Spring 2013 Open House Comment Form

The Corps of Engineers and BPA want to hear from you and we need your feedback!

Open House Date 4/16/17

Was this Open House helpful? Yes

How can we improve? We have more open houses planned so your comments will help make these better.

- [x] Format, room layout, time
- [ ] Level of detail
- [ ] Use of simple language and terms
- [ ] Length of presentations
- [ ] Please explain or provide your own review:

Room was very loud

Treaty Review Comments

1. I want the Treaty Review team to consider these issues:

See attached. Ratepayer impact under various scenarios. Pump storage to increase operational system flexibility, US flood control risk and variable resource integration. BPA funding to Army Corps/BoR dams to keep them operating and provide assumed levels of revenue.

2. Is there any key information we missed in our Iteration 2 assessment? Any gaps in our analysis?

Specific Ratepayer impact due to ecological considerations, etc. Pump storage economic feasibility study in the context increasing revenue, decreasing risk, providing nighttime load and energy security. BPA funding to Columbia River US dams to keep them running at assumed levels in analysis. Climate change impact (i.e. less snowmelt, runoff earlier, dry season longer

(see reverse)

3. **As we move into the third phase of analysis, Iteration 3, what are your priorities for our attention?**

Ratepayer impact as it relates to lower Revenue from power generation. Pump storage (vs. "call using upon" economic feasibility assessment. Capital expenditure from BPA to Columbia River dams. Climate change impact (i.e. less snowpack, runoff earlier, dry season longer).

Name: Nathan Sandvig

E-mail: sandvign@gmail.com **Telephone:** 503-477-4029

☒ **Please add my name to the project mailing list**

All comments we receive will become part of the official project record.

There are many ways for you to share your comments:

- **Write them down today at the Open House and hand to any team member**
- **After the meeting, you may comment by:**
  - **Email**: Address your comments to treatyreview@bpa.gov
  - **Phone**: Call the BPA at 800-622-4519 or the Corps at 503-808-4510.
  - **Mail**: Bonneville Power Administration
    PO Box 3621
    Portland, OR 97208-3621
  - **FAX**: 503-230-4563, Attn: Columbia River Treaty Review Team

Nathan Sandvig

8024 SE 35th Ave.

Portland, OR 97202

To Whom It May Concern:

As a citizen living in the Pacific Northwest, I am concerned that the opening of the Columbia River Treaty between Canada will greatly increase our power prices with many competing influences and stakeholders now involved in the process since it was originally signed that need to be taken into account. This risk should be addressed and mitigated in the process.

Additionally, power generation is now one of the lowest priorities of the Columbia River and our world-class hydro and transmission system is not optimized for greatest economic development in the Pacific Northwest. I believe it should be considered as a top priority for economic development in the region.

Major rehabilitation and refurbishment of existing hydro is fleet needed. 90% of the Army Corps of Engineers' hydroelectric projects are 30 years or more older, although funding for new project construction and major rehabilitation has declined steadily since the mid-1980s. More than 50% of the Corps' fleet of plants have exceeded the 50-year lives they were designed for. Hydropower revenues could be increased by increasing the efficiency of turbines and related power generation facilities at Corps hydropower projects. More specific direction from the U.S. Congress regarding priority maintenance investment needs is crucial to sustaining this heritage in our region for future generations.

Lastly, I believe pumped storage feasibility should also be explored on the US side of the Columbia by Bonneville Power Authority and the Army Corps of Engineers, since one of the main reasons for the treaty was to provide storage for the dams located in the US.

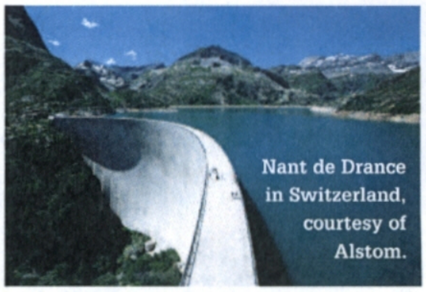
Regards,

Nathan Sandvig

Bringing pumped storage to the table

Prompted by worldwide interest in pumped storage development, IWP&DC invited representatives from the sector to a roundtable discussion. We discover what role Alstom, MWH, the National Hydropower Association and Voith have been playing, and are set to play, in this burgeoning sector of the hydropower industry.


Alqueva dam in Portugal, courtesy of Alstom.


Nant de Drance in Switzerland, courtesy of Alstom.

IWP&DC: Why do you believe there is an increasing demand for pumped storage facilities worldwide?

Alstom:

Managing the balance between energy production and consumption has become an issue of growing importance in order to guarantee the stability of electrical networks. Pumped storage hydroelectricity is the only economic and flexible means of storing grid-scale amounts of excess energy, allowing power plant dispatchers to successfully manage the balancing act.

Alstom strongly believes that pumped storage is the only mature technology capable of allowing large and CO_2 free energy storage and quick load variation to compensate wind and solar variability. For these reasons, this market segment should grow substantially in the future.

In the past five years, almost 150GW of hydroelectric capacity has been built worldwide. In parallel, wind capacity has increased and 238GW had been installed by 2011. Unlike thermal power, the amount of energy produced by solar and wind is by nature unpredictable and poses problems to the grid's stability. Without energy storage, power grid operators need to use fossil fuel-fired energy to match the rise and fall of energy produced with variable sources in order to meet demand. Pumped storage is the most efficient and flexible means of storing energy on a large scale.

Variable pumped storage, the latest in large scale storage technology, enables operators to integrate large scale wind and solar capacity, match supply to demand minute-by-minute and further enhance energy production efficiency throughout their fuel portfolio.

MWH:

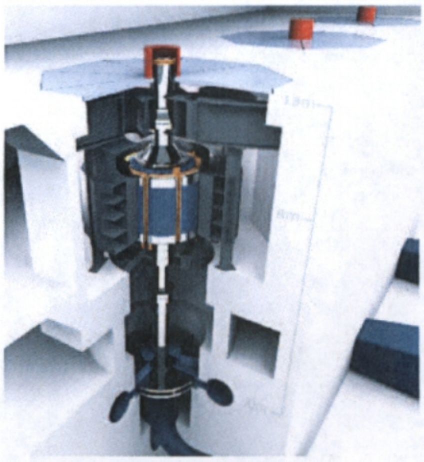
Pumped storage is the most widespread form of large electric energy storage systems in use worldwide. Projects were developed in the 1970s and 1980s to help integrate large coal and nuclear base load plants, especially at night during hours of low electricity demand and to replace high cost oil and gas peaking generation.

Today, the demand is mostly driven by the uncertainties associated with intermittent renewable energy generation and energy storage. Pumped hydro is available at almost any scale with the largest operating plant capacity of just under 3000MW, and with storage times ranging from several hours to a few days.

Low current natural gas prices, low load growth due to the economic recession, and regulatory uncertainties around climate change initiatives (such as caps on greenhouse gas emissions) are having a profound short term impact on electric power investments. At the same time, security and stability of power grids and the growth of non-firm renewables has spurred new interest in energy storage as a whole.

One of the main reasons energy storage, and pumped storage in particular, is coming to the forefront is the speed of response. Wind, solar and thermal power plants cannot respond as fast as hydropower plants and pumped storage from a standing start, with synchronisation in seconds and full power in under a minute at most facilities. From synchronisation, large pumped storage plants have the capability of ramping in excess of 100MW per second with single unit ramp rates in excess of 30MW per second being achieved.

Pumped storage also has the ability to operate at low power output with turn down ratios down to 25% of maximum power occurring currently in the operating fleet. This eliminates the synchronisation time and allows full power in some plants in less than five seconds. Gas turbines and diesel engines also play a role in fast start ramping but they are slower orders of magnitude: taking minutes or portions of an hour to be at full synchronised power. Thermal power plants also lack the capability to become a load, such as when a pumped storage plant switches from generation to pumping mode. Therefore a 1000MW pumped storage project can perform the balancing equivalent of 2000MW of thermal. It can do it faster, with higher quality and dependability while providing simultaneous ancillary benefits such as frequency regulation.


Nant de Drance, courtesy of Alstom.

National Hydropower Association (NHA):
Pumped storage hydropower has played a vital role in providing grid stability and reliability in the past and will continue to do so in the future. The intermittency of variable energy resources, like wind and solar power, makes it essential that we build additional large grid-scale storage, and pumped storage hydropower is just the solution.

As we saw this year, oversupply conditions in the US Pacific Northwest, brought on by spikes and plunges in wind generation, resulted in companies essentially wasting electricity. Pumped storage hydropower is an essential tool in meeting these types of grid challenges, offering the ability to store overabundant generation for later use.

Voith:
Large pumped storage power plants will be essential in the further development of renewable energies, as they will function as 'batteries' for the fluctuating electricity from wind and solar.

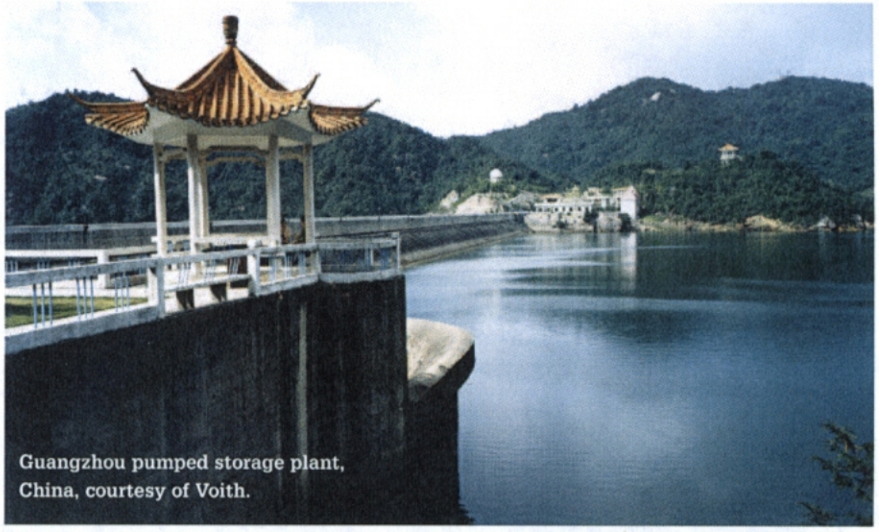
Up-to-date pumped storage power plants are the only economically feasible, flexible and technical proven solution with an average efficiency factor of 75-80% which can guarantee to provide and receive fast, reliable large scale electricity into and from the grid.

Will we see more newly built pumped storage facilities in future?

Alstom:
The pumped storage market is expected to grow 60% over the next five years, with an average of 7.5GW of additional pumped storage capacity to be ordered each year. We expect 65% of the market to come from China. In Europe, which accounts for approximately 20% of the market, opportunities are mostly focused around the alpine regions (Switzerland, Austria, Germany), Spain and Portugal.

MWH:
Regions of the world that have in excess of 15% or so of their power from non-firm renewables will be looking at increasing their balancing and firming capabilities through energy storage technologies. The higher the percentage above 15%, the greater the need will be for energy storage. When different energy storage technologies are compared on an equal basis, pumped storage hydro has proven to be the technology of choice based on cost, performance, scale, reliability and flexibility to adapt to various market conditions.

Geographically, regions like the western US that have a large potential for new wind and solar are more likely to invest in new pumped storage than in the east, where there are fewer large capacity wind developments and there is an existing fleet of pumped storage projects. Intermittent renewables, such as wind and solar, are expected to increase installed capacity at least through 2020 in the majority of the US, Europe and other countries.


Guangzhou pumped storage plant, China, courtesy of Voith.

Energy storage can avoid costly situations that are beginning to occur more frequently where wind generation is either curtailed or goes into negative price territory due to excess generation in the region at times when it is not needed. Some are espousing that pumped storage is the only large scale option available to accommodate the 2020 renewable energy targets for the EU as well as California's aggressive RPS targets.

NHA:
We will definitely see newly built pumped storage facilities very soon. There is interest in the industry to do this. Over 56,000MW of new US pumped storage capacity are currently in the regulatory pipeline at the Federal Energy Regulatory Commission. Most of it is in the west where we are seeing the greatest penetration of new wind and solar resources.

Voith:
Pumped storage is the most economically and environmentally developed form of energy storage to date. To further support secure energy supplies all forms of renewable energy will be needed. Therefore we are sure pumped storage will have its share within this future energy development. Major markets for pumped storage will be China, Europe and the US.

Are we likely to see increasing investment in uprating and refurbishment of existing facilities to squeeze out more capacity and storage?

Alstom:
Both new plants and refurbishment will be needed in order to achieve the needed developments. The market will be composed of new plants with new reservoirs (for instance in China), conversion of existing hydro plants to pumped storage by adding pumping back capability, rating increase of existing pumped storage plants and upgrade of existing plants to maximise their flexibility.

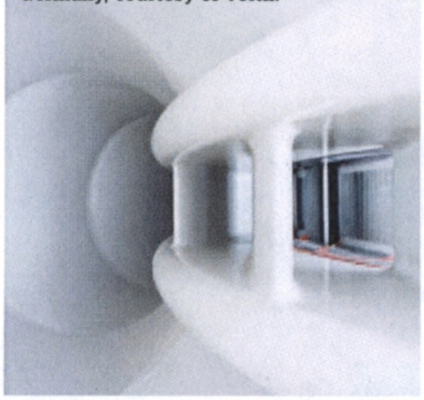
MWH:
MWH has seen a large increase in the rehabilitation needs of the existing US fleet, partially due to ageing infrastructure and equipment, but also in part due to the number of starts and stops and ancillary support the existing fleet is being asked to perform. In every situation where an upgrade has been evaluated, it has been the lowest cost option to provide additional storage, additional capacity and flexibility or increased reliability. This will serve to extend the life of the existing fleet more than replace the need for a new plant.

The time horizon to develop new pumped storage may not be quick enough for states to meet renewable energy generation goals.

Voith:
Both the installation of new plants, as well as the modernisation of existing plants is important. Voith has experience in both fields.

Do you agree that future development trends may focus more on installing pumped storage at existing infrastructure? What do you think are the advantages and disadvantages to this?

Inner view of a spiral case at Goldisthal, Germany, courtesy of Voith.



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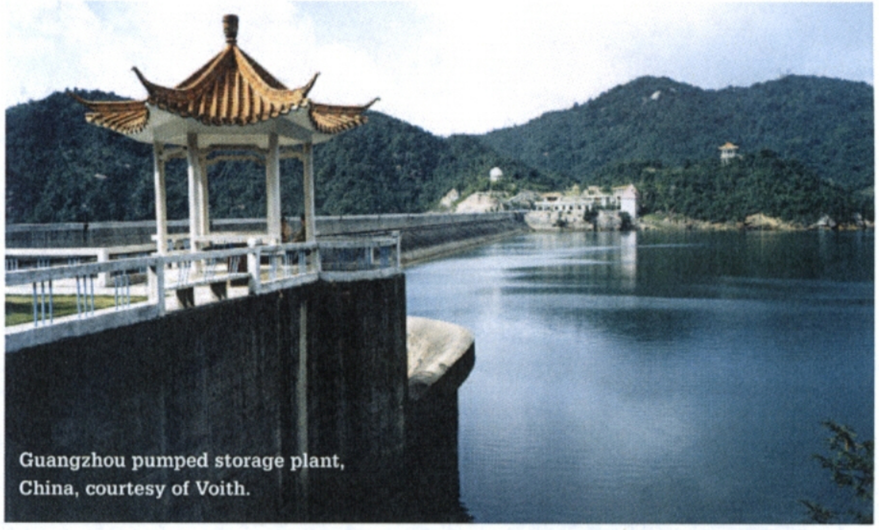
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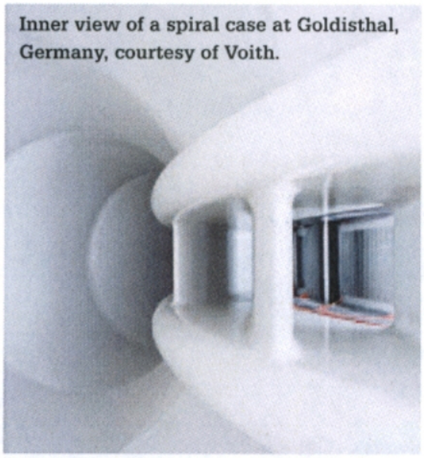

Inner view of a spiral case at Goldisthal, Germany, courtesy of Voith.

Alstom:
This will definitely be part of the market. The obvious advantage is to minimise the investment cost as well as a lot of development issues. There will be minimal environmental impact as the hydro scheme already exists with the presence of transmission lines etc. The challenge is technical: pump turbines are often more complex to design and the use of existing infrastructure adds constraints to developers in terms of head, head variation or even setting if the existing powerhouse must be used.

MWH:
The utilisation of existing infrastructure for a pumped storage project is not a new concept. It has been done many times incorporating existing or natural reservoirs as in Ludington in the US which utilises one of the great lakes as a lower reservoir.

The prototypical infrastructure re-use is to use an existing reservoir as a lower or upper reservoir. This can be on a river, a lake or even the ocean. We are currently working with Gas Natural Fenosa of Spain to investigate three potential projects at existing hydro facilities. We are also seeing renewed interest in converting conventional hydropower plants to reversible pump turbines at storage dams where they have low plant utilisation factors.

There also is a renewed interest in utilising brownfield infrastructure such as abandoned mine sites and/or quarries as hydro power projects. Dinorwig in Wales uses an old slate quarry as the lower reservoir so this is not a new concept, but rather an old concept coming to life again.

NHA:
Obviously there is a focus within the industry at building hydropower at the US' nearly 54,000 non-powered dams. Utilising that existing infrastructure minimises environmental impact and allows us to tap clean energy without significant construction. Now, whether those sites are suitable as pumped storage facilities is a question we are seeking to answer. That's one reason it's important to have a well-funded Water Power Programme at the Department of Energy to invest in that basic research.

Another trend we are seeing is a growing interest in 'closed-loop' pumped storage: facilities that utilise two reservoirs not located on a river or other natural waterway. In fact, more than half of the permits and licence applications at FERC are for these types of low impact systems. In one instance, Eagle Crest Energy, a developer in California, is taking a brownfield site and turning it into a pumped storage project that would use two abandoned coal mines as the upper and lower reservoirs of the project.

Voith:
The extension of facilities which already exist will always be an option depending on the age of the facility, the specific location and design of the facility as well as investment issues and grid requirements. Given these favourable conditions, existing infrastructure will be expanded. Advantages for uprating existing plants are faster permission processes, plus that there is greater general acceptance of large infrastructure projects at existing facilities.


Raccoon Mountain Plant at Tennessee River, US, courtesy of Voith.

What barriers are there to the successful development of pumped storage? How can these be overcome?

Alstom:
The key barrier to overcome now is the demonstration of a fruitful business case. Pumped storage requires important investment costs and long payback: to justify the development of new facilities the developers must be confident an adequate market for electricity and service will exist during the full payback of the investment. It means having a stable market and regulatory framework over decades and having an adequate remuneration for the services pumped storage delivers to the system.

MWH:
The primary barrier to pumped storage is uncertainty in future revenue streams. A typical pumped storage project operating today has two revenue streams:

- Energy arbitrage from buying low-priced pumping energy during off-peak hours and selling at higher prices when the energy demand is increased.
- Revenues from ancillary services such as spinning reserves to the grid.

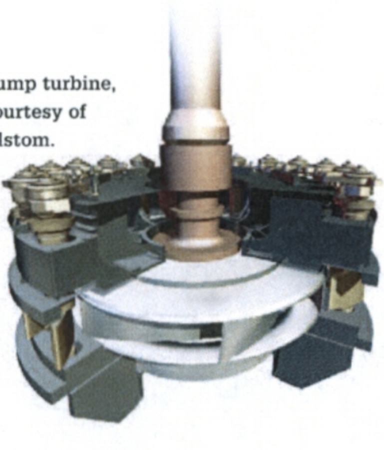
Storage also provides several other functions that currently have no revenue stream but do have economic value.

The first non-revenue producing benefit is fleet-wide efficiency improvements in the generation that come about through optimising thermal plant heat rates for longer periods every day or with fewer starts and stops. Only large utilities can actually see an economic benefit but often the benefits via cost savings stay with the thermal plant that run more efficiently and are not distributed back to the storage project, although utility planners do recognise the soft economics at play.

The second non-revenue producing benefit is delivery of required ancillary benefits to the grid that currently have no market price such as fast and ultra-fast ramp rate capability. Finding a way for developers to get a revenue stream for these last two benefits is critical for private pumped storage projects.

Greenfield pumped storage projects are very capital intensive and in the US it takes four to six years to obtain all permitting and licensing agreements, plus another four to five years to build. With the cost of new construction between US$1000 per kW and US$2500 per kW, the payback period is typically at least ten years depending on the expected revenue streams. In deregulated power markets, traders can barely forecast power prices over the next three years and certainly not for the next 15 years. To complicate matters, the average spread between peak values and pumping costs has been narrowing in the past two to three years, mostly due to lower gas prices and renewable energy availability during peak demand. This makes it difficult to project accurately financial viability under varying assumptions.

In public debates about existing electricity demand, supply and reliability, the lack of positive recognition of pumped storage as a strategic technology is a major challenge to further development. The general population, including regulators and policy makers, generally do not fully understand the multiple benefits of pumped storage. Even in regions where power utilities operate large facilities, they have taken for granted the energy security component provided by pumped storage projects. It is well known that dispatchers like pumped storage as it provides a



Pump turbine, courtesy of Alstom.

safety valve on an everyday basis that can be used to stabilise or even save the grid in the event of unforeseen disturbances, forced outages or even natural disasters.

NHA:
While benefits of expanding pumped storage capacity are clear, current US market structures and regulatory frameworks do not present an effective means of achieving this goal. Policy changes are needed to support the timely development of additional grid-scale energy storage. Longer licensing processes drive up the cost and introduce a lot of uncertainty, making it harder to secure private financing for projects. NHA has been working to reduce that time to two years for low impact projects, like building a closed-loop pumped storage system that is not on a natural waterway. We've also been working to ensure that pumped storage qualifies for tax incentives available to other renewable energy projects. One bill in Congress would extend the 20% investment tax credit to pumped storage projects. Policies like this help projects leverage additional private investment.

Perhaps the greatest challenge for new US pumped storage development is the lack of market valuation. The current markets are not structured in a way to value the ancillary services of pumped storage. The regulation in these markets also makes them problematic for energy storage as it prohibits engagement by transmission assets in wholesale energy, and requires the independence of grid operators and storage markets. Regulation also does not allow public utilities to purchase ancillary services in order to satisfy their own obligations to customers. Although these policies are designed to prevent market manipulation, they draw too clear of a distinction between transmission and generation assets that is bad for energy storage, which has components of both.

Voith:
Although pumped storage today is the only proven, economically attractive technology to store electricity from other renewable sources, the financial incentives in the compensation structure for fast power reserves are not yet fulfilled sufficiently. In addition, it has become increasingly difficult to calculate the profitability of investments in recent years. Predictable planning is much more difficult than in the past. Instead of a clear on/off schedule, the phases are scattered throughout the entire day. The demands towards flexibility have increased, and the tariff models for compensation have become more flexible too.

The approval procedures for new plants are too long and too complicated, like with many large infrastructure projects. To improve these parameters remains a key task which must be resolved at the political level. A fair promotion and faster approval procedures would be helpful.

The lack of financial incentives for rapid energy reserves, both ways, must be resolved. Compared with other renewable energy sources, hydropower should not be disadvantaged by legislation.

Are there any significant technological developments which have taken place in recent years, or which you believe need to take place, to help maintain the successful development of pumped storage?

Alstom:
Between 1953-60 pumped storage orders were predominantly for low head units. Recent market trends indicate the need for high speed pump turbines at very high heads. Alstom has invested heavily in pump turbine R&D. In 2008, we extended our turbine hydraulic scale model test laboratory in France to have two dedicated pump turbine test-rigs, thus doubling the facility's overall test capacity.

Unlike conventional hydropower plants, variable speed pump storage plants use asynchronous motor-generators that allow the pump turbine rotation to be adjusted. Alstom has a strong position in the field of variable speed pumped storage, gained through early R&D initiatives. This key expertise has resulted in the signing of significant contracts such as Linthal 2015 for 4x250MW and Nant de Drance for 6 x 157MW units, both in Switzerland.

MWH:
The primary technology development has been the advancement of adjustable speed double fed induction machines (DFIM) initially developed in Japan. Adjustable speed DFIM machines allow substantial improvement in the operating range and total plant cycle efficiency, but most importantly allow units to do fast and ultra-fast ramping during pumping operations. They actually allow for automatic generation control (AGC) while in pump mode.

Current synchronous machines provide fast and ultra-fast ramping and AGC only while generating, but not in pump mode where they can only turn pumps on or off at full load. Also DFIM machine technology actually allows the machines to be full inertia flywheels in pump, generation and synchronous condensing modes. This new technology allows adjustable speed machines to more efficiently use wind power as a pump to match pumping loads to the available non-firm renewable online such as wind.

A recent trend in the pipeline of proposed projects is the use of closed-loop configuration. This is actually not a new trend as the largest operating pumped storage project in the world, Bath County in Virginia US, is a closed loop system but it is something the regulators have begun to focus on. Closed-loop systems are generally viewed as more environmentally benign because their operations do not impact flows, water levels and habitats in streams or rivers.

NHA:
The Department of Energy's Water Power Programme has been involved in and will continue to be essential for research and development that will bring more pumped storage online. In 2011, two projects were awarded US$6.8M by DOE to spur deployment of advanced pumped storage hydropower in the US. Although globally, new pumped storage plants with the latest technologies (such as variable speed) are being constructed both in Europe and the Far East, there are unique conditions here that require

Upper and lower basin of Limberg II plant, Austria, courtesy of Voith.

Who's who at the roundtable?

Alstom: ***Represented by Olivier Teller, R&D Product Director of Pumped Storage at Alstom Hydro Global.***
Alstom says that more than 25% of the world's global hydropower installed capacity contains equipment and services installed or provided by the company. It provides a complete range of pumped storage electromechanical equipment which includes pump turbines, motor-generators, control systems and optimised hydro-mechanical and balance of plant equipment. Alstom has built up an extensive pump turbine hydraulic design portfolio, with more than 50 pump turbine prototypes.

The company is developing turbines for variable speed energy production. It has been providing pump turbines for over 50 years and has supplied a total of 145 to date totalling over 24,000MW .

Over the past ten years Alstom has completed 15 major pump turbine projects. Among these 11 are located in Asia, including eight in China. More recently in 2011, in consortium with Hindustan Construction Company (HCC), Alstom was awarded a contract worth over €285M by Tehri Hydro Development Corporation (THDC) to install a 1000MW variable speed pumped storage hydro power plant on the river Bhagirathi in the state of Uttarakhand, India. It will be India's first pumped storage power plant to use variable speed technology. Alstom will supply four 250MW variable speed turbine and generator units and other equipment including main inlet valves and control and protection systems.

In Portugal, Alstom has also won a contract worth over €55M by Portuguese utility EDP (Energias de Portugal) to supply and install a new power generation unit at the Salamonde dam in Portugal. Alstom will supply and install the entire unit, consisting of one 207MW Francis reversible pump turbine, a 244MVA motor-generator, butterfly valve and other hydromechanical equipment and mechanical and electrical balance of plant.

MWH Global: ***Represented by Don Erpenbeck and Bruno Trouille, MWH Vice Presidents.***
MWH Global operates as an engineering and management consultant with more than 50 years of experience in pumped storage, having been involved with the design and rehabilitation of more than 7800MW of pumped storage capacity in the US and 8200MW internationally (China, Korea, South Africa, Israel, Ukraine, UK and Spain among others). The projects range from 40 to 2100MW in installed capacity.

The company's pumped storage references comprise more than 50% of the existing pumped storage portfolio in the US. In addition, MWH has conducted a multitude of preliminary siting, planning and concept studies of potential pumped storage hydro sites for purposes of site screening, permitting, licensing, and preliminary evaluation of construction costs and economic benefits.

Along with several thousand megawatts in Europe, Africa and China, MWH has recently looked at more than 10,000MW of new pumped storage capacity in the US. It completed the design of the Rocky Mountain project in Georgia, including the capacity increase of 200MW during a recent upgrade, and the 40MW Lake Hodges pumped storage project that recently went on line in California. In addition, the company has provided services for numerous rehabilitation projects such as replacement of the upper reservoir linings at Seneca in Pennsylvania and a full condition assessment of the two units of Mount Elbert in Colorado.

National Hydropower Association: ***Represented by Linda Church Ciocci, Executive Director NHA.***
NHA is the unified voice of the US hydropower industry both in Washington, DC and across the country. Due to growing interest from the industry, an increased number of filings at the Federal Energy Regulatory Commission for such projects, and the growth of intermittent renewables, four years ago NHA started its Pumped Storage Development Council to assist in the development of policies to support growth in the pumped storage sector.

Voith: ***Represented by Ralf Grether, Head of Corporate Product Management, Voith Hydro***
Voith is working as a full-line supplier and offers broad services for pumped storage plants. The company's portfolio of products covers the entire life cycle of new and existing large and small hydro power plants. Voith offers turnkey plant solutions applying to both the field of power generation and the area of storing electric power, as well as stand-alone solutions for plant automation and lifetime services for all types of hydro equipment.

Voith has more than 100 years of experience with pumped storage power plants and equips the most modern and powerful stations in the world. The company's market share in pumped storage equipment has been about 20% over the last decade and is comparable to Voith's share in the hydro power business overall.

Today, over 200 Voith Hydro pumped storage units have been installed worldwide with a combined output of well over 24,000MW. These include:

- Hong Ping, China: Awarded to Voith in 2012 with planned commissioning in 2015/16. Scope of supply is for the complete electromechanical equipment with a total capacity of 1200MW.
- Hongrin Leman, Switzerland: Awarded to Voith in 2011 with planned commissioning in 2014. Scope of supply for radial pump and start-up torque converter with a total capacity of 240MW.
- Frades 2 (Venda Nova 3), Portugal: Awarded to Voith in 2010 with planned commissioning in 2014/15. Scope of supply for complete electromechanical equipment.
- Ingula, South Africa: Awarded to Voith in 2008 with planned commissioning in 2014. Scope of supply for complete electromechanical equipment with a total capacity of 1368MW.

considerable R&D in order to optimise equipment design for the US.

Voith:
The most significant technical development in recent years is certainly the increased flexibility of the plants. Today the change intervals are counted in minutes, not happening twice a day like years ago. Variable speed pump-turbine units are the focus of this trend.

With the use of an asynchronous motor-generator the rotational speed of the pump-turbine can be varied. Thus the pump capacity can be adjusted to using just the currently available amount of energy. This allows for highly efficient stabilisation of the grid.

Also ternary systems come back into focus. These consist of a motor-generator and a separate turbine and pump set. As two separate hydraulic machines, the rotational direction of the motor-generator can be the same in both operational modes. This results in considerable commercial value for the power plant's operation. As a ternary system, the facility is even more flexible and response times are even shorter.

One unique value proposition at Voith is the torque converter which provides extremely short switching times between turbine and pump operation. Within seconds the storage pump can be connected or separated from the shaft system. ■