KTH ROYAL INSTITUTE
OF TECHNOLOGY

A piece of history

SCHOOL OF ELECTRICAL ENGINEERING 2005 – 2017

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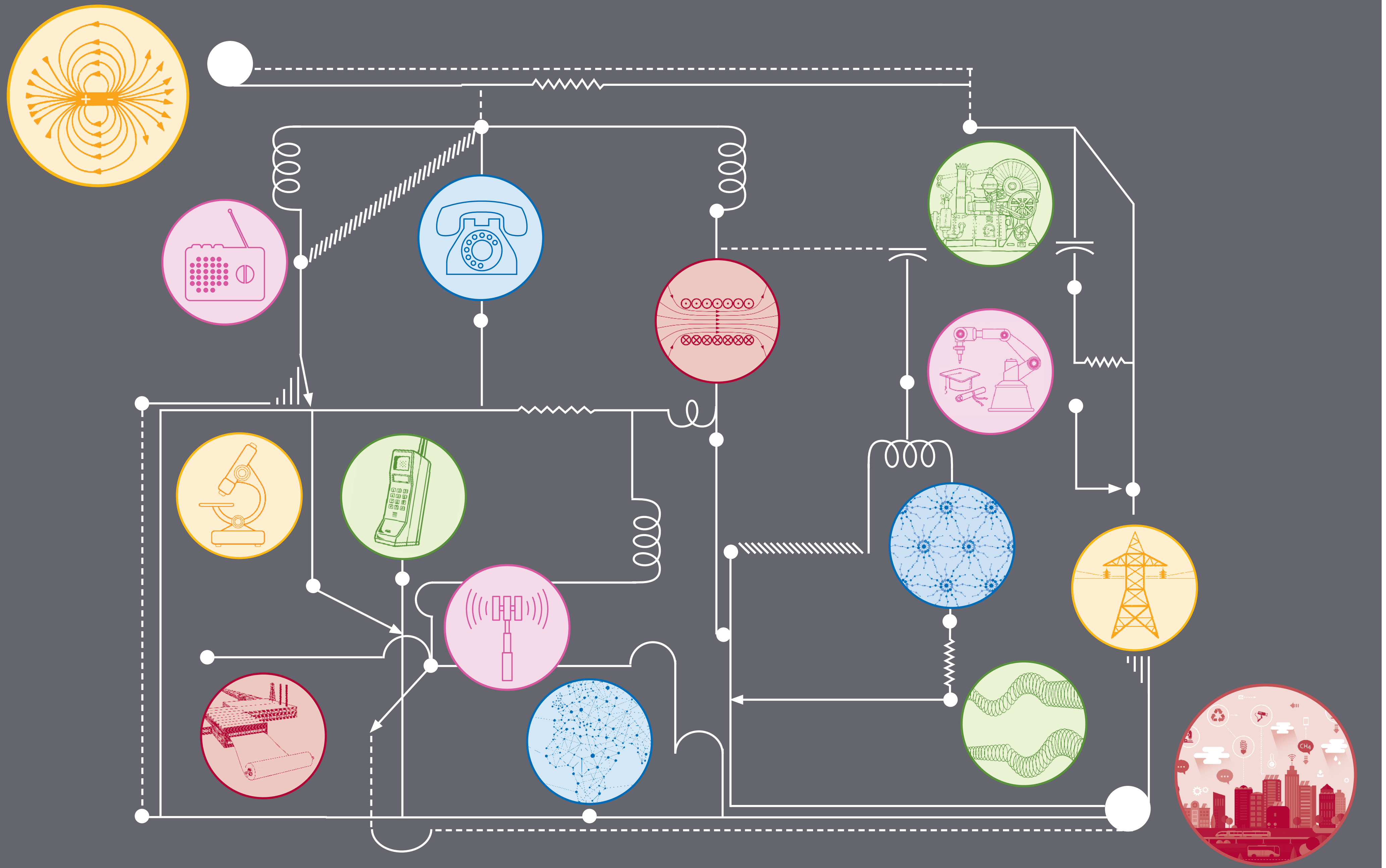


Content

Quality is made through culture

When looking back at the thirteen years as the School of Electrical Engineering, there are a number of things I am proud of. Some things are easy to measure: bibliometric, the degrees we have awarded and the eminent placement in various rankings. But there are other things I would like to highlight as the main factor for our success – our common vision for how to create an environment which give us quality. Quality in everything we do in research, education, co-operation and administration.

I believe that our recurring platforms for dialogues and discussions have built the foundation for this. We have always taken the time to meet prior to the decisions being made. It has, in some cases, led to long and tough arguments but once the decisions have been made the implement phase has been easier. The anchoring of change has driven us forward.

The school has had thirteen successful years. Our impact in both the educational and scientific world is unquestionable. Throughout the last years, impact and how to tell 'our impact story' has been top of mind for a lot of us. This is something we owe to our 'impact leader' Tobias Oechtering, Associate Professor at the Department of Information and Science Engineering. His work together with our research communicator Louise Gustafsson has given us a framework for how we should think and reflect upon our own impact. Many of the stories you are about to read in this booklet has been made through the influence of their work.

I'm not going to spoil any of the stories beforehand but I am especially proud of, not only activities at the departments such as research publications and courses offered, but what all employees have created together. Which I hope is a feeling that we all belong to the same culture where we have strived towards common goals, regardless of our specific roles.

The origin of the quote "The only thing constant in life is change" is a bit unclear, but it is nevertheless a good summary for what's going on at KTH and the EE school at the moment. It is built into the academic DNA – to be in a never ending moment towards something new. We should be on the side glancing in and in the forefront leading the path of society at the same time.

When we enter 2018, we will join forces with two other schools at KTH: the School of Information and Communication Technology and the School of Computer Science and Communication. KTH's ten schools will be five. Our new School of Electrical Engineering and Computer Science will be a key player right in centre of attention.

But before that story starts, I would like us to take a minute and reflect on everything that has brought us here through the stories in this booklet.

Merry Christmas!

Stefan Östlund

Stefan Östlund, Head of School and Vice President at KTH

In numbers

The School of Electrical Engineering has been successful in research and education on both national and international level. Together we have accomplished something truely great.

Enjoy some facts about the school from its start in 2005 to today.

Organisation

3615 Annual man powers 2005 – 2017

15 Departments

2 Research centres

3.26 bn SEK
Incomes in billion SEK

1.69 bn SEK
External funds in billion SEK

KTH prizes

1 Janne Carlsson's grant for Academic Leadership

2 President's equality and diversity prizes

3 Educational prizes

Education

1055 Degree of Master of Science in Electrical Engineering

1 Master of Science Programme in Electrical Engineering

2524 Degree of Doctor

Research

8963 Publications in DiVA

16 & 17 Best QS placements (2015 and 2016)

1.56 Best Journal Impact Factor score (2014 – 2016)

EXACTLY WHERE THE PHYSICS IS HAPPENING

The keen observation of the night sky has long been a recognised part of Swedish scientific life, now we're closer than ever to understanding it.

FROM THE EARLIEST DAYS, the night sky — particularly the colourful aurora borealis — seen prominently over northern Scandinavia, has sparked curiosity.

Over time, this curiosity sharpened into scientific fact-based research. The naked eye was soon assisted by ground-based observations from magnetometers, all-sky cameras and radars. In time, first sounding rockets and then satellites were launched to further investigate *in situ* the physical mechanisms behind the aurora (such as acceleration of auroral particles needed to create the intense auroral displays) and the mechanisms driving the auror.

Scientists at the Department of Space and Plasma Physics have long played an internationally key role in studies of the aurora and the auroral particle acceleration. Both Professor Göran Marklund and research scientist Per-Arne Lindqvist have studied the aurora and the mechanisms behind it since the late 1970s.

"We often call our research 'auroral research'. But the aurora is not the result of processes confined only to the Earth's ionosphere where it is observed, but the result of a long chain of interactionprocesses between the Sun's and the Earth's magnetosphere. As the continuously emitted, highly variable solar wind hits the Earth's magnetosphere, a process named reconnection will transfer energy and momentum between particles and magnetic fields. To further understand this process, in-situ measurements by satellites crossing the magnetosphere's outer boundary are needed says Lindqvist as the two scientists explain their role in the continued study of an ever more vital area of space physics.

Electromagnetic hydrodynamic waves (or magneto-hydrodynamic waves) play an important role in the above mentioned processes behind the aurora. They were first described in 1942 by the late KTH professor Hannes Alfvén (1908 – 1995). As an electrical engineer and plasma physicist he had long promoted his theories on electromagnetic hydrodynamic waves and, although at first not universally accepted, his theories were soon fully recognised. Now these waves are commonly referred to as 'Alfvén waves'. It is his pioneering work, recognised with a Nobel Prize for Physics in 1970, that has continued in earnest at KTH.

The success of the launch of Sweden's first satellite VIKING in 1986 and its achievements as the first satellite to explore plasma processes in the Earth's magnetosphere and ionosphere led not only to successive satellites FREJA and

Göran Marklund and Tomas Karlsson, holdning their MMS instrument.

> "We showed the world we were capable of making rocket and satellite experiments which worked."

ASTRID-2 and their further investigations, but also to a recognition from the international community that Sweden had a serious research capability and a frontier position in the field.

"We showed the world that we were capable of designing and building advanced rocket and satellite experiments which worked," says Marklund.

WHEN SCIENTISTS AT KTH learnt that NASA was getting a team together for a space physics project which would involve four satellites to launch in 2015, the KTH team worked hard on their contribution to a project close to their heart. The Magnetospheric Multi-Scale (MMS) mission was targeted to deepen our understanding of the process of reconnection operating between the solar wind and many of the planets, including Earth. Magnetic reconnection, transferring energy and momentum between particles and magnetic fields, is a well-known process in fusion plasmas, solar flares and probably in astrophysical plasma jets.

A key parameter in this process is the electric field. The world-leading position of the KTH group in measuring electric fields was the reason for being invited to provide the spin-plane double probe electric field experiments on the four MMS spacecraft. It was on the 13th of March 2015, after ten years of hard work on a one billion dollar NASA mission, an Atlas V 421 rocket entered space carrying their instruments. All three components of the electric field in the earth's magnetosphere are now being measured with the highest resolution possible and frontier science is already being explored. As a result of this large scientific effort, "close to 400 papers have been published in international journals with many authors to each paper," says Lindqvist.

WHAT 'S NEXT FOR Space Physics at KTH? "We are moving away from the earth's magnetosphere to explore other regions," Lindqvist explains. "One project that we are involved in, and which is already on its way to be launched, is BepiColombo. It will go to Mercury, carrying an electric field instrument we have built. There will be two spacecraft, one will observe the planet and the other is a magnetospheric orbiter which will measure the electric fields, in situ around the planet Mercury, for the first time ever."

Almost by way of further explanation, and especially to clarify the importance of the study of in situ space physics, Marklund explains. "Astronomers are forced to rely only on the light in different wavelengths emitted from stars, however, our in situ measurements are from exactly where the physics is happening, where there are electric fields, particles and currents. That is a real contrast between us and the astronomers." ■

A SMARTER WAY OF MOVING

At the Smart Mobility Lab, researchers and students have helped industry create the transport systems of the future.

SINCE THE SMART MOBILITY LAB was created in 2012, its researchers and students have developed various information and communication technologies for smart and energy-efficient transportation.

The lab is currently working on projects related to aerial robotics and autonomous mining vehicles, among others. But it is in the field of cooperative vehicle systems, and in particular heavy-duty vehicle platoons, that the lab has had the biggest impact.

Some 40 patents on vehicle platooning have come out of the Smart Mobility Lab. And as a direct result of the lab's work, truck manufacturers such as Scania and Volvo are putting vehicle platooning technology into production.

PLATOONING INVOLVES operating freight trucks in convoys where the vehicles are driven

Jonas Mårtensson in the Smart Mobility lab.

at a constant speed and distance to each other. This reduces air drag and therefore lowers fuel consumption.

The Smart Mobility Lab has shown that vehicle platooning can reduce fuel consumption by over 10 percent, which reduces CO2 emissions. Given that road transport accounts for 18 percent of greenhouse gas emissions in the EU alone, the environmental implications are considerable.

The Smart Mobility Lab was initially established to develop networked control systems that make the operation of interactive vehicles, and the concept of vehicle platooning, possible.

"We have been doing basic research about interactive control systems with multiple vehicles for over 15 years," says Karl Henrik Johansson, Professor at the Department of Automatic Control and founder of the Smart Mobility Lab with Assistant Professor Jonas Mårtensson and Professor Dimos V. Dimarogonas. "We wanted to be able to test these systems with toy vehicles in a lab. So in 2012 we brought that proposal to the Head of School of Electrical Engineering and the President of KTH. They thought it was a great idea and the lab was created."

THE GROUP'S EARLY RESEARCH on vehicle platooning was done in collaboration with Scania, who also became very interested in the Smart Mobility Lab. The lab is also part of the joint KTH, Scania and Ericsson Integrated Transport Research Lab, and many students who have worked or studied at the Smart Mobility Lab have gone on to work at Scania and other industry leaders.

"We have the philosophy that to get the kind of research engineers that we need we should grab people that are just on their way out to industry," says Johansson. "They get a boost by being engaged in a cutting edge project for a year or two and we get the best people. We are one of the leading places in the world for vehicle platooning research and that is because we are able to get excellent students and research engineers. The whole idea is to be agile and move fast."

Johansson adds that the lab enables potential results from basic research to be demonstrated and evaluated on something that is almost a real system very quickly. "We can combine the theoretical research and computer simulation work done by doctoral students with implementation on something that can mimic a real transport scenario," he says. "Other research groups either just do applied research, working with real vehicles only, or are limited to computer simulations. We bridge fundamental and applied research."

ON ANY GIVEN DAY around 20 students or researchers work in the Smart Mobility Lab. It is used for teaching, research projects, workshops and welcomes visits from schools.

Johansson says that it has almost become a victim of its own success. "We are running out of space," he says. "We would like to have something that is two to three times larger now to accommodate all the activities."

But the physical space limitations are not stopping the researchers at the lab from looking at the next stages of transportation systems.

"We will soon see these platoons doing business on the roads," Johansson says. "They are currently being tested on roads, but at the moment the convoys consist of just a few trucks. Platooning will soon have influence on other traffic. Now we have a new project with both Scania and Volvo to look at how to coordinate multiple platoons and integrate them with other traffic. Another question for the future is to understand the implications of autonomous vehicles."

The Smart Mobility Lab researchers are also working on augmenting the lab with live data from various transport systems, which will enable even more realistic scenarios to be tested.

ONE PROJECT in this area involves the control of traffic lights in Stockholm. "We will see much more of these types of experiments in Stockholm," says Jonas Mårtensson, one of the project leaders. "Where things that are happening downtown in real-time will be happening at the same time in the lab. It will become an augmented reality type of lab." Perhaps this is one way to solve the physical space issues! ■

"We wanted to be able to test systems with toy vehicles in a lab"

Karl Henrik Johansson

CONTINUING THE COMMUNICATION REVOLUTION

Remember the time before smartphones and ‘mobile solutions’, before all the talk of autonomous systems and the Internet of Things? Remember when there was no 2, 3 or 4G? Remember wires, everywhere.

"I **REMEMBER WHEN**, perhaps twenty years ago, what we were doing here was seen as interesting but too expensive to develop," reflects Mikael Skoglund, Head of the Department of Information Science and Engineering and Vice Head of Electreical Engineering.

For many years both he and his colleague Mats Bengtsson, Professor of Signal Processing and Programme Director for the MSc programme in Wireless Systems, have been performing theoretical and experimental research, using numerous tools from information, communication and coding theory to signal processing, machine learning and statistical physics to further develop wireless networks.

Skoglund and Bengtsson, along with colleagues and students, have worked to develop a technology we have come to take for granted, a technology which becomes more reliable, trusted, able, efficient and capable with each new ‘generation’. By the time we arrived at ‘3G’ that enabled mobile devices, they had capabilities that made it possible for us to access everything almost anywhere. The wireless networking capability gave birth to the “smartphone”. It was easy to play games, send videos and images. Microblogging and sharing numerous selfies had become part of our everyday lives. This was all made possible from rapid, constant data transfer.

THE NEXT LEAP in wireless technology, 4G, became known as ‘mobile broadband anywhere and everywhere’ and it changed the atomic unit of the web from images to videos. The EE team were involved from the start and between 2000 and 2010 they worked on 4G development. Their work was given a boost in 2004 when the European Commission began the project "Wireless World Initiative New Radio" (WINNER) with the aim to define the fourth generation radio standard. WINNER united 4G industry and researchers from Finland, France, Germany, Italy, Netherlands, Poland, Spain, Sweden and the UK. By 2010 4G was a reality and the European Commission decided to invest 18 million Euros in the further development of the technology. Overall, the years 2007 to 2013 saw the EU invest more than €700 million Euros into research on future networks, half of which was allocated to wireless technologies contributing to the development of 4G and beyond 4G networks.

THE WORK ON 4G has been a resounding success. Aside from download and streaming speeds, it has been a success from a societal point of view. It has led to a decrease in the digital divide between urban and rural communities. Worldwide standardisation has meant the use of a single technology from across the world without changes between Europe, the United States and Japan – areas which previously all operated on separate systems. The internet on our phones is now taken for granted and mobile internet usage surpassed desktop usage for the first time (2016). Around 80 percent of time spent on social media is spent on mobile devices and social media itself has been supercharged from Snapchat stories to the 8bn video views on Facebook per day. When asked about their role in the development of this disruptive and enabling technology Skoglund explains that it was “Through our research, networking and working on the huge European projects that we contributed.”

LOOKING TO THE FUTURE we can glimpse just how the work done by Bengtsson, Skoglund and the EE school continues to have an impact. Both 4G and now 5G have been influenced not only by the work of Skoglund and Bengtsson but also by their former doctoral students, now working with major telecommunication companies such as Erisson and Huawei.

In the early 2010’s Skoglund and Bengtsson were involved in the development of the new 5G technology. WINNER was soon followed by another European project, the Mobile and wireless communications Enablers for Twenty-twenty (2020) Information Society (METIS). METIS, a consortium of 29 partners focusing on developing a concept for 5G was coordinated by Ericsson whereas WINNER was led by Siemens. This time the technical objective was to develop a concept for the future mobile and wireless communications system that would support the connected information society.

“5G will be different again,” says Skoglund. “If you browse the internet over the phone a two-second delay can be okay, but if you wish to control a robot over wireless or an autonomous car, the requirements on real-time and reliable communication are much tougher. 4G can’t deliver that.”

We should be in no doubt that 5G technology will be transformative. It will affect almost each and every industry, and will supercharge virtual and artificial reality. The Department of Information Science and Engineering has made its mark on the way in which we live our lives today and will continue to have influence on how we will live them tomorrow. ■


Mikael Skoglund

> “5G will be different again”

TINY DEVICES MAKING A BIG DIFFERENCE

In the age of mobility and the Internet of Things, there is an ever increasing demand for portable devices: the smaller the gadget, the better. At the Department of Micro and Nanosystems, Sweden's biggest microelectro-mechanical systems (MEMS), researchers have developed miniature integrated technology that makes a real difference.

IMAGINE AN ultra-miniaturised blood pressure sensor that is so small it's invisible to the naked eye, a tiny embedded smart system that can be guided along the coronary artery to collect accurate data. This life-saving MEMS technology is the result of the pioneering research carried out in the late 1990s by Professor Göran Stemme and his team of researchers at the Department of Micro and Nanosystems.

"Our collaboration with clinicians and the adoption of our technology in the medical arena is perhaps the most interesting and rewarding aspect of our work," says Stemme. "It's when the platforms and tools we create answer a call from a mobile society for microscopic solutions that we realise our efforts are absolutely necessary. Because ultimately, we're saving lives."

Stemme's team's blood-pressure sensor was eventually adopted for commercial development by Radi Medical Systems under a licensing agreement.

It was some earlier research carried out by Stemme and Edvard Kälvesten, one of his first doctoral students, that originally caught the attention of Radi. Their project (a joint effort run by Stemme and fluid dynamics expert Professor Lennard Löfdahl at Chalmers University of Technology) involved the development of a microphone that could be used to measure eddy current flow around the wing of an aircraft in wind tunnel experiments.

When Radi indicated that they needed a company that could manufacture a miniature blood pressure sensor, Kälvesten decided to establish such a company, bringing on board four of Stemme's former doctoral students: Niklas Svedin, Thorbjörn Ebefors, Marianne Henke (formerly Meckbach) and Thierry Corman.

In 2000, the MEMS manufacturing

company Silex Microsystems was born.

Today, Silex is still manufacturing the sensor for Radi, which has since become part of Abbott Laboratories, the multinational US healthcare company. The product has been a phenomenal medical success, reducing mortality by around 50 percent and preventing myocardial infarction in patients with coronary heart disease all over the world. It is now used as standard practice in cardiovascular medicine, and some 600,000 patients have it fitted every year.

"I am very proud of taking this technology from my research at KTH to the product it is today. We have sold tens of millions of pressure sensor chips so far."

The sensor chip manufactured by Silex is exemplary in demonstrating the way many electrical and mechanical components can be integrated into a single microchip. Comprising a series

Göran Stemme

of sensors and integrated circuits, the miniaturised system is fitted to the tip of a 0.35mm-diameter guide wire catheter and fed along the pulmonary artery.

MINIMALLY INVASIVE, the surgical procedure involved in embedding the sensor allows the patient to go home in a matter of hours, secure in the

"Ultimately, we're saving lives."

knowledge that their physician will be able to monitor their cardiac health on a remote basis. In the event of a localised drop in blood pressure owing to the narrowing or blockage of an artery, the constriction can be located and a stent can be inserted to restore a steady blood flow and prevent heart failure.

The inspiration for Stemme's and his current team of 30 doctoral students' work continues to be born from a demand from society for their advanced technological systems.

More recent innovations developed at the department include a blood collection device that may be used by patients themselves for microsampling – a business idea that has led to the establishment of another start-up called Capitainer, which was co-founded by Stemme and several other academics from the department including Associate Professor Niclas Roxhed and doctoral student Gabriel Lenk.

"As people become ever more mobile and an increasing number of devices become connected, our aim is to develop eminently portable and efficient MEMS tools with added functionality," says Stemme. "I see more and more opportunities coming up for us, with the increasing need for miniaturised integrated technology."

Kälvesten says he is looking forward to Silex's continued collaboration with researchers at KTH on projects in the future. "And of course," he says, "the school will remain an essential recruitment pool for us." Now staffed by 160 engineers (by which at least 50 come from KTH), Silex's unique sensors and actuators have secured an annual turnover of 400 million SEK for the company, and it is growing by 20 percent every year.

IN THE AGE OF IOT, when the market for devices with silicon-based discrete microsensors continues to grow at a rapid rate, the integrated microchip has massive potential. Meanwhile, the need for microelectronics, microactuators and other optical systems creates endless possibilities for applications in the fields of biotechnology, medicine and telecommunications.

"Our technology offers the combined benefits of miniaturisation, low power consumption and extreme performance," says Kälvesten. All is set then for the technological breakthroughs of the future. ■

A MAGNET FOR SUSTAINABLE SUCCESS

The higher efficiency that permanent magnet motors bring to industrial applications means that they could play a key role in global sustainability. Therefore it's a good job that the School of Electrical Engineering has been on the case.

PERMANENT MAGNET MOTOR technology has matured considerably in recent years and is at a point where its benefits to numerous industrial applications are clear.

One of the key benefits of permanent magnet motors is their compactness. "Because of this you can integrate the power electronics you need to control the motor in the same housing," says Oskar Wallmark, Associate Professor at the Department of Electric Power and Energy Systems. "In a conventional induction motor there is not enough space to combine the electronics and the motors."

Permanent magnet motors provide higher efficiency than conventional motors and can therefore reduce energy loss. "A large part of all the electricity generated in the world passes through electrical motors," says Wallmark. "Hence, if the efficiency of electric motors can be improved, significant amounts of energy can be saved."

This is why permanent motors could be so important for global sustainability. "They are a key component of the drive by industry to be sustainable and reduce environmental harm," he adds.

The EE school became interested in the technology when some of these benefits became clear, particularly when Swedish industry started to see the potential opportunities.

A NUMBER OF RESEARCH PROJECTS have been carried out between the school and industry, many of which have involved students.

"Nowadays, permanent magnets motors are on the course curricula," Wallmark says. "They are a large part of my course focusing on design of electric machinery. We are running projects on them and have masters and doctoral theses on the subject. The work that the EE school does in this area has matured, as has the technology. This means that more uses for permanent magnet motors have been found and they are much more common in industry."

Some of the industrial companies that the school has conducted permanent magnet motor projects with includes ABB, who undertook a project with the school on integrated electric drives, Atlas Copco, with whom there is an ongoing project to improve the efficiency of their electric hand tools and ITT Waste Water where the technology has been explored for use in water pumps. A full-scale prototype for a heavy hybrid vehicle has also been developed and tested in industry.

ONE OF THE SCHOOL'S MOST SUCCESSFUL permanent magnet motor projects with industry was the Green Train project with Bombardier Transportation.

The project involved Wallmark and Juliette Soulard, former Associate Professor at EE, working at Bombardier's site in Västerås to develop the use of the permanent magnet motor technology in high speed trains.

"Bombardier made a huge investment to learn about and develop the technology for trains," says Wallmark. Prototypes were built and tested resulting in higher power, increased efficiency and the subsequent sale of trains with permanent magnet motors.

"The permanent magnet motors propelled the trains forward with less losses than conventional induction motors," he says. "For some train applications, this technology is now common and many train actors have permanent magnet motors in their portfolio today."

One disadvantage of permanent magnet motors is that the rare-earth based material that the permanent magnets are made from is currently mined in China, and not in a very environmentally friendly way. Opening new sites in other places to produce the material in a more sustainable way would be beneficial from an environmental point of view, but it would most likely result in higher material costs.

Wallmark says that the school is looking at this indirectly through researching methods that uses as little of the material as possible in the motors while still maintaining a high efficiency and compactness. The EE school has worked with permanent magnet motors for a long time and is developing the technology further.

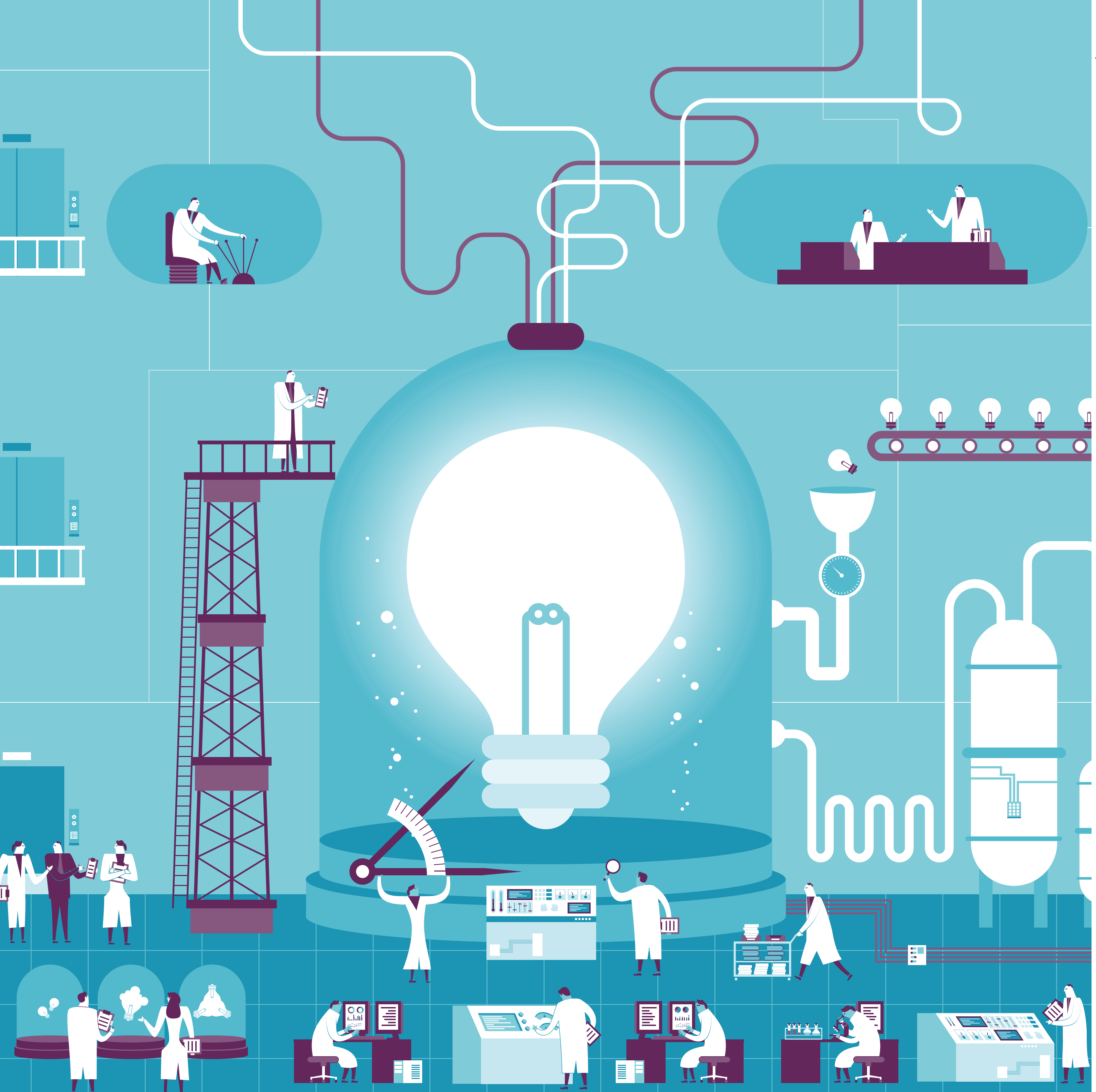
Wallmark credits retired Professor Chandur Sadarangani as being a key factor in the school's involvement. "He worked closely with ABB and saw the need for higher efficiency motors," Wallmark says. "He identified permanent magnet motors as being very important to reaching higher efficiencies. That is a key reason why we now have so many activities at the school around permanent magnet motors."

Permanent magnet motors are today a important component in servo drives used in for example industrial robots. They are also common in wind turbine generators and have in fact become key components in a number of important industrial applications.

Oskar Wallmark

"For some train applications, this technology is now common"

And, Wallmark adds, there is now an even larger interest in the technology from the automotive industry due to the revolution in electric transportation. "You need a very high efficiency and very compact solutions for electric and hybrid vehicles," he says. "Permanent magnet motors fulfil these requirements. Today, we see even more opportunities for researching the technology." ■



ENGINEERING THE PERFECT BALANCE

Engineers have been trained at KTH Royal Institute of Technology for over 100 years. Teaching practice has always evolved and adapted both with the college and society at large. Today, striking a balance between theory and practical experience is at the centre of the most recent education reforms.

THE BALANCE ENSURES that the university delivers professionals with relevant practical experience, in addition to being schooled in the fundamental scientific rigour that must underpin that practice. However, a balance between science and practice has not always been to the aim of the university.

Post-world war one KTH was very different compared to today's university. If you were to visit you would have found a male-dominated training college, much more of a 'workshop' with an apprenticeship style. Similar to today's facility it was a proud institution in which students could expect the best training in the latest methods when studying in fields such as materials science. But it was certainly, without question, more traditionally focused and very much a 'hands-on' school. Training was rooted in the apprenticeship system for tradesmen.

However, after time, it had become clear that the school was going to need to move towards more theory. And so in 1867 "scientific training" was entered into the university's statutes. Theory began to occupy more space in the curriculum.

A LEAP FORAWRD and we find ourselves in the 1990s, and now the tables have very much turned. By this time there were few internships being offered by industry and the practical requirement for a degree was removed altogether. At KTH many professors themselves had little or no practical experience and theoretical work and research became all dominant.

"In engineering education in the 1990s there was nothing about conceiving, there was nothing about implementing or operating, it was all design or calculations," says Joakim Lilliesköld, Associate Professor in Industrial Systems Engineering and the man responsible for education at the EE school. Critics were looking to engineering colleges around the world and feeling that the focus on the profession was being left behind. In the US, Boeing, the multinational corporation and engineering giant, had made the observation that they were unhappy with the graduates that they were getting. As Lilliesköld describes it "they, as well as many other companies, were not really happy with the engineers that came out of the system. They wanted to see a change in their education so that they would get more practice into it and took a systems approach to how to re-train them." It was out of this that the 'CDIO' method was born in the early 2000s. The method focuses on four key areas that the students need to work with in order to become rounded engineers: conception, design, implementation and operation.

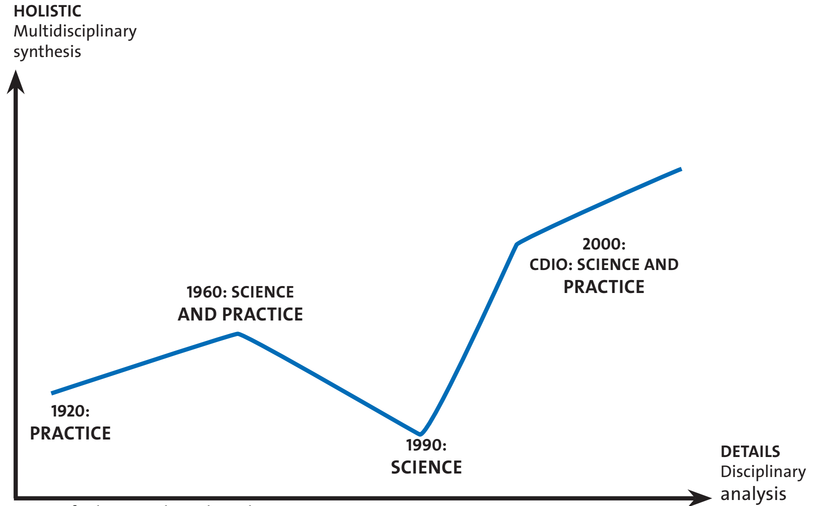
"CDIO was a project funded by Wallenberg and the goal was to educate engineers that actually can engineer," says Lilliesköld.

CDIO said that engineering programmes needed to have all four fundamental puzzle pieces. Additionally, it was realised that for the 'hands-on' aspect, project courses would also need to be added to the curriculum. Lilliesköld explains how the model was added and adjusted.

"Another dimension was realised – that you had to have a progression of skills. A long set of engineering skills was developed and you needed to be able to work in a team, do a project plan and be able to communicate. All of the skills of the engineer were examined," Lilliesköld says.

A key feature of CDIO was the way in which it was 'baked in' as the skills were not taught separately — there was not a project management course or a technical writing course — they were integrated into the actual technical courses. CDIO has continued to develop and the curriculum at EE has adapted and evolved.

THIS MOST RECENT EVOLUTION of education at KTH started in 1999 when the first year project course began. According to Lilliesköld it created a lot of discussions as to whether or not you could present an application before all relevant theories were known. Another issue was the product focus of CDIO. In early 2000 it was difficult for many at the departments to talk about products for Electrical Engineering. Then something changed and project courses were developed in many of the master programmes. In 2007, the bachelor thesis was added to the curricula as a result of the Bologna reform. Ten years later, the next step was taken to introduce a more challenging project course in the second year at the bachelor level. In 2013 the curriculum was rebuilt. The result was a programme to create world-class electrical engineers, a programme with a strong theoretical base and one project each year which aims to tie the theoretical courses together. As Lilliesköld says, "Altogether, students now leave with a good mix of skills, ready for the demands of 21st-century industry". ■



Focus of education throughout the years at KTH.

"It was all design or calculations"

Joakim Lilliesköld

IT TAKES A TEAM

When we think of university education we think all too often about a large lecture hall with numerous students facing a single all-knowing lecturer whose job it is to impart his or her knowledge as best they can. However, just as society is undergoing significant change so are education methods.

A **THE EE SCHOOL**, research projects are now becoming increasingly more and more prominent. A project-based approach has meant big changes for teaching staff and students alike.

Researcher Hans Sohlström and Associate Professor Ragnar Thobaben have worked on the new project courses and both have opinions about just how the new structure is working.

Hans Sohlström works at the Department of Micro and Nanosystems where he is responsible

"The interplay between teachers and students becomes a three-way dialogue"


Hans B. Sohlström


Ragnar Thobaben

for courses in measurement technology. First as a KTH student Sohlström began teaching in 1978 and as he reflects from his vantage point of several decades of teaching experience, it is clear that he is positive about the changes. You soon realise that his enthusiasm for his subject is easily matched by his passion to teach. He readily admits he was quite happy with the traditional lecture structure, "I really like giving lectures, it's kind of a show, and I try to get as much two-way communication going as possible." Communication is a thread that is often returned to as we speak about the new process.

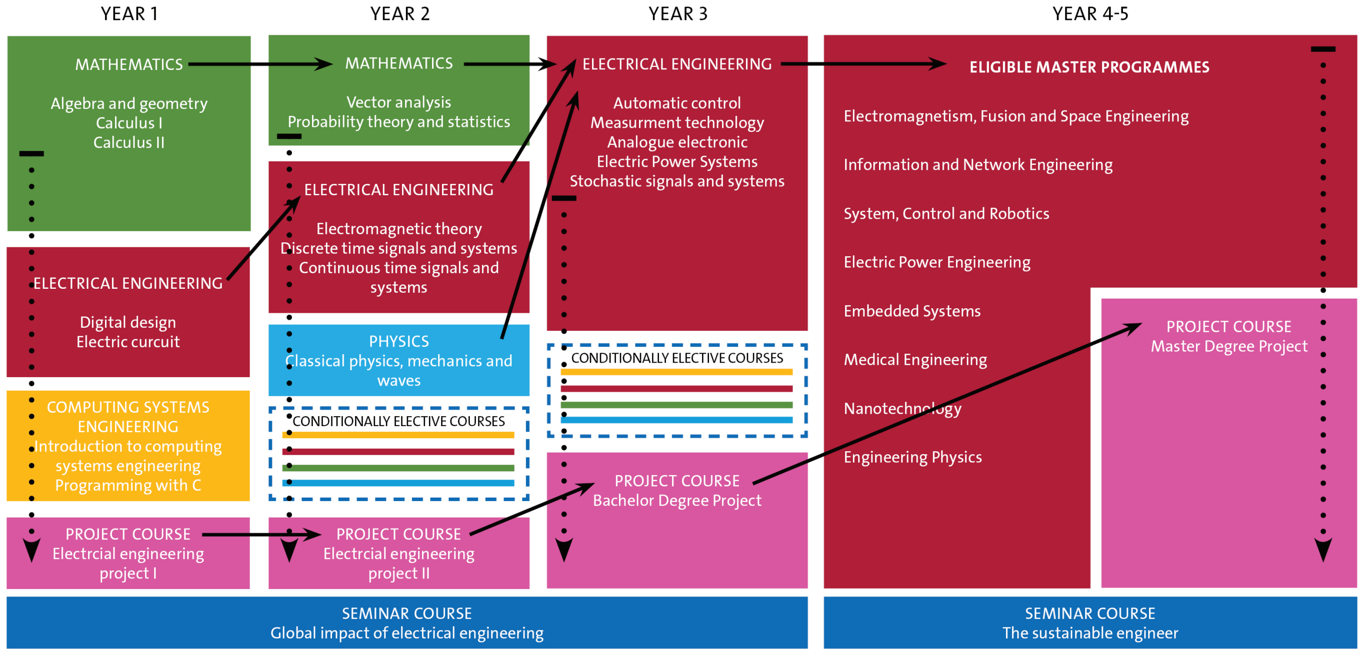
STUDENTS HAVE NOW been introduced to a project element of their degree. The project itself takes the form of a challenge. One challenging project set was for students to wirelessly boil a container of water through a wooden partition. Adding this new project element has meant that the teachers and researchers have had to work more closely together. It has led to an increased awareness of each-others roles amongst the teaching staff and resulted in a less siloed, more collaborative approach and more energised meetings.

"We are not only meeting to talk, we are meeting to work," says Sohlström. The tutors work through questions such as "What are the goals of this project? Why are we teaching this? How do we tackle the problems best?" together.

Sohlström explains that one of the greatest benefits of this approach is the working together and as a result getting to know your colleagues better. "You get much better contact with people by solving problems together."

DURING THE BACHELOR THESIS COURSE, there is a seminar series with a project element, in addition to a skill being taught in parallel. The skills element is new and can be anything from communication (writing, presentations techniques or recording video for YouTube demonstrations) to project planning — all essential skills for rounded engineers. At times there can be two teachers in the room which is quite a different dynamic for both teachers and students. "Learning can be accelerated in this way," says Sohlström. "The interplay between teachers and students becomes a three-way dialogue during which the secondary teacher can actually act as a prompt for the students and help move the class forwards."

Ragnar Thobaben from Department of Information and Science Enginger, and one of the staff prominently involved in the administration and new method, reflects on the 'nuts and bolts' practical side of how the courses function. "The project courses are designed to be interdisciplinary and simply to have enough coverage you want to have multiple teachers, then every problem that appears can be properly addressed. Another reason is that you have many students and need to distribute the workload," says Thobaben. Again, this is not only beneficial to the students as they are provided with a



The five year programme in electrical engineering is divided into two parts, where the first three year consist of bachelor courses and the last two years of master courses. There is progression in learning in each subject respectively, from course to course and year to year. At the same time the courses each year, ties together in a project course. The students also have a seminar series where the societal benefits of electrical engineering is discussed under the supervision of faculty.

different perspective and additional assistance, but also the teachers see the benefit of working alongside one another. Sohlström certainly sees the benefits, "Teaching together certainly helps me develop as a teacher."

Are interdisciplinary, project-based courses the future of engineering education? Not exactly, despite their attractive nature. Thobaben says that it can be difficult to realise their full potential owing to the fact that they require additional time and resources which are not always available. Despite this he is also positive about the future, "This faculty is always positive about doing new things, although it might not always be easy."

In Sohlström's opinion courses are now connected in a more meaningful way. Additionally, the project/challenge element gives more to the students. "When you go into the industry, you want to do everything right but here you should also be allowed to fail. You always learn from mistakes."

It is clear that project-based courses at the EE school are certainly bringing students and teachers together, in addition to providing the kind of well-rounded professional engineering that society needs more than ever. ■

Ready for renewables:

SWEGRIDS TAKES THE LEAD

The Swedish Centre for Smart Grids and Energy Storage (SweGRIDS) was established at the EE school in 2011 to research ways to reduce the carbon emissions that threaten life on the planet. Director of SweGRIDS Professor Rajeev Thottappillil reports on its progress.

GLOBAL TEMPERATURES ARE RISING and carbon emissions are responsible for the issue. All we have to do is stop burning fossil fuels for electric power generation and transportation. It's as simple as that.

"Just imagine if all our electric power was produced from renewable sources..." says Rajeev Thottappillil, Director of SweGRIDS and Professor. The world would certainly be a better place. The Swedish Government has committed to 100 percent renewable energy by 2040, and it's on track to meet that target. SweGRIDS supports this goal, developing improved devices and methods to help the European Union achieve its ambitious targets for greater use of renewable energy sources, improved energy efficiency and smart electricity networks.

Run by academics, the centre is jointly funded by the Swedish Energy Agency, KTH and Uppsala University as well as industry partners such as technology leader ABB and public utility providers such as Vattenfall.

"In working with multinationals like Vattenfall and ABB, the impact of our work reaches way beyond Sweden's borders," says Thottappillil. "That said, it's easier for us to develop new technology in Sweden and then have multinationals export it for use where it is most needed, in say China or India".

A KEY AREA OF WORK for SweGRIDS is coming up with sustainable solutions. Specifically, ways in which to secure a sustainable, renewable power supply and store that energy effectively. This is a surefire way to make a difference as the world grapples with the issue of climate change.

Given that the biggest producers of carbon emissions are transportation and electric power generation operations, the focus is on helping them to clean up their act, says Thottappillil. "But while cars, "While cars, trucks and trains can be run on 'clean' electricity, we also need to find cost-effective ways to store that energy."

trucks and trains can be run on 'clean' electricity, we also need to find cost-effective ways to store that energy."

At SweGRIDS, doctoral students and postdoctoral researchers from KTH and Uppsala University run some 30 different projects – at any given time.

In December 2011, the Swedish Energy Agency provided 22.5 million SEK for the establishment of SweGRIDS, envisaged as a ten year programme. Another 82 SEK million was awarded in 2014 and 76 million SEK for the period of 2018-2021.

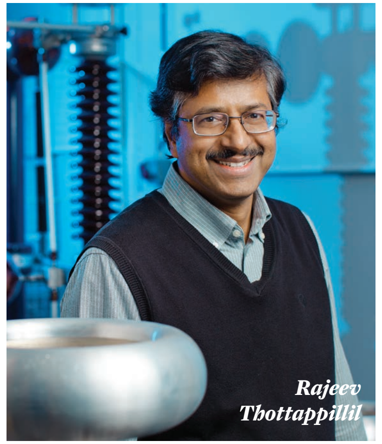
With joint funding from its partners, the centre runs projects on a range of subjects including ICT for electric power, renewable integration, controllable and intelligent power components, new materials for use in insulation or batteries, and energy storage.

A board meeting is held every three months, during which research proposals are evaluated. "We define the projects that are aiming for both scientific excellence and relevance to industry. The active participation of at least one industry partner is required for a project to run. Ultimately, we are helping industry by generating fresh knowledge and sharing our competence," Thottappillil says.

Meanwhile, new knowledge is channelled into education, with many doctoral students teaching undergraduates and sharing their findings at their annual conference.

DESCRIBING THE FOCUS of SweGRIDS work Thottappillil says, "Our main aim is to create new technology that will enable the smooth integration of renewable energy into the grid." This work is essential given that today's power networks are badly suited to renewable energy sources, which tend to be both modest, intermittent and distributed (Sweden's biggest wind turbine generates just 5 MW of peak power compared with a single 1,000 MW nuclear power generator).

While the energy flow from a traditional centralised power plant is predictable, with the vast proliferation of different smaller renewable energy sources,



Rajeev Thottappillil

SweGRIDS needs to develop advanced technologies to maintain a steady power supply for consumers.

Thottappillil reflects on how the school's administrative staff have helped in the process, "SweGRIDS has benefited greatly from the support of administration staff at the EE school, and we hope this will continue with the new organisation in 2018."

Over the last six years of operation, SweGRIDS has created an industry-university cooperation with more than 20 doctoral graduates working in industry, research organizations or universities contributing to the development of the future electric power system. It is a unique research eco-system that has resulted in spin-off companies and laboratory proof of concepts. Now SweGRIDS looks forward to the next four years of new challenges. ■

THE IMPORTANCE OF TEAM SPIRIT

In an operation that has been located at four addresses and had 450 employees separated in at most 12 departments and one Dean's office, building team spirit could seem like a challenge. But at the EE school this has been prioritised since the get-go, resulting in a strong sense of community among staff.

"**SINCE OUR SCHOOL** started in 2005, the school management has worked actively together with the HR-unit to create a good work environment and build strong relationships between staff from all professions and departments," says Irina Radulescu, HR manager at the School of Electrical Engineering.

Too feel part of a bigger team increases engagement and efficiency. Early on, the school made a conscious decision to enforce group spirit by creating platforms where colleagues were given the opportunity to meet. The school's introduction day is a good example. Upon arrival, new employees at EE are directly given the chance to interact with people from other departments and functions on an introduction day.

Besides the employee introduction, the school arranges other activities, from small to large, that are meant to create a good work environment and unify the staff. Annual events, such as the Christmas party and Summer barbeque, have become EE traditions and something everyone looks forward to each term.

"It is important to set internal traditions," Radulescu says. "Besides the more festive events we offer different wellness activities, such as floorball, basketball and our own race "The Electron Race", which are not only great for physical exercise but also to meet colleagues and establish new connections. Such occasions are excellent opportunities for co-workers from different groups to get to know each other in a context which is not related to work."

BUT EFFORTS NEED TO BE MADE in all parts of the organisation in order to be successful. At department level, faculty, doctoral students and administrators plan and discuss relevant matters for the operation during annual kick-offs and planning meetings. Another example is the conference for First and Second Cycle education where teachers and staff from the Office of Student Affairs meet to plan the coming term.

"It is extremely important to have a place of work defined by co-operation, trust and mutual respect for other's competence. An effective operation needs clarity and transparency in its

Irina Radulescu

"The personal meetings will become more meaningful than ever."

processes and structure, as well as co-operation-building efforts and teamwork. And that starts with the meeting between people," explains Radulescu.

THE SCHOOL'S EFFORTS have created team spirit and made everyone aware of what the school does in different areas, from administration to education. It has deepened the understanding for each other's professions and made it clear that everyone plays an important part in a successful operation. Becoming part of the School of Electrical Engineering and Computer Science in 2018, Irina Radulescu is certain that co-operation and team spirit will be prioritized topics at the new school.

"Platforms where staff from different departments and professions meet are important and great ways for people to get to know each other. The new school might dare to think big and organize events for all its 900 employees, but one should not underestimate the importance of the casual, everyday meetings. It may sound like a paradox but in a modern place of work, where so much of the interaction is digital, the personal meetings will become more meaningful than ever." ■

"The only constant in life is change"

– Unknown

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