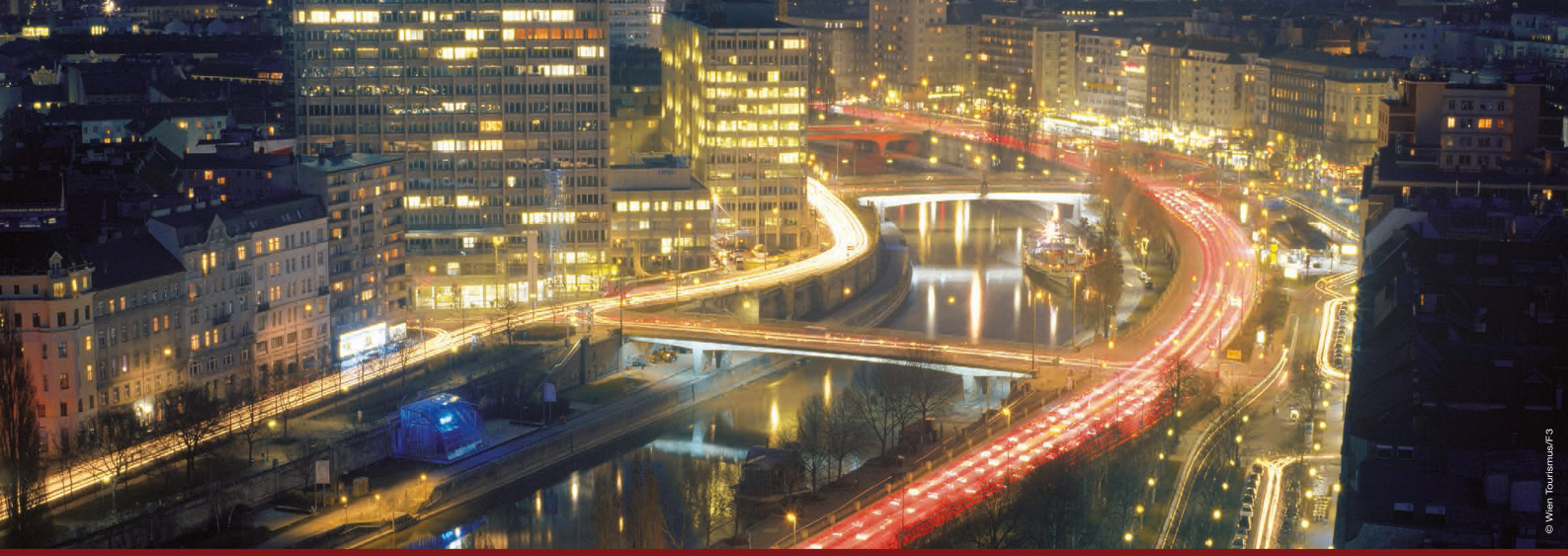

IECON 2013 November 10–13 2013, Vienna, Austria

Conference Booklet

IECON 2013

39th Annual Conference of the IEEE Industrial Electronics Society

in conjunction with

ICELIE 2013: 7th International Conference on e-Learning in Industrial Electronics

IWIES 2013: 1st International Workshop on Intelligent Energy Systems (14.11.2013)

Austria Center, Vienna, Austria
10-13 November 2013

Sponsored by the
IEEE Industrial Electronics Society

MONDAY 11th of November

	D-349	D-351	D-355	D-358	D-441	D-445	D-446	D-447	G-5432	G-560	G-631	H-633	Hall-D	Hall-G	Hall-H	Hall-I	Hall-K	Hall-P	I-140	I-141	K-142	K-246	K-253	K-255	K-261	S-357	U-556	U-637
08:00-09:30													Opening						PC Brief									
09:30-10:00																												
10:00-12:00	TT02 12	SS68-1	SS73	TT08 1	TT06 1	SS52 1	SS27 1	SS18 1	SS17 1	TT07 1	TT07 12	TT12 1	TT01 2	TT01 13	TT01 21	TT01 40	TT01 18	TT02 1	TT00	SS16 1	TT06 12	Press Conf	SS23 1	SS01 1	TT03 1	TT02 15	TT10 1	SS06 1
12:00-13.00																												
13:00-15:00	TT01 37	SS68 2	TT01 5	TT08 2	TT06 2	TU ZSI	TU Ind 4.0	TU MCS	SS17 3	TT07 3	TT07 14	TT12 3		TT01 16	TT01 6	TT01 1	TT01 19	TT02 6	TT00	SS16 2	TT09 1	TT06 13	SS23 2	SS01 2	TT03 2	TT02 2	TT10 2	SS06 2
15:00-15:30																												
15:30-16:30	SS48 1	SS68 3	SS47 1	TT08 3	TT06 3				SS17 3	TT07 3	TT07 14	TT12 3		TT01 17	TT01 7	TT01 4	TT01 20	TT02 14	TT00	SS35 1	TT09 2	TT06 14	SS23 3	SS01 3	TT03 3	TT02 3	TT10 3	SS06 3
16:30-17:30						TC ESOC	TC SG																					
17:30-18:00	TC AT	TC BACM	TC IA	TC HM	TC CRM	TC EEIT	TC EEIT	TC MEMS	TC II	TC FA		TC ES							TC NCSA	IFC	TC RES		TC MC	TC RSIA	TC EM	TC SA	TC STD	TC PETC
18:00-18:30																												

TUESDAY 12th of November

	D-349	D-351	D-355	D-358	D-441	D-445	D-446	D-447	G-5432	G-560	G-631	H-633	Hall-D	Hall-G	Hall-H	Hall-I	Hall-K	Hall-P	I-140	I-141	K-142	K-246	K-253	K-255	K-261	S-357	U-556	U-637
08:00-10:30	SS60 1	SS71 1	SS72 1	TT08 4	TT06 4	TU-EVCIDG	TU-PHM	TU-IETCPC	SS46 1	TT07 4	TT07 15	TT12 4		IF	TT01 8	EI13	TT01 27	TT01 29	TT00	SS41 1	TT09 3	TT06 15	SS23 4	TT05 1	TT03 4	TT02 4	SS62 1	SS09 1
10:30-11:00																												
11:00-11:30	SS60 2	SS71 2	EE67	TT08 5	TT06 5									IF	TT01 9	EI13	TT01 22	TT01 30	TT00	SS13	TT09 4	TT06 16	SS23 5	TT05 2	TT03 5	TT02 5	TT1 1	SS09 2
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13:00-14:00																												
14:00-16:00	SS58 1	SS20 1	SS57 1	SS63 1	TT06 6	TU-FCIRS	TU-MDPEM	TU-XENPI																				
16:00-16:30									SS45 1	TT07 6	TT07 17	SS21		IF	TT01 10	EI13	TT01 23	TT01 31	SS64 1	SS10	TT09 5	TT06 17	SS28 1	TT05 3	TT03 6	TT02 13	TT11 2	SS03 1
16:30-18:30	SS58 2	SS20 2	SS53	SS63 2	TT06 7				SS45 2	TT07 7	ICELIE 1	SS42		IF	TT01 11	EI13	TT01 24	TT01 32	SS50 1	SS34 1	TT09 6	TT06 18	SS28 2	TT05 4	TT03 7	TT02 7	TT11 3	SS03 2

WEDNESDAY 13th of November

	D-349	D-351	D-355	D-358	D-441	D-445	D-446	D-447	G-5432	G-560	G-631	H-633	Hall-D	Hall-G	Hall-H	Hall-I	Hall-K	Hall-P	I-140	I-141	K-142	K-246	K-253	K-255	K-261	S-357	U-556	U-637
08:30-10:30	SS32 1	SS15 1	SS59	TT04 1	TT06 8				SS26 1	TT07 8	ICELIE 2	SS43 1		IF	TT01 12	EI13	TT01 25	TT01 33	SS02 1	SS04	TT09 7	TT06 19	SS28 3	SS19 1	TT03 8	TT02 8	SS49 1	SS44 1
10:30-11:00						TU-EH	TU-SSTC	TU-NET																				
11:00-11:30	SS32 2	SS15 2	TT00	TT04 2	TT06 9				SS26 2	TT07 9	ICELIE 3	SS43 2		IF	TT01 15	EI13	TT01 26	TT01 34	SS61		TT09 8	EI13	SS28 4	SS19 2	SS07 1	TT02 9	SS49 2	SS44 2
11:30-13:00						IES WIC																						
13:00-14:00																												
14:00-16:00	SS32 3	SS38 1	IES AT	TT04 3	TT06 10	SS01 4	SS12 1	SS37 1	SS29 1	TT0710	ICELIE 4	SS43 3		IF	TT01 14	EI13	TT01 3	TT01 35	SS14 1		TT07 18	TT06 20	SS28 5	SS19 3	SS07 2	TT02 10	SS51 1	SS69 1
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16:30-18:30	SS32 4	SS38 2	IES Chap	TT04 4	TT06 11	SS01 5	SS30 1	SS65 1	SS29 2	TT07 11	ICELIE 5	SS43 4			IES JT	EI13	TT01 28	TT01 36	SS14 2		TT01 39	TT01 39	SS08 1	SS19 4	SS07 3	TT02 11	SS51 2	SS69 2

THURSDAY 14th of November

	D-349	D-351	D-355	D-358	D-441	D-445	D-446	D-447	G-5432	G-560	G-631	H-633	Hall-D	Hall-G	Hall-H	Hall-I	Hall-K	Hall-P	I-140	I-141	K-142	K-246	K-253	K-255	K-261	S-357	U-556	U-637
08:30-10:30				IES Prep		IES Prep				IES Prep	IWIES 1																	
10:30-11:00																												
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13:00-14:00																												
14:00-16:00				IES Prep		IES Prep		IWIES 5		IES Prep	IWIES 4																	
16:00-16:30																												
16:30-18:30				IES Prep		IES Prep				IES Prep	IWIES 6																	

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Welcome Message of the IECON 2013 Chairs

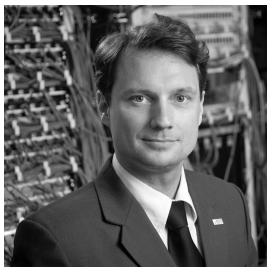
The 39th Annual Conference of the IEEE Industrial Electronics Society (IECON2013), November 10-13, 2013 at Austria Centre Vienna, Austria, is focusing on industrial and manufacturing theory and applications of electronics, controls, communications, instrumentation and computational intelligence. The purpose of IECON 2013, following the footsteps of the previous editions, is to promote activities in various areas of industrial electronics by providing a forum for exchange of ideas, presentation of technical achievements and discussion of future directions. The IECON2013 brings together an international community of experts to discuss the state-of-the-art, new research results, perspectives of future developments, and innovative applications relevant to Power Electronics & Energy Conversion, Renewable Energy & Sustainable Development, Power Systems, Electronic System on Chip & Real Time Embedded Control, Signal and Image Processing & Computational Intelligence, Electrical Machines & Drives, Control Systems & Applications, Sensors, Actuators and Systems Integration, Mechatronics & Robotics, Factory Automation & Industrial Informatics, Information Processing and Communications, and related areas.

IECON is the Industrial Electronics Society's flagship conference. IECON 2013 is the biggest IECON ever, has the largest industry forum, exhibition, number of contributed papers, number of high-quality tutorials, student events, number of countries and side events. IECON 2013 had 1983 papers submitted from more than 80 countries. We will have 1350 papers for oral presentation at the conference after first going through a rigorous review process, then by second going through a quality control process conducted at the Program Committee (PC). The technical Program of IECON 2013 consists of two Keynote Talks, an Industrial Forum, a Student Forum, 311 technical sessions in 12 tracks and 66 special sessions, and 12 tutorials.

We would like to express our sincere appreciation to the IECON 2013 organizing committee members. The conference with such scale will not be possible without their strong commitment and efforts. Last but not the least, our sincere gratitude go to all the authors and invited speakers, for your participation and for providing the intellectual sharing on experiences. We hope you will enjoy Vienna experience while you find IECON2013 a fruitful, memorable conference technically and socially. Welcome and enjoy your stay in Vienna!

Program Chairs

Peter Palensky, Luis Gomes, Mo-Yuen Chow



General Chairs

Dietmar Dietrich, Ren C. Luo, John Y. Hung



Welcome Message of the ICELIE 2013 Chairs

Dear Participant,

We would like to welcome your contribution in the IEEE-ICELIE 2013. Our Conference is focusing this year on: "Engineering Education in Sustainable Development" and is co-located with IECON 2013, the 39th Annual Conference of the IEEE Industrial Electronics Society.

The purpose of ICELIE conference series is to provide a forum for presentation and discussion of modern education and electronic learning methods for teaching in the field of industrial electronics and the related disciplines. Never before have the challenges in engineering education been as strong as today. Never has so much been demanded of engineers. There are two main reasons for that:

- Firstly, we can observe an enormous (and accelerated) growth of the area of engineering. In addition to the traditional fields, new engineering disciplines emerges, e.g.: Bioengineering, Software Engineering, Information Engineering, Data engineering, Medical Engineering, Neuro Engineering, Gene Engineering and Systems Engineering as integrating discipline.

- Secondly, we can observe a terrific acceleration of the life cycles of technical (or engineering) products. The field of engineering has never seen such growth and suffered such reduced times to bring their innovations from concept to market. Competition in the field of technology nowadays is measured in month and weeks. As a result new integrated philosophy in engineering education has emerged to serve the reduced design cycle time such as Mechatronics and concurrent engineering.

Those and other factors show the growing challenge and needs for flexible learning of modern Engineering Education and Pedagogy, exactly the focus of our conference! The conference committee had the challenge of keeping the conference focus on the specific eLearning of the educational process as applied specifically on industrial electronics. Therefore, many good papers had to be rejected as deemed to be outside the scope of this conference.

ICELIE 2013 is the output of the collaborative work of the Industrial Electronics Society’s technical committee on education with the IEEE Education Society. We hope you will find this focussed conference intellectually stimulating and culturally enjoyable. We wish you an enjoyable time in Vienna.

ICELIE General Chairs

Yousef Ibrahim, Michael Auer

Welcome Message of the IWIES 2013 Chairs

Dear Participant,

We would like to welcome you and your contribution to the 2013 IEEE International Workshop on Intelligent Energy Systems (IWIES). This event takes place on November 14, 2013 the first time. It is collocated with IECON 2013, the flagship conference of the IEEE Industrial Electronics Society.

The purpose of IWIES is to bringing together researchers from academia, industry, standardization and public authorities to discuss recent developments in architectures, concepts and algorithms for managing the increasing complexity in energy systems.

The main focus of this year's workshop is on managing the complexity in energy systems, especially in Smart Grids. Today's power and energy systems are currently in a transformation process towards a smarter grid in order to cope with the large scale integration of Distributed Energy Resources (DER), Intelligent and Controllable Loads and E-vehicles. Advanced Information and Communication Technology (ICT) solutions and management concepts are one of the key enablers of the future Smart Grid. In order to cope with ever increasing complexity of the Smart Grid itself and its corresponding Cyber-Physical components and devices new architectures, concepts, algorithms, and procedures are necessary.

Overall 48 papers have been submitted to IWIES 2013. The above mentioned topics will be covered by 32 accepted papers which have been carefully selected during a quality controlled review process supported by the IWIES Program Committee. These papers will be presented in 6 different technical sessions. In addition a keynote presentation about the usage of artificial intelligence for Smart Distribution Grid control will give insights about the newest trends in Smart Grids research.

We would like to thank all members of the IWIES 2013 organizing committee as well as all contributors making this workshop possible. Moreover, we want to express our special thanks to the IEEE Industrial Electronics Society supporting IWIES 2013 as well as to the IEEE Systems, Man, and Cybernetics Society as technical sponsor. Many thanks go also to the IEEE Austria Section promoting this event.

We wish all participants an interesting workshop day and fruitful discussions in Vienna!

IWIES General Chairs

Thomas Strasser, Xinghuo Yu, William Gruver



Welcome Message of the Industry Forum Chairs

Dear Delegates,

We would like to welcome you to the Industry Forum of the 39th Annual Conference of the IEEE Industrial Electronics Society (IECON2013).

The Industry Forum series of the IEEE Industrial Electronics Society provides specialized conference sessions hosting speakers from industry to discuss product and technology directions, challenges, and other industry issues with creation, application, and production of products using Industrial Electronics Technologies and necessary computational, communications, and security infrastructures needed to use these technologies.

For IECON 2013 – the Flagship Conference of the IEEE Industrial Electronics Society – we are having interesting industry forum sessions to the following topics:

- *Automation:* Industrial Electronics Technologies are evolving with application areas being driven from cloud services. Challenges and industry directions in this area are presented and discussed.
- *Security:* It is an increasingly growing and complex problem particularly for industry solutions where critical infrastructure can be attacked. During this session industry speakers addressing different technology area exposing the challenges and directions of security across industrial electronics technologies including control systems, remote power management, and others.
- *EV Technologies:* Industrial electronics play an important role in the development of EV technologies. Demands of the EV market are changing with adoption growing slower than expected. The goal of this session is to discuss challenges and solutions in the area of E-mobility.
- *Power and Energy Systems:* The demand for advanced Industrial Electronics solutions is growing in the power industry satisfying Smart Grids needs. These sessions examines challenges and trends dealing with power electronics, information and communication technology, smart energy management systems, power utility automation, smart consumers and the integration of renewables into the future energy grids. Also results from demo projects are presented.
- *LED Lighting:* Recent developments in LED lighting provide a big potential for energy savings. Industrial trends and developments regarding LED technology (new material), LED lighting and applications are the main focus of this session.

These topics are presented and discussed in 7 different sessions with overall 34 presenters mainly from industry.

We wish all participants an interesting Industry Forum and fruitful discussions in Vienna!

Industry Forum Chairs

Michael W. Condry, Victor K. L. Huang, Thomas Strasser



Overview

Exhibition, Coffee Breaks and Lunches are in Foyer GH and Foyer D

Sunday

- Welcome Reception –- 19:00, City Hall

Monday

- Opening Ceremony –- 8:30 in Hall D
- IECON Sessions, IECON Tutorials
- Technical Committee Meetings – 16:30/17:30, see program
- IES student scholarship posters, absent authors posters -- 18:00, Foyer A
- Banquet –- 18:45, Hall A

Tuesday

- IECON Sessions, IECON Tutorials
- Industry Forum, Hall G
- ICELIE Exhibition, Room G 631

Wednesday

- IECON Sessions, IECON Tutorials
- Industry Forum, Hall G
- ICELIE Sessions, Room G 631
- IECON closing and Farewell Party, 18:30 in the cellar

Thursday

- IWIES Sessions, Rooms G 331 and D 447
- IES AdCom Prep-Meetings

Friday

- IES AdCom

General Information

CONFERENCE LOCATION

The Conference location is the Austria Center Vienna (ACV).

ACV is situated next to the United Nations Office Vienna at the following civic address:

Bruno-Kreisky-Platz 1,

1220 Vienna,

Austria

Tel: +43 1 260 69 0

http://www.acv.at

HOW TO GET THERE

Using the public transportation in Vienna

The ACV is located in Vienna's Business District Donau City, so it is easy to reach the Conference site using the subway U1. The closest subway station is "Vienna International Center" (VIC). Exiting the subway station turn right, cross the street, go straight ahead and reach the ACV in a few minute walk.

From Airport Vienna/Schwechat

By Car

Follow Highway A4 towards Vienna up to Highway A23 (direction Praha/Brno/A22). Take Highway A23 up to Highway crossing Kaisermühlen and take there Highway A22 (direction Praha/Brno). Then follow Highway A22 until Exit Austria Center/Vienna Int. Center. Now follow the signage for the ACV parking lot.

By City Airport Train CAT

Frequency: every 30 minutes

16 minutes to Landstrasse/Wien Mitte Station. Then take subway line U3 (direction Ottakring) to station Stephansplatz and change to subway line U1 (direction Leopoldau) to station Vienna International Center.

Tickets: 12 EUR (for CAT, excl. subway)

By Rail S-Bahn commuter railway (S7)

Frequency: every 30 minutes

27 minutes to Landstrasse/Wien Mitte Station. Then take subway line U3 (direction Ottakring) to station Stephansplatz and change to subway line U1 (direction Leopoldau) to station Vienna International Center.

Tickets: 4.30 EUR

By Airport-Bus

Frequency: every 30 to 60 minutes

30 minutes directly to the ACV (stop: Wien Kaisermühlen-Kagran)

Tickets: 8 EUR

WELCOME RECEPTION

A welcome reception will be held on Sunday November 10th, 19:00 in the Vienna City Hall, entry is at 18:45 at Felderstraße 1 (take the Feststiege II up to the festival hall). Bring your personal invitation sheet to get entry to the building.

BANQUET

The conference banquet will be held on Monday November 11th at 19:00 (Cocktail at 18:45). Both formal and smart casual dress is acceptable for the banquet. Please take your badge with you. The event will take place at the conference venue ACV, main hall A.

IES TECHNICAL COMMITTEES MEETINGS

The Industrial Electronics Society's technical committees (TC) will meet during the conference program, most of them on Monday late afternoon. Check the program for the TC of your interest and join the discussion!

INTERNET SERVICES

Wireless Internet access for Laptops and Smartphones will be provided to IECON2013 participants during the Conference days. The following information is needed in order to access the wireless network:

Wireless Network: IECON2013

Username: IECON2013

Password: Join_IES_at_the_IEEE_desk

PARKING AT THE AUSTRIA CENTER VIENNA

The Austria Center Vienna provides covered, secure parking for delegates.

- Approx. 1,000 parking spaces
- Parking for about 40 coaches at main entrance level
- Disabled parking spaces in the multi-storey garage
- Fees: 3 EUR/ 1. Hour, every additional hour 1 EUR, max. daily fee 10 EUR

USEFUL ADDRESSES

Website of the conference: www.iecon2013.org

E-mail address of the conference: office@iecon2013.org

REGISTRATION

Registration is required for all Conference participants, including officials, session chairpersons, tutorial presenters, exhibitors and authors. Family members need not to register for the Conference but must register and prepay for the Banquet. The Conference registration fee includes admittance to all technical sessions, a copy of the conference program, the conference proceedings on USB, lunches and refreshments.

Registration Desk

The registration desk is located in ACV, on the second lower level (U2) and is open during the following hours:

Monday November 11th 2013 7:30 to 17:00

Tuesday November 12th 2013 7:30 to 17:00

Wednesday November 13th 2013 7:30 to 12:00

Thursday November 14th 2013 7:30 to 12:00

Badges

Badges must be worn at all times in order to gain entry to the scientific sessions and other functions organized by the conference. Accompanying persons who complete the appropriate section of the registration form will be given distinctive badges.

AUDIO-VISUAL EQUIPMENT

Each session room will be equipped with an electronic projector. To avoid presenters overlap and disruption of the session, author/presenter will not be allowed to use her/his own computer and all files will need to be downloaded to the computer from a USB key. All presentations will be supported with Microsoft PowerPoint software. Each author/presenter must assure that all fonts needed for his presentation are embedded in the files, which are compatible with Microsoft Office 2007. You should have your presentation on a USB key and download it before the session starts.

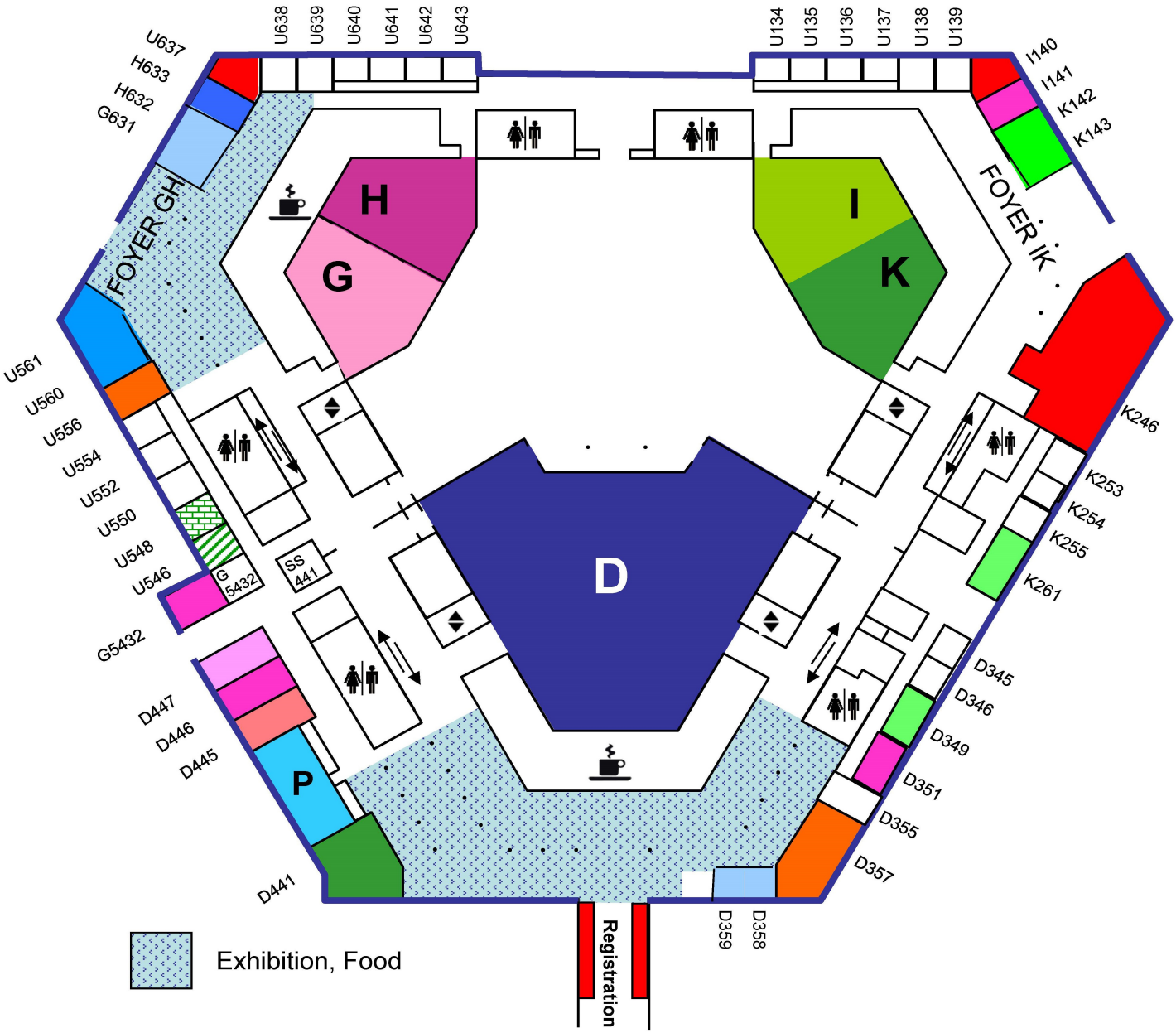
ORAL PRESENTATION

For all oral sessions, each paper is allotted 20 minutes for the presentation, including 5 minutes for questions. Session Chairpersons have been asked to adhere strictly to the timetable to allow delegates to attend the papers of their choice where no conflicts exist; special effort been made to reduce such conflicts to the minimum possible. The presenters are required to meet their session chairman in the session room at least 15 minutes before the scheduled time in order to introduce themselves and receive the appropriate instructions from the session chairs. Each author/presenter has to provide the session chairman with a PowerPoint or PDF presentation, as well as a short (10-line maximum) printed bio.

STUDENT SCHOLARSHIP AND ABSENT AUTHOR POSTERS

Authors that could not come due to unforeseeable reasons provided posters that are displayed in the absent author session. Also the IES student scholarship winners present posters there. Check the program for the location and time.

Floor Plan AUSTRIA CENTER Level U2



Opening Keynote

Gerald Deboy, INFINEON

Challenges and System Solutions for Maximizing Energy Efficiency in SMPS and PV applications

Energy Efficiency is the major requirement to our modern society both within generation from Renewable Sources as well as along the entire conversion chain to the final load such as a CPU processor. We will start with a look into todays system architectures and its inherent limitations. Based on this analysis we will review alternative scenarios and discuss their requirements in terms of topologies, control and needed power devices. Examples will include 380V DC distribution, combined energy generation and storage, DC/DC converters and decentralized power management for PV systems. The resulting requirement profile and Figure-of-merits for power devices will be discussed on the basis of a fundamental analysis of the switching transition. The talk will review the latest achievements in silicon-based power devices in comparison to the value proposition of wide-band gap devices. An outlook into ideal combinations of topologies and devices will close the talk.

Gerald Deboy received the M.S. and Ph.D. degree from the Technical University Munich in 1991 and 1996 respectively. He joined Siemens Corporate Research and Development in 1992 and the Semiconductor Division of Siemens in 1995, which became Infineon Technologies later on, contributing mainly to optical investigation methods for ICs and power devices during this period. His research interests were later focused on the development of new device concepts for power electronics, especially the revolutionary COOLMOS(tm) technology. From 2004 onward he has been heading the Technical marketing department for power semiconductors and ICs within the Infineon Technologies Austria AG. Since 2009 he is heading a business development group specializing in new fields for power electronics. He is a Sr. member of IEEE and has served as a member of the Technical Committee for Power Devices and Integrated Circuits within the Electron Device Society. He has authored and coauthored more than 70 papers in national and international journals including contributions to three student text books. He holds more than 50 granted international patents and has more applications pending.

Banquet Keynote

Sabine Seidler, Vienna University of Technology

German-born Sabine Seidler studied at Merseburg University of Applied Sciences from 1979 until 1984. In 1989, she completed her Doctorate in Material Sciences and moved to the Martin Luther University in Halle-Wittenberg, where she worked for seven years in the Institute of Material Science. In 1996, she became the first ever female professor at Vienna University of Technology. Between 2001 and 2007, she managed the Institute of Materials Science and Technology, before becoming Vice Rector for Research in 2007. On 4 March 2011, she was appointed as the Vienna University of Technology's first ever female rector. She assumed this post on 1 October 2011.

Sabine Seidler's research focuses on the areas of structure-property relationships in polymers, fracture mechanics and plastics testing. She has produced numerous publications and conference papers. She has also co-edited several books.

Sabine Seidler is a member of the scientific advisory committee of the Helmholtz Centre in Geesthacht, the Centre of Material and Coastal Research, the Leibniz Institute of Polymer Research in Dresden, Fraunhofer Austria Research and the supervisory board of AMAG (Austria Metall AG). She is also a member of numerous academic committees, associations and networks.

IWIES Keynote

Sebastian Lehnhoff

University of Oldenburg / OFFIS

ICT-Challenges in self-organizing provision of Ancillary Services in future Smart Grids

Future electrical power systems will be composed of large collections of autonomous components. Sensors and actuators, aware of their environment, with the ability to communicate freely, will have to organize themselves in order to perform the actions and services that are required for a reliable and robust power supply. Monitoring and efficiently operating such a system is a challenging task for the underlying information and communication (ICT) infrastructure as well as the system's "intelligence" to efficiently perform these tasks while guaranteeing the necessary power quality.

Self-organization is an organizational concept that promises systems with the ability to adapt themselves to system perturbations and failures and thus may yield highly robust systems with the ability to scale freely to almost any size.

Prof. Dr. Sebastian Lehnhoff is a Professor for Energy Information Systems at the University of Oldenburg. He received his doctorate at the TU Dortmund University in 2009. Prof. Lehnhoff is member of the executive board of the Energy R&D division at the OFFIS Institute for Information Technology. He is speaker of the special interest group „Energy Information Systems“ within the German Informatics Society (GI) and active member of numerous committees and working groups focusing on ICT in future Smart Grids. His research interests are self-organizing energy systems, distribution grid automation as well as methods for real-time power system analysis and computation.

IEEE IECON 2013 Organizing Committees

Honorary Chairs

Leopoldo G. Franquelo (Spain)
Kouhei Ohnishi (Japan)
Gerard-Andre Capolino (France)
Okyay Kaynak (Turkey)

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Dietmar Dietrich (Austria)
John Y. Hung (USA)
Ren C. Luo (Taiwan)

Technical Program Chairs

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Luis Gomes (Portugal)
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Mariusz Malinowski (Poland)
Yoichi Hori (Japan)

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Andrés Meléndez Augusto Nogueiras (Spain)

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Dietmar Bruckner (Austria)
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Juan J. Rodriguez-Andina (Spain)

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Heimo Zeilinger (Austria)
Carlo Cecati (Italy)
Seta Bogosyan (USA)

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Georg Lauss (Austria)

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Hao Ma
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Aleksander Malinowski

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Roberto Oboe
Kioshi Ohishi
Yousef Ibrahim
Makoto Iwasaki

Factory Automation & Industrial Informatics

Valeriy Vyatkin
Paulo Leitao

Information Processing and Communications

Thilo Sauter
Stamatis Karnouskos
Jose Fonseca

Electric and Plug-in Hybrid Electric Vehicles

Sheldon Williamson
Akshay Kumar Rathore
David Dorrell

Special Session Organizers

SS01-Matrix Converters
Marco Rivera Abarca
Jose Rodríguez
Patrick Wheeler
Haitham Abu-Rub

SS02-Power Management based on Advanced Identification and Classification Techniques
Thomas Bier
Djaffar Ould Abdeslam
Dirk Benyoucef
Jean Merckle

SS03-Induction heating systems
Óscar Lucía
Claudio Carretero

SS04-Control and Filtering For Distributed Networked Systems
Qing-Long Han
Josep M. Fuertes
Mo-Yuen Chow

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Edgar Weippl (AUSTRIA)
Alois Zoitl (GERMANY)
Gerhard Zucker (AUSTRIA)

Tutorials

Ellabban, Omar (Texas A&M University at Qatar)	Z-Source Inverter: Basics, Modeling, Controlling, topology modifications and applications	Nov 11 Afternoon
Markus Aleksy (ABB Corporate Research, Germany)	Industry 4.0 - Utilizing Wearable & Mobile Systems for Improved Service Delivery	Nov 11 Afternoon
Suzanne Lesecq (Campus, Grenoble, France)	Tools, Services and Engineering methodologies for Robust, Adaptive, Self-organising and Cooperating Monitoring and Control Systems	Nov 11 Afternoon
Johan Driesen (ESAT--ELECTA, Belgium)	Electric Vehicle Charging Integration in Distribution Grids	Nov 12 Morning
Daniel Hissel (FCLAB Research Federation (CNRS))	PHM of fuel cell system – a state of the art	Nov 12 Morning
Thilo Sauter (Vienna University of Technology)	Industrial Ethernet – Technologies, Comparisons, Practical Considerations	Nov 12 Morning
Francisco M. Gonzalez-Longatt (Coventry University)	Frequency Control and Inertia Response Schemes for the Future Power Networks	Nov 12 Afternoon
David A. Staton (Motor Design Ltd, United Kingdom)	Modern Design Process of Electric Motors	Nov 12 Afternoon
Olivier Tremois (Xilinx: Le Val Saint Quentin – Bat B)	Xilinx - Enabling New Product Innovations Across Markets with Zynq-7000 All Programmable SoC, Vivado HLS and IP Integrator	Nov 12 Afternoon
Andrew S. Holmes (Imperial College London)	Energy Harvesting from Motion: Fundamentals and Recent Advances	Nov 13 Morning

Johann Walter Kolar (Power Electronics - ETH Zurich)	Solid-State Transformer Concepts in Traction and Smart Grid Applications	Nov 13 Morning
Toshiaki Tsuji (University of Saitama, Japan)	New Emerging Technologies in Motion Control Systems	Nov 13 Morning

Panel: “Criteria and Expectations for Publishing Papers in IES Journals”

The editors of the IEEE IES publications “Transactions on Industrial Electronics”, “Transactions on Industrial Informatics” and “Industrial Electronics Magazine” will discuss issues for publishing journal papers. You are kindly invited.

Chair: Dave Irwin

Panelists: Carlo Cecati, Bogdan 'Dan' Wilamowski, Juan Jose Rodriguez Andina, Kim Man, Mo-Yuen Chow, Leopoldo Franquelo, Marco Liserre, Kouhei Ohnishi and Maria Ines Valla.

Room: Hall H

Time: Wednesday Nov 13, 16:30

Technical Committee Meetings

All IES TC Meetings are on Monday Nov 11 late afternoon and are open to everyone.

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Building Automation, Control and Management	D - 351	17:30	18:30
Control, Robotics and Mechatronics	D - 441	17:30	18:30
Data Driven Control and Monitoring	D - 446	17:30	18:30
Education in Engineering and Industrial Technologies	D - 445	17:30	18:30
Electrical Machines	K - 261	17:30	18:30
Electronic Systems on Chip (ESOC)	D - 445	16:30	17:30
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Factory Automation	G - 560 / 561	17:30	18:30
Human Factors	D - 358 / 359	17:30	18:30
Industrial Agents	D - 355	17:30	18:30
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MEMS & Nanotechnology	D - 447	16:30	18:30
Motion Control	K - 253	17:30	18:30
Network-based Control Systems and Applications	I - 140	17:30	18:30
Power Electronics Technical Committee (PETC)	U - 637	17:30	18:30
Renewable Energy Systems	K - 142 / 143	17:30	18:30
Resilience and Security for Industrial Applications (ReSia)	K - 255	17:30	18:30
Sensors and Actuators	S - 357	17:30	18:30
Smart Grids	D - 446	16:30	17:30
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TT5 Signal and Image Processing & Computational Intelligence

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SS17 3 - Predictive Control for Power Converters and Drivers

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SS19 2 - New Trends in Converter Topologies and Control Methods for Active Power Distribution Grids II

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SS43 4 - Power Converters, Control and Energy Management for Distributed Generation

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SS51 1 - Intelligent Information Processing for the Smart Grid: Innovative Estimation, Control and Optimization Methods

SS51 2 - Intelligent Information Processing for the Smart Grid: Innovative Estimation, Control and Optimization Methods

SS52 1 - Advanced Control Strategies for Wind Turbines Fault Ride-Through Capability Enhancement

SS53 - Self-organising Robust Automation Systems

SS57 1 - Advanced Power Electronics for Power Factor Correction in Distributed Generation Systems

SS58 1 - Current Status of Intelligent Spaces - Conversion of Robotics, Mechatronics, Control and Interfaces I

SS58 2 - Current Status of Intelligent Spaces - Conversion of Robotics, Mechatronics, Control and Interfaces II

SS59 - Systems and devices for promoting energy efficiency in compressed air systems

Increasing Energy Efficiency with Traffic Adapted Intelligent Streetlight Management

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***Abstract*— Street lighting consumes a non inconsiderable amount of energy. First promising approaches include the deployment of LED based lights to reduce energy consumption. The paper presents a further step of increasing energy efficiency by implementing traffic adapted intelligent management strategies of the luminaries. The idea is to include a communication module into each streetlight that exchanges data via a field aggregated point device with a streetlight management center being an integral part of a traffic management system. Information of the current traffic situation is delivered by traffic sensors and applies traffic adapted control of the luminaries. Consequently, additional energy savings and CO2 reductions are possible without decreasing road safety because a traffic dependent level of luminosity can be provided if needed.**

Keywords*— *Intelligent infrastructure, services and functions, LED based streetlight

I. Introduction

In the last years some effort has been made to reduce energy consumption of street lighting. A promising solution is the deployment of LED based luminaries. A next step has been the integration of intelligent functionality in today's streetlights. The basic idea is to add a communication module to each streetlight making it possible to control and monitor each luminary individually from a central station via wireless or wired communication [1,2]. This strategy has been introduced step by step with growing levels of 'intelligence'.

At the beginning, the focus was on integrating monitoring functionality which could reduce maintenance costs by reading out for example operational status and light failures. Successively and due to the emerging use of LED (Light Emitting Diode) technology in outdoor lighting, sensor-based control functionalities were integrated in order to save energy, reduce CO2 emission and energy costs. All approaches, however, propose a closed system, totally separated from any other system, such as a traffic management system (TMS).

The paper presents a system approach of a combined lighting and traffic management system to realize traffic adapted intelligent management of streetlights. Section 2 deals with state of the art and motivation. Section 3 presents a typical use case to be realized with integrated streetlight management. Section 4, in turn, details the system architecture and whereas section 5 gives information of preliminary results of energy assessment.

II. State of the Art and Motivation

Street lighting consumes a non inconsiderable amount of energy. Nowadays, they are switched off and on according to inputs of day and night sensors. Energy efficiency of lighting installations can be significantly increased as requested by European Commission (EC) directives by deploying LED based lights. In addition, sometimes level of luminosity is reduced on a time based manner during the on-time. A further and innovative step to raise energy efficiency is an integrated approach to intelligent streetlight management with a TMS.

A. Directives

In the lighting sector, a significant step was taken in 2005 with the EuP (Energy Using Products) 2005/32/EC directive issued by the EC, requiring that traditional light bulbs should be replaced by 2016 with more efficient technologies such as LED based luminaries. Moreover, European Commission issued the so-called 20/20/20 targets setting three key objectives for 2020:

- A 20% reduction in EU greenhouse gas emissions from 1990 levels;
- Raising the share of EU energy consumption produced from renewable resources to 20%;
- A 20% improvement in the EU's energy efficiency.

For example, in Austria it is planned to increase deployment rate of energy efficient streetlight installations from 3-5% to 6-10% per year as a means to meet 20/20/20 targets [3].

B. LED-based Streetlight and Management

In today's streets and parking areas various types of luminaries are installed such as high pressure sodium, high pressure mercury, metal-halide lamps or lamps with traditional light bulbs. In recent years LED technology has been introduced to street lighting with numerous advantages because luminous efficiency (lumen per Watt) has reached a critical value where it makes sense to use them from a technical and economical point of view.

- Up to 80% energy saving compared to other lighting techniques
- Reduced maintenance costs thanks to high lifetime
- Wide dimming range for intelligent lighting applications
- Full light output immediately after switching on the lighting system
- White light for high light quality
- Significant decrease in light pollution (i.e., dark sky friendly) due to light being directed only onto the road

Intelligent management of streetlight is not a new idea created in the last months [4,5]. In general, such a system consists of a communication module for each luminary, a data concentrator collecting data from the lights and a management platform to monitor and control the system.

At the beginning, intelligent management was mainly used to monitor streetlights and therefore ease maintenance of installations. Next, time-based control mechanisms were introduced where level of luminosity was changed from one predefined value to another within a specified period of time. It was a first possibility to save energy and reduce energy costs. Dynamic control of streetlights based on sensor inputs, however, could not be realized. The reason on the one hand was that traditional light sources need some time to adjust to a new level of luminosity. On the other hand, due to their technology dimming of streetlights was only possible in a small range.

With recent LED and communication technology it is possible to realize innovative use cases because LED lights can be dimmed in a wide range and adjust the level of luminosity almost instantaneously. Additionally, wireless technologies such as ZigBee are proven in use to exchange data with luminaries reliably [7].

C. *Traffic Management Systems*

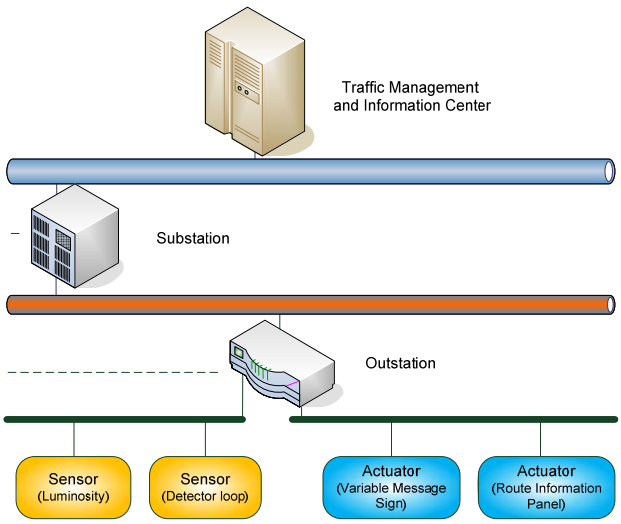

Fig. 1. Traffic management system

Today there is a common understanding that a possibility of optimizing traffic distribution and increasing road safety is the use of traffic management systems (TMS). They are typically structured in a hierarchical way [6] as shown in Fig. 1. At the top there is the Traffic Management and Information Center. It collects data from underlying substations and provides it to the operator for global strategies regarding traffic monitoring and control. Substations, in turn, take care of intermediate data collection. They are linked to one or more Outstations where Actuators (e.g., Variable Message Signs) and also Sensors (e.g., detector loops) are connected to. Outstations are responsible for data processing and autonomous control jobs.

Put succinctly, a TMS requires sensor data to get a picture of the current traffic and environmental status and controls actuators to manage traffic in cities or on motorways. The approach to intelligent street lighting proposed in the paper is to include intelligent streetlight as an application into a TMS. Available sensor data is applied to control streetlights (being a further actuator in the system) according to the current traffic situation.

The benefit of this kind of approach is manifold:

- Traffic adaptive adjustment of luminosity level of streetlights can be realized
- No additional deployment of sensors for streetlight control
- Reduction of energy consumption without endangering road safety
- Reduction of CO2 emissions
- Reduced installation and maintenance costs

III. Use Case

For developing and evaluating the integrated streetlight management system various use cases are defined. Section III.A discusses terms that are required to understand the use cases that, in turn, are discussed in Section III.B.

A. *Terms*

- *Use case* describes all possible scenarios that could proceed in order to reach a pre-defined objective.
- *Scenarios* represent one possible sequence of events that lead to the objective of the use case.
- *Situation* is defined by all received input data. This group contains low level information, high level information and user commands received via the user interface (e.g. configuration or monitoring tasks)
- *Low level information* is represented by raw sensor data which are received from street lighting site.
- *High level information* is traffic information, like the level of traffic flow, weather forecasts or lane consistence provided by e.g. motorway operators.
- *Energy profile* specifies all mappings of possible situations to control commands within a use case. They vary with the use cases and are optimized towards low energy consumption.

- *Source area* defines a subarea at the lighting system location. All sensors that are positioned within this subarea belong to one source area.
- *Impact area* defines a group of streetlights at the site. Control processes actuate all lights within at least one impact area. Impact areas are specified for every use case. Streetlights are assigned to only one impact area.

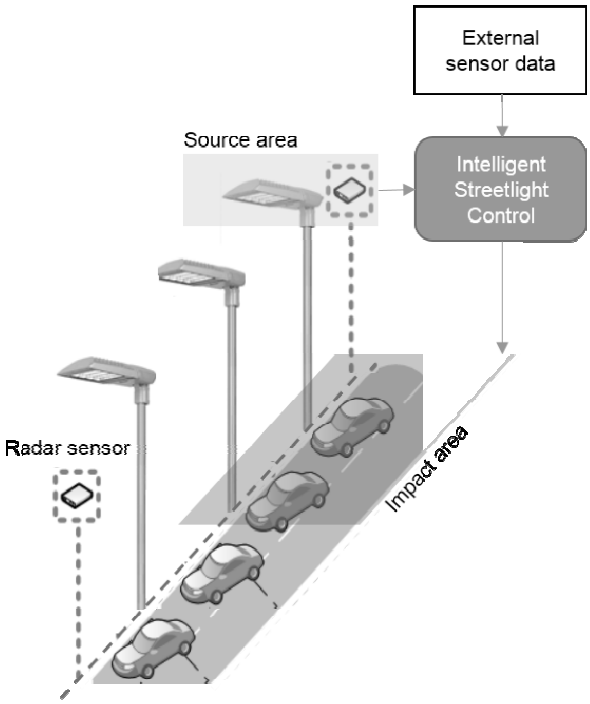

Fig. 2. Typical architecture for use cases

B. Use Cases

In the following typical use cases are presented that shall be realized with an intelligent streetlight management system. It is a prerequisite that system functionalities are specified decoupled from particular scenes and use case characteristics which are introduced through varying sensor and actuator nodes at the site as well as energy profiles and system parameters. Hence, when introducing a new scene, only configuration tables must be accessed.

Specified scenes should cover a wide area of possibilities, so that new use cases mainly base on already existing ones. As result, three scenes are defined with respect to the traffic type:

- Moving traffic: Straight road
- Mixture of stationary and moving traffic: Parking area
- Stop and go traffic: Bus stop

For further explanations, we stay with the "Moving traffic" scene which is also the most common one (see Fig. 2). At site a number of streetlights are positioned along the lane. Traffic sensors (e.g., based on radar technology) detect passing vehicles as well as their direction. It is important that the system's reaction time is incorporated in deciding for the location of the radar sensor. It should be avoided that the level of luminosity of a streetlight is adapted after the vehicle had passed. Cross roads, parking areas along the road as well as pedestrians are ignored at first for the sake of reduced complexity.

Radar sensors, ambient light sensors as well as humidity sensors are part of sensor array that provides input to the intelligent streetlight management. In addition, input from external information provider like motorway characteristics or weather forecasts are received. Section IV.B discusses the control module architecture in detail. All sensors are assigned to one source area. Actuators are assigned to impact areas and are controlled via the control module output. For the proposed use case, actuators are restricted to streetlights.

The following situations are identified for the proposed scene in a qualitative manner:

- Single traffic
- Heavy traffic / congestion
- No traffic
- Inactive site

Furthermore, three use cases are identified that depend on time and events:

- Dimming up
- Dimming down
- Inactive street lights

Use case 1 is applied when the traffic situation changes from low to high and a vehicle passes the radar sensor. Then the sensor informs the streetlight management (see Fig. 2) where the vehicle is registered. The traffic flow is calculated (no/single/heavy/congestion). Based on available system information, the control module identifies a situation. The appropriate impact area is selected and an actuator command generated. This command is forwarded to the streetlights that are registered to the impact area. Use case 2 becomes relevant when the traffic situation changes from high to low. During day as well as during certain events the intelligent management could be deactivated. Both scenarios are related to Use case 3.

As mentioned above, the straight road scene as well as its assigned use cases forms the basis for extensions like cross roads, parking lots, or additional control options like a dynamic light-band. In the following section the system architecture is discussed in detail.

IV. System Architecture

In the section the system architecture of the whole enhanced TMS with included streetlights management is presented. It starts with an introduction to the whole system and continues with a presentation of the streetlight management center.

A. Overview

Fig. 3 gives an overview of the system architecture. Although architecture strongly depends on existing installations and legacy systems, typically, the following devices are necessary.

- Intelligent streetlight: This is the light fixture at a field point. It includes a monitoring and control device (controller) that monitors and controls the luminary. It can read status information or dim a luminary at field point. The device interfaces to the Gateway.
- Field aggregated point device (Gateway): This is the field device used to collect information from individual controllers and to interface with the Streetlight Management Server. The Gateway acts as a bridge between the local communication network used to reach the Controllers and the wide area communication network to the Streetlight Management Server.
- Streetlight Management Server: This is the server that runs application software, graphical user interface, and web services. It interfaces with the gateways through the wide area communication network.

In addition, an intelligent streetlight management includes communication networks to exchange data among the various devices. Typically, the link between management server and gateways is based on wired Ethernet/IP connections. Data exchange from the gateways to streetlights can be realized by UMTS/UDP links for long distance coverage, short distance technology such as ZigBee (wireless) or Powerline (wired).

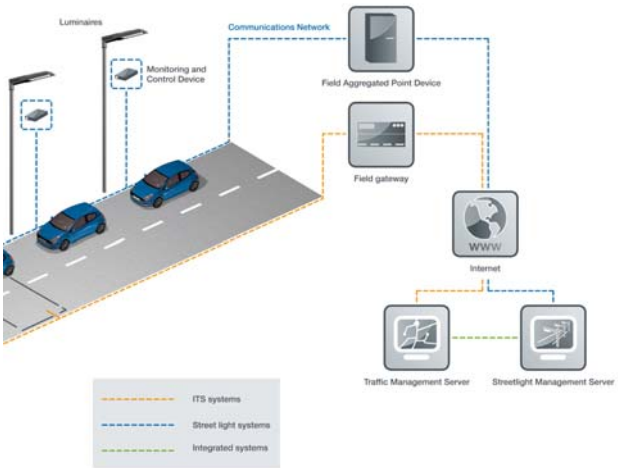

Fig. 3. System architecure

Given the fact that streetlight installations have a life time of up to 30 years, integration of streetlight applications into a TMS is realized on server level for the time being. In case of new installations other architectures are possible such as:

- The same field level gateway is used for accessing streetlight and traffic devices, but logical integration remains at management level with two independent servers. This scenario is a hybrid approach and might be of interest where parts of streetlights installations are retrofitted. Still, integration effort at field level is rather low, but overhead regarding the number of devices and data exchange is given.
- Full integration approach at field level is realized in such a way that only a single system is used at field and management level. This is preferable in general, but applicable almost only for new installations because of some effort to install and interconnect devices at the field level. The approach of integration reduces the amount of equipment to be deployed in the field.

B. Architecture of Integrated Management Center

Fig. 4 provides a rough overview of the streetlight management center that is an integral part of a traffic management center and provides interfaces to peripheral devices of three types: Streetlights, sensor arrays, user interfaces. In particular, five layers are identified: “Communication”, “Conditioning”, “Business”, “Service”, and “Persistence”.

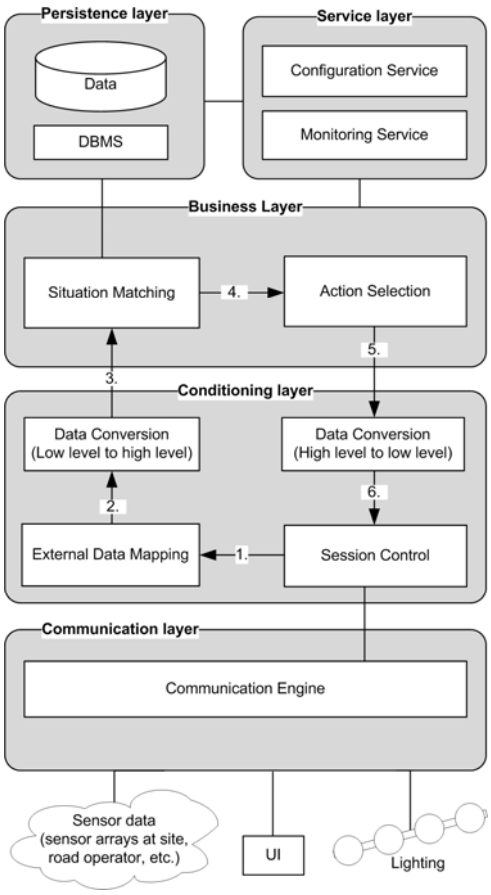

Fig. 4. Architecure of streetlight management center

Any data exchange between the management unit and its peripheral devices is conducted via the communication layer that provides a communication preparation as well as communication handling. The communication preparation handles incoming requests from the conditioning layer and triggers processes within the conditioning layer and service layer. The communication with peripheral devices is accomplished by applying the server-client model. Thereby, remote method invocation and remote procedure call methods (e.g. Java RMI [8], JSON [9]) are introduced.

The conditioning layer handles several tasks:

- Provision of a session control for opening, managing and closing communication sessions
- Management of polling and triggering routines which become relevant for different data sources and their time dependence; for instance, as the transit information of vehicles is time critical the radar sensor triggers an event any time a vehicle has passed. Contrariwise monitoring information (e.g., heat level or power consumption of streetlights) is temporarily not critical and therefore the control unit need not be aware of events immediately: they are polled after a specified time interval.
- Mapping of input data to an internal data structure as well as convert low level input to high level data (see Section III.A) and the other way round regarding the system output. Fig. 4 sketches the basic information flow marked by the arrows 1-6.

The database management system (persistence layer) holds configuration files, logging data as well as situation and scenario definitions that vary with the use case. The business layer and the service layer share an interface with the persistence layer.

The business layer is responsible for situation matching and the selection of lighting control commands. First, the input is mapped to matrices containing intervals for sensor values. These matrices represent situations. Afterwards the matched matrix is compared with the currently chosen matrix that represents the current system state. In case both matrices differ (at least one of the input values is within a different sensor interval) a situation transition is identified. Therefrom an energy profile is picked that leads to the lighting control command which is forwarded to the streetlight system via conditioning layer and communication layer.

The service layer holds the configuration service and the monitoring service. Both are accessed via the user interface. The configuration service provides an interface for adapting energy profiles, situation matrices or configurations of periphery devices. The monitoring service provides insights to logged messages and the current system state.

V. Energy Assessment

A major reason for installing intelligent LED based streetlight systems as part of a TMS is increasing energy efficiency without endangering road safety. In the following, calculated results regarding energy savings are presented and verified by preliminary results from field tests.

The installation scenario is a main road in a city with 10.000-15.000 inhabitants. The impact area (cf. Fig. 2) consists of 16 streetlights. We use SWARCO FUTURIT streetlights with 86 Wh of average energy consumption at 25°C without management. The streetlight includes 6 LED modules (see Fig. 5, lower part) with 12 LEDs each. They are controlled and monitored by a LED driver (see Fig. 5, upper part). It interfaces with the ZigBee based communication module. A change of the level of luminosity corresponds to altering the LED current.

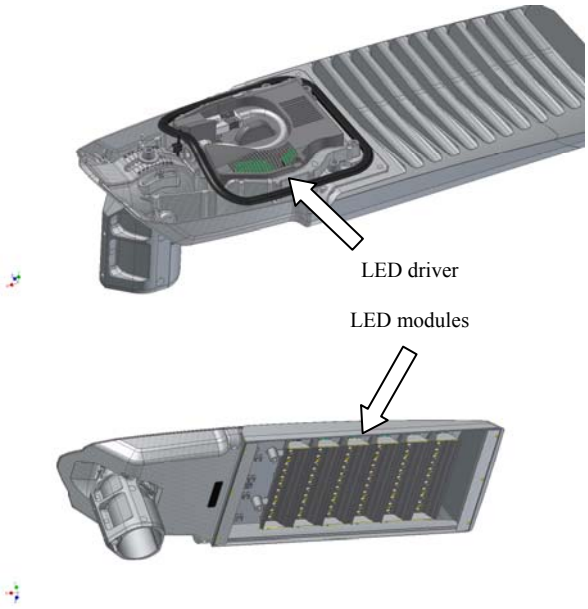

Fig. 5. LED based streetlight

We compare energy consumption with and without management under average winter and summer conditions. In average, two percent of further consumption for intelligent streetlight management is added to each streetlight. In winter scenario streetlights are on for approximately 15 hours a day, in summer for 9 hours. As mentioned in section III.B, the specified scene is “Moving traffic: straight road”. Moreover, four different levels of luminosity are specified (100% to 70%) and applied depending on the traffic situation (cf. section III.B). Note that level of luminosity with 100% and 90% corresponds to congestions or heavy traffic, 80% are used in case of single traffic and 70% as default. In case of management being off, level of luminosity is not changed and remains at 100% constantly.

TABLE I. Energy comparison of a single streetlight

Season	Luminosity	Duration [h]		Energy consumption management [Wh]	
		without	*with*	*without*	*with*
Winter	100%	15	4	1290	1114
	90%	0	2		
	80%	0	1		
	70%	0	6		
Summer	100%	9	0	774	615
	90%	0	1		
	80%	0	1		
	70%	0	6		

As shown in TABLE I. significant savings from 12-20% are possible on using intelligent streetlight management in such a scene. Since traffic volume is typically higher on week days than weekends (i.e., lower level of luminosity for longer period of time), savings can be increased on weekends. Additionally, seasonal effects (e.g., holiday season where traffic flow is different) are not considered because in today's installations all weekdays are treated equal.

VI. Conclusion

The paper presents a way of increasing energy efficiency in street lighting with the help of intelligent management of LED based luminaries and the adaption to traffic. It contributes significantly to a reduction of energy consumption, costs and CO2 emissions. In contrast to standalone systems not interfacing with traffic management systems road safety is not endangered because required level of luminosity is always provided.

The idea is to adapt the level of luminosity to the current traffic situation that, in turn, is monitored by traffic sensors. Since LED lights can be dimmed in a wide range and within a few seconds, the system can react with short delays on changing traffic conditions. Management of streetlight is included into a TMS to get detailed information on the traffic situation. Additionally, the deployment of further sensor infrastructure is not necessary because existing sensors of a TMS are used.

Further work comprises a broader assessment of energy consumption accounting different use cases and types of installations. Consequently, the benefit of such a solution is going to be proven and an increase of user acceptance is expected. In addition, such a system is an excellent tool for a platform deployed for smart cities.

Acknowledgment

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