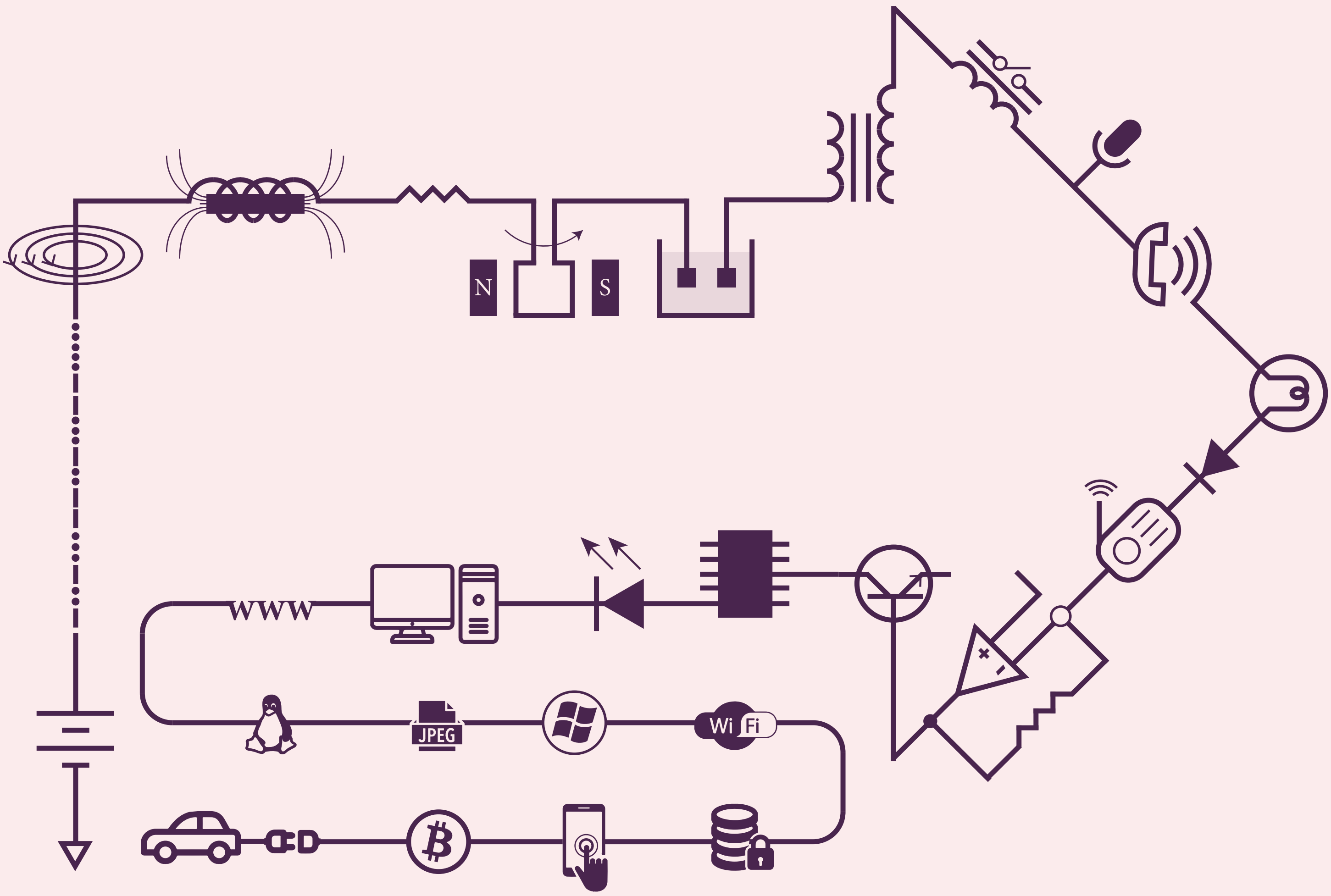
MAXWELL

Electrotechnische Vereeniging

Issue 23.2 | February 2020

Transition



A Dive Into the Abyss
Testing the Limits of Deep-Sea Exploration
The Energy Transition
The Time for Changing Mindsets
Lighting Up Lives
Bringing Clean Energy to Refugees in Greece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From the Board

President

By Joos Vrijdag

When Shea and I came together the first time as a potential board, I did not know Shea very well, but she did organise the Electrip where I was a participant. During company visits on that trip, I was very impressed with how professional she was towards the employees of those companies.

During the evenings of the Electrip, it was not always serious business and Shea proved that she was not only professional but also very fun to hang out with. That combination of fun and professionalism makes Shea a great president of the ETV.

As the president of our association, Shea Haggerty has quite a public function, so you might have seen her already. When you encounter her in the board room or the faculty, the first thing you'll see about Shea is that she is always very busy. Shea is constantly running around trying to help everyone, because she is very caring of the members, association and the rest of the board.

When she finally takes a break from sitting behind her computer and phone, Shea is actively trying to get to know all the members that come by in the board room. During the EOW she actually knew the names of all 80 present first year students within two days!

After two quarters of being on the ETV board with Shea, I think I can say that I know her a lot better now and I am glad that I do. Working together was a lot of fun and I am looking forward to another three quarters of being on board with Shea!

Treasurer

By Sam Aanhane

When I was first introduced to Max, the treasurer of the ETV, I instantly knew we would become good friends. Little did I know he would also turn out to be very capable. I would trust him enough to do my personal finances. Max is the oldest of our Board, which he intends to let everybody know for as little a reason as who gets the last piece of food. I, the second oldest, usually disagree with this. Hanging out with Max at parties is a lot of fun. Except for the part when you have to go home. For one, Max is not easily convinced to leave. On top of that, he is terrible company in the train because he always falls asleep and it becomes my responsibility to get the both of us in Delft. Then again, he always ensures that everybody has a good time and has provided me with plenty of opportunity to make fun of him for the things he does when he is bored. All jokes aside, Max is a great guy and I absolutely love him. I wouldn't have wished for anybody else to do a Board year with. He does his job well, along with having plenty of time to make jokes. Looking forward to a great year, both for the ETV and us as a group!

Colophon

Year 23, edition 2, February 2020

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Editorial

Dear readers,

Electrical Engineering is a constant developing field with wide impact on the society as a whole. A Transition within this field might as well lead to a significant change in society. For example, it is amazing that the rise of the smartphone and widespread mobile internet has only started 12 years ago, with the announcement of the iPhone 3G. Nowadays, it is almost unthinkable to live without for example WhatsApp.
Many more influential transitions are to come, in which Electrical Engineering plays a big role: Microwave transmission will find the consumer's hands with the upswing of 5G. The world will transition from fossil fuels to electrified systems. Fully-integrated microelectronics will allow new products. As always, backgrounds on these trends can be read about in the Maxwell.

In this second edition of the Maxwell this year, we have managed to include more scientific articles, while also trying to have interesting articles about the faculty and the Electrotechnische Vereeniging as well. For example, in the last few pages will, as always, be an overview of the past and upcoming activities. I hope that we succeeded in providing an interesting and enjoyable Maxwell for this quarter!

Happy reading!

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Marco Postma

Index

The Philips GM5655

A simplistic cathode ray vacuum tube oscilloscope

Jelle Boele

The Philips GM5655 [1] is a compact, and back then affordable, cathode ray tube (CRT) oscilloscope used by many of the faculties of the university. It was introduced in 1946 and was still in production in the early sixties. During this quarter of the century, both the internal construction and circuit changed, whilst the exterior remained unaltered. The study collection owns all different versions, as well as a special exploited view-version, where the modules are separated. The intended purpose of the device was to measure low frequency signals or signal tracing in radio circuits using an optional probe, the GM4575. The probe uses a non-linear tube for detecting radio signals and will not be further discussed in this article. Owing its simplicity, the GM5655 is good specimen to study the basic structure of an CRT based oscilloscope. When introduced in 1946, comparable scopes were heavy and bulky pieces of equipment. The GM5655 is exactly the opposite: it is small, even compared with modern digital storage scopes!

The cathode ray tube (CRT)

The most important components in a CRT are the glass envelope, the source (electron gun), the deflection plates and a phosphor coated screen. Almost all CRTs have the typical Erlenmeyer-flask (conical) shape. The device is evacuated to allow electrons to travel freely without interacting with oxygen or other particles.

The electron source relies on the thermionic effect to free electrons into the vacuum. These free electrons are produced by a so called emitting surface, the cathode, coated with specially selected materials such as barium to lower the work voltage. The cathode is heated by a filament, or heater, to drive the electrons out of the coated surface. A cloud of free electrons is formed surrounding the cathode. Part of the electrons are extracted from this cloud by an anode having a high positive voltage (several 100V).

The anode consist of a metal plate, having a very tiny hole. Electrons accelerate towards the anode, and a part of the electrons hit the plate and form a so called plate current. The other part passes through the hole forming an electron beam or ray, hence the name cathode ray tube. Typically a CRT has multiple anode plates cascading each other, focusing the beam whilst passing through them.

Figure 1. The GM5655 in use

Using two pairs of deflector plates, arranged in X and Y direction, and an electrostatic field, the beam can be deflected. After the deflection plates, the electron beam propagates further through the vacuum and hits the screen. The screen is uniformly coated with a layer of phosphor. By luminescence, the phosphorus layer is emitting light when impacted by the electron beam.
The deflection plates need to be supplied with large amplitude signals because electrons pass through them at very high speed. This is also why early CRTs always are quite long compared to the display diameter: a lower control signal can be used. Further development showed the possible use of magnetic deflection, enabling CRT tubes to become shorter whilst obtaining larger screen diameters.

The GM5655 uses the DG7-3 CRT tube (L4)[3], with a screen diameter of 7 cm: half the typical smart phone screen. The tube uses a relatively low supply voltage of 600V DC. Typical beam currents are in the order of several hundred microamperes. The DG7-3 has a grid in be-

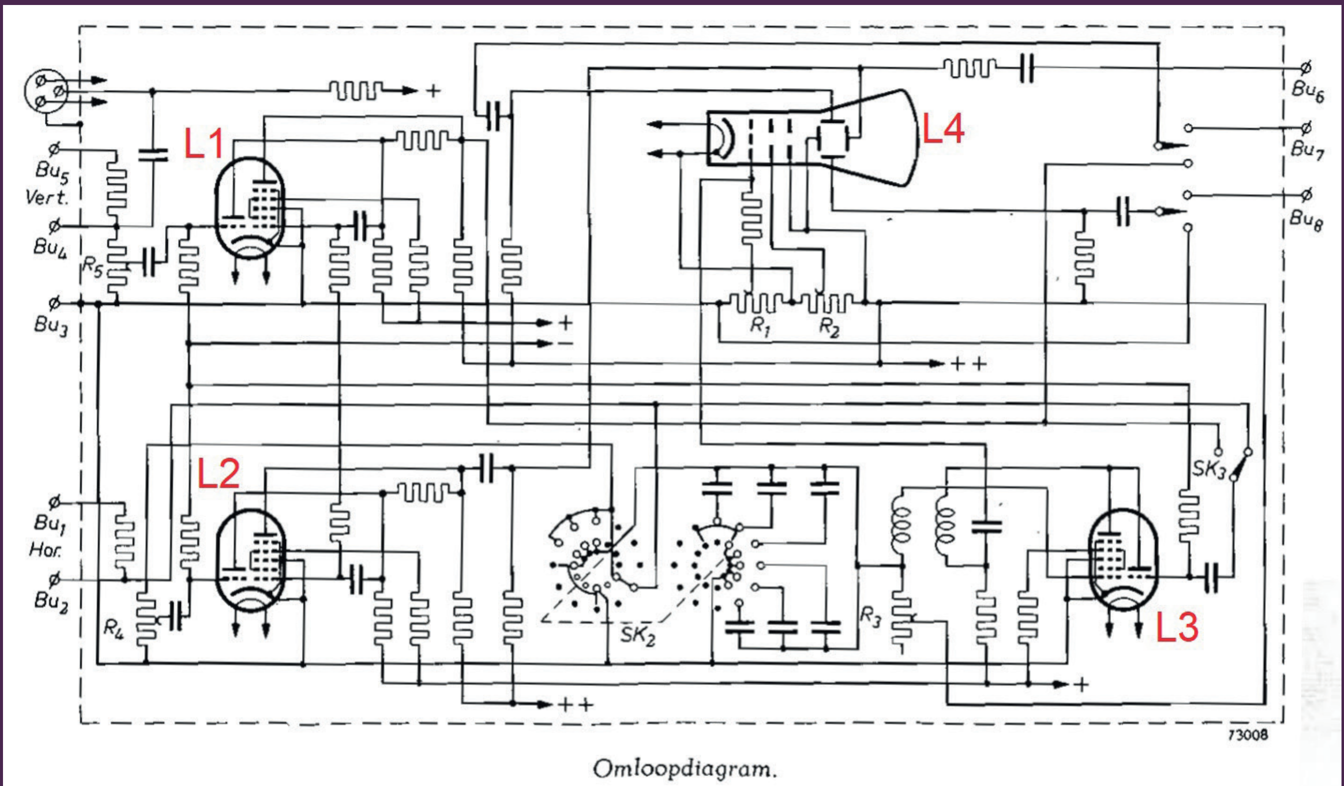

Figure 2. The circuit schematic

tween cathode and its anodes. With this grid, the beam current can be controlled (using a low negative potential), altering the intensity of the visible light.

The simplified circuit of the GM5655, obtained from the original user manual is shown in figure 'GM5655 circuit'. It consists of 2 linear amplifiers, an oscillator, a synchronization stage and the CRT. All these units receive power from a power-supply consisting of four different voltage levels. For simplicity, the power supply circuit is omitted in this drawing.

In the GM5655 three ECH21 [4] tubes, two EZ2 tubes and a DG7-2 tube are used (figure ECH21, EZ2, DG7-3). Two of these tubes form the linear amplifiers for driving the X and Y deflection plates of the CRT tube. The linear amplifier comprises a two stage design around L1 and L2, were the first stage is a high gain common cathode triode amplifier followed by another high gain common cathode pentode stage. The heptode section of the ECH21 can be used as a high gain pentode, by connecting the grids in a specific manner, as shown in the circuit diagram. To work around the fact that the cathodes of the heptode and triode section are interconnected, the cathode is grounded and the grids obtain the right bias potentials via a negative supply line.

The third ECH21 tube forms an oscillator and a synchronization stage . The heptode is generating a ramp-shaped wave for the horizontal sweep, whilst the triode is used for synchronizing the ramp signal to the input signal.

The power supply needs to provide 4 different potentials: 300V DC, 600V DC, -5V DC and 6.3V AC. The 300V and -5V are needed for the linear amplifiers, oscillator and synchronization stage. For the CRT screen the highest potential is needed (600V DC). All tubes use the 6.3V AC winding for heating their filaments.
The high voltage supplies are realized using two identical stacked 300V supplies consisting of two EZ2 [5] full-wave rectifier tubes, a gapped filter inductor and some electrolytic capacitors. The inductor has a gapped core to increase its capability of supplying DC current without saturating.

The ECH21: a combined heptode-triode tube

The GM5655 makes use of three pentode-heptode tubes of the type ECH21. This was a very popular vacuum tube in the late 1940s. Vacuum tube engineers at Philips developed a new vacuum tube for use in radio receiving sets. Tree important design requirements were set:

1. The tube needed to be very compact
2. The construction must allow a fully automated manufacture process
3. It should have low device capacitances to allow high frequency use

Shortly before and during WW2, Philips put a lot of effort in developing tubes having an all-glass construction. Advantages of this new construction were the ability to fully automate production and very low device capacitances. The latter was very important in the development of VHF and UHF RADAR. After the war, the new all-glass construction quickly became the standard, and was adopted to almost all vacuum tubes. All the tubes in this oscilloscope use the all-glass construction.

The ECH21 tube contained two systems: a triode and a heptode, reducing the tube count in a typical radio set. The tube was useful in many applications. The main application was found in super-heterodyne radio sets, popular back than for AM reception. The triode would act as local oscillator and the heptode as mixer/multiplier. The GM4655 uses three ECH21 tubes. Tube L1 and L2 are used as x and y deflector amplifiers. The triode section is used as input stage, with the heptode section, wired as pentode, as final stage. From the third ECH21, L3, the heptode is used as saw tooth oscillator and the triode to synchronize the signal under test with this saw tooth signal.

Construction

A typical electronic device made in the 1940s uses the so called 'hard-wired' construction. No carriers (PCBs) for the components are used, resulting in messy internals. The components are placed and soldered in the right place, using their lead wires for support. The GM5655 in contrary uses circuit boards, without a printed circuit, figures 'boven' 'rechts' and 'links' show the internals. In the boards, soldering turrets are mounted. The interconnection of the turrets is done using wires, located at the backside of the boards. All components have their designated location, and can be easily reached for service. This is a really unique and ahead of its time feature of this vintage oscilloscope.

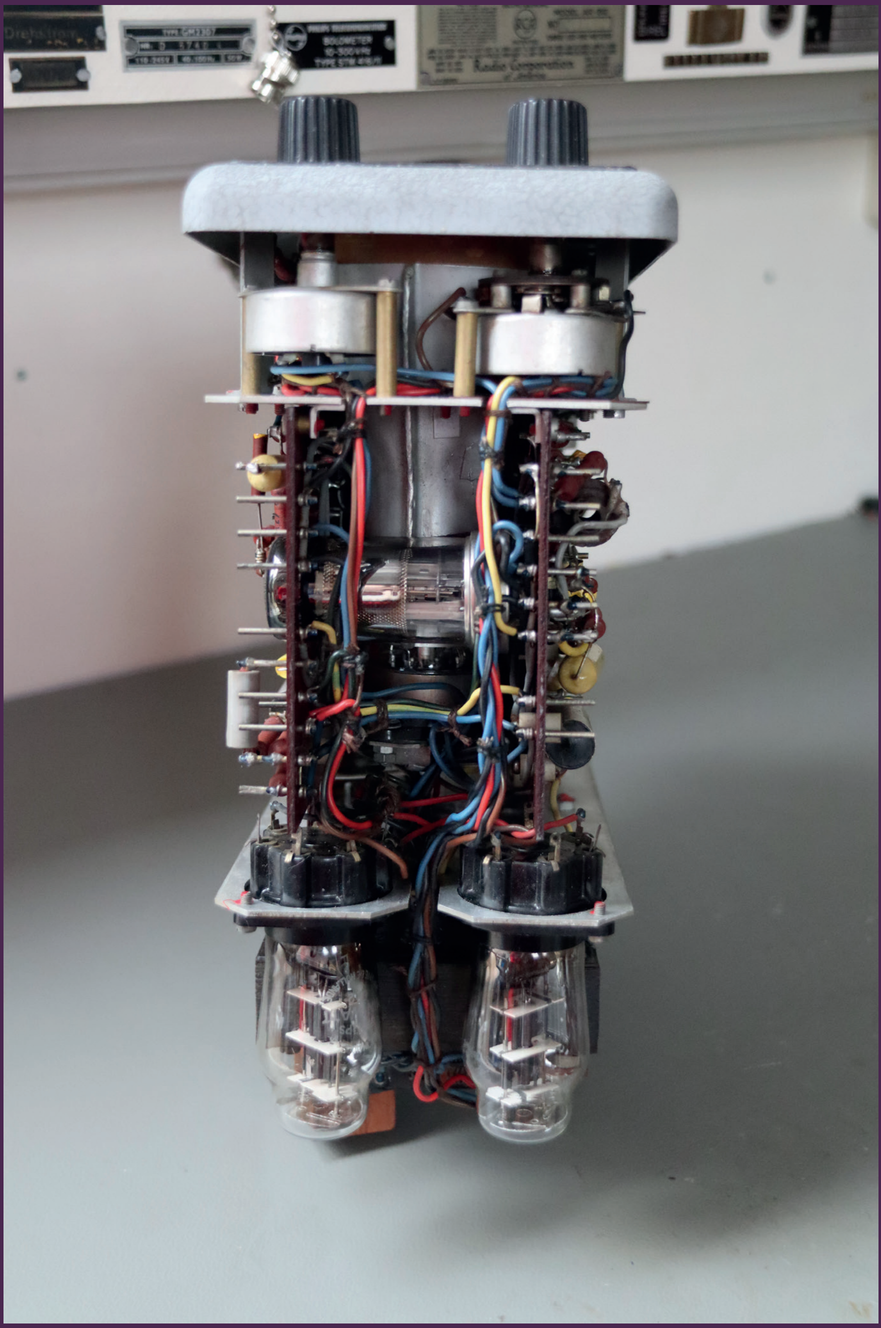

Figure 3. The osciloscoop without casing

Bringing her back to life

Waking up an old unknown electronic appliance is always a challenge. Capacitors dry out over time, insulators become brittle and tubes may lose their vacuum due to flaws in the glass envelope or glass-to-metal seals. On top of that is the unknown factor of repairs and modification carried out by previous owners. Especially equipment contained in the study collection have a high likelihood of tempered internals, since engineers and scientists do not throw away stuff without attempting repairs.

By slowly powering the scope with a variac, it came to life, barely. During the heating of the tubes, the beam became shortly visible, but it quickly got deflected outside the screen area. Consulting the schematic, two possible culprits were found: the two tar-sealed capacitors coupling the X and Y amplifiers to the deflector plates of the CRT. After replacing these components, the beam was centered in the middle of the screen. A sine wave was fed into the scope to verify the operation of the X and Y amplifiers. The wave showed on the screen but was badly distorted. Using a multimeter and the voltages indicated in the schematic the problem was quickly found: the negative supply rail which is used for biasing was at zero instead of -1.5V. The negative supply uses an selenium-cell as rectifier, an early semiconductor. These are pronoun to fail, as even the manual from 1952

Figure 4. The tubes used to create this machine

already states a typical repair method using an OA50 GE diode. The faulty rectifier was replaced by a conventional silicon diode with a resistor in series, to roughly match the internal impedance of the old device. After some additional preventive repairs the scope was fully working as intended.

Measuring or indicating waves

The X and Y amplifiers in the scope do not use any form of feedback. Therefore the transfer of the linear amplifiers is highly dependent on device parameters. As vacuum tubes have a large spread in parameters (up to +/-20% is assumed to be normal) the gain is not constant during operation. In general, a new tube has well over 2 times the typical transconductance stated in the datasheet. During its operational lifetime it will decrease until it has reached about 80% of the datasheet value, where it is said to be at the end of its life. To make things worse, the input level of the X and Y amplifiers is continuously variable using a carbon-film potentiometer, which have a +/- 20% non-linearity.

The screen does not have a grid. Combined with the above mentioned problems in the linear amplifiers, it becomes clear that the GM5655 is not very useful for doing absolute measurements. Therefore it was common practice to have a GM6005 voltmeter (also in the collection) in parallel with the input of the GM5655.

Conclusion

The GM5655 gives a wonderful insight in the technology involved in a CRT based oscilloscope, as well as an insight in the state of electronics in the mid-20th century.
For further information regarding oscilloscopes, measurement equipment in general and / or vacuum tubes, please feel free to visit the study collection down in the basement below DEMO. You're welcome on Mondays after 10 AM.

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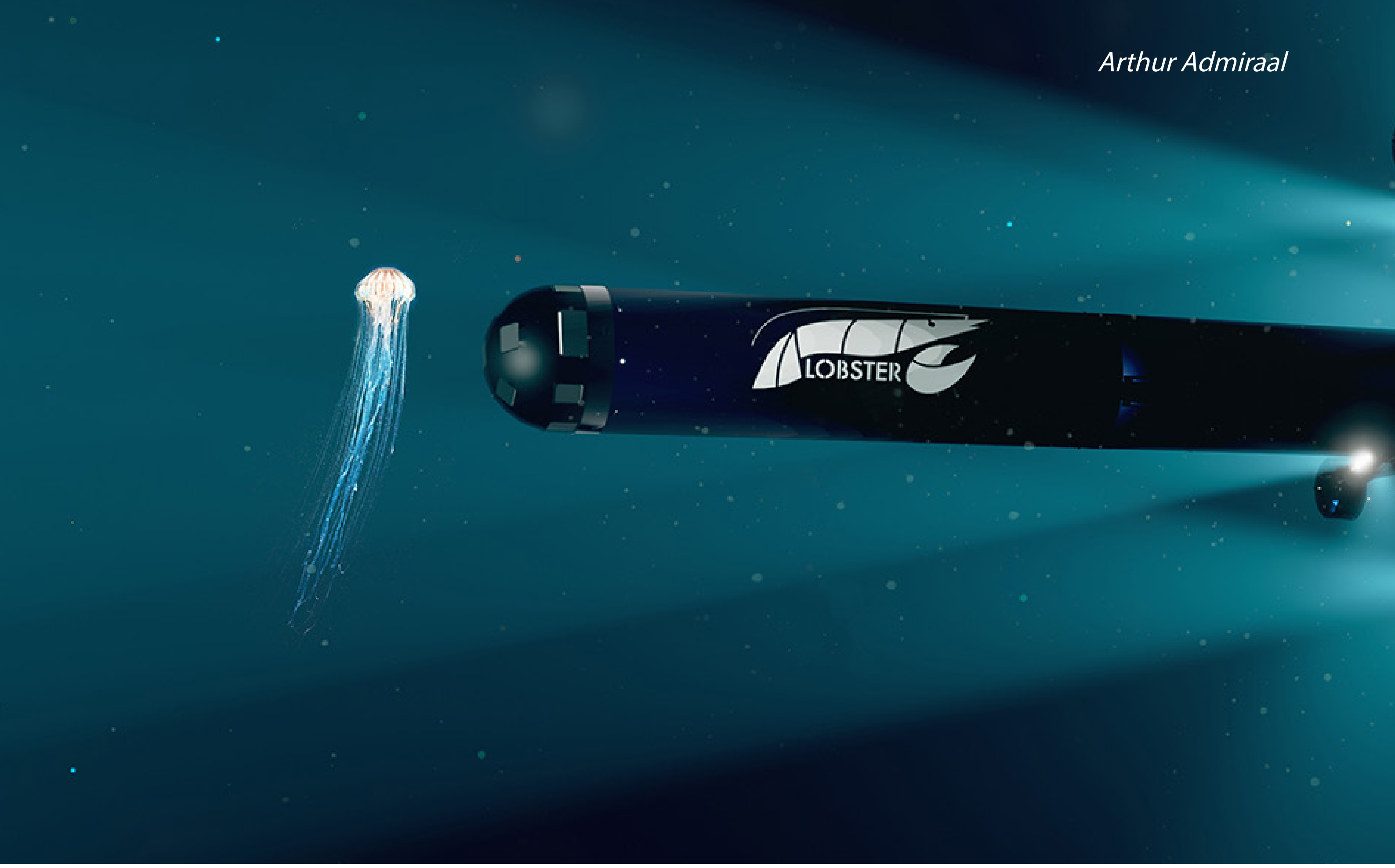
[1] https://www.pa3esy.nl/Philips/meetinstrumenten/html/gm5655/pdf/GM5655_3.pdf
[2] "Saga of the Vacuum Tube", Gerald F.J. Tyne 1977, page 37, (available in the library of the study collection)
[3] https://frank.pocnet.net/sheets/030/d/DB7-3.pdf
[4] https://frank.pocnet.net/sheets/033/e/ECH21.pdf
[5] https://frank.pocnet.net/sheets/102/e/EZ2.pdf

A Dip Into the Abyss

Testing the limits of Deep-sea Exploration

Arthur Admiraal



Taking a page from cubesats

Our team has its background in the Lunar Zebro project, and we see a lot of parallels between deep sea research and space exploration. Like satellites, deepwater robots are usually fairly big. They may weigh as much as a small car and have a similar size. Satellite launch costs scale with the mass of the satellite. Similarly, big marine robots are expensive to deploy, requiring large ships accompanied by sizeable crews. Operating these costs upwards of tens of thousands of dollars per day. Traditional satellites are constructed using space grade components. These are very resilient, but this resilience comes at a cost. Usually, deepwater robots consist of similarly expensive specially-designed deep sea grade subsystems. These two cost factors make conventional deepwater robots too expensive for a student budget. The space industry has long faced a similar problem, but in recent years cubesats managed to bring down the cost of space exploration. This was achieved by replacing space-grade components with consumer electronics selected to be inherently capable of surviving in the extreme environment, shrinking down the mass and thus launch cost of satellites. A similar trick can be applied to deepwater robots.

Pressure tolerant electronics

There are two main approaches to designing deepwater systems: pressure shielding and pressure tolerance. When designing with pressure shielding, regular industrial or even consumer grade systems are housed in atmospheric pressure vessels. These are connected to other parts of the robot such as sensors and thrusters using high pressure differential feedthroughs. The great thing about this approach is that the internals of the robot can use standard components. However, the approach necessitates expensive and bulky pressure vessels and feedthroughs. This bulk contributes to the large size of conventional deepwater systems.

The other approach is designing for pressure tolerance, where the pressure between the inside and outside of the robot is equalised, such that no pressure vessels are required. This entails filling the robot with some nearly incompressible fluid and using a flexible membrane to compensate for the shrinkage of this fluid. The advantage is that a lot of the bulk of pressure vessels and high pres-

Every dive to the deep sea brings with it a wealth of discoveries. Making the 1800m dive is a challenge of its own however - a challenge which the TU Delft LOBSTER student deep sea team has been eager to take on. Since early 2018 we have been hard at work on researching, designing, building and testing a student-built deep sea exploration robot. Coming into 2020, that work is finally starting to pay off with the third iteration of our design, and electronics are at the heart of it all.

sure differential feedthroughs can be avoided. The obvious disadvantage is that all internal systems have to operate under the immense pressures of the deep sea. Due to our limited budget, our only option was to avoid expensive big ships by pursuing miniaturisation through designing the entire robot to be pressure tolerant.

Luckily, most components are inherently pressure tolerant. Resistors, ceramic capacitors, inductors, LiPo batteries and even integrated circuits may be compressed by the pressure, but happily continue operating to pressures such as 600 bar. Non-solid state components can create issues though. Components with even the tiniest internal air pockets, such as quartz crystals and electrolytic capacitors, bring the risk of implosion or internal short-circuits.

It is relatively straightforward to avoid vulnerable components for new designs. Even adapting commercially available electronics for pressure tolerance can be as simple as identifying vulnerable components and either potting them to shield them from the pressure, or replacing them with a pressure-tolerant alternative. For example, we modified a Raspberry Pi compute module for pressure tolerance to serve as our On Board Computer (OBC) by replacing a single oscillator.

Though the basics of pressure tolerant design are simple, the devil is in the details. Passive components drift under pressure, but stable circuits can still be made using ratiometric approaches. The drift does cause certain analog ICs to become unusable under pressure though, which is always a ‘fun’ time. Internal oscillators on digital ICs also tend to drift, but can easily be brought back in sync using external pressure-tolerant oscillators. Repeated compression and decompression cycles can also cause fatigue fractures in interconnects between ICs and the circuit board.

The need for autonomy

Despite the many commonalities between space exploration and deep sea research, the differences can be the most striking. Space is a nearly ideal medium for radio communication, allowing contact with probes at the farthest reaches of the solar system. In contrast, seawater absorbs nearly all signals. After

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Figure 1. On-board computer module, hosting two Raspberry Pi's. Tested to work unto 400 bar

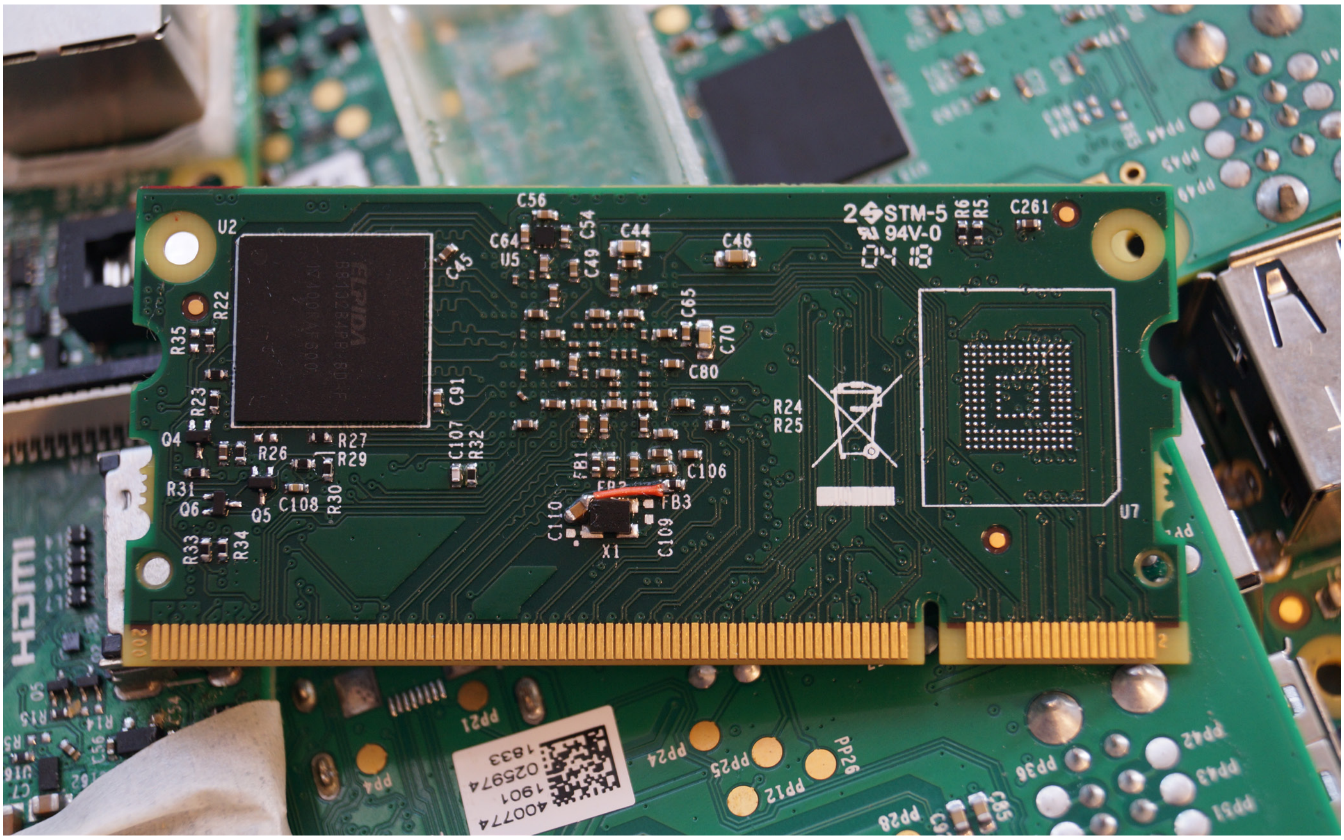

Figure 2. Raspberri Pi compute module, modified to withstand the extreme deep-sea pressure

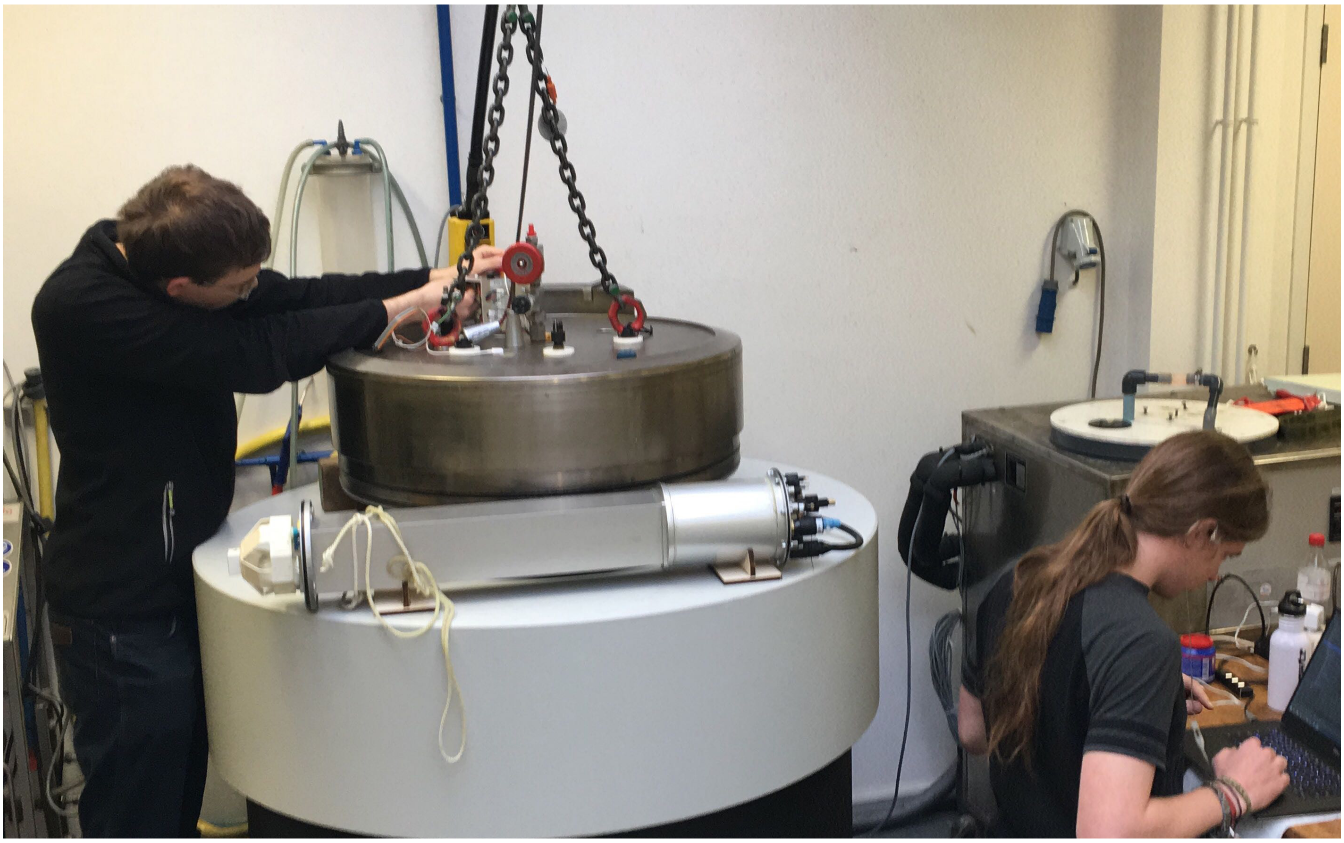

Figure 3. Testing the subsystems with a pressure chamber

a couple of millimeters, GPS coverage is gone. After a meter, even relatively long wave VHF radio becomes difficult to receive. At 200m, only 1% of sunlight remains. Extremely Low Frequency (ELF) systems allowed communication to hundreds of meters, but transmitters couldn't be practically fitted on even the largest submarines. From a kilometer, there is only pitch-black darkness across the electromagnetic spectrum. Sound waves can penetrate farther, but even their reach stops at some tens of kilometers. Worse, the bandwidth of the longer range approaches is very limited, such that only low-speed wireless communication is possible. Hence, remotely operated systems are all tethered, dragging around kilometers-long cables. The drag on these cables can be handled using bulky systems, but becomes more and more significant for smaller systems. Furthermore, the ships required to prevent the cable breaking under cyclic loading in the waves are large and thus costly. Hence, we were forced to adopt autonomous control. This is enabled by creating modern pressure tolerant computers.

What's next?

Our first two iterations taught us a lot of lessons about how to miniaturise deep-water robots, which we have started to implement in a third iteration. We found partners to test our systems at sea, giving us a much better idea of what is required to use marine robots in the field. Also, we are building a 600 bar chamber to hugely increase the speed at which we can validate pressure tolerance, allowing us to troubleshoot problems at the component level. We believe these developments give us a good chance to reach the deep sea by the end of 2020. If you want to keep track of our progress, be sure to check out www.lobster-robotics.com or @lobster_project on twitter.

Getting to space requires highly complex controlled explosions which are at the very pinnacle of human ingenuity, yet reaching to the deep sea only requires something that is heavier than water, like a brick. The hard part is getting back up. Unscathed. Because unlike space, we know that we're not alone down there.

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[1] Thurber, Andrew R., et al. "Ecosystem function and services provided by the deep sea." Biogeosciences 11.14 (2014): 3941-3963.

[2] Bingham, Nic. "Designing Pressure-Tolerant Electronic Systems." Designing Pressure-Tolerant Electronic Systems, Unmanned Underwater Technology, 2013, https://www.uutech.com/ptepaper/.

The Energy Transition

The Time for Changing Mindsets

Prof. Dr. Ir. Arno Smets

The research at the department of Electrical Sustainable Energy (ESE) aims at accelerating the energy transition towards sustainable energy. The research covers electrical energy generation from renewable energy sources, its transmission, distribution and storage. The ESE department is the ideal place to accomplish my ambitions: to inspire younger generations –through my research and education- to work on the challenges related to the energy transition. In this contribution, I would like to discuss 'the why'. I would like to introduce you to some of the challenges that need to be tackled for the realization of a successful energy transition.

One of the biggest challenge for Mankind in the 21st century is energy. Currently, every person around the world uses ~65 kWh of primary energy per day. The access to this energy is unequally distributed over the world population. In the Netherlands, 125 kWh of energy per day per capita is available and without this energy access our modern society could not exist. In more than 10 countries in Africa, in contrast, the daily energy available per capita is below 4 kWh. Improving living standards and securing a sustainable population growth, requires access to energy. This demonstrates that energy is crucial for achieving almost all sustainable development goals. In addition, the far majority of this energy is provided by burning fossil fuels accompanied with the emission of large amounts of CO2. Per year, we emit 4.4 tonnes of energy related CO2 per person which is 70 times the average weight of a person. Around 20% of this anthropogenic emissions are consumed by the oceans and 30% is consumed by our biosphere. The remaining 50% adds to the atmospheric CO2 concentration forming a 'blanket' around the earth that hinders its cooling mechanism. The current rate of increase in atmospheric greenhouse gasses and the rate of increase in global temperatures are both 100 times faster than ever seen in the last million years of climate history. The models from the international panel for climate change (IPCC) predict that the impact of our energy consumption on the planet's climate and our regional habitats can have disastrous consequences for the next generations. 'Business as usual' scenarios predict a global warming of above 3 °C in reference to preindustrial times at the end of this century. Our addiction to fossil fuels is like playing Russian Roulette with a fully loaded revolver cylinder. Therefore, it is not surprising that we see representatives of the young generation demonstrating in the streets around the world trying to convince governments, industry and society to make a change: we need an energy transition. This energy transition will be an enormous challenge. A successful energy transition requires an integral approach, all stakeholders have to take responsibility such as governments, industry, the financial sector and the consumers. The energy transition is not just a technological challenge, it is a societal and economic challenge as well. I will discuss some examples.

Let's first focus on technology. If we consider the current value change of generation, distribution, storage and consumption of energy, the entire infrastructure needs to be changed. Replacing coal, oil and gas with renewable energy generation technologies as hydro-, wind and solar electricity would mean that electricity will become the dominant energy carrier. In the last years, various models and potential scenarios for the global energy transition have been published by academics, various organizations and industry. One of the most 'progressive' studies is the study published by Christian Breyer and the EnergyWatchGroup [April 2019] on 'Global energy system based on 100% renewable energy'. In this study the energy transition per region in the world is modelled in great detail. The study demonstrates that an energy infrastructure fully based on renewable energy by 2050 is feasible. Electricity will become the dominant energy carrier (90% of all energy) in such an energy system. At the generation side, solar PV and wind energy will lead the energy transition, with contributions of 69% of solar electricity and 18% of wind electricity to the total energy supply. This all can be achieved with competitive levelized costs of energy between 5-6 eurocents per kWh over the entire transition period. The energy consumption needs to be decarbonized by electrification. It implies that new technologies need to be introduced like the electrical car, powered by renewable electricity stored in its battery and electrified heating systems such as heat pumps to replace gas heating boilers. Even more challenging is the transition from fossil fuel powered industrial processes to electrified processes without jeopardizing the competiveness of the industry.

Another challenge is the transition in the distribution and storage of renewable energy. The first challenge is the intermittency of solar and wind energy. Intermittency of renewable energy means the irregular generation of electricity due to weather conditions, i.e. the local solar irradiance and wind varies in time. These fluctuations occurs on different timescales: clouds passing by, daily fluctuations (day-night) and seasonal fluctuations (more solar irradiance in summer and more wind in the winter).

As a consequence the generation (supply) does not match the consumption (demand) in time and therefore some of the generated renewable electricity needs to be stored. Batteries are a promising storage technology that can play an important role to tackle supply-demand mismatches in the order of days. Currently, the retail prices of batteries are dropping very fast due to the unprecedented upscaling of battery manufacturing to supply the e-mobility market. However, batteries cannot tackle seasonal fluctuations.

"Improving living standards and securing sustainable population growth requires access to energy."

Storing the excess of solar electricity in the summer for the dark winter months requires different solutions. Converting solar electricity into a chemical energy carrier is one of the very few solutions nature has given us.

A solution that is recently attracting more attention in the Netherlands is the production of hydrogen by electrochemically splitting water using renewable electricity. Another solution is the electrosynthesis of CO2 into chemical fuels powered by renewable electricity. This latter concept is being developed in the e-refinery program at the Delft University of Technology. Another challenge for distribution is that the future generation of energy is decentralized: the generation of wind and solar energy

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is distributed over land and sea and is not centralized anymore as for conventional coal and gas plants. To tackle the intermittency challenges, the storage challenges, the significantly larger required distribution capacity and the decentralized generation, intelligent electrical power grids need to be developed.

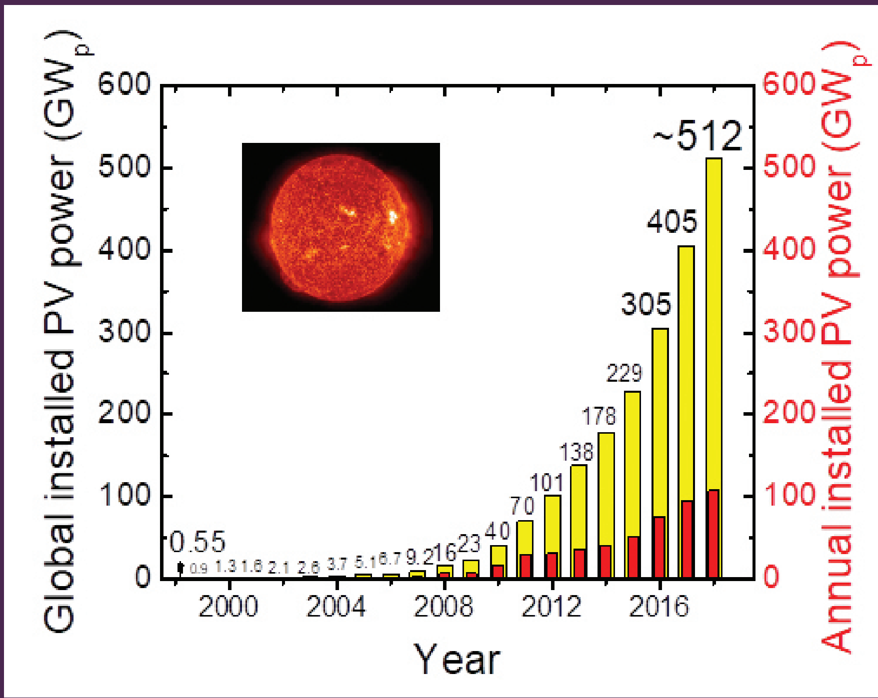

Figure 1. The evolution of cumulative installed global PV power (yellow) and the annual installed PV power (red). Funny detail: the international energy agency predicted 20 years ago that at the end of 2018 in total 2.1 GWp of PV was installed. They was only a factor of 250 wrong.

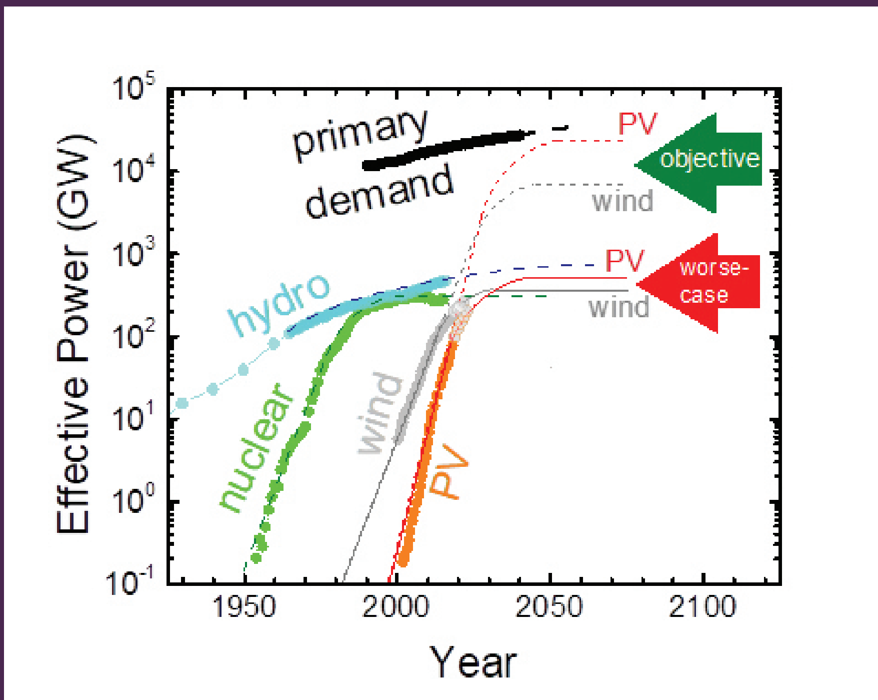

Figure 2. The evolution of the global effective power of hydro-electricity, nuclear, wind and solar electricity. The dotted lines correspond to the objective of 69% of energy supply from solar and 18% of energy supply from wind. The worse-case scenario would indicate the final power if the recent market outlooks would be correct.

Development of sustainable energy technology has seen enormous successes. Microgrids powered by solar energy are the cheapest routes to give everyone in the world access to electricity. Large scale utility of PV and wind farms have become in many regions around the world the cheapest form of electricity generation. Figure 1 shows that cumulative and annual global installed PV power has shown an exponential trend for the last 20 years. However, the question is: can we maintain this growth?

In figure 2, the evolution of the effective global power (rated power times the capacity factor) of generation technologies over time are illustrated. The evolution of a new generation technology can be categorized by three phases in time. The first phase is an exponential growth phase in which both the cumulative installed power and the annual installation are growing exponentially, like shown for PV in Figure 1. The third phase is the saturated phase which means that the total cumulative installed capacity remains constant. The market of annual installations is equal to annual capacity that needs to be dismantled: wind turbines and PV modules have a certain lifetime. In the second phase, the effective power grows linearly and the annual installations equals the replacement market in the final saturated phase. Economical restrictions will never allow the market to grow beyond the final replacement market. It is important to realize that if the growth becomes linear, it only takes the lifetime of the generator to arrive at the final saturated phase. The final saturated power can be determined by various limitations, such as physical (lack of space or suitable location), financial (too expensive, lack of investments), societal (ac-

> *" Our addiction to fossil fuels is like playing Russian Roulette with a fully loaded revolver cylinder."*

ceptance of technology, change of own behaviour), resource, human capital etc.

In figure 2, the earlier mentioned '2050' goals for solar energy (69% of total energy generation) and wind energy (18% of total energy generation) are indicated. To achieve this level, it would mean that the coming 15 years the annual market of PV installations maintain its exponential increase, i.e. every year with 30% in reference to the previous year.

Unfortunately, figure 2 implies that global wind energy is already 7 years in a linear growth phase! The outlook for the PV market in the coming years suggests that solar electricity enters the linear phase as well. This would be bad news, as shown by the worse-case scenario included in Figure 1. But what are the limiting factors that currently might hinder the further exponential growth of PV installations? First, the last three years, the global value chain is lacking investments to facilitate the exponential growth. Financial markets are ruled by the metric of return of investment and according to this metric solar energy has not the highest priority. Secondly, to facilitate an exponential growth of PV installations, an integral investment through the entire energy value chain is needed.

Unfortunately, the updating of distribution systems and the development of new storage infrastructure are simply not going fast enough. A national example: the installation in large scale PV utility triggered by the SDE+ subsidies (still 9 GW in the pipeline) is likely to slow down due to congestion problems of the Dutch electricity grid. This demonstrates the need of an integral approach. The above trends show that the energy transition is an extremely complicated political, administrative, economic, social and technological challenge. The Dutch Climate Agreement is a positive step forward. With this agreement presented at the end of June, the Dutch government is accepting its responsibility in the global challenge of the 21st century. But I fear that it will not be sufficient. Although some measures will definitely deliver better results than anticipated, I foresee that achieving other key targets will not prove so easy or predictable in practice. The energy transition towards sustainable future is crucial for the societies as we know them today. Therefore, I am dedicated to inspire younger generations to work on and tackle the challenges related to the energy generation through my research and education. The clock is ticking, we have not much time left, to implement the technological, economical and societal solutions to realize the energy transition to a sustainable world.

"Generation, distribution, storage and consumption of energy, the entire infrastructure needs to be changed"

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A Pan-European Transition

Towards Large-distance Laboratory Coupling

dr. ir. Arjen A. van der Meer and Vetrivel Subramaniam Rajkumar, M.Sc.

No self-respecting electrical engineer can live peacefully without having access to a proper laboratory, be it at home, at the faculty, or at work. A lab provides means to prototype ideas, validate new setups, and assess component and system behaviour more realistically than simulations do. Labs are commonly specialised for a certain purpose. A laboratory is usually designed and optimised for a specific purpose, like testing high voltage components against their design specifications, developing integrated circuit components, or assessing power system interactions. The scope of such tests is usually limited: inputs, outputs, type of expected behaviour, and test criteria are well known, which allows limiting the system to be tested considerably. A typical example from the energy domain can be found in testing the correct triggering of power system protection relays against certain conditions in voltage and current: As the inputs (3-phase voltage and currents from the measurement transformers), and outputs (phase tripping) are well known, the size of the test setup can be limited to 1) a device that emulates the input conditions, 2) a protection relay, and 3) measurement devices capturing the behaviour of the object under investigation; the relay. The same applies to testing high-voltage components. The common denominator of the above examples is that the purpose of investigation is to characterise, validate, or verify the behaviour of a component on triggers coming from external systems. But what if it is the other way around–if we want to know what the systematic effects of the protective relay, which on its turn will switch off a component or interrupt a high-voltage cable, need to be studied? In this article, which is a summary of a European H2020 ERIGrid project and an associated master thesis project, we will highlight two specific options that are at our disposal for energy systems: combined simulations, and large-distance laboratory coupling.

The Power in Transition

The power system ensures that electrical power generated at conventional power stations, wind parks, and your neighbour's solar panels reaches you, the consumer. Traditionally, it comprised mainly physical components like rotating electrical machines, transformers, cables, and resistive loads like light bulbs. Over the past decades, however, the power system was subject to a transition: gradually, more and more actively controllable components like wind parks, digital protective devices, and HVDC links were installed. This transition, mainly caused by technological developments (power electronics at high-voltage and high-current levels, ICT, digitisation) made the grid more active and intelligent. Such technology fosters more active and optimal operation of the system and allows to push the design to its physical limits in the planning phase. ICT forms the glue between the physical power system components on one side and advanced automation and control schemes on the other side. These heterogeneous power systems are commonly referred to as cyber-physical energy systems (CPES).

Testing and Simulation Approaches

One of the consequences of the transition towards CPES is that subsystems tend to show much more mutual interactions than before, which needs to be assessed accordingly. Consider for instance the system consisting of two mutually coupled subsystems A and B, shown in Fig. 1a. The common approach once was to study system interactions with a specialised domain-specific simulation tool, and abstract out or tremendously simplify the other subsystems and domains (Fig. 1b). For CPES, this approach cannot be applied any longer and the system shall be studied holistically. In case of relatively small systems, a common solution is to including a model of the entire system inside a general-purpose tool like MATLAB or OPENMODELICA (Fig. 1c). A few exceptions aside, the simulation engines of these tools usually scale badly with system size, so more sophisticated solutions are needed. The ERIGrid research project [1] elaborated on two specific solutions: so-called co-simulations and long-distance laboratory coupling.

Co-simulations

Combined or cooperative simulation is the assessment of a system by two or more tools that conduct one overall simulation. This concept is illustrated for two tools in Fig. 2. The idea is that each model is simulated by its specialised simulator (and solver) while both tools (and hence models) exchange information on how certain variables at the boundaries of each model behave over time. The master simulator orchestrates the overarching simulation. It 1) determines which variables to exchange between models A and B and vice versa, 2) initialises both models before starting the co-simulation, 3) time steps and synchronises both tools, and 4) does type casting or transformation of variables if needed. The arrows between the master and the tools are the interfaces, which

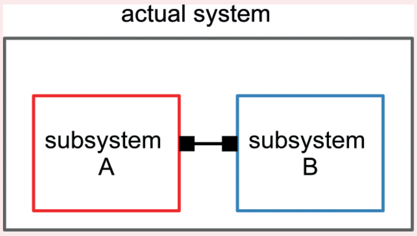

Figure 1.a. Exemplary System Definition

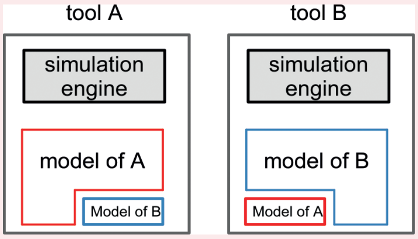

Figure 1.b. Subsystem Specialised tool

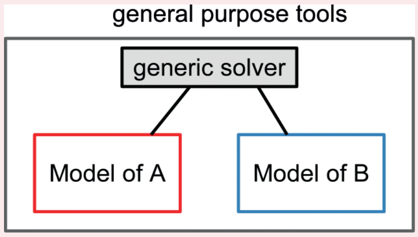

Figure 1.c. General Purpose Simulator

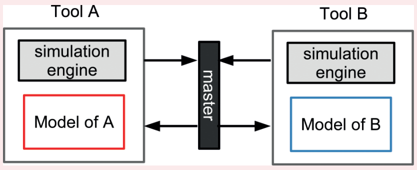

Figure 2. Cosimulation Architecture

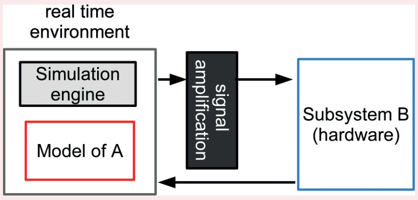

Figure 3. HIL Testing of Subsystem B

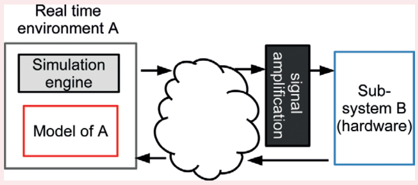

Figure 4.a. A real-time simulator connected to a remote hardware representing the subsystem B

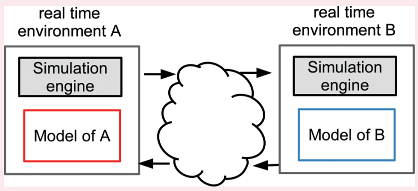

Figure 4.b. A real-time simulator connected to another (remote) real-time simulator running a model of subsystem B.

can for instance be achieved by sockets or memory sharing. Co-simulation has a number of advantages. First, the subsystems can be modelled in the highest level of desired detail, which supports the validity of the overall study. Second, the internals of tool B can be shielded for tool A (black-boxing), which is advantageous in legally sensitive situations. Third, the both tools do not necessarily need to be on the same workstation, which enables transition towards distributed assessment of CPES.

Real-time Simulation and Hardware in the Loop

With the advent of more powerful computational tools, real-time simulation of Electromagnetic Transient or Dynamic Phasors (DP) for large-scale electricity became feasible over the past two decades. This enables Hardware in the Loop (HIL) testing, the concept of which is shown in Fig. 3. The main principle is to include as much as the overall model into the real-time environment as technically feasible, and have the device under test as subsystem B placed in the lab. The real time simulator produces signals sampled at 50 µs at its analogue output interface. The signals commonly range from -10V to 10V, and might, depending on the type of hardware connected, require appropriate amplification. The response of the subsystem is subsequently captured and looped back to the real time environment, hence hardware in the loop. The main advantage of such a setup above offline approaches is that one of the subsystems is the actual hardware, the setup allows studying system-level interactions. The faculty of EEMCS has two commercial implementations of such real-time environments for intelligent energy system applications, OPAL RT and RTDS [2]. Sometimes, the desired level of detail for such simulations cannot be concentrated in a single site for technical, financial, and organisational reasons. Technical because scaling real-time assessment of large power systems requires a stronger simulator when maintaining the same level of detail. Financial because such simulators and their peripheral devices are expensive. Organisational because the physical components to be tested need to be brought to the laboratory. The latter also yields confidentiality issues as device information, expecially in the design phase, and is inaccessible to others. Geographically Distributed Real Time Simulation (GD-RTS) presents an approach which aims to resolve these issues, by distributing the simulation as well as human work load across a set of participants and research infrastructures. This concept is shown in Fig. 4 Small time steps, often in the range of micro to milliseconds, impose strict real-time computational burdens on the underlying computer and operating system. This allows for the expansion of testing capabilities; Real-time simulation resources, Power Hardware in Loop (PHiL) setups (like Fig. 4a) and hybrid co-simulation frameworks (like Fig. 4b) may be interconnected to form a comprehensive research infrastructure that allows the sharing of resources and integration of facilities with different hardware setups located far from each other. Thus, virtual interconnection of laboratories allows for expansion of capabilities of individual laboratories for studies of large-scale, system level and interdisciplinary scenarios for CPES.

Lab Coupling

Geographically distributed real time simulation allows for the expansion of testing capabilities–Real-time simulation resources, Power Hardware in Loop (PHiL) setups and hybrid co-simulation frameworks may be interconnected to form a comprehensive research in-

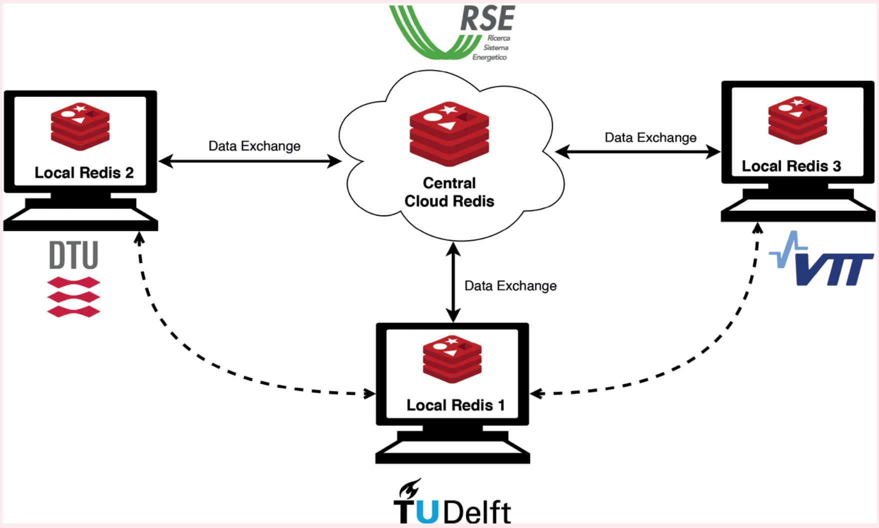

Figure 5. JaNDER Communication Setup

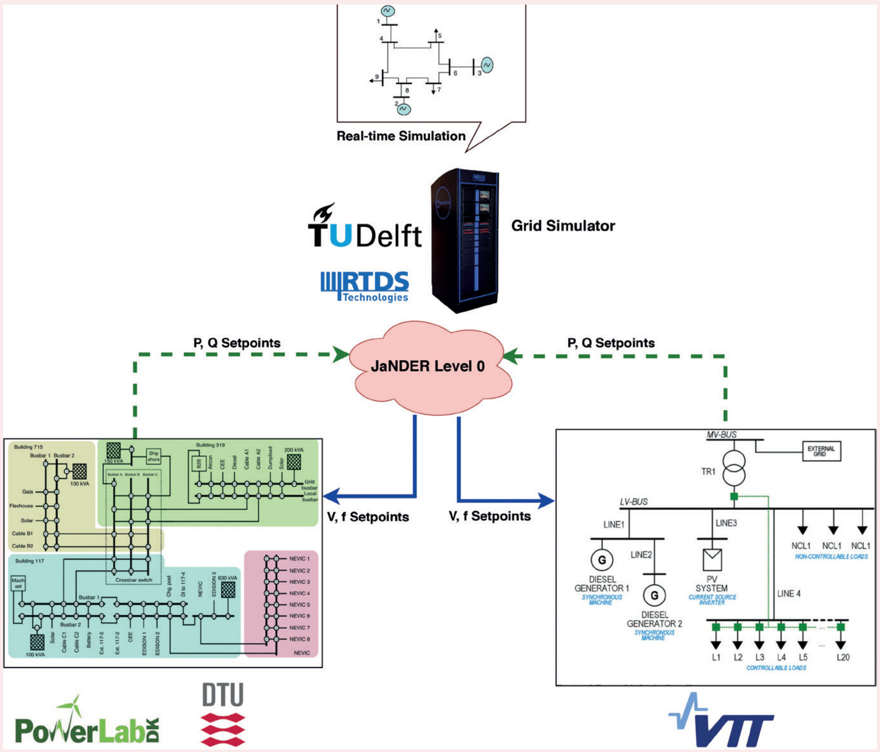

Figure 6. Software based remote Hardware-in-the-loop configuration

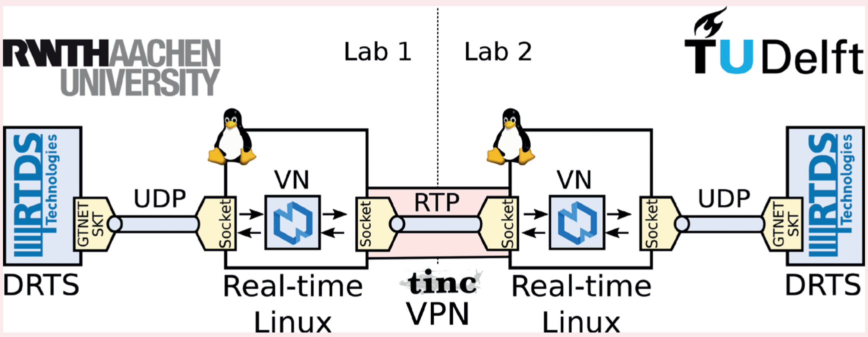

Figure 7. Architecture of VILLAS framework implementation

frastructure that allows the sharing of resources and integration of facilities with different hardware setups located far from each other. Thus, transnational coupling of laboratories allows for expansion of capabilities of individual laboratories for studies of largescale, system level and interdisciplinary scenarios. As part of the ERIGrid's Transnational Access research exchange forming the basis of the M.Sc. thesis, the real-time simulation laboratories at RWTH Aachen and TU Delft were interconnected. Broadly, two types of interconnections were tested and studied in this thesis: 1) coupling of remote hardware and software assets (like Fig.4a), and 2) coupling of remote software assets (like Fig.4b).

Coupling of Remote Hardware and Software Assets

At present, smart-grid laboratories are not connected by a common framework or infrastructure. Various European labs have their own specialised facilities and interconnecting them will help in having all the required and important features under a common virtual platform. This work was undertaken for partial fulfilment of the objectives of developing interfaces, supporting software infrastructure for virtual integration in ERIGrid. The interconnection of labs was achieved using the innovative JaNDER specification over the internet and involves exchange of critical real-time simulation information like measurements and control signals (see Fig 5).

A case study involving interconnections between TU Delft, The Netherlands, Technical University of Denmark, Denmark (DTU) and VTT Multipower Laboratory, Finland was carried out. In the studied test case, the RTDS at TU Delft has been virtually interfaced with power hardware at at DTU and VTT. The proof of concept of a virtual research infrastructure is presented through a joint experiment involving all three labs, to study a CPES in a geographically distributed way (Fig. 6).

Coupling of Remote Software Assets

Subsequently, the real-time grid simulators at RWTH Aachen and TU Delft have been interconnected through the public internet. The setup is shown in Fig. 7. The interconnection is realised through a software toolset called the VILLAS framework [3]. A systematic and comprehensive analysis of a co-simulation interface algorithm for GD-RTS, based on dynamic phasors was successfully carried out. The packet routing and measured latencies are shown in Fig. 8. The obtained results show that, to ensure simulation fidelity in a GD-RTS on a shared communication medium, an automated approach to monitor the network and adapt to network congestion is required. Therefore, this collaboration introduced the application of a real-time protocol in the CPES simulation domain.

Conclusions

Our energy system is in a transition towards a cyber-physical energy system: a system in which multiple domains are mutually entangled. This unmistakably will bring us a lot of technological benefits. However, system-level interactions must be carefully studied, which cannot be done accurately any longer with traditional offline simulations. In this article we explained a couple of methods on how the transition from legacy time-domain simulation towards co-simulation, real-time simulation, and eventually pan-European distributed real-time simulation might look like and which challenges are still on our way. This thesis was done as part of the H2020 project ERIGrid, for more information about the specific methods and protocols adopted, please refer to the dissemination website (https://erigrid.eu/dissemination)

[1] https://erigrid.eu
[2] https://www.rtds.com
[3] https://villas.fein-aachen.org/doc/index.html

Figure 8.a. Geographic Map of Trace Route

Figure 8.b. Latency of routing path

Lighting Up Lives

Bringing Clean Energy to Refugees in Greece

Jose Carrasco

During 2019, more than 70 thousand people risked their lives to cross the Mediterranean sea to seek asylum in the Greek islands, just to find themselves stranded for long periods in refugee camps with very poor conditions and limited access to basic services.

This situation was no different in 2018 when the Energy Club at TU Delft was looking for ways to help in this crisis by using the knowledge developed at the university and came up with the idea of Energy for Refugees (EfR). EfR was then born to help refugees by providing affordable, reliable and sustainable energy (UN Sustainable Development Goal 7). That year, a group of master students from different faculties and nationalities designed and installed a 5KW solar PV system in a classroom in the Kara Tepe camp in Lesvos, Greece, in the summer of 2018.

After the first project, a new board was selected and started working towards the same goal, this time it was possible to collaborate with Eurorelief, an NGO in charge of the main section of the Moria refugee camp in Lesvos, Greece (the largest refugee camp in Europe). The second EfR project consisted of the design, funding, procurement, and installation of a 25KWp Solar PV system to reinforce the capacity of the grid and try to avoid as possible the duration of black-outs (mainly increased in the winter as the heating demand increases).

It took seven months of preparation before the team travelled to Greece to install the solar PV system, during this time the team had to get the required training, design the solar PV system, get the required funding (the most difficult part) and make sure the components were safely shipped to the destination. Once the Q4 exams were over, the team travelled to the island of Lesvos, during 3 long and sunny weeks the team worked against the clock to install 90 solar PV modules, 2 inverters and required cabling and electrical protection devices.

This project is expected to displace the use of 9,000 liters of diesel per year, or about €12,600 (based on the local price of diesel), this resource can then be used by the NGOs to improve other areas of the camp. Additionally, this also implies that around 24,000 Kg of CO_2 are not going to be emitted.

EfR profoundly appreciates TU Delft and all companies and persons that contributed to making this project possible, as collaborations are key for the continuity and future growth of EfR.

EfR was legally established as a foundation in February 2019, and upon a successful project this past summer the team is more committed than ever to continue the hard work. Starting on January 2020, 13 new master students from different faculties of TU Delft will join the team to start working on two new projects, one in Greece and one tentatively in Nigeria, where EfR was invited to work in the Internally Displaced People camp in Abuja, Nigeria (people displaced by terrorism and climate change).

EfR's master plan can be explained in 3 main points:

1. Help governments and NGOs save thousands of euros in fuel costs by deploying PV to displace diesel generators in refugee camps

2. Use those PV installations to train refugees so they can get good, high-paying jobs in the solar industry

3. Satisfy the solar industry's demand for highly-skilled, properly-trained PV installers/designers

"In line with our Global Strategy for Sustainable Energy, we aim to ensure that refugees can meet their basic energy needs in exile while also minimizing environmental degradation. Sustainable energy access will bridge this gap, enabling refugees to pursue education, supporting businesses and social enterprises, spurring innovation and exponentially enhancing the safety and well-being of people and communities, until such time that they can return home," said UN High Commissioner for Refugees, Filippo Grandi (at the Global Refugee council celebrated in Geneva, Switzerland, 17-18 December 2019) during the presentation of the report generated by IRENA showing the potential of Renewables as a reliable power source in refugee settlements.

For a TU Delft master student, to be part of EfR represents an opportunity to put into practice all the knowledge acquired in class, and also an opportunity to develop skills working in a multicultural and multidisciplinary team, even without prior knowledge in the solar PV technology all members receive training for the installation of a solar PV system and participate actively in the design, funding, and installation of the project.

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Climate Models for the Future

An Energy Leader's vision of Tomorrow

Detlef van Vuuren

Detlef van Vuuren is an internationally prominent researcher in the field of global sustainability. He is one of the initiators of research into how the world can meet the objective of the Paris agreement. He coordinated the development of the Representative Concentration Pathways (RCPs) and Shared Socio-economic Pathways (SSPs) which are now used in the IPCC's assessments. Detlef is ranked the 11th in the Sustainable 100 in Trouw. As part of the Delft Energy Initiative guest speaker series 'Meet the Energy Leaders', van Vuuren visited the campus to share his work on the prediction of climate change as function of the actions taken by the public. As part of the Delft Energy Initiative guest speaker series 'Meet the Energy Leaders', Detlef visited the campus to share his thoughts on the energy crisis.

You work at both PBL (Netherlands Environmental Assessment Agency) and at the University of Utrecht. What is your role at those institutions?

PBL is about informing the government on the subject about the environment, so that they can make good decisions based on good knowledge. In that role working for IPCC (Intergovernmental Panel on Climate Change) is very similar, they too try to provide information about the climate change to governments including the Dutch government. Sometimes I inform the governments directly, but most of the time it goes through IPCC where I work as an author. The products I make there help policy makers.

One of your messages during your lecture was a focus on more intense agriculture, but doesn't this go straight against the current messages that we need more area per animal?

Globally we are going to have roughly 9 or 10 billion people in the world around 2050. Right now, we are at 7 billion. We also expect an income growth in that period, so we are going to need a lot more food than we need today. If that would mean 60% more land, we can forget any biodiversity goals, because we are already using a third of the planet for agriculture. This means we need to become more efficient and need to produce more food per amount of land. This has also been the trend in the past. 80% of the gained produce has come from new techniques and crops, 20% from newly acquired lands. In the future we need to gain most new profit again from intensity improvements globally. If not, we are losing even more forests.

Does PBL have a roll in the IPCC or just you personally?

The IPCC is based on individual researchers, and PBL only exists since 2007 and it was a merger of 2 other institutes : A department of RIVM (National Institute for Public Health and the Environment) and a similar institute on spatial planning. RIVM was holding the technical support unit of IPCC at this point. So one of the IPCC reports on mitigation by was coordinated by RIVM.

You speak about new trends and techniques to improve the yields. Where are these coming from?

These emerge from different ways in places. We've seen revolutions from all over the world. This also had downsides like increased water and fertilizer use. This means we will also have to look at a balance. But there are places where the intensification really needs to happen still like Africa. This can be done in many ways: Mechanicalizing, fertilizers, but maybe also different clever ways like greenhouses with modeled suns. I was also emphasizing the diet problem. Globally we use almost 30% of the surface for agriculture. 2/3rds of this is for livestock, and of the 1/3rd half of it is feed for the animals. This shows you how much consumption is into the meat industry and shows that even a small reduction in the amount of meat we eat can allows us to use land more efficiently.

Isn't that going against the trend in The Netherlands, where we want to reduce our current livestock with 50%?

That's an interesting problem to discus in the Netherlands, but globally this is not yet the main problem. There we really need to focus mainly on intensification.

When we look at all the organizations you work for and with, we were a bit stunned by just the sheer amount. How do you manage that?

My main employer is PBL. I work there 4 days a week. When I work for RIVM it is mostly under the responsibility of PBL. 1 day a week I work at Utrecht University. Those jobs can nicely be combined. I can put a lot of emphasis on research there

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and reach out to different researches and work with students there. PBL is then an extremely nice place to do policy relevant research. Given the fact that it is connected to the government, we are certain we are at least heard by someone, but also can we be inspired by someone from the government asking the right questions. So for me it is a very nice combination.

During your presentation you assumed that the prices of renewables will go down a lot. But people often fear that these products can not be stored or stored at huge losses. Did you consider this or do you have a different opinion about this?

In a short timescale this is not a problem yet. We can still expand renewables and we still have enough fossil fuels to pump into the system to make things work. But at some point, this will become a problem, both seasonable storage and daily storage. We will have to find solutions for this. But we are already working on this. It is also not like this is still unthinkable technology. We see people making energy storage using hydrogen. These things will emerge once the demand grows. That is assumed in our models. We assume technologies that cannot keep up with the demands of the world and system will be penalized.

"It would be stupid to allow these risks and do nothing"

There are large groups of people who still underestimate or don't believe in global warming and the problems that come with a growing population. Does this concern you?

As far as I can see, these people are losing numbers. At this moment there is no discussion between scientists, only about the exact extent of the problem. There is also a discussion about if we should act upon the problems. I think that the risks that would come with doing nothing and the things we could lose are so important that it would be stupid to allow these risks and do nothing.

Your job right now is making and looking at models of the future. Wouldn't you sometimes want to focus on the now and the implementation of the scenarios?

I came to this business after reading "The Limits to Growth", which was firstly published in 1972. At this time a few people made a very simple model and they started to calculate the amount of food and the amount of energy would be able to keep up. They then started to run more kinds of scenarios and became very influential under businesses and governments. When I read it I was studying and I thought "this is something

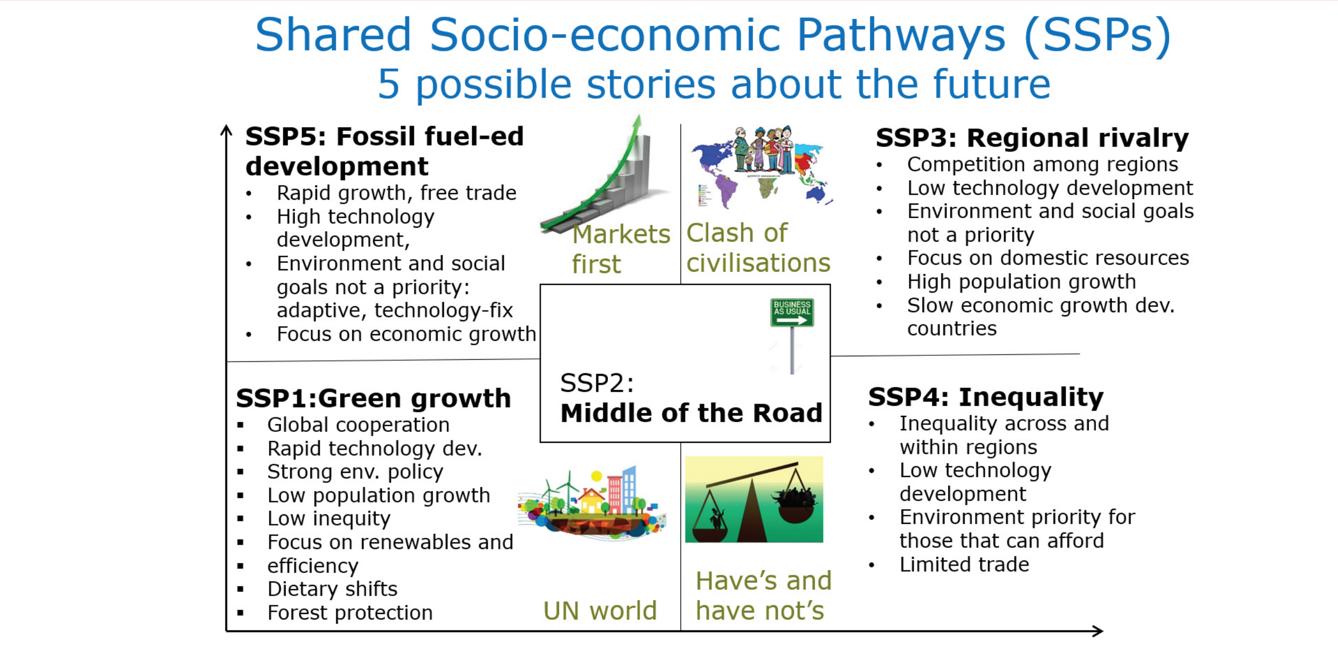

Figure 3. The five possible social economic scenarios according to Detlef

I want to do!" At the beginning of the book, Bert de Vries from the RIVM was acknowledged, so I called him and asked "Can I do my master thesis with you?" and that how I got into this. I still like it a lot. I run into a lot of curious things that makes me wonder how things work which makes it interesting for me.

But also we have been quite success-

"Making sure that everyone reaches a consensus is necessary, but it won't be easy."

ful to create a pathway for the climate, in 2015 we also published 17 goals regarding sustainable development. We don't have scenario for these goals yet. Nobody published a scenario yet how to get everyone through secondary education by 2030 either. So one area I want to move in is how to solve some of these other goals and see how they might be correlated. If we use biomass for fuel, that will impact the amount of land available for food. I still enjoy making these models. Of course the system will have to change, but for now I'll leave that to other people.

You spoke about five different social economic scenarios. Do you think we are drifting towards one of these as a continent or even as a world?

I don't think we will go towards one of the extremes. It is much more likely that we will see elements of these all the time and maybe one scenario a bit more than the others in certain areas. You also interpret our own time in terms of there scenarios. I must admit that around the 2000's I thought the SSP1 scenario was a very likely case. The world was developing towards collaboration, technology was developing quickly. But I fear I see more SSP3 elements in the world. But this could change back, hopefully it goes to a more positive scenario.

What do you like about the Delft university?

That one very nice thing in Delft: almost everything I mentioned during my presentation is being worked on in some aspect. We know the direction we need to move to. We know we want to reach zero emissions around 2050 here, and globally around 2060. That will have a number of challenges and we need people solving these right now, such as storage of energy, or maybe nuclear. Maybe something more radical like negative emissions will become important. These are great challenges. But we also need the short terms solutions that will not bring us to the goal of zero, but can lower the emissions in the meantime, maybe by using more natural gas.

You mention nuclear power as a possible solution, but Germany has abandoned nuclear power the last couple of years. What do you think about that?

In many of our models, nuclear power does appear as a potential attractive opportunity. But there are other issues like waste and safety which also can influence what happens. The same models also show we could do without with only paying slightly higher costs. This means we will have to discuss whether we want to have this, but we don't need to. Germany has made a choice about this which will make it harder to reach their climate goals, but it surely doesn't prevent them.

We spoke a lot about the technical possibilities and changes, but there are a lot of different changes that contribute to this as well.

These changes will be hard as well, some people do not want to give up for example their flying behavior for the climate. But these are social acceptance problems which also have to build up. The way we did it here this year with the energy debates might be the right way to do so. Here we at least agreed on what the goals needed to be. Then we can start talking about how we can reach these and what will need to happen. But we will not get there without society's support, so I don't see another way.

"In 2015 we also published 17 goals regarding sustainable development. We don't have scenario for these goals yet."

Are you afraid this support is mainly in the academic layer of society?

This is a problem, but that just means we need to show that it is possible to tackle the problems we are facing, and why it is needed to make these transitions and to be aware of the problems they will face. For example: if the price of energy will increase this might be a bigger obstacle for someone with a low income compared to someone with a high income. That means we will have to deal with somehow. Making sure that everyone reaches a consensus is necessary, but it won't be easy.

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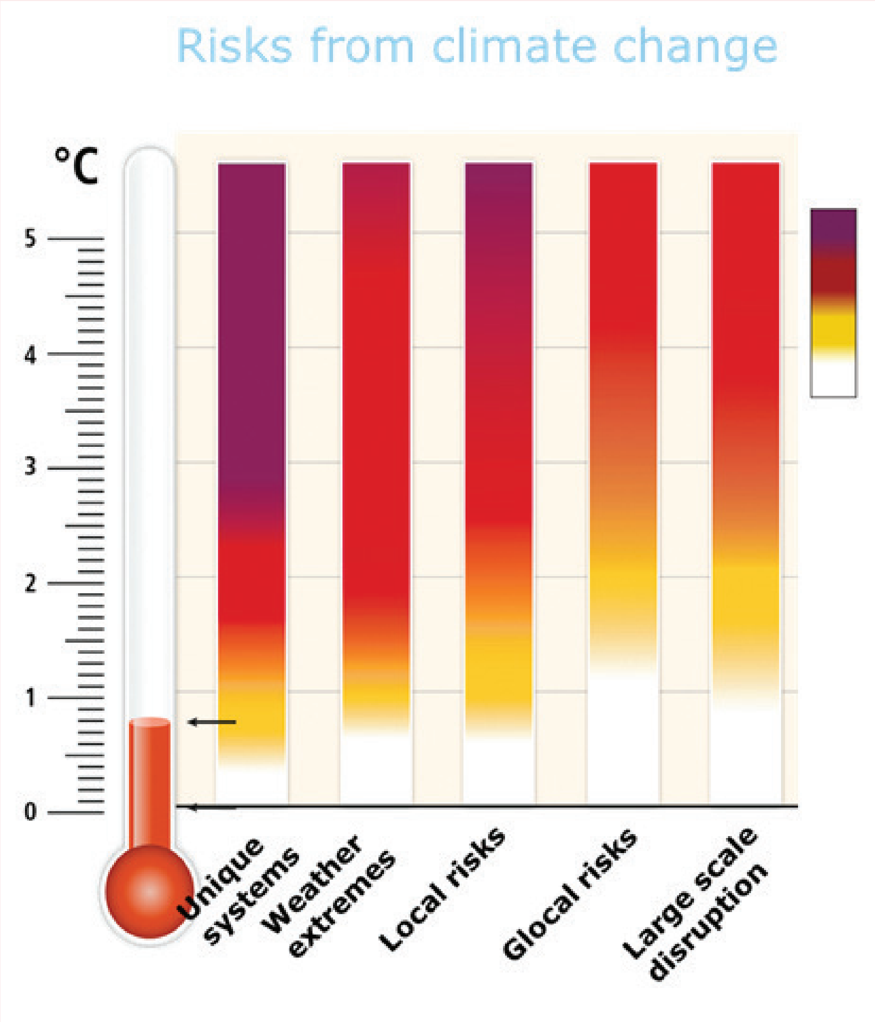


Figure 3. Nightime cityscape of Silicon Valley, California

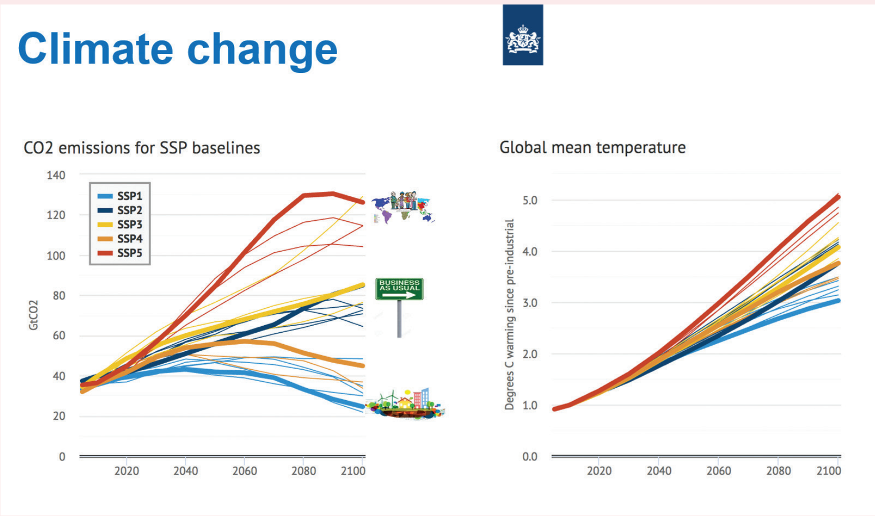


Figure 3. Nightime cityscape of Silicon Valley, California

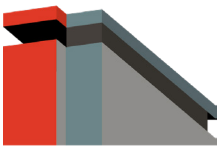
Faculty Student Council

Representing the students of EEMCS

Adeep Santosh

What is the Faculty Student Council?

The Faculty Student Council (FSC) is a legally student-elected student body that is involved in the decision making in the facility. The council has the right of consent or right of advice, which gives us the chance to be involved with the key decision making bodies inside the facility. The FSC of EEMCS represents all students from Electrical Engineering, Applied Mathematics, Computer Science and Sustainable Energy Technology. We as the FSC have internal meetings every week where we discuss the key issues which we come across inside the faculty. Once a month, the FSC takes part in a meeting where we meet with the decision making bodies within the faculty and discuss with them the key issues which we came across during our internal meetings. The FSC also takes part in the budget allocation within the faculty and has a right to advise on how the money is spent. The FSC of EEMCS along with other FSCs and Central Student Council (ORAS and Lijst Beta) strive to make the faculty a better place to study and allow all students to grow.



The Four Chambers of FSC

The FSC is subdivided in four chambers which represents a particular section of students within the EEMCS. The total number of seats which are up for election every year is 12, distributed as 4 for Electrical Engineering, 4 for Computer Science, 3 for Mathematics and 1 for Sustainable Energy Technology. This year after the elections, the students were chosen who would represent each chamber and together would form the

Faculty Student Council of EEMCS.

What are we up to now?

The FSC is currently working in full force to make the faculty better for everyone. Some of the topics which FSC is currently looking into are as follows:

- To make the faculty better for studying by checking if the silent rooms are actually silent and if there is enough study space for students.
- Working towards making the online course evaluation more effective.
- Getting to know about the renovation works being carried out in the faculty and suggesting areas which would need further renovation.

Would you like to join the FSC?

The FSC is an elected body and the student who wishes to join the FSC needs to get elected into it. Every student can sign himself up as a candidate and pitch themselves, which is then displayed on the election website. The candidates with the most votes are elected into the respective chambers.

How to get in touch?

As the FSC we would love to hear from you on how to improve the faculty and the difficulties you are facing. This would help us in taking steps which benefit you and the faculty as a whole. We organise a coffee moment every quarter to talk to students and conduct a survey. During these coffee moments, we can be found in the entrance of the building with free coffee. You can come and talk to us and fill the survey about the difficulties you face in the faculty. This helps us in getting a good picture of the major focus points that need our attention. In case you can't attend the coffee moment or like to have our attention immediately, don't hesitate to send us a mail at fsr@ewi.tudelft.nl. You can also get in touch via social media. Follow our Instagram @fsceemcs to keep you updated about what we do!

Transition

The FSC is making a transition every year in regards of new members. So, is it in your identity to help all the other students and do you want to make a change within the faculty? Then you have to become part of the next FSC! Every student can sign up as a candidate and makes a pitch about him or herself. This pitch will be displayed on the election website. After the election days, the candidates with the most votes are elected into the respective chambers. So if you want to be part of the FSC next year, the ETV board would like to hear from you!

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Advertorial

“15 Defence, Safety & Security expert groups alone!”

Olga Zeijpveld is senior project manager in the Electronic Defence department at TNO. She has been working there for less than a year, but was immediately in awe of the enormous breadth of expertise at the research institute. The alternation between short- and long-term projects is also really appealing to her.

“Our department deals with the use and misuse of the electromagnetic spectrum. On the one hand, we come up with clever things that help our clients optimise the deployment of their radar and communication systems. On the other hand, we want to detect and prevent an adversary from interfering with the signals. I work on multiple projects at the same time, like everyone here. Soon I will be working on a four-year research programme in the field of Radar Electronic Warfare and Communications Electronic Warfare. This is where we build up knowledge that we can put to concrete use at a later date. Shorter projects are running in parallel for the Royal Netherlands Navy, the Royal Netherlands Army and the National Police. Our work ranges from drawing up the technical part of the programme of requirements to advising on the selection of suppliers and testing their systems. In addition, we build our own simulators and prototypes. In short, the work ranges from exploratory research to provision for practice. In the latter case, we sometimes respond to needs that have to be met within a month, for example because a new mission is imminent.”

Devil’s Advocate

“As project manager, I keep an eye on the big picture and look further ahead. The first step is to translate customer demand into what TNO needs to do – and always with an eye on planning and budget. What is the customer’s priority? And if it’s a bulk question: how can we divide it up into manageable pieces for ourselves? As a link between the client and the project team, I then make the translation back into words that the client understands. Some customers want to know the ins and outs, while others are a little less involved in the technical content. This means that I have to be able to understand and explain all matters up to a certain level myself. That’s why I always call on the team. How exactly does that work? Is that really necessary? Maybe there are other roads to Rome? I regularly play devil’s advocate to challenge the project team. It makes a difference that I have a technical background: I did Electrical Engineering at Delft University of Technology, specialising in Telecommunications.”

Super Broad

I hadn’t immediately thought of TNO myself. But once the organisation was in the picture, I saw how innovative TNO is and what relevant projects they are working on here. I also enjoy working with very highly educated colleagues, people who are smarter than me! No, my switch wasn’t a seven-year itch. If an employer offers enough variety, I can keep working there for a very long time. As far as that is concerned, I’m all right here. TNO is super broad: 15 expertise groups in the field of Defence, Safety & Security alone. Let alone outside that field!”

Well-Oiled Activities

“I had a well organised entry. Beforehand I was able to find all the information on the website and on the first day the laptop and phone were there for me. It felt like a well-oiled machine. Even as a senior I was assigned a mentor! Now that I’m at work, I notice that you are given a lot of autonomy – along with a lot of responsibility that comes with it. The same goes for the young people in the department. All projects have to be done of course, but TNO also looks at the background and personal preferences of people. What kind of work suits you? What motivates you? That’s what I always ask myself when I’m working with a project team.”

Project Management as a Common Thread

“My day is good when I’ve had a lot of contact with colleagues and clients. I don’t have to sit at the computer all day. The other day I got stuck writing a project plan. I was then able to join a few other seniors who were happy to make time for me. That helped so much, I had my thoughts back on track. How do I see my future? I never look far ahead, often things come my way, and I’ve just started this job! Maybe someday I would like to work in a different field, but project management is the thread that runs through my career. And I’m in a good place at TNO. One project takes a few months, another sometimes years. There’s so much variety in that alone”.

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Do(n't) Do It Yourself

Watering Plants the Right Way

Bram den Ouden

In Maxwell 22.2 of last year, Bram described the issues that occur when keeping plants whilst not remembering to water them: they die. Stating the obvious will solve nothing, which is why this insight was accompanied by a design proposal and initial draft: a device which could monitor the water level of a plant and possibly supply water when required.

Microprocessor

In Maxwell edition 22.2 I proposed and compared three possible processor-transmitter combinations for this project: the AttTiny84 using a 433MHz transmitter, a WEMOS D1 mini featuring the ESP8266 and a processor able to support a Bluetooth module. Out of these options I chose to use the ESP8266 module, because of its bidirectional communication abilities and the Wi-Fi network which was already in place all around my home and balcony.

Power supply

At least 90% of my plants are not close to an outlet. To be able to use this device on my plants, it must be able to operate using battery. Preferably, this battery would be powered by a solar cell. A design for a solar charger was supplied in the original article. This first design, however, will not have this solar charging circuit integrated to reduce the complexity. It is of course possible to develop this solar charging circuit as a stand-alone-unit and connect the 5V out to the micro-usb connector of the design. The power source for this design will be a power bank which will supply a 5V output with a maximum of 1 Ampere. Since the ESP8266 operates at 3.3 Volts, the 5V output of the power bank poses the need for an additional part of the power regulation to generate a 3.3V line. This task will be performed by the 1117-3.3 low dropout linear regulator. Although this is not the most power efficient way of achieving this goal, it is the least complex way and was therefore chosen for this first design.

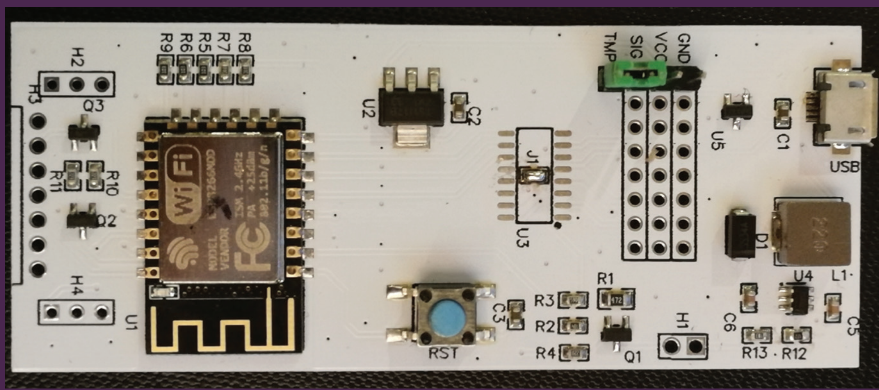

Figure 1. The resulting board

Water pump

The originally proposed water pump was a small 3-6V submersible water pump able to deliver 120 liters per hour with an adapter for a tube with a diameter of 5 mm. This pump had the advantages of being cheap and being able to operate on the nominal voltage of the USB powerbank. Unfortunately, during testing it was barely able to supply water through the 10M water hose with a diameter of 8mm that was available. Although this pump might be an ideal solution for indoor plants much closer to the pump, for my purposes this pump was not good enough. The second pump I tried was a 12V submersible pump advertised to deliver 240 L/H. This pump was able to deliver a nice flow of water through the same hose although a boost converter was required to operate it using the 5V power bank.

Sensors

In order to measure the amount of water in the soil, a soil moisture sensor is required. The available choices are a resistivity-based sensor and a capacitive sensor. The first type of sensor sends a small current through the soil and determines the amount of water in the soil based on the resistance measured between its two terminals. This sensor is the cheapest option but is also prone to corrosion due to the metal areas exposed to wet soil. The second type of sensor, the one I chose, is about 4 times as expensive but at a whopping €1 a piece this is still quite manageable. The capacitive sensor accepts an input voltage of 3.3V up to 5V and outputs an analog value between 0V and its input voltage. The chosen microprocessor, the ESP8266, features a single analog input which can only handle voltages up to 1.1V before destroying it. Using a resistive voltage divider on the output of an analog sensor would allow us to connect devices with almost any output voltage to this analog input but would still only allow for 1 sensor to be connected. Such a shame… A complete device required to monitor a single plant…. If only there were ways to connect multiple sensors…. Just kidding, of course there is: multiplexers. In order to attach up to 8

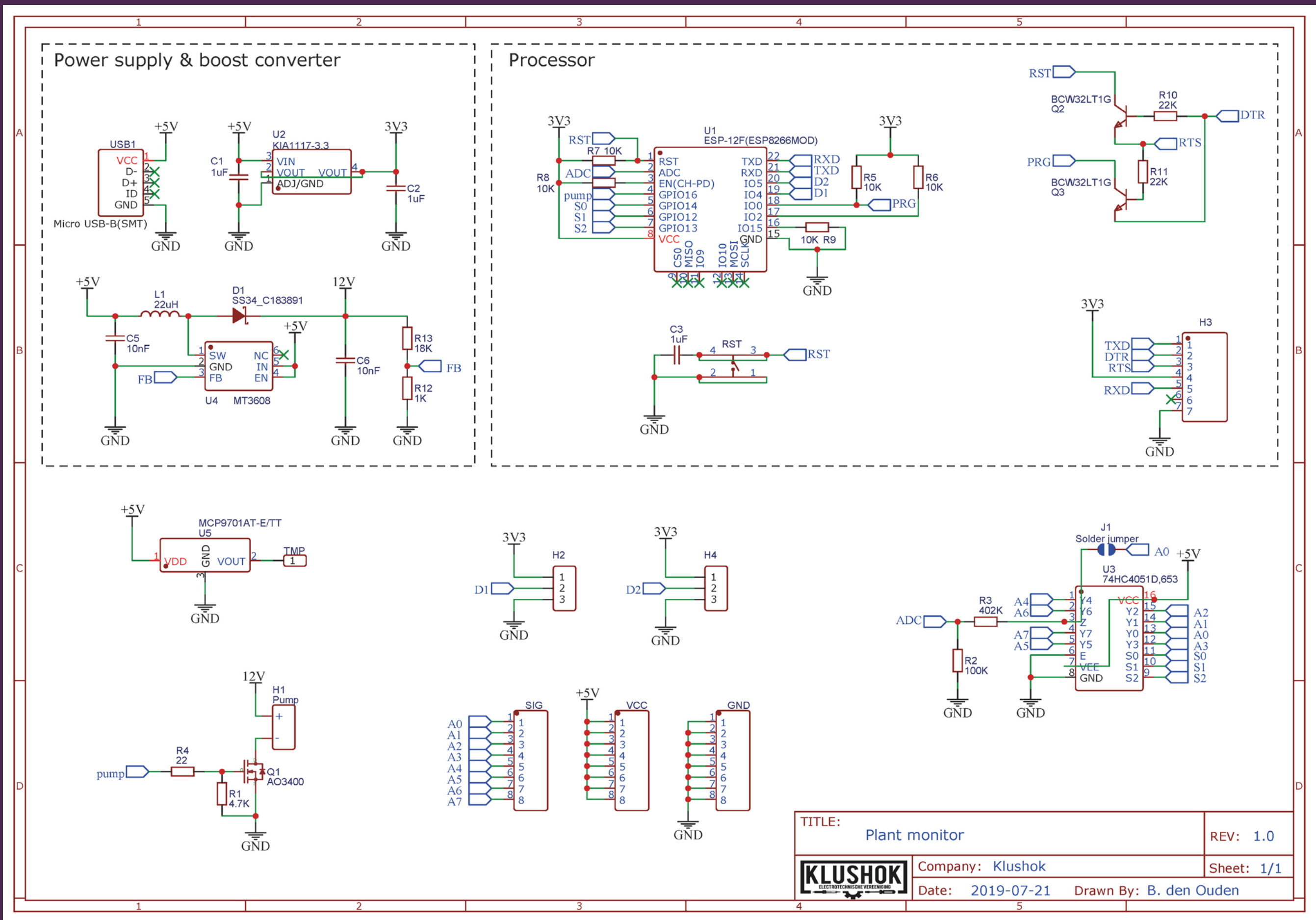

Figure 2. The schematics of the board

different analog sensors to a single device, a 74HC4051 multiplexer is added. This multiplexer requires a 5V power supply and 3 digital signals to select which of the inputs is connected to the output. To be able to connect the multiplexer to the ESP8266 without destroying it, the earlier mentioned resistive voltage divider must be applied to the output of the multiplexer.

PCB design

For this design to work, all of the above-mentioned components have to be connected so it was time to design a circuit board for this first design. For the ESP8266 to work in the desired mode, its reset pin, enable pin, pin 0 and pin 2 have to be pulled up to 3.3V whilst pin 15 has to be pulled down . To be able to reset the processor, a reset button has to be able to pull the reset pin to ground. Programming the ESP8266 after it has been soldered onto the PCB requires the chip to boot or reset whilst pin 0 is pulled to ground. This can either be done manually by adding a button or can be done by the programmer by adding transistors Q2 and Q3. Header 3 is used to connect the programmer. A soldering jumper was added to connect A0 directly to the analog input of the ESP8266 if the multiplexer is not soldered onto the PCB. This limits the amount of analog sensors to 1 but also reduces the power usage of the device. A MCP9701AT temperature sensor is added to the PCB to be able to measure the on-board temperature. This sensor can be connected to A0 by adding a jumper across the TMP header and the SIG header right above it. As mentioned earlier, the analog input of the ESP8266 can only handle up to 1.1V and therefore a resistive voltage divider is used. This divider consists of R2 and R3 and their values are extremely important; If Vcc*R2/(R2+R3) exceeds 1.1 V, the ESP8266 can be damaged. Header 2 and 4 (H2 and H4) feature a 3.3V line, a ground line and a digital input/output pin to connect external devices to.

Conclusion

Having designed and assembled the first version of the plant monitor, the time has come to start thinking about software:

- How and where will the data be collected?
- How will the data be communicated to the plant owner?
- What level of autonomy must the plant monitor have?

You can read this project and download its files or find inspiration for next projects on klushok.etv.tudelft.nl!
Here you can also:

- Discover and submit projects
- Find devices in the klushok and their manuals
- Check/order available components

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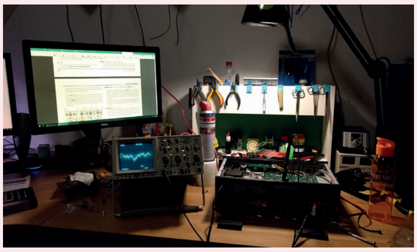
Bachelor Column

A day in the life of...

Reiner van der Leer

Hey there! My name is Reinier and I'm a second-year bachelor EE student, currently doing courses from both the first and second year, as I failed almost all the subjects of Q1 and Q2 last year.

I had a pretty bad start, only achieving 10EC up to February 1st, but I didn't give up and passed all remaining subjects of Q3 and Q4. To make the BSA threshold of 45EC, I had to come back from holiday in Sweden early to take a resit: a journey of 20 hours by train. No regrets on that by the way, travelling internationally by train is really fun! After getting my BSA, I decided I would try doing 4 subjects in Q1 this year, to make up my backlog and so still be able to get my degree in 3 years. Not unexpectedly, that didn't work out. Now I'm on a 4-year planning and that's going a lot better.



What else keeps you busy besides studying?

Every time I get asked that, I wonder where to start. During the weekends I work at a retail company where I am the sysadmin, and lead developer on a couple of projects. My work is mainly on systems that are only used internally to make the work of my colleagues easier and more productive, but I also build connectors to link mission-critical systems together.

I have been a participant of "hackerspace The Hague", Revspace, for 4.5 years now. It's currently located in Leidschendam, hence the quotes. At the space, I can work on my own projects (using equipment I don't have at home), engage in really technical conversations, eat some ice cream, have dinner... It's a really cool place, if you like nerdiness. About my own projects, I'm working on a few but the most notable at the moment is a plug-and-play device and web platform to get detailed energy usage statistics from any Dutch so-called "smart meter".

How does all this influence your study?

In some cases, it gave me a head start because of my existing experience with projects, building/debugging systems and writing code. But for me it's a tradeoff between making consistent course progress and gaining experience working on projects. My grades could definitely be higher if I only focused on studying, but I really like working on projects, inside or outside of my courses. I do think it helped achieve good results in EPO-1 (1st) and EPO-2 (2nd place), together with the teams I was in.

Is there something you would like to tell your fellow (beginning) students?

Make sure you can keep up with the workload you give yourself, but don't give yourself too much slack. That way, it will stay fun but challenging. If you're having trouble with your course progress, listen to the advice of tutors and counselors, every time I thought I knew better they turned out to be right.

Master Column

A day in the life of...

Subhitcha Ramkumar

What made you choose TU Delft?

Approximately two years ago, during the last few months of my undergraduate studies , I decided to apply for my Masters in various reputed universities as I felt that I wanted to be exposed to the latest developments in the field of electrical engineering. Amidst several acceptance letters, I decided to pursue my graduate degree in Electrical Power Engineering from Delft University of Technology. This decision was motivated by the specializations and the curriculum offered by the faculty.

How do you like studying here?

This was the first time I have stepped out of my country, to a place where I barely knew anyone; however, as time progressed, I found myself making new friends and getting accustomed to the education pattern. Though I initially intended to specialize in solar energy, I also got fascinated by the opportunities and challenges faced by the power grids due to the current transition towards sustainability.

Can you tell us a little bit about your thesis?

Three months ago , I completed my internship in a startup company called PHYSEE, which uses electricity generated by solar panels to improve the indoor building quality. Working in an international environment was an enriching experience, both technically and culturally. Currently, I am doing my thesis on real time market based control of flexible distributed energy resources. I aim to investigate the performance of such a mechanism in co-ordinating several types of loads under uncertainty introduced by renewable energy sources.

Besides academics, how do you like to spend your time?

Apart from the regular academic life, I like to keep myself occupied with other extra curricular activities. Currently, I am the secretary of the student group of my master program, SterkStroomDispuut. I also work as a student assistant for the IEPG group for building their MOOC on edX platform. Additionally, I will, start working as a teaching assistant for the course 'electrical power system of the future' scheduled in Q4.

What plans do you have after graduation?

After my graduation, I aim to apply the knowledge and skills gained in these couple of years in an international company by working in a challenging role. I am eagerly waiting to experience what life has in store for me!

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Activities

An overview of last quarter's events

Wackie Ice Skating

9 January

The first activity of this year's winter activity committee was ice skating in Rotterdam. We went with a group of around 15 people, varying from beginners to very good ice skaters. It was a lot of fun seeing how everybody enjoined themselves, regardless of their level. After a bit of skating, there was the opportunity to get a nice 'broodje bal' just next to the skating track. A few hours later it was time to go back to Delft and enjoy some beers in the /Pub.

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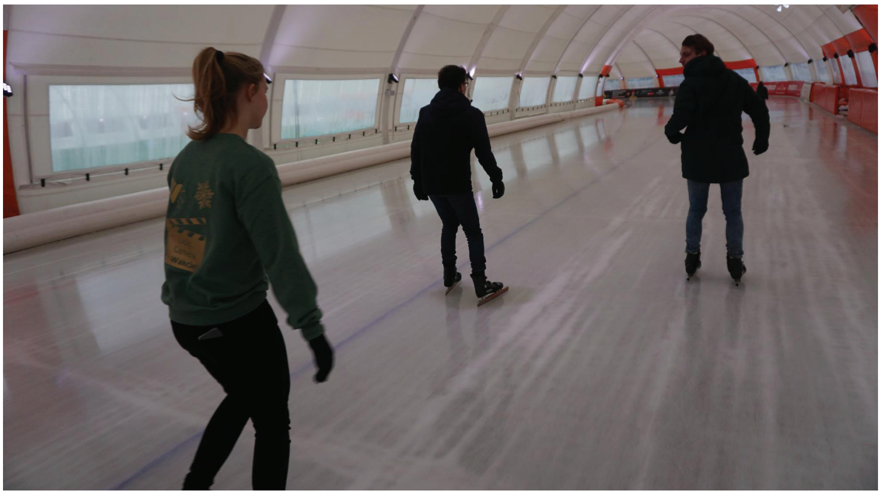

CODETV LED'S GLOW Party
27 November

Studying Electrical Engineering can be quite hard, so sometimes it is good to blow off some steam. To do this we went to Leiden to have a party with the study association Corpus Delicti. The theme was LED's GLOW and a lot of people made sure their outfit matched this theme, which was really nice to see.

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Sinterklaas lunch
5 December

During November, the ETV members got the chance to craft their own paper shoe. Not one to wear, but one to receive presents in. On the fifth of December, all the shoes were filled with gadgets and 'pepernoten' in the /Pub. Concluding it was a lunch for the members of the ETV, where many people attended.

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Alcmaeon-ETV Gala
12 December

We went with a kwibus full with to the beautiful Utrecht for a gala with Alcmaeon. At exactly 11 PM all the people from the ETV arrived with the bus, so the party was very nice right from the start. Most members of the ETV where partying in front of the podium or getting a free drink at the bar. Thanks to performances by a band and DJ van Hox the music was good the whole evening, so everybody was dancing. Unfortunately all things have to come to an end, even this amazing party. Luckily a bus was ready for the way back which, after a bit of trouble with the battery, brought everybody back home safe

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Christmas Lunch
20 December

As is tradition on the last day before the Christmas break, the ETV hosted a Christmas lunch. There were a lot of students, but also staff members and even some honorary members of the ETV. Santa Claus also made an appearance, but it was a shame that the president of the ETV just missed him. After Santa's beautiful Christmas story, the lunch continued with a lot of snacks and glühwein. It was really fun for everybody to have one great event together before the holidays..

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Anagrams

Letter Routing!

Koen Peelen and Archana Ranganathan

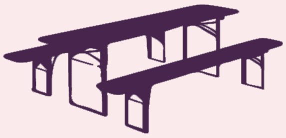
Anagrams are puzzles where you have to rearrange the letters to get the hidden word. For example: "Meat Pelt" can turned into the word "Template." The following Anagrams are all related to Electrical Engineering. We've given some hints on the right!

BACK LOCH IN	_ _ _ _ _ _ _ _ _ _	Absolutely Safe.
CONCERT SODIUM	_ _ _ _ _ _ _ _ _ _ _ _ _	Not as good as metal, but better than rock.
CUTE PROM	_ _ _ _ _ _ _ _	Use it when alone.
FERRIC TIE	_ _ _ _ _ _ _ _ _	Getting things straight.
HANG TWELVE	_ _ _ _ _ _ _ _ _ _	Size does matter.
HOB OUTLET	_ _ _ _ _ _ _ _ _	Dentists can't help.
IN CONDUIT	_ _ _ _ _ _ _ _ _	AC ~~DC~~
PRY NOT NICE	_ _ _ _ _ _ _ _ _ _	WhatsApp "uses" this.
SHYEST SIN	_ _ _ _ _ _ _ _ _	Creation.
SOCIAL TURN	_ _ _ _ _ _ _ _ _ _	Eminem's rap speed.
STIR NATION	_ _ _ _ _ _ _ _ _ _	Beautiful.
DOPED IN	_ _ _ _ _ _ _	Everyone needs direction.
REAP EM	_ _ _ _ _ _	One is deadly.

Upcoming Activities

For members of the Electrotechnische Vereeniging

Joos Vrijdag



CoDETV Cantus

This year will be yet another edition of the CoDETV Cantus with lots of drinks and singing. Together with Corpus Delecti from Leiden we will make this a great event. There are only thirty places for ETV members available, so register quick at the ETV desk.

When: 25th of February 2020
Where: Augustinus, Leiden
Price: 16,50

Evening General Assembly

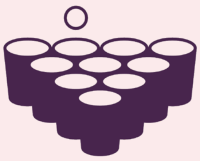
The 148th board will host a general assembly in the evening. There will be lots of important topics to discuss and vote on and there will be a lot of committees installed and discharged. Additionally, there will be a few drinks and snacks to enjoy during the assembly. For everybody who is still hungry after the snacks, pizzas will be ordered!

When: 2nd of March 2020
Where: /Pub
Price: Free

Recruitment Days

During the recruitment days, master students get the chance to have a one on one conversation with a lot of companies. These conversations can lead to an internship, thesis project or even a first job. At the end of each day, there are drinks where students get the chance to have a casual conversation with some of the recruiters.

When: 16th till 20th of March 2020
Where: EEMCS Third Floor
Price: Free



/Pub Beerpong

The /Pub beerpong tournament will be the second event hosted by the /Pub board. It will (of course) be in the /Pub with lots of beers and other drinks. You can buy your ticket at the ETV in a few weeks.

When: 18th of March 2020
Where: /Pub
Price: TBA

ETVerjaardag Cake

On the 26th of March, our association will be yet another year older and that is cause for a celebration. Everybody from the EEMCS is welcome to have a piece of our enormous Dies Cake. A whole week filled with activities to further celebrate the ETV's birthday will take place in the fourth quarter.

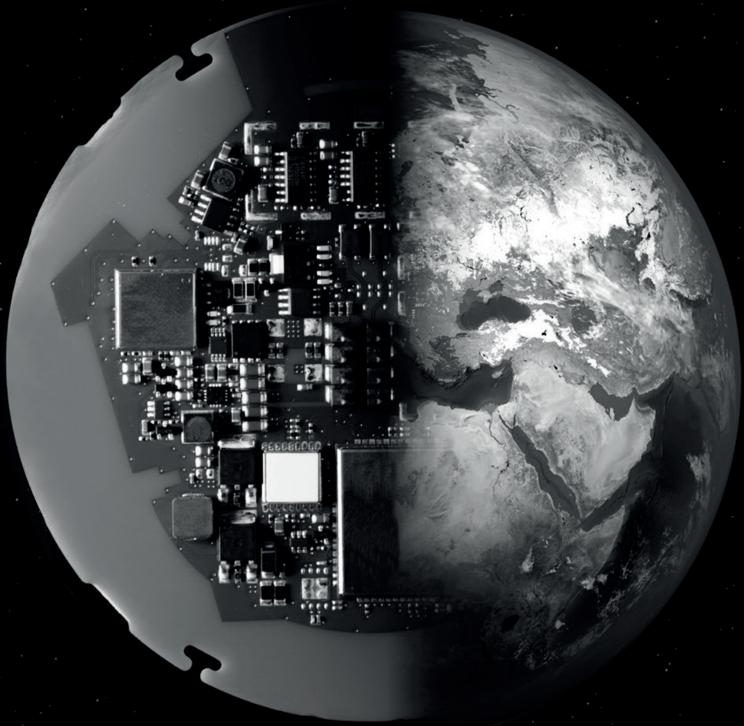
When: 26th of March 2020
Location: EEMCS Central Hall
Price: Free

Parent Day

For all the first year students, the ETV hosts a parent day. During this day parents can see the faculty, but also attend a lecture from a real electrical engineering professor and solder a small device. This way, the first year students can give a slight impression of what they do all day long.

When: 18th of April 2020
Location: EEMCS
Price: 5,-

Creating meaningful technologies that make the world work



Baseboard of an IP67 compliant Asset Management Gateway qualified for harsh industrial environments.

The Prodrive Technologies Mindset

Responsibility

You don’t just go to work, you feel resposible for your project

Flexible

You decide when, where and how much you want to work

Manufacturing

You like to think about manufacturability when designing

Initiative

You don’t sit and wait, you have a hands-on mentality

Have you got what it takes to become a Prodriver?
prodrive-technologies.com/careers

PRODRIVE TECHNOLOGIES