Magazine of the
Electrotechnische Vereeniging

MAXWELL

Edition 13.1

Study collection
A history of electrical engineering

A tiny dot can change the world
ABB on their High-Power Technology for IGCT's

Interview with Alert Solutions
Monitoring the health of dikes

Renewable energy systems
An answer to conventional energy

Hier invoegen: pagina2TNO.pdf

From the Board

Within the Delft University of Technology (DUT) it's a commonly heard term: innovation. Lots of research done within the DUT focusses on renewing and improving a product or creating a completely new product. This shall often be done because of a technical stimulus, not really surprising for a technical university. One of the main aspects to keep in mind with such an innovation is your market. Even if your product is really ingenious, it's doomed if there isn't enough demand for it.

This brings the second big stimulus for an innovation to mind, a stimulus because of demand. A stimulus which is equally important within the DUT. Not so much for the students but even more for the faculties. After all students create a demand for the DUT, so the faculties have to make sure their product (education) fits in with the students. No wonder the faculty has worked hard to create a new curriculum for the bachelor Electrical Engineering. A bachelor degree which better fits in without losing essential basic knowledge of electrical engineering.

Innovation because of demand is also important within the ETV. As a study association students are your main spearhead and because students and their wishes are dynamic; so should we. Offering what the student desires in the best possible way, but without losing sight of the ETV's character and spirit. So as Board of the ETV your practically innovating whole year long, improving the product "ETV".

Now we're approaching the end of our year as Board of the ETV, a nice moment to look back on what's improved in the last year. An increasing part of the ETV's members are international students, more international students require a more international product. Resulting in a shift from Dutch to English, but also activities focussed on international students. But the Dutch students are changing as well. Last year the expectations of the freshmen weekend are investigated and as a result of that this freshmen weekend is changed, to better fit the expectations.

So the ETV keeps innovating year by year. For us, the 137th Board, a year of innovating is coming to an end. After one year we will return to our courses, improving ourselves. But there are five fresh students to succeed us, ready for next year, as 138th Board. They will also innovate and improve the ETV in their way, so that the ETV keeps fitting in to the students wishes and can bring them fun, support and relaxation.

On behalf of the refreshing Board,

Thijs van Leeuwen

Editorial

AN ENDING

Where the previous edition of the Maxwell started with 'What else is new', it now starts with 'an ending'. First of all, it is the ending of the academic year. It's almost summer holiday, where you can clear your mind, study for the re-exams and read this Maxwell.

Secondly, some of the editors will end their membership of the Maxwell committee. As you may have read in the advertisement in this edition, we are looking for new members of our committee to present an even better Maxwell to you the next year.

This edition features the usual sections of the Maxwell, like an interview and the newsflash. The interview was done with Alert Solutions. This company is doing research for a wireless dike monitoring system, aided by a bachelor graduation project. Undersigned coöperates with these students by doing another project in the same room.

There is still no circuit scheme featured in this edition, however, if you have some spare time, then you should definitely read the article about the 'Study Collection' and visit it. It is possible to spend many hours there.

On behalf of the committee, enjoy reading.

Joost van Driel, Editor

Contents

Renewable energy systems

The growing demand for electrical energy and the depletion of fossil reserves motivate a quest for new technologies. At DENLab decentralized and renewable energy systems are being researched.

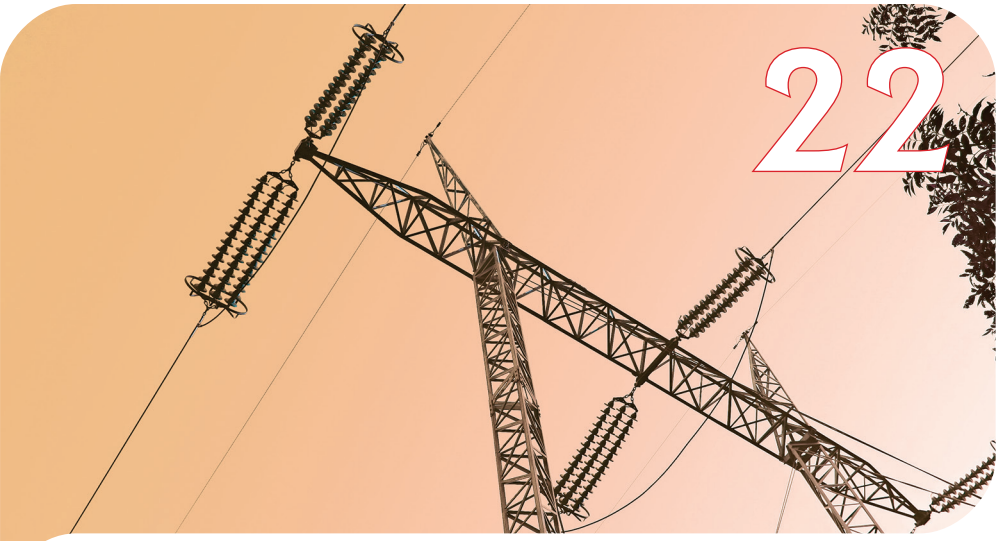
Interview with Alert Solutions

Real-time monitoring of dikes was not possible until recently. Alert solutions jumped into this niche and developed a sensor network. And not only dikes benefit of this technology.

ETV MAGAZINE "MAXWELL" Year 12 – edition 4 – June 2009 **PRINTING** Thieme Media Services, Delft **NUMBER OF COPIES** 900 **EDITORS** Joost van Driel, Thijs van Leeuwen, René van der Meij, Jeroen Ouweneel, Johan Splinter, Erwin Stout, Imke Zimmerling, Joost van Zwieten **CONTACT** Maxwell, p/a Electrotechnische Vereeniging, Mekelweg 4, 2628 CD Delft, phone: 015-2786189 or 015-2781989, fax: 015-27 81002, e-mail: maxwell@etv.tudelft.nl, website: www.etv.tudelft.nl **CHANGE OF ADDRESS** Please send your changes to the address above, or use the website. Alumni can change their address via the Alumni Office website: www.alumni.tudelft.nl. **ADVERTISEMENTS** TNO (p.2) Technolution (p.5 & p.18), Smit (p.20), Frames (p.33), Deerns (p.39), Tennet (back cover) **SUBSCRIPTIONS** Non-members can receive the Maxwell four times a year, against a contribution of e10,- per year. For more information, please contact the Maxwell Committee.

A tiny dot can change the world

ABB has developed a new technology to optimise the performance of the integrated gate-commutated thyristor (IGCT)



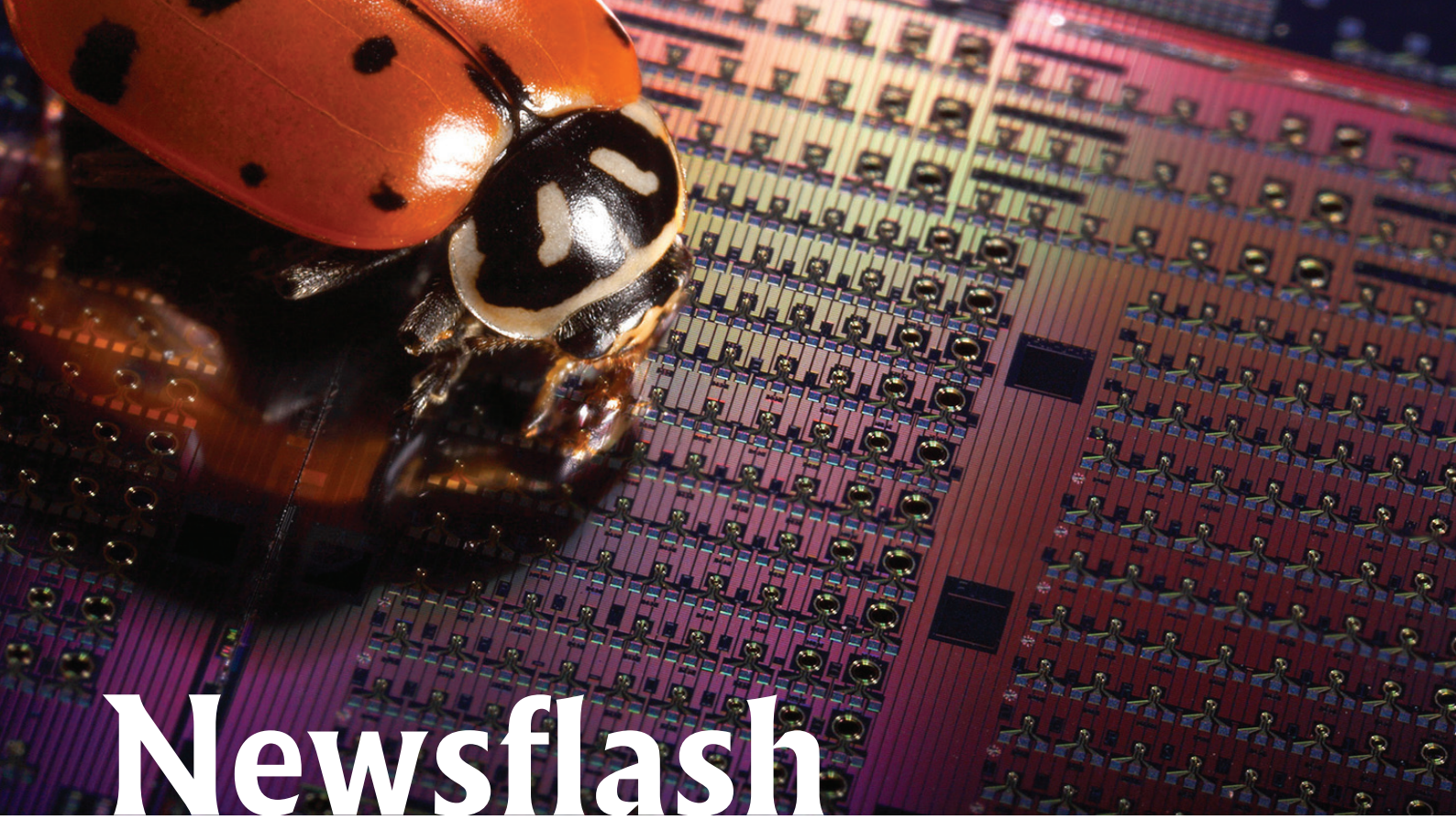
Study collection: A history of Electrical Engineering

In the basement of the EWI building is a large collection of electronic devices: from telephone switchboards (see front page) to large control panels of a nuclear reactor. A brief overview of the museum.

Technolution
AUTOMATION TECHNOLOGY

And more...

- From the board 3
- Newsflash 6
- Activities of the ETV 10
- Dies report 12
- Photos of ETV-Sail 2009 19
- Joost may know it 21
- International Column: Salim Alahdab 27
- Column: Nick van der Meijs 38



Newsflash

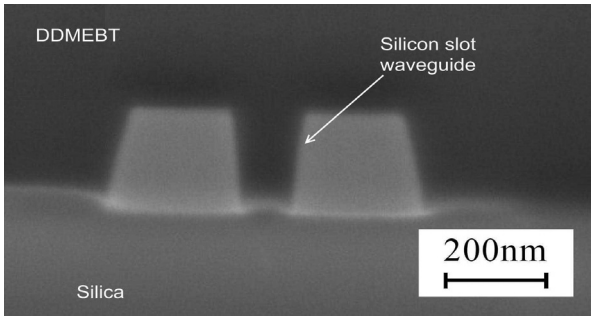
Research team reports breakthrough in optical silicon communication

Christoph Hammerschmidt, EE Times Europe

Transmission speeds beyond 100 Gbit/s based solely on silicon devices have become possible through the efforts of an American-European research group. In particular telecommunications industries are possible beneficiaries. The researchers believe they have paved a promising way to handle the increasing global data traffic.

Researchers of the ETH University (Zurich Switzerland), the Inter-university Research Center IMEC (Leuven, Belgium), the Lehigh University (USA) and the University of Karlsruhe (Germany) have succeeded in manufacturing an optical waveguide structure with highly non-linear behavior and ultra-fast performance. Since in these devices, photonic signals do no longer need to be converted to electronic ones, they are regarded as a key element to all-optical signal transport. In order to achieve that goal, the researchers took the silicon-organic (hybrid SOH) approach, combining standard CMOS processing, deep ultraviolet lithography and organic molecular beam deposition.

The device in question is a tiny SOH waveguide only 4mm long — but with a record nonlinearity coefficient of 105 (Wkm)-1 in the 1.55 μm telecommunications window. This piece of silicon is announced by the researchers as proof of the SOH concept, and it made it possible to confirm for the first time the record values predicted by theory.



A silicon slot waveguide

The researchers mixed four signals with data rates of 42.7 Gbit/s each to achieve a multiplexed 170.8 Gbit/s signal — the fastest silicon photonic optical signal processing demonstrated to date. According to the researchers, the experiment proved the viability of SOH waveguides for all-optical processing of high-bandwidth telecommunication signals. In particular, the researchers were able to overcome existing obstacles in all-optical switching due to slow dynamics. The data rate achieved by using bare silicon waveguides was limited to about 40 Gbit/s. The ability of organic material used to homogenously fill the slot between the waveguides is a key feature of the deposition process.

The silicon circuits were designed by researchers of the Karlsruhe University and fabricated on IMECs silicon photonics platform through the ePIXfab service, a European funded initiative coordinated by IMEC.

VIRAL BATTERY PUNCHES ABOVE WEIGHT

Leila Sattary, labnews.co.uk

Viruses genetically engineered at MIT can build batteries with the same energy capacity and power performance as state-of-the-art rechargeable batteries used in hybrid cars.

The virus batteries are non-toxic and could be manufactured in a cheap and environmentally friendly way.

Three years ago, the team led by Professor Belcher from MIT showed that their engineered viruses could build an anode by coating themselves with cobalt oxide and gold and self-assembling to form a nanowire. However, this only went half-way to building a self assembling battery as a high powered cathode was needed to match the anode. Cathodes are harder the build because they need to be highly conducting, but the best materials for cathodes tend to be insulating.

To solve this problem, researchers from MIT used genetically engineered viruses that coat themselves with iron phosphate and then attach to carbon nanotubes to create a network of highly conductive material. The viruses used are a common bacteriophage that is harmless to humans.

Using carbon nanotubes gives a highly conductive and lightweight cathode. Other advantages of using a nanotube structure include the possibility of making flexible and conformable batteries that take the shape of their container.

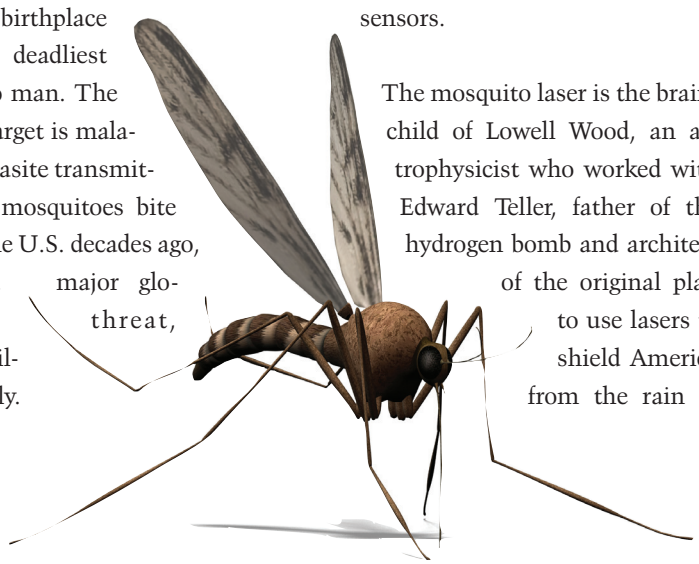
Now the group has demonstrated that they can produce virus batteries at the nanoscale, they intend to use materials with higher voltage and capacitance, such as manganese, phosphate and nickel phosphate. The group hopes that the next generation of virus batteries could go into commercial production.

Scientists developing anti-malaria laser to shoot down mosquitoes

Gail Overton, laserfocusworld.com

A March 14 article from Robert A. Guth on page A1 of The Wall Street Journal describes how scientists are developing laser weapons to shoot down malaria-bearing mosquitoes. Incredibly, there is no shortage of funding available to design a laser-based 'weapon of mosquito destruction'.

In a Bellevue, WA lab, researchers are among those exploring a "WMD: Weapon of Mosquito Destruction." "We'd be delighted if we destabilize the human-mosquito balance of power," says Jordin Kare, an astrophysicist who once worked at the Lawrence Livermore National Laboratory, the birthplace of some of the deadliest weapons known to man. The scientists' actual target is malaria, caused by a parasite transmitted when certain mosquitoes bite people. Ended in the U.S. decades ago, malaria remains a major global public-health threat, killing about 1 million people annually.



The article goes on to describe how big-money donors like Bill Gates, the United Nations, the U.K. and non-profit such as Malaria No More re-launched the war on malaria, devoting billions of dollars to vaccines, methods of prevention and novel ways to kill mosquitoes.

"You can say we are very lucky -- the right place at the right time," says astrophysicist Szabolcs Márka, a Columbia University specialist in black holes. He has a grant to develop a "mosquito flashlight" designed to knock out the bugs' eye-like sensors.

The mosquito laser is the brainchild of Lowell Wood, an astrophysicist who worked with Edward Teller, father of the hydrogen bomb and architect of the original plan to use lasers to shield America from the rain of Soviet nuclear arms. Its rebirth as a bug killer came thanks to Nathan Myhrvold, a former Microsoft executive who now runs Intellectual Ventures LLC, a company that collects patents and funds inventions. His old boss, Bill Gates, had asked him to explore new ways of combating malaria. At a brainstorming session in 2007, Wood, the Star Wars architect, suggested using lasers on mosquitoes. Soon Wood and another Star Wars scientist teamed with an entomologist with a Ph.D in mosquito behavior and other experts. They killed their first mosquito with a hand-held laser in early 2008.

They now face one big challenge: deciding how strong to make the weapon. The laser has to be weak enough to not harm humans and smart enough to avoid hitting useful bugs.

Tiny particles make LED light more pleasing

Peter Svensson, Associated Press

Light-emitting diodes are prime candidates for replacing inefficient incandescent bulbs, but have a few things working against them. They can provide a pleasing warm light or they can be energy-efficient, but they haven't been able to be both at the same time.

On Tuesday, two small companies showed off an LED lamp that's both very power-efficient and produces a light similar to that of a standard tungsten or halogen bulb.

The LEDs in the lamp shine through a thin layer of "quantum dots," a scattering of particles of very small but precisely controlled size. When light hits them, they emit light of a different color, much like the "phosphor" layer of a fluorescent tube. The magic of quantum dots is that the color they emit can be controlled very accurately by adjusting their size, which means less wasted energy and more pleasing color.

The dots are so small that more than 10,000 of them could be could be lined up over the width of a human hair.

The Quantum Light lamp is made by Nexxus Lighting Inc. of Charlotte, N.C., which demonstrated it at the Light Fair trade show in New York. The lamp will go on sale late this year at an as yet undetermined price. Nexxus already sells a version of it that lacks quantum dots, yielding a bluer, harsher light, for around $100.

The more pleasing light produced by quantum dots could allow LEDs to outshine compact fluorescent bulbs, which are energy-efficient but have taken time to win over consumers, said Bill Blackley, vice president at Nexxus.

"A hundred years, incandescents have been around. That's what people want," Blackley said.

Given the high price of LED lights, the main use for them so far has been in commercial applications, like restaurants and hotels, where the longevity of the lamps makes up for their purchase cost. Nexxus says the lamps last up to 25 times longer than halogen alternatives.

The layer of quantum dots in the lamp is the first commercial product of QD Vision Inc., a Massachusetts Institute of Technology spinoff based in Watertown, Mass. It hopes to spread their use to many other applications, including TV backlights, where they could improve brightness and color saturation.

Quantum dots have shown up in an LED lighting product before — in strings of colored Christmas lights launched last year by QD Vision competitor Evident Technologies Inc. of Troy, N.Y.

Sharp Develops Five-Primary-Color LCD That Faithfully Reproduces Real Surface Colors

Prototype to Be Exhibited at the SID 2009 International Display Symposium

Sharp Corporation has developed a five-primary-color display that faithfully reproduces the real surface colors that humans are capable of perceiving. A prototype of this display will be exhibited at the international symposium of the Society for Information Display (SID) to be held in San Antonio, Texas, US from May 31 through June 5, 2009.

Demand for displays that can render colors in a manner faithful to the appearances of naturally occurring surface colors or designed colors is growing stronger in fields such as industrial design, digital archiving, network-based remote medical care, and electronic commerce. Thus various efforts to satisfy these requests are intensifying, prompting, for example, the development of natural vision technology.

This five-primary-color display comprises "Multi-Primary-Color Technology" that features special image processing circuitry, in addition to the display panel whose pixel structure is based on five-color filters that add the colors C (cyan) and Y (yellow) to the three colors of R (red), G (green), and B (blue). This combination expands the color gamut (range of reproducible colors) that can be rendered within the color spectrum that humans can discern with the unaided eye, and enables the display to reproduce more than 99% of real surface colors. Nearly all real surface colors can be rendered faithfully, including colors that have been difficult to render using conventional LCD monitors—the color of the sea (emerald blue), brass instruments (golden yellow), and roses (crimson red), for example. As adoption of this technology will enable more efficient use of light energy produced by the backlight, this display will also provide greater energy savings.

In the future, Sharp will be working to further improve the basic performance of this display and making efforts toward its practical application.

GPS System Could Begin To Fail Within a Year

David Coursey, PC World

The Global Positioning System faces the possibility of failures and blackouts, a federal watchdog agency has warned the U.S. Congress. Mismanagement and underinvestment by the U.S. Air Force places the GPS at risk of failure in 2010 and beyond. The problem: Delays in launching replacement satellites, among other things.

According to the Government Accountability Office report, "In recent years, the Air Force has struggled to successfully build GPS satellites within cost and schedule goals" as part of a $2 billion modernization program.

"If the Air Force does not meet its scheduled goals for development of GPS IIIA satellites, there will be an increased likelihood that in 2010, as old satellites begin to fail, the overall GPS constellation will fall below the number of satellites required to provide the level of GPS service that the U.S. government commits to."

Considered by the GAO to be "essential to national security" the GPS is also widely used by business and consumers and is a driver for next-generation location-based mobile applications used with smartphones and other devices.

"Such a gap in capability could have wide-ranging impacts on all GPS users," the GAO report states, "though there are measures the Air Force and others can take to plan for and minimize these impacts."

It is hard to imagine the U.S. government could allow this to happen. Actually, that's a lie, it's easy to imagine, but there is also time for corrective action to be taken. The first replacement satellite is expected to be launched this November, some three years after the original launch date. Speeding up future launches can solve the problem, but is likely to come at a high price.

The American GPS, though the pioneering consumer satnav system, is not alone. Russia, China, and India each have systems of their own, which are being expanded.

The European Union's Galileo system, intended as a rival for GPS, is expected to begin its rollout later this year.

The delay and potential failure of GPS gives these other nations the potential to rival the U.S. in space, something the U.S. government is unlikely to accept. The report is a black eye for the Air Force, which developed the GPS system during the 1980s and has maintained it since.

Transistors that Keep their Cool

Intel recently disclosed advancement details on a P-channel transistor, built on a silicon substrate, that makes use of compound semiconductors, also known as III-V materials because they are made of elements that straddle silicon in the periodic table, silicon being in column IV. This research resulted in the highest performing P-channel transistors reported to date. A year earlier, Intel described III-V N-channel transistors, also built on a silicon substrate. When combined, these two results could form the building blocks for CMOS logic circuits, which use both N-channel and P-channel transistors. Potentially suitable for future microprocessors, they run far cooler - at about half the voltage, consuming only one tenth the power of today's transistors.

Activities of the Electrotechnische Vereeniging

Lunch Lecture by Deerns

Author: Thijs van Leeuwen

The 22nd of April all students, equipped with a lunch, sat ready for the lecture given by Deerns. The main subject of the lecture was about new, smart solutions to build more environmentally friendly, which was illustrated with the Burj al Shams, Tower of the Sun. This tower is a new concept building of Deerns, and is planned to be built in Dubai.

After a short introduction about the company Deerns, a consultancy firm in the field of electrical, mechanical and energy engineering solutions and building physics, Menno Termijn started his presentation explaining Trias Energetica. This is the developing philosophy for a climate neutral building on which the Burj al Shams is based. It consists of three separate aspects to build more environmentally friendly. First, it's necessary to use as little energy as possible. In the Burj this is done by giving the building an upside-down conic shape. Because of this, the roof blocks direct sunlight on higher floors which reduces heat by direct sunlight. The energy required for cooling is reduced with more than 50% thanks to a cylindrical shaped building. By making sure that as many rooms as possible benefit from the sunlight, the energy demand of artificial lighting is reduced. Since climate control and artificial lighting consume the most energy in a building, big energy reductions can be made.

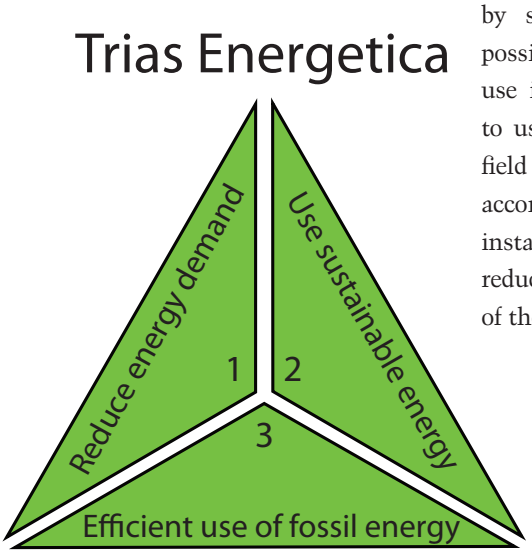


Figure 1: The Trias Energetica

The second aspect of the Trias Energetica is the maximum use of sustainable energy. In the Burj this is done by a special roof. The top layer is filled with solar panels, using the strong sun of Dubai. Underneath the top layer small wind turbines are located, using the wind that is strengthened by the tower's shape.

The third aspect of the Trias Energetica is the use of energy not generated by the building. If possible, use energy generated by sustainable sources. If that's not possible and only fossil energy is available, use it wisely. Therefore it is important to use it as efficient as possible. In the field of electrical engineering, this can be accomplished by reducing losses in the installation by choosing components with reduced heat losses and good calculation of the cables.

An extra detail for good design is not only reducing the energy consumption, but also using environmentally friendly components, components which are easy to recycle, contain no polluting materials and are produced environmentally friendly.

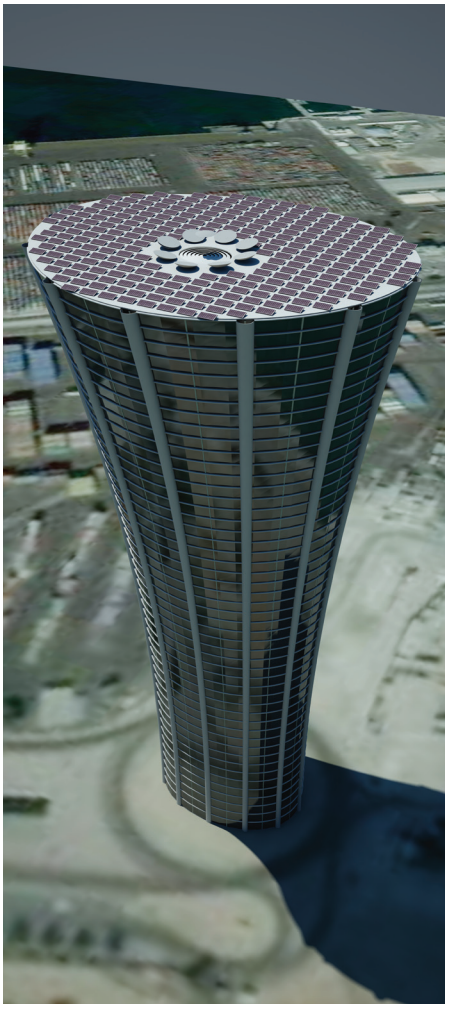


Figure 2: Artist impression of the Burj of Dubai

After this nice story, everybody in the lecture room knew all the ins and outs of sustainable building technology. It's reassuring to see that a lot can be accomplished within the field of electrical engineering.

Lunch lecture by Bosch

Author: Johan Splinter

On the 26th of may Bosch gave a presentation for students Electrical Engineering, during which the ETV provided a lunch for the participants. The title of the lecture was "Product development, how hard can it be?" and was focussed on the department of Product Development within Bosch. The lecturer gave an introduction about the company, after which he spoke about a specific development, a wireless meeting system.

Bosch GmbH already provided a wired meeting system. These systems can be used wherever groups of people meet to talk, like conferences. The system consists of a number of sets with a microphone and earphones and a basic station for control. If needed an interpreter can use a special terminal to translate the text, so that people with different nationalities can discuss together.

A number of reasons suggested Bosch needed to develop a wireless communication system. Our lecturer did not give us these triggers in detail, but talked about the process after this decision instead. A number of decisions had to be made, like the choice for the wireless technology to be used. None of the available wireless technologies like Dect, WiFi and Bluetooth, were able to meet the demands, so Bosch had to develop a new wireless standard to be used. After these decisions prototypes of circuit boards were made. The lecturer brought some of these prototypes with him to give us a general idea. He also had brought some final product terminals which could be used by the audience to play with for a little while. After the presentation dr. ir. G.J.M. Janssen, being a member of the audience as well as a member of the faculty, encouraged everyone who would like to do an internship at Bosch to contact him (G.J.M.Janssen@tudelft.nl).

ELECTRIP

The next Maxwell contains an extensive report on the Electrip. The Electrip took place in the weekend of Whitsun (Pinksteren) and was in Vienna.

Figure 3: The Bosch lunch lecture

Dies Natalis

Author: Stephen van 't Hof

In the week of May 11th the ETV celebrated it's 103th anniversary. Organisations and, in particular, universities and students unions call this the 'Dies'. Dies originates from 'Dies natalis', which is Latin for birthday. As every year the ETV celebrated its Dies in a week full of entertaining activities. This year the activities were very different from other years, but of course we continued some of the traditional activities. Hereby, I present you a report of this nice, but busy week.

Monday (May 11th)

The ETV Dies traditionally starts with a second hand electronics market. This market has always been a formula for success. Employees of the faculty give us their unused electronics and we sell them for a small price to whoever interested. This year we received a huge stack of thin-clients, which boosted the sells. The market gained enormous profits!

In the afternoon the reception was held. The Board received congratulations from members of honor, faculty staff and other boards. As the sun went down, the whole group of enthusiastic ETV members went to the Breintje Beer to enjoy a nice meal of spare-ribs. Many people joined this activity, so it was a good begin of a fantastic week.

Tuesday (May 12th)

The next day the /pub was open all day, but not to consume drinks and sit at the bar. In the morning and afternoon games could be played on computer, (Super) Nintendo Entertainment System, and Wii. At night, the gaming hall turned into a movie theatre. In combination with the activity of tutor group 1, it was Monty Python-movienight! The couches were brought into the /pub, so a comfortable seat was available. Then we ate some pizzas and later that night free fried snacks were passed along.

Wednesday (May 13th)

On this day, one of the highlight activity of the week was planned. The Dies organized 3 hours of paintball at a very low fee. It didn't take very long to drive to Paintball Delft in the ETV limousine and on the bicycle it also cost only a couple of minutes. It's located in a small forest near the aerospace faculty. Upon arrival, everybody received an army suit to complete the setting. Due to a good sponsoring deal and the high yield of the electronics market, we could buy a lot of extra paintballs. The group was divided in two teams, which played 'capture the flag' against each other. After some headshots and bruises all over the body, we went home with smiles on our faces.

Should I buy this or not? Happy shoppers at the electronics market.

The Dies Committee gives a fan to the Committee, which represents a fresh breeze.

A comfortable way to watch Monty Python.

The paintballers, ready for battle!

Watching the game in the warm sun.

Singing side by side.

Thursday (May 14th)

Thursday was a busy day for the committee. At 1 o'clock 7 teams went to the soccer field to compete against each other in a soccer tournament. First, al teams played in two groups. The winners of these groups played the final. The final match turned out to be very exciting. After 15 minutes the teams were equal, so extra time was added. During the extra time, both teams scored, so there still wasn't a winner. The decision was made with penalties. Thanks to the nice weather and the enthusiastic teams, this event was very successful.

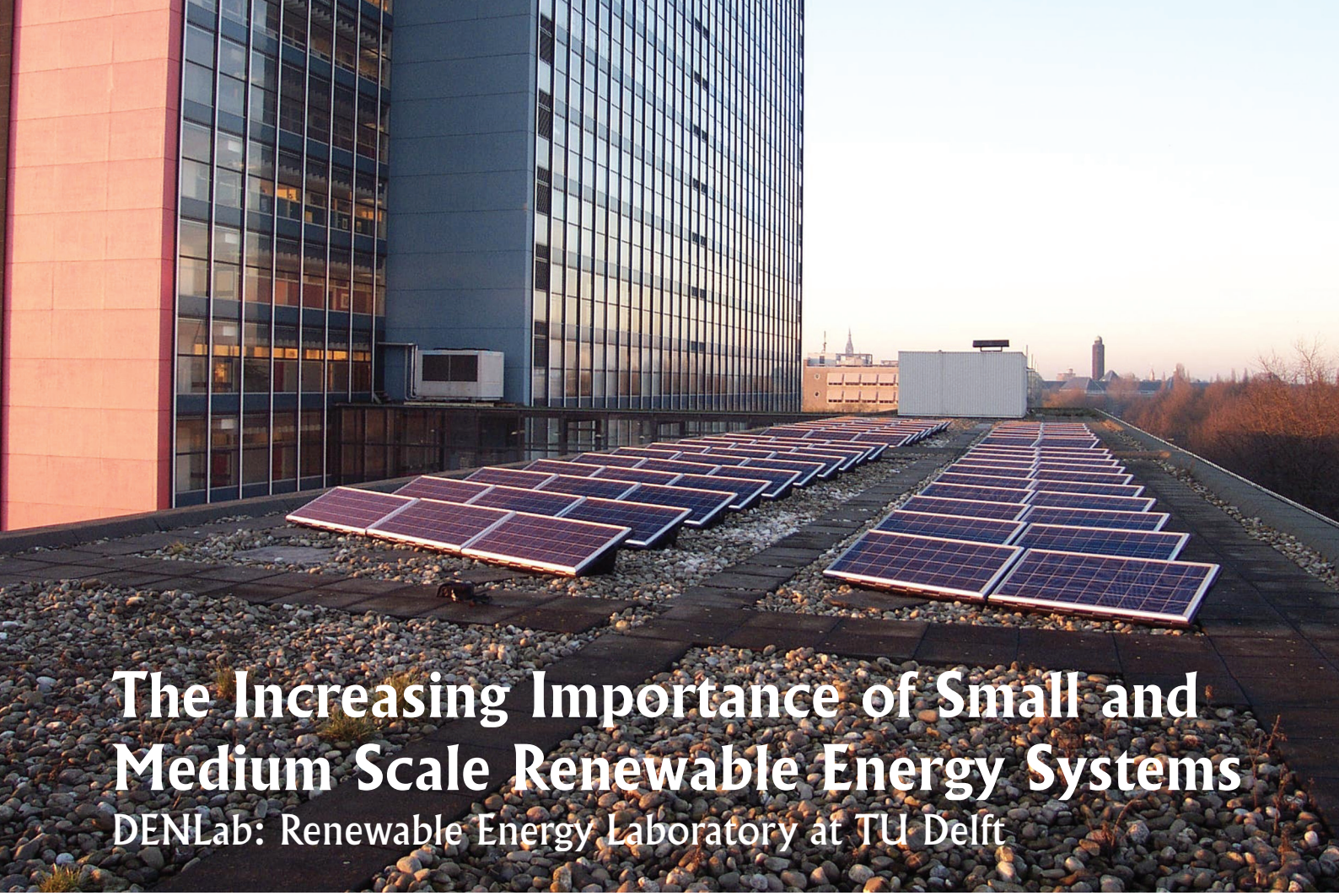
Then it was time to fire up our barbecue. The barbecue was busier than last years because of our campaign, so everybody had to wait a little longer for the meat. With the stomachs filled, the traditional ETV-karaoke could commence. With the remaining snacks of the Monty Python-movienight and two free casks of beer, the vibe was great. The ETV has a huge collection of karaoke-DVD's, so everyone could pick a song they liked.

Friday (May 15th)

On Friday the only activity was a hangover-lunch. After a busy week and a heavy night on Thursday, it was very necessary to gain some energy with a good lunch. This lunch was also the end of our Dies. It was time for us to sit back and look back on a very nice week, with a lot of different and great activities.

Profit of the lunch: waste.

Another nice week full of activities had ended well. Next year another team of enthusiastic students will arrange a new Dies-week. They better make it at least as nice as this year!



The Increasing Importance of Small and Medium Scale Renewable Energy Systems

DENLab: Renewable Energy Laboratory at TU Delft

Author: Laura M. Ramirez-Elizondo

Due to the economic and industrial development that occurred during the twentieth century, electrical energy has become one of the most important needs for society. However, the contemporary energy scenario is jeopardized by the following circumstances:

- There is a continuous increase in energy demand.
- There is a high dependency on fossil fuels and a predicted depletion of their reserves.
- There is an uneven distribution of fossil fuel reserves in the world.
- There is an increasing environmental concern.

These circumstances motivate new technologies to emerge, such as renewable energy technologies and decentralized systems. This article provides a general picture of these four aspects and gives some insight on how decentralized and renewable energy systems can help to deal with these problems. Also, some of the main challenges of these systems are mentioned. Later, a description of current research work made at DENLab will be presented.

DENLab is a renewable energy laboratory located at the HCPS-Power Systems Group of the Electrical Sustainable Engineering Department of Delft University of Technology (TU Delft). This laboratory was created with the objective to analyze the system integration of renewable energy sources to a limited power scale of 50 kVA, the size of 10 households. In this system, the power is delivered by 120 m2 solar cells (12 kWp), a wind turbine emulation system of maximum 30 kW and a combined heat and power emulation system of 5.5 kWe. The storage system consists of a lead-acid battery emulation system of 100 kWh (720 V, 140 Ah). The solar panels are placed on the roof of the Electrical Engineering building.

Three important concepts that will be used in this article are: renewable energy, decentralized systems and autonomous renewable energy systems.

- Renewable energy is energy derived from resources that for all practical purposes are not substantially depleted by continuous use [1]. Ideally, these resources do not entail significant pollutant emissions or other environmental problems, and do not involve the perpetuation of substantial health hazards or social injustices [2].
- Decentralized systems are systems in which the electricity production occurs at or near the point of use, irrespective of the size or technology. They can operate off-grid or on-grid [3].
- Autonomous renewable energy systems are off-grid decentralized energy systems where most or all its generation units are supplied by renewable energy sources.

Continuous increase in energy demand

The International Energy Agency (IEA) indicates in one of its predictions that between 2010 and 2030, the total primary energy demand will increase by 35% [4]. Developing countries will play an important role in this increase. Some of the challenges that emerge from this increase are: to ensure sufficient energy supplies, to reduce the dependency on fossil fuels, and to tackle the environmental impact of our consumption habits [5].

Renewable sources are abundant and they are present in developed and developing countries, so they can contribute in supplying the increasing demand. On the other hand, decentralized energy systems can provide access to new potential markets. Many developing countries do not have the appropriate infrastructure to supply new costumers, especially in remote areas. With the introduction of decentralized systems, there will be a reduction in the investment costs intended to upgrade current systems and there will be no costs associated with transmission and distribution systems, since the production is developed at the point of use [3]. Decentralized systems may contribute to the social and economic development of rural areas in view of the fact that they become a possible option to provide these areas with energy [6].

High dependency on fossil fuels and predicted depletion of their reserves

Fossil fuels have been the most important energy sources to supply both the primary energy and the electricity demand. According to the International Energy Agency (IEA), about 86% of the primary energy demand was supplied by fossil fuels in 1973. In 2004 this percentage was reduced to 80,3%, mainly due to the higher participation of nuclear and hydro energy, and in a small percentage due to the introduction of other technologies such as geothermal, solar, wind, and heat. In the case of the fuel shares of electricity generation, fuels occupied 75,1% of the total shares in 1973. Later in 2004, this percentage was reduced to 66,1%.

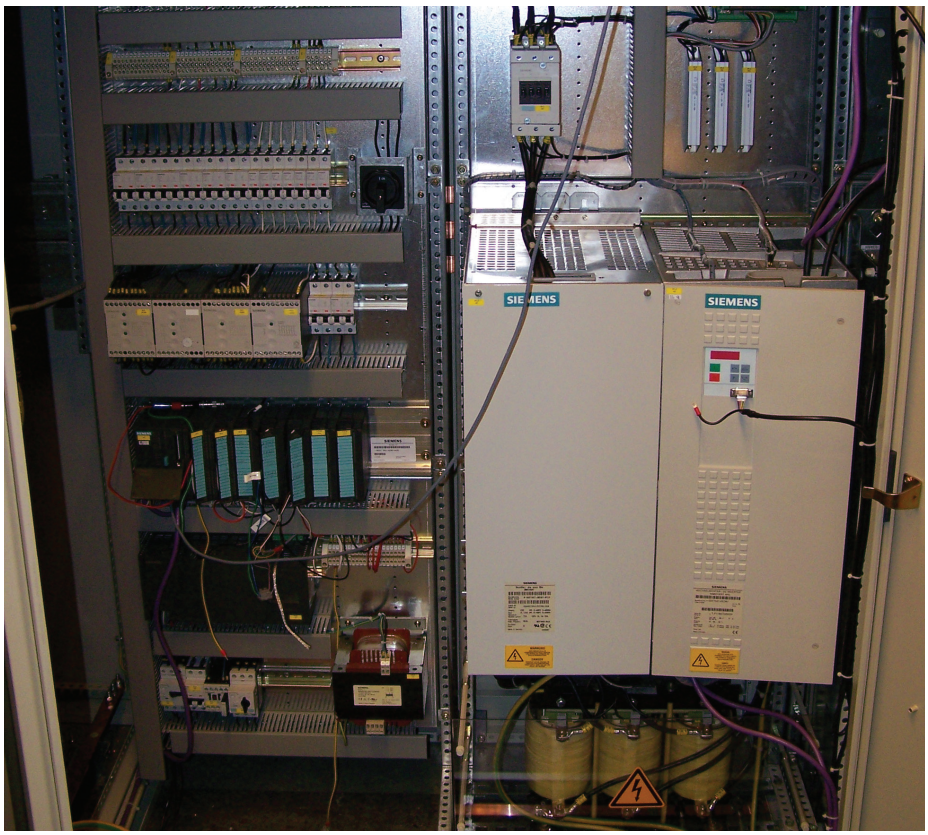


Figure 1: The control cabinet

Despite the fact that there is an existing debate within the scientific community about how many years are left for fossil fuels, the increasing demand and the high fossil fuel dependency ask for alternative options. If the current situation does not change, the reserves of fossil fuels will be reduced at a faster rate. By implementing renewable energy it will be possible to relieve fossil fuels from being the major suppliers and in that way extend their remaining lifetime. Moreover, decentralized systems with combined heat and electricity technologies can attain higher efficiencies than conventional systems; this reduces the fossil fuel consumption. In the future, the remaining fossil carbon could better be reserved for the production of vital chemical products, such as plastics.

Uneven distribution of fossil fuel reserves

Fossil fuels are not evenly distributed on Earth and this creates a dependency among countries. The depletion of fossil fuels and the associated increasing prices have created political and economical tensions during the last decades, which jeopardize the international security and the international energy market [3].

With the introduction of renewable energy technologies, a wider range of sources could be used to cover the national energy demand. These resources are more evenly distributed than fossil fuels. Governments could be able to recognize the renewable sources that better suit them, take advantage of these sources, and consequently reduce the dependency on other countries. Despite the fact that the oil prices will continue rising, these actions will help developing countries not only to supply their energy demand, but also to improve their economies through the reduction of import costs, the creation of

local jobs and the stimulation of investments.

Increasing environmental concerns

The way in which we produce and consume energy is affecting the environment. There are various ways to address this problem, for example: to reduce consumption, to change people's habits and/or to support research and implementation of renewable energy systems. Nowadays, governments of many countries have ambitious targets in their policy agenda to increase the share of renewable energy in their generation system. Since renewable energy technologies use sources that are continuously replenished and abundant, they represent a safe option for the near future [7].

According to the World Alliance for Decentralized Energy (WADE), approximately one third of the global CO2 emissions in 2005 resulted from heating, cooling and power supply systems in residential and commercial sectors [3]. A recent study performed by WADE estimated that in the United States of America, 20% of the total growth of CO2 emissions can be displaced by integrating decentralized energy technologies in buildings with combined heat and electricity technologies due to the increased thermal efficiency of these systems.

Some Challenges of Decentralized Renewable Energy Systems

The challenges faced by decentralized renewable energy systems can be divided into technical, economical, social and political. One important technical challenge is to design suitable control strategies that will allow a reliable operation under the uncontrollable fluctuating conditions that originate from renewable sources like the sun and the wind. Additionally, storage systems are required to take advantage of any surplus of electrical energy and to serve as the backup of the system, in case the system is autonomous (off-grid).

Other technical challenges are: to find the appropriate materials, to find proper structural arrangements and to increase the efficiency of the devices. The development of better models for certain devices is also required, since there are several aspects that have not been resolved yet, just like the optimal system configuration, the proper power electronic interfaces, and the power management and control among different energy sources.

In relation to economical challenges, it is important to mention that for some technologies, the initial capital investment is higher than for conventional systems, even though the maintenance and operation costs may be lower for some of them. Currently, there is insufficient access to finance opportunities [6]. In the political field, it is necessary to implement a legal framework and policies to encourage investments on renewable technologies [6]. Energy markets are not yet prepared for renewable energy and in some countries licensing procedures are considerably longer than for conventional ones [8]. Furthermore, there are insufficient mechanisms for international cooperation in terms of technology transfer and trade [6]. This is necessary in order to expand the use of renewable energy in countries with abundant resources but with a lack of technical skills. A successful implementation would depend on the good identification of resources to be employed, the identification of potential for development and financial costs, and the viability of the project in the context of social and environmental impact [9].

Clear policies in relation to decentralized plants are also necessary. The current policy landscape mostly focuses on centralized plants. This landscape could be improved in aspects such as application procedures, tariffs and metering, interconnection, insurance, location permits, skilled labor and standby fees [3]. By enhancing these policies and supporting investment, the market will increase and it will open new possibilities for people interested in investing in the field.

Research at DENLab

DENLab is a renewable energy lab that facilitates the research on physical small scale energy systems including their various components. This kind of small systems is envisioned by some research groups as one of the solutions to supply

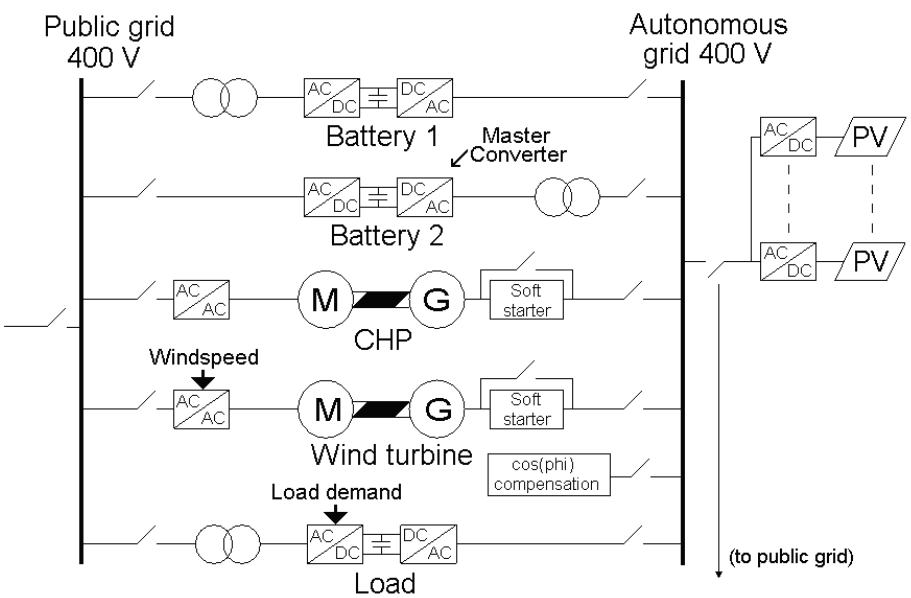


Figure 2: The configuration of DENLab

Figure 3: The invertors from the solar panels on the roof

part of the energy demand of the coming future in a sustainable way [10]. In the previous sections it was possible to recognize that renewable and decentralized systems have the potential to positively contribute in the future energy scenario. As was mentioned, more research is required in technical aspects such as choice of circuit arrangement, control and integration of different energy sources; these kinds of studies are performed at DENLab.

For example, an autonomous system for 10 households, a wind turbine, a CHP and two battery arrangements was emulated in the following way in DENLab. The characteristics of the various components are programmed in a PLC, which, via a Profibus, controls the power converters that are physically placed at the lab and that correspond to each one of the components. There is a real power flow at the 3-phase autonomous grid at DENLab. The currents that flow through the system represent the currents that would flow at an analogous physical system. The configuration of DENLab is shown in the figure 1.

Some of the current work done at DENLab includes the addition of a fuel cell and an electrolyzer emulation system to study the system integration of these two devices in an autonomous system and also to include a supercapacitor emulation system to enhance the operation of the fuel cell. The models of these devices will be simulated at a Real Time Digital Simulator (RTDS). The output will be linked to DENLab, so that the corresponding power converters can provide power to the autonomous grid in the way that a real fuel cell would do. Suitable control strategies will be programmed at the PLC to evaluate the system integration of the devices. Another project that will be performed at DENLab deals with the evaluation of a power management system for multiple energy carriers. Until now DENLab has been only used to evaluate electrical flows. In this project and in future projects heat, gas and hydrogen flows will also be included.

Summarizing, DENLab together with the RTDS forms a flexible laboratory that facilitates studies on system integration for all kinds of new renewable energy devices (models or real devices of a suitable power rating). Therefore, it can be used as a test facility to evaluate new decentralized renewable technologies.

References

[1] U.S. Department of Energy, Energy Efficiency and Renewable Energy, http://www.eere.energy.gov

[2] Boyle, G., Renewable Energy: Power for a Sustainable Future. Oxford University Press: USA, June 6, 1996.

[3] The World Alliance for Decentralized Energy, http://www.localpower.org/index.html

[4] International Energy Agency Key World Energy Statistics, http://www.iea.org

[5] Eurobarometer, surveys conducted on behalf of the European Commission, http://ec.europa.eu/public_opinion/archives/ebs/ebs_258_en.pdf

[6] The expert group on renewable energy convened by the United Nations department of economics and social affairs, Increasing global renewable energy market share, recent trends and perspectives. Beijing International Renewable Energy Conference, 2005.

[7] U.S. Environment Protection Agency, http://www.epa.gov/cleanrgy/renew.htm

[8] Energy Analyses and Centre for Solar Energy and Hydrogen Research Baden-Württemberg, http://www.iea-retd.org/library/RETD%20Brochure.pdf

[9] Painuly, J.P., Barriers to renewable energy penetration; a framework for analysis. Renewable Energy, Volume 24, Number 1, September, 2001, p.p. 73-89.

[10] Fischer, C., Users as Pioneers: Transformation in the Electricity System, MicroCHP and the Role of the Users. Governance for Industrial Transformation, Proceedings of the 2003 Berlin Conference on the Human Dimensions of Global Environmental Change, Environmental Policy Research Centre, 2004, p.p. 319 – 337.

Hier invoegen: pagina18Technolution.pdf

ETV Zeilweekend 2009

Hier invoegen: pagina20Smit.pdf

Joost may know it!

Sometimes the members of the Maxwell committee ask the strangest questions to each other during the Maxwell meetings. We decided to make a new category called "Joost may know it!" In every copy of the Maxwell, one of the members will look for the answers on the strangest questions. If you have a question, please send an e-mail to the committee.

Author: Johan Splinter

Everyone who

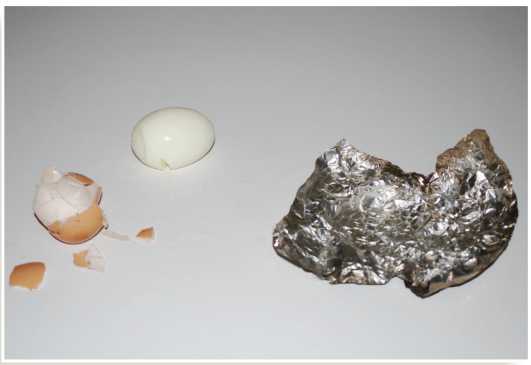
has been lazy enough to heat an egg in the microwave knows this device is not designed to prepare eggs. Those that have been inventive enough to heat an egg in a bowl filled with water will know this doesn't change the outcome of the experiment. The egg will be heated inside and explode.

Our proposal

is to wrap an egg in a piece of aluminium foil and lay this in a water filled bowl. The foil should keep the Electromagnetic Waves outside, while the water should heat up and eventually boil. This boiling water should prepare the egg. We asked dr. ir. Remis, teacher of the EM-Waves course, to evaluate our theory.

Your reasoning

seems OK. I just think that you should watch out for the waves not to "leak" through the aluminum foil. Aluminum is conductive in the frequency of the microwave. The frequency and the conductivity determine the penetration depth of aluminum. If the thickness of the foil is smaller than the penetration depth the waves will reach the egg. Best is to calculate the penetration depth of aluminum (see book EM waves), then pack the egg with a layer of sufficient thickness.



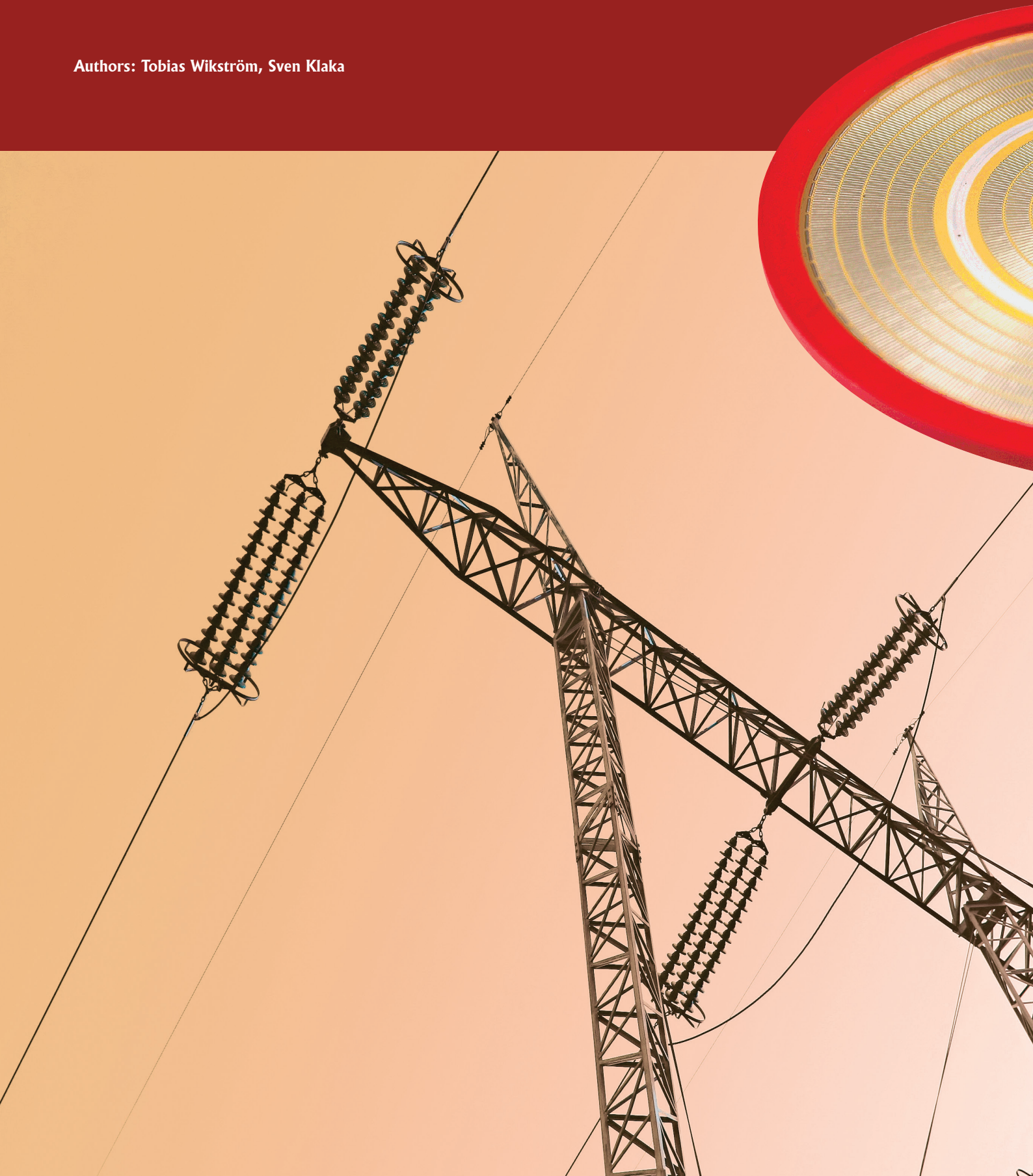
After this

response, one of our editors calculated the penetration depth of aluminium to be $1{,}7\times10^{-6}$ m. Since kitchen foil has a thickness of at least 6×10^{-6} m this should be sufficient. One editor took the risk to verify the theory and perform the experiment. First a mug of water was heated in the microwave. Secondly the wrapped egg was deposited in the boiling water. When the water started boiling again the power of the microwave was lowered to keep the water calmly boiling. Five minutes later his microwave-boiled egg was ready.

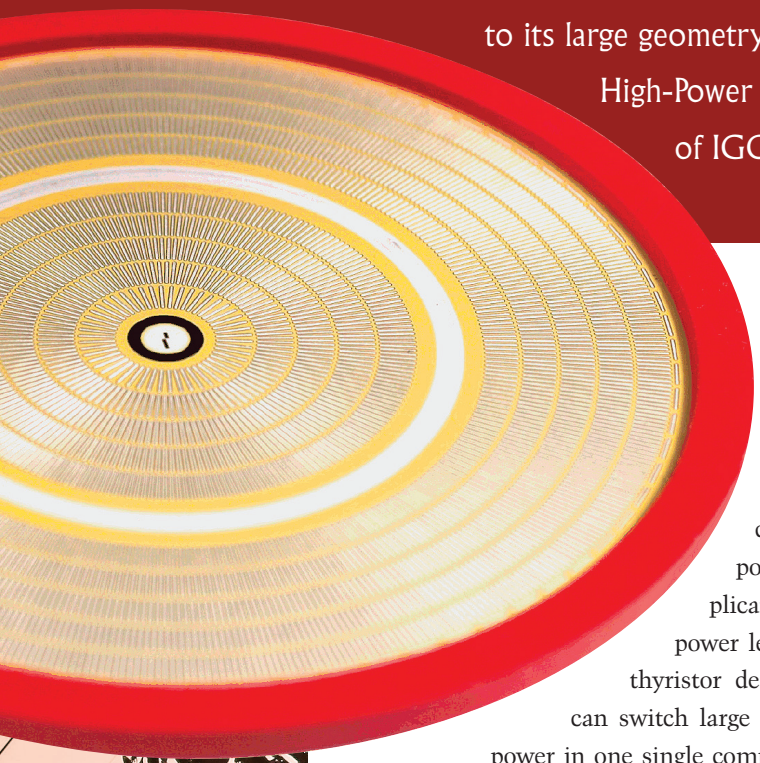
A tiny dot can change the world

High-Power Technology for IGCTs

Authors: Tobias Wikström, Sven Klaka



To improve performance, reduce the size and cost of power electronic systems and allow more flexibility in designing power-electronic applications, the development trend in high-power semiconductors is toward higher current and voltage ratings. The integrated gate-commutated thyristor (IGCT) is the unit with the highest power ratings, but due to its large geometry, is the most challenging to switch. ABB's new High-Power Technology (HPT) has paved the way to ratings of IGCTs that were impossible to reach before.



The integrated gate-commutated thyristor (IGCT) is a power semiconductor switch designed for use in power-electronics applications at the highest power levels. Thanks to its thyristor design inheritance, it can switch large amounts of electric power in one single component. Due to this capability, the IGCT has been used in medium-voltage drives, electric grid interties, static compensators (STATCOMs), solid-state breakers, and choppers.

FACTBOX

Normal thyristors can only be turned on but cannot be turned off. Thyristors are switched on by a gate signal, but even after the gate signal is removed, the thyristor remains in the on-state. A gate turn-off thyristor (GTO), on the other hand, can also be turned off by a gate signal of negative polarity. Turn-on is realized by a positive current pulse between the gate and cathode connections. To keep the GTO in on-status, a small positive gate current must be provided. Turn-off is made by a negative voltage pulse between the gate and cathode. About one-third to one-fifth of the forward current is diverted, which induces a cathode-gate voltage and transfers the GTO into the blocking status. The turn-off phase takes some time until all charges are removed from the device. The maximum frequency for GTO application is thus restricted to about 1 kHz.

When the IGCT was introduced in the 1990s as a hard-driven gate turn-off thyristor (GTO), its basic design still bore many resemblances to the standard GTO (Factbox). The main difference was the switching mode, the hard drive, a means of turning off the thyristor exclusively in p-n-p transistor mode, like the IGBT.

Because the p-n-p switching is more homogeneous than the GTO's n-p-n-p, operation without protective "snubbers" and a design using low-loss silicon are possible. In the on-state, the IGCT behaves like a latched thyristor, which gives it very low on-state losses and a wide design window for tuning its properties to fit the application.

Extending the range for safe operation

The challenge of IGCT technology has always been to scale up its turn-off capability, described by its reverse bias safe operating area (RBSOA[1]). In small-area IGCTs, RBSOA has been shown to exceed 1 MW/cm^2, well above the limit where other parameters, like losses and surge-current capability are more limiting. The

[1] A safe operating area (SOA) is defined as the voltage and current conditions over which a device can operate without self-damage. The RBSOA is the safe operating range when the device is turned off.

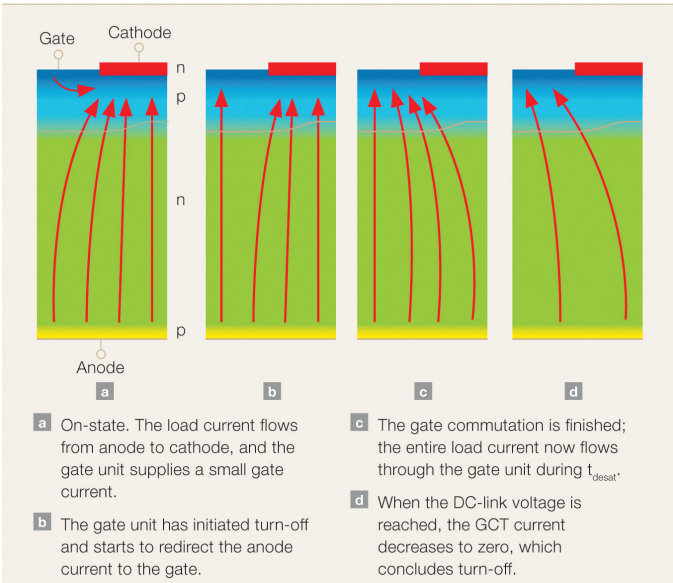


Figure 1: The current flow (red arrows) of an IGCT segment during different stages of turn-off. The phases (a-d) are indicated in 2.

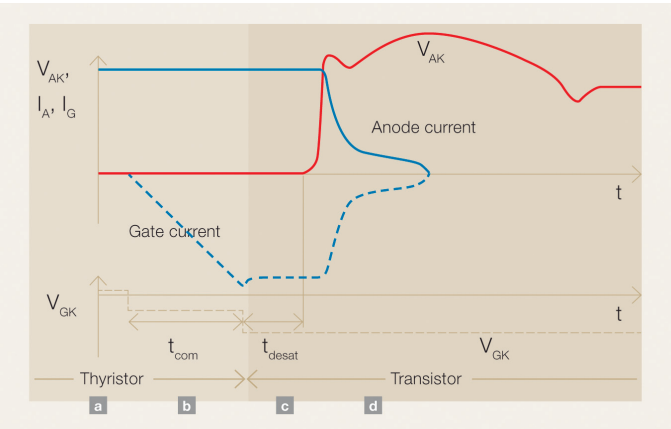


Figure 2: Voltage, gate and anode current waveform during switching.

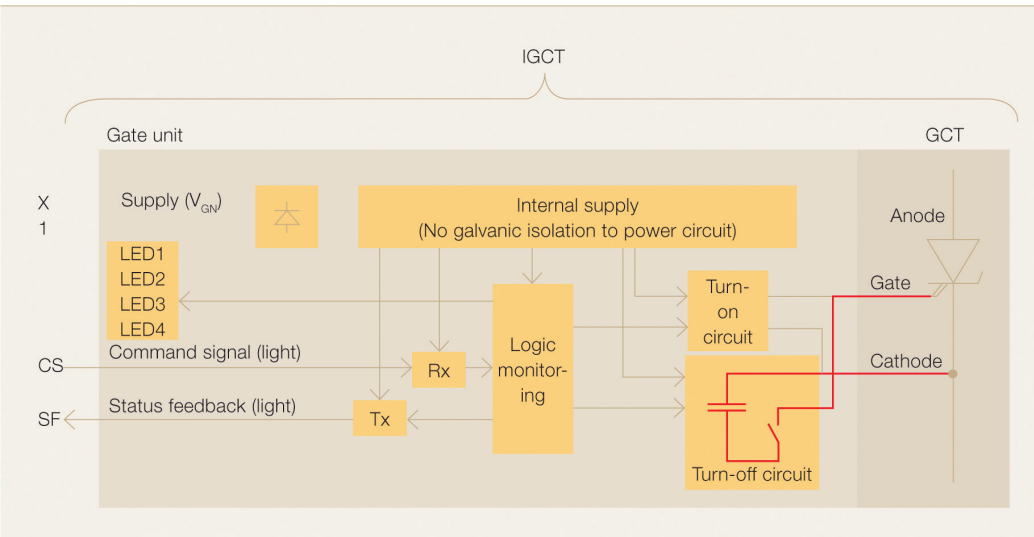


Figure 3: A schematic circuit diagram of the IGCT with the gate unit and its outside connections on the left, and the GCT power semiconductor on the right.

larger the area gets, the lower the specific power-handling capability becomes. A reasonable approximation is that RBSOA scales with the square-root of the device area. The RBSOA of ABB's most current 4 inch diameter IGCT has been specified to 3,500 A at 2.8 kV DC. With the state-of-the-art High Power Technology (HPT) described below, its specification increases to 5.5 kA – close to twice the old capability. The actual HPT capability exceeds 7 kA.

With the High-Power Technology IGCT, ABB introduces a new design feature – the corrugated p-base.

IGCT in operation

The rationale for the sub-linear scaling of RBSOA lies in the details of how the IGCT is turned off. The schematic layout of an IGCT consists of the main switching element, the GCT and the gate unit, which controls the bias of the p-n junction between the cathode (n) and gate (p) contacts. In the on-state, the gate unit provides a small forward current that keeps the thyristor latched (Figure 1). During turn-off, the gate unit reverse-biases the p-n junction by activating its turn-off channel (marked in red in Figure 3). The turn-off channel is a low-inductive voltage source biased just below the reverse-blocking capability of the p-n junction. It forces the cathode current into the gate circuit at a rate governed by the stray impedance of the gate circuit (Figure 2 shows this current increase during tcom). The entire load current must be diverted from the cathode until the device functions as a p-n-p transistor.

In addition to handling the full anode currents, the gate unit has to complete the commutation in much less than 1μs. Once this time has elapsed, the IGCT starts to build up voltage (after completion of t_{com} and t_{desat} (Figure 2)); it is essential for safe operation that the device now operates in the p-n-p transistor mode.

Looking at the IGCT as a discrete power device, there apparently is a macroscopic speed condition that must be fulfilled for safe operation: the hard-drive limit. This is the crossover point in the graph in Figure 4. It is a characteristic of the GCT wafer because different wafer designs react at

different speeds ($t_{com}+t_{desat}$), as well as of the gate unit (t_{com}) because of its stray impedance.

Challenges of the real device

Large-area devices are more challenging because the higher the current, the harder the demands regarding the gate-circuit stray impedance.

The title picture of this article shows the latest 5.5 kA GCT wafer with thousands of parallel GCT-segment connections, all of which need to be synchronously operated to avoid current redistribution. The segments are arranged in 10 segment rings on the wafer. The gate contact is ring-shaped and located between segment rings five and six.

Unavoidably, these segment rings have slightly different impedances to the gate unit. A simulation of the wafer, housing and gate-unit geometry reveals the different stray inductance load of individual segment rings dependent on the ring number (Figure 5). This imbalance results only from the constraints on how the current flows from the wafer to the gate unit. Considering that the active area of a segment ring increases with the square of the ring number, the current is by far the largest in the outermost rings. Hence it is to be expected that the impact of this imbalance affects primarily the outermost rings. This is also confirmed by experiments, the vast majority of segment rings resulting in RBSOA failures are the outermost rings.

This inductance imbalance is a result of mechanical constraints in the IGCT package assembly. Subsequently, the GCT device will inevitably be subject to some current redistribution as the gate signal propagates over the wafer. This is the second reason why scaling up the area makes life tougher for the IGCT: The cells remotest from the gate contact become loaded with a higher stray inductance. The only antidote from a silicon-technology perspective is to make a wafer that shows less sensitivity to impedance imbalance.

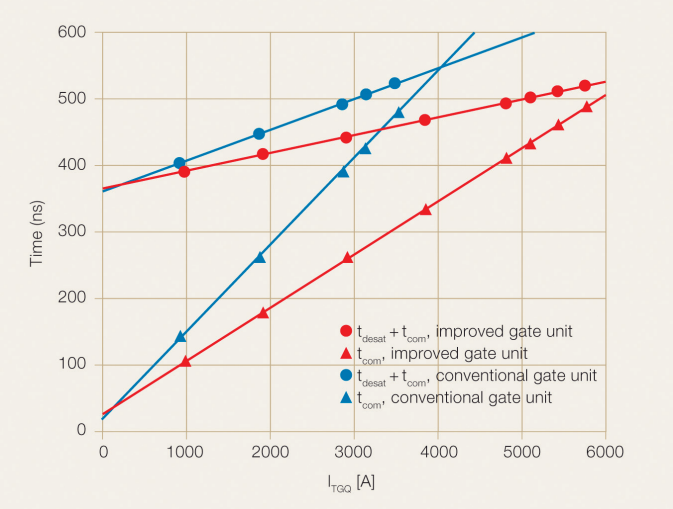


Figure 4: The current dependence of tcom and tcom+tdesat shown for the improved HPT technology (red) and conventional technology (blue).

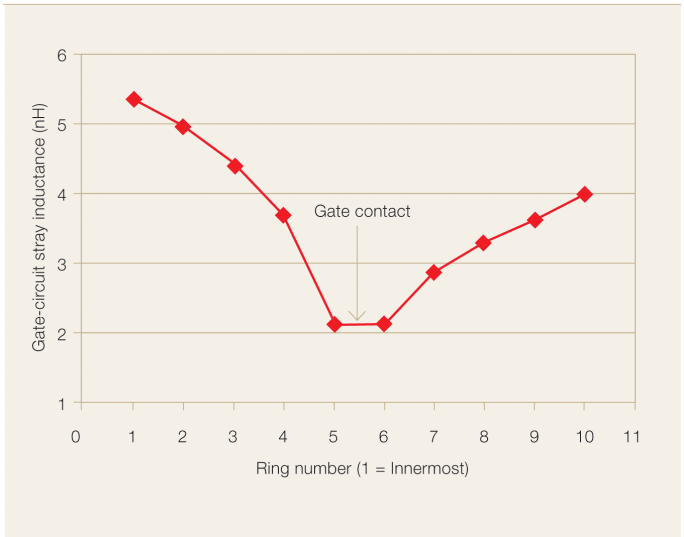


Figure 5: The stray inductance of the individual segment rings on a GCT wafer as a function of their placement.

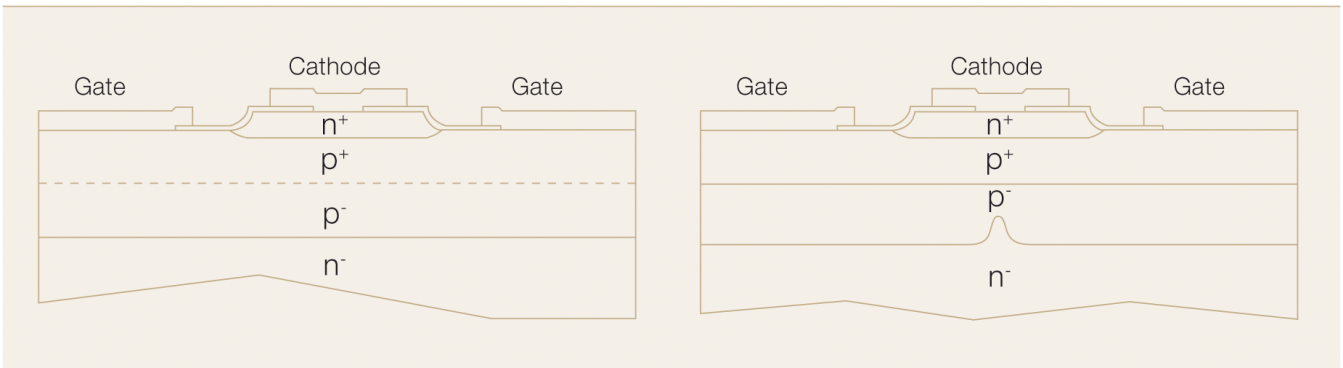


Figure 6: The structure and doping design of a conventional GCT cell (left), and the HPT technology with the corrugated p-base (right).

With the HPT IGCT, ABB introduces a new design feature, the corrugated p-base. In Figure 6, the main characteristics of this technology are sketched: In conventional technology, the p-base diffusion is homogeneous over the whole wafer. In HPT technology, the lower p-diffusion layer is masked underneath the cathode fingers. As a result, the p-base has a corrugated appearance. Together with the new gate unit, it has a substantial impact on RBSOA. It is breathtaking that such a tiny spot with reduced doping can in fact make this tremendous change.

The new capability...

The HPT technology is available in 4.5 kV and 6.5 kV asymmetric IGCT versions. Figure 7 shows the new ABB design of an IGCT with HPT.

With HPT technology, the destruction limit of the IGCT has increased by 50 percent at 125 °C and by 80 percent at room temperature. The IGCT demonstrates a negative temperature coefficient of maximum controllable current, illustrating that the device is now limited in the same way as IGBTs (Figure 8).

With its new robustness, the HPT IGCT is also able to withstand switching self-clamping mode (SSCM), which is a harsh benchmark of ruggedness extensively described in connection with IGBTs over the last few years.

THE ROBUST HIGH-POWER TECHNOLOGY IGCT IS ABLE TO WITHSTAND SWITCHING SELF-CLAMPING MODE (SSCM), WHICH IS A HARSH BENCHMARK OF RUGGEDNESS.

...and its future development

Apart from the immediate benefits mentioned above, this novel technology allows future expansions of the IGCT range:

- 10 kV IGCTs will have competitive turn-off current ratings comparable with today's ratings of 6 kV devices.
- In principle, HPT will allow for better homogeneity of the turn-off process over the diameter of the wafer.
- A further increase of the wafer diameter appears feasible.

Combining these advantages, it is highly possible that in the near future, larger IGCTs will be capable of switching more than 4 kA against DC voltages of more than 6 kV, enabling three-level 20 MW medium-voltage drives for 6 kV AC motors without any need for series or parallel connection.

At the other end of the application range, due to the enormous turn-off capability in combination with a potentially thyristor-like on-state voltage drop, additional possibilities arise for the use of IGCTs as wear-resistant static circuit breakers.

Tobias Wikström (tobias.wikstroem@ch.abb.com)
Sven Klaka (sven.klaka@ch.abb.com)
ABB Semiconductors, Lenzburg, Switzerland

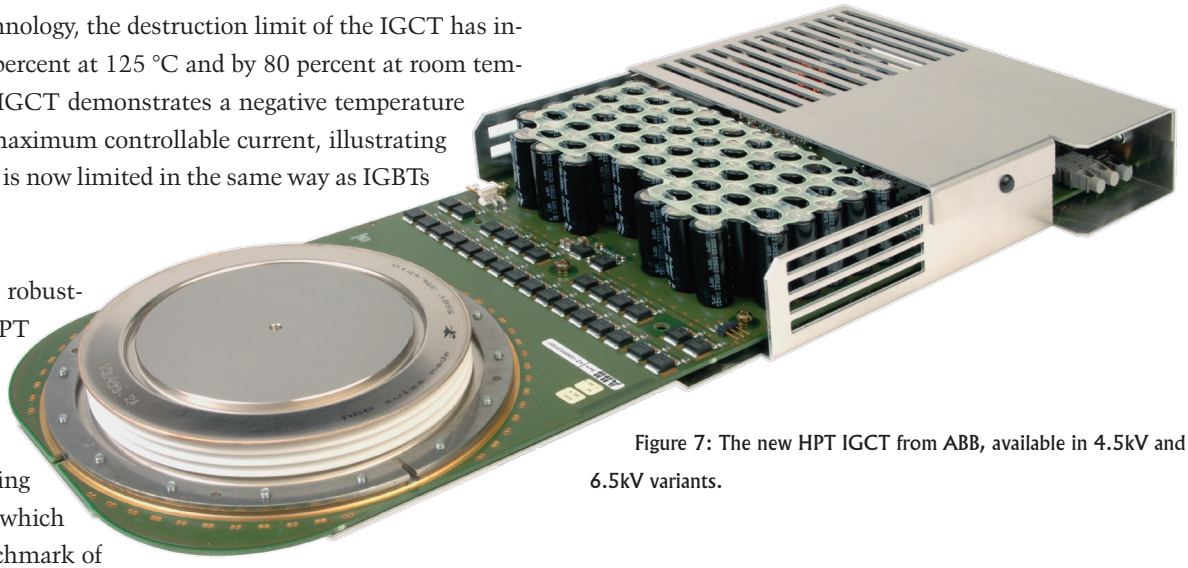


Figure 7: The new HPT IGCT from ABB, available in 4.5kV and 6.5kV variants.

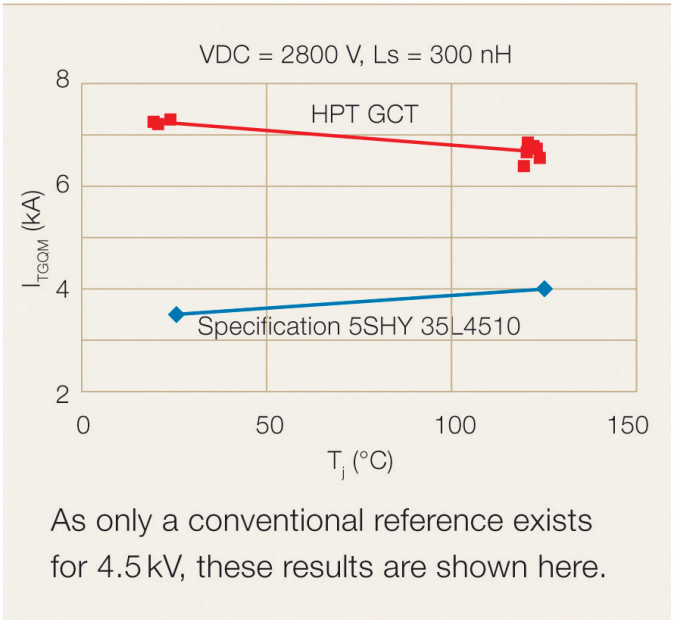


Figure 8: The maximum turn-off current of the HPT compared with the conventional IGCT specification.

Column

Salim Alahdab, BSc
Student Electrical Engineering

I have a Syrian nationality and I was born and raised in Saudi Arabia. I got my Bachelor degree from the American University of Sharjah, which is located in Sharjah, a city near the Dubai-United Arab Emirates. So far, there is nothing strange about the last statements. Surprisingly enough, I had three nationalities when I came to The Netherlands. I was Syrian for the International Office, Saudi for the housing company and Emirati for ABN-AMRO. At the end of the day, I was looking a for fourth nationality, Dutch I guess. I'm sure some of you are opening Google Maps right now to see where these countries are?

Since I have a white skin, most of people could not guess that I'm Syrian or even Middle Eastern. Some people think that I'm American or British since I have an American accent and sometimes a British accent as well. The closest guess was Turkish, since Turkey is neighbour of Syria, I was satisfied.

Now I'm on one of the flattest pieces of land on earth, The Netherlands. This might bring us to the conclusion that this land is very windy! I can describe the winds in Holland like false alarm for a tornado, every single day. I think that the wind in Holland has nothing to hit or bush in its way expect people. There are no mountains or hills. You could have noticed this is not a very scientific explanation, but it brings peace to my heart! Even though I was trying my best to come up with an explanation for the crazy weather in Holland. I very strongly believe that the weather in Holland suffers from short term memory loss and I can prove it. Let me walk you through my own logic. It is August, everybody knows it is summer time. However, the weather in Holland forgets about this for almost a week and it starts raining like it is winter all over again. The mental disorder might get really bad, and it might snow on the first day of the spring season like what happened last year.

What I like about the Dutch culture is the whole concept of socializing around the coffee room. Since I'm a big fan of caffeine, this suits me very nicely. Therefore, everyday around afternoon, all my colleagues in the lab go to the coffee room like the March of the Penguins. Ironically the coffee room is located very close to the girl's bathroom. Therefore, we march like penguins, sleepy, tired and desperately looking to meet any female on the way.

CSI:

COMMITTEE SEARCH INVESTIGATION

The ETV is looking for:

Maxwell Committee

Creating, designing, writing articles, taking company interviews and much more! Are you interested in creating THIS magazine?

Symposium Committee

Every two years, the ETV organises a Symposium, a day full of interesting lectures. Interested in participating in the organisation?

Then we are looking for you!*

SYMPO

D - CSI - WANTED - CSI - WANTED - CSI - WANTED

MAXWELL

*If you are interested in joining one of these committees, please contact the Board at board@etv.tudelft.nl or stop by at the Board room!

Bedrijfsinterview

Een interview met Alert Solutions

In maart 2003 kwam het plaatsje Wilnis in het nieuws. Door het warme en droge voorjaar was het grondwaterpeil zo ver gezakt dat de ringdijk van de polder Groot-Mijdrecht doorbrak. Om dit soort problemen enerzijds te voorkomen en anderzijds geen dijken onnodig te verstevigen richt Alert Solutions zich op apparatuur om dijkdoorbraken te kunnen voorspellen.

Auteurs: Joost van Driel en Johan Splinter

Pepijn van der Vliet heet ons welkom in zijn kantoor bij YES!Delft, de incubator in de TU-wijk. Hij stelt zichzelf voor en vertelt dat hij bedrijfseconomie in Tilburg heeft gestudeerd. Zijn collega Erik Peters, de oprichter van Alert Solutions, heeft natuurkunde in Leiden gestudeerd.

Geschiedenis

In 2006 is Alert Solutions aan het brein van Erik Peters ontsproten. Na jaren bij Philips te hebben gewerkt was hij zijn eigen consultancybedrijf begonnen. In deze hoedanigheid kwam hij in contact met een project dat later zou leiden tot stichting IJkdijk en de eerste grootschalige proeven voor het realtime monitoren van dijken. Na een rondgang bij marktpartijen bleek dat er op dat moment geen product op de markt was dat in staat was om realtime dijken te monitoren. Bovendien was er geen bedrijf bezig met de ontwikkeling van een dergelijk systeem. In 2007 daagde Rijkswaterstaat het bedrijfsleven uit tot de ontwikkeling van een nieuwe techniek die dit mogelijk moest maken. Inmiddels had Peters zijn concept op papier staan en besloot de uitdaging op te pakken.

Medio 2007 besloot Peters om Van der Vliet bij zijn bedrijf te betrekken. Door de technische achtergrond van Peters had hij behoefte aan een bedrijfseconoom om de successen en tegenslagen van het inmiddels formeel opgerichte Alert Solutions te kunnen delen. Van der Vliet, die Peters nog kende uit zijn jeugd, had op dat moment een eigen marketingadviesbedrijf. Dat beide heren een ondernemersgeest hadden bevorderde de samenwerking van de start-up.

De eerste fase van de opdracht van Rijkswaterstaat bestond uit een haalbaarheidsstudie die moest uitwijzen of het product technisch, organisatorisch en economisch haalbaar was. Deze eerste fase bracht het aantal deelnemers terug van 25 naar vijf, Alert Solutions hoorde bij deze vijf. Daarop zou een tweede fase volgen waarin de opdracht tot de ontwikkeling van een werkend prototype werd verstrekt. Mede door vroegtijdige toetsing bij marktpartijen voor het bepalen van de ontwikkelingsdoelstellingen voor het prototype kon een uitdagend idee voor een realtime dijkbewakingssysteem worden neergelegd. Uiteindelijk is Alert Solutions ook één van de twee partijen die de tweede fase ingaan.

De tweede fase ging van start in maart 2008 en het eerste prototype van GeoBeads, het sensornetwerk van Alert Solutions voor dijkmonitoring, was in juli van dat jaar beschikbaar. Korte tijd later deed zich een uitstekende gelegenheid voor om GeoBeads in de praktijk te beproeven. Stichting IJkdijk ontwierp een dijk van honderd meter lang, zes meter hoog en ongeveer twaalf meter breed. Deze dijk werd onder meer opgezet om nieuwe technologieën voor het monitoren van dijken te toetsen. Naast de twee deelnemers aan het project van Rijkswaterstaat deden ook acht andere partijen metingen. De apparatuur van Alert Solutions maakte elke minuut een meting van verscheidene variabelen gedurende drie dagen. Tijdens deze periode werd de dijk onder gecontroleerde omstandigheden tot bezwijken gebracht, een wereldwijd uniek experiment. Meetsysteem GeoBeads van Alert Solutions bleek ruim voordat de dijk doorbrak een groeiende instabiliteit

Figuur 1. GeoBeads worden in de dijk geplaatst

Titelpagina: De watersnoodramp in 1953 benadrukte meer dan ooit het belang van bescherming tegen de zee. Dit werd onder meer vorm gegeven door de Deltawerken.

in de dijk zichtbaar te kunnen maken. Alert Solutions hield aan de proef ruim 1,2 miljoen meetpunten over. “Een schat aan informatie om het gedrag van dijken beter in kaart te kunnen brengen.”

Meettechnieken

Om de stabiliteit van een dijk te kunnen bepalen, kijk je naar de grondopbouw van het dijklichaam en de waterhuishouding, vertelt Van der Vliet. De dijk zelf en de bodem waarop een dijk is gefundeerd kan uit diverse grondlagen bestaan, bijvoorbeeld een combinatie van zand, klei en veen. Om de stabiliteit te bepalen is een aantal parameters van belang. Deze hebben te maken met de waterhuishouding en bewegingen. Door het meten van waterdruk en temperatuursveranderingen kan de druk en waterdoorstroming in een dijk bepaald worden. Daarnaast is de beweging van de dijk uiteraard een belangrijke parameter voor groeiende instabiliteit. Iedere door Alert Solutions gebruikte sensormodule meet dan ook deze drie waarden: de beweging, de waterdruk en de temperatuur. Dit zijn parameters die ook aansluiten bij de wijze waarop dijkbeheerders naar de dijken kijken. GeoBeads van Alert Solutions is het eerste meetsysteem dat gelijktijdig en realtime deze drie waardes meet.

Van der Vliet toont ons enkele prototypes van sensormodules, voorzien van een kabel om de stroomvoorziening te verzorgen en de data door te geven. Het zijn cilindervormige doosjes, van ongeveer 2 cm breed en 10 cm lang. In de ontwikkeling is een aantal ontwerpslagen gemaakt. De modules bestaan uit een RVS-behuizing die met giethars worden ingegoten, dit om een hoge waterdichtheid te bereiken. Op een kabel van 1 km kunnen ruim 250 van deze modules worden geplaatst. De kabel zorgt voor de dataoverdracht en de stroomvoorziening van de modules. In iedere module bevindt zich een microprocessor, die van buitenaf aangestuurd kan worden,

Figuur 2. De dijk kan op afstand in de gaten gehouden worden

bijvoorbeeld om de meetfrequentie aan te passen. Tevens is deze processor verantwoordelijk voor bewerkingen op de meetgegevens. Zodoende geeft de sensor geen abstracte waarden als spanningen en stromen door. De processor zorgt er voor dat deze gegevens worden omgezet in interpreteerbare gegevens, zoals graden en millibars.

Voor de communicatie heeft Alert Solutions een eigen protocol ontwikkeld die leunt op de RS485-communicatiestandaard. Deze bus biedt genoeg bandbreedte voor de grote hoeveelheid gegevens. De modules hebben een spanning tussen de 9 en 30 Volt nodig om te kunnen functioneren.

Toepassingen

Van der Vliet laat ons plaatjes zien van de Vlaardingsekade, een kade in beheer van het waterschap Delfland. Hoogheemraadschap Delfland heeft GeoBeads, de sensormodules van Alert Solutions, ingezet om deze boezemkade te kunnen monitoren. Voordat de dijk in 2008 met 40 cm opgehoogd werd is de dijk voorzien van het sensornetwerk. Volgens Van der Vliet is dit een interessante dijk omdat hij een relatief steil talud heeft en bovendien aan de oppervlakte enige deformatie toont. In de dijk zijn via verticale boorgaten de ketens met GeoBeadssensoren geplaatst. Deze gaten zijn zoveel mogelijk opgevuld met het materiaal dat uit het gat gewonnen werd, om de metingen zo weinig mogelijk te beïnvloeden. Voor verticale ketens werd gekozen omdat een horizontale boring de structuur van de dijk veel meer aan zou tasten. Met een horizontale kabel vlak onder het maaiveld worden alle meetgegevens naar de netwerkcontroller gestuurd. Middels een kastje dat via UMTS in verbinding staat met het internet kunnen de gegevens wereldwijd en op ieder gewenst tijdstip uitgelezen worden. Op deze manier kan het waterschap op ieder moment de meetgegevens en bijbehorende visuele weergaven opvragen.

Alert Solutions noemt hun product multisensor en multinode. Multisensor verwijst naar de drie sensoren die in een enkele module worden geïntegreerd, terwijl de term multinode er op moet wijzen dat een netwerk uit meerdere nodes bestaat. Van iedere geplaatste node wordt bijgehouden wat het bijbehorende unieke ID is en waar de node zich bevindt.

Op de vraag of de communicatiebus vervangen kan worden door draadloze technologie antwoordt Van der Vliet dat dit op dit moment nog niet haalbaar is. Enerzijds is draadloos zenden onder de grond een uitdaging, anderzijds wordt de autonomie te laag doordat de kabels ook verantwoordelijk zijn voor de energietoevoer. Momenteel wordt overigens wel onderzoek gedaan naar de mogelijkheden om draadloze varianten uit te werken. Een groep studenten van de TU Delft is hier in het kader van een Bachelor Eindproject ook bij betrokken.

Van der Vliet noemt een aantal andere toepassingen van de GeoBeads. Bij veel bouwprojecten kunnen de werkzaamheden

een negatieve invloed hebben op de stabiliteit van omliggende panden, met zelfs verzakkingen tot gevolg. Door GeoBeads tegen de gevels van gebouwen te plaatsen kunnen deformaties van deze gebouwen (zelfs als het slechts om honderdste van graden gaat) al in een vroeg stadium geregistreerd worden en kunnen indien nodig maatregelen worden genomen. Op dit moment zijn GeoBeads geplaatst bij de bouw van een parkeergarage in Rotterdam. Door meerdere malen per dag een meting te doen kunnen de risico's van een bouwproject beter worden ingeschat. In de Franse Alpen zijn GeoBeads geplaatst om het verschuiven van berghellingen te monitoren en het gedrag van dergelijke verschuivingen beter in kaart te kunnen brengen.

De meetgegevens van GeoBeads biedt beheerders interessante mogelijkheden. De gegevens kunnen bijvoorbeeld gecombineerd worden met andere data, zoals neerslag en het waterpeil, om het inzicht in waterkerende constructies te vergroten. Zo bestaan voor het bepalen van de stabiliteit van dijken grondmechanische modellen. De gegevens kunnen als input voor deze modellen worden gebruikt. Aan de andere kant kunnen ook statistische analyses op de gegevens worden uitgevoerd. Op dit moment is een EWI-student bezig met het verwerken van meetwaarden om statistische modellen te kunnen maken. Dit is kenmerkend voor de bedrijfsvoering van Alert Solutions. Het bedrijf geeft studenten graag de gelegenheid interessante opdrachten te vervullen. Het bedrijf heeft slechts twee vaste medewerkers, het overige personeel wordt ingehuurd. Hierbij wordt voor een groot deel gebruik gemaakt van studenten. Hiernaast worden verschillende leveranciers ingeschakeld, bijvoorbeeld voor embedded software en fijnmechanische techniek. Tenslotte maakt Alert Solutions veel gebruik van de diensten van DEMO, de werkplaats van de TU Delft.

Huisvesting

Oorspronkelijk was Alert Solutions gevestigd in Hilversum. Het bedrijf is naar Delft gekomen om een goede aansluiting met de TU Delft te krijgen. Zij heeft zich tussen andere High-tech start-ups gevestigd in YES!Delft. Voor Alert Solutions bood dit aantrekkelijke mogelijkheden. Onder meer directe toegang tot de verschillende werkplaatsen, het aantrekken van studenten en de toegang tot de kennis van bijvoorbeeld de faculteiten EWI en CiTG. Daarnaast worden door YES!Delft interessante marktcontacten gelegd.

Naast de voordelen die YES!Delft biedt, werkt Alert Solutions ook graag mee om studenten op de mogelijkheden van start-ups te wijzen. Alert Solutions is zoals eerder genoemd onder meer betrokken bij een Bachelor Eindproject van Elektrotechniek.

Toekomst

De opdracht van Rijkswaterstaat was een belangrijke mijlpaal voor Alert Solutions. Het gaf niet alleen de financiële middelen om een gedegen haalbaarheidsonderzoek uit te voeren en om vervolgens een eerste prototype te ontwikkelen. Maar het gaf ook aan dat een belangrijke marktpartij als Rijkswaterstaat in GeoBeads een potentieel zeer interessant monitoringsysteem ziet. Zodoende heeft Alert Solutions een product kunnen ontwikkelen met een breed toepassingsgebied.

Figuur 3. Pepijn van der Vliet met op de achtergrond de symbolische cheques van Rijkswaterstaat.

Van der Vliet ziet de toekomst rooskleurig tegemoet. Grote gebieden moeten tegen het water worden beschermd. Nederland alleen heeft al 22.000 kilometer dijk liggen. Wereldwijd ligt een aantal grote economische centra midden in rivierdelta's. Dat vereist continue inspanningen om een veilig leef- en werkklimaat te handhaven. Monitoring is een belangrijk middel om deze veiligheid te kunnen vergroten en het beheer van waterkeringen zo efficiënt mogelijk uit te voeren. Naast dijken zijn er bovendien diverse andere interessante toepassingen, zoals de monitoring van bouwactiviteiten. Voor concurrentie is hij bovendien niet bang. Integendeel, naarmate de kracht van aanvullende monitoring steeds beter op de kaart wordt gezet zal de markt in omvang groeien.

Meer informatie

Voor meer informatie over Alert Solutions kunt u contact opnemen met Pepijn van der Vliet.
e-mail: p.vliet@alertsolutions.nl

Hier invoegen: pagina33Frames.pdf

Studieverzameling Elektrotechniek

Een rijke traditie als bron voor het nieuwe

De Studieverzameling, die al sinds de opening van ons gebouw in november 1969 te vinden is in de laagbouwkelder, herbergt een uitgebreide collectie nostalgische, meest elektrotechnische apparatuur van de faculteit EWI.

Auteur: J.A. Geijp,
Commissie Studieverzameling

Het is alweer drie jaar geleden dat wij in de kelder, samen met de toen 100-jarige Electrotechnische Vereeniging (ETV), een succesvolle tentoonstelling hebben opgezet ter ere van dit 20e lustrum. Met eigen ogen heeft men toen kunnen waarnemen dat er "beweging" zit in de presentatie van onze geëtaleerde objecten uit de "korte" maar rijke Electrohistorie. En dat is maar goed ook, omdat wij in algemene zin merken dat geschiedenis een hot item is. Populaire tv-programma's als 'In Europa' met Geert Mak, of 'Andere tijden' zijn daarvan het bewijs. Ook in den lande is men druk in de weer met het opzetten van canons om het verleden meer onder de aandacht te brengen.

In het tweestromenland, balancerend tussen inpakken-en-weggooien en behouden, dit laatste uit eerbied en bewondering voor wat met zeer veel denkwerk, inspanning en zeeën van tijd ontwikkeld en ooit toegepast is, heeft een kleine groep vrijwilligers, meest oud-medewerkers, de euvele moed opgevat dit erfgoed van de faculteit voor het nageslacht te ordenen en 'veilig te stellen', zoals men het zelf noemt.

"De vele objecten, die in de loop der jaren vorm en inhoud hebben gekregen, hebben toegepast of anderszins een plek gekregen hebben, zijn nu een tastbare bron voor de hedendaagse student", zo schreef de bekende schrijfster Janneke Matser over ons erfgoed. Maar ook: "Dat er een grote 'toekomstwaarde' is voor de verzamelde apparaten. Zoals op ieder denkbaar gebied heeft ook het dynamische vakgebied van de elektrotechniek in korte tijd grote veranderingen ondergaan.

Een proces overigens dat heden ten dage in een wellicht versneld tempo nog steeds gaande is. Wat eens hoogst moderne elektronica-apparatuur was, is door nieuwe inzichten en technieken achterhaald. Door de materie te behouden en overzichtelijk te ordenen en te huisvesten wordt een rijke historie aan nostalgisch en technisch vernuft aan de vergetelheid ontrukt.

Voor menig (toekomstig) student zal deze verzameling een bron van inspiratie zijn. Het is tevens een Walhalla voor de ouder wordende techneut, die menig plezierig

uurtje van herkenning zal beleven bij het zien van deze uitstalling".

Met en in deze "uitstalling", zoals Janneke dit noemt, worden demonstraties en tentoonstellingen gehouden of testen uitgevoerd. Ook worden objecten naar de collegezalen gebracht ter ondersteuning van de theorie. Natuurlijk is er in de huidige "PowerPoint-tijd" veel te visualiseren, maar het geeft iets extra's wanneer men het object in het echt kan zien en voelen. Dat alles komt zomaar uit onze "schatkamer".

Er is een goede samenwerking met het Techniek Museum in Delft, waar tevens een deel van de collectie, de zogenaamde A-collectie van Elektrotechniek, is ondergebracht in een depot aan de Rotterdamseweg, waaruit men eveneens kan putten.

De collectie

Wie nog nooit in de studieverzameling is geweest krijgt via de "kijk" van Janneke Matser een aardige indruk. Ze beschreef ons erfgoed als volgt: "Een grote collectie nostalgische radiotoestellen, een stereo(!) bandrecorder uit 1961, alle soorten, maten en modellen lichtschakelaars, de ontwikkeling van de gloeilamp in al zijn glorie tot en met de spaarlamp en de nieuwste toepassing met ledjes, heel veel verschillende modelletjes draaischijf-telefoons, een mobiele opstelling met de eerste beeldtelefoons, morse-apparatuur, een telexmachine, bestuurssystemen van treinen, één van de eerste elektromechanische rekenmachines, de voorloper van de huidige computer, een TU-ontwerp met de bijnaam Testudo, (Latijn voor schildpad: hetgeen aangeeft hoe traag alles in het begin ging), diverse andere modellen computers in opeenvolgende ontwikkelingsfasen."

Er is een sfeervolle nostalgische vergaderzaal gecreëerd met karakteristiek eiken en grenen meubilair, die naast voor vergaderingen ook voor cursussen dienst doet. Verder is men bezig alle oude boeken, waaronder zeer waardevolle exemplaren, te ordenen in stijlvolle vitrinekasten. Om maar niet te spreken van het sorteren van alle foto's en dia's die ooit door de "huis"-fotograaf, J.C. van der Krogt, van Elektrotechniek gemaakt werden.

Voor de meer gevorderde techneut onder de lezers noemen wij een opstelling van de Proef van Hertz, (replica van het origineel uit 1888, in het Deutsches Museum in München), de zogenaamde Nipkow-schijf, het ontwerp voor beeldoverdracht, (huidige tv), oscilloscopen, een aantal gyrokompassen, (toen was er nog geen GPS). Aan deze laatstgenoemde verzameling werkt al ruim 40 jaar dhr. K. de Wilde. Voorts een zeer grote en waardevolle verzameling elektronenbuizen als voorlopers van de transistor, een schakelpaneel uit de kernreactor (IRI), isolatoren van hoogspanningsmasten, telefooncentrales en een uniek project van de student Wouter Cozijn: een elektronisch schaakspel, bestaande uit computergestuurde robots die zich op wieltjes voortbewegen. Deze intelligente stukken van circa 60 cm hoogte bepalen zelf het verloop van het spel. Er worden pogingen ondernomen deze schaaktafel weer gangbaar te maken. Wellicht een leerzame uitdaging voor een groep studenten!

Divers bezoek

Vele bezoekers hebben met bewondering gekeken naar ons erfgoed. Zo kreeg ik een bedankbrief van Wim J. de Leur, directeur van Siemens Nederland, die, samen met de beheerder van hun erfgoed, dhr. Arnold Knoppert, een kijkje in onze keuken nam. Hij schreef het geweldig

Presentatie van het boek "Wervelstromen" door Roos Schongs en Prof ir. L van der Sluis

te vinden nog eens te mogen kijken in onze verzameling, maar dan samen met de voorzitter van de Raad van Bestuur, Martin van Pernis. Algemeen genomen zijn wij actief op maandag en vrijdag van 10.00 tot 18.00 uur.

"Alles moest nog worden uitgevonden" is de titel van een boek, waarin het ontstaan is vastgelegd van een van de belangrijkste uitvindingen in de geschiedenis van de mens: de computer. Cordula Rooijendijk beschreef hierin voor het eerst de Nederlandse geschiedenis van de PC, die gezorgd heeft voor een ware revolutie.

Dit gaat over de voorlopers van gigantische ronkende machines naar de huidige compacte huiscomputer. Het is dan ook niet zo gek dat Rooijendijk enthousiast en opgetogen huiswaarts keerde, na foto's te hebben gemaakt en materiaal betrok ken te hebben uit onze verzameling. Zo kwam o.a. onze Testudo (schildpad) het afstudeerproject van Prof. dr.ir. Van der Poel, de eerste geavanceerde rekenmachine, weer eens onder de aandacht in haar boeiende boek (ISBN 9789045013671). Een aanrader!

Hulp van de ETV

De ETV-besturen, altijd goede supporters van ons erfgoed, wisten ons telkens weer te vinden bij menige activiteit. Onlangs kregen wij van een vertegenwoordiging van het huidige ETV-bestuur, een nieuw gastenboek met daarin de volgende tekst: "Dat men de studieverzameling vol bewondering bezoekt, niet in het minst vanwege de enorme inzet en het enthousiasme dat uit elk bezoek weer blijkt". Verder schreef men het belangrijk te vinden af en toe te kunnen terugkijken naar revolutionaire vindingen van weleer met de constante verbeteringen en veranderingen, die hieraan ten grondslag liggen…en daarnaast is het ook gewoon enorm leuk, aldus de secretaris Jeroen Ouweneel. Voor ons vrijwilligers altijd weer een aardige opsteker!

De vergaderzaal vormt een schitterend decor voor afstudeerpresentaties

Saai is het in ons domein zeker niet. Zo zijn wij in beeld tijdens open- en ouderdagen, maakt men gebruik van de bibliotheekruimte voor voorlichting en cursussen, voor een afstudeerpraatje of verwelkomt men er nieuwkomers. Onlangs was er een presentatie van het boekje "Wervelstromen" ter nagedachtenis van een gewaardeerd medewerker van de werkgroep Geschiedenis, ir. Walter Schongs.

Uren poetswerk en liters schoonmaakmiddel gingen aan de tentoonstelling vooraf

In samenwerking met de Stichting Historisch Genootschap 'De Blauwe Tram' hebben wij een tentoonstelling ingericht over het 100-jarig bestaan van de eerste elektrische spoorlijn in Nederland, de Hofpleinlijn. Deze spoorlijn verbond het centrum van Rotterdam via de stations Pijnacker, Nootdorp en Leidschendam- Voorburg met Den Haag en Scheveningen. Tachtig wissellijsten met uniek fotomateriaal gaven de bezoeker een kijkje in de geschiedenis van deze bekende spoorlijn.

In de kelder is ruimte vrijgemaakt voor een actieve groep studenten van de Delft Aerospace Rocket Engineering, (DARE), die de elektronica met de hardware verbinden om vervolgens een "stratos"-raket te vervaardigen met als doel het Europese hoogterecord voor amateurraketten te verbeteren, hetgeen onlangs in Zweden is gelukt. Een prestatie zonder weerga!

Af en toe worden attributen voor tentoonstellingen elders ingezet, zoals onze eerste dynamo met ringarmatuur van Gramme en een model van de Maglev magneettrein aan het Nederlands Spoorweg Museum. Met dit museum onderhouden wij goede contacten. Ook de

Aan het begin van de studie wordt iedere student een stukje cultuur bijgebracht

Het automatische schaakspel, een project van Wouter Cozijn

inzet van de DEMO-werkplaats, waar ik nooit tevergeefs een beroep op kan doen, is van grote waarde en geeft een goed gevoel er nog bij te horen.

Nog lang niet klaar

Er is nog veel werk te verzetten, teveel om hier op te sommen. Na de brand in de faculteit van Bouwkunde hebben wij onze bakens moeten verzetten en hebben kritisch gekeken naar onze situatie. Hierdoor moesten onze plannen enigszins worden bijgesteld. Door de flexibele inzet van de enthousiaste groep vrijwillige vutters, zoals Richard den Dulk, Ben Morien, Cees Wissenburgh en Jan Meijers, stuk voor stuk specialisten, zijn wij op de goede weg en werken wij inmiddels weer aan onze actiepunten. Meestal op maandagen treft men hen aan in de kelderruimten van de laagbouw. Hun expertise, opgedaan in het verleden, is zeer waardevol. Zij zijn in staat het erfgoed te herwaarderen, waardoor de student van morgen meer inzicht krijgt in het turbulente leven van o.a. Elektrotechniek, Wiskunde en Informatica.

Zelf heb ik het altijd op prijs gesteld in samenwerking met anderen iets tot stand te brengen waardoor je een wezenlijke bijdrage kan leveren voor de toekomst. Dat was evenzo in mijn vorige werkkring als projectleider in de ET-Ontwikkelingswerkplaats. Hopelijk kunnen wij als vrijwilligers nog lang doorgaan met “schatgraven”, zodat de tastbare materie blijft bestaan en de plaats krijgt die het verdient.

Tot ziens bij ons erfgoed!

Column

Dr. ir. Nick van der Meijs
Opleidingsdirecteur Elektrotechniek

"Maak geen gebruik van een bestaande onderwijsideologie, althans, niet van de naam." Dat was het advies dat ik kreeg van een collega toen ik hem van onze plannen vertelde voor het veranderen van ons Bachelorprogramma. Eén van de ideeën achter deze plannen is om meer projecten in het onderwijs te gaan doen.

Dit idee komt overigens niet uit de lucht vallen. Het is één van de uitkomsten van de werkgroep Vernieuwing Bachelor Onderwijs, die in het studiejaar 2007-2008 nagedacht heeft over manieren om meer studenten te trekken. De gedachte hierachter is dat de maatschappelijke relevantie van Electrical Engineering (EE) beter getoond moet worden in het programma. Wanneer dit beter getoond wordt, kan daar veel beter op ingespeeld worden in de marketing, en zullen studenten die onze opleiding volgen hopelijk nog enthousiaster worden en zorgen voor goede mond-tot-mond reclame. Daarnaast zijn projecten natuurlijk heel geschikt om de grote invloed van EE op de maatschappij tot leven te brengen.

Meer projecten in het onderwijs dus. Maar noem het bijvoorbeeld geen 'Project Based Learning', want de afkorting is dan PBL en dat betekent ook al 'Problem Based Learning', of in het Nederlands 'Probleem Gestuurd Onderwijs' (PGO). Waarom moeten we het niet zo noemen? Omdat aan iedere bekende term onmiddellijk een lijst van voordelen, maar ook een lijst van nadelen gekoppeld kan worden, en die kunnen weerstand oproepen. Natuurlijk zijn de nadelen van PBL (in zowel de 'project' als de 'problem' versie) bekend, denk maar aan 'meeliften'. En hoewel er best manieren zijn om dat te voorkomen en er goed mee om te gaan, is het op zich correct om het als een mogelijk gevaar te zien. HBO's hebben in het verleden en masse competentiegericht opleiden ingevoerd. Gaan we het HBO achterna met PBL? Worden we dan een HBO? Nee, natuurlijk niet.

OK, geen PBL. Maar wat dan? Ik kwam onlangs een boek tegen met de titel 'Project-Led Engineering Education'[1] (PLEE). Het is een heel goed boek, bijna op ons lijf geschreven. Het lijkt wel of alle vragen, die in je opkomen wanneer je over het invoeren van meer projecten in het onderwijs nadenkt, behandeld worden. Maar ja, PLEE staat wel in de (Nederlandse) Wikipedia. Niet als onderwijsvorm, maar als doorverwijzing naar een andere betekenis van het woord. Dus toch maar niet gebruiken.

Hoe moeten we dan ons Eigen Project Onderwijs noemen? EWI Project Onderwijs? Elektrotechniek Project Onderwijs? EE Project Onderwijs? Ik weet het nog niet. Maar de afkorting is EPO. Is nog niet in gebruik als afkorting voor een onderwijsvorm (of ideologie) en is in ieder geval stimulerend.

[1] Project-Led Engineering Education, Peter Powell and Wim Weenk, Lemma Publishers, Utrecht, 2003.

Hier invoegen: pagina39Deerns.pdf

Hier invoegen: pagina40Tennet.pdf