

**Meeting notes, Energy Systems Integration Workshop
May 27-28, 2014, Copenhagen Denmark**

Day One, May 27, 2014 - Research Task Force on integrated gas-electricity modelling

The research task force meeting provided an opportunity for doctoral and postdoctoral researchers with interdisciplinary analytical and modelling skills to network, brainstorm and ultimately define research priorities on combined gas and electricity analysis as part of the Energy Systems Integration Workshop. This meeting took place on the morning of 27th May prior to the opening plenary session.

The research task force was composed of 20 researchers from leading universities and research institutes across Europe, namely Austrian Institute of Technology, Danish Technical University, EWI Cologne, Florence School for Regulation, Imperial College London, KU Leuven, University College Dublin, University College Cork, University of Cardiff, University of Manchester, University Duisburg-Essen and VTT Finland. Senior workshop participants also joined the group to add industry experience to the discussion.

The participants debated and defined a research agenda in a consensus-based approach in two parallel working groups and two different sessions where participants were mixed between working groups. The main goals of the working groups were to:

- Define real-world challenges at gas-electricity interface and energy system benefits of integrated approach
- Discuss modelling approaches: status of model development (commercial models, research models), challenges with mathematical formulation, data sources

The inter-linkages between gas and electricity are very diverse and were prioritised in decreasing order of importance, as follows:

- Power plants using natural gas; including CHP
- Dual fuel heat source technologies (households, commerce, industry)
- Dual fuel gas compressors and de-compression pre-heaters
- Transport fuel
- Electrolysis

From a system perspective, gas and electricity systems have many common modelling constraints, which mean that common modelling approaches can be developed. Common constraints include security of supply, greenhouse gas emission limits, climate and weather. Weather constraints include short-term (daily) variability (Wind/solar forecast error and gas price), as well as long term (annual/seasonal) variations (e.g wind/PV/hydro and the storage capability of gas system).

Modelling time scales differ considerable between gas and electricity systems due to different dynamics. Electricity is transported very fast (speed of light, steady state can be assumed), but gas at moderate speeds (<100km/h). Therefore, separate and dedicated models for each system will continue to be

important for a dedicated analysis of one system. Integrated models will be able to capture the interactions but will need to carefully choose an appropriate time scale.

The research task force recommended increasing research efforts on the following topics:

- Operations
 - Alignment and coordination of gas and electricity markets for efficient interactions
 - Impact of power system variability on gas network
 - Enhanced line-pack operation
 - Utilise gas system flexibility
 - Gas supply constraint in power system unit commitment
- Planning
 - Co-optimize supply and network expansion
 - Ensuring system reliability and adequacy
 - Reliable gas supply networks for power system backup while gas consumption and revenues are decreasing
 - System-wide opportunities for electrolysis (Power-to-gas) compared to other storage and flexibility resources
 - Market arrangements and governance
 - Impact of common uncertainties and externalities affecting both systems simultaneously

Day One, May 26/27, 2014 - Opening Plenary Session

Marie Donnelly from the European Commission kick started the workshop outlining the challenges that lie ahead for Europe in the energy area. There is currently a major shift in energy policy underway in Europe through the Integrated Road-Map where ambitious agendas for clean energy, integrated markets and access to indigenous sources of energy are being set. There is a need for an integrated approach that combines policy, regulation, technology and new business models.

Dana Christensen from NREL followed with a detailed description on why grid modernisation is important. He then outlined the US initiative on grid modernisation, introduced NREL's Energy Systems Integration Facility (ESIF) and emphasised the collaboration potential that now exists globally with ESIF and Energy Systems Integration.

Marianne Thellersen from DTU welcomed all participants to the campus and **Mark O'Malley** concluded the opening plenary with a synopsis of the Washington workshop and the themes of the Copenhagen workshop. There was general consensus among all speakers of the opening plenary that Energy Systems Integration is important international.

Day One, May 27, 2014 - Session: Regulation, Policy and Market Design Session

Session Speakers: **Ignacio Perez-Arriaga** (Comillas University Madrid, Spain & MIT, USA), **Andrew Ott** (PJM, USA), **Anne E. Hoskins** (Commissioner – Maryland Public Service Commission, USA), **Eric Callisto** (Commissioner – Public Service Commission Wisconsin, USA).

In principle, energy-system integration is a technical issue, characterized by the interaction and feedbacks of the different energy technologies and carriers, and reflected by the non-linear (and hence, largely unexpected, and often undesired) behaviour of the system. In a world with many market players and not always easily controllable energy technologies, energy policy orientations, market designs and the regulatory framework sets scene against which all the action takes place. The regulatory

environment (as a concrete translation of adopted legislation and policies) steers the markets in some directions, with often unintended consequences. Clearly, the policy and regulatory context not only sets the boundary conditions, but also acts as a driver, for certain system responses.

In the session, many examples illustrating the mutual influence on both sides of the Atlantic¹ were discussed. Governments mandate renewables (many of which are non-dispatchable) strongly affecting the usual merit order for electricity generation, sometimes leading to negative wholesale prices. Conventional thermal units are pushed out of the merit order by the renewables in Europe, while in the US low-price shale gas has reversed the classical merit order between gas-fired and coal-fired plants. Resulting low coal prices in the US and the world market combined with the low-price signal of CO₂ allowances in the European Trading Emission, leads to increased coal import in Europe with the paradoxical situation that CO₂ emissions rise in some countries with a strong renewables-injection. Interactions between the gas grids and the electricity generation system are a further case in point, in Europe because of cycling needs of gas-fired plants and because of harsh winter weather conditions in the USA. Could we have avoided such “strange” effects with more systems thinking?

The session further documented that both sides of the Atlantic take quite different approaches, with regard to State/Federal relationships, liberalized & regulated markets, types of pricing (zonal in the EU and nodal in the US), etc. It was further mentioned that investors, although being used to deal with a variety of uncertainties, ‘detest’ regulatory and policy uncertainty, since such exogenous “interventions” may unleash totally unexpected effects, often leading to defacto stranded assets. Unclear policy directions are an obstacle to new investments.

Although it is difficult to compare the EU and US system, the variety of market structures, diversity of electric power pools, and a different set of policy targets and objectives, leads to a perfect situation for system-effects understanding, whereby many insights and lessons can be learned and shared.

It is essential to think about the time frame of the energy provision and security of supply: from the longer term (investment & adequacy) up to real time operations and balancing actions. It was clear that all systems aspects need to be taken into account when designing policies and regulation, and, conversely, that policy and regulation should be taken into account when modelling system aspects.

Day Two, May 28, 2014 - Parallel Session 1: Gas/Electricity Interdependence

Session Speakers: **Christian Hewicker** (DNV GL), **Sandra Scalari** (ENEL), **Roch Drozdowski** (GrDF)

The gas and electricity systems are the backbone of the US-European energy infrastructure (except for transport) and the interdependence between the two systems is growing with increasing gas power generation. Also increasing penetration of variable renewable energies requires flexible operation of the gas infrastructure and markets. Combined with the ageing condition of the networks and the deployment of ICT equipment, new opportunities for gas-electricity systems integration are being explored.

Joint gas-electricity contingency analysis is important to capture system dependencies. Traditional reliability analysis does not include interdependencies of systems and tends to underestimate the potential risk. The value of gas storage to provide strategic reserves and flexible, responsive fuel supply cannot be understated. In Europe, long-term policy vision and role for gas system is unclear.

¹ The next iiESI workshop will be held in Asia, specifically Kyoto on Nov 17th 2014.

Gas-electricity market harmonisation and communication is essential to ensure reliable operations. Intraday gas balancing will grow in importance due to penetration of variable renewables, even with improvements in forecasting. Line-packing can provide fast intraday gas balancing, if prepared in advance. The physics need to be respected in good markets designs. For example, moving gate closure to dispatch is ideal for electricity market design to aid renewables integration, gate closure in gas needs to occur sufficiently in advance (e.g. a couple of hours) to account for the slow dynamics of gas transport.

Increasing cyclic operation stresses the gas plants and increases outage rates. Real-time diagnosis tools for power plants can mitigate the failure risk and optimise the maintenance plan.

Gas network can be decarbonised by a wide set of technologies for example: anaerobic digestion, biomass gasification, electrolysis (hydrogen production). While continuous R&D in the less mature technologies is important, parallel systems integration studies can assess the wider system benefits and deployment synergies. As an example, a methanation process coupled to an electrolysis plant could benefit from the presence of an anaerobic digester. The methanation could utilise as reaction inputs, the waste CO₂ and heat from the digestion process.

Gas-electricity infrastructure can deliver clean, economic and secure energy systems in the long term. Capturing the interdependencies and strategically integration the systems is critical to deliver the long-term goals.

Day Two, May 28, 2014 - Parallel Session 2: Decentralisation and Demand Side Management

Session Speakers: **Laurent Schmitt** (Alstom); **Patrick Liddy** (EnerNOC); **Simon Borresen** (DONG Energy) **Mike Hogan** (RAP); **Patrick Van Hove** (EU)

This session focused on discussing the current challenges and solutions to integration of demand response (DR), demand side management (DSM), and distributed energy resources (DER) at significant levels into the electric power systems. The session provided several examples of successful deployments of DR and range of control mechanisms. Market mechanisms to enable value for DR services were also discussed.

Two major items that are needed to further enable aggregation of loads for DR are regulatory freedom to operate (current rules are usually made for incumbent generators and large interruptible loads) and compatible, inexpensive information and communications technology (ICT) solutions for large-scale rollouts.

The value proposition for DR was also discussed. Several examples included direct customer reimbursement through e.g. the use of \$50 WalMart gift cards in PJM all the way to markets that make different services available to aggregators.

Some additional issues that were discussed included the need for better understanding the impacts of local control and grid interactions when DR and DER are activated. When DR is activated, it may be unclear where in the system this DR is located and how it will respond to calls for activation. This may potential change the value of the response to the grid operator. There are also issues with dealing with large amounts of data necessary to directly control and verify responses from large numbers of disaggregated DR systems.

Day Two, May 28, 2014 - Session: Water- Energy Nexus

Session Speakers: **Joao Grilo** (IWA), **Gustaf Olsson** (Lund University), **Laurent Bellet** (EDF), **Karl Rose** (WEC)

This session began with a presentation by Joao Grilo from The International Water Association with a look at water, climate and the energy programme. Currently, regulatory pressure is encouraging water and wastewater utilities to become energy and carbon neutral while adapting to changing water availability. The goal is to facilitate improvement of utility water-energy efficiency and energy production, develop a communication approach that will inform decision makers on adaptation, support cities to develop approaches for adapting to climate change through urban water storage and a 'portfolio' of water supply options. The greatest possible foreseeable problems will be access to data, getting local partner motivation, and the low value of carbon.

Prof. Gustaf Olsson described the water-energy-food nexus looking at global conflicts and possible solutions. The global energy challenge depends on water. Thermal power generation is occurring in areas of water scarcity. Northern China for example has 60% of its thermal power capacity located at just 20% of the countries fresh water supply with China's Big Five power utilities all located in areas of water scarcity. More efficient pumping, variable pressure control and leakage detection and localisation will help water supply to be more energy efficient emphasising again that water and energy are inextricably linked. Fracking and shale oil production is causing a conflict between energy production and food production where groundwater is now being sold instead of being used for irrigation. With a focus on demand side management and if we can better understand habits, life styles, pricing, regulators and rules then perhaps there is a way of saving energy and therefore saving water.

Laurent Bellet gave an electric utility's viewpoint on energy and water. EDF's water for energy programme looks at the water, energy and food linkages through the multipurpose use of hydro reservoirs. Two examples of Serre-Poncon Scheme in France and the Nam Theun Scheme in Laos were given whereby the benefits of a sustainable and renewable energy generation has successfully translated into good use of water and land, biodiversity and infrastructural development.

The session was closed by Prof. Karl Rose from the World Energy Council (WEC). The WEC are most concerned with access to fresh water predicting that by 2025 80% of future water stress will be created by population and development and not climate change. Again, the interdependence of water and energy was stressed with all types of energy production requiring water. This is offset by the development of many emerging technologies which show promise in the mitigation of the water footprint. There was a call for greater energy efficiency to improve water consumption with a view that increase concern and action by policymakers will drive action that restricts operational flexibility and increased compliance costs. One solution fits all will not work for the water-energy challenges that face us instead there is a call for specific examination and different solutions by region.

Day Two, May 28, 2014 - Energy Technology Perspectives and Panel Session

Jean Francois Gagne from IEA opened this session looking at the transformation that is needed in the future energy environment and whether the investment and scale of challenge can be met through an integrated approach. The session quickly developed into a panel discussion involving **Dana Christensen**,

Laurent Schmitt, Karl Rose, Gustaf Olsson and Eric Callisto on how we collectively move in the direction of the best integrated system – and how iiESI can help this process. General points discussed were:

- i) The iiESI workshops would have more impact if policy makers could be engaged with a consensus message from the Regulators, Industry, and Academia participants.
- ii) There was resounding consensus that the consumer is very important and in many respects is driving the system by personal choices e.g. Photovoltaic on roof tops. Having more consumer behaviour specialists and economists at future meetings would be beneficial.
- iii) Every region/country is different so a one size does not fit all but everywhere has to develop and integrated energy system so each country can learn from each other. This workshop and the previous workshop in Washington DC in Feb. 2014 gave good insights into the differences and similarities of the US and Europe. The workshop in Kyoto, Japan on Nov. 17th 2014 should give an Asian perspective.
- iv) The stages of development are different throughout the world so a range of different solutions will be required.
- v) The energy investment issue is paramount and needs to be included in future events.

List of Attendees

| Name | Organization |
|-----------------------|---|
| Ahmad Faruqui | The Brattle Group |
| Amy Vaughn | NREL |
| Andy Boston | Energy Research Partnership |
| Anjan Bose | Washington State University & PSERC |
| Arun Majumdar | Google |
| Ben Kroposki | NREL |
| Bernard Salha | EDF |
| Beth Larose | General Electric |
| Brian Gutknecht | GE Flexeficient |
| Brigitte Bach | AIT |
| Bryan Hannegan | NREL |
| Carl H. Imoff | PNNL |
| Carl Pechman | DOE |
| Charles Soothill | Alstom |
| Chongqing Kang | Tsinghua University |
| Cris Eugster | CPS Energy |
| Cylde Loutan | CAISO |
| Dan Sowder | Duke Energy |
| David Corbus | NREL |
| David Elzinga | International Energy Agency |
| David E. Parekh | UTRC Research |
| David Sun | Alstom |
| Erkki Leppavuori | VTT & EERA |
| Fintan Slye | EirGrid |
| Gordon VanWelie | NE ISO |
| Guenther Ebert | Fraunhofer ISE |
| Harvey Michaels | MIT |
| Henrik Madsen | Danish Technical University |
| Jack Lewnard | Gas Technology Institute |
| Jacob Klimstra | Consultant |
| Jean-Francois Gagne | International Energy Agency |
| Jim McCalley | Iowa State University |
| Jose Luis Aburto | CFE, Mexican Federal Electricity Commission |
| Jud Virden | PNNL |
| Kevin Lynn | DOE |
| Kim Behnke | EnerginetDK |
| Klaus Baggesen Hilger | DONG |
| Kurt Rohrig | Fraunhofer IWES |
| Le Tang | ABB |
| Mark McGranaghan | EPRI |

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| Mark O'Malley | University College Dublin |
| Mark Ruth | NREL |
| Michael Chertkov | LANL |
| Michael Kintner-Meyer | PNNL |
| Michael Rinker | PNNL |
| Michael Walsh | EirGrid |
| Michael Weinhold | Siemens |
| Nilay Shah | Imperial College London |
| Neil Strachan | UCL – UKERC |
| Patrick Teahon | University College Dublin |
| Paul DiMartini | New Port Consulting |
| Peter Evans | Center for Global Enterprise |
| Peter Lund | EASAC/VTT |
| Pierre Bornard | RTD France |
| Richard O'Neill | FERC |
| Robert Pratt | PNNL |
| Ron Ambrosio | IBM |
| Ron Dizy | ENBALA |
| Saifur Rahman | IEEE & Virginia Tech |
| Sally Benson | Stanford University |
| Santiago Grijalva | NREL |
| Sarah Truitt | NREL |
| Sauro Pasini | ENEL |
| Sila Kiliccote | LBNL |
| Simon Hogg | University of Durham |
| Sophiede Richecour | Total & Sun Power |
| Steve Hammond | NREL |
| Steve Lindenberg | DOE |
| Steve Malnight | PG&E |
| Stuart MacMillan | NREL |
| Suresh Baskaran | PNNL |
| Terry Boston | PJM |
| Terry Oliver | BPA |
| Tom Fenimore | Duke Energy |
| Tom Key | EPRI |
| Trip Doggett | ERCOT |
| Venkat Banunarayanan | DOE |
| William D'haeseleer | KU Leuven |
| William Parks | DOE |
| Xavier Viteri | Iberdrola |