VOITH

MAGAZINE FOR HYDROPOWER TECHNOLOGY

HyPower

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SECURING THE FUTURE
WITH MODERNIZATION

MOVING FORWARD

INNOVATIVE SOLUTIONS

A CLOSER LOOK AT SMALL HYDRO

GREEN ENERGY MIX

WHY HYDROPOWER LEADS THE WAY

IMPRINT

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COMBINING EXPERIENCE AND INNOVATION

There is no substitute for experience. As the only manufacturer to have remained in the hydropower industry for more than 140 years, Voith Hydro has experience in abundance. Hydropower might be a mature, well-established technology, but this does not mean there is no room for improvement. Continuous enhancement and life-long learning are targets we strive for, not only in terms of our products, but also with a view to our personnel.

The combination of long-standing experience and a hungry, forward-looking approach means that we are constantly searching for technical innovations in order to improve efficiency and minimize the impact of hydropower on our natural surrounding environment. This will enhance hydropower still further as the main source of reliable green energy.

In recent years we have seen a growing trend towards modernization of long-serving hydroelectric power plants. Having trusted Voith's expertise during the original construction phase decades ago, many of our partners are today once again calling on our technical knowledge as they look into the future.

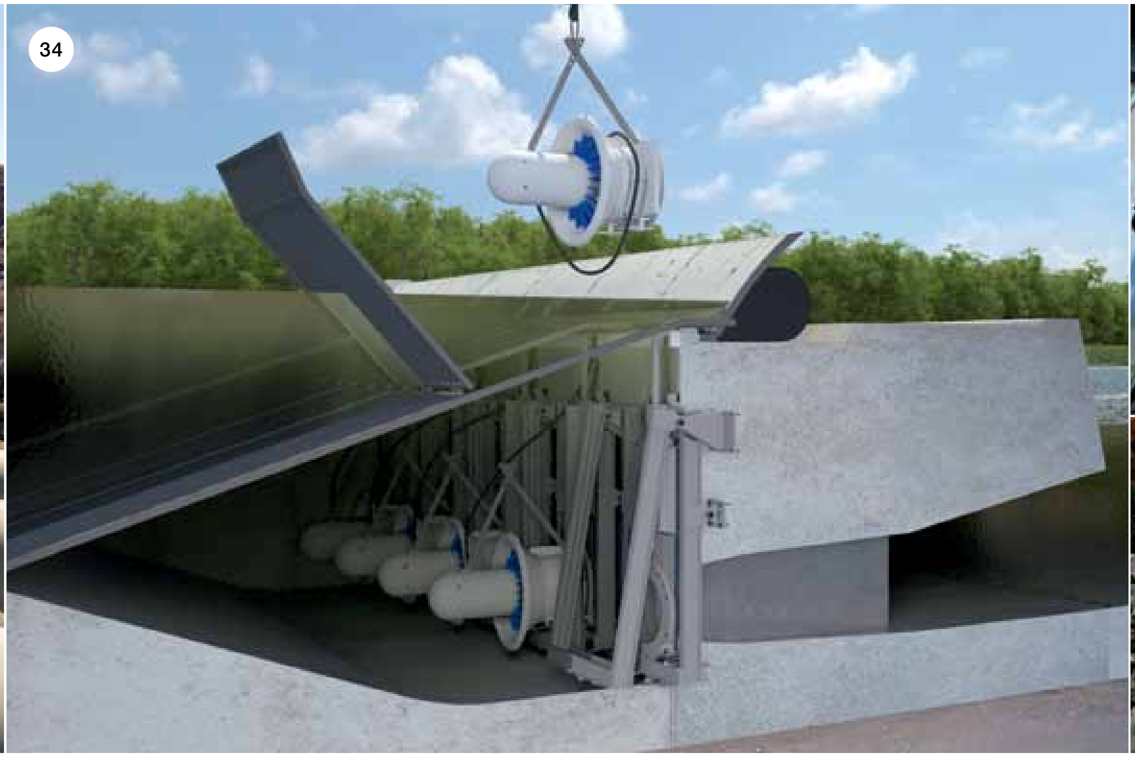
And the future of hydropower is bright. The International Energy Agency expects the amount of electricity generated by hydropower to double by 2050. Having already experienced the successful development of hydropower over time, we are confident that it will continue to contribute significantly to climate-friendly power generation in the years to come.

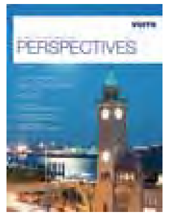
In this issue, we hope that you will gain valuable insight into our technical skills and project work around the globe, and how to best pass on this knowledge and expertise to the next generation.
Enjoy the read!

Yours sincerely,

Ute Böhringer-Mai
Head of Communications

CONTENTS





Discover more about Voith in its other insightful publications.

The Voith pavilion at the Indo-German Urban Mela showcased the company's wide range of services on the subcontinent.

CELEBRATING INDO-GERMAN RELATIONS

INDIA As part of the celebrations for 60 years of diplomatic ties between Germany and India, Voith was present as a city partner at Delhi's Indo-German Urban Mela in October 2012. The fourth of five city visits across the subcontinent for the *mela* (Sanskrit for 'fair'), it showcased the best of Germany in all possible fields. Over 140,000 guests made their way through the exhibition. In its company pavilion, Voith provided insights into the firm's portfolio of activities in India, focusing on the challenges of rapid urbanization on the subcontinent. India is a key market for Voith, which has successfully operated in the country since 1911. Services are diverse and include, among other things, solutions to provide efficient infrastructure (including components for the Delhi metro), clean energy, safe water supply and resource-friendly factories.

At the Voith pavilion in Delhi, visitors could view the film "Megacities of the World – Their Challenges" on a special large screen. The film was developed with the support of students from the Indian Institute of Technology, with which Voith has an ongoing cooperation. A highlight for visitors was the interactive iPad presentation of a hydropower project, including a quiz on hydropower and the environment. The quiz served as the basis for a school competition, in which 19 top schools from Delhi and its surroundings participated. Each school team consisted of four members aged 14 to 17, and three top teams were awarded with trophies and certificates.

Voith was also able to welcome a special delegation to the company pavilion, consisting of Philipp Rösler, German Federal Minister of Economics and Technology, Dr. Hubert Lienhard, President & CEO of Voith GmbH, Dr. Roland Münch, Chairman of the Board of Voith Hydro, Siemens CEO Peter Löscher and numerous other high-ranking representatives from business and politics. //

VOITH AT HYDRO 2012 IN BILBAO

SPAIN Voith Hydro took its place alongside 1,300 participants from 80 different countries at the HYDRO 2012 conference in Bilbao. The annual hydropower trade fair hosts an array of exhibitions and discussions on the many concrete plans for global hydropower and pumped-storage development. Voith Hydro experts from different operating units from all over Europe attended the fair, once again proving the company's high technological expertise by contributing several conference papers on special technical aspects as well as project case studies. During the gathering, Voith hosted a conference dinner at the Museo Maritimo on the banks of the River Nervio in the Basque city. In addition, the event was also the premiere for Voith Hydro's all new exhibition booth in the new design. //

EXPANDING AFTERMARKET SERVICES

NORTH AMERICA Voith has further strengthened its services portfolio for hydro plants and expanded existing aftermarket business activities by establishing a new operating unit in Canada. With the acquisition of Québec-based Vortex Hydro, Voith will benefit from the company's expertise in new auxiliary mechanical systems, specialized hydropower products and expert consulting services. "Offering long-term comprehensive services is increasingly important as it is in demand by our customers," states Kirsten Lange, Member of the Board of Management and Chief Business Development Officer of Voith Hydro Holding. Responsible also for aftermarket business, Lange joined the management board in 2012. Aftermarket services include preventive maintenance, repairs, quality spare parts and inspection. //

EXPLORING POTENTIAL IN MYANMAR

MYANMAR January saw the first official Myanmar Power Summit take place in the city of Yangon, with Voith acting as co-sponsor and the only hydro company to have its own booth on site. Over 50 delegates from the local Ministry of Electric Power attended to discuss development and investment opportunities in the Myanmar energy sector. Only select parts of the country's population have access to electricity, while those who do are faced with regular power outages. The potential for hydropower in the region is considerable. Voith Hydro has already realized two projects: at Yeywa, Myanmar's largest hydro plant, Voith Hydro supplied turbines, generators and automation systems, while at Kinda Dam the company delivered two units back in 1986. //

MISSION SUCCESS IN SOUTH AMERICA

BRAZIL Voith continues to succeed with its hydropower business in the key South American market. At the turn of the year, the company received several major orders for the modernization of hydropower stations in Brazil. The combined contract value is around €185 million and includes modernization of two plants on behalf of Tractebel Energia S.A., as well as one for operator Duke Energy. In the 1,420-MW Salto Santiago, the four turbines, generators, electromechanical equipment and automation technology are all to be completely refurbished and renewed. At the 226-MW Passo Fundo plant, Voith will modernize the two generating units, automation systems and the turbine governors, while at Chavantes it will renew three generating units, including turbines and generators, and the electro-mechanical systems in the 414-MW plant. //

Dr. Norbert Riedel: after joining Voith in 1998, the engineer has held numerous senior positions, most recently Managing Director of the Voith Hydro Engineering Center.

PASSING THE BATON

After more than 30 years at Voith Hydro, **Chief Technology Officer Dr. Siegbert Etter is retiring, with Dr. Norbert Riedel taking over his responsibility.** We sat with both of them to discuss technical innovations at Voith and the importance of effective knowledge transfer.

What have been the most important technological developments in the hydropower industry during your time at Voith Hydro?

Dr. Etter: As far as the basic principles are concerned, not much has changed in the last 30 years. Hydropower is a very mature technology that we at Voith have been working with for more than 140 years. However, there have been many changes on a smaller scale which have also altered the industry as a whole. Driven through these developments, power, power density, size and efficiency have increased. Take material development, for example. Today, steels are tougher, more flexible, sturdier, more corrosion-resistant and the overall quality has improved enormously. We have reproduced and were actively involved in huge quality improvements in our laboratories and our foundry.

Dr. Riedel: A lot has happened in the field of automation, the digitalization of control technology, and in instrumentation and sensor technology. This has opened up new possibilities for external control and shorter response times, so the power plant can earn more money through increased availability. There has also been considerable progress with electrical equipment, for example in the insulation materials area. Or take the air-cooled generator that has enabled higher efficiency rates.

Dr. Etter: Environmental aspects have also come into focus more strongly: oil-free hubs, the aeration of process water using corresponding blade wheel designs or technologies to lower the risk of injury to fish.

Has the industry changed faster or more significantly than you expected?

Dr. Etter: Looking back, I think so, yes. There were many changes as a result of the consolidation of the hydropower industry, starting in the late 1980s. The development into a full-line supplier that manufactures the entire product portfolio for hydroelectric power plants occurred surprisingly quickly and thoroughly. For Voith this came through the joint venture with Siemens in 2000. Many major and established names disappeared during the course of the industry consolidation, but Voith maintained its excellent name and is the only manufacturer to remain in existence for more than 140 years.

Have there been any technical innovations that truly surprised you, or innovations that you expected but were never realized?

Dr. Etter: Some innovations did not catch on, such as the 'Straflo' principle or the high-voltage generator, often for economic reasons rather than technical ones. But we haven't really seen any surprises. Not even the variable-speed turbine, which we certainly saw coming.

Dr. Riedel: What hasn't happened yet is that the model tests have become obsolete. This temporary assumption proved to be unrealistic and I don't expect it to happen in the future either. Despite developments in computer technology, model tests will remain. Quite simply, they represent a unique form of risk minimization for our customers.

What have been the most notable changes at Voith Hydro during your time with the company?

Dr. Riedel: The development into a true full-line supplier was a gigantic step forward. We have seen technical expertise for generators, automation and the plant as a whole gradually added to our knowledge of turbines.

Dr. Etter: Correct. And the knowledge that we at Voith were able to benefit as a result of the integration of employees from other companies.

Which technical innovation at Voith Hydro are you most proud of and why?

Dr. Etter: Ocean energies. We have developed new, robust technology in this field, such as water-lubricated and seawater-resistant components. In some cases we have even been able to transfer this knowledge back into conventional hydropower, such as with the StreamDiver, a new development in small hydropower plants [see page 34].

Which important technological developments do you expect to see for hydropower in the near future? What are the current areas of research?

Dr. Riedel: We expect further new developments and applications in material research in the future. Environmental ▷

Dr. Siegbert Etter: in 1982, Etter joined Voith as a construction engineer for turbines, before going on to become Head of Corporate Technology and later CTO.

▷ aspects will continue to push technical development, for example with oil-free hubs in Kaplan machines. With regard to generators, we can expect continued optimization of insulating technology, cooling and even more robust machines for ever-increasing output. We are monitoring the developments in semiconductor and superconductor technology in order to integrate the right elements at Voith Hydro at the right time. Ultimately, all this helps us to better serve the needs of our customers, such as with different operating modes, increased flexibility, more frequent load changes and greater on-time availability. Our skill as engineers and technicians must be to listen carefully to the customers and anticipate where they want to go in order to promote innovation based on this information.

How has the transfer of knowledge and experience developed during your time at Voith Hydro?

Dr. Etter: Due to our global presence in all important hydropower markets and our range of services we have to gather, bundle and redistribute a lot of knowledge within the company. Our engineers in different regions have the local expertise, which flows through the company, but they also need access to the accumulated expertise that we have gathered at Voith. This is our challenge and our goal: to be a local full-line supplier throughout the world.

Dr. Riedel: That will also be one of my aims as the new CTO; to learn, retain and expand on Voith's experience, and to continuously integrate this expertise into our products. My role will also require me to manage knowledge transfer across all the regions to ensure this know-how is close to the customers on a local level, throughout the world.

What other goals do you have as the new CTO?

Dr. Riedel: To be a challenger and partner – someone to challenge the company from the inside in order to drive performance and innovation. And a partner both internally and externally: to listen to our customers and staff in order to see the requirements of tomorrow and develop our technology accordingly. In doing so, we want to maintain the right balance between innovation and risk. Hydropower must remain a safe and secure renewable energy source.

Has the transfer of knowledge and expertise become easier, due to technological developments, or more difficult, because so much knowledge is available today?

Dr. Etter: Both. Computer technology has definitely made some things easier. But at the same time the complexity has increased heavily; the amount of know-how, interfaces, the documentation requirements and so on.

How important is a detailed transfer of know-how and expertise in order to achieve the best possible results?

Dr. Etter: Extremely important, which is why it is also vital that we develop suitable successors within the company in the long term – like Dr. Riedel. Trust, both internally and externally, and diverse experiences from different areas of the company are important in order to be able to do the job properly. Also, actual plant experience is crucial for this.

Dr. Riedel: I agree, only once you have experienced a power plant start-up in person can you understand the power involved, as well as gain the level of respect for the technology and the force of nature, not to mention the risks.

What was the best advice your predecessor gave you and what advice do you want to give your successor?

Dr. Etter: Firstly, the human factor is crucial. Rely on the right employees in the right positions – trust on their abilities and allow them to rise to the challenge. The CTO's job is also to attract younger talent to the company. I am always surprised by the appeal of the label "German engineering" around the world and it is important to make the best use of it. Secondly, avoid being proud, because it prevents you from listening. And listening – to both employees and customers – is the most important skill a CTO needs to have. Of course, I am proud of the company's market position, of its great development and the integration of new products and employees, but one thing has definitely risen above all in my more than 30 years in the hydro industry: my love of and respect for hydroelectric power. //

"My role is to ensure that our technological know-how is close to customers throughout the world."

Dr. Norbert Riedel, new Voith Hydro CTO

KNOWLEDGE IS POWER

Knowledge-transfer expert Steve Trautman explains how companies should go about **retaining expertise before it's too late.**

Succession planning – recruiting and developing employees to fill key roles – almost always focuses on top executives. It should, however, include all experts with critical and unique knowledge. Knowledge-transfer programs reduce the risk of losing knowledge and experience. Much more than on-the-job training, it means replicating the expertise, wisdom, and knowledge of critical professionals in the heads and hands of co-workers.

Scientists and engineers need knowledge transfer to be practical. It should start with a clear goal, such as: "Teach her how to analyze that data by Tuesday. You'll know she's ready when she can answer five questions and she sounds like you when she's talking." Technically oriented employees need help prioritizing knowledge-transfer relative to their regular tasks, as well as tools to aid the communication of their experience and ideas. Step-by-step instructions can be particularly useful. Consider these steps concerning an effective knowledge-transfer strategy:

Prioritize information

Long-time employees are tremendous repositories of information, but not all of it is equally important. Sort the high-risk/high-value expertise from knowledge that is out of date or already exists sufficiently within the organization.

Different types of knowledge

Knowledge transfer must move both explicit knowledge (how to follow a certain procedure) and tacit knowledge, such as what to look and listen for, which rules must be followed and which ones can be ignored under what circumstances, who you have to know to get things done, and so on. Tacit knowledge is the "secret sauce" that makes experienced people so good at their jobs.

Transfer on the job

You cannot afford to have your experts stop work to run formal classes. Knowledge transfer must be part of the fabric of regular work or it will never happen. Since there are many nuances to what must be taught, transferring knowledge on the job is the best environment.

Understanding is key

Knowledge management (storing data) does not solve the problem. Risk is not reduced until critical knowledge is understood by the next generation. Use a mix of knowledge-management tools and knowledge transfer to achieve this.

Measurable approach

A clearly structured plan of what knowledge should be transferred and when allows busy experts to schedule and prioritize knowledge transfer relative to their other work. In terms of accountability, a measurable plan lets managers record progress, ensuring the risk of knowledge loss is reduced.

Not long ago, an employee on the job for five years was still "the new guy" because many of his peers had been there 20 or 30 years; taking five years to get up to speed didn't seem crazy. Today, employees entering the workforce can expect to change jobs at least every seven years, so there is much greater urgency. Knowledge transfer must be fast and methodical to meet the needs of today's changing workforce. //

Steve Trautman
With over two decades of experience advising clients such as Microsoft, Nike and Boeing, Steve Trautman advises senior executives on practical ways to secure effective knowledge transfer.

RESETTING THE CLOCK

Around the world, Voith Hydro is helping its customers to realize the true potential of their hydropower plants. Innovative modernization work can increase efficiency, boost power output, make plants more environmentally friendly and extend their lifetime by decades.

Guide vane for the equipment of the completely rebuilt Rheinfelden plant at the Swiss-German border.

In Uglich, Russia, Voith Hydro carried out extensive modernization work, boosting the unit's capacity by almost 20 percent.

When you embark on modernization, you are essentially investing in the next generation," says Lars Meier, Chief Engineer at Voith Hydro York in the United States. He has no illusions about the financial imperatives that drive the company's large refurbishment and modernization business. This business accounts for a large portion of the company's overall hydro activity in the United States and significant proportions of its business in other markets.

Voith Hydro's portfolio of services covers many aspects of hydropower, providing solutions for every type of turbine, generator and automation system, encompassing everything from small hydro to the largest projects in the world.

The balance of the company's work between new build and refurbishment or modernization differs from region to region, reflecting the age and level of maturity of the hydro sector in each.

On average, automation systems are refurbished after 20 years, generators every 30 years and turbines every 40 years. The business comprises three broad categories: what could be termed "after-care," which can involve replacement of items prone to wear as well as spare parts; refurbishment, which involves "setting the clock back to zero" on an existing facility by extending its lifetime for further decades; and modernization, which typically goes hand-in-hand with refurbishment, but seeks to improve the original design and equipment in a variety of ways.

"The improvements in computational fluid dynamics, along with the focus on off-design operation in both the head range and flow range, allowed significant improvements in operating characteristics for all types of turbines," says Meier. Similarly, magnetic flux simulations have resulted in improvements in generator design. These tools, used in combination with scaled-down turbine model testing for larger projects, ensure that Voith supplies the most-modern and, crucially, the most-reliable designs.

Employing a combination of more-modern design approaches and manufacturing techniques may deliver an increase in efficiency from an existing unit, while installing new and improved runners can capture a significant increase in flow, therefore boosting power output. In addition, runner improvements may also reduce cavitation problems, reducing long-term turbine maintenance costs.

However, for most operators cost-benefit analysis of a wide variety of options is necessary to achieve the optimum balance in terms of expenditure against returns. "Real teamwork with the client is essential," Meier points out. "We have a reputation in the marketplace of bringing the best technical solutions to our customers. State-of-the-art technology is key to maximizing the full benefits of plant modernizations."

"State-of-the-art technology is key to maximizing the full benefits of hydropower plant modernizations."
Lars Meier, Chief Engineer, Voith Hydro York

One of the single biggest problems for service-provider and customer alike are the unknown challenges. Dismantling inner workings that last saw the light of day 40 years ago can be like opening a Pandora's box. From asbestos insulation to hot spots in generator cores, you can never be quite sure what you are going to find, Meier says. "However, there is a solution to every problem."

Arguably the biggest challenge of all is organizing the work to keep outage times to the absolute minimum, keeping the plant in operation while work is undertaken on individual units and quickly finding solutions as each new problem is identified. It requires a unique blend of organization and technical expertise. But wherever there are operators in need of Voith Hydro's technical expertise – from Conowingo in the United States to Uglich in Russia – Voith is there, bringing with it proven project management skills and worldwide manufacturing facilities.

The chosen results of a Voith Hydro refurbishment in terms of performance may vary from project to project, but for every one it means a guarantee of increased reliability and reduced maintenance outages for the coming decades.

There are many examples from around the globe where Voith has brought in its long-term experience in modernization and realized increases in efficiency and life-time extensions, especially in established hydropower markets like North America or Europe.

In the mature North American hydropower market, modernization and refurbishment has played a significant ▷

▷ role in the hydro equipment business for over 30 years. Over the past 15 years it has accounted for up to 70 percent of Voith Hydro's annual US turnover.

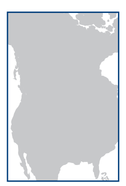
Examples of modernization projects Voith has recently carried out in the United States include the refurbishment and upgrade of 10 56 MW turbines at Bonneville Lock and Dam First Powerhouse in Oregon, extensive renovation work at Conowingo Dam in Maryland and the rehabilitation of 10 111 MW turbines at Wanapum Dam, located at the Columbia River in Washington state.

With its long-established presence in the North American market, Voith frequently finds itself in a position to undertake refurbishment and modernization of equipment originally manufactured by either Voith or one of its integrated companies such as Allis Chalmers or Westinghouse.

Since these plants were built, says Marcel Bos, project manager at Voith Hydro in York, there have been significant improvements in materials, offering potential benefits in terms of efficiency. In the heart of a turbine, for example, tolerances on runners are down to plus or minus one five thousandth of an inch, held over a part measuring several meters in diameter. To put that in perspective, a sheet of paper is about four one thousandths of an inch thick – some 20 times thicker.

However, Bos is quick to pay tribute to his Voith predecessors who installed the plants several decades ago. "There's a lot we can do today in terms of design and computer simulations, but when you do a refurbishing job like this it's still amazing to me just how good they were without today's computer technology."

Apart from the technological excellence, a good partnership with the customer is an important success factor, Bos stresses. "It's not just us doing the work," he points out, "it's a real joint effort. If you don't have a good relationship with the customer, you have nothing. Communication is vitally important; you have to understand their needs and meet them."



Hydropower in the USA

Installed capacity: **91 GW**
Potential not yet installed: **82 GW**

Hydropower in Germany

Installed capacity: **10 GW**
Potential not yet installed: **6 GW**

Hydropower in Russia

Installed capacity: **47 GW**
Potential not yet installed: **425 GW**

"It's not just us doing the work – it's a real team effort. If you don't have a good relationship with the customer, you have nothing." **Marcel Bos,** Voith Hydro engineer

Modernization work on generators can help extend a plant's life span by decades.

Several thousand kilometers away, on the Swiss-German border, Björn Reeg, project manager at Voith Hydro in Heidenheim, confirms this statement without hesitation. He worked on a rebuild at Rheinfelden, the largest single investment in renewable energy in Germany at the time, for which Voith was commissioned to supply a number of components. "A persistently trustful and reliable cooperation with the customer throughout the entire duration of the project was one of the key factors for the successful modernization of Rheinfelden," Reeg says in his agreement with his colleague in the United States.

Originally built in 1898, Rheinfelden was the first large hydro plant to be used for electricity generation in Europe. In what amounted to significantly more than 'mere' modernization, the plant was largely dismantled and then rebuilt with state-of-the-art, eco-friendly technology. "It's quite amazing what was achieved at Rheinfelden," Reeg recalls. Thanks to four new Voith bulb turbines, the plant now has a capacity of 100 MW, almost four times as much as the previous 26 MW. This also means that the operator can now produce four times as much electricity from the Rhine River, generating 600 million kWh per year.

Voith's ability to significantly increase power output through its modernization work has also been displayed in its work at the Uglich hydropower plant on the Volga River in Russia. By replacing one unit at the plant, consisting of a vertical Kaplan turbine and generator with 65 MW output, the electrical and mechanical equipment as well as the automation system, output of the modernized unit has increased by approximately 18 percent, raising the installed capacity by 10 MW.

Also impressive were the dimensions, with the turbine runner alone weighing 221 tons and measuring nine meters in diameter. "This was the first time Voith delivered a complete turbine-generator set to a customer in Russia," says Voith lead engineer Sebastian Paul. "Given the all-round success, it certainly won't be the last." //

I. EXTENDING LIFE SPANS

In the mature Canadian market, **modernization is improving performance** at the Gordon M. Shrum power plant.

Another well-established hydropower market is Canada, where Voith is modernizing the Gordon M. Shrum hydropower plant. Equipped with 10 turbine/generator power units, the plant has a rated output of 2,730 MW.

Units one to five were originally installed in the late 1960s with a nameplate capacity of 266 MW. In 2008, the operator BC Hydro initiated a project to upgrade the turbines. The aims were to increase the rated power of each turbine from 266 MW to 310 MW, to realize the performance improvements associated with modern turbine designs (hydraulic efficiency, cavitation resistance, stability), and to eliminate the historical issue of runner blade cracking.

Model-development contracts were awarded to Voith Hydro and to another world-class turbine supplier, and each company was given one year to design, analyze and test the new components being integrated with the existing turbine water passages.

At the end of the development period, each supplier's design was independently tested at Swiss technology institute École Polytechnique Fédérale de Lausanne, with Voith's design selected for implementation as it offered the better technical and economic benefits.

The lead operating unit is Voith Hydro in Montreal and the hydraulic design and tests were performed by Voith Hydro Engineering Center in York. Three different runner designs, along with various versions of wicket gate and stay vane, were tested in order to find the best combination between the stay vanes, wicket gates and runner. Each iteration was first computed using computational fluid dynamics' steady and unsteady numerical analysis and later tested on the model.

At the beginning of the project, stay vanes had been identified as a great contributor to the losses in the distributor. Various designs were tested, always keeping in mind that the stay vanes are embedded in the concrete and cannot be replaced. Each design kept most of the stay vane shape, with only leading and trailing edges modified by the addition of steel extensions to better align water flow with the wicket gates. Casting the new wicket gate out of martensitic stainless steel means they can be thinner than the original ones. This helps further reduce distributor losses.

The final runner design features longer blades to allow an output power increase and better cavitation protection. The runner band is also somewhat longer that the original, which meant embedded parts at the site needed modifying. The lower part of the discharge ring has been extended in the upper part of the draft tube cone liner, involving some minor civil work along with discharge ring and draft tube liner construction in the pit.

Modifications to the stay vane proved a further challenge due to the machining, grinding, fitting and welding of steel extensions using templates for proper alignment. For this particular turbine design, the bottom ring was embedded during the original power plant construction, meaning any modifications had to be performed on site.

A limited number of weeks are available for site work, and given the extensive modifications needed on the embedded parts (discharge ring, draft tube liner, bottom ring) the site crew is working around the clock to meet the contractual deadlines.

Besides the supply of new runner and wicket gates, BC Hydro also required new components such as head cover, turbine guide bearing, main shaft seal and wicket gate mechanism. The turbine shaft and gate operating ring are refurbished.

The first refurbished unit had been handed over to BC Hydro in late fall 2012, while the commissioning under the responsibility of BC Hydro was completed in late February 2013. //

Hydropower in Canada

Installed capacity:	**74 GW**
Potential not yet installed:	**162 GW**

Turbine modernization at Venezuela's Guri II hydroelectric plant will see power output jump by 5.5% for each of its five turbines.

II. FACING THE FUTURE

Innovative modernization work is helping China and South America go some way to fulfilling their massive hydro potential.

Hydropower in Venezuela

Installed capacity:	**15 GW**
Potential not yet installed:	**58 GW**

For decades hydropower has offered some of the cheapest, most ecological and reliable power to a number of emerging countries in Asia, South America and beyond. For some of these plants, the time has now come to undergo modernization work.

Voith Hydro has developed a range of technologies to serve the modernization market and combat those challenges where conventional engineering solutions are not sufficient. Some of its latest innovations in hydro modernization and rehabilitation are also thanks to the insights it gained during a joint Sino-German research project to develop sand-erosion protection techniques for turbines.

The project was carried out for the silt-laden Yellow River, one of the most extreme hydropower operating environments. The first stage involved a comprehensive evaluation of likely protection techniques in a 'slurry pot' test facility at the Max Planck Institute in Stuttgart to compare the erosion-resisting properties of a range of materials. The best of these were then re-evaluated in a high-velocity test rig at China Institute of ▷

▷ Water Resources and Hydropower Research, designed to replicate real-world conditions.

As a result of this combination of Voith Hydro's extensive manufacturing experience and its research and development work, the company has created a toolkit of several surface protection technologies called the Wear Inert Surface Enhancement (WISE) system.

The toolkit consists of three main solutions: DIATURB, a thermally sprayed hard coating technology based on tungsten carbide materials; SOFTURB, a thick-film advanced polymer coating; and TECTURB, replaceable wear elements that offer life extensions for critical turbine components.

DIATURB coatings are high-velocity oxy fuel sprayed cermet coatings offering erosion-coating protection. The coatings consist of extremely dense layers with excellent bond strength and abrasion resistance. Application is a technically demanding process, where the correct spray parameters are vital, including gun velocity and distance, and where application using robotic methods is often required. These coatings can improve wear resistance of turbine components by a factor of three to seven times with layer thicknesses of typically less than 0.4 millimeters, permitting its use where component dimension tolerances are tight.

SOFTURB coatings offer excellent abrasion resistance at comparatively low cost, in part because they can be applied by toweling, brushing or spraying in thicknesses of 1.5 to 2 millimeters. TECTURB wear elements, meanwhile, can be applied to 'hot spots' on turbines that are exposed to more rapid wearing, thus, extending their lives.

At San Men Xia, Voith Hydro is now applying some of these innovations at the location where it originally tested them. The company is modernizing two 50-MW turbines at San Men Xia, as well as other components, and is also carrying out automation work.

The scope of work to Units 2 and 4 of the facility includes modernizing the entire runner, the wicket gates and the wearing plates for the head cover and bottom ring, as well as automating the turbine elements. Voith will apply tungsten carbide coatings for the flow-through surfaces and convert the discharge ring from semi-spherical to fully spherical.

The works will increase prototype turbine optimum efficiency from 91.5 to 94.35 percent, increase the rated efficiency from 89 to 93.8 percent and boost unit output from 50 to 60 MW. In addition to ensuring improved resistance to erosion, the modernization will increase the facility's annual power output by just under 8 million kWh per unit, says Mr. Xu Gang, Head of Sales for Voith Hydro in China.

With less than a quarter of its technically feasible hydropower potential already installed, South America is understandably a popular market for new construction, although modernization work is also ongoing at various key locations. Voith Hydro is currently part of a consortium modernizing the Guri II hydroelectric plant in Venezuela, the country's largest hydro plant and the third-largest in the world (after China's Three Gorges and Itaipú, on the Brazil/Paraguay border).

Guri II is the first of these giant plants to be rehabilitated, which also makes it the largest such modernization hydro challenge ever taken on, says Telmo Gomes, project manager for Voith Hydro at Guri II.

Voith Hydro's part in the project includes rehabilitating five turbines and 10 governors and accessories, installing new Francis runners, head covers and five new sets of wicket gates. The project additionally involves installing a new operator ring and rehabilitating four others, installing 10 new sets of screw pumps for the hydraulic governor and 10 control panels for the digital governor.

The overhaul will see the power output of the facility greatly improved. "After concluding our job, the maximum output power of the five machines of Guri II will rise from 730 MW to 770 MW each," says Gomes.

Voith completed the rehabilitation of the first unit in May 2011 and has completed around 80 percent of the second, with a scheduled return into operation of late 2013. Following that Gomes and his teams will start the rehabilitation of the other three turbines and eight governors.

Such large projects offer a range of challenges, in this case the problems posed by transporting equipment to the remote site and the fact that Voith Hydro has to work with legacy equipment that it did not make. The greatest challenge of all, though – as with all modernization projects – is time, something Gomes says he and his team never forget. "Considering the importance of Guri to Venezuela, the greatest challenge was, and will continue to be, to find the fastest solutions to bring the units back into operation in the shortest possible time." //

Hydropower in China

Installed capacity:	249 GW
Potential not yet installed:	466 GW

Modernization at San Men Xia
- Increase prototype turbine optimum efficiency from 91.5 to 94.35 percent
- Increase the rated efficiency from 89 to 93.8 percent
- Improve unit output from 50 to 60 MW

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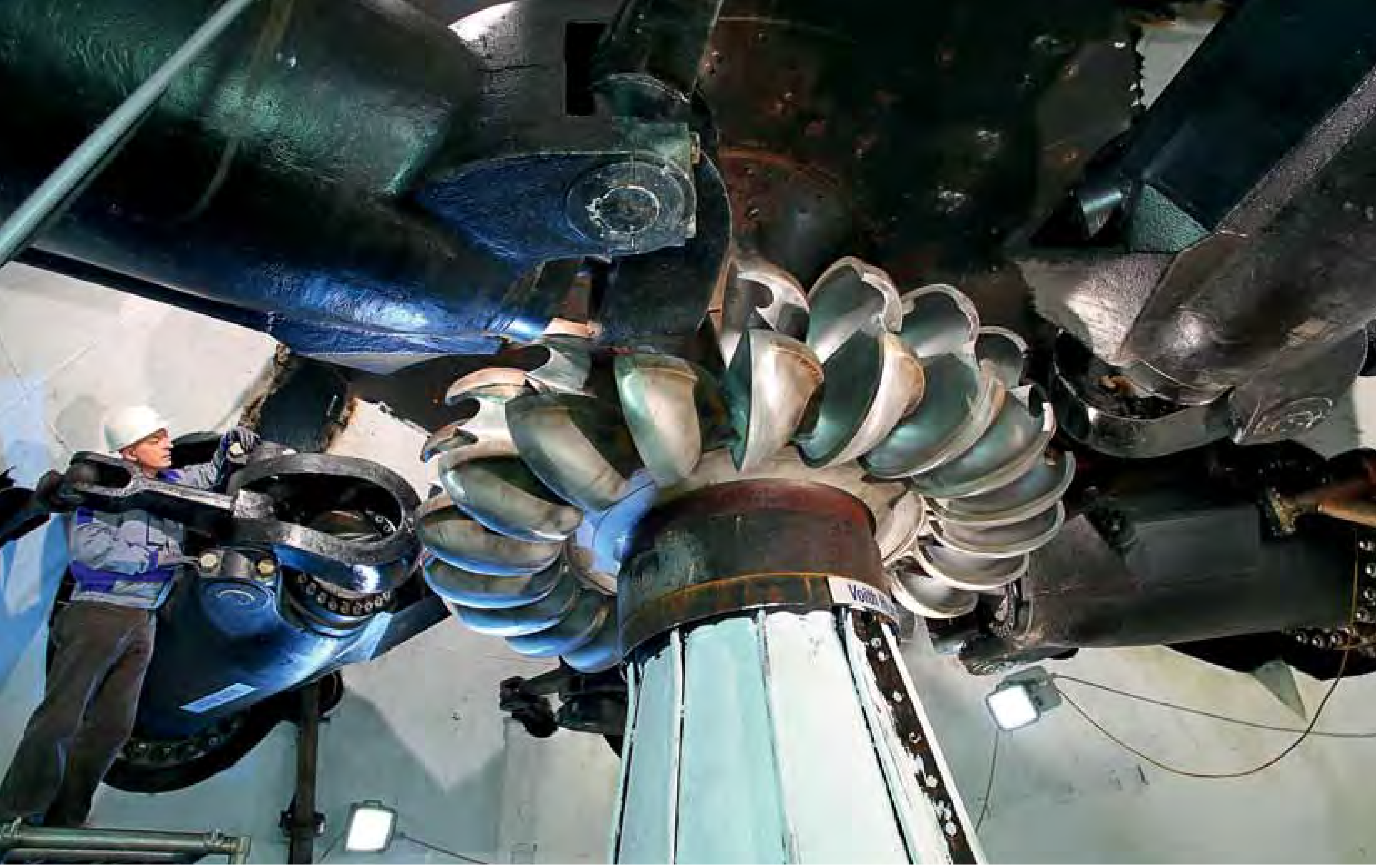
1&2 The SOFTURB polymer coating offers excellent resistance against abrasion. It can be applied by conventional means, such as brushing or spraying.
3 Improvements to the San Men Xia plant will increase efficiency, output and erosion resistance.



Pelton runner with modified Tosi injector, fully assembled after revision and ready for commissioning.

A view of the different power units inside the Roncovalgrande cavern.

III. HIDDEN TREASURE

Located underground at the foot of the Alps, the **Roncovalgrande hydroelectric plant is one of Europe's largest**, and now, thanks to Voith Hydro, one of its most modern and efficient.

From its underground position by the picturesque Lake Maggiore in northern Italy to the combination of its technological and ecological innovation, the Roncovalgrande hydroelectric plant is truly unique. Originally constructed in the 1960s, the plant recently underwent a major modernization, updating what was a smorgasbord of the finest available engineering at the time into one of Europe's most efficient hydroelectric plants with an installed power output of 1,000 MW. Together with the international Musignano-Livargo link, Roncovalgrande is one of the main power restoration lines in the event of a power blackout in Italy.

"The modernization demanded very high standards in performance and reliability," explains Vincenzo Marino, Technical Director at Voith Hydro in Italy. "Regulators of the main groups were replaced to increase operating capacity, while the volumes of lubricants and hydraulic fluids were also addressed. The grease that once lubricated the 44 Pelton injectors was eliminated by redesigning the needle shaft slide mechanism, to now use a self-lubricating system, coupled with stainless-steel casings on the original carbon steel shafts." While rather simple in itself, this modification was complicated by a complete overhaul of the hydraulic system, which now operates at four times the original pressure (80 bars instead of 20) and required a redesign of the force-balancing system for the needle mechanism.

Given the original pump generators were supplied by different manufacturers, a uniform approach was not possible. As Marino explains, it was a relatively simple task for the 24 injectors in the units supplied by Riva Calzoni, which were already set up with an oil and spring system, where the overall closure thrust was generated by the combined action of the water and the spring. Here, the only necessary modification was to reduce the thrust surface of the internal servomotor.

"However, it was more complicated for the 20 Franco Tosi injectors, where reducing the thrust surface of the internal servomotor required modification of the equilibration system so that water alone could be used to provide the closure thrust, since the original mechanism used hydraulic oil for both opening and closing." Having overcome these difficulties, the new high-pressure hydraulic system allows a significant reduction in oil required for operation thanks to the reduced thrust surface. Considering the high number of injectors, this is a large saving, in terms of both provisioning and storage costs.

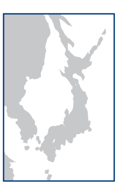
Hydropower in Italy

Installed capacity: **23 GW**
Potential not yet installed: **12 GW**

"But we mustn't forget the other benefits at Roncovalgrande," Marino says. "The new hydraulic system also achieves energy savings. Overlapped proportional valves significantly reduce oil loss and pump engagement times without compromising the response speed of the system to the regulator controls. An algorithm in the regulator recovers the deadband arising from the overlap in the proportional valve. What's more, the hydraulic oil controlling the operation of the machinery, while more costly than mineral oil, is now biodegradable; an environmentally friendly solution that befits a plant overlooking Lake Maggiore." //

IV. GOING VERTICAL

The world's largest vertical bulb turbine and generator will increase power output by 10 percent at **Japan's Toyomi plant.**



Hydropower in Japan

Installed capacity: **50 GW**
Potential not yet installed: **16 GW**

Boosting efficiency without excessive financial outlay is the goal in all hydropower modernization projects. Voith Hydro is at the forefront of achieving this by the use of vertical bulb turbines, and the upgrade of a major plant in Japan illustrates just how such a balance can be achieved. At Toyomi, which was originally built in 1929, the six existing vertical Francis turbine units (installed capacity of 56.4 MW) are being exchanged in favor of two high-efficiency, vertical bulb turbines (installed capacity 61.8 MW).

The project will increase Toyomi's existing power output by 10 percent, reinforcing Voith Hydro's market-leading operation in Japan. This is crucial in a country in which hydroelectricity is the main renewable energy source.

A particular highlight is the use of the largest vertical bulb turbine and generator in the world at 32 MW and with a runner diameter of 4.4 meters. "One of the technical features is the application of a couple of cooling methods in order to eliminate auxiliaries," explains Toyomi plant engineer Masahide Masuo. "The heat created in the generator stator and rotor is transmitted to the equipment's outer cover and then discharged to river water. The heat generated in the bearing is cooled in a double-walled oil chamber arranged in the bulb bracket," he adds.

Voith Hydro has proved that this modernization work can be carried out efficiently using a technique that allows the runner to be dislodged without taking apart the generator and turbine itself – thus reducing construction time. Installing a bulb turbine remains the most obvious solution for high outputs at low-head sites, enabling elimination of the linear water channel required for horizontal units. "This reduces the powerhouse plane area, making the powerhouse building itself compact and significantly cutting construction costs," says Masuo.

Scaling down this area also means vertical turbines can be used in sites which have severe geographical limitations, such as where there is a dam upstream. "Selection of the most suitable powerhouse location and type of turbine is indispensable in constructing new power plants and redeveloping existing ones," concludes Masuo.

This bulb turbine technology has been supplied by Voith since the 1950s, with new designs approaching high outputs in excess of 80 MVA. For those companies with older plants, vertical bulb turbines provide an ideal way of upgrading, with higher full-load efficiency and higher flow capacities offering many advantages. And when it comes to low-head projects, the equation becomes simple: turbines, such as the ones recently installed at Toyomi, offer higher annual energy output and lower building costs. //

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1 The new small hydro plant will generate around 9 GWh of clean energy a year.

2 The special Kaplan turbine featuring integrated generator.

A CULTURE OF HYDROPOWER

In southern Finland, a modest new construction houses **a link between hydroelectric power of the past and the very latest in cutting-edge technology.**

When the Finnish utility Suur-Savon Sähkö put out a call for bids on a new hydropower plant to be installed at the Kissakoski dam, southern Finland, it presented a project with cultural and technical challenges. The new plant was to replace the two hydroelectric power plants built in 1932 and 1940 that had played a major role in the history of electrification of the region. In order to gain approval from the authorities to develop the site, one of the key requirements was the historical preservation of the old plants, machinery and intake structures, as well as the creation of an industrial museum with a focus on hydropower.

The main technological challenge was installing a modern turbine into the existing dam structure. The old weir presented extremely wide variations in operation and unusual hydraulic conditions: a typical water supply of 40 m^3/s that might sink at times to 6 m^3/s and a fall rate that could vary between two and six meters. In addition, Suur-Savon Sähkö was looking for a sensibly packaged and economic solution to keep costs manageable. Further requirements included interruption- and vibration-free operation, while also preventing cavitation.

Unlike any of its competitors, the offer from Voith Hydro subsidiary Kössler included a specially designed Kaplan bulb turbine. These turbines are widely used throughout the world for electrical power production, though typically on larger installations. Karl Henninger, Offer Project Manager for Scandinavian countries at Kössler, says: “Once we invited Suur-Savon Sähkö to see a similar installation on Munich's Isar River, they were convinced.”

But meeting the parameters was not easy, explains Gerald Hochleitner, Head of Design at Kössler: “Integrating the turbine housing, bulb and 20-ton generator while coming up with the entire cooling system was an incredible challenge. The end result was a synchronous generator flanged on the extended shaft of the turbine.” Austrian-based Kössler provided both the turbine and generator, and all necessary auxiliary equipment as well as accessories and spare parts. The company was also responsible for transportation, installation, supervision and commissioning.

Despite the arctic weather conditions that accompanied the January 2012 start, the project ran like clockwork and the hydropower plant entered operation barely five months later. And although this signaled the beginning of a new era in hydropower on the Kissakoski dam, the Kissakoski Power Plant and Electricity Exhibition housed in the old groundwood mill ensures it will never forget its past. //

MULTINATIONAL MILESTONE

Voith Hydro's **Cubujuquí project in Costa Rica** is a small hydro plant with big international reach.

Dense forest at the Cubujuquí site. Terrain prevented the use of surge tanks, so an innovative solution had to be found.

It may have been installed in Costa Rica, but Cubujuquí is the result of equipment made in Brazil, Italy, Colombia and India. Commissioned by Voith and one of the largest local cooperatives, Coopelesca, Cubujuquí was launched into service in December 2012. The plant is equipped with two 11.4 MW horizontal Francis turbines designed by Voith Hydro Brazil and Voith Hydro Noida (India), and manufactured by Voith Hydro Vadodara (India); two 13.8 MVA generators and butterfly valves, supplied by partner companies in India and Italy, with the valves supervised by Voith Hydro in Milan; hydromechanical parts supplied from partners in Costa Rica; substation equipment from Siemens Colombia and Siemens Costa Rica; and lastly, mechanical and electrical balance-of-plant and automation systems from Voith Hydro Brazil.

Why this multinational involvement in one small hydro plant? Leonardo Penteado, Voith Hydro Brazil's project manager for Cubujuquí, explains: "In the increasingly competitive global small hydro market, you have to be creative to achieve the best possible quality-to-price ratio. Bringing in equipment from these different sources allowed us to minimize our costs and maximize our supply chain while keeping quality high."

Cubujuquí is Voith Hydro's first project in Latin America to employ a power unit designed, manufactured, tested and delivered from India, but it will certainly not be the last. Not only did the products meet Voith Hydro's quality standards, but the Indian team also had a firm handle on costs. Sumeet Mazumdar, Head of Communications and Project Management & Field Services, Large Hydro, for Voith Hydro India, notes that the company benefits from tax breaks, low labor costs and incentives from the Indian government for hydro plants when producing for export, all of which means considerable savings for customers.

Rohit Uberoi, Head of Small Hydro Engineering at Voith Hydro Noida, points out that the Cubujuquí project was a steep learning curve in a number of ways. "Our plant in Vadodara opened in 2010 and at that time did not have many workers with experience in this kind of project. In addition, we were set up to implement standard solutions, but for Cubujuquí, the generator was a type that we had just developed. We also discovered that we needed to improve our sourcing network to avoid delays."

In spite of the challenges, the Vadodara plant managed to satisfy Voith Hydro Brazil's criteria with the help of teams worldwide. "A quality manager from Brazil came to our plant and helped train the workers to ensure we would meet Voith standards," Uberoi explains. "We also had regular design reviews with Voith Hydro in Brazil and Germany to ensure that we were all on the same page. Our team learned a lot of lessons from Cubujuquí that we have already been able to carry over into other projects, including producing turbines for a hydro plant in Canada, which we managed to deliver ahead of schedule."

Partnering with colleagues on the other side of the globe presented several challenges, including linguistic and cultural differences as well as distance, although as Penteado explains, the time-zone gap actually turned out to be a plus in some ways for the project. "We would e-mail the team in India in the middle of their night, and by the time we got back to work the next day, they had answered our questions. It was as though we were working on the project 24 hours a day."

In addition to coordinating input from all over the world, the project had to overcome a number of daunting constraints. Terrain at the site prevented the use of surge tanks, and relief valves would have been prohibitively expensive. So, the team in Brazil got innovative: they designed a hydraulic solution in which the turbine functions as a relief valve.

"There were very few references for something like this, so the Brazilian team had to carry out a number of computer simulations to test the feasibility, with Voith engineers in Germany verifying their proposals," Penteado explains. "The system is working very well at Cubujuquí. In fact, this plant is now a benchmark in Costa Rica's energy sector." Extensive testing may have proved time-consuming, but the project was still completed less than two years after it had begun.

Another first at Cubujuquí was the "basic" automation solution developed by Voith Hydro Brazil. "This is a simplified automation solution that focuses on the customer's specific needs," says Penteado. "It is much more cost-effective than traditional systems." Such is its success, Voith is already implementing the automation in another Latin American project. The reach of Cubujuquí continues to expand. //

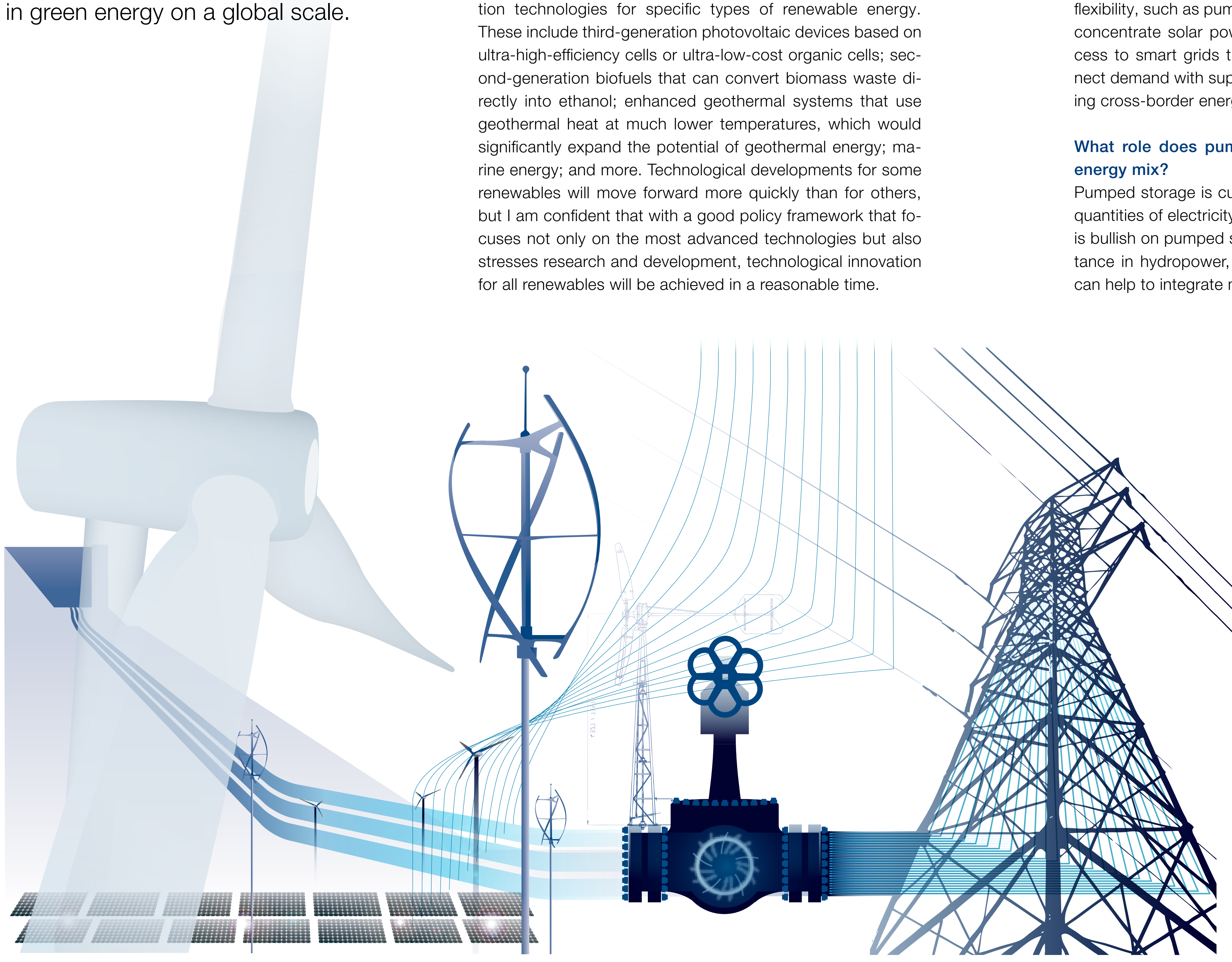
Global effort: the turbine runners were designed in Brazil and India, and manufactured in India.

GREEN ENERGY MIX

HYDROPOWER LEADS THE WAY

Dr. Paolo Frankl, **head of the International Energy Agency's Renewable Energy Division**, discusses the role of hydropower in green energy on a global scale.

What are some of the new technologies that you feel will be most important in green energy development?
While renewable energy in general is becoming more mature, we are eagerly looking forward to second- and third-generation technologies for specific types of renewable energy. These include third-generation photovoltaic devices based on ultra-high-efficiency cells or ultra-low-cost organic cells; second-generation biofuels that can convert biomass waste directly into ethanol; enhanced geothermal systems that use geothermal heat at much lower temperatures, which would significantly expand the potential of geothermal energy; marine energy; and more. Technological developments for some renewables will move forward more quickly than for others, but I am confident that with a good policy framework that focuses not only on the most advanced technologies but also stresses research and development, technological innovation for all renewables will be achieved in a reasonable time.



Enabling technologies are crucial to all of this. There are two main types of these for renewables: storage and smart grids. They both contribute to flexibility and this is the key to making viable renewable energy more readily available. Power systems of the future will need the flexibility to adapt to a variety of energy supplies, including ones that can be ramped up and ramped down very quickly, such as hydropower and gas. Power systems will also need storage systems that give them flexibility, such as pumped storage and new technologies that concentrate solar power. Power systems will also need access to smart grids that efficiently and cost-effectively connect demand with supply, including wide-grid systems involving cross-border energy trading.

What role does pumped storage play in the renewable energy mix?
Pumped storage is currently the cheapest way to store large quantities of electricity. The International Energy Agency [IEA] is bullish on pumped storage – not only because of its importance in hydropower, but also because this type of storage can help to integrate much larger quantities of wind and solar energy to the global power system in the future. Totally new pumped storage systems can be expensive, but some types will remain economically attractive, for example ones using cascading lines between energy systems.

Paolo Frankl
Currently head of the Renewable Energy Division, Frankl joined the IEA in 2007. He has a PhD in energy and environmental technologies from the University of Rome.

A recent IEA report says that hydropower is now the leading renewable energy in use worldwide. Will it maintain this dominant role?
Hydropower will remain the leading single renewable energy employed globally at least until 2050, although other types of renewables, especially solar and wind power, will steadily gain larger shares of the green-energy market. Hydropower is in fact a special case among renewables because the technology is already mature. Technological advances in hydropower in the future will improve the sustainability of hydro systems, limit environmental impact, such as through fish-friendly turbines, and eventually expand pumped-storage options, for example through developing storage systems that can use seawater. New technologies for small hydro plants, which are very important in many parts of the developing world, will help enhance energy security in those countries.

What are some of the key current global trends in renewable energy?
One striking recent development is the rapid growth in the number of countries that are developing renewable energies – some of them for the first time. We are also seeing a significant increase in the number of countries that are setting ambitious renewable energy targets, such as China. Emerging economies are playing a more and more important role in green energy development, particularly China and Brazil, but also South Africa, Mexico and others. One sign of the growing focus on renewables worldwide is that the International Renewable Energy Agency, founded in 2009, already has 160 members, including the EU.

What are your own priorities as the head of the IEA's Renewable Energy Division?
The IEA is committed to providing a factual, reliable and neutral picture of the status, progress and potential of all types of renewable energy. We want to make sure that green energies are fully integrated into the global energy system, that they are competitive and that energy markets provide a level playing field for them. The IEA is currently calling attention to the fact that subsidies for fossil-fuel development vastly outweigh those for renewable energy development. In the global energy market, we need to change the current rules of the game to focus more on policies aimed at developing secure, clean and affordable energies for the future. The IEA will continue to identify and promote global best practices in green energy. //

Harmonizing wind and water energy: Frades II

A HIGHER PLANE

With energy demand on the rise, three key developments in pumped-storage technology are helping provide **greater flexibility and efficiency** to our grids.

As the mix of renewable energies in the world's electricity supply grows, so does the need for reliable, high-efficiency short-term storage of energy to reduce fluctuations in the grid. According to a 2011 study by Germany's Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, the German grid will need more energy in the coming years for hourly and daily balancing of load fluctuations than it will for balancing over longer intervals, such as weekly, monthly and yearly (see chart on following page). "Over the long run, a minimum of 70 to 80 percent of the storage business will be short-term," explains Alexander Schechner, Head of After-Market Business at Voith Hydro in Germany.

Fortunately, hydropower pumped storage is already helping to meet the need for cost-effective grid-scale energy storage the world over. The design of the plants allows energy to be stored as water and then generate electricity: first, water is pumped up to an elevated reservoir; when electricity is required, it is released through turbines down to a lower reservoir.

In operation for more than seven decades, new developments to the various pumped storage applications, namely variable-speed systems, ternary systems and multi-stage pumps, are now making this technology more effective.

So far, pumped storage was considered an ideal supplement to nuclear and thermal base-load power plants, since it is costly for those plants to reduce production, for instance overnight, even if demand changes.

"Because of the ability of a hydropower pumped storage plant to increase or reduce output within minutes, or even seconds, pumped storage is an all-rounder – it's the wunderkind on the block when it comes to power plants because it provides grid support and storage," says Schechner.

A differential is made between long-term and short-term storage, where short-term typically means a few hours, or 10 at most. Contrary to popular opinion, short-term storage is actually what is needed most, Schechner says. "Producers need maximum flexibility to combine stored energy with fluctuating renewable energies, such as wind and sun."

In Portugal, where the government is developing a further 5,400 MW of wind-power capacity, Voith is equipping a pumped storage plant called Frades II in the northern part of the country, featuring variable-speed pumped storage units that will help local wind power become more profitable and more reliable.

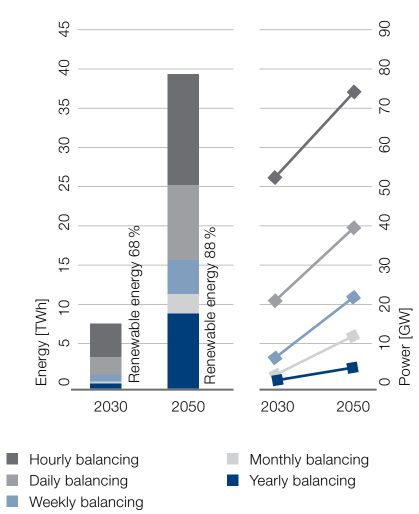
The plant, with two units of Francis vertical variable-speed pump-turbines, will be connected to the grid in 2015 ▷

Aerial view of the lower and upper reservoirs at Wehr, southern Germany.

Modernization work carried out on one of Wehr's generators.

Pumped storage to the fore

The growing need for short-term load balancing in Germany's power grid



Source: Fraunhofer Institute

and produce a maximum of 383 MW per unit. It will use two asynchronous motor-generators to serve the grid.

Grid frequency, which must not vary more than +/- 0.1 hertz, is stabilized when the motor-generators react extremely fast to provide power to the grid or absorb power from it; they can react within milliseconds due to highly sensitive control systems that can tap the kinetic energy of the flywheel masses of the motor-generators.

For the project in Portugal, Voith is delivering variable-speed technology for pump-turbines, made feasible with asynchronous generators, namely double-fed induction machines.

Using an asynchronous generator to regulate pump speed and power is not new in industrial equipment. The machines operate independently of the network frequency as pump-motors with variable power, but also optimize turbine efficiency during generation at reduced speed at partial load.

In applying the concept to hydropower plants, the problem has always been the larger scale. Now, however, Voith Hydro has developed an asynchronous motor-generator for a large-scale pumped storage plant. This enables the pump-turbine to change its rotational speed, meaning the pump capacity can be adjusted using just the currently available amount of energy, allowing for highly efficient stabilization of the grid during pump and turbine operation.

"Typically, pump-turbines are connected via synchronous generators to the grid and cannot be regulated in pump mode – they always pump with the same power," comments Wieland Mattern, project manager for Frades II. "Using variable rotational speeds represents a new level of pumped storage that better meets requirements for electrical grids in the future. In addition to transporting variable power into the grid, as with synchronous pump-turbines, variable power can also be pumped out."

Two further advantages also exist, says Mattern. "Asynchronous pump-turbines are particularly suitable for dynamic peaks in grid load variation and they can be operated at optimum efficiency in both pump and turbine mode."

For plants that are already operating with synchronous generators, particularly smaller pumped storage plants, Voith is developing a full-scale convertor solution to provide similar functionality.

Elsewhere in Europe, Voith Hydro is also at work with another technology that has been further developed to improve the performance of pumped storage plants – ternary systems.

As the name implies, ternary systems are a three-part set: a turbine connected to a motor-generator on the one side and a pump on the other. As two separate hydraulic machines, the rotational direction of the motor-generator can be the same in both operational modes, giving considerable commercial value for a plant's operation. "The technology enables the highest flexibility between power delivery and power consumption modes," says Johannes Roest, Voith Hydro project manager.

For Forces Motrices Hongrin-Léman S.A., plant owner at Lac de l'Hongrin and Lac Léman in Switzerland, Voith provides two vertical multi-stage pump units as part of the plant's ternary units (together with the Pelton turbine and the motor-generator).

The technology has been recently refined so that customers can use both pump and turbine simultaneously to efficiently pump the water within a hydraulic short circuit. "Ternary systems are the most flexible. They are more expensive than standard technology but allow the plant to be customized to the operator's needs. Improving the application and use of hydraulic circuits enhances flexibility further," Roest says.

Across the border in neighboring Germany, at the pumped storage plant Wehr, the operator, Schluchseewerke AG, recently hired Voith to modernize the four horizontal motor-generators at one of the world's largest pumped storage facilities in the world. The 4x300 MVA ternary system was in operation for more than 40 years, providing high levels of reliability and flexibility. In recognition of Voith's expertise in this field, the company was asked to update the technology with the latest features.

The final piece in the development of pumped storage is multi-stage technology. With this concept, water is pumped to the upper reservoir in stages inside a single pump.

The pumps are built in a row (in five stages at Lac de l'Hongrin) because of a plant's location high up in the mountains or significant height differences between the upper and lower reservoirs. Overall grid efficiency is increased since multi-stage pumps can be used during times of over-production from renewable energies, consuming that excess energy to get the stored energy of the water into position in the upper lake to be released when needed.

The enhancement of these three technologies is bringing pumped storage to unprecedented levels of flexibility and efficiency. Trianel, a network of municipal utilities in the western part of Germany, is designing pumped storage plants in consultation with Voith and the group is optimistic about the efficiency gains and additional flexibility that the plants will provide.

"As the energy mix in Germany transitions to a high proportion of renewables, a flexible power supply is vital," states Christoph Schöpfer, project manager at Trianel. "In addition, it is now possible to design pumped storage plants so that they are adapted to the ecosystem. From the outset, designers work to minimize the impact of the power plant and keep in mind what plants and animals need to thrive." //

MAXIMIZING POTENTIAL

StreamDiver® is a new compact and eco-friendly turbine from Voith, designed to step in where conventional hydropower plants may not be viable.

Ecological concerns were a key factor in the development of the StreamDiver. An important feature is the bearings, which are lubricated entirely by water to prevent contamination from oil and grease.

Hydropower today accounts for the largest share of renewable energy generation in the world, with more than 3,000 TWh generated annually. In more than 60 countries, hydropower covers at least 50 percent of the electricity supply.

Nevertheless, there remains a large portion of untapped hydro energy potential worldwide. The reason for this is often economical, as energy production can be considered unviable in some areas. Another common hurdle is ecological concerns in areas where large hydropower plants may have a profound impact on the local environment.

In order to take advantage of this unused potential, in cooperation with its subsidiary Kössler, Voith has developed StreamDiver, a new compact propeller turbine particularly suited to taking over where bigger plants may not be viable.

Inspired by ocean energy research, the patented StreamDiver offers a compact and low-maintenance alternative in fields where conventional hydropower plants were previously impossible due, for example, to natural reserves. The small turbine will allow construction work to be kept at a minimum as the entire drivetrain, consisting of the turbine, shaft, bearings and generator, is situated in a bulb-turbine-type housing that negates the need for a visible or accessible power house. The power unit is installed directly in the water with only the power cable coming out. In addition, the bulb is filled with water, which completely lubricates its bearings, ruling out any risk of water contamination.

The turbine itself is designed as a propeller turbine, meaning that neither rotor nor stator is adjusted. Water flow can be controlled by switching individual turbines on and off, or by regulating variable-speed operation. For shutdowns a separate gate is used, which simultaneously allows for speed to be controlled in order to start and synchronize the compact turbines. All these design solutions allow for a comparatively low total cost of ownership.

The StreamDiver offers a flexible alternative to conventional hydropower plants. It can be installed as a stand-alone turbine or in sets, as seen here.

The technical features of the StreamDiver represent the very latest developments in the field of small hydropower, although the underlying concept is actually a relatively simple one, says Gerald Hochleitner, Head of Design at Kössler. The turbine takes in water through a rack, which retains branches, leaves and other debris. The remaining hydropower generation process is then taken care of by the turbine's fully integrated drivetrain. Through its design, maintenance requirements and the risk of unforeseen outages are reduced to a minimum.

The compact make-up and eco-friendly features make the StreamDiver especially helpful in locations where existing weirs or dams are already in place to regulate small riverbeds, says Product Manager Jörg Lochschmidt, who has been in charge of the StreamDiver project since 2010.

> "StreamDiver is a serial product with numerous possibilities."
>
> **Jörg Lochschmidt,** Project Manager

"There are a lot of locations with existing dam structures. In Europe, due to new ecological regulations, these structures must be bypassed to recultivate the river. Combining these necessary measures with the installation of a StreamDiver has a double effect: renaturalization and power generation at the same time, helping to make the investment affordable," Lochschmidt says. "The StreamDiver is very special to us. Conventional hydropower plants are ▷

Due to its small size, the StreamDiver is especially helpful in fields where sills and buildings are already in place to regulate small riverbeds. It requires low levels of maintenance and will only need technical checks every five years.

How it works:

The turbine, apart from the stator entirely filled with water, takes in water after a filtering rack has secured a steady water flow (1). The water intake is then sent through the integrated drivetrain (2) before being converted into clean hydro energy (3).

▷ designed according to individual circumstances and the project at hand. StreamDiver, in contrast, is an affordable serial product with numerous application possibilities around the world."

A pilot project began in 2011 in cooperation with Austrian energy providers VERBUND Hydro Power, Grenzkraftwerke, evn naturkraft and Wien Energie, in addition to the first prototypes still in operation near Voith Hydro headquarters in Heidenheim. Recently, with the backing of German Federal Environment Ministry and the help of Stuttgart University, another initiative has been started to develop a solution adapted to the StreamDiver to meet current tough ecological requirements.

In Germany alone, the new power generation concept could generate an additional 3.5 TWh of clean, renewable energy each year, a rise of more than 15 percent on the current national hydropower production level, or enough to power almost 300,000 households for a year. //

NEW GENERATION

Voith Hydro's Swedish operating unit has a remarkable depth of hydro expertise, **particularly in the field of generator manufacturing.**

There is a proverb that goes, "Only Sweden has Swedish gooseberries." It is a statement of pride about the unique characteristics of this northern country that says Sweden is different; Sweden is special. And, over the years, a number of companies have emerged onto the world stage with the lessons they learned in the Swedish market.

Sweden is ideally suited to hydroelectric generation, both geographically and politically. With plenty of mountains to provide a drop and precipitation to generate running water, there is no shortage of locations suitable for hydro facilities, and following the oil crisis in the 1970s, the government moved to decrease the country's dependence on fossil fuels. This involved heavy investment in both nuclear and renewable energy generation, and hydro currently accounts for almost 50 percent of the nation's electricity. All of this means that the hydro market in Sweden is different to most of the rest of the world. "It's a mature market," says Magnus Wenna, Marketing Director for Voith Hydro Västerås (VHV), "with 80 to 90 percent of feasible hydro locations already utilized."

Formerly known as VG Power AB, VHV is the Scandinavian market leader in large generators. Founded in 2002, it specializes in large generators and the refurbishment and maintenance of Hydro facilities. Voith Hydro became majority shareholder in 2006, and at the turn of this year moved to cement its stake in the company by taking the ownership to 100 percent.

In a mature market like Sweden's, projects to build new hydro facilities are rare and most of the market is in refurbishment and optimization of existing facilities. The country was an early adopter of hydroelectric power and many of its more than 1,000 operating hydro facilities date from the first two decades of the 20th century. Refurbishing and upgrading the generator equipment in these older facilities is the perfect opportunity to provide benefits for the operator without the environmental impact of building a brand new facility. And it is on projects like these that VHV has developed its expertise.

VHV designs and builds state-of-the art generators to fit new or existing hydro facilities, as well as offers maintenance support and full refurbishment and upgrade services for hydro generators and turbines, pump motors and generators, bulb generators, synchronous condensers, rotating and static excitation systems, and other components. "Our services give operators a range of benefits, including increased lifetime and power output alongside reduced service costs," says Stefan Borsos, who took over as President and CEO of VHV in October 2012. "We offer the best way to increase capacity and efficiency in a mature market with only rare opportunities to build new generator facilities."

The expertise that VHV has accumulated will continue to be central to a number of Voith Hydro products around the world, including the Red Rock project in the United States plus sites in Norway, Iceland, Wales and Switzerland. In these and other future projects, VHV will deliver new generators or components, while local Voith Hydro offices provide the turbines and overall project management. It's a partnership for the future, forged in Sweden. //

VHV brings expertise to the Voith Hydro portfolio in several areas, as seen in the US, Norway, Wales and Switzerland.

Runners for improved fish passage will be installed for testing at Ice Harbor.

SAFE PASSAGE

A new technological achievement **makes hydroelectric facilities safer for native fish** and improves the efficiency of this invaluable energy source.

Schematic view of a minimum gap runner Kaplan turbine

The huge benefits of hydroelectric power for humans are indispensable. However, it must not be forgotten that rivers, streams and oceans are the natural habitat of many species of fish. As hydropower is a truly sustainable energy source, advancements in technical equipment for improved fish migration is a constant focus for Voith Hydro engineers.

For traditional applications, spilling water over the dams, collecting fish in the upper reservoir or diverting them around turbines has helped improve fish survival rates during downstream migration, although they are costly solutions that can impact efficiency.

From the fish's point of view, threats stem from low pressure, high shear, high-pressure change rates, blade strike and poor flow quality. Large gaps at the inner and outer peripheries of turbines can increase the probability that fish will be exposed to these harmful flow characteristics due to the leakage vortices originating at the gap.

To improve fish survival for smaller radial flow applications, Voith partnered with Alden Research Laboratory to develop and test a new three-bladed runner technology that reduces mortality caused by strike, pressure and shear. The predicted juvenile survival rate for passage through the Alden turbine is 98 percent or higher for various species of fish.

With support from the Electric Power Research Institute, the US Department of Energy and industry partners, this development is set to enter the market. "The technology is unique," says Voith Hydro hydraulic engineer Jason Foust. "It incorporates the latest environmental criteria for fish passage into one design."

In the area of adjustable blade axial flow turbines, Voith's Minimum Gap Runner (MGR) has already been providing safer fish passage for several large units, including Bonneville and Wanapum Dams in the Pacific Northwest. MGR concepts are also being implemented in a recent collaboration with the US Army Corps of Engineers, and will be installed for testing at Ice Harbor Lock and Dam.

The goal is to identify blade turbine geometries that improve fish passage by addressing each cause of mortality. "We are working with the US Army Corps of Engineers to develop fixed and adjustable blade replacement runners on Kaplan turbines," Foust explains. "These turbines are being developed and evaluated according to fish-passage design criteria and the new components tested in our laboratory." Ice Harbor fish survival rate is expected to surpass the 95 percent for previous MGR applications. //

SUSTAINABLE PAPER PRODUCTION IN TURKEY

MODERN KARTON – one of the largest manufacturers of board and packaging paper in Europe – has commissioned Voith Paper to supply its new PM 5 for lightweight packaging paper production at its plant in Çorlu, Turkey. The machine is expected to startup by the middle of 2015 at a speed of 1,500 m/min. It will have a wire width of more than 8 meters and will produce around 400,000 metric tons of packaging paper. The paper machine will be a particularly sustainable investment for Modern Karton, as it consumes little fresh water. Due to installation of an innovative dosing system in the approach flow system of the PM 5, it is possible to precisely coordinate the use of chemicals. In addition, software localizes and visualizes all energy consumption in the paper production process. So, energy and water are saved. Modern Karton will also set up a power plant on the mill premises to fully utilize residual materials from the manufacturing process and generate additional energy. //

FIRE PROTECTION FOR DANISH OIL TERMINAL

3 miles of underground water pipes

VOITH INDUSTRIAL SERVICES has equipped Danish oil terminal operator Inter Terminals with a new automatic fire-protection system. New regulations mean 12 oil tanks built in the 1960s will be fitted with modern firefighting and cooling systems. Voith worked for 12 months on the project, building three miles of underground water pipes as well as three miles of an above-ground piping system that will distribute foam in case of an emergency. The work brings the system in line with the latest standards, providing the Danish company with an up-to-date manual and automatic protection against fire hazards. //

GEARING UP BRAZILIAN FPSO UNITS

VOITH HAS RECEIVED A MAJOR ORDER for the delivery of 60 variable-speed planetary gears of the type “Vorecon.” The Vorecons will enter service in offshore production at the oil fields on the huge pre-salt cluster in the Atlantic, approximately 300 kilometers outside Rio de Janeiro. The operator is a consortium led by the Brazilian Petrobras Group. With this order, which will run for several years, Voith Turbo is strengthening its leading position in the growing oil and gas markets of Latin America and the NAFTA region. Voith, active in Brazil for nearly 50 years, will also build a new dedicated assembly hall with a test field in São Paulo. The Voith technology is an important building block for the technically reliable and commercially viable exploitation of the oil reserves located off the Brazilian coast. By 2017, the consortium of operators is setting up eight floating production storage and offload units (FPSO) in the area for a total of $3.5 billion. These FPSOs are to extract the oil reserves contained in the pre-salt cluster up to seven kilometers below the water surface.

The exploitation involves the penetration of a salt layer with a thickness of up to two kilometers, as well as a three-kilometer stone layer. To overcome this, the operator is taking a new approach: first, a mixture of oil, gas and water is moved to the surface from the oil fields. The three constituents are then separated on special vessels. The crude oil is bunkered on ships, while the gas is returned to the subsea oil field and thus preserved for later utilization. In the past, most of the gas was combusted and therefore lost. Special compressors densify the gas for return transportation into the oil field. The compressors, whose speed is controlled by the Voith Vorecons, are driven by electric motors. Due to its compact, robust design and its high reliability, the Vorecon is ideal for the rough conditions in the Atlantic Ocean. The variable-speed planetary gear from Voith is a product that has proven itself for decades in reliable operation in the oil and gas industry. The Vorecons for the Brazilian pre-salt oil field build on this technology and experience. //

SAVING LIVES

Inspired by two of the worst natural disasters in recent years, **Michael Pritchard's simple but ingenious LIFESAVER invention** is living up to its name.

Creating genuinely innovative solutions to the most intractable problems is a talent possessed by few. When that problem happens to be supplying water to people to whom it can mean the difference between life and death, the innovation is all the more significant.

Like millions across the world, in 2004, Michael Pritchard watched on television in horror as an Indian Ocean tsunami killed more than 200,000 people. He was astonished to discover that in its aftermath people continued to die as a result of a lack of access to clean drinking water. "I kept thinking how ridiculous it was," he recalls, "This, in the 21st century – why couldn't we get clean water to them?"

The tragedy planted a seed for future action, though it took Hurricane Katrina a year later to spur him on to establish a method of providing clean water to disaster areas. "I remember

1

2

3

1 Michael Pritchard's invention has already brought clean water to many communities …
2 … by allowing them to make the most of the natural resources around them.
3 LIFESAVER technology provides an appealing alternative to transporting vast amounts of drinking water.
For more information: www.lifesaversystems.com

GUEST PERSPECTIVE

thinking, 'Here is the world's greatest power, with the greatest economy, and it cannot provide clean drinking water.'"

Though Pritchard, from England, does not have a classic science background – insofar as he doesn't have a science PhD, for example – he does have the mind of a radical innovator. His clean-water concept is both simple and ingenious: his initial creation, the LIFESAVER bottle, looks pretty much like many other bottles for carrying water: it is largely plastic, lightweight, fits in one hand, and has a drinking nozzle and cap. In fact, the only noticeable difference with most bottles is that it has a "pushable" bottom, which happens to be a pump, and the magic ingredient in producing clean water.

The science of Pritchard's clean water is filtration, though several steps beyond the usual systems based on "holes" measuring 200 nanometers – at such a size, they are unable to prevent all bacteria and viruses creeping through. In contrast, Pritchard's way of producing 100-percent-clean drinking water is to filter dirty water through holes of just 15 nanometers, "a size that does prevent all living things getting through." The challenge, however, was to create sufficient pressure to force the liquid through such small holes.

Knowing that it is pretty much impossible to compress water, his solution was to create a bottle with a pump, which is used to compress air, subsequently forcing the water through the filter holes. The corollary to this was to ensure that water, not air, went through the filter, so Pritchard turned to nature for inspiration: "Certain natural materials absorb water; with others, water bounces off," he explains. "I realized that if I had a membrane that was hydrophilic – something that prefers liquid to gas – then the gas would not pass through and I could build up huge pressure." In short, the effect is that the compressed air forces dirty water into the filter's 15-nanometer holes, leaving the "dirt" behind and clean water in the bottle.

It didn't take long for Pritchard to implement a similar principle on a 18.5-liter jerry can, giving users access to far larger amounts of clean drinking water. The results of this innovation have already had a positive impact in disaster areas and other regions where access to clean water is a problem. With each filter providing thousands of liters of water before clogging up, villages from Malaysia to Africa and across disaster zones are a few easy pumps of a plastic bottle away from converting dirty water into clean drinking water.

And such has been the impact of Pritchard's LIFESAVER that it is standard issue for the British army, while Oxfam uses the bottles and jerry cans in the field. This, however, is just the initial stages of a much bigger challenge, hopes Pritchard. "It may sound great," he says, "but I want to end water poverty, and hopefully in my lifetime." //

COFFEE BREAK

Voith Hydro **CEO Dr. Roland Münch** reveals his personal connection to the world of hydropower.

Dr. Münch, do you start to think about hydropower as soon as you turn on the water in your bathroom in the morning?

To be honest, no. I really enjoy working in the hydropower business, and I am convinced of the advantages of hydropower as a climate-friendly and efficient way to produce energy. But in the morning, I am much more likely to be thinking about a cup of coffee.

Which also contains water …

Yes. And to brew coffee, you need electricity. What we do at Voith has ensured – for more than 140 years – that a great deal of this electricity comes from hydropower.

I see. So you are more likely to think of hydropower when you switch on your coffee machine in the morning?

Actually, that's quite rare, as well; even though we make a significant contribution to producing eco-friendly electricity, and even though I have a PhD in electrical engineering!

Why is an electrical engineer like you working in hydropower?

Predominantly because of generator and automation technology. Since the joint venture in 2000, when Voith and Siemens merged their hydropower operations, we have been a true full-line supplier. Voith Hydro covers the whole range of services, including turbines and generators, all the way to complete plant automation.

What role does the generator play at Voith, a company with a long tradition as a turbine supplier?

It is a vital one. We have been at home in both sectors for a long time and we are very successful in them. We make use of our high level of expertise in our own generator workshops in Shanghai, São Paulo and Västerås.

Speaking of generators, we're talking about big numbers when it comes to power output now.

Indeed. We're getting close to a generator class with a capacity of 1,000 MVA – an amazing development.

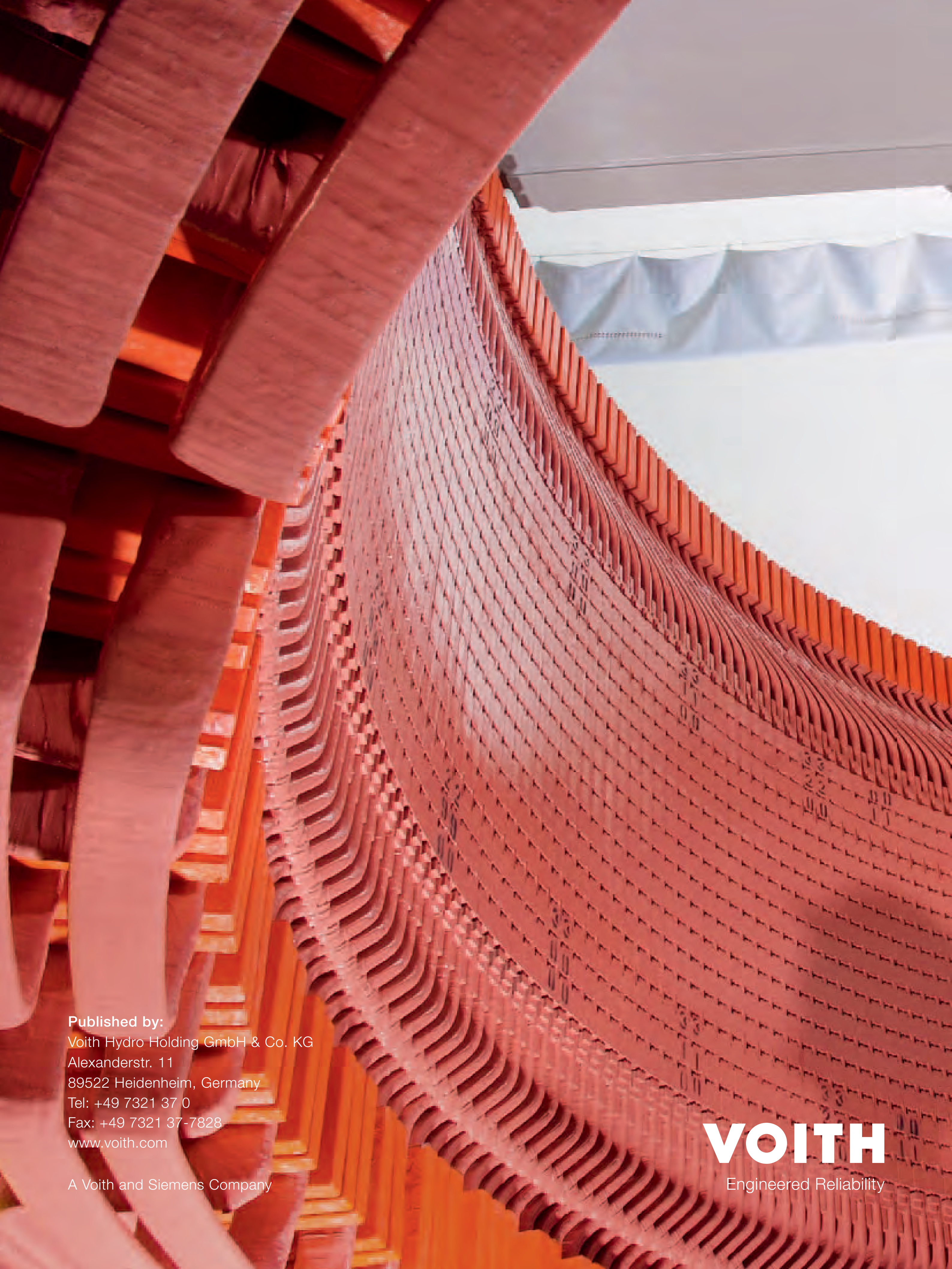
So, you're a numbers person?

Yes, definitely. In both positions, as an engineer and a CEO, numbers are absolutely essential. //

PROJECT DIRECTORY

All plants mentioned in this issue and **Voith's scope of supply**

1 Guri II, Venezuela: Rehabilitation of five Francis turbines plus automation systems with increased output of 770 MW.
2 Cubujuquí, Costa Rica: Supply of two 11.4 MW Francis turbines plus balance-of-plant and automation systems.
3 Gordon M. Shrum, Canada: Rehabilitation and upgrade of five turbines with an increased output of 310 MW each.
4 Kissakoski, Finland: Supply of a special bulb turbine and synchronous generator with 1.5 MW output.
5 Wehr, Germany: Modernization of four 300 MVA horizontal generators including rotor and stator rehabilitation.
6 Rheinfelden, Germany/Switzerland: Supply of four new 25 MW Kaplan bulb turbines quadrupling the power plant's output.
7 Hongrin-Léman, Switzerland: Supply of two vertical multi-stage pump units for two 120 MW ternary units.
8 Frades II, Portugal: Two variable-speed vertical pump turbines, each with 383 MW output and two asynchronous motor-generators with rated output of 419.5 MVA.
9 Roncovalgrande, Italy: Rehabilitation of eight turbine units with a total capacity of 1,000 MW.
10 Uglich, Russia: New machine set for one generating unit with an output of 65 MW, including vertical Kaplan bulb turbine, generator, electrical and mechanical equipment, and automation system.
11 San Men Xia, China: Modernization of two turbines, including components and automation to increase output to 60 MW.
12 Toyomi, Japan: Refurbishment of the plant by replacing six Francis turbines with two new vertical bulb turbines plus generators with an output of 61.8 MW.



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