

# top engineer

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*"CFD allows us to create complicated and detailed vessel motion simulations."*

*– Ivan Maksić and Patrik Rautaheimo*

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# The eternal quest for optimization

On 1 November 2014 the United Nations published its latest report on climate change. In a nutshell it indicates that drastic steps need to be taken to decarbonize energy supply by the end of the century if we want to avoid the potential catastrophic consequences of climate change. Current energy consumption levels and related emissions need to be drastically reduced. This requires behavioral changes and efficiency enhancements across the board from individuals and corporates alike.

Increasingly stringent environmental regulations and directives are only one side of the story behind the drive for optimization. The old forces of globalization and ever increasing competition are still at work, and their effects only seem to be increasing. They are not going away. This never ending quest for efficiency is further enhanced in the current demanding global economic conditions where inefficiency is often harshly exposed.

As consulting engineers our role is to assist organizations to achieve their optimization goals. In short, we should help them reduce costs, increase efficiency, profitability and competitiveness and meet regulations. In this regard some of the key tools at our disposal are innovation and making use of advanced engineering technologies and tools and, when necessary, to develop tools and solutions when they don't exist. The continuous and strategically focused development of our own know-how and its application to our customers' benefit is of crucial importance.

There are several approaches available to create development-orientated organizations. In our case it started by including it in our vision already in the late 1970s, which states that 'we are known as a forerunner in developing engineering methods and products'. It requires a corporate culture that embraces know-how and engineering tool development and good supporting structures and processes. Above all, it requires hard work.

Problems or challenges that obstruct optimization can sometimes seem insurmountable. It is essential that we are able to transform problems areas into the sources of new innovations. The innovation process itself needs to be efficient and managed properly. Everything does not need to be invented, however, and often modifying or combining different existing technologies and/or applying them to new fields can bring excellent results.

This edition of the Top Engineer magazine contains several articles that discuss how new technologies or tools are utilized or being developed that aim, among others, to bring operational and energy efficiencies to commercial and public operations.

The challenges we face are not insurmountable. With the right mixture of know-how, technology, tools and innovation the sky is the limit.



Olli Manner  
Editor-in-Chief  
President, CEO



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# Ship operability analysis



– ensuring passenger safety and comfort

*Passenger and crew safety are primary concerns in modern shipbuilding. In addition to continued strong cruise industry growth, shipowners pay special attention to passenger and crew comfort, enjoyment on-board and smooth operation. This places limits on ship behaviour at sea and on permissible vibration and acceleration levels in the most critical parts of the ship. Sophisticated operability studies for specific routes and navigational parameters can provide a good picture of the expected level of passenger/crew comfort in specific operational conditions.*



Image courtesy of RCCL

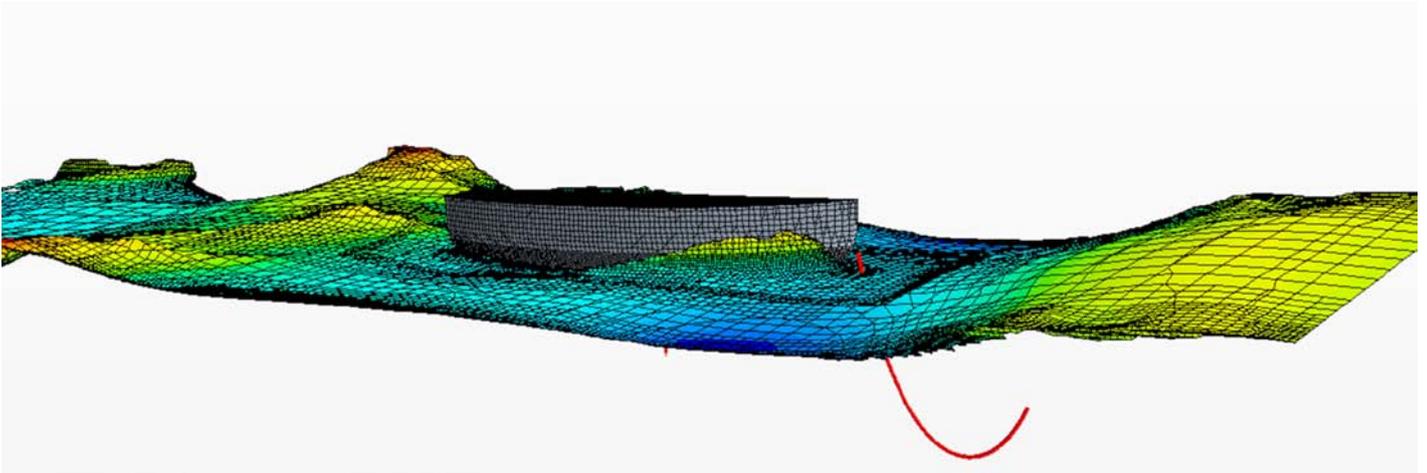
**S**hip operability analysis should be performed to estimate seakeeping performance as an essential criterion for overall passenger comfort and/or crew operability in specific weather conditions.

### Ship operability factors and limiting criteria

Ship operability is estimated by using known wave statistics, routes and ship performance. It is of great interest to operators and designers alike to know the percentage of time a vessel's motions or accelerations remain within permissible levels in a given geographical area.

In practice this means calculating the probability of not exceeding given criteria at defined positions onboard for each leg of the ship route, and combining wind and wave conditions (based on statistical sea scatter diagrams) with the ship course, hull form, cruising speed and behavioural inputs. The impact of stabilizing devices, such as fin stabilizers, is also taken into account.

As indicated above, operability shows the probability of not exceeding limiting criteria, in other words, the probability of seakeeping not inducing seasickness, passenger discomfort or insecurity, or negatively affecting normal crew operation under specific conditions. For operators, operability is an indication of future cash flow and can assist them in making investment decisions.



Limiting operability criteria can be based on acceleration, motion and the probability of extreme events: slamming, deck wetness, helicopter operations, environmental forces on the structure, propeller emergence, etc.

### Computing the operability index

In order to compute the operability index as a percentage of time a vessel can carry-out normal working conditions, knowledge of the vessel's motion characteristics, a set of operability criteria and a set of environmental conditions are essential. Thus, the index is computed by evaluating vessel motions against a set of criteria for all sea states in a scatter diagram.

### Floating structure behaviour in different wave conditions

There are multiple methods available to analyse the behaviour of floating structures in different wave conditions. These methods include strip theory, Computational Fluid Dynamics (CFD) and basin model testing.

In strip theory the ship is divided into 20 to 30 cross sections for which the two-dimensional hydromechanics coefficients and existing wave loads are calculated. In order to obtain three-dimensional values, these values are integrated numerically over the ship

length. Finally, the differential equations are solved to obtain motion values. These calculations are performed in the frequency domain.

CFD is modern tool for ship motion calculations. It enables complicated and detailed simulations if sufficient computational resources are available. The simulations can include, e.g., the estimation of accelerations or forces experienced by the ship in ensuring the comfort of passengers, if the mass and inertia moments of the ship are known. In addition, the wave motion and the ship's rolling motion can be simulated.

With the help of CFD analysis it can also be ascertained how much the ship's wing stabilizer reduces the ship's motion. For smaller vessels, for which the effect of the waves is more significant, the trim angle can be simulated. This allows better prevention of vertical swinging. It is similarly possible to analyse green water on decks or structures.

Sea condition data (also for individual routes) is specified according to custom spectra taken from wave height measurements, or by Pierson-Moskowitz, JONSWAP, Bret-Schneider or ITTC spectra for all headings.

### Developing a solution for operability calculation

To calculate precise operability estimations and conduct accurate analyses a large number of parameters and

▲ *The wave motion and a ship's rolling motion can be simulated with Computational Fluid Dynamics (CFD).*

factors that influence ship navigation need to be taken into account.

At Elomatic we set our sights on developing a solution for operability calculation for particular ship parts and locations onboard.

The main input of the analysis is RMS accelerations in three directions (x, y, z), which can be calculated using one of the aforementioned methods. Ship speed and heading angles have a great impact on these values, and so do stabilizing devices; they can be activated to improve overall operability.

It is important to consider and analyse the heading which causes the highest accelerations. For greater precision, ship routes (from port to port) are divided into small segments (legs) where the ship course and speed are constant. The calculations must be made for each leg of operability to get the final average value for the complete route.

Depending on the purpose of the operability analysis, various criteria for permissible acceleration may be used: seasickness, MSI – motion sickness incidence, MII – motion induced interruption, etc.

## CFD allows us to create complicated and detailed vessel motion simulations.

The availability of wave measurements has introduced so-called scatter diagrams, which reflect joint statistics about significant wave heights and average zero-upcrossing periods. Global wave statistics by BMT provide a practical basis for the design of ships. Calculations based on scatter diagrams for every season can also be included in the final results. This provides the shipowner with the option of analysing seasonal impacts and differences during ship operation all year round.

Elomatic engineers have developed a software program (ELOPER) that takes all the above-mentioned parameters into consideration and calculates operability (in %) and down-time periods. The software inputs can be varied: limiting criteria, speed, ship course, route length, scatter diagrams.

### Ensuring comfort on RCCL "North Star" gondola ride

A recent project where these techniques were applied is the Royal Caribbean Cruise Lines' Quantum and Anthem of the Seas. The cruise vessels are equipped with the "North Star", a "gondola" or "platform" suspended from a "crane" on the top deck, which is designed to offer a spectacular view of the ship and her surroundings. The ships will be built by Meyer Werft shipyard in Germany.

Apart from accelerations at the centre of gravity of the ship, local (longitudinal, transversal, vertical) accelerations were calculated for specific gondola positions. Irregular wave conditions and those of the JONSWAP wave spectrum were used in the calculations. Scatter diagrams for certain global areas were also employed.

Elomatic was tasked with reviewing current research and results and, in particular, with analysing the limiting acceleration criteria and proposing limits for maximum passenger comfort during the gondola ride.

The seasonal operability was calculated for each segment of the ship route and presented in easy-to-read graphics. Special attention was paid to gondola down-time and analysis of the system when in use.

The ELOPER software was a useful tool on the project, especially to vary and check input parameters with the customer. It was also used to emphasize the most critical ship headings and positions with the maximum generated acceleration.

The final results were included in a forecast booklet for all year round cruising and comfortable gondola rides.

### About the authors



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Ivan Maksić joined Elomatic in 2007 as a Naval Architect at the Elomatic Turku office on the Oasis of the Seas project. He specializes in ship behaviour in different wave conditions and seakeeping, ship outfitting and piping, business development and project management. From 2008, he has worked as Manager of the Elomatic Serbia office. Before joining Elomatic, he worked at Vik-Sandvik Norway as a ship outfitting engineer and at the Serbian Academy of Science and Arts as a research engineer where he received an internationally recognized award for his research work.

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Patrik Rautaheimo has worked in seakeeping and hydrodynamics for big cruise ships as well as in risk management related to the commercial and technical performance of all ship systems in the world's biggest cruise ship project. He has worked as a shipyard engineering director both in Germany and Finland. He has extensive experience in ships and shipbuilding. Currently Mr Rautaheimo is responsible for the Elomatic's Marine Business and heads the company's consulting & engineering unit. He works at the Elomatic Turku office.

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## Remote monitoring in oil fields

*Remote monitoring has been used in oil fields for decades already, but has nevertheless remained a hot talking point. Ideally monitoring should cover the entire oil field from the well all the way to the treatment facility. It should allow the operator to optimize production and minimize costs. The increasing remoteness of oil fields and ever stringent environmental regulations place increasing demands on monitoring systems.*

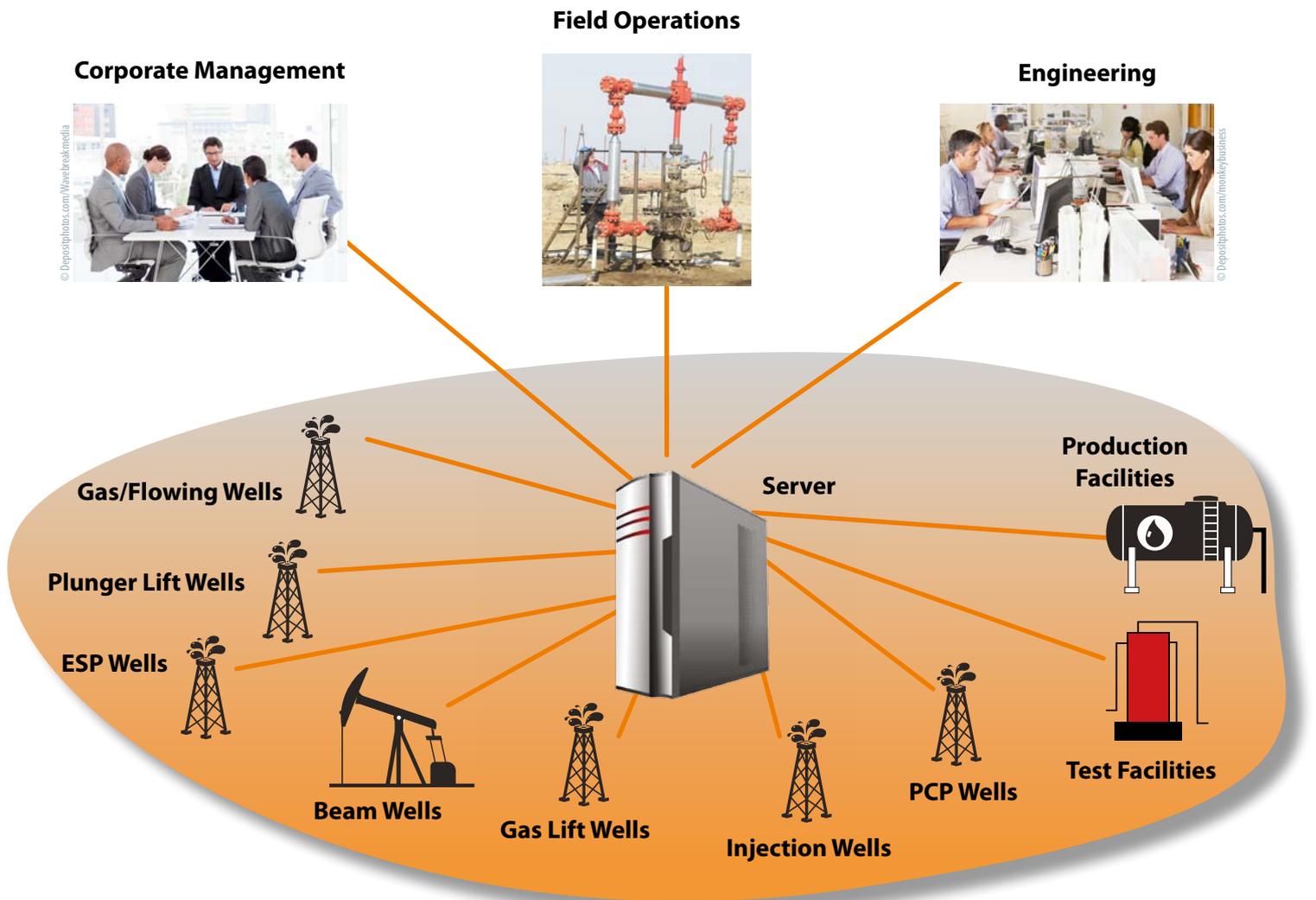
This article provides a brief overview of onshore remote monitoring in FSU (Former Soviet Union) areas and looks in more detail at how remote monitoring is used in oil production.

The West and East have approached the development of remote monitoring use in oil fields differently. In Western countries oil and gas producers are mainly privately-owned and each company has its own strategy with regards operational environment development. In the East most oil companies are government-owned and have long-term strategies and operating models, which means that the

introduction of new technology is slower, but in a way more all-encompassing than in the West.

It is not true that no modern technology is used in FSU oil fields today. In reality, most oil fields in the FSU areas already have several monitoring systems, but the problem is that these systems do not communicate with each other and work as individual units. For oil field monitoring service providers FSU countries provide an attractive market as there is growing demand for comprehensive monitoring systems and production optimization.

◀ FloWQ jet pump production system



**Oil field structure and monitoring points**

A working oil field has several points that need to be monitored (See diagram 1). In order to get a better overall picture of the oil fields and their monitoring points it is useful to divide the fields into three parts as follows:

**1. Wellhead**

Depending on the production method used the type of data measured varies a lot. Self-flowing wells require only minor monitoring, but as soon as the well is operated with artificial lift the equip-

ment used needs to be monitored and maintained. The most commonly used artificial lift methods are Rod Lift, Gas lift, ESP, Jet Pump and Plunger Lift. In some cases the reservoir characteristics are also measured with downhole monitoring.

**2. Pipeline network**

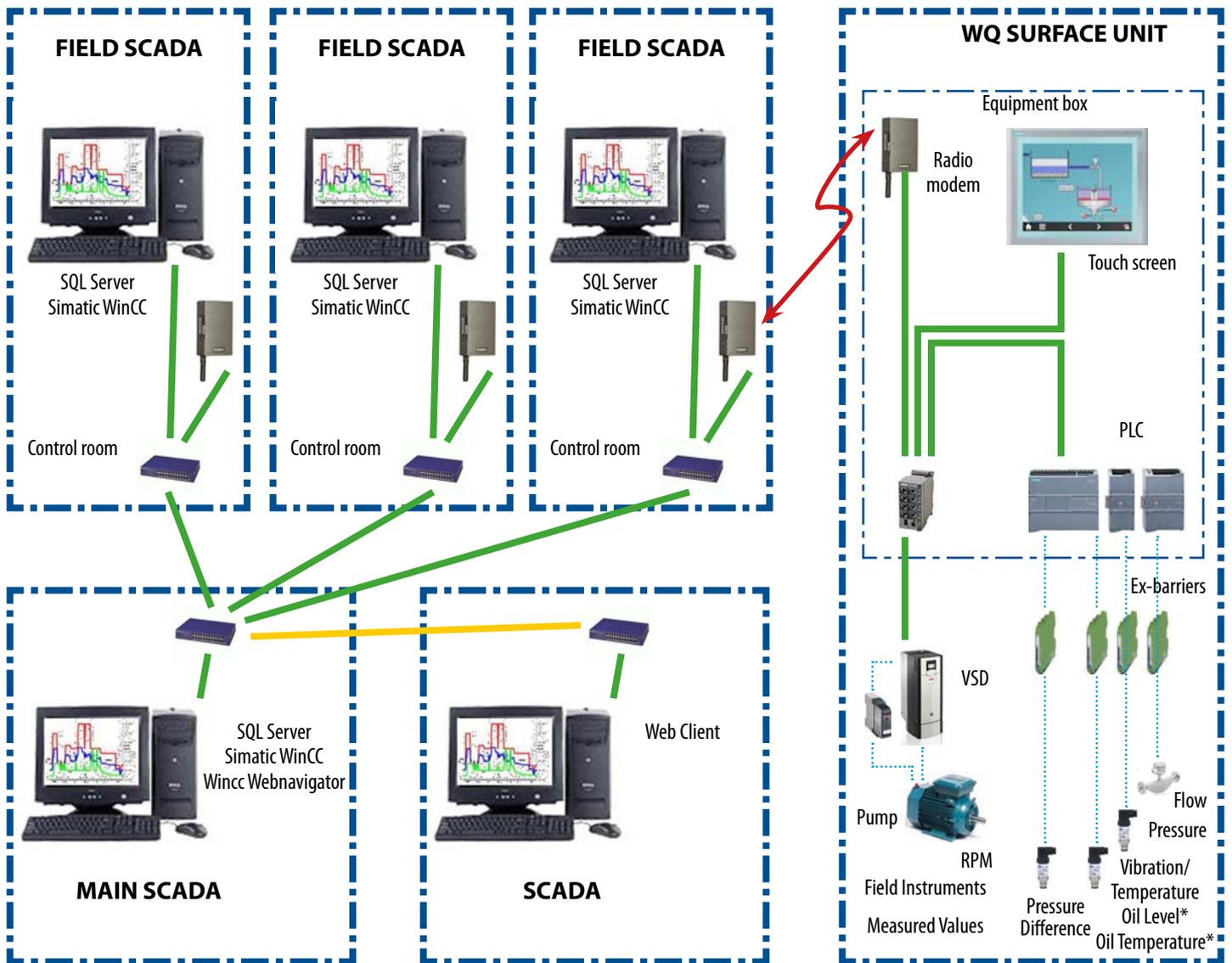
Each well is connected to a collector with a pipeline. A remote well normally has several kilometers of pipeline that connects it to the crude oil treatment facility.

**3. Crude oil treatment facility**

Includes separation, heating, dehy-

▲ *Diagram 1. General diagram of all-encompassing oil field remote monitoring*

dration, stabilization, storage, metering and pumping. The collector gathers the production from the wells and separates the oil, gas and water. Each oil field normally has several crude oil treatment facilities.



## Wellquip monitoring system

Wellquip Ltd's technology is based on a jet pump system. The product family that can handle most oil field production challenges. Adding equipment such as heaters, solid knock-outs, chemical injection and pipe watches to the basic system allows for operation in harsh environments.

Wellquip also has a development program to analyze well production data to optimize the jet pump system for increased production. See diagram 2 for a detailed overview of the FLOWQ control and monitoring system.

▲ Diagram 2. Detailed diagram for remote monitoring of FloWQ Jet Pump System

SCADA = Supervisory Control And Data Acquisition

— Ethernet

— Optical Ethernet

↔ Radio comm.

## Increased remoteness and stringent environmental requirements place greater demands on the monitoring system.

### Monitoring the entire oil field

From a monitoring service supplier perspective the best approach is a simple one: the operator requires a system for remote monitoring of the entire oil field from the wellhead all the way up to the crude oil treatment facility. They also require assistance in developing their maintenance programs and in optimizing well production.

With the help of a comprehensive overall picture of the entire field, the operator gains a clearer understanding of the many problems and challenges faced. This assists the operator to develop the oil fields in order to achieve higher and more stable production levels, as well as prolonging the wells' production life cycles.

### Overcoming challenges faced by producers

Oil and gas producers always want to produce more at lower operating cost levels. In order to achieve this goal they need to overcome many challenges. Nowadays oil is produced in more remotely located oil fields than before and environmental requirements are much more demanding than before.

The challenges faced by producers include heavy oil that needs heating, paraffin problems that require chemical injection, solid production problems and extremely cold environments that limit maintenance. HSE requirements stemming from isolated locations and possible H<sub>2</sub>S problems should also not be underestimated.

A key factor in producing oil and gas in fields that face one or more of the aforementioned challenges is the selection of an optimal artificial lift system; with the correct supporting equipment that ensures that the produced liquids reach the crude oil treatment facility. In order to control this whole process cost effectively and safely the producer needs a reliable remote monitoring system. See the info box and diagram 2 for how Wellquip Ltd has tackled these challenges.

A well-designed monitoring system monitors the production process for the field operator, but also provides the management team with proper production reports in real time. It should maintain service records and follow up execution of planned maintenance plans.

With an up-to-date service history available, management can do much more cost effective planning as the maintenance plan and chemical injection amounts are optimized for each well separately. Having better overall information available and understanding the process is to key to produce more with less downtime.

### Remote monitoring outlook good

The outlook for remote monitoring systems looks bright. There is demand for centrally operated oil fields and the market is still developing. The technology and customers are ready for a field-wide approach to remote monitoring; as service suppliers we just need to ensure that we are a part of it.

### About the Author



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Pekka Kaunisto was appointed as Director of Production Systems and Services at Wellquip\* in 2011. He has worked in the oil and gas sector since 2007. After being involved in offshore modernization projects in Russia, Kaunisto acted as the Wellquip company representative in Houston Texas. In the USA he became familiar with artificial lift and, in particular, jet pumping. After returning to Finland he mainly worked in project management, product management and purchasing. Currently he is responsible for the Production Systems business area, where his responsibilities are EPC turnkey deliveries, technical support, business development and product development. The majority of his work experience stems from international operations.

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*Wellquip Ltd is an affiliate company of Elomatic.*



# Modern tools ease environmental retrofits and reduce risks

*In the autumn of 2014 several more states have ratified the International Ballast Water Management (BWM) Convention. As a result the 35% world fleet tonnage requirement for the convention to enter into force is closer than ever. Once ratified, shipowners that have delayed making BWM preparations and a decision may face a shortage of service and equipment suppliers. Making a timely decision will be key in ensuring compliance. Modern tools such as laser scanning and computational fluid dynamics can be employed to expedite and ease BWM retrofits while also reducing associated risks.*

In addition to the impending ratification of the BWM Convention the requirements of the EU sulphur directive also enter into force on 1.1.2015. The sulphur directive sets, among others, requirements for the pH value of wash water from open loop scrubbers.

## Laser scanning eases decision making

The space challenge remains a significant issue when considering a retrofit installation of ballast water treatment systems as well as other environmental technology on existing ships. This holds true even if equipment suppliers have been able to develop the technologies to significantly reduce the system footprint.

Numerous environmental technology retrofit cases have shown that laser scanning is an extremely valuable tool in the early design stage of retrofits.

Point clouds generated by laser scanners can be used in combination with powerful 3D modelling tools to compare alternative retrofit solutions (see Picture 1). This significantly facilitates the decision making process. The arrangement for the chosen solution can thus be optimized and at the same time the direct inputs required for making the accurate detail designs needed for pre-fabrication and installation are created.

Generally the laser scanning required for a ballast water retrofit project takes anything from one to two days and should preferably be conducted while in port. Tankers should

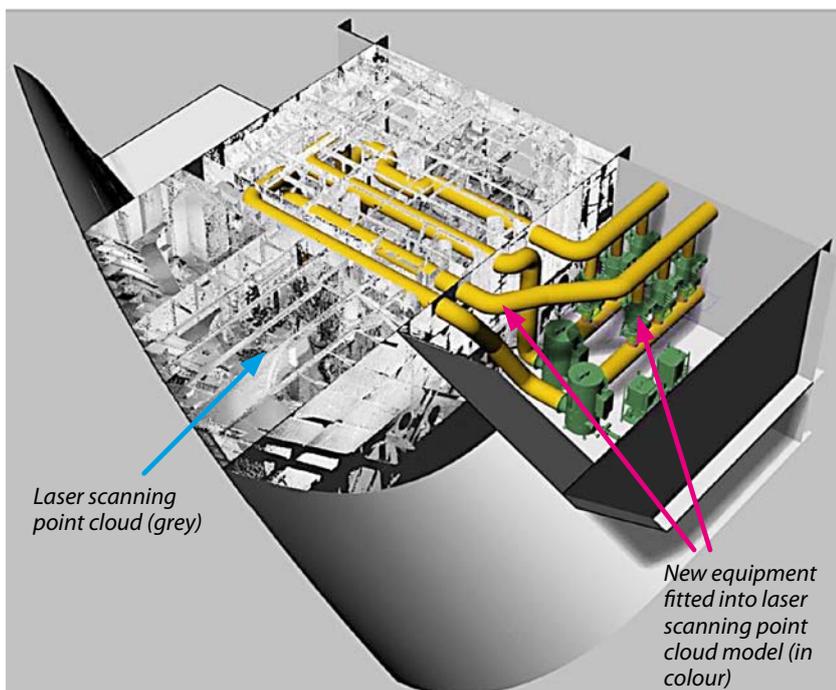
always be scanned while in dry dock and spaces should be gas free in order to avoid timely and costly Ex-scanning.

On a BWM retrofit project additional components such as filters and UV reactors commonly have to be integrated with existing ballast water systems. The limited space available means that sharp pipe bends are often needed, which in turn can lead to significant pressure drops and reduced or uneven water flows if not designed correctly.

Carrying out CFD calculations at an early design stage provides designers with a clear indication of the flow elements of the intended arrangement (see Picture 2). This allows them to make the necessary corrections and improvements before any installation takes place.

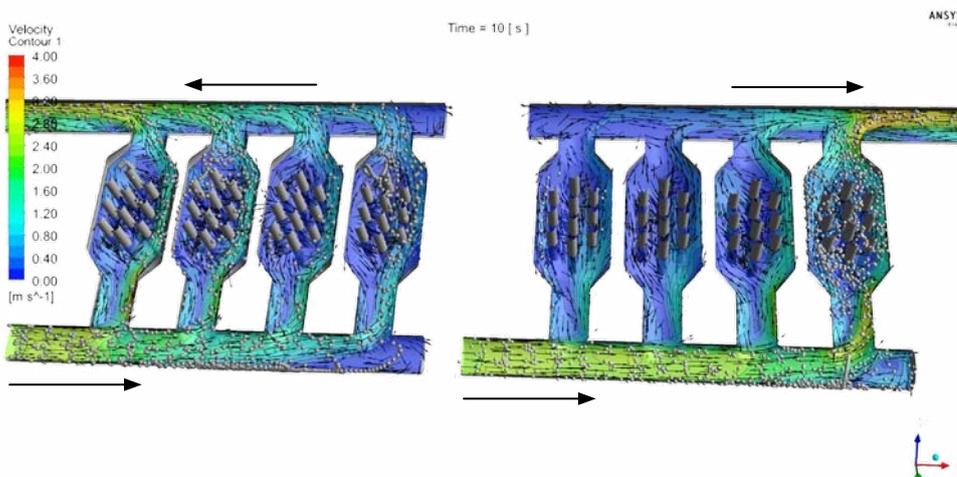
## CFD employed to verify wash water pH values

In order to meet the EU sulphur directive various types of scrubbers are currently being installed on a number of ships operating in Sulphur Emission Control Areas (SECA). The sulphur directive sets requirements, among others, for wash water pH values from



Picture 1. An example of utilizing scanning results from a 106.000 tdw crude/product carrier. The ballast pumps were 1 x 3000 m<sup>3</sup>/h and 1 x 2500 m<sup>3</sup>/h. Using point clouds in combination with advanced 3D modelling tools allows different alternative retrofit solutions to be easily compared.

Picture 2. The CFD calculations show that the BWM solution on the left creates a much more even flow through the four UV reactors than the solution on the right, thus ensuring a more reliable functionality of the installation.



open loop scrubbers and how these levels should be verified.

Since verification has proven extremely difficult, if not impossible in practice, significant efforts are currently being made in the European Sustainable Shipping Forum (ESSF) working groups to solve this issue. CFD calculations have been proposed as a reliable and efficient verification solution.

### A small investment can lead to significant savings

The costs for both laser scanning and CFD calculations are minor in relation

to the overall retrofit investment, but can produce significant savings by reducing risks and eliminating errors.

Many ship owners are currently waiting to the last minute to act. This may lead to a shortage of design and engineering capacity due to the expected bottleneck.

Laser scanning should be carried out in good time in order to create an exact starting point which enables a controlled and systematic design process. Timely and correct implementation of laser scanning can lead to significant long run cost savings.

### About the author



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Mr Bachér's experience covers competences from technical development and project management to marine management of the most advanced passenger vessel fleet in the Baltic. He has been a pioneer in developing environmental management for the maritime industry and in adopting environmental impact reducing technology on a number of ships. Henrik Bachér joined Elomatic in late 2008 as Vice President, Consulting & Engineering.

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# Risk-based validation

– *knowing what and how much to validate*

*In times of increased competitiveness and ever more stringent regulatory directives and norms, pharmaceutical companies have to continually optimize their operations; reduce operating costs and increase efficiency. An effective risk-based validation approach saves time and effort spent on validation and can assist organizations to achieve these optimization goals.*



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**T**he FDA defines validation as “establishing documented evidence that provides a high degree of assurance that a specific process or system will consistently produce a product; meeting its predefined specifications and quality aspects.” The phrase “high degree of assurance” enables companies to regulate the appropriate level of inspection for the system being implemented themselves.

The traditional method or approach to validation involves the assessment of each system requirement in the same comprehensive manner without taking into account how much risk a failure of the function would add to the patient, product, machine and operator. All functions are systematically tested, which may result in testing of positive and negative scenarios to ensure all oversight points are equally and exhaustively tested.

This approach ensures that every requirement is thoroughly verified, but experience has shown that it causes unnecessary delays in the validation process of the system; it usually produces tonnes of paper to review and delays further release of critical systems.

By implementing a risk-based validation solution the mountains of paperwork can be avoided. See the info box on page 16 for a definition of risk.

## Basic risk assessment steps

A risk assessment exercise essentially consists of the following steps.

1

### What might go wrong?

*Risk Identification:*

- What components/functions might fail within the system.

*Risk Analysis:*

- Components of the risk associated with failure can be commercial, technical or regulatory.

3

### How severe are the consequences?

*Risk Prioritization:*

Based on the evaluation, the various risk elements can be prioritized as 'High', 'Medium' or 'Low' or 'No Risk'

2

### What is the probability that it will fail?

*Risk Evaluation:*

Calculated on the basis of the severity of impact, probability of occurring and detectability associated with the risk

4

### How to minimize consequences?

*Risk Mitigation Tactics:*

Decide on the precautions to counter risk. The risk assessment exercise output may be a quantitative estimate of risk (Risk Score), depending on the risk evaluation methodology, or a qualitative description of a risk range (using qualitative descriptors: "High", "Medium", or "Low" or "No Risk").

## Implementing risk-based validation

Risk-based validation is now a commonly heard expression in the pharmaceutical industry, but the methods to implement it are not clear. An effective risk-based validation process can reduce the overall time and effort spent on validation, thereby increasing productivity and profitability within the company.

Risks could also be assessed at the functional requirement level, thereby focusing validation efforts on those system functions that are at high risk with respect to data security, system security, operator safety and product and patient safety.

Risk assessments are conducted to determine the risk level of the requirements in the system, in the case of adverse events related to the requirements. The risk levels help to determine the scale of testing that is needed to be performed on that function. This

requires the ability to approach the requirements at a system-level, in order to identify the broader risks and to identify the specific risks concerning that function at a micro-level.

It is also important to ensure individuals from various cross-functional disciplines within an organization participate in the process. This ensures that risks are assessed from

commercial, technical, regulatory and other aspects. This is an acceptable investment in view of the validation efforts saved thereafter.

## Getting started with a risk-based approach

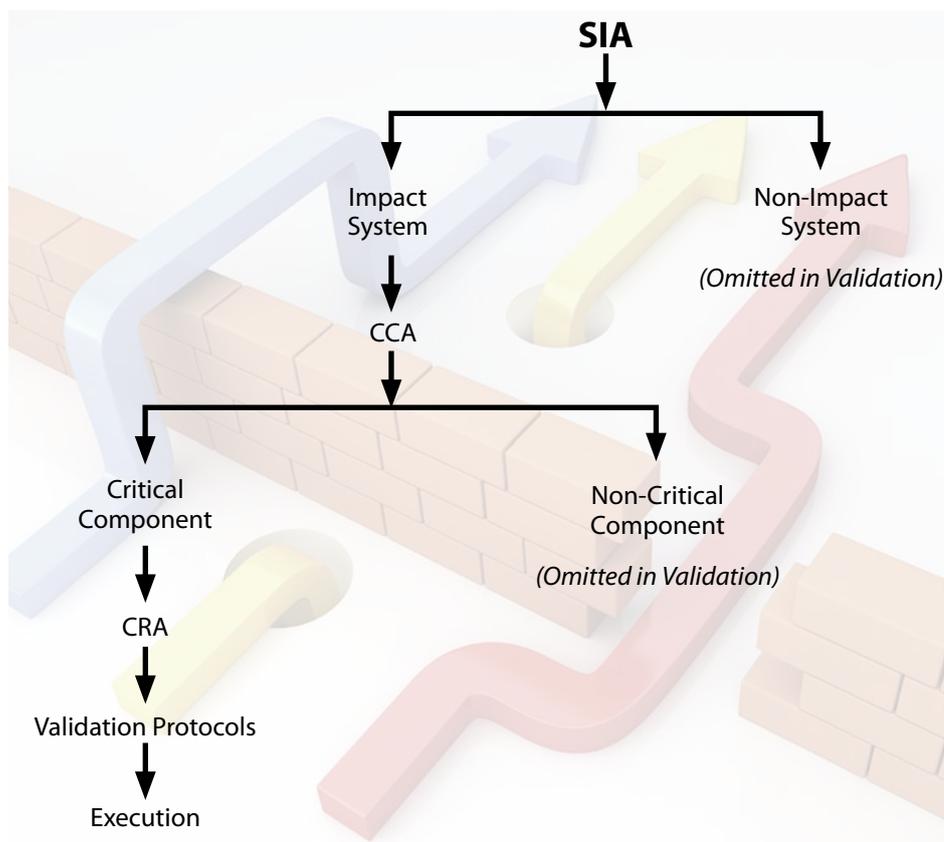
Diagram 1 provides an overview of the risk-based validation approach and the steps involved.

The first step is the System Impact Assessment (SIA) where the individual system is assessed for its impact on the product, operator safety and patient safety. The systems are divided into two groups as either having 'No impact' or 'Impact System'.

This is followed by the Component Criticality Assessment (CCA). Based on the SIA, only impact systems are considered for validation and component criticality assessment is done for 'Impact System' only. This allows the

## Risk definition

*From the Pharmaceutical Industry's perspective, risk can be defined as the resultant of the probability of occurrence of harm and the severity of that harm to the company and its shareholders and employees, regulatory agencies, producing systems and the population at large.*



▲ *Diagram 1. An overview of risk-based validation*

system components to be divided into 'Critical & Non Critical Components' based on factors such as data security, system security, operators safety and product and patient safety.

Only 'Critical Components' are considered for validation and are subjected to a Component Risk Assessment (CRA). Based on the SIA, CCA and CRA, validation protocols are generated and executed.

Validation protocols are then written for Impact systems only. Each validation protocol includes only the critical components of the Impact Systems. The protocol contains the parameters on which basis it is segregated as a critical component.

### The advantages of adopting a risk-based validation approach

Risk-based validation enables organizations to focus more closely on the

areas of the process or system that pose the greatest threat to product quality and patient safety, in the event of a failure.

It reduces the cost of validation within the organization, and as a result throughout the industry. An industry-wide shift towards a risk-based validation approach, as opposed to a conventional validation approach, would allow innovations to be introduced without adversely affecting product quality or patient safety.

#### About the authors



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Mr Gupta heads the most diverse department in Elomatic India where he manages the process & validation discipline. With a degree in Biochemical Engineering from HBTI, Kanpur and a Masters in Chemical Engineering from the Indian Institute of Technology (IIT) in Kharagpur, he possesses extensive expertise in handling various process upstream and downstream operations and aseptic processes. He has over 5 years' experience in process engineering of small to large scale operations. In the past he worked as a process engineer at Lupin and Biocon.

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# Innovation: an interdisciplinary team effort

– *case: urban farming*

**Text:** Kalevi Rantanen



◀ Elomatic FEI team members Mika Patrakka (right) and Jukka Mikkonen in their workshop.

*Urban Farming is an irresistible concept. You can order the due date of your lettuce in advance and even follow the lettuce's progress inside the growth incubator's clean micro-ecosystem on your mobile device. The only thing more fascinating than this is the methods used by the concept developers. The concept was devised in a few months with the help of innovative thinking tools and by turning ideas inside-out. The story behind the concept is an indication of what Front End of Innovation (FEI) is at its best.*

A few years ago the right people met by chance.

"I was at the Virola greenhouse in Kangasala talking to the owners, the Oksanens, about this and that. Among others, we also discussed LED lighting as a promising technology. Timo Oksanen had an idea what kind of LED light could be used in greenhouses. The problem was that the available LED lights at the time were not optimized for plant growth", says Juha Koriseva from Koriseva Oy.

This is where Elomatic's Pekka Koivukunnas joins the story. At the time he was running his own innovation company.

"I started working with Pekka to come up with ideas for a LED light and quite quickly the first prototype was created", Koriseva continues.

After the initial development work with Koivukunnas, Koriseva continued developing the light. It became apparent that that it could not be manufactured cost-efficiently from Finnish parts



© Depositphotos.com/baranq

and as a result suitable components were sourced from Asia.

After two years of development work the first lighting solution was ready for greenhouse testing. The results were good and the first sales were made.

The story could ordinarily end here, but Koriseva was thinking about crop farming on a global scale.

Koriseva approached Elomatic for help with his internationalization plans. As it so happens, his early LED light development colleague, Pekka Koivukunnas, had in the meantime started working at Elomatic as an innovation expert.

While discussing cooperation generally, a range of other topics and ideas were covered. These included using a greenhouse application to control lighting and different automated warehousing systems. Elomatic's Rami Raute suggested that a self-sufficient energy and nutrient cycle should be considered. It was at this stage that Koivukunnas came up with the idea of building a closed module for crop farming. As

such, the idea for a plant factory had been formed.

"It is important to remember that innovation processes include combining a lot of spontaneous elements", says Koivukunnas.

A joint development project between Elomatic and Koriseva was started in the summer of 2014 based on the different discussions. Along the way it was suggested that a prototype plant factory could be built in an abandoned industrial hall.

The actual factories can be built where there is demand, e.g. in the downtown areas of large cities. The modules can be stacked on top of each other; from there the term Vertical Farming. Future cities can be built around plant factories. Container farming solutions have been on the market for some time, which raises the question: What is new in the Vertical Farming concept?

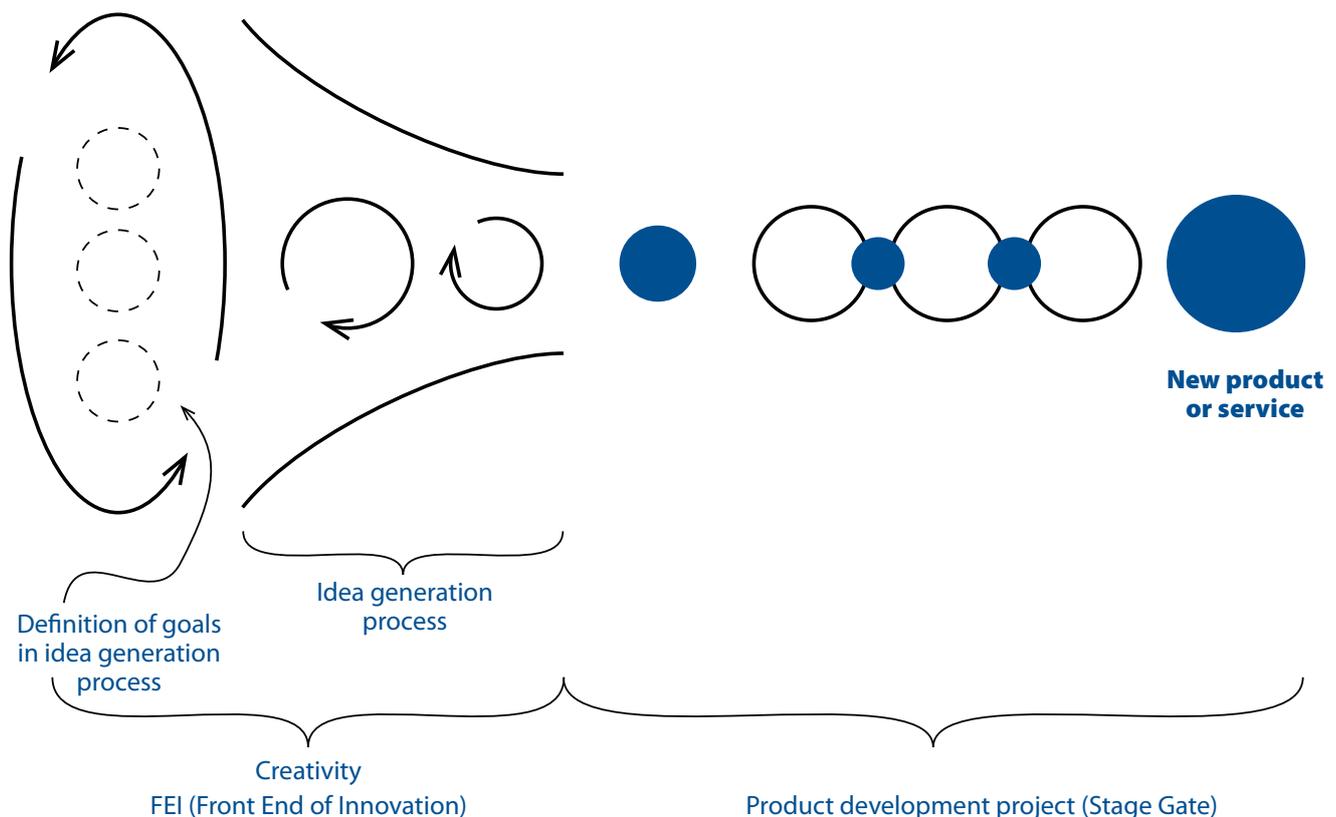
According to Koriseva the big picture is missing in discussions about crop farming.

▲ *In the urban farming concept a person who orders, e.g. lettuce can follow its growth online and chat with the crops growers.*

"There is a lack of interdisciplinary cooperation and all opportunities have not been taken advantage of. In Vertical Farming we brought all kinds of viewpoints on board. The innovation process has been very open. Elomatic played a key role here with their development and design expertise. A small company cannot develop international business operations on its own", explains Koriseva.

### **Don't always invent, modify a lot**

At Elomatic Pekka Koivukunnas, Jukka Mikkonen, Mika Patrakka and Rami Raute form an innovation team, i.e. a FEI team. It is focused on the Front End of Innovation, which precedes



systematic research and development work (Stage Gate, see diagram above).

The team members stress that they don't lecture, but rather invent new things. Their ability to develop such a wide range of diverging technologies and services is based on the similarities between otherwise very different innovations.

When they speak about lettuce production, they say something important about everything. The plant factory example lifts the veil of mysticism that surrounds the FEI team's operations.

Pekka Koivukunnas indicates that what is new here is the fact that they are bringing technology from other industrial sectors to the greenhouse.

"In a way the whole concept has been reinvented, we are not just adding LED lighting to a current greenhouse. Our strength in Finland is the development of new innovative concepts that combine several different technologies and know-how areas".

According to Mika Patrakka application needs to be highlighted; linking

elements with each other, even matters that do not seem related at all need to be linked.

Simon Litvin, a leading developer of the TRIZ theory related to solving technical problems, once said "Adapt Existing solutions, don't always invent".

In recent years Litvin and his Boston-based team have focused on innovation. According to them inventing and managing inventions is tough if you start from zero. It is much faster if existing technology is transferred from another field and modified skilfully. Space technology has, for example, been applied in nappy production and construction technologies in bread baking.

### Flip it around

Another element that is new in the Vertical Farming concept is that the starting point is warehousing technology, not production technology. This means a warehouse that is not passive, but active, where the stored items are

▲ *The beginning of an innovation process with FEI and Stage Gate.*

self-sufficient during the storage period.

In traditional solutions water, nutrients and other supplies are taken to the plant. At the same time controllers (human beings) also go to the plants.

"In our concept the plants are brought to the different actors. We have an intelligent filling station where everything required for the container and plants is done. After that the container is taken to the warehouse. Light, water circulation, CO<sub>2</sub> administration etc. are all included in the container", explains Koivukunnas.

Here we recognize innovation principle thirteen as proposed by TRIZ founder Genrich Altshuller: do the opposite.

## *It's more interesting when you create new operational models and break down traditional business models.*

### Think business and think big

The ideal solution is another TRIZ notion. One should aim for extremely good technology and business, even if the ideal is only realized 99%.

The name of the FEI team's concept has also been processed radically. They talk rather of Urban Farming than Vertical Farming, which is only one technological aspect. This is an indication of a focus on entire business areas, not only technologies.

"Innovations are more interesting when you create new operational models and break down traditional business models", says Mika Patrakka. "It is not always about new technologies, but rather about creating new business models and even industrial revolutions. Digitilization is the key to the birth of new industries"

There is still room for LED technology development. In the 2000s Physicist and LED Specialist, Roland Haitz

formulated a rule of thumb for LED development. He predicted that every ten years the price of LED lighting per lumen will be cut by 90%.

The closed factory is insulated from weather and climate change and, therefore, can be located practically almost anywhere where there are people. Imagination is the only limitation.

Production is next to the customer, but the business can be global. The plant factory can be run through a data network from the other side of the world.

Familiar models are broken down in many ways. In the long run the automated technology and way of working can be replicated on a franchise basis. Entrepreneurs who join the business don't need to be farmers. This can actually be an advantage, as a long tradition in any field can also deter renewal.

The modern technology used retains the human element to farming and creates new interactivity; the end

user orders the lettuce and can follow its growth. He/she can also see who is producing the lettuce and chat with them. Plant factory communities can be created that develop new ideas and schools can have their own teaching containers.

### Upward spiral of innovations

Good ideas generate questions and solutions. Can plants that are pollinated by insects be grown in containers? Does this include an adjacent pollination container and honey factory? Bee pollination has, in fact, already been tried in greenhouses.

In 2014 The Chiba University in Japan published the results of a feasibility study on rice factory farming. According to the study it would, among others, increase sales per hectare a hundred times and allow elderly and retarded people to work in the farming industry. It also identified some problems, such as the high use of energy and the fact that hazardous substances can become enriched in closed circuits, as well as the lack of automation.

Problems can be approached in two different ways. One could say: "You see, this is going nowhere". Another approach would be to turn the problems into new innovations. How can we reduce energy consumption? How can we optimize the material cycle? Crop farming just received a development boost.

What is needed are plants suited to containers. What stops us from growing potatoes in containers? Potato blight would not be a problem and "new potatoes" could be cultivated all year round. If rice can be grown in a plant factory, why not wheat?

## Innovation principles and examples

### Case: urban farming

1. Loan from other fields and modify, don't always invent: warehousing technology for use in greenhouses
2. Turn it around: humans and robots in one place, move the plants around
3. Think big: the whole crop farming business
4. Search for forgotten resources: abandoned industrial areas
5. Take advantage of emotions too: anger is also a resource



### With know-how and emotion

The innovation team comes up with ideas when needed and acts analytically when needed. The work requires patience and courage, such as the courage to allocate sufficient time to an idea in the initial phases. The motto of the Elomatic FEI team is that the “slowest path is sometimes the fastest”.

According to Jukka Mikkonen the FEI team’s ability to innovatively connect different know-how areas, services and technologies is a key strength. Positively motivated and innovative people cooperate openly. When supported wisely by process management and the ability to apply different innovative working methods, this results in success stories.

Koivukunnas highlights emotions and how to benefit from them. “At the first level emotions are banned. In engineering organisations we are generally at this level. At higher levels the classification of emotions as negative or positive loses meaning and all

emotions, even anger, are benefited from”.

Koivukunnas gives a classic example of jealousy: “In the USA when a neighbour gets a fancy new car (or anything else), his neighbour compliments him and says that he would like to get the same (or even better). In Finland we try to put a spanner in the works. One can find similar examples with regards anger; when you are angry you swear that you will do something and then you also stubbornly do so. With knowledge also these traditionally negative values can be benefited from in a constructive manner”.

### The journey continues

Soon the plant factory project will advance to systematic product development. New problems have to be solved and commercialization has not traditionally been a Finnish strength.

As they proceed towards a commercialized product the way of working

▲ *Mika Patrakka believes that in a true innovation process it is crucial to link different and even seemingly unrelated elements.*

will have to change partly. Openness will, e.g., have to be curtailed. Open innovation brings IPR problems to mind. How can the solutions be safeguarded? “Open innovation and funding replace each other in a way”, says Koriseva.

“When an investor gets interested, we will need to solve IPR issues. Then our way of working can become more secretive, but also more focused on generating profits. In the beginning open innovation is also required due to a lack of other resources.”

The turning point where an investor joins the fray could be near.

“When one module is up and running and producing lettuce, investors may have seen enough to make their investment decisions.”



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# Radiative cooling from the sky

– ongoing research points to significant energy savings

*The sky should not only be seen as a potential source of energy in the form of sunlight, but also as a low-temperature reservoir for cooling. This cooling can be obtained through a longwave radiative heat exchange between a radiator, located on the surface of the earth, and the cold air masses above it. Passive cooling methods such as radiative cooling can significantly reduce dependence on carbon-based fuels.*

**A**ir-conditioning produced by a traditional vapor compression cycle is an energy demanding operation. Today 10–15% of the world's electricity is used for cooling and this percentage is

increasing; for instance, air-conditioning energy needs in Finland are expected to grow tenfold by 2050.

This electricity is mostly generated from carbon-based fuels and thus contributes to climate change via the greenhouse effect. By using passive cooling methods is it possible to avoid, or at least reduce, the need for vapor compression cooling. A significant amount of cooling could be obtained by using the sky as an alternative thermal reservoir.

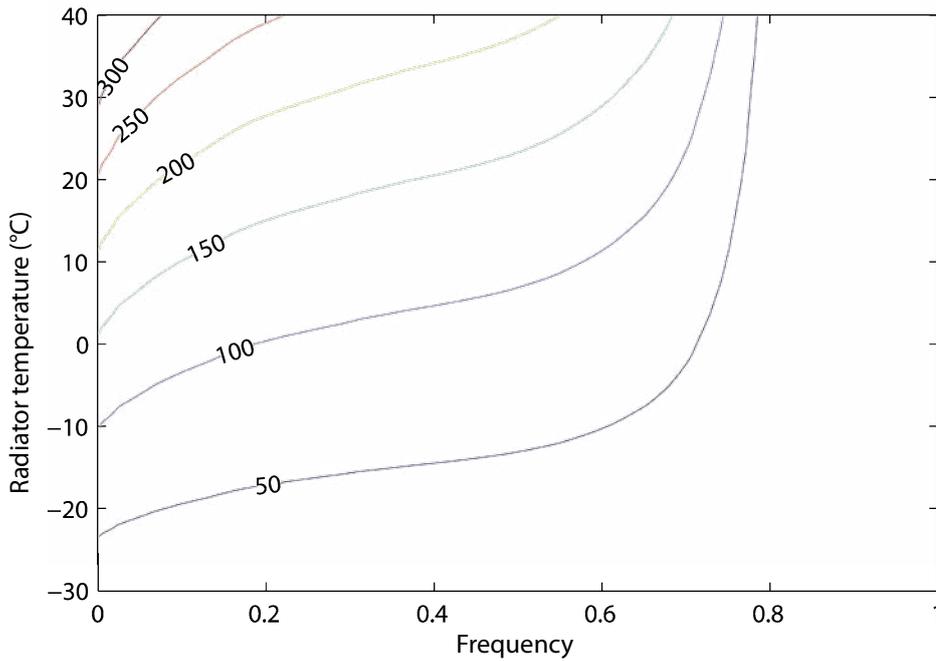
## Radiative coolers serve diverse cooling needs

Radiative coolers can achieve savings not only for air-conditioning, but also for the refrigeration of foodstuffs. The

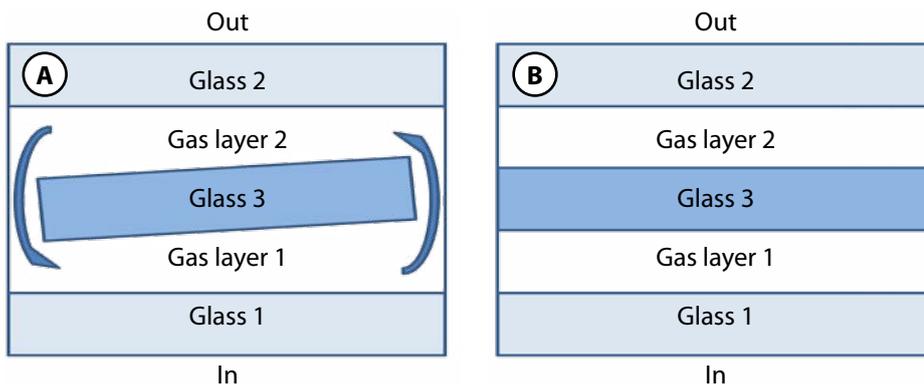
radiative coolers could also be used as solar collectors when sufficient cooling is not needed or attainable. Radiative cooling, yet to be exploited for cooling in northern Europe, can be used for air-conditioning and for cooling to even lower temperatures.

With the use of meteorological data obtained from the Finnish Meteorological Institute, the heat exchange from a flat plate radiator has been modelled.

Figure 1 presents the cumulative frequency distribution at varying radiator temperatures. It describes for what length of time, a specific heat transfer could have been achieved, for a defined radiator temperature during the two-year measurement period. It shows, for example, that a heat transfer of 50 W/m<sup>2</sup> could have been attained 50% of the time at a radiator



◀ Figure 1. Cumulative frequency distribution of radiative heat exchange in  $W/m^2$  at different radiator temperatures in Helsinki



◀ Figures 2A & 2B. Conceptual design of the skylight

temperature of  $-12^{\circ}C$ . The results are comparable to the cooling obtained from a PV-cell driving a refrigerator. The biggest differences are that the availability of radiative cooling is higher and that lower temperatures can be reached with the PV-cell hooked to a refrigerator. [1]

There are already commercial products such as paints and roofs that utilize a radiative cooling effect. However, the cooling effect of skylights has been largely overlooked.

### Double-glazed windows control radiative heat flux

With the use of a double-glazed window, of which the inter-glazing space can be filled with a greenhouse gas,

it is possible to control the radiative heat flux from a room (or buildings in general) to the skies. Calculations show that expanding the wavelength range for window material transmittance increases heat fluxes through the system while using greenhouse gasses gives an insulation effect.

However, since cold winters are common in northern Europe, there is a need for a certain amount of insulation. One option would be to pump out the greenhouse gas from the skylight whenever cooling is required and to pump it back in when insulation is again needed. As this pumping is somewhat impractical, an alternative was developed.

### Controllable skylight concept

The controllable skylight has two different operating modes, one for cooling and one for insulation. It consists of two windows made of a transparent material for longwave heat radiation and one of regular silica (opaque to longwave heat radiation).

By filling the volumes between the glass sheets with a so-called participating (greenhouse) gas that both absorbs and emits heat radiation it is possible to provide a room with cooling or thermal insulation when needed in a manageable fashion. In the skylight such a gas works as the heat carrier of the system, when the skylight is in cooling mode (See Figure 2A), and as a heat barrier, when in the insulating mode (See Figure 2B).

This means that when in cooling mode the gas found in gas layer position one will absorb heat from the space (room) located below it. As the gas temperature increases, the gas density increases and it flows to gas layer position two. Here, the gas is cooled down by radiative cooling from the sky, which in turn increases the density of the gas and thus makes it flow back down to gas layer position one. When the skylight is in its insulating mode, the thicknesses and temperature differences are so small that convective swirls will not be formed; consequently, forming an insulating barrier. [2]

### Selection of materials critical

One of the most critical points in this work was the selection of materials. Gases used in similar applications have not worked or are detrimental to

human health and/or the environment. Therefore, another gas is needed that can be used for radiative cooling.

To address this demand, the list kept by the Agency of Environmental Protection (EPA) of gases that possess a global warming potential (GWP), is used. It lists the GWP of different gases with their related atmospheric lifetime. The GWP compares a gas' heating effect in the atmosphere to that of CO<sub>2</sub>.

The gas preferred for the skylight should have a high GWP but disintegrate rapidly if subjected to the elements outside the skylight. From this evaluation, HFC-125 stands out as being suitable for use in windows, but it will, however, presumably also be prohibited in the future. [3]

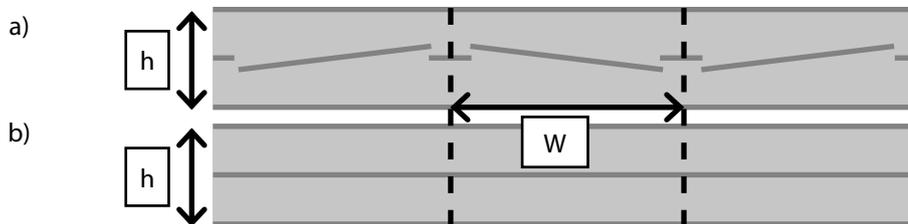
As regular windows are opaque to longwave heat radiation other materials were needed. A low-density polyethylene (LDPE) film was used in preliminary experiments as it is partially transparent to heat radiation at

the required wavelength interval and cheap.

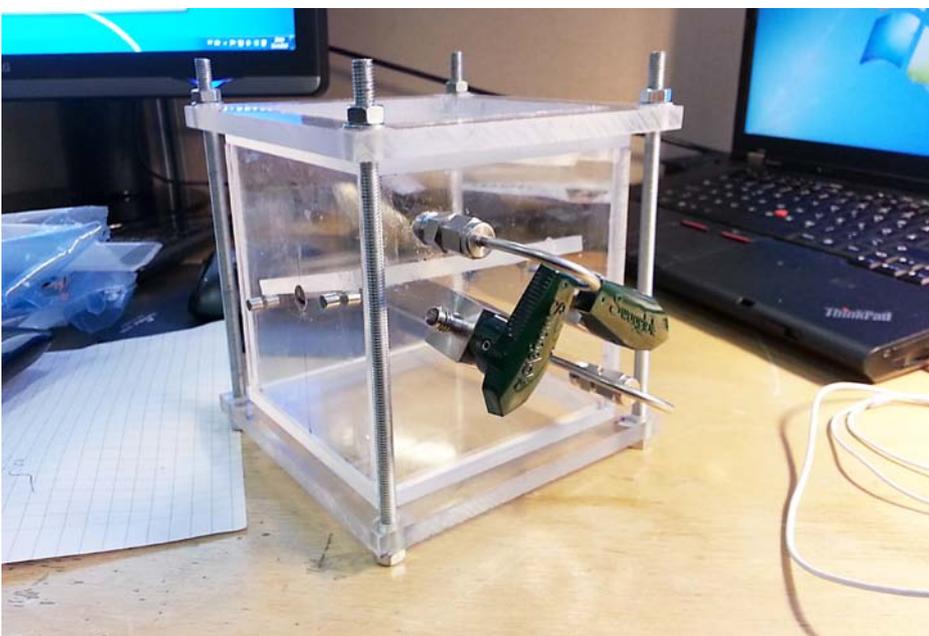
The problem with an LDPE window is that it needs to be thin to be transparent and, therefore, is too fragile to be used in real-life applications. Zinc sulphide (ZnS) was identified as an interesting material with promising properties and thus investigated further. The material was measured to have a transparency of 64% in the 8 to 14 μm interval (the so-called atmospheric window) when 4 mm thick. [4], [3]

### Optimizing the skylight design

Adverse convective cells were observed in skylight simulations for both the cooling and heating cases of the model presented in Figure 2. [5] These cells decrease both the cooling and insulating capacity and should therefore be minimized.



◀ Figure 3. The shutter-type skylight



◀ Concept prototype of the skylight

▶ Figure 4. The results of the optimization. The Pareto front is noted with "o" and the inferior solutions are marked with "+".

The solution was a redesign of the skylight that used a genetic algorithm to optimize the dimensions of the skylight into a shutter-type skylight as presented in Figure 3. This design enables an assembly of the skylight in different sizes without losing either cooling or insulating properties.

The aforementioned optimization has two conflicting objectives; for summer use the cooling needs to be maximized, corresponding to the maximum heat transfer through the window, while for winter use the insulation properties need to be maximized, corresponding to a minimal amount of heat transferred. The variables studied were the skylight width ( $W$ ) and height ( $h$ ) as shown in Figure 3. More variables could be considered; however, this would make the computation time unmanageable.

The results from this optimization are presented in Figure 4, where every point is a separate window with its

dimensions. The circles form a Pareto front, which represents the trade-offs between the conflicting optimization problems.

Due to calculation limitations, the radiative heat transfer was initially excluded from the optimization. Later the radiative heat transfer was calculated for the different designs of the Pareto front. The results indicated that the cooling effect varied between 47 and 53  $W/m^2$  and the insulation effect varied between 22 and 32  $W/m^2$ . [3]

The work was finalized after an experimentation stage. The research results will be published in the coming months in the sixth and final paper of the thesis. [6]

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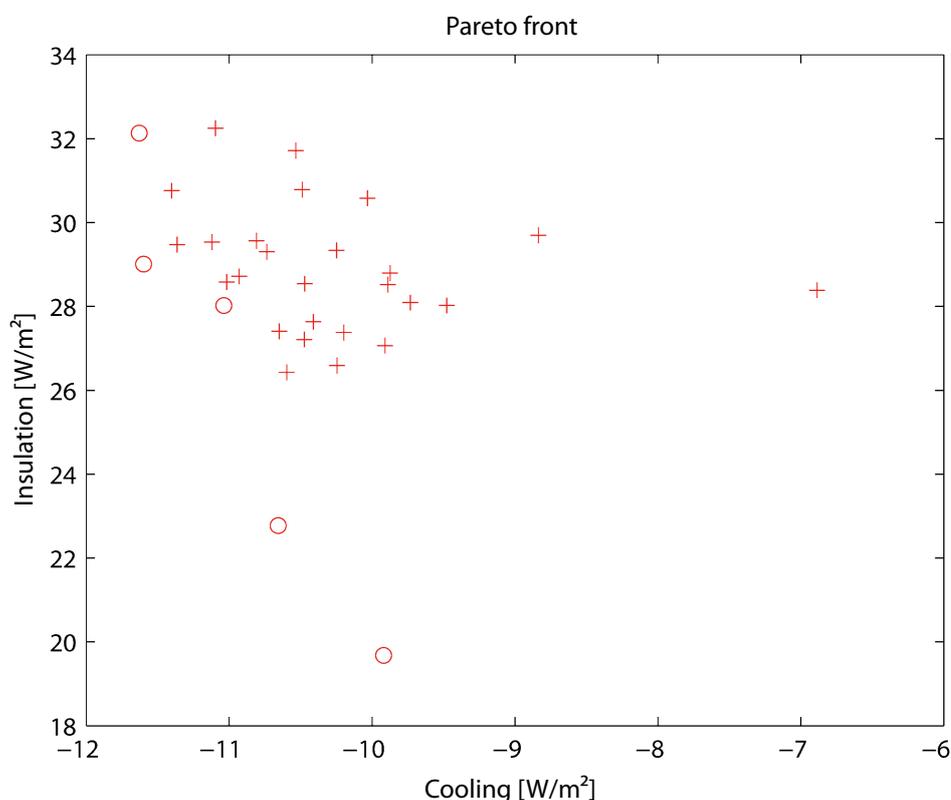
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Martin Fält joined Elomatic at the Helsinki office in 2014. He works as a Senior Consulting Engineer and is specialized in preliminary studies in the process industry and energy sector. Before joining Elomatic, Martin worked at Åbo Akademi University as a researcher on the subject of radiative cooling. He will defend his doctoral thesis on radiative cooling at the beginning of 2015.

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Photo © Depositphotos.com/peshkova. Artwork © Maija Hakuli

# The risk of assuming

## – upgrading product design to meet customer needs

*Product development often entails facelifts of previous projects and occasionally the design of completely new products from nothing. What are the key decisions that the design is based on? When a deadline is breathing down a designer's neck, the most important thing is often forgotten: the user. Why?*

In product development there are always decisions that need to be made. These include decisions about mechanical design such as the thickness of a wall to the location of a button, or software decisions such as how the user interface should look or where and how information should be placed.

This is a very crucial moment. The product may require a specific feature, but if this feature is located in a place that makes it difficult for the actual users

to even notice, it does not meet the customer's or the users' needs. Another example would be if the handle of a product is designed so that it makes using the product more challenging even though the main goal was to improve usage by designing a new handle.

This problem is especially an issue for large design projects where the design team consists of different teams with varying responsibility areas. It is not unheard of that at some point the

## *The earlier a usability study is conducted, the greater the potential savings are.*

control of the whole design is distributed around the team and nobody has time to think how the user can handle the design as a whole.

It is unfortunate that this happens, as it means that a lot of design effort, time and money has been invested in a project, after which the user cannot use the product as well as she/he should. What is even more unfortunate is that this could have been prevented.

### **Brave designers admit knowledge gaps**

The bravest and wisest designers are those that admit that they don't know how something should be done and then start looking for answers. This takes courage. It is not easy to question your own professional skills or your designs. Yes, it will hold and yes, it will work, but how usable will it be?

The fact is that designers are usually so married to their designs that it is very challenging for them to think about the product from the first time user's point of view. The users do not know the design and its features as well as the designer does. There is, however, a simple and very effective solution to this challenge – a usability test.

### **Usability testing for prototypes**

There are several methods available to check the future usability of a product before it is actually finished. If there are, for example, different possible physical alternatives, such as differently shaped handles, the options can be printed with a 3D printer and tested in a real environment with the required variables, e.g. with gloves on or off.

Another example; a control panel user interface can be evaluated with the help of users before a single string of code is written. The entire product concept can even be evaluated before a single line is drawn. The visibility from a car cabin can be verified in a virtual reality laboratory with 3D glasses and an actual view of the model.

### **No room for guesses and assumptions**

It goes without saying that a vast amount of time and money can be saved when unnecessary resources do not have to be employed to fix errors after the fact. There is no room for guessing, or assuming anymore. Design decisions can then be based on actual user opinions. There will, however, always be some exceptions.

The earlier usability studies are conducted, the greater the chance of saving money later on. When existing designs need to be revised, or even re-coded or re-assembled, it costs much more. Usability studies should, therefore, be conducted more during R&D processes and not only when the product is finished or almost finished.

### **Pay special attention to crucial elements**

Crucial elements should be given special attention and considered from the user's point of view; how do these elements affect the product as a whole? Another useful idea is to conduct tests on existing designs before the facelift project starts. This provides the design team with valuable information regarding the most challenging user situations that need to be addressed to meet the users' needs more comprehensively.

Usability testing is an indispensable tool in removing a large part of the risks associated with product development.

The user should be the focus from the very beginning of R&D projects and this focus should be maintained throughout the entire design and production process. Not only does this negate potential downtime or an unpleasant escalation in costs later on, but it also increases productivity – happy users are more efficient users.

#### **About the author**



**Maija Hakuli**

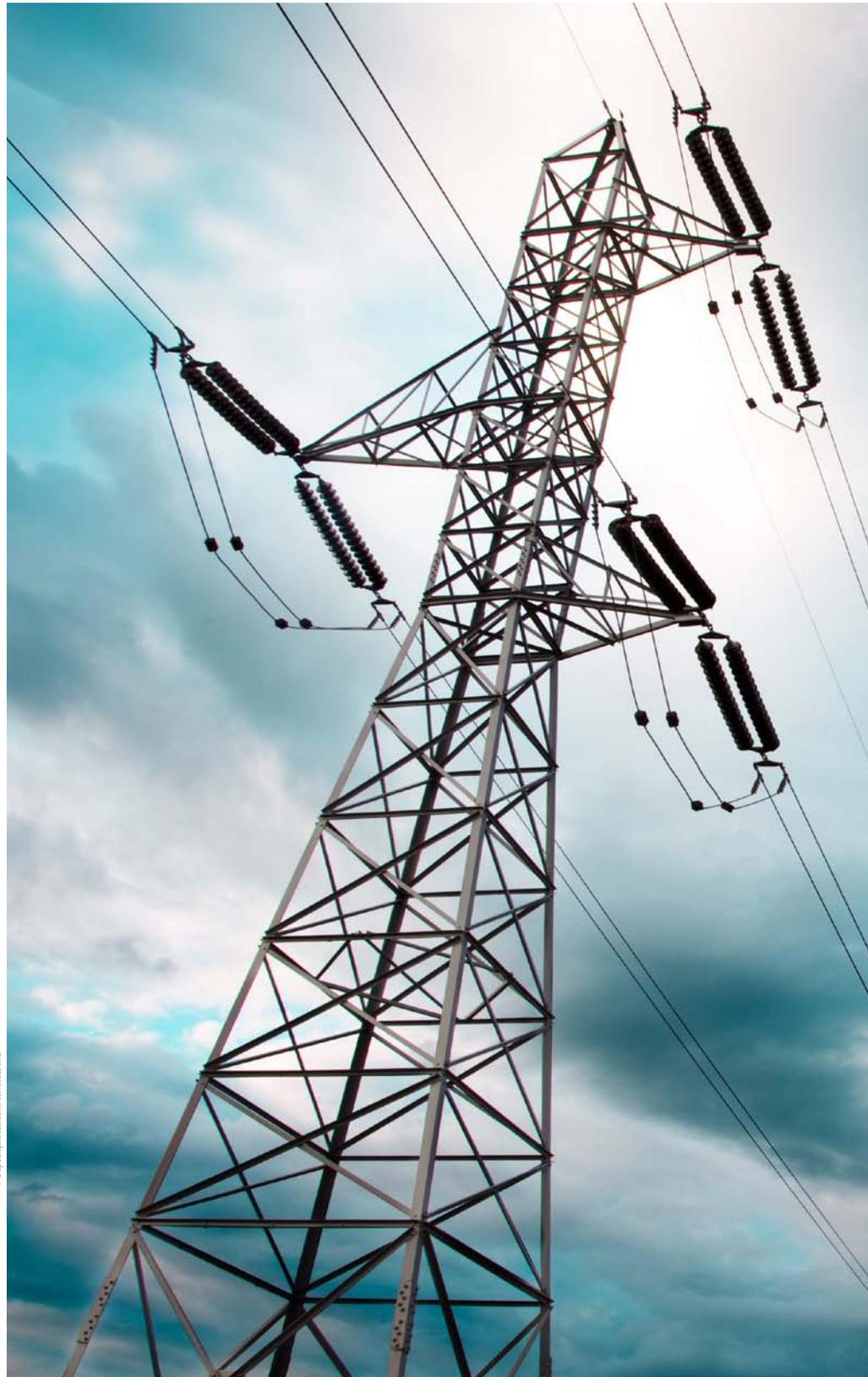
B.Sc. (Wellness Technology)

Maija Hakuli is senior designer of user experience as well as mechanical design and has been working at Elomatic since 2005. Recently she moved from the Jyväskylä office to the Tampere office to serve local customers in the Tampere area. Ms Hakuli has worked on a wide range of projects and has conducted different kinds of R&D phase usability studies in Finland and other European countries, as well as the United States and P.R. China.

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# In search of power network reliability

*It is of utmost importance for owners and operators of electrical networks to always have up-to-date and accurate knowledge regarding the status and safety of their networks. According to new directives and standards they are required to ensure that basic safety standards are met already in the design phase of projects. When implementing projects abroad unfamiliar standards place additional demands on design. In all cases comprehensive documentation is of crucial importance. New power network calculation software tools on the market significantly ease the design and management of power networks.*



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The left side of the page features a vertical blue gradient background with a faint image of power lines against a cloudy sky.

**T**he owners and operators of electrical networks have to ensure that their networks are safe to use and that human life and property is protected in all network connection situations and possible failure situations.

### **Economically efficient networks a primary goal**

Power distribution networks constitute significant long-term investments. For this reason it is essential that the network is reliable, easy-to-manage and adaptable to changes in future power requirements.

In order to ensure uninterrupted power distribution the electrical magnitude of the distribution network needs to be calculated and dimensioned and the results need to be thoroughly analysed. Accurate network calculation avoids the over-dimensioning of network parts and makes room for future needs in the right way.

If the network has been designed correctly it should facilitate quick fault location, enable operators to limit the areas affected by faults and reduce the length of possible resultant downtime. Comprehensive documentation that allows the easy location of device and network information eases the work of operators considerably.

### **Well-designed protective elements guarantee safety**

Failure situations in power networks can occur as the result of adverse weather conditions or inadvertent or

deliberate human action. Inaccurate dimensioning can also lead to the overloading of a part of the network and subsequent device failure.

In order to design protective elements that are effective sufficient knowledge of load levels and operational uses of the different parts of the network is required. The method of implementation depends greatly on how different parts of the network are used in different situations.

For some network parts it may be necessary to use temporary connectors to reduce the size of the failure area. Protecting elements should work in these situations as well and should be adaptable to expected increases in future power needs.

Regulations prescribe requirements for failure disconnection in relation to operational time. In other words, the failure needs to be disconnected within a prescribed time depending on the failure type and its effect on the environment. The failure may result in humans touching electrified parts or being exposed to excessive electromagnetic fields or electric arcs.

Power network protecting elements should be implemented selectively: the area affected by the failure should be minimized as close to the failure point as possible.

### **New software tools ease network calculation**

Designers of electrical networks need to be able to quickly manage changing directives and standards. With the help of network design software even large

## With modern network software we can reliably manage large amounts of information.

amounts of information can be managed reliably and network changes and additions can be implemented later with ease. Software programs can also be used as supporting tools in e.g. managing connector changes.

Such software packages allow different network solutions to be studied. This allows the optimization of the network's power distribution and related costs. It also facilitates managing different countries' IEC standards and requirements, as well as the presentation of calculation materials in the correct formats.

The software enables the efficient management of very large amounts of documentation. The network structure can be described in graphs or scale maps and the shielding can be shown graphically or in tables.

An example of this kind of software is NEPLAN, which is used in Elomatic's power network design projects. A particular advantage of the software is that it allows the calculation of both low and very high voltage networks as well as DC networks. This means that it can be effectively used to manage and

calculate public distribution networks and factory networks.

In Marine industry electrical and offshore projects different standards apply than those of common power networks. In NEPLAN the standards can be selected before starting calculations, which results in the correct documentation and information for the intended purpose.

### Don't forget the man behind the machine

A software tool is however only that, a tool. It still needs a skilled and experienced power network expert to interpret and analyse the results correctly. By combining advanced software tools and top expertise with reliable initial data about networks and their future requirements both safe and economically viable networks can be designed, implemented and operated.

If project planning has been conducted properly and modern tools have been used in the process the networks should serve both their present and future needs.

### About the author

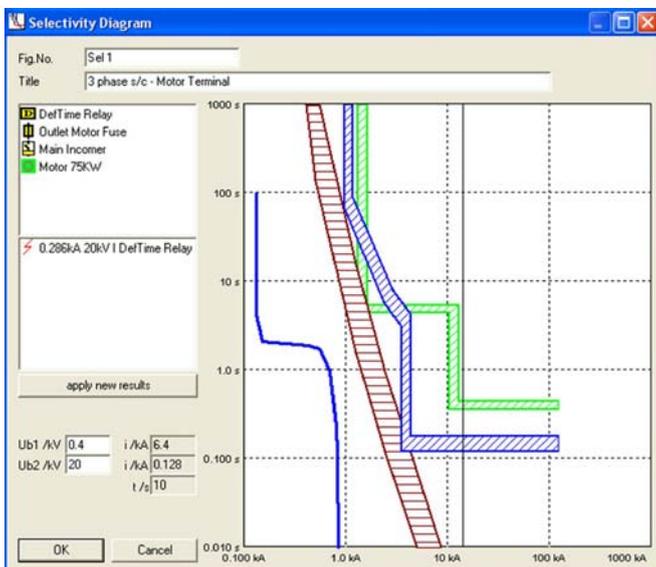


**Jari Åberg**

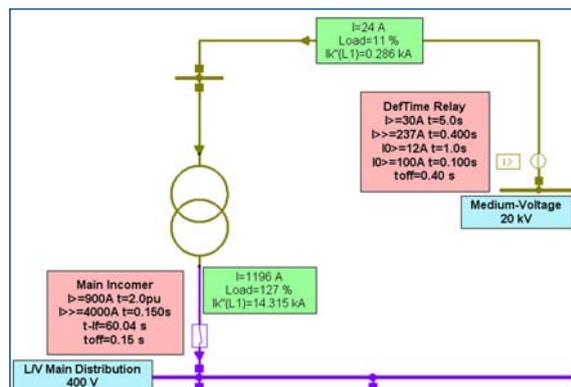
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Modern software tools such as Neplan allow the user to study different network solutions and optimize the power distribution network.





# Shallow water offshore structures

## – foundation stability: an essential part of design work

**Text:** Raimo Saarikoski, Wellquip Ltd

*When evaluating the feasibility of shallow water offshore concepts attention has to be paid to foundation stability from the very beginning. If the designers involved are naval architecture orientated and used to working mainly with floating structures and not soil properties, they may not pay sufficient attention the latter area. As a consequence, civil engineers are often called on to provide the solutions. Civil engineers, however, commonly do not fully understand the "offshore" features of the concepts. Both the aforementioned cases may lead to end results that are not satisfactory.*

This article mainly concentrates on Gravity Base Structures (GBS) for two reasons. Firstly, the problematic for other structures such as Jackets and jack-ups is very much different from Gravity Base structures and should be the topic of a separate article. Secondly, Wellquip Ltd is actively involved with shallow water GBS concepts and the topic is very current.

To fully understand the importance of foundation stability already at the earliest stage of concept design it is instructive to refer to Det Norske Veritas (DNV) Classification Note 30.4. It states that 'Requirements for foundation stability are often the most decisive factor for the determination of the foundation area, foundation embedment (i.e. skirt penetration depth) and submerged weight for a structure with a gravity type foundation. It is therefore essential in an optimal design process

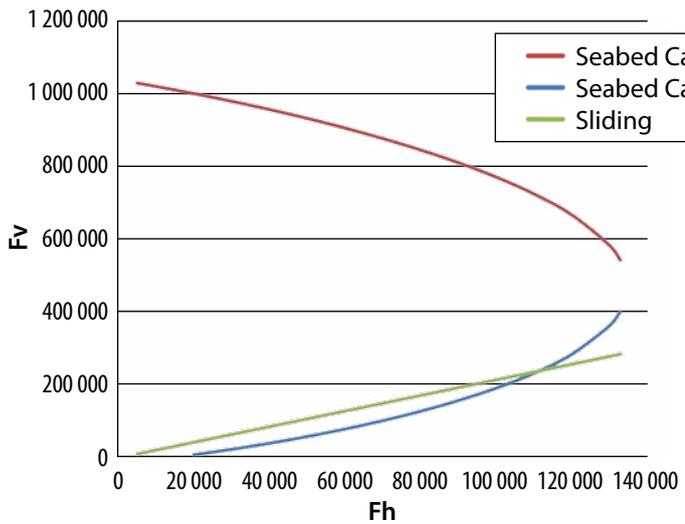
▲ *Artist's impression of Wellquip Multi-Caisson Structure module (WMCS) for shallow water. Picture by Piirtopalvelu Rautio*

to heavily emphasize foundation stability calculations.'

This means that foundation stability has to be taken into consideration already when determining the main dimensions and weights of the concept and continuously thereafter as the design work proceeds.

### Calculating foundation stability in conceptual phase

There are several possibilities for the very first conceptual evaluation of foundation stability, some of which can be loaded from the Internet (Hansen's



Fh	Fv		$\Phi=25$ Sliding
0			
5000	1030064		10722.535
10000	1020703		21445.069
20000	1001008	8400	42890.138
30000	979916	23468	64335.208
40000	957285	40093	85780.277
50000	932929	58600	107225.346
60000	906602	79200	128670.415
70000	877967	102210	150115.484
80000	846551	128070	171560.554
90000	811646	157465	193005.622
100000	772125	191515	214450.692
110000	725958	232230	235895.761
120000	668732	284010	257340.831
130000	585343	361990	278785.900
133000	543587	402110	285219.420

▲ Figure 1. An envelope for safe horizontal FH and vertical FV force combinations (inside boundaries) for a given eccentricity of the load. The straight line describes the sliding capacity. As can be seen from the graph it can also be a significant factor for low FV values.

▶ Picture 1. A scaled model of a WMCS module



Bearing-Capacity Equations). The American Petroleum Institute (API) has also issued a method in API RP 2A WSD and DNV has a system in their aforementioned Classification Note and also in their standard DNV-OS-J101.

The equations look very simple, but working with them raises many questions and the support of either the issuing institute or of a professional civil engineer is often needed. The equations normally simply provide the actual bearing stress together with the safe bearing capacity.

The results can also be presented in the form of a foundation stability envelope for horizontal and vertical load combinations inside which the foundation is stable. Figure 1 depicts this kind of envelope for one eccentricity of loading. The eccentricity also defines the effective area on the seabed to be used in the calculations.

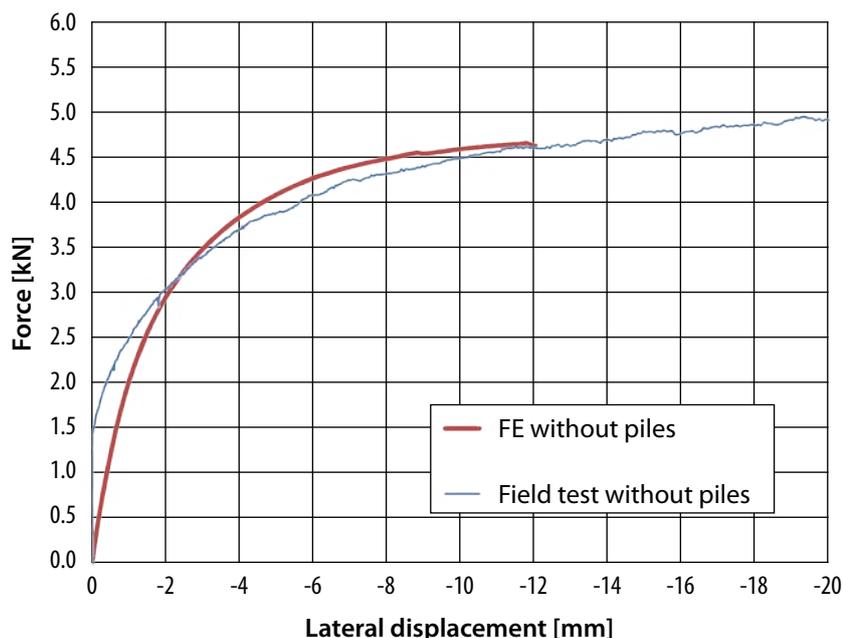
The lower straight line indicates the sliding capacity. The envelope was developed for a WQ GBS concept based on the DNV method in Classification Note 30.4 with a computer program developed for the purpose; first to test the program itself and thereafter to test the feasibility of the actual concept.

It is to be noted, that the aforementioned consideration is generally only to determine the basic dimensions of the concept and to provide some confidence to continue. Even DNV states in their Classification Note that 'for gravity foundations with relatively small areas, e.g. mudmat foundations for temporary supports of jackets or foundations for small subsea structures, bearing capacity formulae may be acceptable'. Further analysis is required depending on the concept type and especially on its design life.

### Plaxis 3D used to confirm analysis results

An example of such further problems, which cannot be solved with conceptual evaluation analysis, is lateral displacement under loading. Advanced Finite Element programs can be used for this purpose. In the spring of 2013 a Wellquip GBS concept (See image on pg. 33) was tested at the Tampere Technical University in Finland at their laboratory with a scaled model. The results were confirmed with Plaxis 3D. A photo of the scaled model can be seen in Picture 1. Figure 2 shows the model test results as verified by Plaxis 3D.

The analysis indicates that Plaxis 3D can be fully trusted. It seems that model testing is not necessary for future concepts, especially, when it is difficult to simulate the actual full-scale



◀ Figure 2. Comparison of model testing and Plaxis 3D results

situation accurately enough with the scaled model.

### Cyclic loading can cause failures

The second problematic area is cyclic (wave) loading and its influence on the shear strength of the soil, which in combination with the number of cycles can lead to failure. DNV generally requires cyclic (wave) loading to be studied, but the guidance provided for the analysis is somewhat unclear and several cross references are provided to documents, which in turn refer to others.

As such it is difficult to find a definitive source that would provide a complete understanding of the matter. It, nevertheless, seems to be an item worth studying in more detail in order to clarify whether in-house analysis is in general possible.

Another issue with cyclic loading is that the displacements caused by cyclic loading are not reversible. A kind of hysteresis phenomenon takes place throughout the design life. The maximum deviation from a location is, of course, of interest to engineers when designing e.g. a safe piping connection from the top of GBS to the bottom of a well. It has become clear that the

deviation caused by long term wave action cannot be evaluated with Plaxis 3D.

### Special analyses required to study liquefaction

Another important phenomenon that cannot be evaluated with Plaxis 3D is liquefaction caused by earthquakes or vibrations that result from ice/structure/soil interaction. Consolidation and scouring are also interesting items, which may appear fairly minor, but could have severe effects. A lot of guidance is provided in the literature with regards how these special analyses should be performed.

### Model tests only provide part of the answer

There has been much discussion about shallow water model testing in basins. In model testing the scaled model lies at the bottom of the basin and a moving ice field places loads on the model. This allows the seabed pressure distribution and displacements to be measured.

There are some institutes and laboratories around the world that have

the facilities required for this kind of testing, but it seems that they produce more qualitative than quantitative results. Real engineering, on the other hand, produces quantitative results and makes the use of finite element models and advanced analysis necessary.

### Summary

Foundation design is an essential part of offshore shallow water structure design work. It needs to be analysed at the very beginning when determining the main dimensions of the concept and considered until the end of design work to guarantee the safe operation of the unit over its entire lifetime. At the conceptual phase it is important that designers are familiar with the systems used to evaluate the soil bearing capacity and the feasibility of the new concept in general. For later phases a more detailed analysis using highly developed software programs and professional assistance are needed.

Foundation design of offshore structures is a challenging and interesting part of offshore design and project managers should have a broad general understanding of this design area in order to guarantee good end results.

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## **Ski jumping simulator for Lahti Ski Museum**

*Early in 2015 the Lahti Ski Museum in Finland will be sporting a brand new attraction, a ski jumping simulator. The simulator is currently being developed and tested at Elomatic's Jyväskylä office.*

**T**he ski jumping virtual environment used in the game is based on a 3D laser scanned environment. To succeed the would-be ski jumper needs the right body position. The timing of the jump is also crucial, not forgetting the wind effect. For a taste of the simulator see the promotional video.

➔ See the ski jumping simulator video:

<https://www.youtube.com/watch?v=Acn0jTvtfGA>



Elomatic has donated this year's Christmas gift funds to the Central Hospital in Jyväskylä, Finland. The funds will be used to develop the hospital's pediatric ward.

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