Electrotechnische Vereeniging

MAXWELL

FUTURE

Issue 21.1

Wireless communication goes massive
Massive MIMO for 5G

Fluid arhitecture
Computer Engineering's hypothesis of the future

Hybrid grids
Power electronics and storage technology

From the Board

Commissioner of Education

Thomas Roos

Dear reader,

There is a fresh face behind the Education updates in Maxwell! My name is Thomas Roos and I am the new Commissioner of Education. It is my function to monitor and improve our education. In this section, I will update you on what happened in the world of education in the past quarter.

Just like previous years, many new students arrived in Delft in the start of the previous quarter. Transitioning to a (different) university can be challenging without the proper introduction and mentoring. For the past 35 years, the ETV has been organizing special weekends for freshmen to get them started, but for new Master's students this used to be subpar. This year, the Master Kick-Off program was drastically improved by making it more relevant and adding mentor groups.

Traditional chalk blackboards have been slowly making way for new beamers and display screens in the lecture halls. In the same way, this year, Blackboard has been phased out and replaced by Brightspace. Brightspace does not only look much more modern, but also standardizes more to make the user experience better. Although it is not perfect yet, it has been improving and listening to the feedback of its users.

Our current cohort of freshmen and the ones following them will be taught in English. While the Master's programs have been fully English for a while, the Bachelor's program used to be mixed. Changing with this freshmen's cohort, the Bachelor's program will be completely in English. The planned official change to English will not happen next year, thus the bachelor students will still need to master the Dutch language upcoming year.

Our faculty has many different separate places and people that can help students, but it has become complicated to figure out where or whom they should go to. We are working with the faculty to visualize these places and people, and make those different purposes more understandable for students. More awesome projects and improvements are being worked on by the faculty and me, so keep an eye on this section in the upcoming editions of the Maxwell!

If you have any questions or complaints regarding education, please send me an email at education-etv@tudelft.nl

President

William Hunter

Dear reader,

After a well-deserved vacation, our students picked up their books again. By the time you're reading this, the exams of the first quarter have already passed. For a lot of people, this new year marks the start of a new era. For some, this year marks the beginning of their final year in Delft; for some however, the adventure here has just begun. I'm talking, of course, about our new freshmen. A fresh start in a new city, a whole new approach to studying and a completely new group of people to meet: it's the start of a new chapter in their lives. It all started in August with the freshmen's weekend. It was then and there that I noticed the overwhelming enthusiasm present in the group.

With that same ardor these men and women started following their courses here in September. Looking ahead, I see a bright future for them. We, as the Board of the ETV, will commit ourselves to providing their time here in Delft with a wealth of activities and to creating a bond between the balanced group of students whom I hope to see for years to come. I hope you enjoy this splendid new edition of the Maxwell and I hope to greet you in our Board room!

Colofon

Year 21, edition 1, November 2017

Editors
Charlotte Zwart
Duco Veldhuijzen
Tom Salden
Simon Verkleij
Ainee Ansaari
Jun Feng

Contributors
Zaid Al-Ars, Emil Björnson, Marcel Brouwers Ronald Dekker, Tom Heijnders William Hunter, Rosario Incandela, Jasper Insinger, Olindo Isabella, Himabindu Kopally, Mart van der Meijden, Stefano Roos, Thomas Roos, Fabio Sebastiano, Sep Ursone, Peter Vaessen

Advertisements
Page 2 – Royal IHC
Page 10 – Huisman Equipment
Pages 20, 21 and 40 – Technolution

Printing
Quantes, Rijswijk, 1200 copies

Electrotechnische Vereeniging
Mekelweg 4
2628 CD Delft
The Netherlands
Phone number: +31 15 278 6189
Email: board-etv@tudelft.nl
Website: www.etv.tudelft.nl

146th Board of the ETV
President – William Hunter
Secretary – Tijs Moree
Treasurer – Wouter Kayser
External Affairs – Karen van der Werff
Education – Thomas Roos

Subscriptions
Non members can receive the Maxwell four time a year, against a contribution of €10,- per year.

Change of address
Please send your changes to the (email) address above, or use the website.

Editorial

Dear reader,

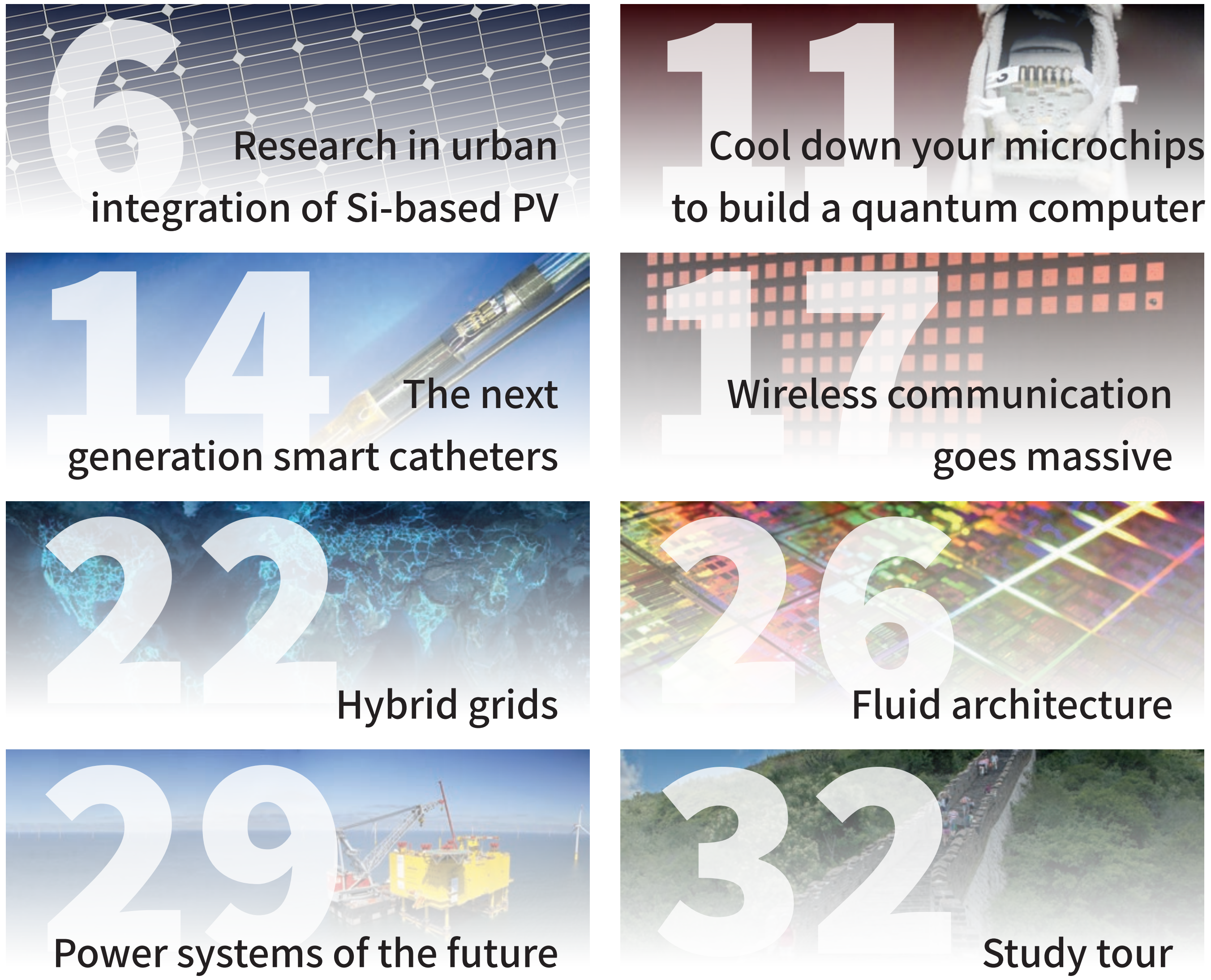
A lot has happened since the last Maxwell took a trip to the past. As Abraham Lincoln once said “The best way to predict the future is to create it”, therefore we will raise the bar even further and create a window into the future.

This year we’ve (once again) started from scratch with an all new Maxwell Committee and a different look. However, on some parts we have applied the principle ‘If it ain’t broke, don’t fix it’, therefore we’re continuing the themed editions.

This issue has the theme, ‘future’ with articles from every (sub)domain of Electrical Engineering elaborating on their future vision. It covers everything from internet connection on your phone to interconnection of the grid and everything in between. I hope you enjoy reading this edition and may it help shape your vision of the future!

Charlotte Zwart

Index



Research perspectives in urban integration of Si-based photovoltaics at the PVMD group

Dr. Olindo Isabella

The *Doomsday Clock* in the Bulletin of the Atomic Scientists [1] was set in early 2017 only *two and a half minutes to midnight*, not only because of nuclear weapons and cyber-attacks, but also because of climate threats. Mankind, whose energy greediness has led to excessive use of fossil fuels, is rapidly spending its *carbon budget* [2]. If fast actions are not taken within the next twenty years, the next generations will experience a different, more threatening climate than today's.

Current problems

In 2013, the world's total primary energy supply (TPES) reached a stunning value of 567 EJ, mostly based on fossil fuels [3]. However, having entered the declining phase of fossil fuel's age [4], in order to meet increasing global energy demand, renewable energy sources have to replace fossil fuels. Energy conversion technologies have to keep pollution low and avoid an irreversible increase of the global temperature. As shown in Figure 1, solar, geothermal, ocean, wind, hydro power, and biomass are renewable energies that may fit this scenario, but only solar energy *alone* possesses the potential of becoming the actual successor of fossil fuels [5]. Solar energy can be directly converted into electricity by photovoltaic (PV) technology. PV technology will contribute to the electrification of energy system, that will deliver electricity for many application areas, from communication, to healthcare, to mobility.

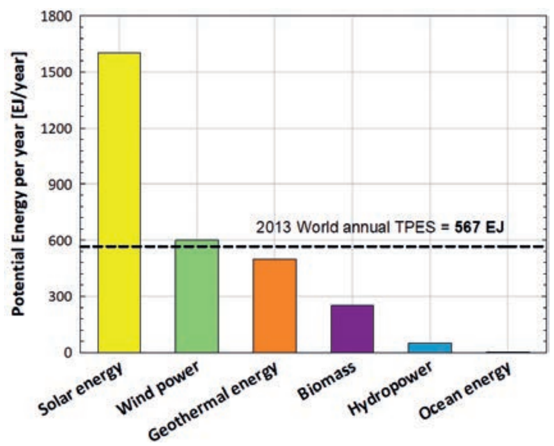


Figure 1. Potential energy production per year of various types of renewable energies. The horizontal line indicates the world energy consumption in 2013. One exajoule (EJ = 10^{18} J) is equivalent to the amount of energy released by burning about 2.4 million tons of crude oil.

As human population clusters in megacities, providing the megacities with energy, water and food is among the world's top ten challenges over the next fifteen years [6]. The share of electricity in the total final energy consumption will grow in the future and this trend is particularly valid for cities. Today, electricity networks are mostly mono-directional with power flow being transported and distributed from central power stations mostly run on gas, coal, and nuclear to the end users. However, there is a transition in the mix of primary energy sources from fossil fuels to renewable energy sources [7]. This transition will be further accelerated because the G20 countries agreed in Hangzhou (China, 2016) *to increase substantially the share of renewable energy in the global energy mix by 2030* [8]. The energy transition will have a strong impact on the electrical energy system since most renewable energy sources deliver electricity as useful energy. The electricity networks must be re-designed to allow a high penetration of electricity generated from renewable sources, such as solar and wind energy. In these future networks (see Figure 2), often called *smart grids*, power flows in two directions, from and to the consumer, since the consumer can generate electricity, use it on site, store it for later deployment or just feed it to the grid. This *smart* electricity infrastructure will be implemented in present and future (mega)cities making them *smart* too.

Smart City

The future electricity infrastructure in cities will be based on four pillars: (i) urban integrated photovoltaics (UIPV), (ii) energy storage, (iii) intelligent power control, and (iv) market management (see Figure 3 left). These four pillars are intimately intertwined, allowing instantaneous power flows to be used on site, stored, shared at urban level or even used as commodity exchange. The notion of UIPV systems embraces all possible kinds of PV systems. They will include not only classical built-added PV (BAPV) and modern building integrated PV (BIPV) systems but also those PV systems that are incorporated both aesthetically and functionally in the place of installation. These can be modular energy systems that can be easily expanded and that can be designed for a high annual energy self-consumption (see Figure 3 right). From *now on*, the hope is to limit climate threats by means of global electrification. In this respect, UIPV systems play a crucial role in providing sustainable electrical energy. These systems will be more efficient, cheaper, nicer and omnipresent in our cities. This will be achieved by combining innovations from different disciplines such as physics, engineering, architecture, industrial design, etc. In this multi-disciplinary context, the research at the Photovoltaic Materials and Devices (PVMD) group is carried out on three levels: (i) PV cells, (ii) PV modules and (iii) UIPV systems.

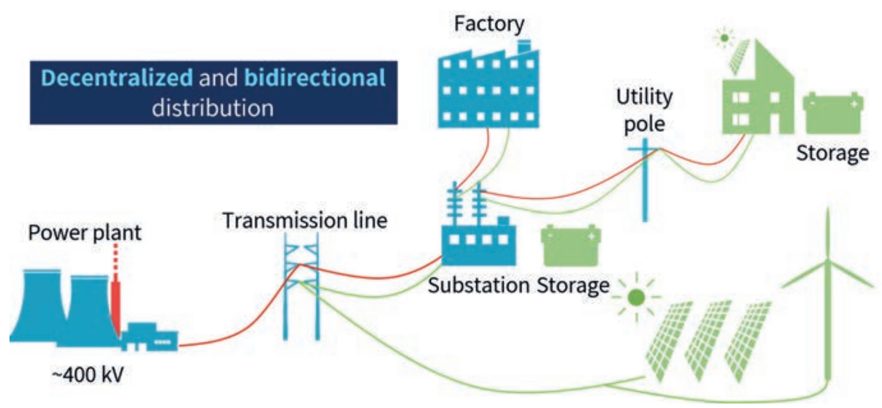


Figure 2. Conceptual schematic of decentralized and bidirectional distribution network. The electrical connections stemming from renewable sources are coloured in green.

Crystalline silicon (c-Si) PV technology

In 2016, crystalline silicon (c-Si) PV technology had a market share of 93% [9] with an average conversion efficiency at cell level of about 20%. This technology, whose theoretical conversion efficiency limit is 29.1% [10], is expected to keep on dominating the market for a long-time due to an unrivalled balance between performance and cost. The highest efficiency of c-Si solar cells demonstrated to date is beyond 26% and based on interdigitated back contacted heterojunction [11], which is a cell architecture not (yet) compatible with industrial-scale processes. At present, R&D efforts at the PVMD group related to c-Si solar cells are in three areas: (i) achieving high conversion efficiency with industrially-compatible approaches, (ii) developing highly-efficient ultra-thin c-Si solar cells and (iii) developing multi-junction solar cells.

"From now on, the hope is to limit climate threats by means of global electrification"

A detailed roadmap for c-Si PV technology at PVMD group was designed three years ago and is presented in Figure 4. The roadmap leverages on our three expertise: advanced opto-electrical modelling for loss analysis and device improvements [12], advanced nano-materials for high quality surface passivation based on carrier-selective passivating contacts [13], and advanced light management for maximal light harvesting [14].

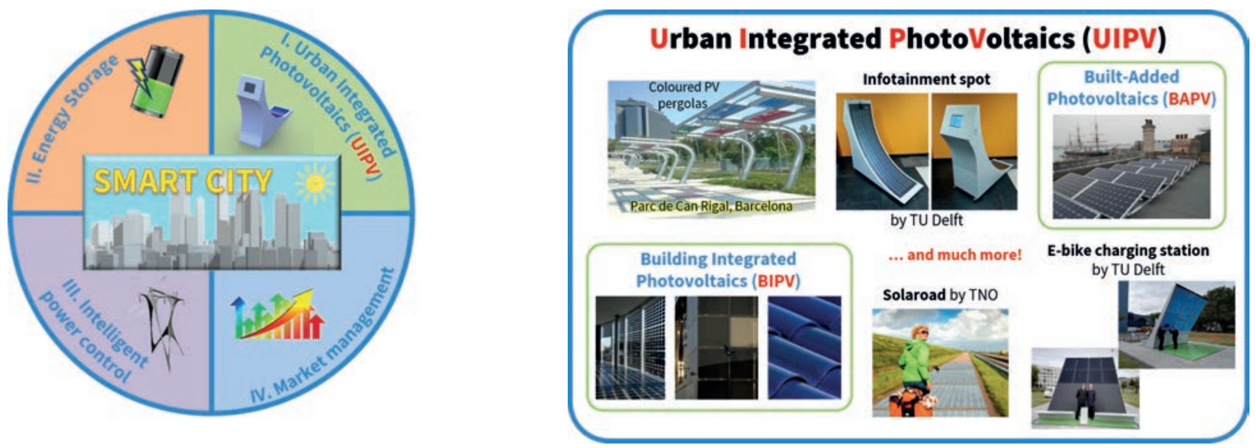


Figure 3. (Left) The four pillars defining the electrification of society in future smart cities; (right) Visual definition of environment integrated photovoltaic (UIPV) systems.

Developments at TU Delft

For research in area (i), we developed a reference c-Si solar cell in the Else Kooi Laboratory. Recently we have laid down foundations aiming to achieve the short-term challenges. Addressing long-term challenges in area (ii), we work on ultra-thin c-Si solar cells that can be highly efficient and bendable/flexible for implementation in UIPV systems. In particular, as cutting wafers below 80 μm proves to be challenging, three routes to obtain ultra-thin Si-based absorber will be followed. These are the epitaxial growth of c-Si on a seed layer, the crystallization of thin amorphous Si layer deposited on a substrate, and the development of novel low band gap (LBG) Si-based alloys, such as promising barium-disilicide ($BaSi_2$) films [15] . In area (iii), in cooperation with colleagues in the Netherlands [16], we develop multi-junction devices by stacking perovskite solar cells on our state-of-the-art c-Si solar cells. This approach can deliver solar cells with efficiencies beyond the Shockly-Queisser efficiency limit of single junction solar cells [17].

Regarding developments at module level, we are establishing expertise on module design and manufacturing for customized applications. With this aspect, we can cover the whole R&D value chain of UIPV systems, from manufacturing our own lab-scale solar cells to the realization of our own PV system demonstrators. For these purposes, lamination and laser cutting of solar cells are the enabling technologies that we have installed in the laboratory. Both rigid and flexible mini-modules will be fabricated following three main lines of innovativeness: aesthetics, performance, and cost-effectiveness (see Figure 5). In addition, we are contributing to the shift from simple PV systems to *smart* systems with PV + storage solutions, power management and communication capabilities.

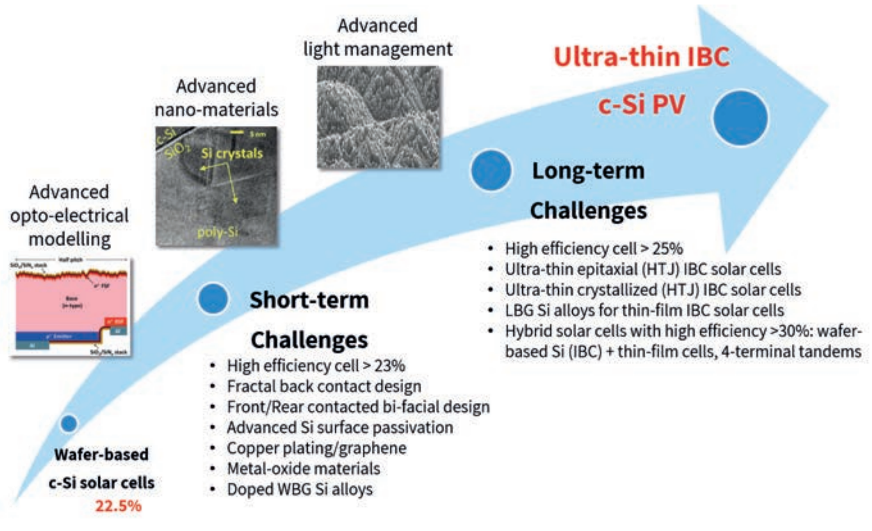


Figure 4. Roadmap of c-Si PV technology at the PVMD group. HTJ and IBC stand for heterojunction and interdigitated back contacted architectures, respectively.

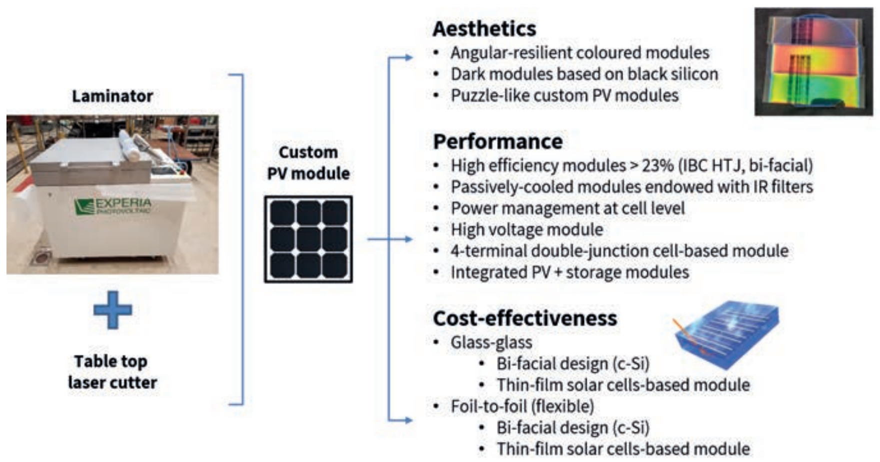


Figure 5. Enabling technologies (lamination and laser cutting, left) for fabricating custom mini-modules for three lines of innovativeness (right): aesthetics, performance and cost-effectiveness.

In the area of UIPV systems, we have recently developed a generalized comprehensive model [18] that accurately describes the opto-electrical behavior of any UIPV system. This model includes both the DC and the AC side of the system, i.e. from power generated from a module to the power injected into the grid. This model helps us to design UIPV systems and accurately predict their energy yield. We can present three examples of practical results of using the model: the Dutch PV Portal web application [19], the solar-powered e-bike charging station and the solar-powered infotainment spot (see Fig. 6). The roadmap for UIPV systems at the PVMD group is presented in Figure 6. For massive penetration of UIPV systems in society, research efforts will focus in the future on multi-functional building components with integrated PV modules, on PV louvers combined with LED for sustainable internal illumination [20] and smart PV modules solutions combining power generation, power management and storage.

Education

These three areas of research evolve continuously owing to advances in physics and in engineering techniques. We reflect on these advances and update our educational courses on solar energy. The Solar Energy MOOC (Massive Open Online Course) by prof. Smets [21] demonstrated how important transfer of knowledge in PV technologies and systems can be for individuals or entire villages in developing countries. Learning how to harness the energy from the sun in the form of electricity improves the quality of life. In addition, access to electricity and internet enabled by PV technology can change the access to education for 1.2 billion people who have no electricity at their disposal. Education is another top spot sustainable development goal of UN. At the PVMD group, we strive to provide everybody education in utilization of solar energy both on campus and on-line with our recently launched Solar Energy Engineering MicroMasters program [22]. In particular, we use solar energy as a vehicle for inspiring students to solve grand societal challenges such as energy transition and climate change. Our ambition is to make TU Delft the global leader in solar energy education. Based on this vision, the PVMD group offers [23] successful courses at BSc. level, a well-organized MSc. profile on solar energy, hands-on practical courses and workshops as well as a PV Systems Summer school.

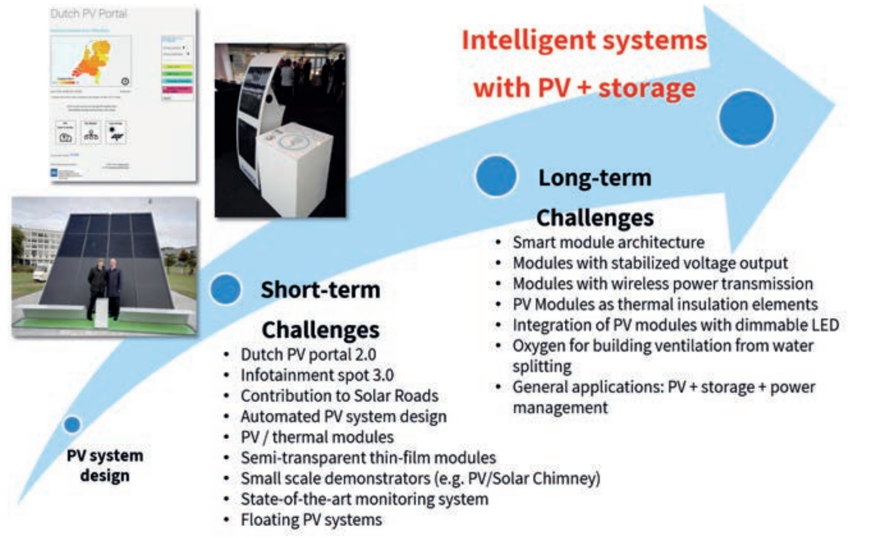


Figure 6. Roadmap of UIPV systems at the PVMD group. Efforts aim at smart UIPV systems with storage and multi-functional elements.

[1] http://thebulletin.org/sites/default/files/Final%202017%20Clock%20Statement.pdf
[2] https://www.carbonbrief.org/analysis-four-years-left-one-point-five-carbon-budget
[3] https://www.iea.org/publications/freepublications/publication/KeyWorld_Statistics_2015.pdf
[4] http://news.nationalgeographic.com/news/energy/2010/11/101109-peak-oil-iea-world-energy-outlook/
[5] http://www.worldwatch.org/files/pdf/SOW09_chap4.pdf
[6] http://www.un.org/sustainabledevelopment/
[7] http://www.planete-energies.com/en/medias/close/about-energy-mix
[8] https://ec.europa.eu/energy/sites/ener/files/documents/G20%20voluntary%20Actio%20Plan%20on%20Renewable%20Energy.pdf
[9] https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/Photovoltaics-Report.pdf
[10] A. Richter, et al., IEEE J. Photovolt. 3, 1184-1191 (2013).
[11] K. Yoshikawa, et al., Nat. Energy 2, 17032 (2017).
[12] P. Procel, et al., Progr. Photovolt. Res. Appl. 25, 452-469 (2017).
[13] G. Yang, et al., Sol. Energy Mater Sol. 158, 84-90 (2016).
[14] A. Ingenito, et al., Progr. Photovolt. Res. Appl. 23, 1649-1659 (2015).
[15] R. Vismara, et al., Opt. Express 25, A402-A408 (2017).
[16] https://www.nwo.nl/en/news-and-events/news/2017/enw/nwo-funds-development-of-hybrid-tandem-solar-cells.html
[17] W. Shockley and H. J. Queisser, J. Appl. Phys. 32, 510-519 (1961).
[18] O. Isabella, et al., 33rd European Photovoltaic Solar Energy Conference and Exhibition, Amsterdam, the Netherlands (2017).
[19] https://www.tudelft.nl/en/eemcs/the-faculty/departments/electrical-sustainable-energy/photovoltaic-materials-and-devices/dutch-pv-portal/
[20] Y. Gao, et al., 44th IEEE Photovoltaic Specialist Conference, Washington, U.S.A. (2017).
[21] https://www.edx.org/course/solar-energy-delftx-et3034x-0
[22] https://www.edx.org/micromasters/solar-energy-engineering
[23] https://www.tudelft.nl/en/eemcs/the-faculty/departments/electrical-sustainable-energy/photovoltaic-materials-and-devices/education/

Research into a new independent drive

Advertorial

'Variable Frequency Drives' (VFD's) are controlling the E-Motors in winches, tensioners, etc. Multiple VFDs and E-motors are used to control a movement. In the past, a custom-made Huisman application was loaded into the VFDs to get a controlled and safe movement. Due to the custom application, only VFDs of some brands were supported while Huisman experiences an increase in customer demand to the support other brands and more advanced features.

The biggest challenges (by moving the VFD logic to a PLC) were the accuracy of the control and torque differences between the VFDs. Firstly, all functionalities of the current Huisman VFD application were analyzed. Then, a model was created for handling the VFD functions in such a way that it was easy to deal with different Huisman installations. In this model, the VFD PLC is acting as a master of the movement, making sure that all VFDs work together. The VFD itself is handled as a "simple" motor controller. For testing purposes, a set-up was created with four motors which could be connected to each other. The motors could be driven with different VFDs (Figure 1).

Figure 1. HIT: two connected motors on the setback drum.

We found out that the new application has much better torque equalization around zero speed and during ramping, while also removing the difference between setpoint and actual speed. The new VDF-application is tested on the HIT (Huisman Innovation Tower). The HIT is a 90m high full-scale drilling tower which is used to demonstrate the Huisman drilling technology and to test new developments. At this moment, the HIT movements are fully operational.

In the meantime, the application will be further improved with functionality based on market requirements. The software will be developed such that we will be able to configure for every order (generate the VFD application automatically including basic settings). This will be more efficient and more accurate (saving time and money)!

Cool down your microchips to build a quantum computer... and do more!

Fabio Sebastiano and Rosario Incandela

Imagine you were the CEO of PostNL and you realize how inefficient your current delivery strategy is. You would like to minimize the fuel consumption by optimizing the delivery routes via a computer. Imagine, now, that you were a biochemist. The cellular mechanisms causing a terminal disease have been identified and your task is to synthesize a drug that inhibits those mechanisms. Experimental trials would take months and millions of euros. To avoid that, you have to run an accurate simulation of the involved molecules so that the new drug is available as soon as possible. What do these two scenarios have in common? Simple: the computer needed to optimize the PostNL delivery routes or to simulate complex molecular interactions, does not exist. Even the most powerful supercomputer will take longer than a lifetime to output the result.

Quantum computing as solution

Nevertheless, quantum computers may be a viable solution in those scenarios, thanks to the speed-up that they promise over their classical counterparts. A quantum computer exploits quantum effects to achieve unprecedented computational power. Classical information is encoded into bits, whose value can be either 0 or 1. On the contrary, a quantum bit used in a quantum computer, or qubit, can exist in a quantum superposition of 0 and 1 at the same time. Eric Ladizinsky, co-founder of D-Wave, gave a very intuitive example of what a quantum computer can achieve [1]: suppose you are in a library with 50 million books and you are asked to find a particular symbol drawn on one of the books. Classically, you would sequentially scan through all the books, but this would take you several lifetimes, at the very least. But if you had been given the possibility of being in a superposition of 50 million states, each of which checks one book, you would find the symbol in less than a day.

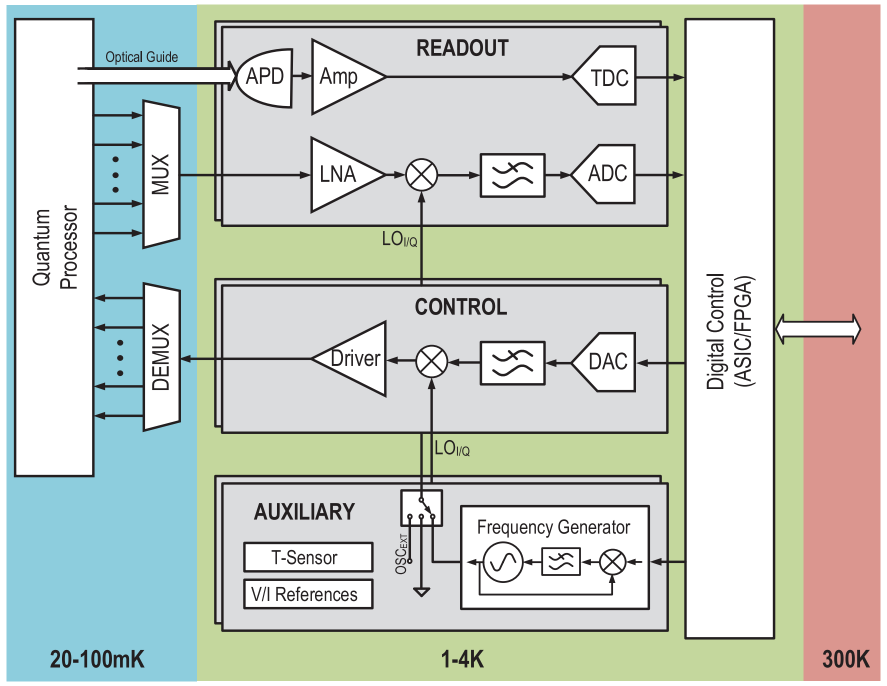
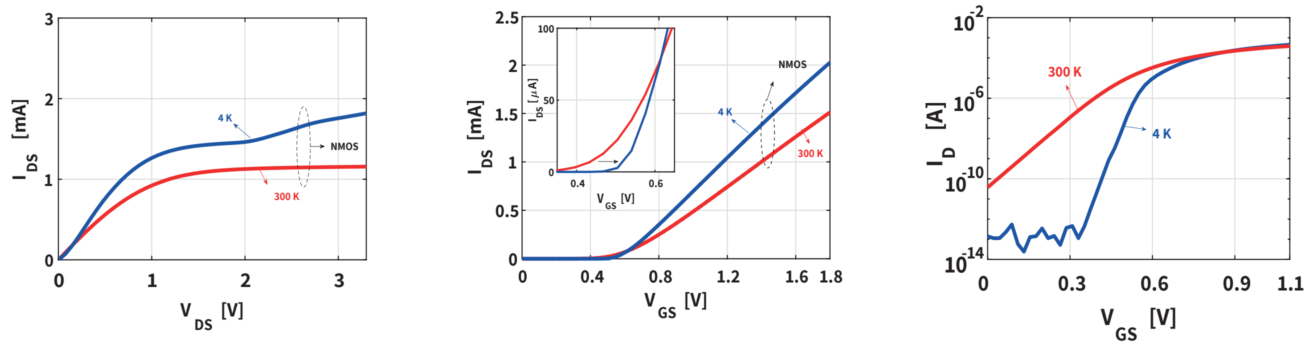


Figure 1. The hardware architecture of a future large-scale quantum computer, with electronics for control and read-out operating at cryogenic temperatures.

Scaling up current quantum technologies

Quantum computers have recently triggered the attention of the media when previously this year IBM and Intel both announced quantum processors with 17 qubits. Although the release of 17-qubit processors is an outstanding milestone, quantum technology is still far from addressing computationally-intensive problems. Even the simplest quantum algorithm with a practical application, e.g. the simulation of simple molecules such as Fe_2S_2 [2], requires millions of those qubits. Quantum scientists cannot yet build such machines since they face several arduous challenges while trying to scale up quantum computers. Differently from classical bits, qubits are extremely sensitive to the surrounding environment.



(a) (b) (c)

Figure 2. Behavior of cryo-CMOS devices: (a) the increase in mobility at 4 K results in larger current for the same bias voltage, while substrate freeze-out leads to a "kink" in current for large drain-source voltage; (b) increase in threshold voltage (zoom-in in the inset) for a 160-nm CMOS transistor due to substrate freeze-out; (c) an increase in subthreshold slope is observed for a 40-nm CMOS transistor.

The quantum information stored in qubits can rapidly degrade and become unusable unless qubits are cooled down to temperatures very close to the absolute zero. For this reason, qubits in state-of-the-art quantum computers are operated in special dilution refrigerators at temperatures as low as 10 mK and controlled by conventional electronics working at room temperature. At least, one high-frequency coaxial interconnect is required to connect each qubit to the control electronics. While this is feasible for the 17 qubits available today, this approach will become impractical for the millions of qubits required in useful quantum computers, because of cost, size, and reliability issues. It would be equivalent to taking the 12-megapixel camera on your mobile phone and trying to individually wire each of the million pixels to a separate electronic circuit, which is clearly unrealistic. A more viable solution is to operate the electronics controlling the qubits at cryogenic temperature and to place it as close as possible to the quantum processor, possibly on the same chip, so as to simplify the interconnections. To implement this concept, our group at the Department of Quantum and Computer Engineering proposed a hardware architecture for a large-scale quantum computer employing cryogenic electronics, as shown in Figure 1. Operating most of the electronics at 4 K is a practical choice driven by commercial dilution refrigerators offering a large cooling power at that temperature.

Electronics at cryogenic temperatures

To realize the electronic controller for quantum processors shown in Figure 1, several hurdles must be overcome. First, what is the most appropriate technology for electronics working at cryogenic temperatures? Many technologies can operate at cryogenic temperatures, such as SiGe, HEMT, JFET, and superconducting electronics. However, only one technology offers both operations down to (at least) 30 mK and the possibility to reliably integrate billions of devices on the same chip. This technology is CMOS, the very same technology used to manufacture today's computer chips. Although it is a mature technology, successfully employed for more than 50 years, CMOS devices behave differently when cooled down to deep cryogenic temperatures, as shown in Figure 2. Transistors show a large deviation from their room-temperature behavior, and we can observe higher threshold voltages, larger currents, and higher subthreshold slope. In addition, bizarre unexpected effects, such as current "kinks" and hysteresis, appear. Such large deviations and cryogenic effects are not captured by standard room-temperature device models. The unavailability of consistent cryogenic models and, therefore, the inability to simulate complex circuits, makes it hard to design high-performance cryogenic chips. Second, controlling qubits requires circuits with extreme performance, such as generating signals with high accuracy while contributing negligible noise, and reading out very weak signals from the qubits without altering their quantum state. The required performance is already very demanding for state-of-the-art room-temperature CMOS electronics. The main challenge is providing such performance at 4 K while dissipating very low power, which is limited to 1 W at 4 K by existing dilution refrigerators.

"It would be equivalent to taking the 12-megapixel camera on your phone and trying to individually wire each of the million pixels to a separate electronic circuit"

Cryo-CMOS at TU Delft

Two years ago, our group, sponsored by Intel and led by Dr. Sebastiano, Dr. Babaie and Prof. Charbon, took charge of realizing circuits using cryogenic CMOS, or cryo-CMOS. We soon found out that, on top of the scientific challenges outlined above, many more practical issues complicate the life of a cryo-electrical engineer: thermal anchoring, extremely low-noise requirements, reduced set of discrete components working at cryogenic temperature, the handling of cryogenic fluids, etc. Despite those difficulties, we have already demonstrated the first set of cryogenic models for circuit simulation of nanometer cryo-CMOS technologies [3], and the first set of cryo-CMOS circuits, including an extremely low-noise 4-K amplifier (with 0.1-dB noise figure) and a 4-K LC oscillator with frequency noise of only 3.4 kHzrms [4], as seen in Figure 3. Currently, we keep on extending our portfolio of cryo-CMOS circuits to finally build the complete controller of Figure 1, which will enable large-scale quantum computers.

Do more with Cryo-CMOS

But cryo-CMOS is not only quantum! Cryogenic electronics is also needed in applications where the full system operates at low temperature. Examples include satellites and spacecraft for space and planetary exploration and the read-out for cryogenic detectors in astrophysics. Moreover, cryo-CMOS can offer improved performance with respect to standard CMOS. For example, thermal noise reduces with temperature, thus providing the sensitivity required in very low noise applications, such as high-energy-physics detectors.

The future of Cryo-CMOS

On our route towards a large-scale quantum computer, we will continue exploring the potentiality of cryo-CMOS. One day, at CERN, scientists will measure with the aid of Delft-made cryo-CMOS front-ends hosted in palm-sized cryogenic modules. The latest NASA rovers and astronaut suits will be equipped with cryo-CMOS chips. Our biochemist will sit at his desk, turn on his computer and launch a molecular simulation on his cryogenic quantum accelerator. The long path towards this future will be full of obstacles and surprises but the motivation is high and the goal is worth all the effort. So, stay tuned and check our page: *http://www.qe.ewi.tudelft.nl/*

[1] E. Ladizinsky, Talk at Wired 2014.
[2] D. Wecker et al., "Gate-count estimates for performing quantum chemistry on small quantum computers," Phys. Rev. A, 2014.
[3] R. M. Incandela et al., "Nanometer CMOS characterization and compact modeling at deep-cryogenic temperatures," ESSDERC, 2017.
[4] B. Patra et al., "Cryo-CMOS Circuits and Systems for Quantum Computing Applications," JSSC, 2017.

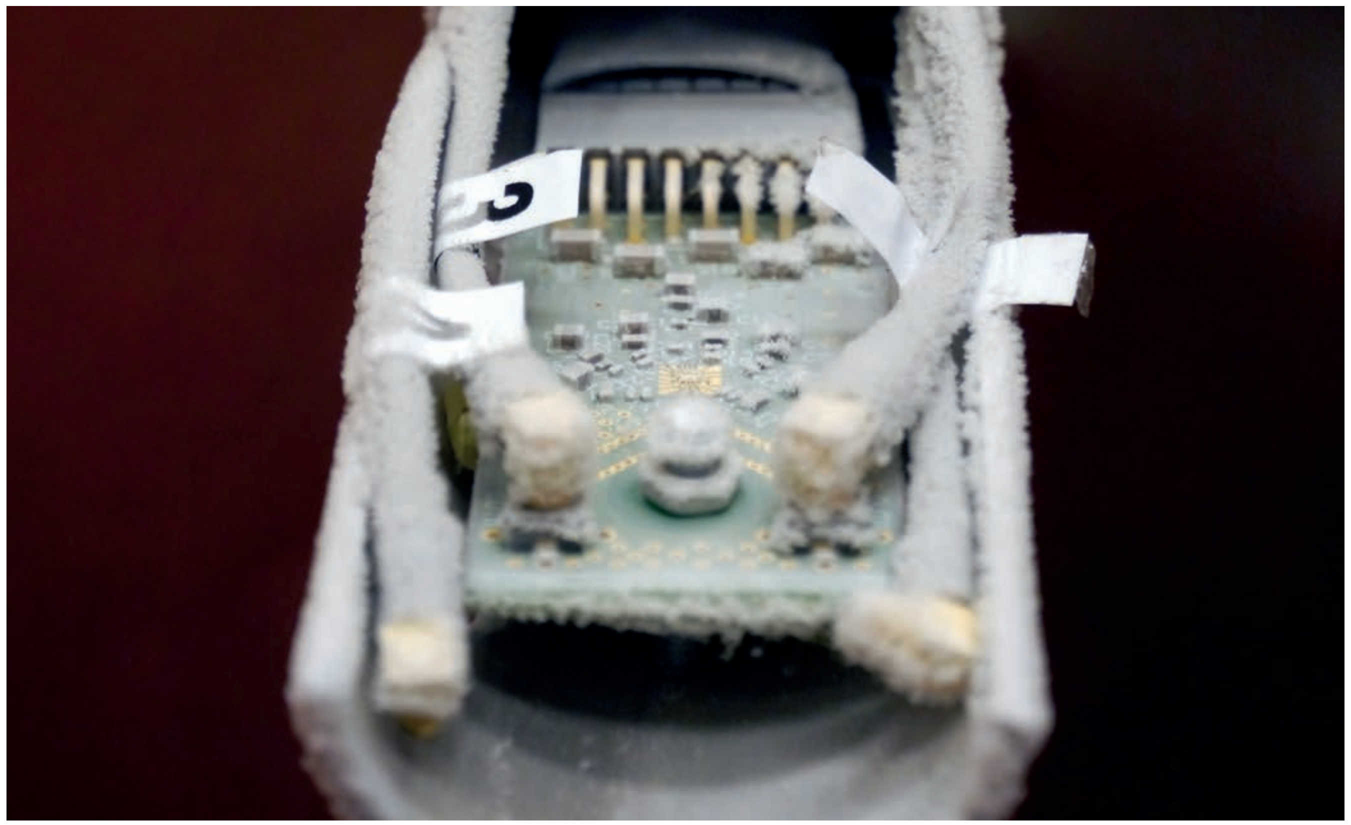


Figure 3. Cryo-CMOS chip (bonded on a PCB) just after a cool-down in liquid helium for cryogenic characterization.

The next generation smart catheters

Prof. Dr. Ir. Ronald Dekker

It is now a little bit more than ten years ago when I woke up one morning and immediately felt there was something wrong with my heart. The doctor told me that it was an atrial fibrillation, something that runs in my family. After a year of trying different medicines, my cardiologist created some scare tissue inside my heart with a cardiac ablation, which finally restored the normal heart rhythm.

The physicians, who treated me, used a minimally invasive technique. This involved guiding a catheter through a vein and into the heart and following its progress on a screen. The advantages of such an approach are immense. No longer do cardiovascular surgeons need to open a patient's chest; instead they can be treated under local anesthetic and often sent home the same day. Such a technique dramatically lowers the risk of complications or infections and offer a much more rapid recovery.

Fast forward

However, although the surgical procedure at that time was state-of-the-art, the catheters my doctors used were something of a blunt instrument compared to current technology. Fast forward a few years and catheters are increasingly 'smart'. The tips can incorporate a range of sensors such as miniaturized ultrasound probes; for a physician dealing with a blocked artery, this can provide vital information. Knowing the size and shape of the occlusion can help tailor the treatment required.

Yet, despite the clear advantages these smart catheters offer, they are only just beginning to realize their potential. This is because virtually all the smart catheters currently available rely on technology that is practically obsolete. Given the rapid advances in so many areas of technology, this may seem surprising. However, it reflects a particular challenge that their development poses.

"The tips can incorporate a range of sensors such as miniaturized ultrasound probes"

Valuable tools

Historically, many of these devices were usually the result of individual manufacturers choosing to add extra functionality to their products. Normally, this was to address a specific problem or situation; a so-called 'point solution'. To do this, they went to local university or institute to help them add the relevant technology to their specification. Once validated, it turned out that these were genuinely valuable tools. However, as one-off solutions, further incremental improvements were not an option, since little, if any, thought was given to how to mass-produce or improve the technology.

If the potential of smart catheters was to be fully realized, it needed an approach to the technology that makes mass production feasible. Herein lies the problem; although the capacity to squeeze more and more components onto silicon wafers has increased dramatically, the area of silicon wafer available within a smart catheter is tiny. Without economies of scale, innovation at this level is bespoke and prohibitively expensive.

Individual needs

The solution lies in developing an open technology platform for smart catheters. Correctly structured, using an open specification, would offer sufficient commonalities to make mass production of relevant silicon wafers viable while allowing tailor-made solutions to be introduced for specific applications. By way of illustration, compare this to pizza production (as everybody likes pizza); all pizzas share a common type of base, and you can use a single production facility for all. However, by varying the toppings, you can still provide bespoke products to meet individual needs.

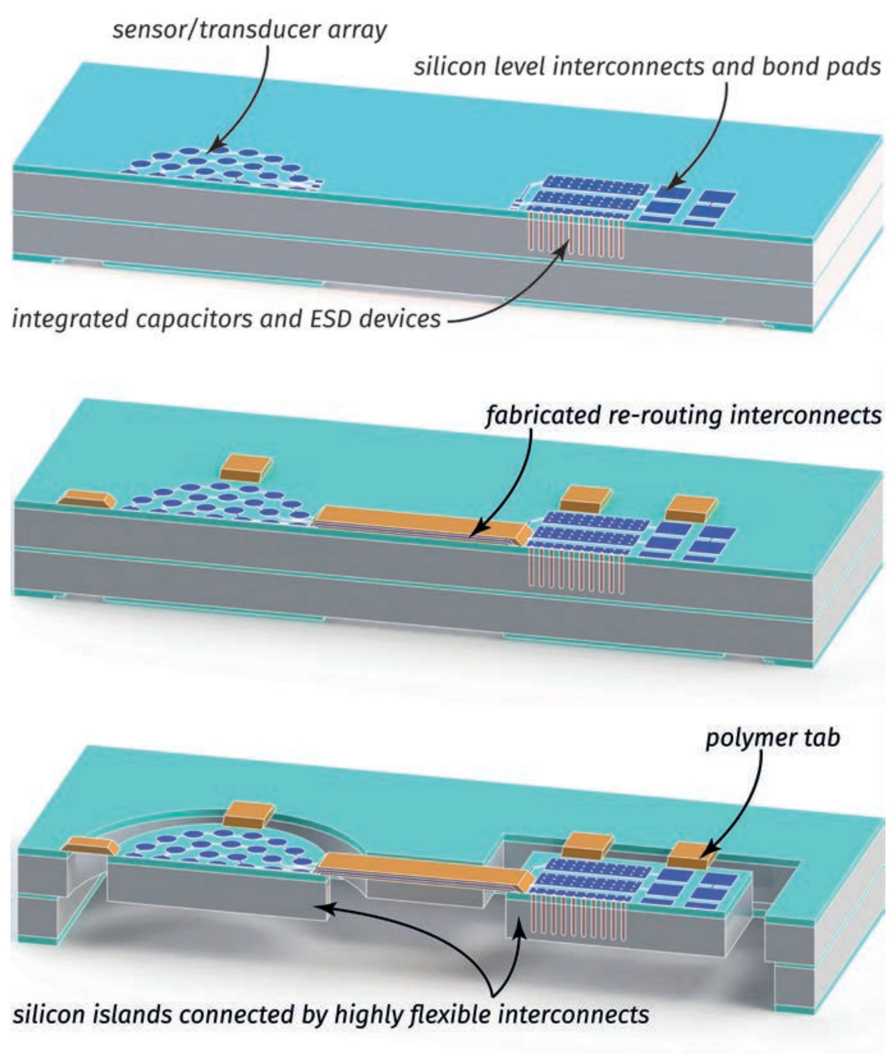


Figure 1. Schematic fabrication sequence of Flex-to-Rigid that uses micro-fabrication technology to assemble complex electronic systems at the tip of catheters.

Over the past ten years, Philips Research has been developing new and open technology platforms for the next generation of smart catheters and implants. They have done this in the framework of a series of large European projects funded by the Electronic Components and Systems for European Leadership (ECSEL) Joint Undertaking. The ECSEL Public-Private Partnership model allows to bring together the wide range of stakeholders needed to make such a platform a success; application developers in academia and small and medium-sized enterprises (SMEs), larger companies with expertise in mass fabrication and scalable electronic technologies as well as potential end users. This was the concept behind the Intelligent Catheters in Advanced Systems for Interventions (INCITE) project, which set out to agree and develop the open platform for developing the 'base' capable of creating the economies of scale needed. In so doing, it allowed all parties – and the outside world – to see the potential of microfabrication. Importantly, by making it clear that this would be an open technology platform it encouraged access from the widest number of potential producers.

"It looks like small is the new big thing; we can already fit more computing power on the tip of a smart catheter than the Apollo mission took to the moon"

Collaborative approaches

However, the open platform was only a part of the solution. Having established the feasibility, the next step was to address manufacturing infrastructure.

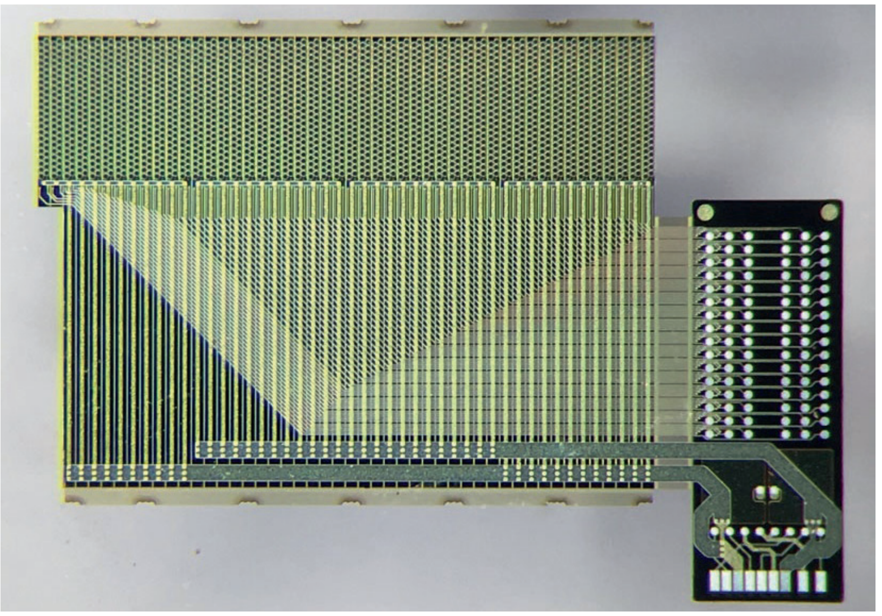


Figure 2. The IVUS ultra-sound engine before it is wrapped around the catheter tip consists of 96 MEMS ultra-sound transducers and an ASIC island.

For medical devices, particularly invasive devices, this is a major consideration. wThey need to be manufactured to highly-specific standards, covering not simply materials but also the need to deploy clean room facilities, etc. In addition, smart catheters create challenges of their own, as they need to combine silicon-based electronics with polymers. The ECSEL-sponsored InForMed project has helped assemble the critical mass of expertise needed to tackle these challenges, ultimately developing a pilot manufacturing facility at the High-Tech Campus in Eindhoven.

Small is the new big

The group Electronic Components and Materials (ECTM) of the faculty of Electrical Engineering Mathematics and Computer Science (EEMCS) is an active partner in these European initiatives, and has been and is playing an important role in the concept creation phase of these technology platforms. Many of the key technology ingredients originated from PhD and even master research projects. This has tightened the links between many groups of our faculty and Philips Research. The new polymer processing facility added to the Else Kooi Lab (EKL) cleanroom in the framework of the InForMed project has brought the processing capabilities of EKL on par with the processing capabilities of the pilot line in Eindhoven. Additionally, gated procedures have been defined to transfer technology from the university to the pilot line. As a result, technology concepts created in our group can be readily translated into products.

The latest ECSEL project submission - POSITION II – intends to address this challenge by establishing a pilot production line for the next generation of smart catheters. If granted, both our group, as well as the group of Bioelectronics will again be heavily involved by developing soft encapsulation schemes to make the technology platforms suitable for the next generation implants. Success in this area will allow Europe to break the existing US hegemony in the field. However, it's the potential of collaboration for technology that excites me. When I compare what can now be achieved compared to the instruments used to treat my arrhythmia, it has been spectacular progress. It looks like small is the new big thing; we can already fit more computing power on the tip of a smart catheter than the Apollo mission took to the moon. Then think where the power of collaboration in Europe can take us from there.

Acknowledements

The INCITE project was funded by the EU ENIAC Joint Undertaking, grant number 621278-2, *http://www.incite-project.eu/*. The InForMed project is funded by the EU ECSEL Joint Undertaking, grant number 2014-2-662155, *http://informed-project.eu/*.

Figure 3. Fully assembled IVUS catheter realised in the INCITE project.

Wireless Communication Goes Massive

Massive MIMO for 5G

Dr. Emil Björnson
Linköping University, Dept. of Electrical Engineering

Imagine a world full of lamps, on rooftops, facades, and lamp-posts. They are connected in an intricate network and cooperate to form a beam of light that is focused right at you. Wherever you go, indoor or outdoor, the beam will follow you as if you were a stage artist in a theater. This might sound like science fiction but is how the fifth generation (5G) of wireless communication technology will work. The only difference is that it is not visible light that reaches you but another type of electromagnetic radiation: radio waves. These waves are transmitted from the antennas of so-called base stations, which are deployed at rooftops, facades, and lamp-posts. The radio signals are received by your cell phone, tablet, or smart-watch. While visible light is easily blocked by walls and other obstacles, radio waves penetrate walls and find their way to the receiver through reflections, diffraction, and scattering.

5th Generation Mobile Networks

This article is about cellular communications, which is the wireless technology that you are paying a monthly fee to use if you have a cell phone, such as a smartphone (see Figure 1). The first generation of cell phones appeared in the 1980s and a new generation has been introduced every ten years since then. 5G is the next generation that is currently being standardized and it will be gradually deployed over the next five years. There is nothing fundamentally wrong with 4G, which is currently used, but since we use our wireless devices more and more, the data usage is skyrocketing. The data traffic grows by almost 50% every year, which corresponds to a 30-fold increase per decade. Therefore, we need a new generation that can handle much more data traffic than 4G. In addition, 5G will be instrumental in creating the connected society, also known as the Internet-of-things (IoT), where all electronic devices become wirelessly connected to the Internet. It is predicted that billions of IoT devices and sensors will be deployed over the next decade and some of these require a very energy-efficient 5G technology so that their batteries can last for 10 years,

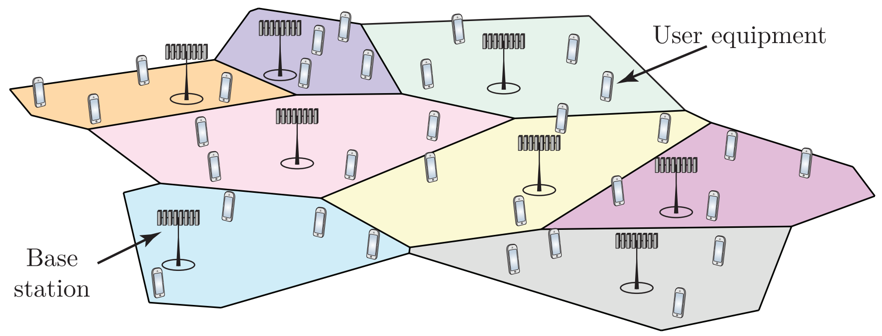


Figure 1. Cellular networks consisting of base stations deployed to serve the users in the surrounding area called a cell.

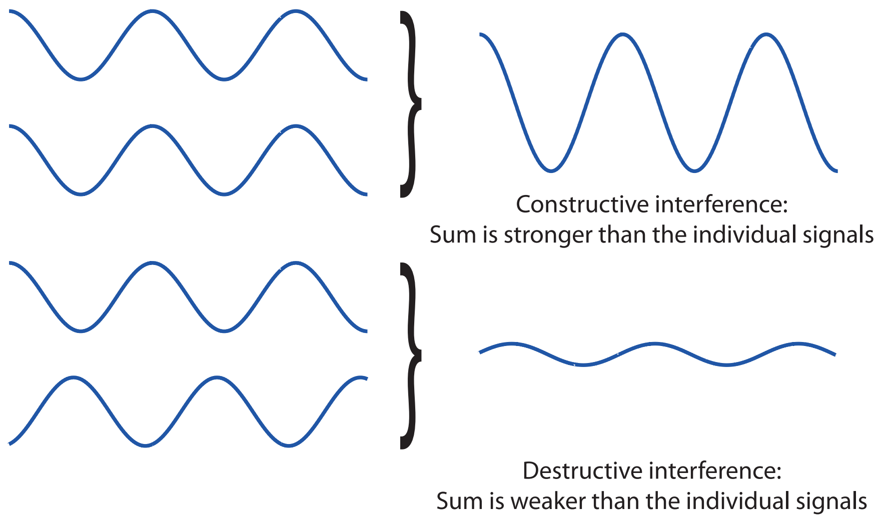


Figure 2. Massive MIMO takes control over the basic phenomena of constructive and destructive interference.

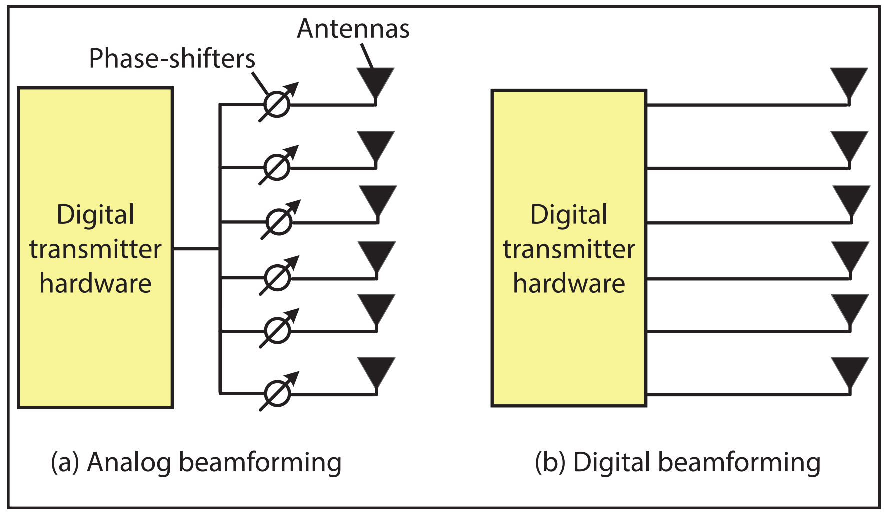


Figure 3. Beamforming, conventionally implemented with analog phase-shifters, as in (a), while Massive MIMO utilizes a fully digital implementation, as in (b).

which is a huge difference from a smartphone that needs to be charged daily. 5G is also designed to be extremely reliable so that we can trust wireless technology as we trust the electricity grid – no more dropped calls or interruptions in video streaming. Extreme reliability is mandatory if 5G is to be used for connected vehicles, remote surgery, and virtual reality applications.

Antenna Arrays

To fulfill the new requirements, radical changes are needed. One of the main and new technology components is Massive MIMO, which is the short-form for "Massive multi-user Multiple-Input Multiple-Output". In a nutshell, Massive MIMO base stations are equipped with many antennas, at least 64, which is massively larger than the 1-8 antennas that 4G base stations have. The antennas are deployed in a compact array and used to direct the transmission towards the receiving user, as described in the beginning of this article. When transmitting signals from multiple antennas, the Maxwell equations dictate that the individual signals are added together at every location, which is known as the superposition principle. This creates constructive and destructive interference at certain places, where the signals are respectively reinforcing or canceling each other. This is illustrated in Figure 2.

Digital Beamforming

Massive MIMO exploits this basic property of physics. The same signal is sent from each antenna but with different phase-shifts (delays) and amplitudes, such that the signal components reinforce each other at the receiving user. This method is known as beamforming and is conventionally implemented by generating one signal in the digital transmitter hardware and then using analog hardware, such as phase-shifters and amplifiers, to steer the signal. Such an implementation is sufficient to direct the signal in an angular direction from the antenna array. However, in most cases, you cannot see the base station and thus transmission with an angular directivity is insufficient to achieve constructive interference at the place where you are. Therefore, Massive MIMO utilizes digital beamforming, where the phases/amplitudes are selected in the digital transmitter hardware and separate analog signals are generated for each antenna. This gives the necessary flexibility to send signals that add constructively wherever you are. The difference is illustrated in Figure 3.

"The data traffic grows by almost 50% every year, which corresponds to a 30-fold increase per decade"

Serving Users Simultaneously

If you transmit a 1 W signal from 1 antenna or divide the same power over 100 antennas then the latter results in 100 times stronger received signal. This might seem like magic, but it demonstrates how strongly focused the transmission from massive antenna arrays is. At other locations than the desired one, the signals will add (semi-)destructive and will thus not disturb other users. This fact is utilized in Massive MIMO to serve multiple users simultaneously, as illustrated in Figure 4. In 4G, the users are typically taking turns or using different frequencies for their communication. In 5G, Massive MIMO enables tens of users to simultaneously share the same frequency, if they are spatially separated by a few meters.

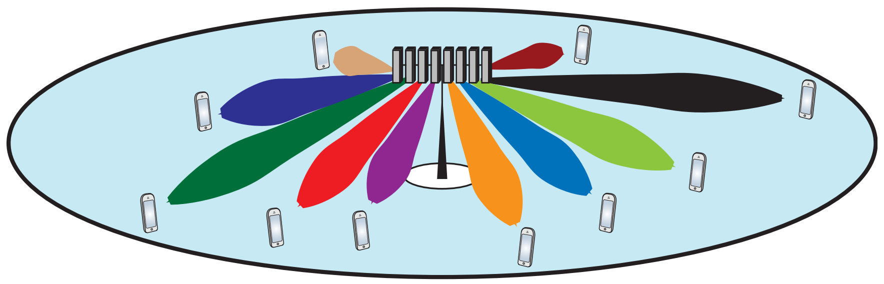


Figure 4. Illustration of digital beamforming in a Massive MIMO system, where ten users are served simultaneously.

For this work in practice, the base station needs to know how to transmit to each user, so that it can make sure that each signal is received with constructive interference at the intended receiver and with destructive interference at non-intended receivers. One of the key differences in Massive MIMO, as compared to 4G, is how the base station acquires this information: each user transmits a known signal, that the base station measures and uses to deduce how to receive data signals transmitted from the user and how to transmit data signals to the user.

Future of Massive MIMO

Massive MIMO was conceived in 2010 by the American researcher, Thomas Marzetta. It was first seen as a theoretically appealing but practically impossible concept. The European project MAMMOET later demonstrated that it is not only possible, but even implementable with hardware that anyone can buy and assemble. The testbed at Lund University, Sweden, was instrumental in this demonstration, while other partners of the project were Ericsson, Imec, Infineon, KU Leuven, Linköping University, Technikon, and Telefonica. The testbed is shown in Figure 5. Today, Massive MIMO is generally viewed as one of the key technologies in 5G.

Looking further into the future, we will see a world full of antennas; some deployed in massive arrays at rooftops and facades, some integrated into walls and windows. In the paper, "Massive MIMO has unlimited capacity", my research team recently showed that there are no fundamental limits to how far we can push the technology. As the data traffic grows, we can always install more antennas to raise the capability of cellular networks.

"In 5G, Massive MIMO enables tens of users to simultaneously share the same frequencies, if they are spatially separated by a few meters"

Figure 5. LuMaMi testbed demonstrating real-time Massive MIMO in the MAMMOET project in Lund, February 2017.

Technolution i.s.m. Ministerie van Defensie

Advertorial
Samenwerken aan soepele security

Security is een vakgebied dat voortdurend in beweging is. Organisaties moeten alle zeilen bijzetten om nieuwe bedreigingen het hoofd te bieden. Meer veiligheid betekent echter vaak minder flexibiliteit. Kan het ook anders? Het Ministerie van Defensie zoekt naar werkbare security voor veilige verbindingen. De oplossing ligt in een onverwachte hoek: hardware.

Veel vraag naar veilige verbindingen

Het Ministerie van Defensie maakt veel gebruik van laag gerubriceerde, beveiligde verbindingen. Dit zijn verbindingen van het beveiligingsniveau 'Departementaal Vertrouwelijk'. Er is een steeds grotere behoefte binnen het ministerie om informatie tussen systemen veilig uit te wisselen. De vraag naar flexibele, toekomstbestendige beveiliging neemt daardoor toe. Voor het opzetten van veilige verbindingen kan het ministerie gebruikmaken van OpenVPN-NL. Dit is een voor de Nederlandse overheid aangepaste versie van het OpenVPN-protocol. Het gebruik van deze software vraagt echter de nodige technische kennis van de gebruikers. De implementatie is bovendien complex en tijdrovend. Een complicerende factor is het feit dat elke beveiliging uiteindelijk altijd weer wordt geconfronteerd met geavanceerdere aanvalsmethodes.

Proof of concept

Op basis van eigen onderzoek en een innovatietraject kwam de IT-innovatieafdeling van Defensie (KIXS) tot een proof of concept: een device met het OpenVPN-NL-protocol ingebouwd in de hardware. Deze hardware-integratie zorgt voor een extra niveau aan veiligheid en een snelle versleutelde verbinding. Technolution kreeg het verzoek om de ideeën te beoordelen. Het concept bleek veelbelovend en er ontstond al snel een samenwerkingsverband (ook wel CODEMO genoemd) tussen Technolution en Defensie om tot een volwaardig product te komen. Ons trackrecord op het gebied van design en productontwikkeling speelde een belangrijke rol bij de keuze voor Technolution als partner.

Natuurlijke rolverdeling

Het initiële doel was duidelijk: de ontwikkeling van een oplossing voor veilige, laag gerubriceerde verbindingen, met een lage beheerslast. Deze moet simpel en snel kunnen worden ingezet door medewerkers met beperkte cryptografische kennis. Inmiddels is echter duidelijk geworden dat er veel verschillende stakeholders zijn, ieder met zijn eigen eisen en wensen. Niet alleen binnen Defensie, maar ook bij andere betrokken overheidsorganisaties. Coördinatie is nodig om een wildgroei van specificaties te voorkomen. Binnen de samenwerking worden de rollen op een natuurlijke manier verdeeld. KIXS onderhoudt de lijnen met de stakeholders en verzamelt de eisen en wensen van de verschillende behoeftestellers. Technolution is verantwoordelijk voor het technisch design hiervan. Wij maken een helder overzicht van alle implicaties van de eisen en wensen, en bespreken dit met de stakeholders. Samen bepalen we de beste designkeuzes. Het uiteindelijke doel is om snel en efficiënt te komen tot een minimal valuable product: effectief, flexibel inzetbaar en zonder overbodige toeters en bellen.

Maximale flexibiliteit

Als er zo veel belanghebbenden en zulke uiteenlopende specificaties zijn, is het belangrijk om maximale flexibiliteit te creëren. Niet alleen in het ontwikkeltraject, maar ook in de doorgroeimogelijkheden van het product. Deze eis lijkt moeilijk te verenigen met een hardwareoplossing, zeker wanneer de focus ook nog eens ligt op gebruikersinteractie, time to market en, niet te vergeten, kosten. Dit is de reden waarom KIXS en Technolution samen hebben gekozen voor de inzet van FPGA's. Dit zijn programmeerbare chips, die het mogelijk maken om te voldoen aan bovenstaande eisen. FPGA's brengen een grote flexibiliteit in de productontwikkeling als het gaat om prototyping. Die flexibiliteit houdt echter niet op als het product klaar is. Heeft de gebruiker behoefte aan een functionele uitbreiding? Dan kan dat, met een korte ontwikkeltijd. De kosten blijven overzichtelijk, zelfs wanneer het om een kleine oplage gaat.

Het resultaat: PrimeLink

Dankzij de nauwe samenwerking met het gebruikersplatform is het resulterende product, de PrimeLink, optimaal afgestemd op de behoeften van de eindgebruikers. De oplossing is een goed voorbeeld van de filosofie achter JelloPrime: na een lean-and-mean-ontwikkeltraject zal de PrimeLink een eenvoudige oplossing bieden voor een veilige verbinding tussen twee locaties. Het OpenVPN-NL-protocol is met behulp van FPGA's ingebouwd in de hardware. Dit biedt een hogere snelheid dan een softwareoplossing, omdat het algoritme in een FPGA beter geparalleliseerd kan worden. Ook de security is beter. Veel softwareaanvallen, zoals bufferoverflows, zijn niet mogelijk in een FPGA, omdat de data fysiek gescheiden zijn van de FPGA-configuratie. Bovendien is het een echte plug-&-play-oplossing die snel kan worden ingezet tegen minimale beheerslasten. Technolution levert ook de bijbehorende tools en services voor een optimale inzet van deze oplossing in het domein van Defensie en andere gebruikers.

Win-win voor beide partijen

De ontwikkeling van PrimeLink is gebaseerd op een goede balans tussen behoeften, noodzaak, technische mogelijkheden en kosten. De gekozen werkwijze heeft voor alle betrokken partijen voordelen. Er is duidelijk sprake van een win-winsituatie. Vanuit het gebruikersplatform van het Ministerie van Defensie zijn de reacties positief: "Dit is de eerste keer dat ik zo nauw betrokken werd bij productontwikkeling." Ook voor Technolution heeft de open en praktijkgerichte werkwijze vruchten afgeworpen. Dankzij de laagdrempelige toegang tot de eindgebruikers kunnen ideeën en technologieën worden getoetst voordat ze worden uitgewerkt. Dit maakt het mogelijk om het ontwikkelproces te optimaliseren en het eindproduct nog beter te laten aansluiten op de verwachtingen van de klant. Bovendien staat deze securityoplossing niet op zichzelf. PrimeLink geeft niet alleen invulling aan de specifieke behoeften van het Ministerie van Defensie, maar het zal ook voor andere gebruikers binnen en buiten de overheid zeker zijn nut bewijzen.

JelloPrime – Security Made Simple

Security is meestal maatwerk. Maatwerk hoeft echter niet gelijk te staan aan ingewikkeld, tijdrovend en duur. De securitykennis en -ervaring van Technolution is gebundeld in JelloPrime: een pakket hoogwaardige securityproducten en -diensten die versleutelingsoplossingen bieden voor domeinen waar high assurance vereist is. Een afgewogen keuze voor de juiste technologieën, zoals het gebruik van FPGA's (Field-Programmable Gateway Arrays, programmeerbare chips) als core-componenten, geeft JelloPrime een grote flexibiliteit voor de snelle ontwikkeling van lean-and-mean-oplossingen op maat. De scheiding van hardware en software creëert een intrinsieke security by design: extra veiligheid, snelle encryptie en een uitstekende upgradeability. JelloPrime biedt bovendien volop ruimte voor gebruikersparticipatie en maatwerk.

Hybrid grids

Prof. Ir. Peter Vaessen

People say: "In the future, we will see more and more blending of technology and hybridization". What is meant by this, more specifically, what is hybridization in power systems and what are hybrid grids that people talk about? In this article, the key aspects of hybrid grids are shown and their implications on shaping the future the future.
First of all, it is important to realize that digitalization, information technology and power electronics are key enablers for the transformational change the electric power system encounters. Due to technological and societal developments, we can observe an acceleration of the changes in the interconnected electricity systems that are the largest man made technical constructs on earth. Experts unanimously agree that the importance of electricity as 'the fuel of choice' will more than double over the next 35 years and it will be greener, more affordable and more accessible than ever.

In Figure 1, the power system is represented schematically from the regional wide area high voltage connected grid on top through distribution via medium and low voltage systems to power delivery to our homes, offices, and industries where the electricity is used.
The four key aspects or technology ingredients that shape the electricity system of the future, commonly associated with hybrid grids, are:

1. *Mix of generation:* By what technological means is the grid accommodating for the ways electricity is produced? This generation can be conventional (will probably be around for some time) but increasingly comes from variable renewables like wind and solar in all sizes, ranging from big offshore wind farms and large solar fields down to rooftop solar panels.
2. *Mix of transmission and distribution:* By what technological means is electricity transported to the point where it is used? Here, we can think of overhead lines and underground cables, but also local generation with micro turbines - with or without storage, mobile sources like batteries from electric vehicles, and even wireless for low energy and/or short distances.
3. *Mix of delivery:* In what technological 'form' or characterization is the electricity delivered during intermediate stages or ultimately to the point of use? Is it direct current (DC), alternating current (AC) (frequencies 16.7, 50, 60 and 400 cycles/second are presently widely used), high frequency or even micro waves?
4. *Mix of control:* How is a safe, stable and reliable electricity system operation at all levels guaranteed? The protection and control is governed by the increasing digitalization; combining prediction of electricity generation and load, sensing/monitoring at global/regional and local level together with an optimal combination of slow (mechanical) and fast (power electronic) actuators.

Mix of generation

The generation of electricity will be increasingly coming from variable renewables like wind and solar in all sizes, ranging from big offshore wind farms and large solar fields down to rural wind turbines and rooftop solar panels at individual homes.
Not only the diversity in generation capacity will increase but also the diversity in ownership from a "few owners" of big power plants in the past to a mix of numerous millions of owners of smaller and dispersed generating plants today and tomorrow.
EU targets for greenhouse gas emissions and share of renewable energy are ambitious. All over the world huge amounts or wind and solar renewables are deployed and you cannot miss it in the news that the tipping point is near or has been reached already. As an example, today there is 40 Wp solar PV installed for every person on earth and in the next 15 to 20 years this will rise to 1 kWp. The conclusion is clear: abundant variable renewables drive the change in power systems.
How is the grid accommodating for the new ways the electricity is being produced? It must become more flexible and should work for and with) renewables, rather than demand the renewables to conform/adapt to the existing grid by requesting (mimicking) similar behavior of traditional power plants.
Technologies to make the grid more flexible and smart, are:

- Strengthening regional interconnections
- Making use of (distributed) storage and microgrids
- Activating inverter capabilities of grid connected renewables
- Rapid response of aggregated loads (Active Demand)
- Technology for power flow steering and control

"A hybrid grid accommodates for changing mixes of generation, transmission and distribution, delivery form and control technologies."

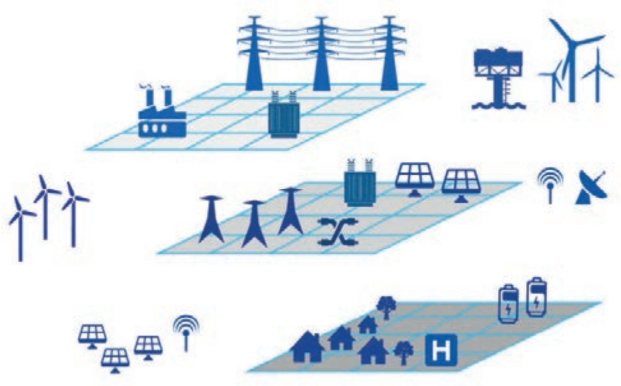


Figure 1. Schematic of the power system (source: DNVGL).

Figure 2. Largest man-made technical construct on earth (source: DNVGL).

Mix of transmission and distribution

Electricity is transported from the point where it is generated to the point where it is used by a network of overhead lines and underground cables, but this can also be done by local generation with solar panels or micro turbines, possibly combined with storage. Even mobile sources like batteries from electric vehicles can serve as a local T&D system. Additionally, wireless technology is becoming popular for low energy or short distance, e.g., inductive charging of phones, cooking applications and fast car charging.
As an example, over the last years we have seen more and more interest in high-power underground cable connections. This leads to the question whether this is a trend, and, if so, what are the consequences for the power system? There are three main reasons that underground cables are preferred to overhead lines, although in general, cable solutions are (much) more expensive.

Reason 1 – Limited Space Above Ground
The available space for new or the expansion of existing transmission lines and substations is not boundless. It is very difficult and costly to acquire the land for substations or establish the necessary right of way for the transmission corridor.

Reason 2 – Public Opinion
Public opinion has been increasingly marked by CAVE-thinking (Citizens Against Virtually Everything). People oppose to transmission lines for various reasons, such as visual impact, nature preservation and decrease of real estate property close to substations and transmission lines.

"...abundant variable renewables drive the change in power systems."

Reason 3 – Availability & Reliability
The increase in availability and reliability is especially true for the distribution grid as cable connections can be made very reliable, easy to monitor and diagnose, e.g., with smart cable guard technology, and most important of all, are not prone to failure during extreme weather events such as storms and flooding. In the Netherlands, for example, it is a common practice to use watertight power cables.
Despite the high cost undergrounding

(a) (b)

Figure 3. (a) Dolwin2, 900MW offshore wind HVDC platform (TenneT) and (b) 0.6kW African off-grid solar panels.

the power system is becoming a trend. For high voltage transmission, there are some technical issues that need to be addressed when the share of cable increases, e.g., the need for qualified new types of power cable with high transmission capacity (presently around 1000MVA). The reliability of long stretches of such high-power cables over land with many cable joints is also an issue.

Mix of delivery

With “mix of delivery”, the technological form or characterization of the electric power during intermediate stages of delivery or ultimately at the point of use is set. It can be DC, AC at a relative low frequency (e.g. 50, 60 or 400 cycles/second), high frequency AC or even microwaves.

Note that the customers do not care if the electric power is delivered as alternating current, direct current or any other form. They want energy functions like force, light, entertainment (music, TV, game) and heat. And most of all, that the delivered electric power is:

- Safe to use
- Affordable with high reliability
- Functional, suitable for the job
- Efficient (limited losses/conversion stages)

The choice between AC or DC, which has led and still leads to a lot of discussions over the years is a typical example.

Figure 4. One of the 48 transformers of the 8000MW UHVDC Hami-Zhengzhou transmission link (source: ABB).

The electric power transmission system has undergone significant development through the implementation of new HVDC systems. These systems have enhanced the bulk power transmission capability, enabled more effective transmission over long distances (including long submarine cables), enabled interconnection of regions with different grid frequencies, boosted the integration of large-scale renewable energy sources, improved the flexibility and controllability of AC systems, and in some cases minimized environmental impacts.

There is a natural (technical) choice for DC when bulk power needs to be transmitted over long distances with low losses to connect remote resources, such as hydropower, to distant load centers. This realm is dominated by ultra-high voltage DC, and can be found at the highest voltage levels, presently up to ±800 kV, and ±1100 kV arriving.

At the other end of the spectrum, we find DC applications — predominantly at the power distribution equipment level — at voltages well below 400 V; think of household appliances, battery (charging) systems, LED lighting, electric vehicles, solar PV systems, and many others. The fast development of power electronics, the availability of efficient AC to DC and DC to DC converters and interoperability allow easy connectivity here.

The AC power system, as we know it, will not be converted to a DC system as some experts advocate. It is more likely that the power system will gradually hybridize into a system combining best of both worlds, a kind of “sandwich structure” with DC technology dominant at top and

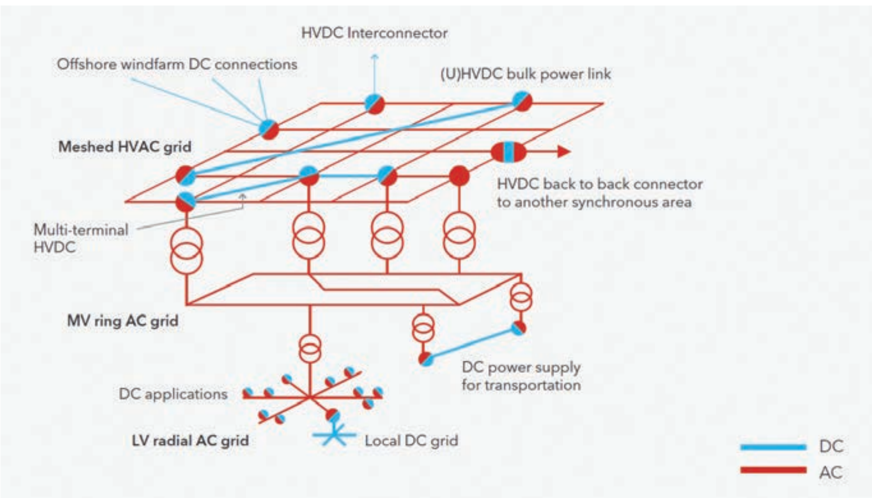


Figure 5. AC and DC in the power system (source: DNVGL).

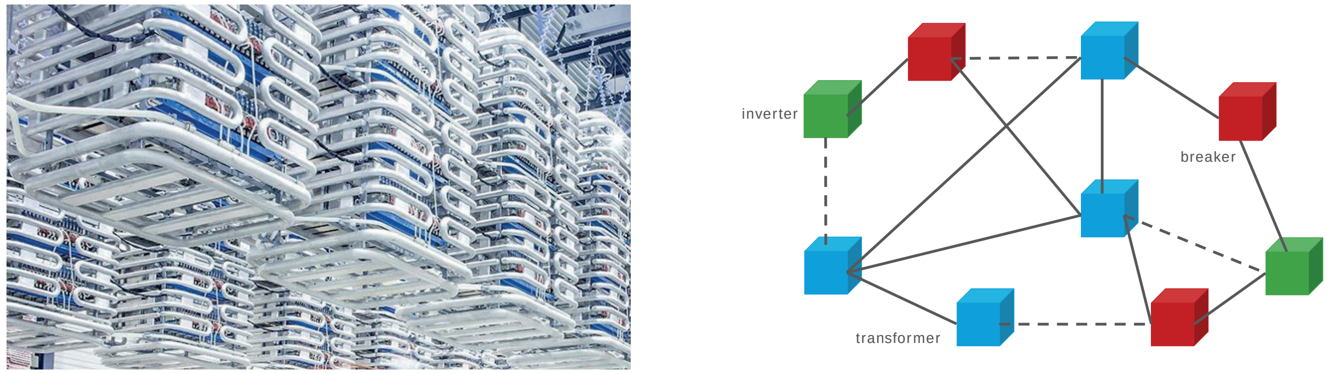


Figure 6. (a) Impression of highly controllable power electronics (source: ABB) and (b) the future grid (source: DNVGL).

bottom layers, and AC still governing the middle layer is the present state.

The trend towards a transmission grid with embedded HVDC is observable in Europe and China, and, to a lesser extent, in the US. The biggest impact from embedded HVDCs is that it signals the end of the single frequency grid as parts of the grid will, and can, operate at (slightly) different frequencies. The hybridized transmission grid —despite its superior features— will become more complex to operate, and will exhibit different, and maybe unexpected, behavior.

Mix of control

With a suitable “mix of control”, a safe, stable and reliable electric power system operation at all levels is guaranteed, even when the complexity increases due to variable renewables, new technology and digitalization. Note that the Control and Protection (C&P) of a power system comprises different generations of technology ranging from mechanical, via electronic to software controlled.

The factors that increase complexity, the different C&P technologies, combined with the new demands on power, frequency and voltage regulation pose a huge challenge on maintaining a flexible, fast responding and robust implementation of the power system controls.

In addition, there are more interfaces and interactions with other infrastructures like telecommunications, sensor networks for monitoring and prediction and the suite of actuators ranging from (slow) transformer tap changers to (fast) grid connected inverters.

How to create confidence that the C&P risks are controlled and the power system works as intended? New ways of system reliability and stability analysis have to be developed as two (rotor-angle and frequency stability) out of three pillars of the traditional power system stability analysis are bound to disappear in the future. Only voltage stability remains, and maybe a new one is emerging e.g. communication stability. Power System Stability 2.0, could be based on procedural generation technology, big data and advanced data analytics.

Since software increasingly determines the functionality of power system equipment and its interaction with the grid, new and unforeseen error modes can emerge. This calls for new ways of validation, not only based on individual performance or compliance with the standard(s), but also based on system performance or fit-for purpose validation.

The future

What does the future of power systems look like? Certainly, it will me more exciting and dynamic than it ever was due to hybridization and the disruptive renewable generation and storage technology. Modular power electronics will increasingly rule and allow for unprecedented changes in functionality and controllability of the generation connection points and substations or “nodes” of the power grid.

> *“Any sufficiently advanced technology is indistinguishable from magic”*
> *- Arthur C. Clarke*

The function of the future modular “node” can not only be dynamically adjusted to changes in load and generation and optimized utilization but also with respect to its function over time, e.g. inverter, transformer or breaker. Due to its modular build and “programmed function” the future node even allows for innovativWe combinations of functions, depending on grid operating conditions and emergencies. Advanced modular power electronic technology will forever change our wired world of power delivery.

You are cordially invited to attend my inaugural speech at TU Delft at 3pm on Wednesday November 29, 2017 if you want to learn more about hybrid transmission systems and how modular and exponential technology will change the future of electric power delivery:
tinyurl.com/vaessen-speech

Fluid architecture

Computer Engineering's hypothesis of the future

An interview with Dr. Zaid Al-Ars

Zaid Al-Ars is an Associate Professor at the Computer Engineering Lab of TU Delft, where he leads the research and education activities of the big data architectures. His work concentrates on addressing the bottlenecks in big data application scalability on multicore architectures and propounding different kinds of optimized solutions for system performance, memory, power, reliability, etc. He also teaches courses like Advanced Computing Systems, Supercomputing for Big Data, Advanced Multicore Systems and Embedded Systems.
The Maxwell committee spoke to him about his views on research in the domain of computing.

Your group, Computer Engineering, is working on optimizing multicore architecture for big data applications, especially for scaling data volumes. Does this align with your view?

We create computing systems that are able to address the computing challenges of our generation. We develop new computing architectures that are able to increase the performance of our computational infrastructures.

If you look around, you see that computing has become a central part of the daily activity of an individual. You cannot think of any environment, situation or context where computing is not present. For example, your watch, mobile phone, fridge, heating system, cars – everything – has processes in it.

The more computing power we have, the more productive we can be and higher level of comfort we can have.

The only reason for not having more computing is that it is expensive. Once we have a cheap form of computing, it will naturally infiltrate and penetrate our daily lives. It will support and automate every single aspect of our daily lives.

Could you elaborate on the bottlenecks you are facing in making computing less expensive?

Computing facilitates a lot of different activities in society at different levels.

Let's start from very simple embedded controllers that support our devices at home or at work like embedded devices. So, this is the low-end computing: embedded devices. It could also be high performance, but it's required to have specific characteristics of low latency. It has to be in real time and respond very fast to any input from the environment. You don't want your car to break just because it was processing some digits or images. So, the requirement of the embedded domain is low latency and real-time, mission criticality and reliability. So, on the lower end, the embedded environment, we are developing computer architectures specialized to ensure low latency, reliability and mission criticality that we expect from these systems. They need to be predictable.

But if you think about processes they are anything but predictable. They have caches, memory delays. These kinds of situations can never be accepted in an embedded environment, especially in mission critical environments like surgical, outer space and automotive environments. So, we are developing architectures that have predictability and ensure specific performance requirements for their application.

Also for embedded requirements: in many cases we require low power.

On the other extreme, high-end systems, its scalability. We want to make sure that the systems are designed in such a way that they are able to add more and more processes, thereby, adding more and more computing power to your system.

We now actually have systems that are able to scale up our big supercomputing infrastructure. But again, at high-level we are limited by…

Power?

Yeah, believe it or not. Somehow, it's the unifying fact that brings the high-end big extreme processing to the low-end embedded processing. In high-end extreme processing like supercomputing, people have been working for the past 4-5 years to develop our next breakthrough, enabling the exascale supercomputer. Exascale supercomputers are computers that are able to perform exa-floating point operations per second. Currently, we are at peta-floating operations per second. It turns out that if we want an exascale machine with our current technology, you will have to build nuclear power plant next to your super computer to feed that computer with power. That is a cost that no single country in the world is willing to pay. You can build it, but it will cost too much.

So, we need to think of new technologies, innovative architectures, breakthroughs of our design and our systems, to enable having the exascale computing without consuming so much power.

> *"...[power is] the unifying fact that brings the high-end big extreme processing to the low-end embedded processing."*

For your students, is the main focus to optimize architectures pursuing low power consumption?

We focus on a number of different aspects of computing. Since computing is involved in every aspect of our daily lives, there are a lot of opportunities to contribute to the society with computing systems. Yes, some of our activities focus on enabling the high-end exascale computer as a goal, but also low power computing or cheaper computing that can be in embedded systems.

At present, there are three paths considered as facilitators for the exascale computing environment or low-power embedded solutions. One of them is to choose our current silicon technologies to manage power effectively. Although we have new generations with lower power. We don't think that this will be as low power that it will enable new generations of computing: just an architectural improvement.

The second alternative is to take exascale computing to new and innovative devices. For example, take memristor technology. Said Hamdioui is a leading researcher in using memristors in computing. He is developing his own architecture to create a memristor computer. Of course, we have quantum computing, where we internationally lead the effort in enabling the quantum computer as reality; and a couple of other solutions like single electron devices lead by Sorin Cotofana. It's still a question if these solutions will be realized.

> *"Now if the software wants thousand threads, the system will stop the single core and will use a lot of simple parallelized core to run thousand threads at the same time."*

The third solution is what we are looking into. It's the heterogenous multicore environment, which is integrating multiple types of processing architectures to reduce the total power of the system by augmenting it with low power solutions for the specific application.

Is the heterogenous multicore environment totally application specific?

Yes, architectural. For sequential operations, threads and programs, we can use regular processors that we normally use in Intel Xeon or AMD's. For highly parallel processes we use GPU's: lot of different cores that can solve a lot of threads at the same time. Another interesting solution is the FPGA (Field Programmable Gate Array). You can use them to do computing at ten times lower frequency, for example the rho-Vex project, where Stephan Wong and I are working on, is the architectural solution that enables you to get high performance with new architectures. You might say, "This is low power, this sounds like it will work; so why don't we use it?". Well, because we still don't know how!

Could you elaborate on this last solution, or give an example in your group?

One very well-known example being developed for a while is the rho-Vex by Stephan Wong and his group. To enable a processer to reconfigure itself, to be one big core with a lot of parallelism inside, or two cores with half the parallelism, or four cores with limited parallelism. So, you are allowed to have one core or two smaller cores, depending on the application.

So far, we have done this the other way around: you have a fixed, static architecture, and the application will have to match the need of the available resources in your hardware. Now, we are flipping it around. Our hardware will be the changing part. The work Stephan is doing, allows a single core to have different representations.

My work is at a higher level - top of the core. I am developing a system, where you are able to reconfigure your whole architecture. Suppose you have a chip like FPGA. It waits for the software to request a specific number of threads. It will make sure that the single thread will run as fast as possible and the system will put on the FPGA, the biggest-fattest-meanest single core performance it can get. Now if the software wants thousand threads, the system will stop the single core and will use a lot of simple parallelized core to run thousand threads at the same time.

> *"...the system will put on the FPGA, the biggest-fattest-meanest single core performance it can get."*

How do you have the FPGA detect how many threads are coming in or deal with the overhead?

The overhead is probably a killer, but we don't know, we are working on it as the research is going on.

Basically, you are reconstructing your architecture depending on the requirements of your software. You always have the overview of threads. The only thing that you need to do is instantiate a system that is efficiently utilized.

In fixed architecture, you can never design your software such that it always runs efficiently on your hardware. Most of the time the software does something else. But with this new idea, this is my hypothesis in my head, we are able to create a multicore system to match the ▷

needs of the software so that it will always be efficiently utilized, even with 10x reduction of performance, we will always be faster than the fastest fixed architecture.

If the hypothesis is confirmed, what application do you see for these fluid architectures?

It will redefine how we do computing. Today, Intel or IBM are the kings of the computing world. They make the processors that everyone buys by the millions and they use as a monolithic kind of device. Now if you want higher performance for a parallel application, you buy a GPU putting as an accelerator. Basically, our systems are already fixed. You have a core, that does single thread performance very well, and if you want parallel performance, you get a GPU next to it.

Now what I am proposing is a revolution in the way we do computing. If we are able to prove the hypothesis correct and the architecture is able to at least reach the same performance of two systems at average (parallel and sequential) at a tenth of the power, we will actually not need our processor and GPU anymore. We just need the simple and single reconfigurable architectures that will be able to manage all your reconfigurable needs.

In addition, this kind of architecture will be able to scale up or down depending on the requirements of your application domain. You can put it in the biggest supercomputers or the embedded devices. Because it will be able to scale up or down depending on the available resources on your hardware.

Do you see this as an all-governing architecture?

Well, of course, there are other requirements we need in the application domain like mission criticality, predictability, etc. But this does not diminish the fact that we can reconfigure the architecture in any form we want. The cores themselves are not important, the efficient utilization of the hardware is. So, when you say, "My application needs predictability.", we can just put a predictable core in there and so on. So, we are developing an architectural template where you can integrate any type of processes you want in your infrastructure, and enable those to be used by the application in the most efficient way possible.

"Why don't we do something more radical? Remove the processor and just keep the accelerator. This is something new."

If this is realized, what is the next step?

I think it will change the way we design our computing systems. Think of a reconfigurable fabric enabling processing in the future and being the center piece of your computing system, the processor and GPU added to it. This piece that will be connected to memory with high bandwidth. We already see that the Power9 by IBM will allow you to connect accelerators close to the processor on the motherboard with full bandwidth to the memory. Nobody has been thinking of the reconfigurable fabric of processors. They are thinking of having specialized architectures dedicated to specific applications.

Intel bought Altera, since they wanted to integrate accelerators in their processor infrastructure, they already have a solution where they have a processor and an FPGA integrated on a wafer with high bandwidth connectivity. They can instantiate accelerators on the fly.

Why don't we do something more radical? Remove the processor and just keep the accelerator. This is something new.

When do you expect to get the constantly reconfiguring architecture working?

We are working on it with a team of two students on the basic concept. We are using existing architectures, two different extreme architectures opposite to each other, one very parallelized and one sequential and see if we can make them talk to each other. The challenge is to have the process running. When it wants a different process, it waits for some time while you change everything. It is difficult to switch between two different architectures in the same context of the program. You have to make sure that they have the whole system around it. By the end of this academic year, I expect to have a demonstrable solution to the hypothesis.

Is there much to do for current EE students in the future to pursue this topic?

Definitely, if the hypothesis turns out be true, there is still a lot of work to be done. To go towards building the best computing system.

Power systems of the future

Prof. Ir. Mart van der Meijden

System integration is a key challenge in future sustainable electrical power systems. The vast growing variable sustainable energy sources like solar and wind are challenging the reliability, stability and affordability of our electrical power system. Choosing a single solution, A or B is not adequate anymore. Only combination of different solutions will answer the challenges of the future. This means a transition in thinking from "or-or" to "and-and".

Our common future

We all know that raw materials and fuels are finite resources, even if new discoveries are made in the future. There are limits to the emission of pollution and greenhouse gases. These messages have been given to us numerous times during many decades.

Ms. Gro Harlem Brundtland's definition, as of 1987, concerning sustainable development is still inspiring me, because of its simplicity and power to imagination: "Humanity has the ability to make development sustainable – to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs."

"...the European transmission network should be able to support the fluctuating and changing direction of the electricity flows"

Figure 1. Renewable energy sources in Europe and northern Africa (source: Desertec Foundation)

European ambition

A sustainable and reliable energy supply does not stop at our Dutch borders, but is a Europe-wide issue. I, therefore, welcome the long-term view of the European Commission: Towards a low-carbon economy by 2050. In other words, an 80-95% reduction in CO_2 emissions by 2050 compared to 1990. Saving energy and using renewable energy sources play an important role in this ambition.

Renewable energy sources

Harvesting renewable energy means combining different sources spread over large areas. An example can be given for Europe: Concentrating Solar Thermal Power (CSP) in northern Africa and southern Europe, building-integrated PV panels in central and southern Europe, wind energy in coastal areas and in the North Sea, the Irish Sea and the Baltic Sea; geothermal energy in southern Europe, hydroelectric power in Norway, the Alps, the Pyrenees and the Atlas Mountains; and biomass in central and eastern Europe. Europe's strength lies in the diversity of renewable energy sources, each with its own characteristics. In the future, the European transmission network should be able to support the fluctuating and changing direction of the electricity flows, for example, wind from the North Sea or solar energy from southern Europe.

Electricity importance is growing

Electricity is one of the fastest growing forms of energy. By the end of 2050, the use of energy worldwide is expected

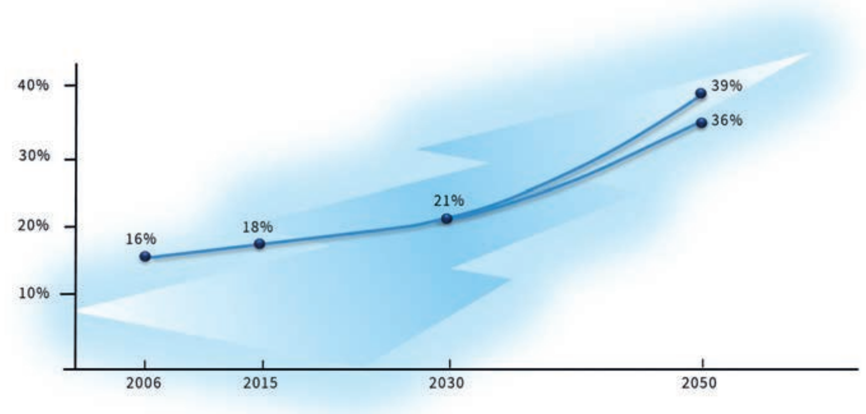


Figure 2. Share of electricity in total final energy consumption (IEA 2008, EC 2011)

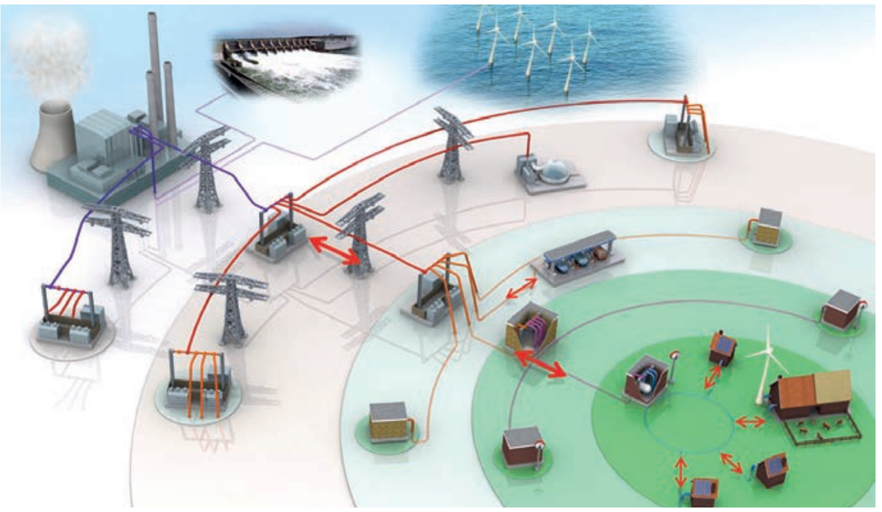


Figure 3. Schematic of tomorrow's electricity grid (Kennisbeeld).

Figure 4. Borwin HVDC platform.

to grow by 40%. There are a number of reasons for this. The growth of information technology is leading to increased use of new information and communication devices. More and more electrical devices are being purchased as the economy is growing. Saving energy on heating/cooling buildings generally leads to a greater use of electricity, for example, gas-fired central heating boilers are being replaced by high-efficiency electric heat pumps (which involve a lower use of fossil fuels in the total chain). Electrically powered passenger cars and light trucks are replacing traditional cars powered by fossil fuels. Improved efficiency in industrial processes is also leading to more and more efficient, applications of electricity. Be aware of another challenge: In 2050, still 60% of the energy consumption consists of (green) molecules for e.g. aviation,

> *"R&D is needed to make these cables more environmental friendly (with oil free XLPE) and more powerful"*

feedstock, heavy transportation, raw materials.

Tomorrow's electricity grid

Today the electricity supply is still essentially one-way traffic, from the power plant to the customer.

In the transition towards tomorrow's low-carbon economy, two different and seemingly contradictory developments can be noticed. The extensive development of renewable energy sources will take place both at local level and at (inter-)national level (see Figure 3).

New technologies

For large scale transmission of electrical offshore wind power, newly developed VSC HVDC has been applied in the Germany. Figure 3 shows a huge converter station with a surface of a football yard and a height of 12 floors.

The size of the platform is mainly determined by the size of the valves and isolators of the power electronic inverter installation (see photo). Research and Development (R&D) is needed to make these converters modular and more compact.

The electrical energy is evacuated to shore by high voltage direct current (HVDC) cables. R&D is needed to make these cables more environmental friendly (with oil free XLPE) and more powerful by doubling the capacity by increasing the DC voltage and conductor size, or increasing the capacity by five/tenfold by applying radical new technology such as high temperature super conducting (HTSC) cable.

50 Hertz: a delicate balance

Electricity cannot be directly stored on a large scale. The supply and demand of electricity on the electricity grid must be in balance. If this balance is disrupted for too long, this can result in a blackout.

Flexibility in the future

Why is flexibility growing in importance? Balancing supply and demand becomes a challenge when electricity is increasingly generated from variable renewable energy sources that are non-adjustable or only adjustable to a limited extent and for which the actual production volume is difficult to predict far in advance.

The current method based on "production follows consumption" will no longer suffice. New solutions and new parties (local, national and international) will be necessary. The following examples demonstrate the same:

- Local storage with batteries in the distribution grid, in the meter cupboard or through the smart charging of electric car batteries.
- Controlling the electricity used by heat pumps for space heating where heat storage provides the necessary regulating margin for the heat pump. Locally some of the load, for example, in cold stores, is geared to the supply (Demand Side Response, DSR). Electricity is stored virtually in either warm water or in frozen products temporarily.
- Controlling electricity production with cogeneration at horticultural companies, with heat storage providing the necessary regulating margin here too.

Water reservoirs (pumped hydro), such as those in Norway and the Alps, can be used to provide flexibility through international electricity transmission connections (interconnectors). Ideas from the Netherlands, such as industrial hybrid (electricity and gas) boilers or an energy island off the coast (PAC) can also contribute to flexibility in the future. There will be a need for flexible traditional power generation units with rapid upward adjustment possibilities. Improved accuracy of predictions of electricity from wind and solar sources with big data and aggregation of these predictions from a larger area will reduce the demand on reserve capacity and flexibility.

(a) *(b)*

Figure 5. Energy evacuation: (a) Norned HVDC cable (TenneT) and (b) HTS Cable (Best Paths).

> *"In my opinion, it would be extremely difficult to control and manage all these millions of flexibility options from a single centralized location."*

In my opinion, it would be extremely difficult to control and manage all these millions of flexibility options from a single centralized location. A system based on market mechanisms and price incentives would provide more scope and opportunities for solutions. It is good that the market mechanisms being developed facilitate optimal access to both decentralized small and large-scale solutions for the use of short and long-term flexibility functions. The online exchange of information plays an important role in designing markets. A lot of research from different angles and disciplines (market mechanisms, blockchain application, system dynamics, regulation, economics, human behavior) is needed in order to find good solutions.

Figure 6. Impression of Power Link islands (TenneT).

Maxwell 21.1
Power systems of the future

Domain Study Tour

A trip to the far east

J. Bout, J. v/d Hoeven, W. Kayser, L. Loopik and M. Zwalua

Every two or three years, the ETV organizes a study tour to parts in the world that play a big part in the electrical engineering field. Following the advice from professors and honorary members of the association, the study tour decided to visit China, Japan and Australia during a very busy month; with twenty-two participants, four committee members and one professor to accompany us for each country. There were five people who took it up on themselves to document all that happened, or at least the parts that are safe to share with our parents. The rest of this article will be a translated account of the first few days.

A long journey and day one

On the third day of August, all of the participants gathered in the big hall of Schiphol. The board, the potential board, family and friends were also there to wish us the best of journey. After a speech from the President, some Vlek jenever and the singing of our association song "Voetstappen", we were ready to leave. Even at the first check-in of the tour, it already seemed that the individual's expected survival chances were realized since one individual already managed to trip over his own luggage. Then it was time to board the airplane and start our long journey.

Once we finally reached Beijing Airport, we went to our hostel by taxi. During this taxi ride, we learned that the emergency lane could also be used to pass other cars. After miraculously reaching the hostel safe and well, our first priority was to turn on the air conditioning and finally sleep in comfortable temperatures.

After taking a shower, we could participate in the chaos - the breakfast. This breakfast was then used as a fuel to take the long walk to the forbidden city in Beijing. This walk was slightly longer than expected, due to China being bigger than the Netherlands. During this walk, we had the chance to see the Beijing Opera house, the headquarters of the biggest Chinese party, and Tiananmen square. The palaces in the forbidden city showed some of the history of the country and also their love for symmetry. During this visit, we first encountered the many Chinese that wanted to take pictures of our blond and tall students. What we also found amusing was the weird clock museum.

After the visit to the forbidden city, we headed out to find some dinner. We walked though one of the old parts of Beijing, were we were shocked (pun intended) by the sight of all the power cables strung over the streets and houses; some of them not even shielded or properly secured.

After everyone had found restaurants with various types of authentic Chinese food, we got our metro tickets. On the way back to the hostel, we had the chance to gather provisions in the form of beer and water. Then in the hostel we could prepare for the next day and rest our feet, so that we could visit the Chinese wall the next day.

A long walk over a wall

The following Sunday morning, we were woken up early, so that we could start early on our journey to the Great Wall of China. When we wanted to get breakfast at the hostel, we had to endure bad news twice. While the breakfast was ordered in advance, this was not communicated clearly with the kitchen. So, we had to wait even longer. Which was made worse by the fact that the staff had declared that is was too early for coffee. Which we all found very strange.

After breakfast, we headed by bus to the Great Wall in Mutianyu. When we got there the explanation was simple: 1. Take the cable car to tower 14. 2. Go left and start walking till you find tower 20. This is where the renovated part of the tower ends. 3. You can find a sign that states 'No tourists allowed'. You can walk past this sign onto the old part of the wall. 4. If you can walk to the highest part of the wall of tower 29, this is where the best view is. Many made it past tower 20 and even a big part of the group made it to tower 28. One or two heroes made it to tower 29 to earn the beautiful view over the hills and valley of China. Another group of students took a small detour to tower 10. This is due to the possibility to take a very long slide down to the restaurant instead of the cable car.

After a short hike of three hours on the wall, we went to one of the restaurants next to the Wall. This is where we first encountered the spinning tables to share food with the entire table. Also, this was the first time everyone was forced to use chopsticks. So, this was a lot of fun. After a shaky trip back in the bus, which had some troubles with bikes, scooters and pedestrians all over the road, we finally reached the hostel at 5 o'clock and everybody drew their own plans for the night.

A visit to Tsinghua University

To be on time for our first serious activity, a visit to Tsinghua University, we had to wake up at 6 o'clock. The previous day we had already learned that we could not rely on the breakfast that was provided by the hostel. So, the study tour committee provided the breakfast instead. After joining up with the previous Dean and honorary member of the ETV, Rob Fastenau, we were ready to start the journey in our formal attire.

Once we reached Tsinghua University we were held up by the guards in front of the university gates. We had to wait until we were let in by the professor that would lead us around the university. It was a long wait and walk till we finally reached a place which had air conditioning. It was very clear that we were not used to the temperatures of China in the summer.

...the group of ETV members were received in a marble lobby that would even had impressed Louis XVI of France.

We were received at the Department of Micro- and Nanoelectronics. Once we were there we got an introduction on the Tsinghua University, in which they told us, full of pride, about their awards and rankings. Xi Jingping, the current president of China and many other important politicians had studied at the university. After this introduction, it was our turn to hold a small presentation about Delft and the university. There were also three students to hold a "short" presentation about their research. When the presentations were over, it was time for lunch. This was also the first time many of us experienced the Chinese version of pizza, which was odd to say the least.

In the afternoon, we had a visit to the startup-incubator, X-lab, where the students have the possibility and can get aid to develop their entrepreneurial skills. The last part of the tour was a visit to the museum of the university. All of the explanations and texts were in Chinese, but fortunately one of the three students could speak English relatively well. After having thanked the professor and the students, given our presents and made a group photo, we left again in groups to find some food before heading back to the hostel.

A visit to State Grid and BD-IIST

The last day already started in the warm Beijing. With twenty-seven pairs of eyes that all needed to have a little bit more sleep, we headed off to the bus. Because the heavy traffic in Beijing had not started at 7 o'clock, the bus ride was quite quick. Once we arrived at the State Grid Corporation of China, the group of ETV members were received in a marble lobby that would even had impressed Louis XVI of France. After this moment of wonder, we resumed our walk to the meeting room, where a presentation was given on all the details of the State Grid. Quite quickly, it became apparent that the State Grid was in a different category than the Dutch grid manager, TenneT. With 1.74 million employees and a small billion customers, the numbers turned quickly in unbelievable size on the big projector screen. Fortunately, the numbers in the following presentation were aided with pictures, graphs and other illustrations. The presentation was concluded with a short tour past all the laboratories of the State Grid.

After lunch and dessert in the canteen of the State Grid, we travelled back to Tsinghua University. We came back for a presentation on BD-IIST (Beijing Delft - Institute of Intelligent Science and Technology). This is the joint venture research center that focusses on micro-electronics. After all these presentations, it became apparent that on the area of culture and politics that there are huge differences between the always cold Netherlands and the, at the moment, very hot China.

The rest of the day has been redacted

A bullet train to Shanghai

The next day we were allowed to sleep till ten o'clock. After these precious hours of sleep, we travelled to the train station. The station was very big and almost resembled Schiphol in size and infrastructure. First of all, we went through the security check, which costed us two scissors that were left in the wrong luggage. Afterwards, we ended in an enormous departure hall, with a gate for every track. Due to some hold ups earlier, we ended up a bit late at the gate. This caused a weird situation in which our luggage suddenly got taken away. However, this was fixed due to heavy usage of text to speech and a translation app. Once we finally got to our seats in the train, we found that they were quite spacious and comfy.

At quarter to one, we waved Beijing good bye. However, even with a train that drove 300 kilometres per hour, it took almost half an hour before we left the Beijing area. This gave us a new perspective on how big the cities in China are. Once underway, we had the chance to eat a Chinese microwave meal as lunch, a lot of positive opinions about this were heard.

Once we reached Shanghai, it became apparent that this city was so much different from Beijing. The skyline was taller and there were way more LEDs on all of the buildings. Some students remarked that the population had a more western clothing style. At the station, which also functioned as the airport, we were picked up by the bus of our host. This bus took us to the guesthouse, just outside the center of Shanghai. This guest house was still under construction. This was due to a decision of the Chinese government to build 500 new canals, which all the builders needed to help with. This caused delays in the renovation of the house. This mostly meant that a lot of things were still wet in paint or had yet to be painted. Despite this surprise, we had a lot more space than in the hostel to store all of our luggage.

A look at the lighting innovation

The students decided to voice their opinions on sleeping on Tatamis. These helped against the high temperatures of Shanghai, as the temperatures are even higher than Beijing. However, these mattresses were not as soft as people were used to; many compared it to sleeping on a floor. After everyone showered and clothed, we had the English breakfast. Then we headed to Lumileds.
Once we arrived at Lumileds, we learned that this company was a part of Philips during an interesting presentation from the General Manager about the company. This presentation also contained some information about Chinese business and also about the difference in how patents work in China and in the rest of the world. Then we had the chance to see new products being developed and tested.

After lunch, we first had some presentations on the fabrication of LED headlight for cars, the creation of upgrades for cars and also about the development of accessories. These accessories were mostly air fresheners and dash cams. There focus was on developing new functions and features before the other Chinese competitors offer the same. We also had a brainstorm session about new accessories for cars. Two of the ideas were a coffee machine in cars and a light in the belt buckle. Also, we talked about the transition to self-driving cars, which the company found very interesting. After a short discussion and a group picture, we headed to the city center.

In Shanghai, we went out together with Lumileds to a restaurant under the Oriental Pearl tower, which is an iconic place for the Skyline of Shanghai. In this restaurant, we had the possibility to discover some delicious and interesting dishes, one of which was the sweet and sour fish, which was recommended by one of the employees.

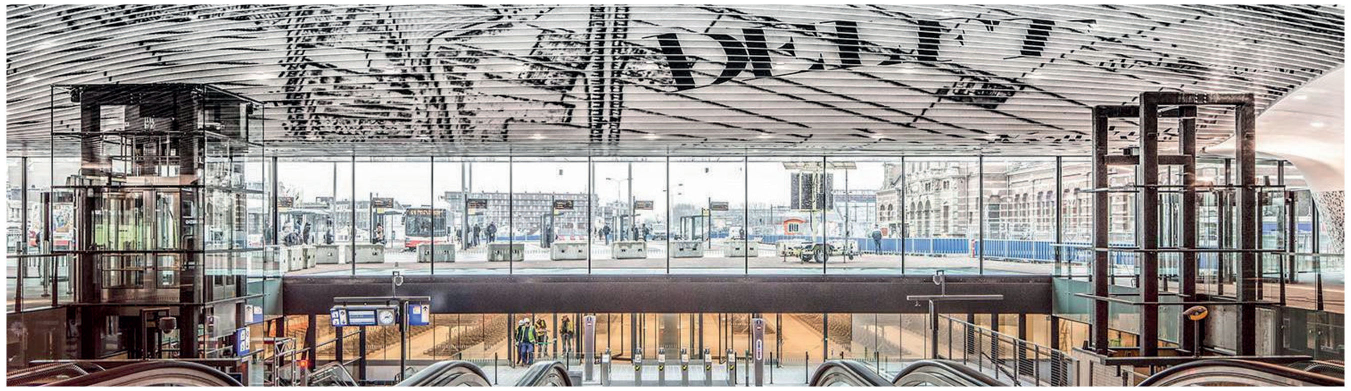
After this delicious dinner, we went out for a walk with the head of research and development of Lumileds to discover some parts of the city. This walk took us through the center of the financial district, where one could see all of the intricately lit skyscrapers. We also walked the boulevard, next to the river running through Shanghai. Next to the lit buildings, there were a lot of boats with even more LEDs. After a short trip in the ferry, we had a short visit to one of the fame rooftop bars of Shanghai.

An invitation

If you want to read more of these stories you can find them on the Facebook page of the Domain Study Tour, or ask one of the participants for their stories.

Future of Delft station

Simon Verkleij and Himabindu Kopally



When you look up and you see a big map of Delft, you probably are at the railway station of this city. The ceiling of this building consists of almost 4000 different pieces, which together form a map of Delft from 1877.

The station opened on February 28, 2015. Before this, underground railway connection was used, an overpass brought trains from and to the city. This new public transport hub connects trains, buses, trams and taxis on just steps away to the historic city center. This innovative and sustainable building received the Good Green Design Award. One of its special features is the reuse of heat produced by the computers to warm up the building.

Future of the rail zone

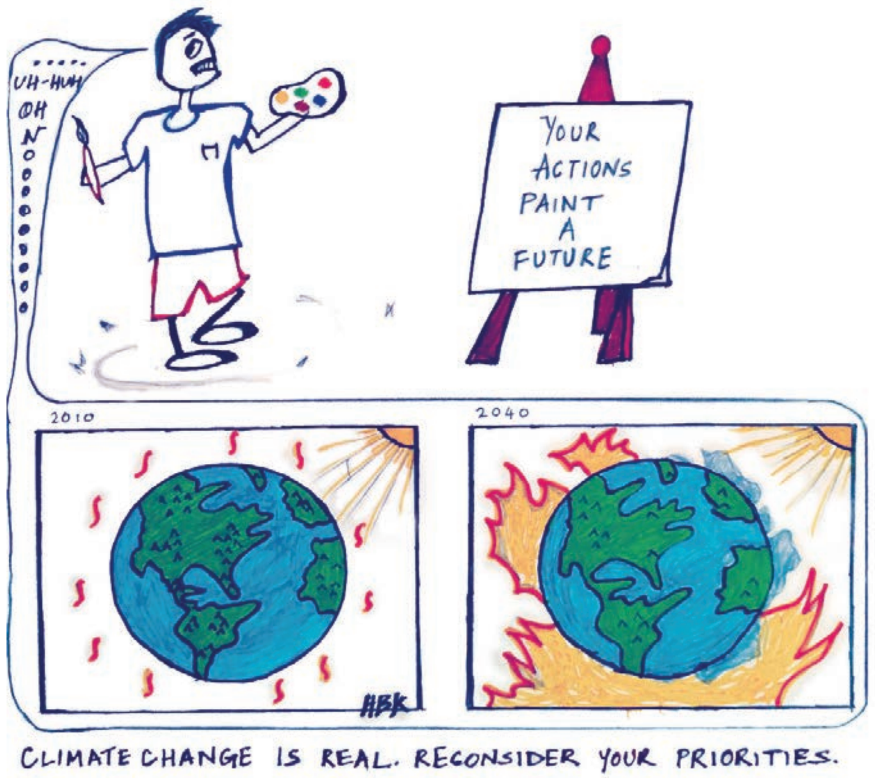
The train station of Delft notes the beginning of a big change in that part of the city which is called the rail zone (spoorzone in Dutch). The area next to the station, which is still a construction site at the moment, will soon be transformed in modern buildings such as a hotel and houses. The building of the old station will be renovated to serve as a restaurant and wine bar with a park behind it. This park will be on top of the newest bicycle parking lot and will be finished in 2018.

Another outstanding project is the House of Delft. This residential building honors the pioneers of the city who have delivered extraordinary achievements in the fields of science, art, craftsmanship and high-tech innovation. The building will be in line with the style of canal houses with a Delfts blue color.

These new buildings increase the sustainability of the city, which is a good step forward in reducing environmental impact. We should also keep an eye on being sustainable in our own needs.

More information

www.spoorzonedelft.nl
www.nieuwdelft.nl
www.houseofdelft.nl



Activities

Elektro Ontvangst Weekend

The beginning of growing older: you get to choose a study program and you get to make new friends. When you are following a particular study program, it is extremely motivating to know each other from the same study program. The Elektro Ontvangst Weekend (EOW) helps you with that, in combination with having a great time.

When the EOW began, we got a tour around the faculty. We were all handed brown electro overalls. After making a group photo and singing the 'Electro' songs with each other, we were dropped in Delft and had to find the way back to the EEMCS faculty. After having a beer at the /Pub in the faculty, we got to sleep there as well.

Next day, we headed to the Staelduin campsite by bike. All the new students got to sleep in one massive tent, which was a lot of fun. At this time, we were already getting hyped about the "Big hero's game", that would take place at the end of the weekend and we had no clue what it had in store for us. During the whole weekend, there was one song which was constantly played, just one song. I think I heard that song more than 400 times that weekend.

During the whole weekend at the campsite, we played a lot of different games, not only drinking games (which some liked quite a lot). We were all given a resistor to trade it for something bigger. My group ended up with having two laptops!

The last day of the weekend, we played the "Big hero's game". The whole weekend you could earn stickers to have a head start for this game. But when we started listening to the explanation of the game, we were all losing our courage and excitement. The game was not very fun… it was about cleaning the whole campsite.

In the end, the EOW was a weekend I will never forget!

Sep Ursone

Welcome Back Barbecue

This year also, the welcome back barbecue was again a great social gathering organized by the zAkCie (the summer activities committee). Probably, for the first time, the barbecue was organized indoors in the /Pub. Because, unfortunately, the summer temperatures and the sunny weather were a bit disappointing.

Nevertheless, it was a great evening with a not to match, like our catchphrase "Niet te evenaren", attendance, although I was outside barbecuing and turning burgers the whole evening. Even though some burgers ended up black and slightly inedible, most of the meat was great and so was the evening, maybe because of the free beer, because that was gone quite fast. Fortunately, there was another keg of beer available to save the evening. At the end, everyone's belly was full and we can say the welcome back barbecue was awesome! I hope to see everyone next year.

Stefano Roos

IFF

A hardworking Electrical Engineering student has got a lot to worry about: upcoming exams, due dates for reports, and so on. The best way to relieve the stress may actually be to indulge in a good party from time to time. The IFF, a party organized by various student associations from Delft, was a great example of this. Even though it started quite early, the ambiance was great from the first moment. Fortunately, the beer was very cheap and this made sure that everyone kept partying until the very last bit, just as the saying 'Inkakken is bijpakken' suggests. The lineup was great as well: all the songs were very well suited for dancing, something that is of utmost importance for any party. In combination with the outstanding dancing qualities of the average TU Delft student, this contributed to an even more memorable night of outstanding escalation. In short: can't wait for next year!

Jasper Insinger

Walibi ETV Weekend

A new year, a new committee, and of course, a new weekend to party. The ETV WeeCo had their first trip this year to the fantastic Jaap van der Linde Hoeve in Vierhouten, a place of wonders and Smirnoff Ice. 24 brave and young ETV members dared to face the horrors of Walibi fright night and the waves of sailing (on a somewhat less windy day, but who cares?).
On Friday, the sixth of October, the group departed to leave for our stay in Vierhouten. A place where we were welcomed by so called 'scheetjes' and plenty of beer in the fridge. An evening of campfire-sitting and drinking games followed; all the time being careful not to look around too much, because of the hidden bottles of Smirnoff Ice, which had to be drunk as a whole if you found one.
The next day, a pleasant wakeup call was provided by the committee and we went to the next stop, Walibi. A day filled with rollercoasters and food, finished by the fright night. Horrors of hell, zombies and chainsaws were all present for the party. It was, for sure, a fantastic day!
To finish off this great weekend, we went sailing on the last day. Daring captains were chosen, tasked with actually making sure we would not sink, which was quite a challenge. But after sailing around for a couple of hours, we all came back safely to the shore, with our empty cans of beer.
A fine end to an amazing weekend and recommended to everyone who wants to have a superb weekend.

Marcel Brouwers

Faculty Student Council

Tom Heijnders

The new academic year started and so did the new Faculty Student Council (FSC). Right after the election results were in, the first couple of meetings took place and the new members were excited to begin.

What is the FSC?

The FSC or Faculty Student Council is a student representative council within our faculty, EEMCS. In practice, the FSC tries to improve the faculty on behalf of the students by giving advice and participating in important meetings and discussions within the faculty. We have a weekly meeting to discuss problems within the faculty. Then we discuss these problems with the board of EEMCS in another monthly meeting. We also attend the budget meetings within EEMCS where we have a say in how the faculty spends its money. Additionally, we also discuss university-wide issues through meetings with all the FSC's from different faculties and the Student Council of the university. The FSC has the right to advise and the right of initiative regarding anything relevant to the students of EEMCS. This allows us to really make a difference in the faculty!

The elections

The FSC is chosen every year by elections. Everyone can sign up for the elections, this makes the FSC very diverse. We have freshmen, master students and international students within the FSC. Then depending on the number of votes you receive as a candidate, you could get a seat in the FSC. Within the FSC, there are different "chambers"; with each chamber representing a program within EEMCS. Depending on our program we could only run for a seat at our own chamber. There are 4 seats available in the Electrical Engineering chamber, 4 in the Computer Science chamber, 3 in the Mathematics chamber and 1 in the SET chamber. This last chamber might be unknown for some students. SET is a relatively new MSc program and was initially represented in the Applied Physics Council. Last year, they became part of the EEMCS council. Most of us are new members, but we have two members who were in the FSC last year. They help us a lot because they can explain everything that is unfamiliar to us. The following members are the members of the new FSC:

Electrical Engineering chamber:

Luc Enthoven (Secretary)
Lotte Zwart (Secretary)
Karen van der Werff
Philip van den Heuvel

Computer Science chamber:

Felix van Doorn (Chairman)
David Allaart (Vice-Chairman)
Bartosz Czaszynski
Jayme Freeke

Mathematics chamber:

Tom Heijnders (Finance)
Elsje Burgers
Dion van Lange

What we're doing now

We've had a training with all the FSC's from TU Delft where we learned all the basics. We are picking up where the old FSC left off. We will continue their work on improvement of Collegerama and we will make EEMCS more accessible for international students. As you all probably know by now, EEMCS has to be moved soon. In December, the teachers will move to a building behind Civil engineering and it's the question whether the students also need to move. We will make sure that the transition is as smooth as possible. We will make EEMCS great again!

We want your input!

We are still thinking of subjects we want to improve this year. For that we will also need your help. Every quarter we organize a coffee moment to talk to students. You can find us then in the hall of EEMCS with free coffee, ready to hear your stories about studying at EEMCS. We would be pleased to hear about all the problems you encounter throughout the faculty or any idea you might have for improving the education at EEMCS, big or small. If you cannot wait for the next coffee moment, you can always send us an email at: fsc-etv@tudelft.nl.

Upcoming activities

For members of the Electrotechnische Vereeniging

Tijs Moree

Lunch Lectures

This quarter there will be a lot of lunch lectures again. Before the christmas break there will be three: Royal IHC, TATA Steel and Deerns on respectively the 30^{th} of November, the 8^{th} and the 18^{th} of December. Of course there will be delicious sandwiches from Leo!

To attend these lectures you need to subscribe to the Facebook event posted on the ETV Business page.

Sinterklaas lunch

Since Sinterklaas will arrive in the Netherlands in a few days, the ETV organises a 'Sinterklaas' lunch on the 5^{th} of December in the /Pub. In advance you can come and craft your own shoe. 'Zet je schoen' as the tradition dictates and get all kinds of goodies from companies!

If you would like to join us, you can come by the ETV counter and subscribe for just €2,-.

Christmas lunch

At the end of the year, Santa will come by. On the last academic day of this year, Friday the 22^{nd} of December there will be a christmas lunch in the /Pub. Santa himself will come by to tell a beautiful christmas story and there will be glühwein to enjoy.

The price of this lunch is €3,-. Don't hesitate to come and subscribe at the ETV counter.

Long-term vision evenings

Do you have an opinion on the long-term vision of the ETV? Give it a voice on one of these evenings!

The ETV is currently formulating its strategic plan for the coming years. Throughout the next three months several brainstorm sessions will be organized, each of them addressing a specific aspect of our association.

The following five discussion evenings will each have a theme and will take place in the Van Der Poelzaal at 18:00.

Association *21^{st} of November 2017*
Career *28^{th} of November 2017*
Education *19^{th} of December 2017*
Finance *16^{th} of January 2017*
Science *23^{rd} of January 2017*

We would like to welcome you to share your insights and opinions on any of these topics during the five brainstorm sessions.

Register through Facebook for free dinner! Can't make it, but need to get something off your chest? Drop us an e-mail on *vicie-etv@tudelft.nl* and we will get back to you shortly!