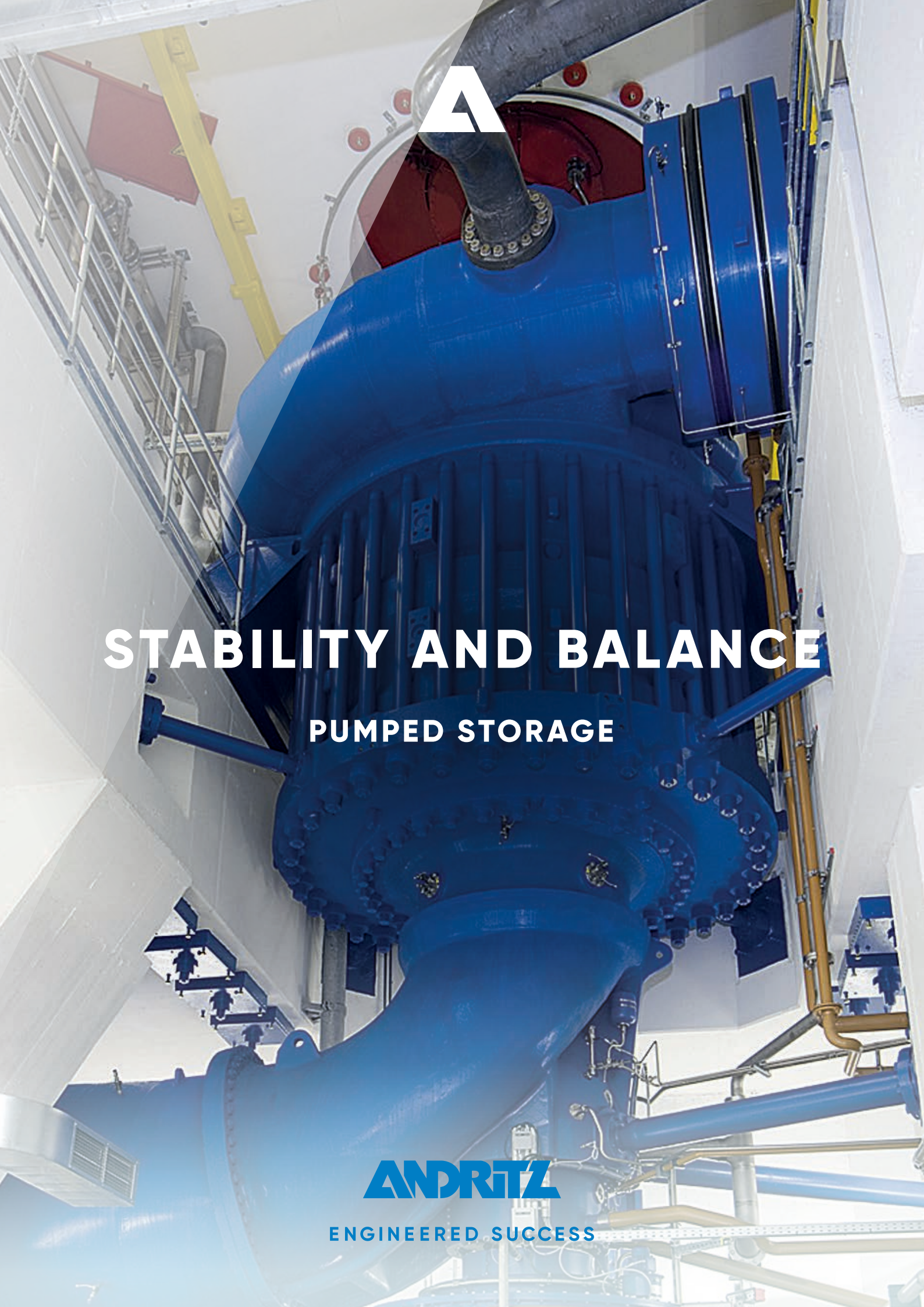


# STABILITY AND BALANCE

## PUMPED STORAGE

ANDRITZ

ENGINEERED SUCCESS

# Pumped storage is an essential player in the clean energy transition

The global energy demand is growing entailing a growing installed base of volatile renewable power generation. As a result, an economic solution for large-scale energy storage is becoming more important. Pumped storage power plants are currently the most economical way of efficiently storing large amounts of energy over a longer period.

As the most proven, reliable and cost-efficient technology for bulk energy storage, pumped storage hydropower is already a significant contributor to our clean energy future. With its high operational flexibility, pumped storage hydropower plants balance grid fluctuations and allow the integration of intermittent renewable power on a large scale. All with low risks and low operating costs.

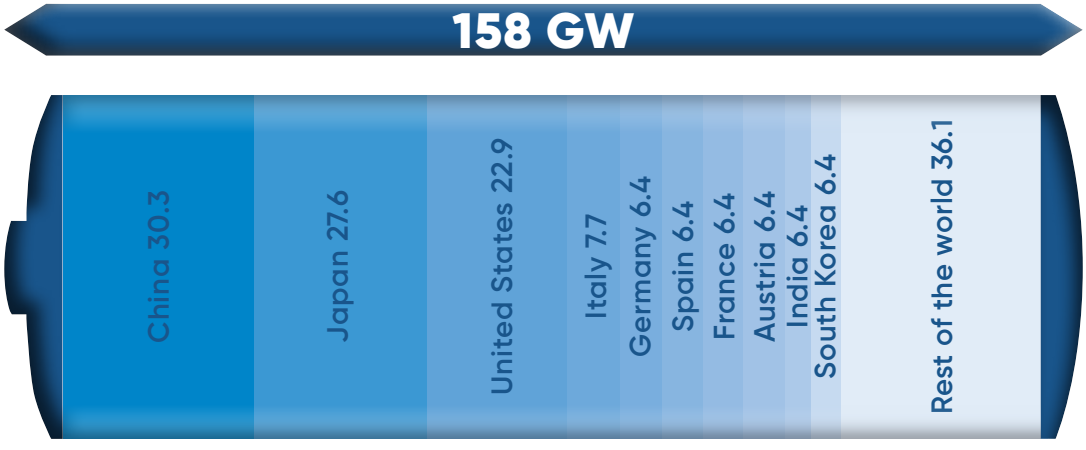
Many countries have readjusted their energy policies in order to support the Paris Climate Agreement goals, boosting power generation from renewable resources. This in turn is triggering an increased need for energy storage.

As the leading technology for energy storage services, pumped storage not only balances variable power production, but with its firm capacity it also serves as a reliable back-up. This ensures grid stability while reducing the risk of blackouts. For small and islanded grids especially, pumped storage is the ideal partner to gain independence from fossil fuels. Pumped storage can also be more than just a back-up for intermittent renewable energy resources and additional grid supporting services. Its inherent operational flexibility allows pumped storage to offer a wide spectrum of benefits and it plays a vital role within local and regional water and energy programs. However, to achieve significant further development and growth, the adoption of appropriate market structures and regulatory frameworks is vital.

## THE MARKET

Today, about 160 GW of pumped storage capacity is installed globally. Over recent years, about 2.2. GW of new capacity has been added worldwide. Numerous projects are in the pipeline, either in planning or under construction. This confirms that hydropower, and pumped storage especially, represents a substantial part of the renewable power sector.

Currently, 94% of the global energy storage capacity, and over 96% of energy stored in grid-scale applications is pumped storage. According to a recent analysis paper by the International Hydropower Association (IHA), the estimated total energy stored in pumped storage reservoirs worldwide is up to 9,000 GWh.



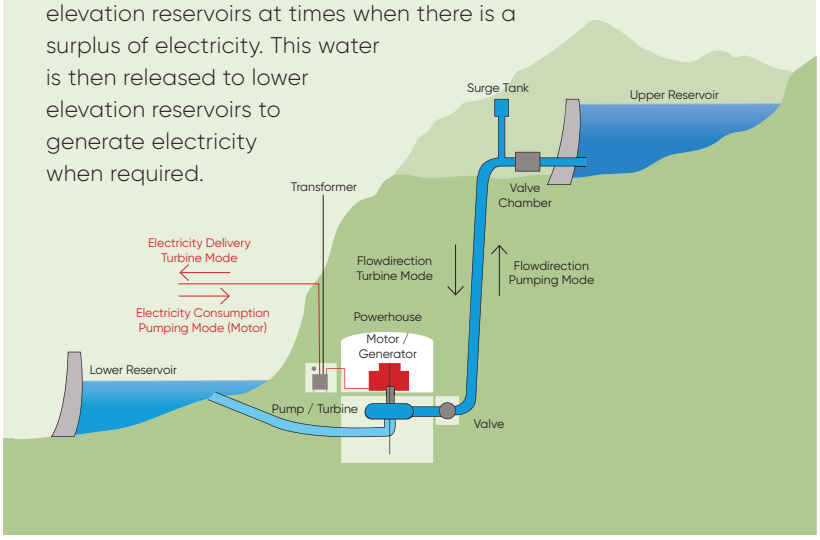

Graphic: Pumped hydropower storage capacity (GW) of top 10 countries and rest of the world in 2019. Source: IHA 2019

Cover photo: Tierfehd (Nestil), Switzerland; extraordinary high-head reversible multi-stage pumpturbine

# Pumped storage is a major contributor to a clean and sustainable energy future.

## The principle:

Pumped storage plants pump water to higher elevation reservoirs at times when there is a surplus of electricity. This water is then released to lower elevation reservoirs to generate electricity when required.




**BENEFITS OF PUMPED STORAGE:**

- Best-proven, low-risk energy storage technology
- Balancing supply of volatile renewables with demand
- Supporting grid congestion management
- Quick response to changing demand or sudden outages
- Increasing grid inertia
- Providing black start capability
- Supporting water resource management

### OUTLOOK

As the energy market is changing to become cleaner, interest in new storage concepts is increasing. Numerous studies identify the extensive potential for pumped storage sites and research is ongoing to develop hybrid concepts. Studies by the Australian National University identified more than 600,000 off-river sites worldwide that are suitable for pumped storage development, for example.

It is possible to retrofit pumped storage capability in disused mines, underground caverns, dams for irrigation and water regulation, and even conventional hydropower plants. Retrofit pumped storage technology is still able to meet new grid requirements, satisfy growing demand and help reach global climate targets.

Hybrid concepts that combine pumped storage with renewable energy sources, such as wind, solar and biomass or multi-purpose use with desalination plants, are all interesting future solutions. Again, such concepts support renewable energy goals and help to reduce dependency on fossil fuels. Hybrids typically mean that environmental impacts and infrastructure costs are reduced. New opportunities to participate in power trading and the balancing energy market are also opened up.

Given their advantages, more than 100 pumped storage projects are currently in the pipeline worldwide, either in planning or under construction. By 2030, the total installed pumped storage capacity could be increased by about 50% up to 240 GW. However, achieving development at this scale requires the right policy settings and market rules.

# Securing a clean energy future with ANDRITZ' top-tier technology

For more than 90 years, ANDRITZ has pioneered pumped storage technology and served as a reliable partner for pumped storage projects all around the world.

**ANDRITZ AND HYDRO**

International technology group ANDRITZ offers a broad portfolio of innovative plant, equipment, systems and services for the pulp and paper industry, the hydropower sector, the metals industry, pumps, solid/liquid separation and other industries. Today, the publicly listed group has more than 29,000 employees and more than 280 locations in over 40 countries.

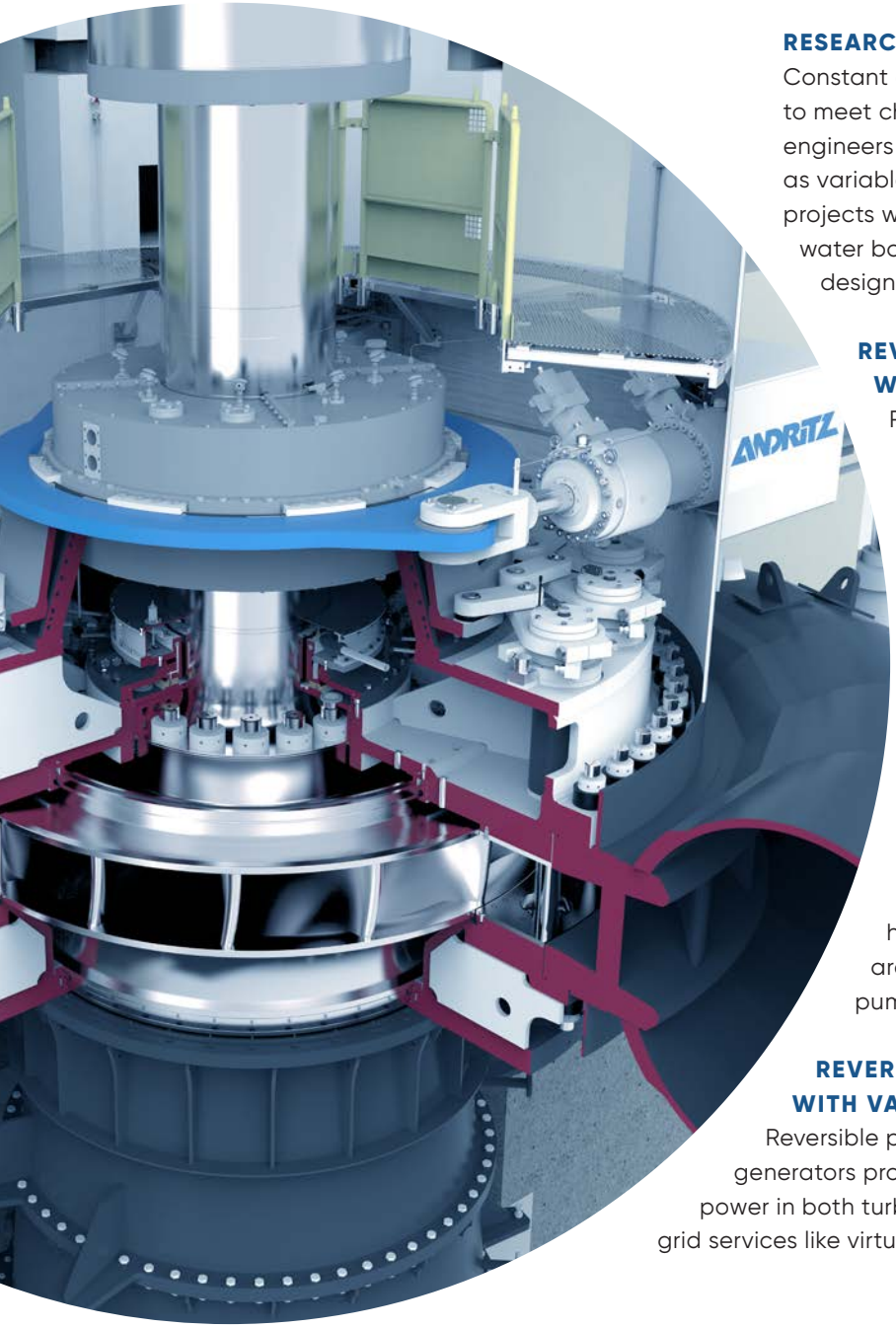
ANDRITZ Hydro is one of the globally leading suppliers of electro-mechanical equipment and services for hydropower plants. With over 175 years of experience and an installed fleet of more than 430 GW output, we provide complete solutions for hydropower plants of all sizes as well as services for plant diagnosis, refurbishment, modernization and upgrade of existing hydropower assets.

To date ANDRITZ has delivered more than 550 pumped storage units with a total installed capacity of almost 40,000 MW.

## TECHNOLOGY KNOW-HOW

At its heart pumped storage power plant technology sees water pumped to a higher elevation reservoir when there is a surplus of electricity. This water is then released into lower elevation reservoirs to generate electricity when needed. There are three basic designs of pumped storage technology currently available, depending on the services required. Today, the focus is on smooth and stable operation, as well as an extended operational range, dynamic operations and a high degree of reliability and flexibility. This is despite the requirement for rapid load changes between pumping and generating. Improved structural integrity of the units ensures a long service life.

**Since supplying the world's first commercial pumped storage plant in Germany in 1929, ANDRITZ has continued to provide ground-breaking technology to the hydropower industry.**




## RESEARCH AND DEVELOPMENT

Constant evaluation and development is necessary to meet changing customer requirements. ANDRITZ engineers are permanently refining technologies such as variable-speed units and closed-loop systems – projects without a continuous connection to a natural water body outside the hydraulic scheme. Customized designs can also be deployed in special locations.

## REVERSIBLE PUMP TURBINES WITH FIXED SPEED MOTOR-GENERATOR

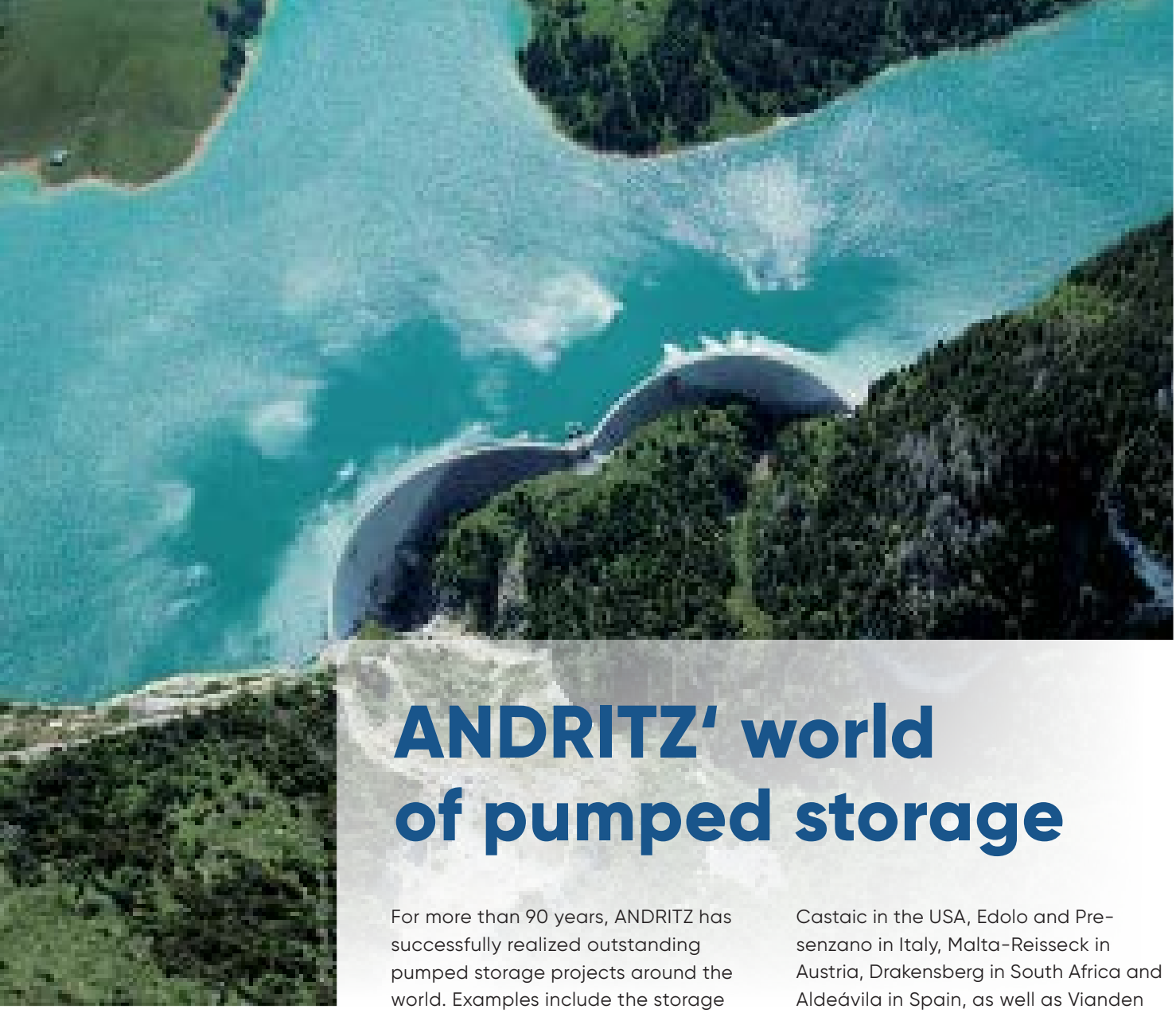
Reversible pump turbines with a fixed speed motor-generator supply full flexibility in turbine operation. Pump operation is restricted to on or off. Operating a set of pump turbines in parallel (usually 4-6 units) allows more flexibility in pump mode by adjusting the discharge rate and power in discrete steps.

## TERNARY SETS

Ternary sets with a separate pump and turbine and with a fixed speed motor-generator provide full flexibility in both turbine and pump mode. Ternary sets are suitable for very fast (within a few seconds) switching between modes. With an optional hydraulic short-circuit, these types of units are able to adjust discharge and power in both pump and turbine mode.

## REVERSIBLE PUMP TURBINES WITH VARIABLE-SPEED MOTOR-GENERATOR

Reversible pump turbines with variable-speed motor-generators provide infinitely adjustable discharge and power in both turbine and pump operation, plus enhanced grid services like virtual inertia.



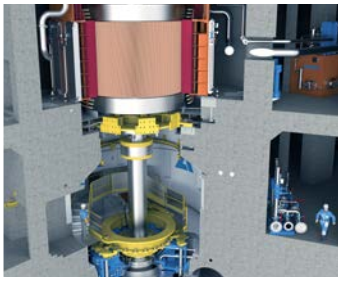
# ANDRITZ' world of pumped storage

For more than 90 years, ANDRITZ has successfully realized outstanding pumped storage projects around the world. Examples include the storage pumps of Provvidenza Italy, 1949, and Limberg Austria, 1954, the world's largest at the time of the contract award. Germany's largest pumped storage plant, Goldisthal, was the first variable-speed pumped storage plant outside Japan. Major ANDRITZ reference projects also include Tianhuangping and Tongbai in China, Northfield, Muddy Run and Castaic in the USA, Edolo and Presenzano in Italy, Malta-Reisseck in Austria, Drakensberg in South Africa and Aldeávila in Spain, as well as Vianden in Luxembourg – the largest pumped storage plant in Europe to date. For Lower Olt in Romania ANDRITZ also supplied the largest low head Bulb-type pumped generating units in the world. It is a vast reference list that demonstrates ANDRITZ' long held expertise and experience in the field of pumped storage power.

**Langenprozelten / Germany - 2014, 2016**
2 x 94 MVA
Most powerful single-phase hydropower motor-generator powering the German railroad

**La Coche France - 2016**
520 MW
Expansion; supply of a 240 MW Pelton unit, the most powerful in the country

**Gouvães Portugal - 2016**
4 x 220 MW
Hydro- and electro-mechanical equipment for the largest hydropower complex in Portugal



**FengNing II China - 2018**
3,660 MW
Two 330 MVA variable-speed pump turbine units for the worlds largest pumped storage plant

Hatta Concept

## POWER FROM THE DESERT - HATTA / UAE

As part of a clean energy development program, a unique concept to build a pumped storage power plant in the desert was developed. About 140 km southeast of Dubai in the Hajar Mountains, an existing reservoir created by the Sadd Hatta Al Awwal Dam will be used to balance other renewable power generation. The concept foresees the creation of a new upper reservoir connected to the existing one through a 1,300 m-long and 7 m-wide tunnel. With a capacity of approximately 200m$^3$/s and partially lined with steel, this tunnel is a key feature of the new Hatta Pumped Storage Power Plant.

The final concept is based on a shaft-type powerhouse with two 125 MW pump turbine and motor-generator units. Capable of providing a total net power of 250 MW over a six-hour generation cycle in turbine mode and a 7.4-hour storage cycle in pumping mode, the project provides an overall storage capacity of some 1,500 MWh.

**Abdelmoumen**
**Morocco - 2018**
2 x 175 MW
Electro- and hydro-mechanical equipment, including two pump turbines for existing dam

**Malta**
**Oberstufe - 2020**
2 x 80 MW
Modernization of two high-performance variable-speed turbines for peak load

**John W. Keys III, Grand Coulee**
**USA - 2020**
6,809 MW
Automation and turbine rehabilitation for the largest hydropower facility in the USA


Electro-mechanical equipment for the largest pumped storage plant in the country; first integrated renewable energy storage project combining photovoltaic solar, wind, and pumped storage.

iha | gold member
advancing sustainable hydropower

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