

## Power quality and energy efficiency in smart cities

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ENERGY DEVELOPMENT AND POWER GENERATION COMMITTEE

## Power Quality and Energy Efficiency in Smart Cities

Wil L. Kling and Johanna Myrzik

*Working Group European Electricity Infrastructure*

2012 IEEE PES General Meeting, July 22-26 2012, San Diego, CA, USA

Wednesday, July 25, 2012, 8:00 a.m~12:00 a.m. (Tentative)

**Sponsored by: International Practices for Energy Development and Power Generation**

Chairs: Wil Kling, University of technology, Eindhoven, the Netherlands

Johanna Myrzik, TU Dortmund University, Germany

### I. INTRODUCTION

**D**URING the last two decades, PQ related problems have increased all over the world. The uses of electronic appliances, computers, data processing equipments, variable speed drives, electronic ballasts, etc. have increased enormously. These devices are quite vulnerable to supply voltage disturbances. In contrast, they produce current emissions in the network because of their non-linear operating characteristics and in this way influence the quality of the network voltage.

The amount of electronic appliances is also increasing through the European energy policy to achieve 20% efficiency in 2020. This strong goal is only achievable by a consequent replacement of for example of incandescence lamps by CFL, standard drives and pumps by variable speed drives, classical oil or gas heating facilities by electrical heat pumps and central power stations by decentralized generators (DG) in order to bring the production closer to the demand. The increasing population in cities is an additional challenge and it requires an enormous effort for reducing the greenhouse gases. Therefore, an optimal use of multi energy systems (mostly based on DG) in the urban environment using smart control and communication technologies and the implementation of e-mobility is the key towards highly efficient and carbon-reduced cities.

Today's DG, electrical vehicles (EV) and electrical storages are adapted and controlled by power electronics with ascending growth in the future. At this moment also developments are

ongoing to improve the performance of grid components by means of power electronics. Several grid components might be replaced by power electronics based versions in the future. Therefore, in the near future energy efficiency issues and PQ problems will be stronger related to each other.

In this session the following subjects will be treated related to PQ, energy efficiency and smart cities:

- Urban multi energy systems and models
- Smart grid technologies in urban environment
- Harmonic measurement and modeling
- PV systems and converter technology
- Ancillary services of PE converters and storage systems
- Data collection and smart metering
- Electrical vehicles as loads
- Distributed storage
- LED lamps, CFL and other non-linear loads
- Regulation and responsibilities.

The panel will provide more understanding of the relation between energy efficiency issues and PQ problems. The main issues of urban multi-energy systems, DSM, EV and urban smart grid technologies will be pointed out under different technical point of views. Measurements and models will be given in order to simulate and calculate the causes of disturbances through electronic devices. In general, the impact of customer equipment and customer behavior on PQ issues as well as how to manage the PQ disturbances now and in the future will be discussed.

## II. LIST OF PAPERS

1. ***Distributed Multi-Energy Options to Increase Environmental Efficiency in Smart Cities***  
**P. Mancarella** (University of Manchester, Great Britain);  
 (invited panel paper 2012GM1030)
2. ***Estimation and Classification of Power Losses due to reduced Power Quality***  
**T. Bantras, V. Cuk, J.F.G. Cobben, W.L. Kling**  
 (Eindhoven University of Technology, the Netherlands);  
 (invited panel paper 2012GM0767)
3. ***Estimation of end user voltage quality including background distortion***  
**C. Debruyne, J.M. Desmet and L. Vandevelde**  
 (Technical University College Howest, Belgium);  
 (invited panel paper 2012GM0730)
4. ***Harmonic Measurement and Modeling for Mass Implementation of Non-Linear Appliances***  
**A. S. Koch, J. M. A. Myrzik, T. Wiesner, L. Jendernalik**  
 (TU Dortmund, RWE, Germany);  
 (invited panel paper 2012GM0943)
5. ***DMS and optimal swarm optimization for minimizing the burden of electric vehicles on active distribution networks***  
**E. Ghiani, G. Celli, F. Pilo, G. Pisano, G.G. Soma**  
 (Unica, Italy);  
 (invited panel paper 2012GM1515)
6. ***Introducing Smart Grids in Flanders: lessons learnt from the Linear project***  
**J.Driesen, E.Peeters, P.Tant, R.Belmans** (K.U.Leuven, Vito, Belgium);  
 (invited panel paper 2012GM1963)

Each panelist will speak for approximately 25 minutes. Each presentation will shortly be discussed immediately following the respective presentation. There will be a further opportunity for discussion of the presentations following the final presentation.

The Panel Session has been organized by Wil L. Kling (Eindhoven University of Technology, the Netherlands), Johanna Myrzik (TU Dortmund University, Germany) and Antje Orths (Chair of WG Europe, IPSC, Energy Development and Power Generation Committee, IEEE and Energinet.dk, Denmark). Wil L. Kling and Johanna Myrzik will moderate the Panel Session.

## III. TITLES, AUTHORS ABSTRACTS AND BIOGRAPHIES

### ***A. Distributed Multi-Energy Options to Increase Environmental Efficiency in Smart Cities***

#### *1) Authors:*

**P. Mancarella** (University of Manchester, Great Britain)

#### *2) Abstract:*

The recent trends in social development show that in the next decades an increasing larger share of the population worldwide will live in cities. Decarbonising the energy footprint of urban areas becomes therefore a critical point in the outlook of meeting challenging environmental targets set by Governments in many Countries and eventually fighting climate change. Optimal utilization of local resources represents a strategic area to improve the environmental efficiency of cities, and integrated operation and planning of the overall urban system is needed to optimize such efficiency. Hence, while various energy vectors such as gas, electricity, heat, and so on, have been traditionally decoupled in terms of operation and planning, the need to reduce emissions and the availability of smart grid technologies represent a significant opportunity to rethink urban energy systems. The objective of this paper is to discuss the main issues relevant to interaction of urban multi-energy systems facilitated by the deployment of smart grid controls.

Specific focus is set on distributed-multi-energy options to integrate natural gas, electricity, heat and cooling at various decentralisation levels (with in case the option of having district energy systems). Distributed Multi-Generation (DMG) technologies analysed include combined heat and power (CHP) and micro-CHP, electric heat pump (EHP), Photovoltaics (PV), solar thermal, electrical and thermal storage, various types of chillers for trigeneration applications, and heat and cooling networks.

Models, benefits, issues, enablers, and performance indicators to develop optimal integrated DMG systems in urban areas from both operational and planning perspectives will be discussed in the final paper, supported by illustrative quantitative examples. While the focus will be on understanding the techno-economic and flexibility potential as well as control requirements and challenges of different DMG options to increase the CO<sub>2</sub> emissions and primary energy performance of Smart Cities, analysis will also be performed to take into account more local issues such as pollution emissions, waste utilization, water requirements, and so forth.

#### *3) Biographies:*

**Pierluigi Mancarella** (M'08) received the Ph.D. degree in Electrical Engineering from the Politecnico di Torino, Torino, Italy, in 2006. After working as a Research Associate at Imperial College London, UK, he is currently a Lecturer in Sustainable Energy Systems and Power System Economics at the University of Manchester, Manchester, UK. His research interests include modelling and analysis of multi-energy systems, impact of distributed multi-generation technologies on distribution networks, system level analysis of integrated energy sectors, sustainable development of energy systems, energy markets, and risk analysis of generation and network investment. He is author of two books, five book chapters, and more than 60 papers in the above topics. He is a member of IET and CIGRE.

## ***B. Estimation and Classification of Power Losses due to reduced Power Quality***

### *1) Authors:*

**T. Bantras, V. Cuk, J.F.G. Cobben, W.L. Kling**  
(Eindhoven University of Technology, the Netherlands)

### *2) Abstract:*

A Power Quality problem is defined as a problem that results in voltage, current, or frequency deviations and subsequently in failure, misoperation or premature aging of customer's equipment. However, beside these consequences, reduced Power Quality also leads to additional losses in the power system. Three phenomena that lead to additional losses, namely Harmonic Distortion, Unbalance and low Power Factor, are presented in this paper and a method for calculating the losses that they cause in the various parts of a typical industrial installation, such as transformers and cables, are analyzed. Additionally, a classification method for these losses is proposed. The goal was to create a classification method which could be implemented in an instrument which estimates the various losses and present them to the end user in a simple and understandable way.

### *3) Biographies:*



**Thomas Bantras** received the Bachelors degree in Electrical Engineering from the Democritus University of Thrace, Greece, in 2010. Since 2010 he is a student at the Sustainable Energy Technology master programme of the Eindhoven University of

Technology.



**Vladimir Cuk** received his dip. ing. (M.Sc.) degree in electrical engineering from the School of Electrical Engineering, University of Belgrade, Serbia, in 2005. During 2006-2009 he was with the Electrical Engineering Institute "Nikola Tesla" in Belgrade. Since 2009 he is a PhD candidate at the Electrical Energy Systems group of the Eindhoven University of Technology. His main research topic is electrical power quality.



**Sjef Cobben** was born in Nuth, Netherlands, in 1956. He received the Bachelors degree in Electrical Engineering from the Technical University of Heerlen in 1979. In 2002 he received the Masters degree in Electrical Engineering from Eindhoven, University of Technology (TU/e).

In 1979 he joined NUON, one of the largest energy organizations in the Netherlands. Since 2000 he is working for the Dutch grid operator Liander, where he is engaged in Power Quality problems and safety requirements. From 2003 to 2007 he worked part time on a Ph.D. project about "intelligent grids" with as special topic Power Quality problems. He is member of several national and international standardization commissions about requirements for low and high voltage installations and characteristics of the supply

voltage. He is author of several books about low voltage installations and power quality. Since 2011 he is also working as part-time professor at the University of Technology in Eindhoven.



**Wil Kling** received his M.Sc. degree in Electrical Engineering from the Eindhoven University of Technology, Eindhoven, the Netherlands, in 1978. Since 1993, he has been a part-time Professor with the Delft University of Technology, the Netherlands in the field of Electrical Power Systems. Up till the end of 2008 he was also with TenneT, the Dutch Transmission System Operator, as senior engineer for network planning and strategy. Since Dec. 2008, he has been appointed Chair of the Electrical Energy Systems group, Eindhoven University of Technology. He is leading research programs on distributed generation, integration of wind power, network concepts and reliability issues.

Prof. Kling is involved in scientific organizations such as CIGRE and the IEEE. As Netherlands' representative, he is a member of CIGRE Study Committee C6 on Distribution Systems and Dispersed Generation, and the Administrative Council of CIGRE.

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## ***C. Estimation of end user voltage quality including background distortion***

### *1) Authors:*

**C. Debruyne, J.M. Desmet and L. Vandeveld**  
(Technical University College Howest, Belgium)

### *2) Abstract:*

Often power electronic converters are used to increase the energy efficiency of electrical loads, even though these power electronic devices create a distortion of the voltage, inversely affecting the energy efficiency of other electrical components integrated in the grid. Summation of current harmonics and the resulting current distortion has been extensively studied, summation of voltage distortion has not yet been addressed.

Within this paper simulations are performed to analyze the distortion generated by loads and a measurement campaign has been set up to estimate the back ground distortion of the supply voltage. The background distortion is integrated in the simulation model leading to correct estimation of the end user voltage quality.

Simulations are evaluated resulting in summation rules to estimate the voltage distortion at end user.

### *3) Biographies:*



**Colin Debruyne** received the Master Industrial Engineering degree in Electrotechnical Engineering from the Technical University HoWest, Kortrijk, Belgium, in 2004. Since 2004 he has been a researcher at the Technical University HoWest, Kortrijk, mainly

in the field of power quality and general electro technical engineering. Since '09 he is a Ph.D. student at the University of Ghent, Ghent, Belgium, where he is working on evaluating the magnetization of permanent magnet synchronous motors when supplied with a non-sinusoidal voltage wave shape.



**Jan M. Desmet** received the Polytechnical Engineer degree from the polytechnic academy in Kortrijk, Belgium, in 1983, the M.Sc. degree in Electrical Engineering in 1993 from the V.U.Brussels, Belgium and in 2008 his Ph.D. degree at the K.U.Leuven, Belgium. Currently he is full professor at the Technical University Howest teaching power quality, renewables and industrial electric measurement techniques. He is also IASTED and IEEE member, member of SC77A (IEC) and TC210 (CENELEC).



**Lieven Vandeveld** was born in Eeklo, Belgium in 1968. He graduated in electromechanical engineering at Ghent University in 1992 and is since then with the Electrical Energy Laboratory (EELAB). He received the Ph.D. degree from Ghent University in 1997.

Since 2004, he is professor in electrical power engineering. His research and teaching activities are in the field of electrical power systems, electrical machines and (computational) electromagnetics.

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#### ***D. Harmonic Measurement and Modeling for Mass Implementation of Non-Linear Appliances***

##### *1) Authors:*

**A. S. Koch, J. M. A. Myrzik** (TU Dortmund, Germany),  
**T. Wiesner, L. Jendernalik** (RWE, Germany)

##### *2) Abstract:*

In order to analyse the effects of a widespread use of non-linear appliances harmonic measurements are done on specific examples like compact fluorescent lamps (CFL) and photovoltaic (PV) inverters. The results of the investigation determine requirements on non-linear models, which are necessary to consider the impact of mass implementation. Particularly, the voltage and operating point dependency of the harmonic currents are taken into account.

Furthermore, this paper provides an overview of existing non-linear models and emphasizes their advantages and disadvantages. Thereby, the main focus is on models, which uses a measurement based approach.

##### *3) Biographies:*



**Anna S. Koch** was born in Herdecke, Germany in 1984. She received her degree in business administration and engineering (focus on

energy management) from the TU Dortmund University in March 2010. Currently, she is research associate at the Institute of Energy Systems, Energy Efficiency and Energy Economics at the TU Dortmund University.



**Johanna M.A. Myrzik** was born in Darmstadt, Germany in 1966. She received her MSc. in Electrical Engineering from the Darmstadt University of Technology, Germany in 1992. From 1993 to 1995 she worked as a researcher at the Institute for Solar Energy Supply Technology (ISET e.V.) in Kassel, Germany. In 1995 Mrs. Myrzik joined the Kassel University, where she finished her PhD thesis in the field of solar inverter topologies in 2000. From 2000, Mrs. Myrzik joined the Eindhoven University of Technology, Netherlands. In 2002 and in 2008 she became an assistant professor and an associate professor respectively. Since September 2009 she is a full professor at the TU Dortmund University, Institute of Energy Systems, Energy Efficiency and Energy Economics. Her fields of interests are: energy efficiency, renewable energy, distributed generation, power quality and power electronics.

**Thomas Wiesner** is head of the asset management unit of the Network Control Division for German distribution grids of RWE. He focuses on maintenance and replacement strategies as well as process optimization in the transmission business area. Mr. Wiesner graduated in Electrical Engineering at TU Dortmund University and received a PhD for his research of decentralized energy infrastructures. In 2002 he joined the RWE group and held various positions, e.g. in regulation and grid management. Since 2007 he is mainly responsible for the subject SmartGrids in the RWE Energy AG and became a member of the experts forum for SmartGrids of the RWE Rheinland-Westfalen Netz AG in 2010.



**Lars Jendernalik** was born in Hagen, Germany, in 1967. After study of electrical engineering and PhD at the TU Dortmund University, Mr. Jendernalik joined VEW Energie AG. He worked in several positions for VEW and RWE. Since 2007 he is responsible for the strategic and operational asset management of electrical networks of RWE Westfalen-Weser-Ems Verteilnetz GmbH.

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#### ***E. DMS and optimal swarm optimization for minimizing the burden of electric vehicles on active distribution networks***

##### *1) Authors:*

**E. Ghiani, G. Celli, F. Pilo, G. Pisano, G.G. Soma**  
(Unica, Italy)



2) *Abstract:*

Many recent factors have boosted the commercialization process of both Plug-in Hybrid Electric Vehicles (PHEVs) and pure Electric Vehicles (EVs). However, without controlled charging, large deployment of electric mobility could increase power flows in the distribution networks, particularly during peak electricity demand, causing critical network operation conditions. On the contrary, if Vehicle-to-Grid technology is implemented, the electric vehicles can become useful resources, because their whole energy storage capacity can potentially help distributors in their active network management (peak shaving, voltage regulation, integration of renewable generation). This vision requires a suitable coordination among the Distribution Management System of the Active Distribution Network and the aggregators of PHEVs and EVs. In the paper, a Particle Swarm Optimization approach is proposed to define the optimal control strategy of the aggregator that maximizes the revenues for the vehicle owners (from the V2G applications) and simultaneously satisfies the technical requests of the DMS.

3) *Biographies:*

**E. Ghiani, G. Celli, F. Pilo, G. Pisano, G.G. Soma**

***F. Introducing Smart Grids in Flanders: lessons learnt from the Linear project;***

1) *Authors:*

**J.Driesen, E.Peeters, P.Tant, R.Belmans** (K.U.Leuven, Vito, Belgium)

2) *Abstract:*

Linear (Local Intelligent Networks and Energy Active Regions) is a large-scale project about smart grids. It is collaboration between industry and research institutes. The Flemish government, as well as the industry, support the project financial with budgets for innovation. The project is carried out by a consortium of around twenty partners and will last 5 years (2009-2014). This project is crucial for Flanders to realize a transition towards sustainable energy supply and is one of the projects to occupy a leading position within the European innovative regions. This paper reports on the early findings and lessons learnt.

3) *Biographies:*

**J.Driesen, E.Peeters, P.Tant, R.Belmans**

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#### V. PANEL SESSION CHAIRS



**Wil L. Kling** (M'95) received the M.Sc. degree in electrical engineering from the Eindhoven University of Technology, the Netherlands, in 1978.

From 1978 to 1983 he worked with Kema, from 1983 to 1998 with Sep and since then up till the end of 2008 he was with TenneT, the Dutch Transmission System Operator, as senior engineer for network planning and network strategy. Since 1993 he is a part-time Professor at the Delft University of Technology and since 2000 also at the Eindhoven University of Technology, the Netherlands. From December 2008 he is appointed as a full Professor and chair of Electrical Energy Systems group at the Eindhoven University of Technology.

He is leading research programs on distributed generation, integration of wind power, network concepts and reliability issues.



**Johanna M.A. Myrzik** was born in Darmstadt, Germany in 1966. She received her MSc. in Electrical Engineering from the Darmstadt University of Technology, Germany in 1992. From 1993 to 1995 she worked as a researcher at the Institute for Solar Energy Supply Technology (ISET e.V.) in Kassel, Germany. In 1995 Mrs. Myrzik joined the Kassel University, where she finished her PhD thesis in the field of solar inverter topologies in 2000. From 2000, Mrs. Myrzik joined the Eindhoven University of Technology, Netherlands. In 2002 and in 2008 she became an assistant professor and an associate professor respectively. Since September 2009 she is a full professor at the TU Dortmund University, Institute of Energy Systems, Energy Efficiency and Energy Economics. Her fields of interests are: energy efficiency, renewable energy, distributed generation, power quality and power electronics.