

VOITH

MAGAZINE FOR HYDROPOWER TECHNOLOGY

HyPower

#24 | Spring 2014



POWER FOR THE FUTURE

SMALL HYDRO

GLOBAL EXPERTISE

CANADA: IMPRESSIVE HYDROPOWER LEADERSHIP

GREEN ENERGY MIX

HYDROPOWER AND WORLD EVENTS IN BRAZIL

IT'S A SMALL BUT POWERFUL WORLD



Good things really do come in small packages. Small hydropower is the foundation Voith Hydro was built on, beginning 147 years ago. But recently, as other green energy sources have taken center stage, small hydropower has been undervalued. Yet, on a global scale, the technically feasible potential is high. Gradually, this potential is gaining recognition. Small hydropower has huge benefits: it's favorable, clean and a proven technology. With specially adapted turbines and machinery, such as our newly developed StreamDiver, our eQ-Solutions or our Voith Small Hydro Generator range, environmental impact is minimized, and output maximized.

However, technology is just one part of the equation. People are another essential part. Excellence in project management is crucial – an area in which Voith is known for its high standards. At Voith, people know what they do. This is our promise to our customers. Along with our offers, we supply the best solutions, a high level of competence and proven reliability. This is reflected in all our hydropower projects around the globe, from modernization in Europe and the Americas, to developing the world's largest generating unit in China, to product innovations and celebrating a 50 year milestone anniversary in Brazil.

It is due to our customers that we have achieved such success and international reach in hydropower over the last century. Long-standing customer satisfaction is the driver behind all we do: from R&D to quality, from project offers to excellence in project management – always supplied with first-class service. Our promise is to never let you down.

In the spirit of maintaining great partnerships, we'd like to invite you to complete our HyPower readers' survey. Visit www.voith.com/hypowersurvey, or complete and return the insert in this issue. As we do with our hydropower solutions, we're working to produce the best hydropower publication we can – to better serve your needs. Thank you very much for your contribution.

Yours sincerely,

Ute Böhringer-Mai
Head of Communications

IMPRINT


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Alexanderstr. 11
89522 Heidenheim, Germany
www.voith.com

Responsible for the publisher:
Ute Böhringer-Mai
Editor-in-chief: Lukas Nemela
Tel: +49 7321 37 0
Fax: +49 7321 37-7828
E-mail: info.voithhydro@voith.com

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All figures on installed hydropower capacity include pumped storage. Figures on hydropower potential refer to technically feasible hydropower potential.



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73 TONS IN FLIGHT

RUSSIA In a spectacular undertaking, the Voith Hydro St. Pölten branch has airfreighted the first of six new Voith runners to Siberia for installation at the large Bratsk hydropower plant – part of a Voith-run modernization project at the plant. An Antonov An 124-100 cargo plane, one of the largest aircraft in the world, transported the first of the 5.6-meter, 73-ton runners from Vienna, Austria, to Siberia. The client, Russia’s largest energy provider, Irkutskenergo, requested airfreight in order to shorten the time to installation. The Bratsk plant consists of 18 units of 255 megawatts each; six of the runners are being replaced by Voith parts. Situated on the Angara River, the only outlet from Lake Baikal, Bratsk was the world’s most powerful hydropower plant when commissioned in 1967. Producing around 30,000 GWh a year, it is still one of the world’s highest-producing hydropower plants. //

VOITH FINALIST IN INNOVATION AWARD

GERMANY This March, Voith reached the finals of the German Industrial Innovation Award. The new, efficient and particularly environmentally friendly small hydropower plant concept StreamDiver took Voith to the upper echelons of a highly competitive field of around 320 participants, finishing among the top four competitors in the large company category, which was eventually won by BMW. The German Industrial Innovation Award is the first of its kind in the world, awarding the most important scientific, technical, entrepreneurial and intellectual innovations of the German economy. //

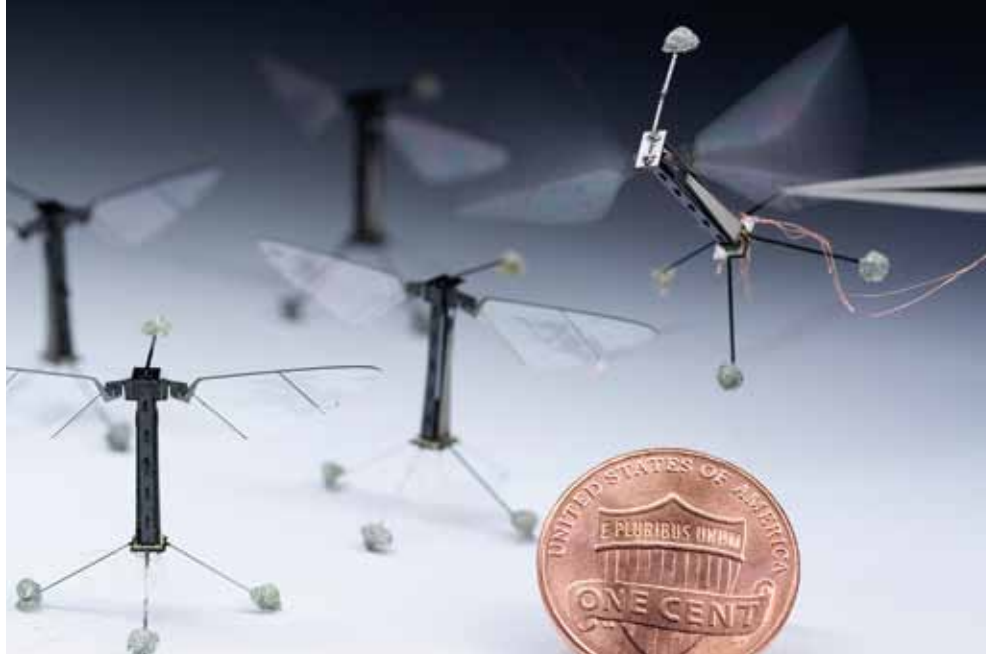
JINPING WINS

CHINA Last year Voith was awarded the “May 1st Labor Medal” by the Sichuan municipal government in China for the excellent performance in the Jinping II project, making it the only hydropower equipment supplier to receive this award. More than 160 companies were involved in the construction of Jinping, but it was the high production quality and service of Voith Hydro Shanghai that won the client’s commendation. “What impressed us most about Voith is their relentless drive to improve and refine technology and design,” said Mr. Zhaocheng Wang, Director of Yalong River Hydropower Development Company. //

ENERGY-SAVING DAYS

WORLDWIDE Voith Hydro shows how conscious behavior can save resources and protect the environment: on the Energy and Water Saving Day in February, employees in all units were called upon to turn power- and water-consuming equipment off or down when leaving their workplaces. The results were impressive: energy savings of 20% on average could be realized, and water consumption was also cut down remarkably. The initiative aimed to raise awareness in daily use of energy and water and sustainably conserve resources. Figures on the consumption of resources are also important for Voith’s sustainability reporting. //





THE TINIEST DRONE

It looks like a bee, and flies like a bee, but it's really a robot: researchers at Harvard have created the world's smallest drone, affectionately dubbed Robobee. They hope the minuscule flying drone will serve in fields such as search-and-rescue, crop pollination, and traffic monitoring. //

GREAT AND SMALL

It's often said that **good things come in small packages**. To mark our focus on small hydropower in this issue of HyPower, we take a look at some remarkable, small – but great – things.

ANT POWER

They're tiny, ubiquitous – and more powerful than appearance belies. According to different estimates, the humble ant can carry between 10 and 50 times its own body weight. In fact, some ant species can support up to 100 times their own weight – even upside down on glass, such as this Asian weaver ant, caught on camera holding 500 mg weight by zoology specialist Dr. Thomas Endlein. //



SMALL BIG SELLER



Though small and humble, the 500 model from Italian car maker Fiat was, as an example, one of Britain's top-selling cars of 2013. According to figures from Britain's Society of Motor Manufacturers and Traders, the petite Italian came in at a respectable number 12. This small favorite continues to be a big hit, over a half-century after the first production run of the original Fiat 500. //

HEART-STOPPINGLY SMALL ART



English artist Willard Wigan, MBE, creates remarkable, microscopic sculptures: they fit inside the eye of a needle, and require a microscope to view. In fact, the sculptures are so tiny and delicate that the artist must enter a meditative state when working, controlling his breathing and hand movements. Wigan's fine technique has made him the subject of many discussions, not just among art lovers, but also within the research, science and medical communities. //

SMALL MIRACLES

It's reliable, economical, efficient and clean. By accelerating development and decreasing greenhouse gases, **small hydropower is gradually – but markedly – improving our world.** But to reach its full potential, it needs support.

With the push toward renewable energy in Europe, and the world, one would think small hydro would be enjoying a boom. It is one of the cheapest forms of clean energy to produce. Yet, says the European Small Hydropower Association (ESHA), less than half of the potential has been tapped. Small hydro contributes about 44 TWh a year toward Europe's energy needs, but more than 50 TWh a year can be brought on line in the future, says Dirk Hendricks, the secretary-general of ESHA. "Done right, small hydro can play a big role in the future architecture of the electricity grid," Hendricks said.

In Germany, there are about 50,000 dams or weirs already installed, but only 7,000 of those are equipped with hydropower plants, leaving a large majority untapped. From a technological perspective, small hydro is already mature and highly developed. Many weak points have been overcome, such as the need for better fish passage. Regulation and policy have disadvantaged small hydro. While wind and solar

installations are bolstered by strong lobbies and large government subsidies, small hydro has been left behind in certain countries, despite the technology's obvious benefits. Units have been dismantled, or permits may be difficult to receive for new projects, often due to a large volume of environmental regulations that are becoming increasingly complex and may be implemented in an uncoordinated way. In Europe, legislation like the Natura 2000 and the Water Framework Directive has impacted the small hydro sector significantly.

"The sector can be financially sustainable if fair market rules are provided," says Hendricks. Policy-makers need to keep in mind that hydropower does far more than produce green electricity. It is a highly efficient way to do so, and it also contributes to grid stability, can be used for flood protection and irrigation, and has a long life cycle. This is a central point from an investor's perspective: a hydropower plant can last up to 100 years, supplying steady revenue for decades from the cost-effective generation of electricity. But it can take some time to obtain a return



This small hydro plant in Blaichach, Germany, features an eco-friendly instream flow drain.

▷ after upfront investment costs. If electricity prices are fluctuating due to changes in the energy market and subsidies for other technologies – and at the same time costs must be recovered – it's easy to understand an investor's hesitation. However, many companies are still pushing ahead with small hydro investments due to the inherent benefits.

Small hydro units are far more than just smaller versions of their larger counterparts. Engineers have adapted turbines and the machinery for the application. One clear advantage of small hydro is a limited impact of the construction on the environment. Typically, small hydropower stations are run of river, and no reservoir is needed. They are usually connected to the grid, while even smaller versions – called pico, micro or mini hydro – may be used in an isolated way.

To keep small hydropower moving forward, Voith conducts special R&D activities in this area, which are closely connected to and strongly profit in particular from Voith's R&D in large hydropower as well as from the company's overall innovative approach. The focus in small hydropower is on improving the ecological standards of the technology, and works to standardize small

hydro components in order to improve project economics for customers. Klaus Schädler, Head of Small Hydro within Voith, says, "All small hydro makers and buyers are in a very competitive situation, therefore standardization is key. With Voith's broad engineering knowledge, we are able to standardize in a highly sophisticated way, while keeping enough room for customized solutions."

Voith R&D is working on low-head applications – for instance less than 10 meters of head. Research has been examining ways to make the technology more efficient and less cost-intensive, since on a global scale huge potential exists in low-head applications. Again referring to the example of Germany: a majority of the country's dams or weirs that are not equipped for hydropower are low-head, according to Schädler. "If you already have a dam, and you just add a hydro plant to it, you could have a new hydropower plant with low impact on the environment, because the dam is already built. The owner would have revenue from the dam, and not just maintenance costs for it," said Schädler.

Voith has already come to market with a breakthrough small hydro innovation for low-head applications. Recently

launched, the StreamDiver is a turbine generator unit constructed to be compact, simple and therefore low-maintenance. In addition to the technical and ecological benefits, this innovative product provides the opportunity to develop new and previously unusable hydropower locations. The power unit is installed directly in the water with only the power cable coming out. The bulb is filled with water, which completely lubricates its bearings, ruling out any risk of water contamination. This new compact turbine has an output of up to 800 kW per unit, which can be used for modular extensions as a minimum-flow turbine, or as an alternative to existing small hydropower plants.

In addition, Voith is also researching ways to simplify the civil engineering involved in small hydropower projects. "We're working on smarter solutions to build the powerhouse or the infrastructure that houses the machine and equipment," says Schädler.

Another area of research is small hydro pumped storage. Due to the shift to a more and more decentralized and volatile energy production, the need for flexible energy storage has been increasing during the last years, raising the interest in pumped storage solutions.

Often the development of new sites for large-scale plants is not possible either for economic or ecological reasons, so smaller sites become more promising.

In this context, Voith is also exploring the idea of small hydro in combination with wind energy. Windmills can be connected with small hydro pumped storage plants, so that surplus electricity generated by the windmill can be used for pumping – and vice versa: to produce energy when wind is not blowing. The combined plants allow for an easier forecast on energy production.

Voith's development efforts lead to successful new products, as shown by the example of Voith Hydro's small hydro generators: "We have thoroughly developed special generator solutions, designed to meet the specific requirements of small hydropower," says Schädler. "They focus on a long lifetime, stable operation at grid, and optimum life cycle costs, and are designed to reliably and efficiently exploit small hydro potential."

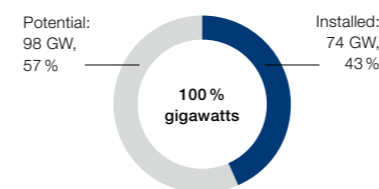
For Hendricks and the ESHA, as well as other participants in the industry worldwide, small hydropower represents enormous potential economically, socially and environmentally: as a provider of jobs, a provider of income to rural communities, a provider of clean energy, and a way to better manage irrigation and flooding. //



www.voith.com/SH

Global status of Small Hydropower

(<10 MW/unit)



Sources: Voith Hydro and smallhydropower.org

SMALL TALK

Klaus Schädler, Head of Small Hydro at Voith, about developments in the small hydro industry.

What is the history of small hydro at Voith?

Small hydro is a Voith tradition. 147 years ago when the company was founded, it started with small hydro. We produced only small hydropower turbines until the 1970s, when we entered the market for large hydro, and today we are once again one of the largest small hydropower manufacturers in the world.

What is the outlook for small hydro?

In Southern Europe, there is low demand right now due to the dampened economy. Other regions are looking for increased energy production. I expect growing demand in South America and Southeast Asia. Also, Canada's rich natural water resources give many hydro energy options.



Klaus Schädler joined Voith in 1985. A mechanical engineer, he has headed Voith's small hydro division since 2009, and previously served as the VP of Operations at Voith Hydro Canada.

Why would a company install four small machines producing 25 MW instead of one large machine producing 100 MW?

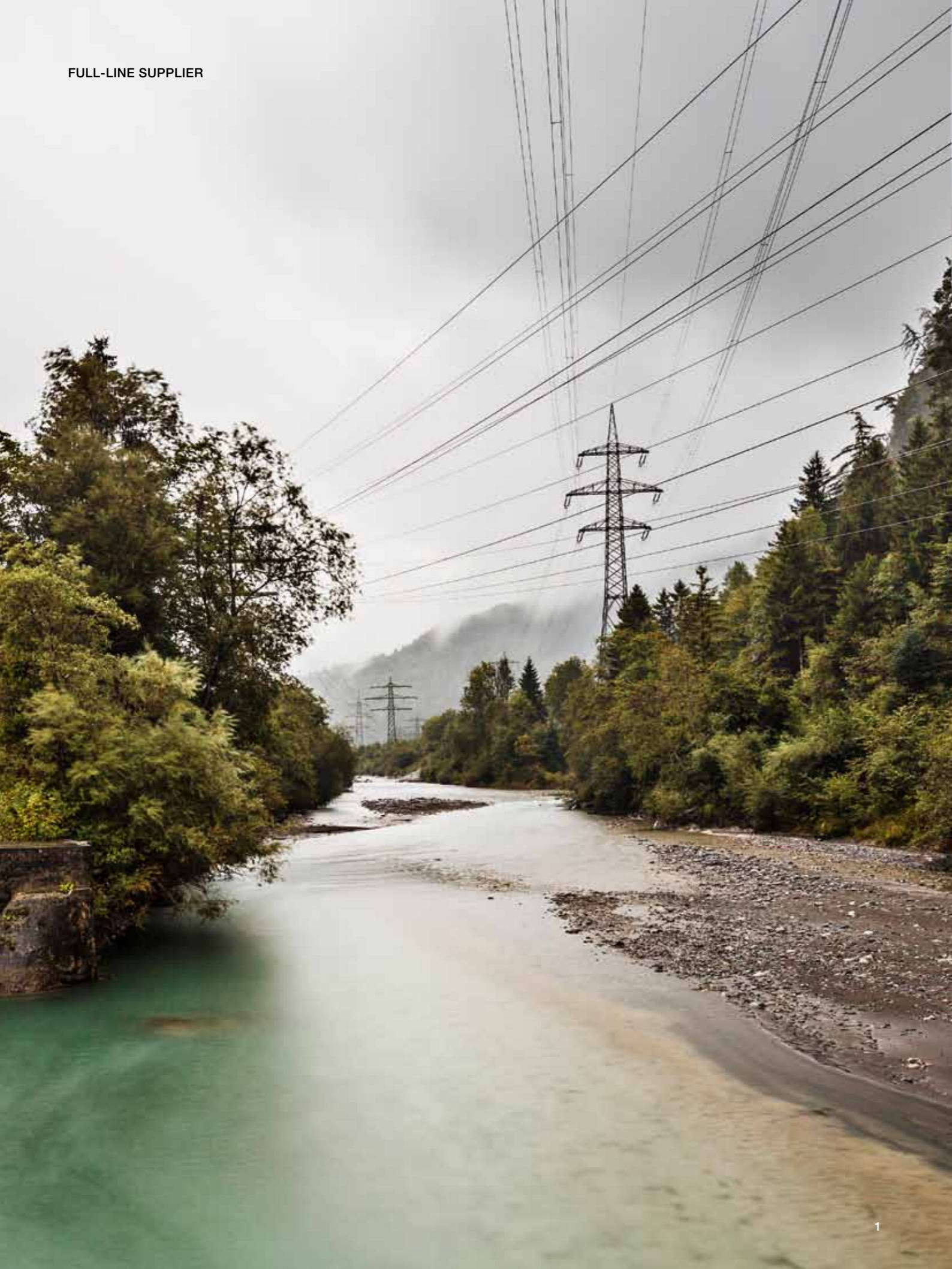
To ensure the optimal output of energy, it often makes sense to avoid installing a larger machine and instead install several smaller ones. Then, when less water is available, one machine can run at full capacity instead of having a large machine running at partial load. When a large machine is run at low capacity, its efficiency is low in comparison to the amount of water that is let through the machine. The operator would produce less energy to sell.

What are good arguments for small hydro?

The technology comes with a long list of environmental benefits. We have developed oil-free machines and turbines that rotate slower than usual, to reduce fish mortality due to blade strikes. Voith has also developed the Minimum Gap Runner technology, which minimizes the effects of gap flows on fish survival and is used both in small and large hydropower plants. Another benefit is that operators can have a complete unit assembled in the workshop, which limits assembly time onsite. Then there's delivery time. It is shorter because the smaller components can be manufactured faster and we offer a modular product concept in small hydropower.

How would you describe the Voith small hydro product portfolio?

Our portfolio covers all equipment that an operator needs for a hydropower plant. This includes the turbine, the generator, the automation, and the balance of plant equipment – the complete water-to-wire solution. Together with our partners, we are a full-line supplier. //



SMALL BUT POWERFUL

They may be little, but **small hydropower plants deliver good return.**

- 1 Harnessing the power of nature: the river at the Brunnenfeld run-of-river small hydropower plant in Austria.
- 2 Kössler technicians working on the StreamDiver.
- 3 An artist's depiction of Kössler's new headquarters in St. Georgen, Austria.

Demand for smaller, more standardized hydropower plants is on the march. At a time when feed-in tariffs for most renewable energy technologies have begun to decline, as they were designed to do, small hydro has never been so heavily promoted. To help cope with the growing number of customer inquiries, Voith acquired Austria-based small hydropower manufacturer Kössler in 2007. Founded in 1928 as a repair workshop for turbines and generators, Kössler has become one of the European market leaders in small hydro. Welcoming the Kössler employees into the company, Voith Hydro CEO Dr. Roland Münch's message was clear: Kössler was to grow based on its roots and competencies by developing further in technology and growing volume in the range of its products.

er everything from single components to complete power plant solutions. The merger has put Kössler in a position to attract new customer segments known for rigid standards and high project management requirements. Today, Kössler acts as Voith Hydro's European center of competence for small hydro.

One of the advantages of small hydropower plants is that they are able to generate energy despite low flows and heads. Voith and Kössler were able to exploit their expertise to deliver a new compact turbine specifically designed for low water levels, for which conventional turbine technology was previously not economically viable. The new product, StreamDiver, offers a compact solution that makes it possible to mount the generator directly into the turbine. Water-lubricated bearings allow oil- and grease-free operation, reducing the environmental footprint. "The successful cooperation between engineers from Voith and Kössler is a good example of how well Kössler has integrated into the Voith Group," says Josef Lampl, Managing Director of Kössler.



StreamDiver®: the latest innovation in small hydropower.

Kössler has a lot to bring to the table: over 80 years of experience in small hydropower, a mature and proven technology, a strong customer base and a very skilled workforce. Profiting from Voith Hydro's engineering excellence and global network, Kössler is able to deliv-



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▷ But development doesn't stop there. Kössler engineers are continuously working to find new materials, develop maintenance-friendly designs and introduce simplified, innovative technologies. One example is its eQ-Solutions, a standardized compact turbine optimized for smaller output ranges. Produced according to high standards of quality and using state-of-the-art hydraulics, eQ-Solutions is helping to meet the challenges of a changing market – one in which building requirements are more strenuous, environmental regulations are more stringent and customers are looking for a less costly small hydro solution – without forfeiting quality, reliability or safety.



A striking red eQ-Solutions standardized spiral casing.

One advantage of small hydro is shorter manufacturing and installation times. Kössler has developed standardized construction manual, shortening delivery times, and cuts installation times by carrying out construction in the factory and delivering them to sites pre-assembled. "There's a lot of competition in the small hydropower market. Customers put a premium on a good price-performance ratio and a reliable partner," explains Lampl. Kössler has increased its volume so successfully that it became necessary to expand its existing facility in St. Georgen, to be opened in 2015. "The investment is a commitment towards the potential of small hydropower," said Lampl at the ground-breaking ceremony.

PRICE AND PERFORMANCE WINS THE BID

Kössler was able to meet high price-performance expectations of the Bosch Group when submitting a tender for the modernization of a 100-year-old hydroelectric plant in Blaichach, Germany. "To win that order, we had to fight hard to come up with a competitive price," says Karl Wieder, Head of Sales and Project Development. "In the end, it was a combination of best price and best technical performance letting us win the tender."

HIGH QUALITY AT A FAIR PRICE

After modernizing an existing plant in Walchau, Austria, in 1987, Kössler was invited in 2013 to counteract efficiency losses caused by wear and tear by carrying out a gap correction and fitting the system with new bearings. Kössler was also asked to expand the plant by supplying a Francis spiral turbine with a runner diameter of 540 mm. As a result of the remediation, the output of the power station was increased by approximately 420 to 630 kW.

GOOD ECOLOGICAL FOOTPRINT

The community of Arjeplogs Allmänning in Sweden launched an initiative in 2005 to optimize its 85-year-old small hydropower station. The goal of the project was to increase energy production with a minimum of environmental impact. By introducing a Kaplan bulb turbine with a runner diameter of 2.2 meters, Kössler was able to increase energy output by more than fivefold, with little adverse effects to the natural surroundings. The upgraded plant went into production in autumn 2013.

Gerald Hochleitner, Head of Design at Kössler, says: "The ecological impact is minimal as the turbine flow is approximately 25% of the average natural flow in Skellefte River and requires no man-made dam. It was a solution provided by nature." //

- 1 Installing a StreamDiver compact turbine.
- 2 At work on an eQ-Solutions compact turbine.
- 3 Upgrades and expansion at Walchau, Austria.
- 4 The new turbine propeller is installed at Arjeplog.
- 5 A look inside Arjeplog's new Kaplan bulb turbine.
- 6 Arjeplogs Allmänning, Sweden: undisturbed nature.



More information on StreamDiver:
<http://voith.com/StreamDiver>

GOOD TECHNOLOGY, GOOD PEOPLE



1



2

- 1 Small hydro plants like Malagone in Brazil generate local jobs and bring environmental and educational programs to the region.
- 2 Projects such as Baba protect and benefit agriculture: from flooding and erosion, and with supplementary water supply.

Small hydro contributes to the positive transformation of the region it serves – but **deploying a project successfully requires particular perseverance and talent.**

The Baba Multipurpose Project in the Los Ríos province of Ecuador has transformed the lives of local people since, and even before, commercial operation began in 2013. The dam mitigates flooding and helps prevent erosion during the rainy season over about 20,000 hectares in the Buena Fé, Valencia and Quevedo cantons. During the dry season, it provides clean water for local people and farmers. The 42 MW small hydropower plant, meanwhile, provides renewable energy to the region.

Here, Voith installed two Kaplan turbines, the first ever in the country, as well as the two generators for the plant's units. Seeing the plant enter into commercial operation with satisfied customers and colleagues was a thrill for Ronaldo Martins, Voith's Project Manager at Baba. "Being part of the official plant inauguration in the presence of Ecuador's president, Rafael Correa, and having my photo taken with him was a great feeling," says Martins. With more than a decade's experience working on small hydro projects in the region, Martins was responsible for making sure Voith's part in the project was a success – and his job was not without its challenges.

Small hydro projects are arguably tougher than large-scale ones, says Martins. "Managing a multipurpose project is much more interesting and challenging than managing a project with just one goal, because of all the elements that are required." Usually, the biggest challenge of a project in small hydro is the time limits for construction – which tend to be very short. The complexity is similar to that of a large hydro project, but the deadlines are shorter, so proper planning is essential for project success. Managing deadlines and risk management are two very important skills, especially when the project is in a foreign country.



"Projects like Baba require an expert team, and at Voith we have a great one – especially the engineering and field service teams. But the success of the project was due to the commitment of the entire project team," says Martins.

Luiz Marighetti is one of the most experienced members of the Voith Brazil team. He joined Voith more than 30 years ago and has worked variously as a turbine design engineer, sales manager, application engineer and lately as proposals manager for small hydro. It is experience like his that enables projects to be planned and executed smoothly. "I have participated in all the small hydro contracts we have signed since 2000. It means I can usually give the team the answers they need quickly to technical and contract questions," explains Marighetti.

Finding and teaching the next generation of engineering trainees to ensure Voith has the skills and resources it needs for the future is another important aspect of his work, he says. "We have very good career planning for the young engineers. We rotate them in different roles and give them early knowledge about various departments, as interns, within a training program lasting one and a half to two years."

Each project is different and each teaches new lessons, adds Martins. "We always learn something on new projects, whether in small or large hydro. We log what we learn and improve our processes."

There is great potential to apply lessons learned from Baba to projects in Ecuador and beyond, adds Martins. "Small hydropower plants are becoming more important worldwide as solutions for low-cost construction and low environmental impact become more important. Ecuador is a country that has a big potential for the installation of new projects." //

Projects like Baba help establish strong infrastructure, critical for agriculture: Ecuador's banana production benefits.



Luiz Marighetti has worked for Voith for over three decades in the small hydro field, in areas as diverse as turbine engineering and proposal management. Experience like his is a treasured asset.



HYDRO EXPERTISE IN ITALY AND BEYOND

With their **new service center and headquarters** together under one roof, **Voith Hydro Italy** is bringing its expertise closer to their customers in Italy – and beyond.

With a new after-market-business (AMB) service center in Milan, Voith Hydro Italy brings a full line of top-quality services closer to its customers. The workshop, which opened last October, has completed its first orders and has many more under way. Roland Kühnel, Head of Voith Hydro Italy, explains, “Our customers like the fact that they can visit us in the new workshop and see for themselves what we are doing. We can also more easily provide customized solutions, and since we are cutting out the middleman and handling more work in-house, we have a stronger competitive advantage.”

The workshop, which covers some 1,300 m², is equipped with two cranes of five and 20 tons. With three installation areas as well as material testing and distribution, it is designed to carry out a minimum of three projects at once. It also benefits from Voith Hydro Italy’s

exceptional expertise. Voith Hydro acquired Italian hydropower supplier Riva in 1992 along with all Riva’s technical drawings, including plans for more than 1,100 power plants. Today, of Italy’s 23 GW of installed hydro capacity, more than half is working with Voith equipment. All of Italy’s main energy providers and a growing number of smaller independent power producers are clients.

The workshop responds to new trends in Italy’s hydropower sector. “Italy is one of Europe’s biggest hydropower markets, and the need for after-market service and rehabilitation is great, so we want to increase our after-market business. At the same time, since almost no new large hydro projects are planned here, we are expanding our small hydro services,” says Kühnel. The workshop aims to establish more long-term maintenance contracts in Italy and worldwide, and involve itself in new hydro projects. In summer, Voith Hydro

Italy will move its headquarters to the workshop location, bringing all Voith Hydro Italy’s activities under one roof. “Having the headquarters here will allow for closer exchanges with Voith Hydro engineers, and our customers will be able to count on even more comprehensive and efficient services.”

Italian expertise in Switzerland

Modernizing a 100-year-old small-hydro plant on a site with a number of logistical hurdles was not easy, but Voith Hydro Italy met such a challenge recently for Switzerland’s Compagnie Industrielle de Monthey (Cimo). The company’s Vièze hydropower storage plant plays a key role in the local economy by providing power for chemical giants BASF and Syngenta, but it urgently needed an upgrade. Its original pressure pipes dated from 1910 and 1921, and production units had been operating since 1959 and 1960.

Daniel Baillifard, who oversaw the project for Cimo, explains that when Cimo chose to modernize the existing plant, it selected Voith Hydro Italy for the project based on a number of factors, including price, respect for deadlines, track record, and the security and quality of materials to be used. Voith Hydro Italy supplied turnkey electromechanical equipment, a 14 MW Pelton turbine, a vertical synchronous generator, complete automation and other equipment.

The project has been a success. As Baillifard points out, “Modernization has allowed us to boost the plant’s energy production by 10% to 12% per year, of which the new Voith Hydro Italy production unit accounts for 5%. Before this project, the plant produced an average 50 million kWh per year. We hope to increase that to about 56 million kWh per year. We can now fully exploit the energy resources of the Vièze, providing reliable, renewable energy for the local chemical industry and for future generations.” The modernization, begun in 2011, was completed on time in spring 2013. Baillifard says, “We are very satisfied with the results of this project and with Voith Hydro Italy’s contribution, especially the quality of their equipment, the competence of the team that installed it, the subcontractors chosen and the plant’s performance. The plant continued to operate while the work was going on, our time and budget targets were met, and we are especially happy to report that we had no accidents during the two-year project phase.” //

- 1 A distributor ring receives final touches after refurbishment at the Milan workshop.
- 2 A Voith Milan AMB service center technician at work.
- 3 Getting equipment onto the Vièze site.
- 4 Inside the refurbished Cimo power plant.



Refurbished distributor for a 38 MW vertical Francis turbine.

Hydropower in SWITZERLAND	
Installed capacity, incl. pumped storage:	15 GW
Potential not yet installed:	2 GW

Switzerland was among the first nations to use pumped storage (ca. 1890s).



- 1 The interior of the Vadodara turbine-manufacturing facility.
- 2 A Voith India employee at work.
- 3 Proudly Voith: the exterior of the Vadodara premises.

“Our strong plant engineering skills differentiate Voith Hydro India from the competition as a full-line supplier in the small hydro business.”

Amresh Dhawan, Managing Director,
Voith Hydro in India

A KEY LOCATION

The strong team at Voith Hydro India provides production and engineering expertise to **supply markets all around the world.**

“India is one of the most important small hydro markets in the world,” says Amresh Dhawan, the Managing Director of Voith Hydro in India. “It was necessary to establish a local footprint by setting up a workshop to be competitive and to set new quality standards in the Indian market.”

Rohit Uberoi, Head of Small Hydro Engineering at Voith Hydro Noida (VHN), tells how in 2007 the company started small hydropower operations in India: “The goal was to develop standardized solutions for small hydropower turbines – a ‘common standard design.’” This was followed in 2009 by a separate small hydro division within VHN, which is “focused towards small hydropower business,” explains Uberoi.

The next step in the development of Voith Hydro in India was a manufacturing facility for turbines at Vadodara, in the state of Gujarat. Operations are so successful, says Ravi Kalra, Head of Small Hydro for Voith Hydro India, that within three years “the unit fulfilled initial expectations by manufacturing and delivering state-of-the-art hydropower products to all corners of the world, including Japan, Italy, Canada and Brazil.”

With customers enquiring about small hydropower capabilities, Voith began developing a special generator for the market, adapted to the requirements of small hydro. For the manufacturing of these generators, a cooperation has been set up with TD Power Systems (TDPS), an India-based company with Japanese roots. The international scale of this cooperation is reflected in the end projects, the first ever order being a horizontal small hydropower generator for faraway Cubujuquí, Costa Rica. Indeed, this was Voith’s first project in Latin America using a power unit designed and manufactured by the Voith India Vadodara branch. “This clearly established Vadodara as a quality manufacturer and supplier of full-line small hydro solutions,” says Kalra. Dhawan confirms that “the quality management systems at Vadodara are an exact replica of Voith quality systems employed in its factories world wide.”

This fundamental focus on quality, as well as the breadth and depth of expertise, have also impressed Voith’s clients. Voith Hydro India has the capability to engineer an entire plant, supplying turbines, generators, cranes, auxiliary sys-

tems, fire detection, alarm and firefighting systems. Moreover, says Dhawan, “Our capability extends to engineering, supplying and commissioning substations and other electrical plant items.” It is, he says, “our strong plant engineering skills that differentiate Voith Hydro India from the competition as a full-line supplier in the small hydro business.”

And the next step in this development is just under way: together with the automation department from Voith headquarters in Heidenheim, the engineering team in India is currently working on the development of a specially designed automation solution with complete functionality, but at the same time adapted for small hydropower applications – another cost-effective, standardized small hydropower solution with room for modular adaptations.

Voith’s future in this highly competitive energy market looks particularly good, says Kalra: “A successful small hydro arm with its own manufacturing facilities in India helps Voith Hydro expand its operations, not only in India but also in South East Asia, which hitherto was not fully served out of Europe. There is a large potential waiting to be tapped. //

QUALITY AND INNOVATION

Recent **modernization projects** by Voith have injected new life into traditional hydropower plants in **Japan**.

Voith has come up with solutions to particularly complex challenges during the recent undertaking of two individual projects in Japan, resulting in very satisfied customers.

Umamichi power station in Tochigi Prefecture is operated by Furukawa Nikko Power Generation. It began service in 1937 fitted out with equipment supplied by Fuji Electric, which has now become Voith Fuji Hydro.

Furukawa Nikko Power Generation recently contracted Voith Fuji Hydro to renovate the aging equipment and to improve overall performance. This involved replacing the turbine, generator and control system, increasing the flow of water to the turbine in the process to uprate output from 4,410 kW to 5,430 kW. The refurbished power station was handed over in April 2013 and is performing exactly as intended.

As Hiroaki Onaka, Manager of the Project Management and Contracting Department at Voith Fuji Hydro, explains, this was a particularly challenging project because it required the installation of new equipment into an existing building – which had to be retained. Just one example: the installation of the new spiral casing in a single piece required a large hole to be made in the side wall of the turbine floor, and the construction of a temporary bridge over the tail race channel. This all had

to be done with due regard for the overriding safety requirements.

This was also Voith Fuji Hydro's first experience of procuring equipment engineered and manufactured at the company's specialized small hydro workshop in India (see pages 20-21 for more on Voith Hydro in India). It was a successful collaboration, particularly in terms of the quality of the equipment supplied by the Indian Voith Hydro team. Due to the success of this project, the same customer has just ordered Voith to undertake another project at Uwanoshiro power station. This project is set to involve an even wider range of refurbishment activities – a challenge which Voith is ready to meet.

Voith's other current challenge in Japan is the modernization of Chugu power station, operated by the Hokuriku Electric Power Company. Voith emerged as the only company in competition capable of providing the innovative technological approach required to work within the confines of the existing narrow powerhouse. Voith's innovative proposal involves replacing two existing twin-nozzle horizontal turbines, with a total output of 3,000 kW, with a single triple-nozzle unit of Voith Fuji Hydro's original design, with an output of 3,100 kW.

Due to restrictions on crane capacity and powerhouse space, the Chugu power station project has required considerable advance planning. Due for completion in December, this is only the second installation of a triple-nozzle unit carried out by Voith Fuji Hydro, and is also the largest. It is an undertaking that reflects Voith's unequalled level of competence and emphasis on unparalleled quality. //



Hydropower in JAPAN

Installed capacity, incl. pumped storage: **50 GW**

Potential not yet installed: **12 GW**



Hydropower is Japan's leading renewable energy resource.



- 1 The exterior of the Chugu power station.
- 2 The generator at the refurbished Umamichi plant.
- 3 Outflow at the Umamichi power station.
- 4 The upgraded Francis turbine at Umamichi.

HEADING FOR NEW DIMENSIONS

Voith takes an important step toward a major goal at the Xiluodu plant, in partnership with the China Three Gorges Corporation.

Consider a bearing that has to carry a load equal to the weight of 17 fully laden Boeing 747 aircraft ready for takeoff. That's just one of the challenges being embraced by Voith's engineers as they develop the next generation of 1 GW generators ahead of further expansion of capacity by the China Three Gorges Corporation at the Baihetan and Wudongde hydropower plants.

Developing the most powerful hydro generators ever seen presents challenges at a number of technical levels, including the design of thrust bearings which will cope with the enormous loads imposed over a lifetime of use. But it is one that Voith has already met with the successful commissioning of 784 MW generator-turbine units at the Xiluodu plant on the Jinsha River – one of the largest single projects ever undertaken by Voith, with Voith Hydro in Shanghai supplying three complete sets of generating units: the three 784 MW Francis turbines as well as three 855.6 MVA generators. When it is fully connected to the grid later this year, it will have a nominal

capacity of 13.86 GW, making it the world's third-largest hydropower plant.

Thomas Hildinger, Vice President Generator Technology at Voith Hydro, says the successful introduction of the 855.6 MVA generators at Xiluodu provides a useful stepping-stone toward even larger machines. "Each unit is tailor made, of course. There is no room for failure," he says. "But you still learn from every project, and it enables you to further refine your mathematical models and design solutions. In particular, it helps you manage residual risk, which is fundamental to Voith's approach to engineering." The design of a modern hydro generator is a well-considered balance between competing demands: reliability, performance, ease of maintenance and – last but not least – project economics.

As air-cooled generators increase in output, the design challenge is to find optimized and reliable mechanical solutions. Thrust bearings must be able to carry loads of several thousand tons, improvements are needed in cooling systems

and related thermal stability, while even better mica-paper-based insulation, suitable for higher voltages, is required so that such machines can be air cooled. The thrust bearing challenge may have a practical solution, which is a unique Voith innovation: the employment of a magnetic thrust bearing to absorb part of the load and to reduce friction losses.

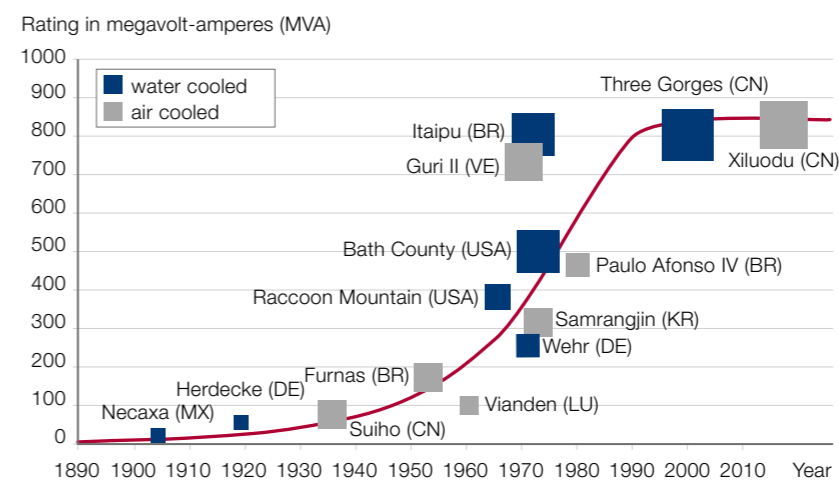
Voith's solution is an elegant one in engineering terms, and is already installed in power stations in South Korea, South Africa, the UK, Norway and Japan. Voltage represents one of the largest challenges to designers of massive generators. So far there are only a few hydro generators worldwide rated higher than 20 kV. None over 23 kV are yet in service. Since 1970, when

Voith provided 23 kV generator bars for the Raccoon Mountain hydropower station in the US, the company has been a leader in pushing this boundary. Voith Hydro in Shanghai has produced samples of the 25 kV insulated bars with the same dimension that will be required for the gigawatt machines. They have been successfully tested, achieving excellent performance in terms of their mechanical and thermal properties.

How large can hydro generators become? "We can go to 1.2 or 1.3 GW for certain, or even higher," Hildinger believes, although this is unlikely before 2020, and there are few sites with the flows and damming potential to achieve this scale. For now, the 1 GW generator is a sufficient challenge to keep Hildinger and team well occupied. //

From Necaxa to Xiluodu: The most powerful generators

How Voith Hydro generators continue to grow



1 Voith engineers discuss a 3-D plan of the generator. 2 Inside the immense Xiluodu generator.





The stay ring is lowered to the turbine floor.

IMPRESSIVE BUSINESS

A “**project of many firsts**” in Canada provides the stage for a grand display of Voith’s multifaceted potential.

“What Voith Hydro does is impressive,” says Wally Penner when asked what he finds special about the Waneta Hydroelectric Expansion Project. Having worked in various roles on many hydropower projects over the years, Penner knows what he’s talking about. He’s now the Regional Project Manager at SNC-Lavalin, a Prime Contractor for the Waneta Hydroelectric Expansion Project and also Voith Hydro’s customer for the Waneta project. His enthusiasm knows no bounds, as revealed by his comments on the project figures, the tunnel, the runner – all of them are “impressive!” he says. And he’s quite right. Anyone who visits such a ▶

Marc Gagnon, Voith Hydro Project Manager for the Waneta Expansion Project, on the powerhouse ground level.



1 Detail of a turbine runner being installed at Waneta.
 2 Working on the stator of Unit 2 of the Waneta plant.
 3 An aerial view of the Waneta Expansion Project on the Pend d'Oreille River.

▷ construction site and takes a look inside is bound to be impressed. From the outside, it all seems fairly straightforward, but inside, the dimensions are truly astounding. Inside the under-construction Waneta, you must descend hundreds of stairs to reach the bottom level, known as the pump floor. The various floors in a power station have different names: pump floor, turbine floor, generator floor and so on. That alone speaks to the magnitude of the building's interior, where the cleanly poured, cool gray concrete walls reach about 30 meters down into the rock. At ground level there's a good view over the construction site and the ongoing work. It's a favorite place of Marc Gagnon,

Project Manager at Voith Hydro in Montreal (VHM). From here, he has an overview of almost all the site's sections, to assess the steady progress of the tasks being performed. "The site changes every day," he says. "When you return after three weeks, it feels like a different place, every time." That comes as no surprise, given the hustle and bustle that pervades the Waneta construction site.

Everywhere, people are drilling, torquing, stacking and welding. Metal clangs on metal, and instructions are called out. It smells both damp and dusty, of freshly poured concrete and of welded steel. And it feels pretty warm despite the wintry outside temperatures

on this chilly January day. Wearing brightly colored hard hats and reflective safety vests, workers focus diligently on their tasks. Inside the stator frame of one of the two power units supplied by Voith Hydro, the workers are installing sheet metal panels for the generators.

Various Voith Hydro operating units from around the world have supplied various pieces of equipment, applying their respective specialized areas of expertise. The generator poles, bars and cores were made in São Paulo, Brazil, as were the two runners, while the bright-red head cover comes from Shanghai – the first time that Voith in Canada has collaborated with colleagues in China on a large hydro project.



4 Inspecting a new equipment arrival: Marc Gagnon standing inside one of the head covers.
 5 Workers inside the scroll case, which is almost as large as an underground train tunnel.

"It's a project of many firsts," explains Gagnon: in this project, Voith Hydro in Canada is supplying heavy electrical balance-of-plant equipment such as generator circuit breaker, ISO phase duct and excitation systems, thereby adding new expertise and new possibilities to VHM's business. VHM is also leading the commissioning of the project. And, after many years of experience in the hydroelectric sector, it's Gagnon's first project as a large hydro project manager. Yet, he comes across as fairly relaxed. "This is a major project for Voith Hydro in Canada because it's a good reference for similarly sized projects and because we can acquire additional valuable expertise," says Gagnon. The contract with SNC-Lavalin is being executed as a design-and-build contract, which results in a differently structured, intensive collaboration. "Their issues are ours and the other way round," explains Gagnon. "As a result, there is a lot of communication in this project. We work very well together in a joint effort." That is important, too, given that one of the challenges of the Waneta job is that many civil- and hydro-engineering tasks are occurring simultaneously, which makes good coordination especially important. The customer is also pleased, as Wally Penner confirms: "Working together

with Voith is very collaborative, very result-oriented, and there is a great willingness to deal with all the issues coming up in a project like this."

Back on site, Gagnon has another favorite spot: the project office – or the "hub," as he calls it – where Voith Hydro colleagues meet daily to discuss the status and issues. "You can feel the energy, you can feel the team spirit in the project," he explains. This team spirit also becomes apparent when representatives of all VHM departments involved in the project meet for a two-day project conference to further improve internal collaboration and project flows. Two things emerge quite clearly: first is how many different specialties, departments

and employees from Voith Hydro alone are involved in the success of such a project; second is how fully all of them are committed to achieving this success. One gets a sense of how they identify with the project when they say, "We need to adapt it to Waneta. It has to be Waneta-style." And it really is: extensive hydropower engineering expertise, custom-tailored to the project. //

Hydropower in CANADA	
Installed capacity, incl. pumped storage:	73 GW
Potential not yet installed:	160 GW

A large majority – over 60% – of electricity in Canada is supplied by hydro.

The Waneta Expansion Project will see the construction of a second powerhouse to share the hydraulic head of the existing Waneta Dam on the Pend d'Oreille River, in British Columbia, Canada, and just a stone's throw away from the US border. The 335 MW hydroelectric project is owned by a consortium of Fortis Inc., Columbia Power Corporation and Columbia Basin Trust, with SNC-Lavalin being the Prime Contractor. Voith Hydro is supplying the complete electromechanical equipment including the two generators, Francis turbines as well as automation systems.

Involving the Community: "We are doing it differently," says Audrey Repin, Director External Relations at Columbia Power Corporation, proud of their high standard of quality, safety and environmental stewardship. They manage the Waneta construction on behalf of the owners, and are committed to consulting local communities and executing socio-economic monitoring and various environmental programs. The Community Impact Management Committee, made up of local stakeholders and corporate representatives, provides ongoing input to encourage a positive impact.

LEADING THE WAY IN CANADA

Talking to **William Malus**, the new CEO of Montreal-based Voith Hydro in Canada, and **Peter MacLennan**, the new COO of Voith Hydro in Mississauga.

You've both been working in the hydropower business, and at Voith, for many years. What is special to you about hydropower and Voith Hydro?

MacLennan: Hydropower is a long-term industry. It is steady, it makes sense, and it stands for continuous progress. To me, Voith, as a market leader in this business, stands for the same principles. It is a company based on values, following a long-term vision and a clear purpose.

Malus: To me, hydropower represents one of the most natural conversions of the earth's resources into energy. As a technology, hydropower is a demonstration of perseverance, stability and stands the test of time. And in this respect, Voith Hydro, through its long history built on technical expertise and strong customer relationships, is a company of credibility and reliability. I really see very congruent aspects between hydropower and Voith Hydro.

Are these the characteristics Voith Hydro is particularly known for in the Canadian market?

Malus: Yes, the values in Voith really emulate our approach in the market. The company has been around for over 140 years. This is built on trustful customer relationships. "Never let a customer down" is very important to Voith in Canada, and we definitely work behind this philosophy.

MacLennan: Customers know they can count on us. They would say we are fair and straightforward. We have a service-oriented company culture, and



William Malus has been working in the hydropower industry for 15 years and joined Voith in 2007. Hydropower, as he puts it, "is in the DNA of Canada." In his role as CEO, Malus aims not only to further improve technology and Voith Hydro's activities, but also to make the company a great place for employees to develop and grow.

"I don't think there is any other technology that generates power as sustainably as hydropower."

we put people with this service culture in their DNA into leading positions. And we have a strong reputation with regard to our technical expertise and one of the deepest OEM (original equipment manufacturer) knowledge bases in the industry ...

Malus: ... and together with the Voith know-how, this allows us to bring the best design and solution perspectives to our customers. We are very responsive to the market requirements and see how we can adapt our offering to meet the market demands.

How would you describe the customer structure in Canada?

Malus: Our customers are very well educated in hydropower. Some of them are leading the way in terms of hydropower development and where the technology could go. We are really

lucky to share our expertise with them because in the end this makes the industry move ahead.

MacLennan: We have a diverse mix of customers: the major state-owned utilities, private utilities as well as independent power producers. They have different approaches, and it is important for us to be close to the customers to understand their needs and what's important for their success and viability.

What is special about the hydropower market in Canada?

MacLennan: We are blessed with an abundant natural water supply. Pretty much all of our provinces have hydropower potential, and roughly only 45% of this has been developed.

Malus: The other aspect: Canada is probably one of the most mature hydropower markets in the world. Hydropower

has very deep roots in Canada, it's what built this country and it goes back to over 100 years ago and is really a core component of our history.

Based on this, do you see the future of hydropower in positive terms?

Malus: Yes. Hydropower is the backbone of the Canadian electricity sector. It represents about 63% of the electrical supply in Canada. With approximately 1,500 units there is a tremendous installed base, and the average age is around 60 years old, which is a great opportunity to support this infrastructure with our after-market services and in modernization projects.

Do you see Voith Hydro in Canada as being well prepared for this?

Malus: Yes, we are: as of today, we are starting off a very solid foundation. Voith Hydro in Canada has grown and developed tremendously over the past years. With our teams in Montreal and Mississauga, as well as Vortex Hydro in Granby, we have a good footprint that positions us well and with very unique capabilities across these locations. Establishing Mississauga as a location dedicated to services, for example, was an important step.

MacLennan: The Mississauga service center is gaining importance, covering all of Canada, especially remote locations, which face logistical challenges. Not only do we have a deep know-how of generator modernization, but we also

have a high service culture across all disciplines. Plus, Voith in Mississauga is the center of excellence for winding and coil technology, both for domestic and international customers. We tailor our products on demand to customer's needs, and we want to continue to expand our expertise and activities to create more value for our customers.

Apart from that, what are your future goals in your new positions?

Malus: We see automation and after-market services as very good segments to further develop in Canada. Also in small hydro, both new and refurbishments, there is huge potential. In addition, asset management is an element we are examining to see what we can do to help our customers in terms of looking at their full hydropower station and seeing how we can best support their assets.

MacLennan: We want to further improve cycle times. This is something our customers are working on as well and where we can work together. Our improvements can help them to improve their cycles. This helps the customer to get their plants back on time ensuring their availability to produce power.

Is there anything that would help support the prospects of hydropower in Canada?

MacLennan: Equal conditions for all renewables would further support hydro-

power as a clean and reliable source of energy. Today, wind and solar experience far more support from some of our government entities. I believe over time, the public and governments will again realize the far-reaching and sustainable benefits of hydropower.

Malus: Budget and environmental approvals could be further improved. The Canadian government made good decisions in the last five years and worked hard to make the process of approvals faster and less bureaucratic. It can always be better, but the good part is: the dialogue is occurring.

You described hydropower as a very mature technology. Is it also a modern technology?

Malus: Although it's a mature technology, hydropower is very dynamic and continuing to evolve. The use of new materials, new processing techniques, new engineering tools – these are all very innovative aspects. I also think in a lot of cases hydropower is taken for granted. It's in the background, it does its job, and it has still the lowest cost of energy when you look at it in the long term. I don't think there is any other source of technology that generates power that has such sustainability in life than hydropower. Each of us as people in hydropower are stewards to promote this message: hydropower is a good aspect for the future and an important part of the renewable mix globally supporting CO₂ reduction. //

Peter MacLennan joined Voith 10 years ago. Working in project management and field service, he gained experience "on the front line," which he says is essential for the business. As COO he wants to continue with sustainable growth and ensure the continued high quality of products and services and, to achieve this, focus on people management, based on his motto: "Once you are in hydropower, you stay there."

"It is important for us to be close to the customers to understand their needs."



POWER ON AN EVEN KEEL

The Erzhausen pumped storage plant is refurbished to keep **contributing to Germany's energy transition.**

On the River Leine, close to the geographical center of Germany, lies the small village of Erzhausen. At only 99 meters above sea level at the riverbank, it is the lowest point in Northeim district. It is this geographical situation, along with the hills to the east of the river, that makes Erzhausen ideal for a pumped storage plant like Erzhausen, which, run by energy company Statkraft, has been operating here since 1963.

After several decades of reliable service, Statkraft has hired Voith Hydro to completely overhaul and service the mechanical components of Unit 3 of their facility, including turbine and pump as well as the corresponding spherical valves, to ensure smooth, uninterrupted operation for further decades. The original

machinery is removed and taken to the Voith facility in Heidenheim, where it is disassembled into its individual components. The pieces are tested to check for stress fractures and other destructive wear, before being repainted, sealed and re-assembled, ready for re-installation. "The goal is to reduce downtime and have the facility operational as quickly as possible," says Daniel Christ, Project Manager for Erzhausen at Voith Hydro in Heidenheim. "During a project like this many technical challenges arise. To solve them reliably, we use proven methods and the benefit of our experience with such power units." This doesn't mean that the refurbished facility will not benefit from technological advancements that have occurred since its original construction. "Where required and possible we are installing new grease-free bearings to replace the previous systems," says Christ. "They are safer and more environmentally friendly." New processes are used to coat original mechanical components, reducing wear and protecting against corrosion, and worn seals and bearings are replaced.

In addition, Voith is fulfilling and even exceeding the demanding Health, Safety and Environment (HSE) setup of Statkraft: "Keeping in line with our

HSE policies is very important in all our power plants, and thus also our rehabilitation projects, and Voith is meeting our expectations" comments Dennis Geyermann, project manager for Erzhausen at Statkraft.

Facilities like the one in Erzhausen were once built to perform a role that no longer exists in Germany's 21st century energy market. Originally, pumped storage plants were filled at night using cheap power from nuclear power stations, and drained to cover the midday peak in electric consumption. Nowadays, the noon peak is amply covered by solar power, and pumped storage has started to play a different role, powering up and down many times a day to even out the fluctuations of a system that increasingly includes input from volatile renewable sources like wind and solar. Besides this flexibility, pumped storage plants score with stabilizing the grid and other services to the system. //



VOITH STANDS BEHIND PUMPED STORAGE

This energy storage solution can play a key role in Germany's "Energiewende."



A debate is currently going on in Germany on the best direction the "Energiewende," or energy transition, should take. Positively, the field of renewable energy is rapidly expanding. But one thing is certain: the transition to greener energy won't succeed without efficient energy storage.

Voith has brought their expertise in the area of short-term energy storage into the public arena with the platform "Pumpspeich-erwerke – Partner der Energiewende" (pumped storage plants – partner of the energy transition), a joint venture with the German Energy Agency (dena) and other prominent industry partners. The platform champions the unique benefits of pumped storage, and makes clear that pumped storage can store energy from solar and wind sources in an efficient and climate-friendly manner.

At the same time, Voith has recently conducted a study with the Rheinisch-Westfälische Technische Hochschule (RWTH) of Aachen, which shows that additional pumped storage in Germany could go into operation as an economically viable replacement to a significant number of conventional power plants currently being used as cold reserve. The capacity of additional pumped storage plants instead could be used to take up even more energy from wind and solar that would otherwise be lost due to down-regulation. //

Voith employees work in the interior of the Erzhausen pumped storage plant.



EYES ON BRAZIL

As **Brazil takes center stage in 2014**, Voith Hydro's work behind the scenes is supporting development and growth.

Brazil has been reaping the benefits of its vast hydropower resources for decades. Eager to generate more clean, reliable energy, the nation is upgrading these resources and has tasked Voith Hydro with several of these projects. They include the 1,420 MW Salto Santiago plant, where Voith is completely refurbishing and renewing four power units, as well as making upgrades to electro-mechanical equipment and automation technology. Voith's scope of work includes building the 130-ton, 6-meter-diameter runners and delivering them to site in a single piece – a logistical challenge that involves trucking them safely through densely populated regions. At Água Vermelha hydropower plant, meanwhile, Voith is refurbishing the six generators, six Francis turbines, complete automa-

tion systems as well as the electrical and mechanical balance of plant equipment.

Roberto Avigni, Business Developer for Modernization Projects at Voith, said both were critical to the grid due to their location near the center of demand for electricity in one of Brazil's most industrialized areas. Taking such units out of service in a national energy system that relies so heavily on hydropower is not done lightly.

The main challenge in completing the projects successfully is the time pressure imposed by the schedule – which cannot be permitted to slip. Refurbishments can be challenging in this regard, because unforeseen issues can always arise, says Avigni. “As the projects unfold, inevitably new challenges arise that no one has anticipated. It's completely different from installing a

new unit. You have to be ready with a mitigation plan for any number of things that could go wrong.”

Part of the reason Voith won the contract over competitors is its reputation for never letting the customer down, Avigni points out. “You have to be sure that in 10 months you still deliver everything ready. It's not just the customer but also the government expecting everything to be punctually back in operation. We have to be on schedule. No matter what, the unit will be there on time.”

Voith is also providing innovative solutions at Salto Santiago, which will be one of the first plants in Brazil permitted to increase the amount of energy it supplies commercially. Brazilian government mandates the amount each plant can supply, based on conservative



- 1 Voith Hydro Manaus and the Arena da Amazônia stadium.
- 2 The Água Vermelha dam on the Grande River.
- 3 Voith Hydro in Brazil headquarters and the Arena Corinthians stadium in São Paulo.
- 4 The Maracanã stadium in Rio de Janeiro – home of the 2014 World Cup final.
- 5 The impressive dam at Itaipu hydropower plant.
- 6 Under Voith refurbishment: Salto Santiago plant.

approaches that allow for low water levels, to guarantee the continuity of supply in all circumstances. After 2010, however, the government permitted producers to generate more than their allocation. Conditional on improved equipment output and efficiency, plants can increase their supply, and reap the financial rewards of doing so.

“Salto Santiago is the first to benefit from the new regulations and we have worked closely with the customer to generate 24 MW extra. We did the calculations and the return on investment was good – so the customer decided to move ahead,” Avigni says. “In fact, they were very happy with tests by an independent lab showing that the results were better than we promised, so they may be able to claim even more energy.” //

ITAIPU



This project in the state of Paraná marked Voith's first major excursion into the Brazilian market. The first unit of the plant went into service in 1984. For more on Itaipu and Voith's history in Brazil, see pages 37-39.

Installed capacity: 14,000 MW
 Turbines: 20 x 715 MW Francis
 Generators: 20 X 737 MVA synchronous

SALTO SANTIAGO



Voith is undertaking a complete refurbishment of Salto Santiago hydropower plant, also located in the state of Paraná. The size of the new parts has posed a big – but not insurmountable – logistical challenge.

Installed capacity: 1,420 MW
 Turbines: 4 x 355 MW Francis
 Generators: 4 X 350 MVA synchronous

ÁGUA VERMELHA



The Água Vermelha dam, where Voith's work includes the modernization of six turbines and generators. The facility, straddling Minas Gerais and São Paulo states, provides both energy generation and flood control.

Installed capacity: 1,396 MW
 Turbines: 6 x 232.7 MW Francis
 Generators: 6 X 323.7 MVA synchronous

HYDRO POWERS BRAZIL'S FUTURE

World Cup football and hydropower meet in the city of Manaus: home to a world-class stadium and **an important Voith Hydro manufacturing facility.**

The city of Manaus is a microcosm of Brazil. New buildings are sprouting up and development is bringing higher living standards and great pride in rapid progress. The city's crowning achievement is the showpiece Arena da Amazônia, which will host four World Cup games this year. With all this development, however, comes huge growth in demand for electricity – and the risk of blackouts if it is not met. The need for reliable energy is greater than ever, as the eyes of the world turn to Manaus and the whole of Brazil in 2014. This scenario underlines Voith's central role in contributing to the success of hydropower. Brazil will have to increase electricity-generating capacity by about 6,300 MW per year, says Wellington Capelari, Head of Sales for the Brazilian market. "Hydro energy represents nowadays around 71% of total electrical energy production."

The economic and political importance of hydropower in the region was highlighted by the recent visit of Brazil's President Dilma Rousseff to Estreito and other hydropower projects in the region. "We will need full capacity there during the World Cup, and the role of Voith Hydro in this development is very important. Our expectation is to have 30 machines operating by then. We should have enough to use all the river capacity," says José Fozzate, Project Manager at Voith for the Santo Antônio project.

Back in Manaus, Voith's factory in the city is key in supporting all the projects in the region. Leonardo Nuzzi, Manager at Voith Hydro Manaus, says the city is well-positioned close to existing and future major hydropower projects in Brazil. "We already manufacture components here while other competitors are far away from the region. We have a modern workshop with equipment including a state-of-the-art vertical lathe and a crane capable of lifting more than 350 tons. And we are well-positioned for the large hydropower projects under development in northern Brazil," says Nuzzi.

The factory is also providing much-needed jobs and training for local people, he says. "Although it's a big industrial district, there was no heavy industry, so this kind of business is new to the region. We trained the local people to weld and operate big machines. A major part of the workforce is now made up of local people." //



The beginning: opening of the Voith facility at São Paulo in 1966.

A SUCCESSFUL HALF-CENTURY

Reflections on **50 years of Voith Hydro in Brazil** – and the commissioning of a landmark hydropower project.

There have been many high points in the history of Voith in Brazil, such as the opening of the manufacturing workshop in São Paulo (1966) and of the foundry (1970), the inauguration of the new facility in Manaus (2011), or major landmark projects like Teles Pires, Estreito, Xingó and Peixe Angical. In fact, Voith's presence in Brazil stretches back to 1905, when the company delivered five turbines to the Itatinga hydropower plant in the city of Santos. The real landmark year, though, is 1964, with the foundation of Voith Brazil in São Paulo. ▶

1905

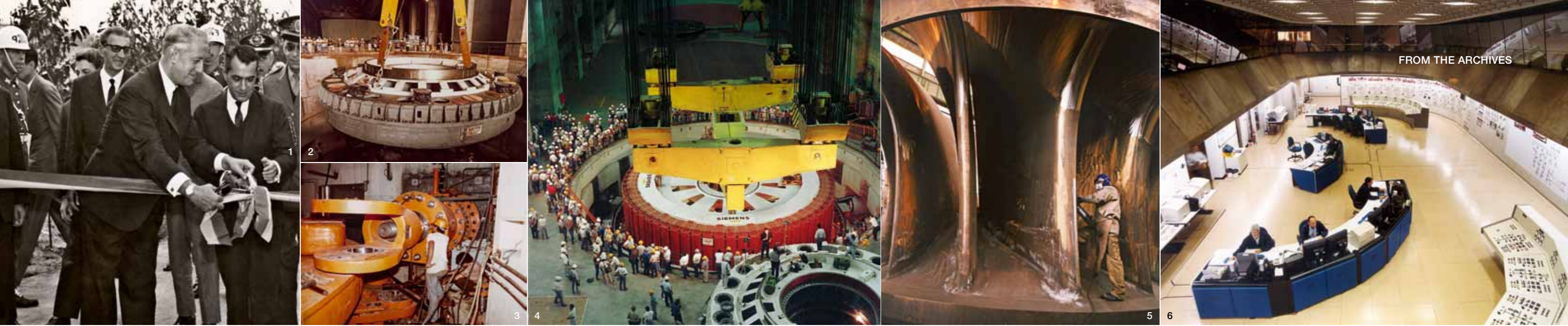


Delivery of first 5 turbines to Brazil for Itatinga hydropower plant

1964



Foundation of Voith Brazil



FROM THE ARCHIVES

- 1 The official opening of the Voith works in São Paulo.
- 2 A 250-ton turbine cover is installed at the Itaipu plant.
- 3 Working on the new regulator at Itaipu.
- 4 Here, the immense size of the Itaipu plant is evident: a rotor is installed as workers look on.
- 5 A big order from China: preparing the world's then-largest turbine for service.
- 6 The central control room at Itaipu.
- 7 Immense power: Itaipu from the air.
- 8 President Dilma Rousseff visits Estreito hydropower plant.

▷ When introducing his country, Gilson Campos, Head of Communications for Voith Hydro in Latin America, talks with justifiable pride: “Brazil,” he says, “is a big country with many natural resources, and it has a lot of potential for generating clean and renewable energy with hydropower plants.”

Campos, along with the rest of his colleagues, is celebrating 50 successful years of Voith in Brazil. He appreciates that it has not been without its challenges. “Competitive prices, deadlines and social responsibility have all been very

strong issues,” he says. But with a dedicated and highly skilled workforce, training programs, and a good work ethic based on continual improvement, Voith has succeeded in securing a strong market position.

Amidst countless high-profile projects, Voith’s work on the Itaipu hydropower plant, located on the Brazil-Paraguay border, is particularly impressive. Construction work started at Itaipu in the mid-1970s, and by 1984, now 30 years ago, the start-up of a Voith gener-

ating unit and turbine heralded the launch into service of the plant. The project was a long time in preparation, remembers Werner Lacher, Sales Director for Voith Hydro Brazil. “I worked in the technical field, and as Head of Engineering, I managed all the design activity here in Brazil and the accompanying manufacturing and site assembly,” he says. And, he adds that he “had the opportunity to see all the work done.” Current Site Manager Alberto Neto charts his involvement in the groundbreaking Itaipu project over more than

three decades. In the 1980s, when he was just 20 years old, he knew that Itaipu represented the “biggest hydropower plant to be built in the world.” Filled with anticipation, he boarded a plane for the first time in his life at São Paulo, and within a few hours – on seeing the “three-meter-diameter wheels of the trucks” employed at the Itaipu site – began to grasp the scale of the project.

By 2007, Voith had supplied 13 of the 20 turbines and 11 of 20 generators for Itaipu. The project not only generates

clean, reliable energy, but also brings ongoing social initiatives to the region, provided by the operator Itaipu Binacional, notably promoting education, science and technology, plus supporting programs that protect children from exploitation. Though not without its ups and downs, in the past couple of decades Brazil has undoubtedly become one of the world’s strongest emerging economies – a development the likes of Gilson Campos, Werner Lacher and Alberto Neto have experienced first-hand. As always, however, Voith is keeping an eye

on the future: “We have the technology, the manpower, the quality and the reliability,” says Marcos Blumer, the new president and CEO of Voith Hydro in Brazil. “There is still plenty of room to grow.” //

Hydropower in BRAZIL	
Installed capacity, incl. pumped storage:	90 GW
Potential not yet installed:	178 GW

No. 1: Brazil is the nation with the world’s greatest volume of fresh water.

- 1966**

Official opening of Voith facility in São Paulo
- 1970**

Opening of the Voith foundry
- 1978**

Delivery of turbines for Brazil’s Itaipu hydropower plant
- 1984**

First generating unit of Itaipu hydropower plant goes into service
- 2000**

To date, Voith has supplied 260 turbines to hydro plants in Brazil
- 2011**

Opening of the Voith Hydro Manaus manufacturing facility
- 2014**

Voith celebrates 50 years in Brazil

CUTTING-EDGE TECHNOLOGY FOLLOWS HERITAGE

Modernity has caught up with tradition at a small but captivating hydropower plant in Pernegg, Austria.

Some may have had pangs of regret on bidding farewell to the historic Francis semi-spirals – affectionately named Eva, Margot and Irmgard – after 80 years of valiant service at Pernegg power plant, near Graz in Austria. But old age and the renewal of water rights made an overhaul of the plant necessary to raise efficiency and the standard operating capacity.

In 1927, Pernegg was Austria's most powerful run-of-river plant when the original turbines were first installed. Built by Voith in Saint Pölten, it has supplied over 600,000 hours of reliable, successful service.

From 2010 to 2013, the facility underwent a thorough modernization, with Voith delivering three new generators, Kaplan turbines and all associated control systems. Today, after Voith has concluded the extensive refurbishment on the plant, it is one of the most productive power plants on the Mur River in Styria and will supply electricity to 35,000 households in the region.

Rupert Emsenhuber, Project Manager at Voith St. Pölten, has vast experience in hydropower turbine rehabilitation and modernization projects. He said that the company decided to replace the old Francis semi-spirals with new Kaplan turbines rather than installing new Francis turbines or building a new power plant. "We faced several daunting challenges, not least because the building housing the plant is a protected historical structure. Therefore, only minor structural changes in the area where the machines were to be installed could be undertaken."

Cavitation safety was another key issue, as the hydraulic development of the project had to account for limited space to install new suction pipes as well as the Kaplan turbines. Eventually, all three suction pipes were changed simultaneously and a subaqueous dam was made. A four-month standstill at the power plant gave the client time to refurbish the upper channel, renew the inlet rake, the rack-cleaning system and high stop-logs, and install suction pipe locks in addition to doing other hydraulic works. But in terms of logistics, just entering the power plant was the first proverbial bridge to cross, as the gate could not be altered, either. Another formi-

dable hurdle was the unusual, vertically positioned engine room gate. This made delivery of large parts difficult. Delicate operations ensued and cranes were needed outside the power plant to uncoil heavy components such as the stator, the rotor arm of the generator and the support blade ring. All this huge machinery had to be reloaded onto special vehicles to get it into the engine room.

Despite the restrictions and the pressure of keeping power outages to a minimum, the entire project went exceedingly well. Its success is due in no small part to the cooperation among all those involved, and the project team's zest to reach their target. "All contractual values and also short time milestones were reached and even surpassed. It was a brilliant experience for the whole team working on this project," says Emsenhuber. In May 2013, the client took over commercial operations, with a grand opening held in September.

Thanks to the upgrade, output per unit has risen from six MW to 8.1 MW at a net head speed of 16.5 meters, a flow of 53 meters and a runner diameter of 3 meters. The efficiency of both turbines and generators has increased, reducing maintenance costs and making the entire plant more reliable in the process.

And the proud old ladies have not been banished: visitors can view one of the three original hydroelectric generating sets in a newly built, light-flooded museum located opposite the power plant. The set consists of a Francis turbine provided by Eva, Margot's generator and turbine control unit, and small parts from Irmgard. A permanent exhibition tells the story of Pernegg and explains how electricity is generated using hydropower. //

- 1 On site is a stunning glass-walled museum housing parts of the historic old Francis turbines.
- 2 The exterior of the historically significant Pernegg plant.
- 3 The new, modern machinery – completely upgraded by Voith.





The Talleres de Tolosa SA plant, now Voith Tolosa SA, in the 1960s (left). Long-term satisfied Voith customer Julian Romeral pictured with his grandson as well as Carlos Aguerre and family after visiting Vadocondes hydropower plant (right).

PARTNERS IN SMALL HYDRO

Celebrating a productive partnership and a milestone anniversary for Voith in Spain.

Eighty-year-old Julian Romeral has small hydropower in his blood. From the 1930s, his family ran flour mills powered by Francis turbines alongside the Duero and Arandilla Rivers in Spain.

Romeral studied engineering, but went into business. Spain's Energy Conservation Law of 1980, incentivizing hydropower production, moved him to buy the old hydropower plant Vadocondes on the Duero River in 1982.

But Vadocondes needed new turbines. Romeral contacted small hydro suppliers with installations in Spain, and finally, a visit with Hermann Fierenz at Voith in Heidenheim and observing Voith small hydropower plants helped him to decide on Voith.

"At Voith, I observed meticulousness in every process, and quality control. These factors led me to choose turbines that were more expensive: but Voith offered the best price-quality ratio, and the most trusting relationship I had found," explains Romeral. And so began work on Vadocondes – and a

partnership spanning 30 years. "During site installation, I met a person who cemented my trust in Voith: Manfred Merz, the 'square head' (a Spanish expression meaning a rigid, mathematical, logical thinker)," says Romeral. "He was a perfectionist, very focused on details – on microns. This was something I was not – I just wanted to see the works done as soon as possible."

Vadocondes went into operation in 1984, with an output of 1,080 kW. Since then, Romeral has contracted Voith to carry out a further four small hydropower projects.

Voith in Tolosa was established in 1963, and in hydropower first specialized in turbine refurbishment. They expanded during the 1980s following the promotion of small hydropower by the Spanish government – at the same time Romeral engaged in the industry. "Customer relationships are the basis of our business, and one of the fundamentals in Voith. Our relationship with Mr. Romeral was important for us in the

development of our presence in the market. He was one of the first investors to install a plant after small hydro installations were promoted," says Carlos Aguerre, General Manager of Voith Hydro in Tolosa.

Now, having reached the milestone of 50 years in Spain, the Tolosa branch is involved in several international projects, having supplied more than 200 small hydropower turbines to 22 countries. The branch is also engaged in modernization of large hydropower plants in Spain.

"We are actively working on supplying new units and the refurbishment of existing plants in Spain as well as in some Latin American countries, where Spanish investors develop activities. We have a long history and exciting future producing machines that produce clean, renewable energy," says Aguerre.

This success is grounded in great customer relationships, as Romeral can attest: "Every time I needed them, Voith was there, for support of any kind." //



Hydropower in SPAIN

Installed capacity, incl. pumped storage:	20 GW
Potential not yet installed:	4 GW

In Spain's renewable energy landscape, hydropower is second only to wind.

DYNAMISM AND PRECISION

VOITH TURBO IS LEADING the way in the field of high-performance punching, nibbling and forming machines. The newly launched HDE high-performance punch system offers convincing performance with high-dynamic behavior and a precise control mode, specifically tailored to the high-end segment.

Newly developed valves and intelligent hydraulic and electronic control circuits enable the high-dynamic behavior of the HDE, which has a punch stroke of 4 mm and can achieve a cycle time of around 18 milliseconds – highly beneficial for the machine operator.

The new DECV valves (Direct Electronic Copy Valve) deliver accurate control of the HDE. A fast and precise impulse response is achieved via direct actuation by a servo motor. A repeatability of up to 0.01 mm permits high-precision bending and forming processes. With its rugged, compact valve, and flexibility of application, integration into a machine or system is simple.

The HDE's load-controlled "two-pressure system," featuring supply circuits for low pressure and high pressure, assures optimal power balance: using the HDE will reduce energy consumption by up to

60%, compared with that of single-circuit systems. Additional pressure sensors and integrated process monitoring provides improved diagnostics, and the software tool "PunchMaster" can retrieve diagnostic data from the HS4 punch controller via Ethernet from anywhere in the world. Maintenance needs can thus be detected quickly, reducing machine downtime – hence costs for repairs and service calls can be avoided. //



FROM WASTE BACK TO RESOURCE

THANKS TO VOITH PAPER, treatment of paper mill wastewater is now more economical. Voith's anaerobic reactors effectively break down paper mill wastewater, dissolving organic contaminants into biogas. In a mill producing 1,400 metric tons of paper daily, up to 780 m³ of methane can be produced per hour. Paper producer Saica chose to include a Voith R2S reactor in the wastewater treatment system of its new mill. The system breaks down up to 80% of the sludge, producing up to 25,000 m³ of methane gas daily. The result? Lower energy costs for paper mills, easily adhered to legal limit values for wastewater, and dramatically reduced sludge – leading to lower sludge disposal costs. In some cases, the treated wastewater can be reused instead of fresh water: all in all, an economical and environmentally friendly solution. //

GREENER TRANSPORT

VOITH INDUSTRIAL SERVICES is assuming responsibility and contributing to environmentally friendlier transportation with an e-mobility pilot project at their Schweinfurt, Germany, location. Here, as one of the first steps of the initiative, three electric cars are now in operation, serving transport needs such as delivery and service trips to customers. The Voith Schweinfurt branch offers technical services to industry in the region. "Acting responsibly and in an innovative manner is a tradition in Bavaria," said Klaus Rehberger, deputy mayor of Schweinfurt, at the unveiling of the cars. This is also a standard

on which Voith bases its own performance. "Electric vehicles are ideal here – they are sustainable, future-oriented and economical," says Schweinfurt branch manager Helmut Walter. //



OUT OF THIN AIR

A practical and low-cost technology is **providing water to those who need it most.**

Water is everywhere around us on earth. In developed nations, we are fortunate enough to have it on tap. But in many other regions of the world, water can't always be accessed via conventional collection means. Water supply and collection may be difficult, hazardous, or unpredictable due to geographical and meteorological factors.

Fog collection, the practice of harnessing water directly from the air, is helping communities with little to no access to water gain access to hundreds – even thousands – of liters per day. It's a simple concept, but one that is making an enormous impact, thanks to Canadian charity FogQuest: Sustainable Water Solutions, which set up fog collection installations (such as those pictured at right) around the world.

FogQuest is the creation of the charity's executive director Dr. Robert S. Schemenauer, a cloud physicist and atmospheric scientist. Schemenauer spent 15 years developing fog collection technology, and organized the First International Conference on Fog and Fog Collection in Vancouver in 1998. But he had even greater plans for fog collection. "I decided that in order for the technology to benefit more people, a formal organization with more resources was required," says Schemenauer. Subsequently, FogQuest was founded in 2000.

So, how does fog collection work? Systems of wide, fine-mesh nets strung up between posts (imagine a volleyball net), are set up in fog-rich spots: generally on slopes or summits, facing prevailing winds. Water drops carried on the breeze are caught in the nets. Droplets combine on the mesh surface and trickle down into a trough. From here, a hose drains the water to a collection tank. As Melissa Rosato, associate executive director of FogQuest, explains, "It is a passive technology in that no energy is required, and there are no moving parts." These factors make fog collection an ideal system for remote locations in the developing world, she says.

It's in these locations where this volunteer-run charity is making a major difference. Since 2000, dedicated teams of FogQuest volunteers have initiated and developed fog collection systems in places as diverse as Nepal and Guatemala – where the charity has its longest-standing initiatives. "Fifty-



- 1 Finding an optimal location is crucial for a successful fog collection system.
- 2 Fog collection technology is simple – but highly effective.
- 3 Locals learn to help maintain the installations.

nine individuals from seven countries have visited the Tojquia project in Guatemala," Rosato says, noting that this is the largest fog-collection project in the world. The charity is also working on projects in Chile, India, Morocco, Peru and Tanzania.

Local people must become the agents for sustainable fog-collection technology, insists Rosato. Locals are involved at every step: from first accessing the terrain, through to building the collectors and planning ongoing maintenance. "This process sets in place the knowledge and confidence needed by the users to ensure there is a sustainable source of fresh water over the long term," says Rosato. "Sustainable technology needs to emphasize local capacity, knowledge, training and access to resources," she says. "Education and participation need to be central to a project."

So, could fog collection perhaps work in our own cities and backyards? "Fog collection works best when there is fog, light wind and ample areas that are relatively free of obstructions that would interrupt the wind carrying the water droplets," says Rosato. In a densely built environment this might be

"Sustainable technology needs to emphasize local capacity, knowledge, training and access to resources."

Melissa Rosato, associate executive director of FogQuest

difficult to find, she acknowledges – not to mention that the demand that a larger population would place on a fog collection system would be too great.

However, Rosato notes that there are interesting applications for fog collection in developed countries where the primary purpose might not be daily human consumption. "In some regions, fog collection is currently being used to provide a water source for fighting forest fires. For educational or eco-tourism type of activities, fog collection can be used in parks as a supplementary source of water for hikers or fauna." //



COFFEE BREAK

Voith Hydro **CEO Dr. Roland Münch** on the significant strength Voith displays in the area of small hydropower.

Dr. Münch, how would you describe “small hydro” in a very simple and visual manner?

Small hydro plants are small but sophisticated. They are small machines with a large output. Just imagine: a single 25 MW turbine can safely and reliably supply a small to medium-sized town with electricity. Just because they're small in size doesn't mean they're small in performance.

Voith Hydro is positioning itself as a complete provider in the hydropower

industry. Does that also apply to the small hydro segment?

The history of hydropower began with small plants that grew to become bigger and bigger over the course of time. We have been actively involved in shaping this history for more than 140 years. Today at Voith, we are developing and able to offer complete systems for small and large-scale hydroelectric power stations. We have specifically developed and optimized our solutions in the small hydropower segment for this area of application.

Is small hydro currently benefiting from the experience and expertise that Voith Hydro has in large-scale hydropower stations?

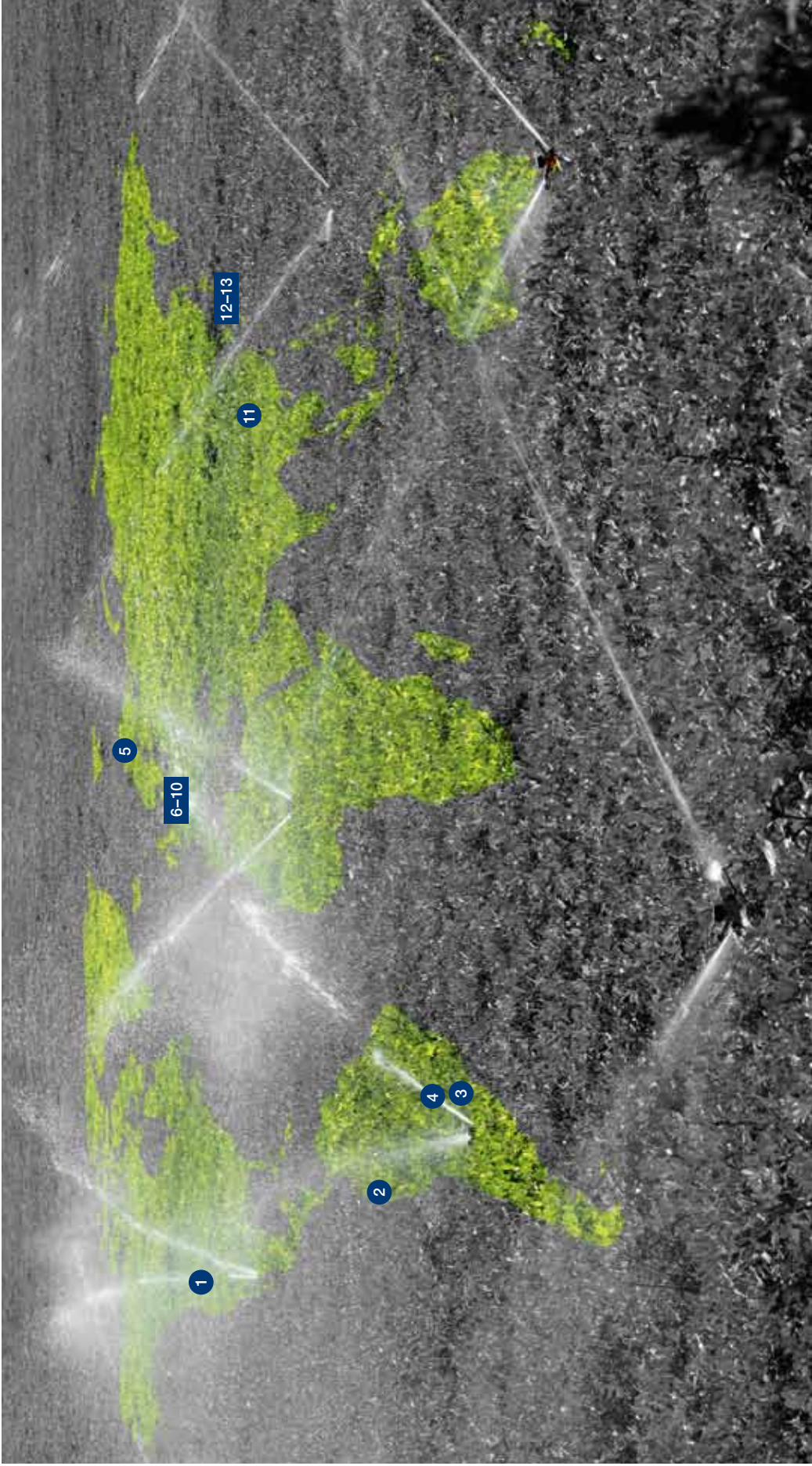
Yes, quite clearly. As one of the world's leading providers in hydropower technology, we have comprehensive expertise in this field. Our small hydro portfolio benefits from the engineering excellence of the global Voith Hydro network. We offer outstanding technology, ranging from engineering, through to the products themselves. That includes 3-D model drawings, complex flow calculations, high-tech equipment featuring five-axis milling machines, and our plants, known for their high operational reliability.

How do small hydro products differ from those created for the large hydro segment?

Besides the size of the plants, small hydro plants have a higher degree of standardization. The focus here is on mature, highly reliable technology and quality products available at optimized costs. With our modular packages in the area of small hydro, we offer a wide range of options and custom-tailor them to the needs of our customers.

Is small hydro also an innovation driver at Voith Hydro?

Yes. For example, with the StreamDiver, we brought a newly developed, innovative product to market, to generate electricity from hydropower in locations where this was previously not possible – perhaps due to environmental reasons, or insufficient heads. The StreamDiver scores points thanks to its compact design, water-lubricated bearings, and minimal maintenance and operating costs. It's just one example of how Voith continues to make advances in small- and large-scale hydropower. //



PROJECT DIRECTORY

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

1 Waneta Expansion, Canada: Expansion project including two 167 MW Francis turbines, generators and complete electromechanical balance-of-plant equipment.
2 Baba, Ecuador: Two Kaplan turbines and generators with a total output of 42 MW including balance-of-plant and automation systems.
3 Salto Santiago, Brazil: Four 360 MW vertical Francis turbines, generators, automation systems

and electromechanical equipment.
4 Água Vermelha, Brazil: Six generators, vertical Francis turbines with a total output of 1,396 MW, automation systems and electromechanical balance-of-plant equipment.
5 Arjeplog, Sweden: Expansion of a community small hydro project, with a Kaplan bulb turbine and synchronous generator with 0.6 MW output.
6 Erzhause, Germany: Revision of a horizontal pump unit with turbine,

pump and corresponding spherical valves.
7 Blaichach, Germany: Three vertical Francis turbines with a total output of 5 MW.
8 Rénovièze, Switzerland: 14 MW Pelton turbine, synchronous generator and complete automation system.
9 Brunnenfeld, Austria: Kaplan S turbine, synchronous generator and automation system with 321 kW output.
10 Pernegg, Austria: Three

generators, 8.1 MW Kaplan turbines and control systems.
11 Xiluodu, China: Three 784 MW Francis turbines and three 855.6 MVA air-cooled synchronous generators.
12 Umamichi, Japan: Modernization project including replacement of a vertical Francis turbine, generator and control system for the 5,430 kW plant.
13 Chugui, Japan: Modernization involving three-nozzle horizontal turbine with an output of 3,100 kW.

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Voith Hydro Holding GmbH & Co. KG

Alexanderstr. 11

89522 Heidenheim, Germany

Tel: +49 7321 37 0

Fax: +49 7321 37-7828

www.voith.com



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