



CONVERTER SYSTEM SOLUTIONS FOR PUMPED STORAGE HYDROELECTRIC POWER STATIONS

GE Vernova's Power Conversion business designs energy conversion systems that provide tailor-made solutions for mission-critical applications.

Power Conversion provides customized solutions for reliable applications

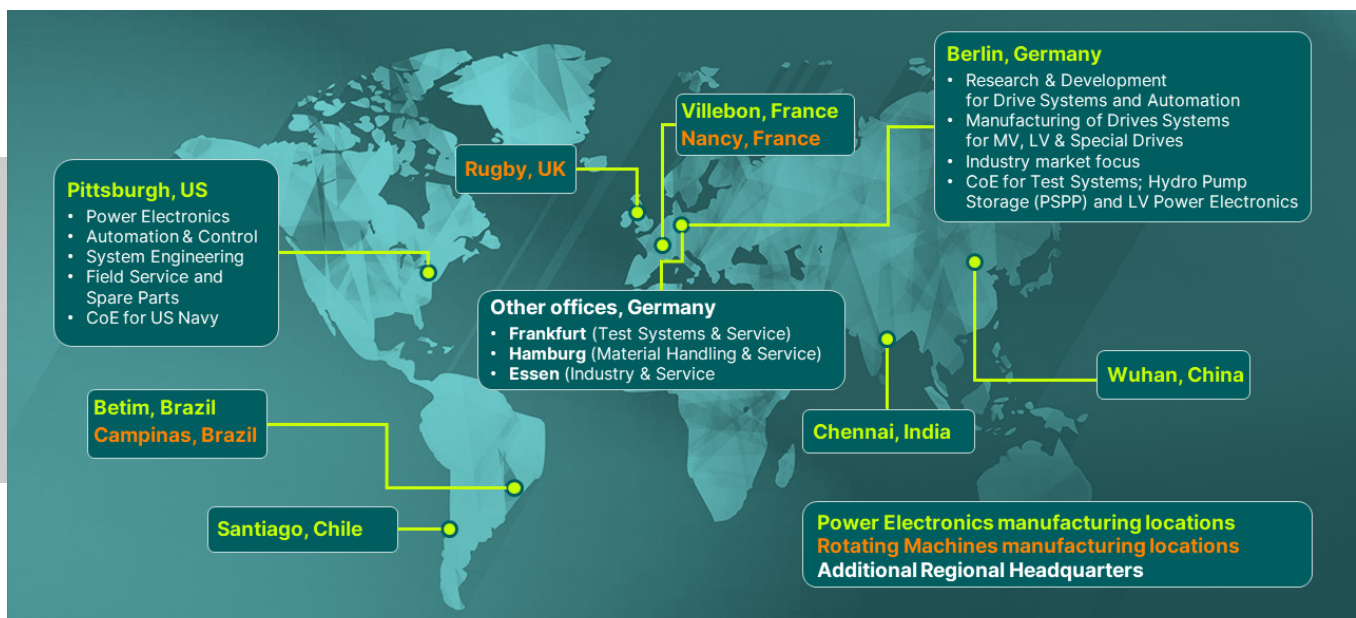
Power Conversion's pumped storage power plant (PSPP) portfolio includes variable speed drive solutions such as AC-excitation systems with 3kV and 6kV converter drives, fully-fed applications, fixed speed solutions with start-up equipment as well as DC-excitation systems.

We offer all power conversion and grid integration equipment for large hydropower plants, such as pumped storage, river and tidal applications, from planning and optimization to manufacturing, installation and commissioning, and lifelong services and consultancy.

Power Conversion - a global partner with a local footprint

Our regional presence with key facilities and the right partners allows us to support your hydro business worldwide.

All regions are directly connected to our Center of Excellence (CoE) for hydro pump storage in Berlin, Germany, where we bundle competencies and use our knowledge to focus on the best solutions for our customers. Due to regional manufacturing, engineering and service facilities in the US and Europe we can deliver tailor-made solutions with high domestic content.



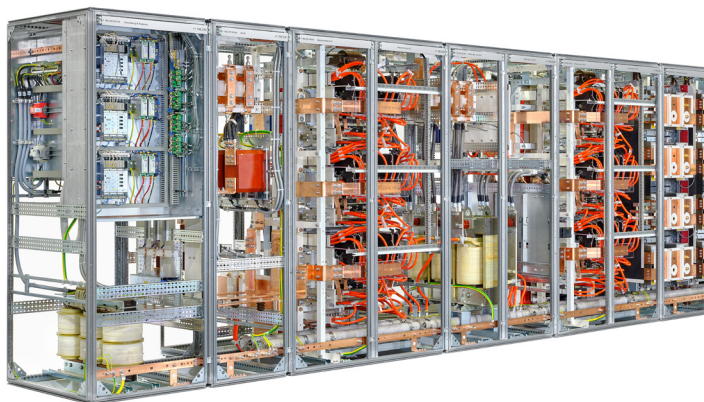
Power Conversion's hydro power capabilities, key products and system solutions

Our hydro power capabilities support electrifying pumped storage and run-off river power plants.

Power Conversion's Variable Speed Drive System (VSDD) can increase productivity in a pumped storage power plant.

Our technology

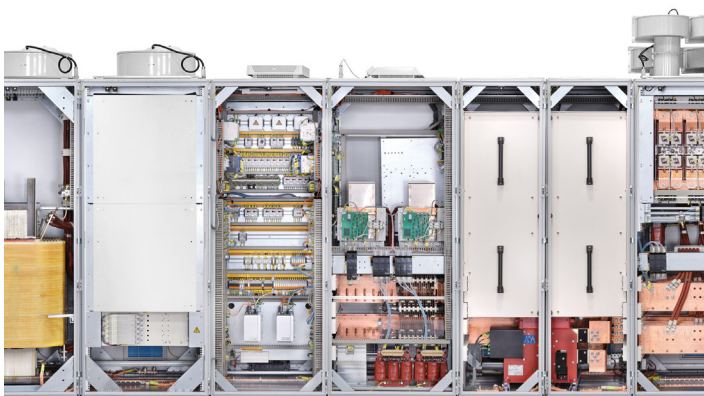
- Our Voltage Source Inverter (VSI) technology enables PSPP to significantly expand their capabilities
- Innovative AC-excitation technology is based on a powerful, robust, and flexible solution of high-end VSDD
- Our Static Frequency Converters (SFC) start-up the units sequentially in pump mode and launch them to the grid within a few minutes



Variable speed AC-excitation



Fixed speed start-up converter & DC-excitation



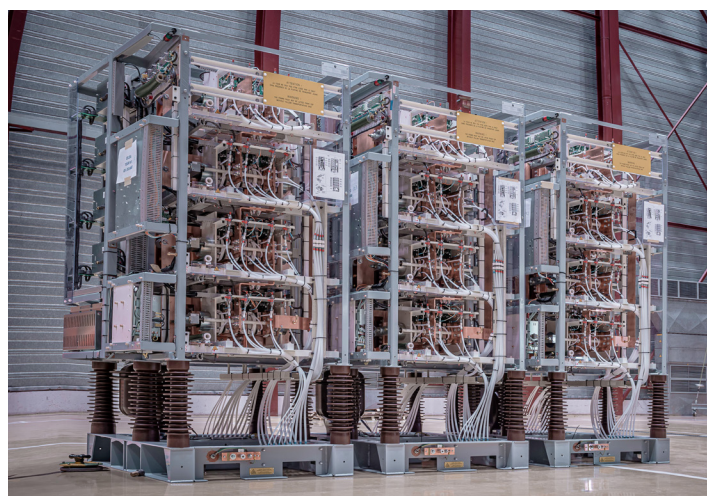
Run-off river DC-excitation



Synchronous condenser - frequency converter



Variable speed full size MV7



Variable speed full size MM7

Our electrical solutions for different pumped storage power applications

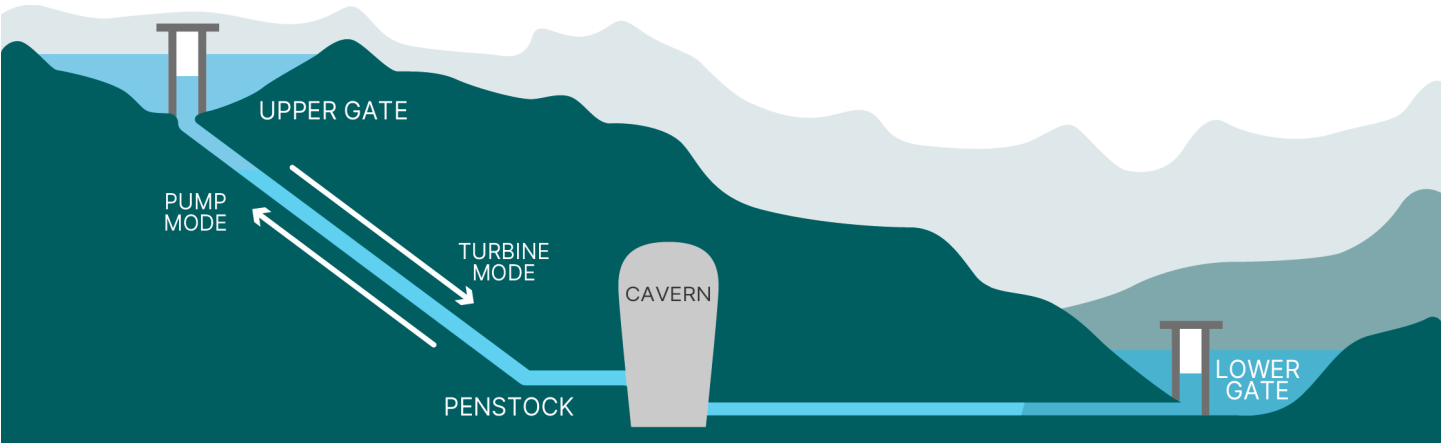
Power Conversion offers integrated solutions for conventional fixed speed, as well as variable speed doubly-fed (as 3kV or 6kV converter technology) or fully-fed systems, helping to minimize cost, maximize energy output and provide optimal grid support.

Each pump storage project is unique

With our full range of water to wire solutions, we help you to optimize your grid performance, reduce system and operating cost, enhance energy output and lower overall project risk by benefiting from our enterprise synergies.

We use leading technology based on standardized components as building blocks for power generation, conversion and grid connection.

Fixed speed (LCI or VSI)	Variable speed AC-excitation (VSI)	Variable speed fully-fed (VSI)	Variable speed fully-fed (direct MM7)	Variable speed fully-fed (indirect MM7)
<ul style="list-style-type: none">• Simple topology• Start-up converter is required	<ul style="list-style-type: none">• 4Q operation (with phase reversal switch)• Self-start possible• Highly suitable for high power pump generator• Small converter footprint• Highest overall efficiency among other variable speed topologies	<ul style="list-style-type: none">• Fully reversible 4Q operation• Suitable for new or revamp with smaller generator power rating, approx. < 80MVA• Bypass operation possible	<ul style="list-style-type: none">• Fully reversible 4Q operation• Improved efficiency compared to VSI technology• Optimized cost and footprint, compared with indirect MM7	<ul style="list-style-type: none">• Fully reversible 4Q operation• Suitable for revamp project, it may be possible to use existing generator• Bypass operation possible



Extensive expertise in variable speed projects for hydro

With our variable speed drive technology, pumped storage plant operators are better able to meet the need for peak supplies of power while in turbine mode. Also, the plant achieves higher efficiency levels in partial-load conditions because the machine speed can be adjusted to meet the grid's changing power requirements while maintaining the turbine close to its highest efficiency point. At last operators have greater control over the plant's performance in pump mode, by being able to control the power consumed from the grid while refilling the upper reservoir.

However, in order to react to changing wind and solar power conditions that can undermine grid reliability, pumped storage power plants need to have greater flexibility and shorter response time. Reversible pump turbines with variable speed motor-generator provide adjustable discharge and power in both turbine and pump operation, plus enhanced grid services like virtual inertia.

Project reference	Rated machine power
AC-excitation	
PSPP Goldisthal	2*306MW
PSPP Linthal 2015	4*255MW
PSPP Nant de Drance	6*158MW
PSPP Frades II	2*400MW, 6kV
PSPP Tehri	4*285MW
PSPP Fengning II	2*330MW, 6kV
PSPP Limberg III	2*240MW
PSPP Ebensee	1*198MVA
Fully-fed	
Limberg I / Kaprun	2*85MVA, 6kV
ReiBeck 2+	1*50MVA, 6kV
Chira-Soria	6*44MVA, MM7

Voice of our customers

With our expertise and extensive know-how with large scale PSPP projects, we are able to support our customers with customized solutions that help minimize costs while maximizing output.



EDP

"GE's converters are in continuous operations since the end of commissioning in April 2017"

KRAFTWERK LINTH LIMMERN AG

"GE's VarSpeed PSP converters are in continuous operations to our complete satisfaction since the end of commissioning in 2017"

VATTENFALL

"GE's VarSpeed PSP converters are in continuous operations to our complete satisfaction since end of commissioning in June 2004 - at this time for 195,893 hours already"

VERBUND HYDRO

"GE's converters for the 1st modernized VarSpeed are in operations since August 2021. Performance and local support are to our complete satisfaction"

3.5 GW / 5.9 GW
INSTALLED POWER
in operation / under contract

>100
installed **CONVERTER UNITS**

>200k
OPERATION HOURS

Power Conversion's technology for variable PSPP applications

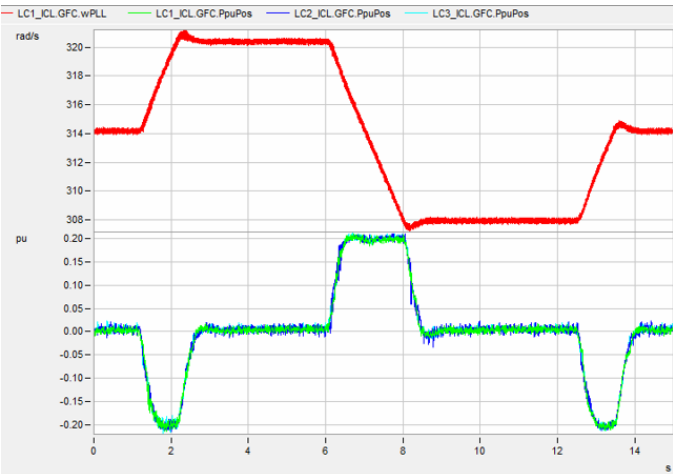
The heart of Power Conversion's converter systems are press-pack IGBTs.

Power Conversion uses rugged, robust press-pack IGBT technology, which is superior to standard grade IGBT technology. Press-pack IGBT yields better surge current rating, improved thermal cycling and longest lifetime. Press pack IGBTs do not use failure prone bond wires.

Power Conversion's control technology supports different algorithms for line side control, as well as various operation modes that are required by grid operators around the world. If required, Power Conversion offers support for grid approvals with HIL simulators.

	Grid-following (GFL)	Grid-forming (GFM)
Voltage source behind an impedance	No	Yes
Voltage and frequency stabilizing	Yes*	Yes**
Black start and island	No	Yes
Sink for harmonics and asymmetry	No	Yes
LVRT/HVRT capability	Yes	Yes
Virtual inertia (dynamic grid support)	No	Yes

*) Only steady state
**) Transient and steady state



Example of GFM response to 1Hz/s roof

Available operation modes

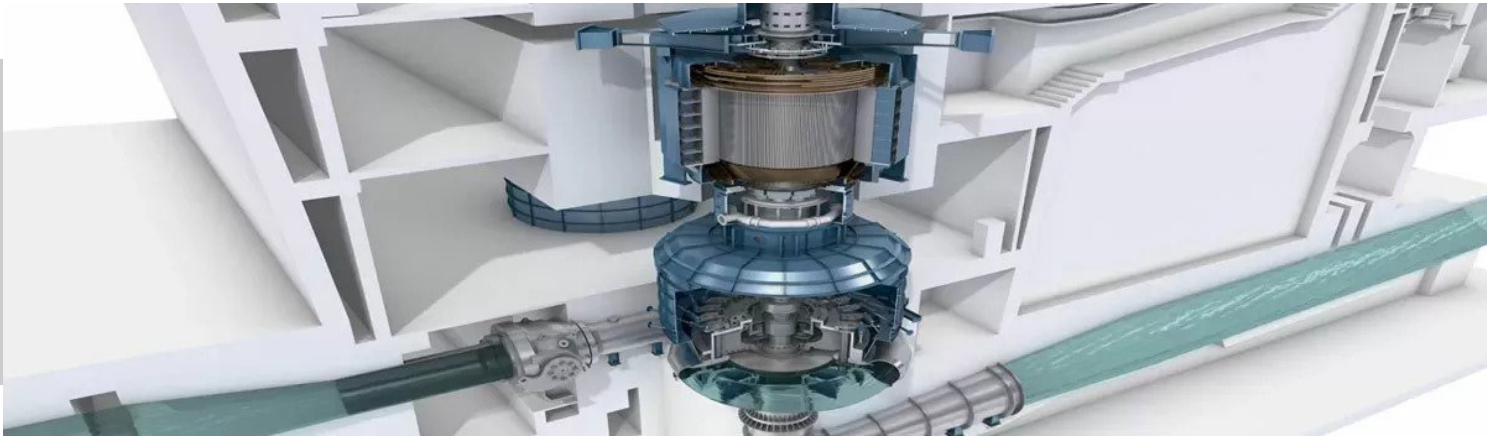
- Variable speed in turbine mode
- Variable speed in pump mode
- Braking mode
- Statcom operation
- Black start
- Island mode
- LVRT/HVRT capability
- Virtual inertia (dynamic grid support)

Support for grid model and approvals

- Support grid approval with hardware in loop simulator (HIL)
- RMS models DIG silent power factory & PSSE
- Transient models MATLAB & PSCAD
- Model validation with HIL

Power Conversion builds customized solutions to meet your specific space requirements

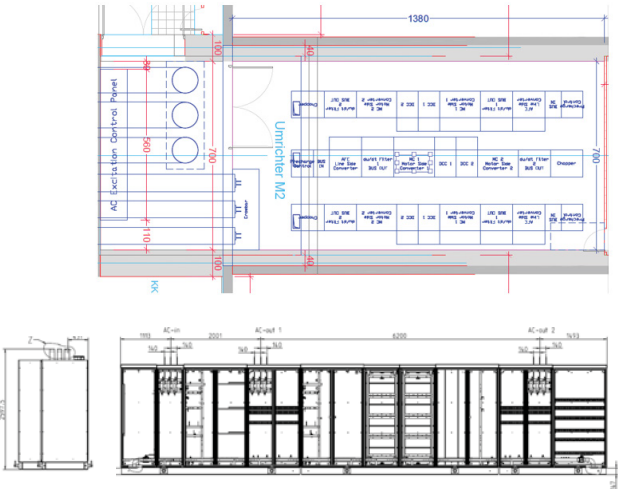
Examples for possible arrangements for each kind of topology which reflected pumped storage power plants with variable speed approach. Needed space inside the power plant is strictly connected to the specific requirements on our equipment and design of the machine set. Power Conversion is investigating and checking all relevant data to provide the best solution to fit in the appropriate rooms for green field and brown field projects.



Example for AC-excitation system

Three converters in parallel

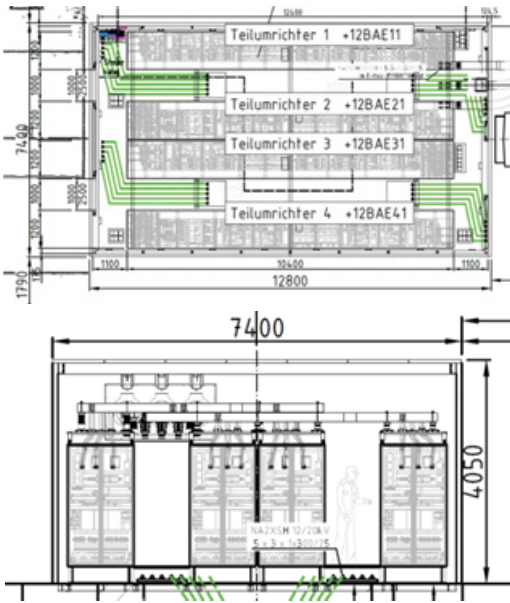
Parameter	Value
Converters per unit	3
Apparent power	48MVA
Speed range	450-550/min.
Rated excitation current	8800A
Rated excitation voltage	3,3kV
Dimensions converter room (w*h*d in mm)	12.800*4.000*7.000mm



Example for fully-fed converter system

6,6kV MV7 drives with four converters in parallel

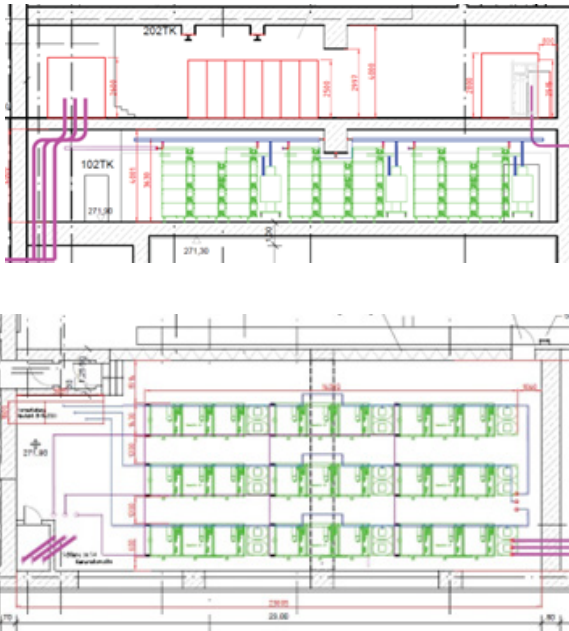
Parameter	Value
Converters per unit	4
Apparent power	80MVA
Speed range turbine mode	450-775rpm
Speed range pump mode	540-830rpm
Rated current	7000A
Rated voltage	6.6kV
Dimensions converter room (w*h*d in mm)	2.800*4.050*400mm



Example for fully-fed converter system

MMC/MM7 drives

Parameter	Value
Number of units	1
Apparent power	56MVA
Rated current	7000A
Rated voltage	16kV
Dimensions converter room (w*h*d in mm)	23.000*4.000*9.200mm



Multiple reasons for investing in PSPP

When investing in a pumped storage power plant, decision-makers identify and define the main requirements the plant has to fulfill. Reasons may vary, for example with the main drivers being to produce power from water as a renewable energy source, to balance the grid or to build a large-scale energy storage system to help manage the power grid and security of supply. Investors and decision-makers need to identify the best technology suitable to meet the project's specific purpose.

Power Conversion's references

PSPP Goldisthal (Germany)

The PSPP Goldisthal is located in Thüringen (in the east-southern region of Germany) and has a capacity of 1060MW. The project has begun in 1997 and produced energy since 2003. There are two variable speed machine sets with AC-excitation and asynchronous machine and two fixed speed machine sets with start-up frequency converter and synchronous machines.

Goldisthal is one of the first pumped storage power plants where the decision was taken to use the variable speed technology to improve operation behaviors and increase the advantages in regard of efficiency in full load and especially the significant improvement in part load operation.

Power Conversion's scope includes:

- Two 100MVA converters for the variable speed asynchronous machines
- Two SFCs with 18kV / 40MW for starting up all machines
- Two static excitation equipment (SEE) units for the synchronous machines

PSPP Linthal (Switzerland)

The PSPP Linthal was commissioned and handed over to operator AXPO in 2016 and is producing energy since then. The 1000MW PSPP is one of the most advanced hydroelectric power plants in the world.

It is equipped with four rotating machines of 250MW each, where the decision was taken to use the variable speed technology to improve operation behaviors and increase the advantages in regard of efficiency in full load and especially the significant improvement in part load operation.

For more information about our solutions, contact us:
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governova.com/power-conversion

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Our advantages

- Proven technology & decades of experiences in power electronics
- Wide range of systems architecture tailored to projects specifics
- Grid code compliance simulation / grid forming control
- Integrated solution with mechanical OEM
- Numerous references of large pump storage system, including largest projects in Europe
- Centralized expert team in Germany (Center of Excellence)
- Global partner with strong regional presence
- Strong presence in North America (local facility with manufacturing, engineering and service)

Power Conversion's scope includes:

- Four 48/48MVA converters for the variable speed asynchronous machines
- Four excitation transformers 18/3.0kV; 28MVA
- Control excitation equipment to start-up the machine and synchronize the units to the grid
- Overvoltage control protection (crowbar) for rotor of the machine
- Low voltage ride through (LVRT) ability according to Swiss grid code

PSPP Kaprun / Oberstufe Limberg I (Austria)

The PSPP Kaprun Oberstufe was originally commissioned 1955-1956 with two horizontal machines sets consisting of Francis turbine, motor-generator and a two-stage radial pump. The overall installed power of this power plant was 112MW.

In 2018 the modernisation started. To increase the efficiency and adapt on the new requirements of the energy market, the Verbund decided to modernize the existing pumped storage station Kaprun Oberstufe. In 2017 the tendering process for both machine groups started. They shall be equipped as a variable speed application with fully fed technology consists of pump turbine, motor-generator as synchronous machine and frequency converter. The converter is located between synchronous machine and main step-up transformer and is feeding the energy to the grid in turbine mode. Since mid of 2021 the first machine group is now producing energy and one year later mid of 2022 the second machine group is connected to grid as well.

Power Conversion's scope includes:

- Four 6,6kV converters in sum 80MVA for the variable speed synchronous machines
- Main step-up transformers 110/6,4kV; 85MVA
- Control excitation equipment to start-up the machine and synchronize the units to the grid
- SEE units for the synchronous machines
- Overvoltage control protection
- Low voltage ride through (LVRT) ability according to Austrian grid code



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