to innovative ideas and creation of smart grid technologies for secure, efficient and flexible use of renewable generation. Real-time monitoring and control is central to coping with the new challenges and assuring safe power transmission.



Luigi is interested in making real-time PMU applications that can be accessed via Internet. His talk described a systematic approach of design–implementation–validation–deployment for creating real-time mobile apps. It starts with capture of requirements from the intended end users, while the technical aspects include interfaces between i-phone or tablet PC to PMUs or the phasor data concentrator. He illustrated his comments with an in-depth account of the technical development of a PMU app that monitors sub-synchronous wind farm oscillations.

Data Mining Techniques to classify inter-area oscillations, Adamantios Marinakis, ABB Corporate Research, Switzerland.

Adamantios discussed data mining of WAMS mesurements and presented three techniques he has been exploring. His message about data mining is succinct:



Currently, an operator can know the frequency and damping of wide area modes in real-time, but the aim for the future is (i) to be able to predict the oscillatory state of an operating point, and (ii) for an observed poorly damped operating point, to be able to explain the reasons and suggest modification for improving the damping.

The techniques examined by Adamantios bring together SCADA and PMU data for analysis by support vector machines, evolutionary strategies and random forests. The results show that these techniques are able to classify the system oscillation and damping on the basis of operational SCADA variables such as dispatch, power flow and PSS status, thus creating the wanted model. He concluded on the relative strengths of the methods, taking account of accuracy and the efficiency of the algorithms.

His final comments considered future challenges, one of which is to close the loop and to select the best system operating point based on models generated from the techniques he has been exploring.

Poster forum

Maxime Baudette, KTH Stockholm: SYMPTOM: SYncrhophasor-based Model calibration for Power systems and conTrol OptiMization.

Rafael Segundo, KTH Stockholm: Power system stability impact assessment using time-series from phasor-time-domain simulations.

Hao Guo, University of Manchester. Substation time synchronization using IEEE 1588.

Xi Chen, University of Manchester. Protection performance evaluation with IEC61850 process bus technology

Christopher Saunders, Brunel University: Enhancing detection of critical generators for transient stability analysis

Hongbo Shao, Durham University, Controlled islanding scheme to prevent imminent wide-area blackouts

Mohammad Golshani, Brunel, Implementation of Wide Area Monitoring Systems and laboratory-based deployment of PMUs.

Herwig Renner, Technical University of Graz, I Mode identification and Damping Estimation

Jan Lavenius, KTH Stockholm: Real-time voltage stability monitoring, assessment and control using synchrophasors

Emilio Barocio Espejo, Imperial College London: Identification and visualization of generator coherency using POD-based hierarchical clustering analysis.

Herwig Renner, Technical University of Graz, Application of dynamic REI reduction.

T. Bogodorova KTH Stockholm: A Modelica Power system library for phasor time-domain simulation.

Notes from discussions

The meeting ended with a discussion and wrap-up session.

The discussion was structured to anticipate where developments in power grid monitoring

might go next. The facilitator (Thornhill) summarized the themes emerging from the talks given by the symposium speakers. Between them, they had focused on measurements from PMUs and other sources, extraction and transformation of information from data, grid status modelling, enhanced visibility of the grid with large amounts of non-synchronous generation, visualization, and availability of grid frequency data through Internet.

The motivations were to make it easier to understand and visualize the operation of the transmission grid in real-time, to control its operation and to understand the whole picture. Many of the poster presenters were also addressing these issues with a variety of tools and methods.

Chris Saunders and Luigi Vanfretti led a lively discussion about "does the method matter?". As could be seen during in the symposium, more one method can achieve the same end result (e.g. damping estimation, correlation of grid operation point with wide area oscillations). Academic research can ascertain which methods are unsuitable, but will generate a suite of tools that are suitable and all about as good as each other. The eventual winner may often be the one selected by an influential technology vendor company.

However, such an approach is top-down and means that users have to accept decisions made elsewhere. An alternative approach is to build tools bottom-up based on experiences and requests from the users such as control room operators. However, these are not the folk who hold the budgets, although managers who do make the purchasing decisions would be wise to get clear ideas of the requirements from the users of the technology for making sense of WAMS data.

There was general agreement that more than one method may give the necessary results, and therefore reliability and robustness are criteria for differentiation. A standard benchmark problem in which the inputs are standardized, and outputs can be evaluated for correctness and robustness would be valuable.

Further discussion concluded that SCADA and phasor data concentrators that are open to implementation of third party and open source codes will be beneficial for getting successful tools into use in the transmission grid.

Vote of thanks

All those present thanked Cristina, Bikash, Emilio, and Guler organizing the event and putting together a varied and interesting programme from a wide range of speakers. We also thanked all the speakers.

The organizers would also like to thank Alex Carter and Phillip Ashton for the visit to the National Grid control room on November 28th.

Organizers

The event was organized at Imperial College by Bikash C. Pal and Emilio Barocio (E&E Engineering) with assistance from Cristina Romano (Centre for Process Systems Engineering) and Guler Eroglu (E&E Engineering). The tour of the National Grid control room was organized and hosted by Alex Carter and Phillip Ashton of National Grid

Further information

Meeting presentations are available from the link below:
http://www3.imperial.ac.uk/realsmart/news
Further information on the Real-Smart project at Imperial College London is available at
http://www3.imperial.ac.uk/realsmart

Acknowledgements

The organizers gratefully acknowledge financial support from the Marie Curie FP7-IAPP Project: "Using real-time measurements for monitoring and management of power transmission dynamics for the smart grid- REAL-SMART, Contract No. PIAP-GA 2009-251304"

Notes compiled by
N.F. Thornhill, Imperial College London
27th December 2013

==========

Additional comments

The notes below are from the discussion following the previous meeting at Imperial College on wide-area mode and damping estimation in AC transmission in 2010. The full report can be accessed here. It is interesting to see how concepts and ideas from 2010 have developed in the past three years.

From 2010:

Emerging themes: Some themes emerging from the event were:

- WAMS offers more than stop/go traffic light application in control centre of a transmission operating company. It is also useful:
  - for control and protection
  - for planning, model validation and P_{max} calculations which are needed as operations become more variable.
  - The information helps with maximising transmission capacity of exiting systems.

- WAMS is feeding into decision support e.g.
  - damping estimates
  - state estimation
  - estimation of the voltage nose curve
- WAMS information can be converted to a signature, e.g. the damping, which indicates changes in the system.

Phillip showed how National Grid is using PMU data for such purposes, and the next target is estimation of system inertia.

Decision support systems and visualization: There were many references during the event on visualization for decision support. It is clear from the talks that there are two distinct groups of users of WAMS data: (i) operators in the control room and (ii) system planners and designers. The displays depend on what people need to know for these two job functions.
The discussion considered how generic operator actions could be, or whether the required action would depend on the configuration and state of the network. It was felt that the operator actions are case-dependent because control measures depend on conditions. Standard counter-measures or maintenance decisions may not be valid if the conditions of the grid change.
Yes, Adamantios is starting to get some answers.

Plug-in PMUs. The event had presentations on the use of PMUs at the 220V level for research purposes. The discussion considered what other uses there could be for PMUs at the 230V level. What might they be used for if everyone had one in their home? One response is that more PMUs make state estimation easier, and plug-in models may have a role. On the other hand, there are other technologies more suited to home applications coming with Smartgrid metering technology. It is not clear that PMUs would have any domestic applications.
Indeed. Now Luigi and his team bring us system frequency on an i-phone.

Photo Gallery