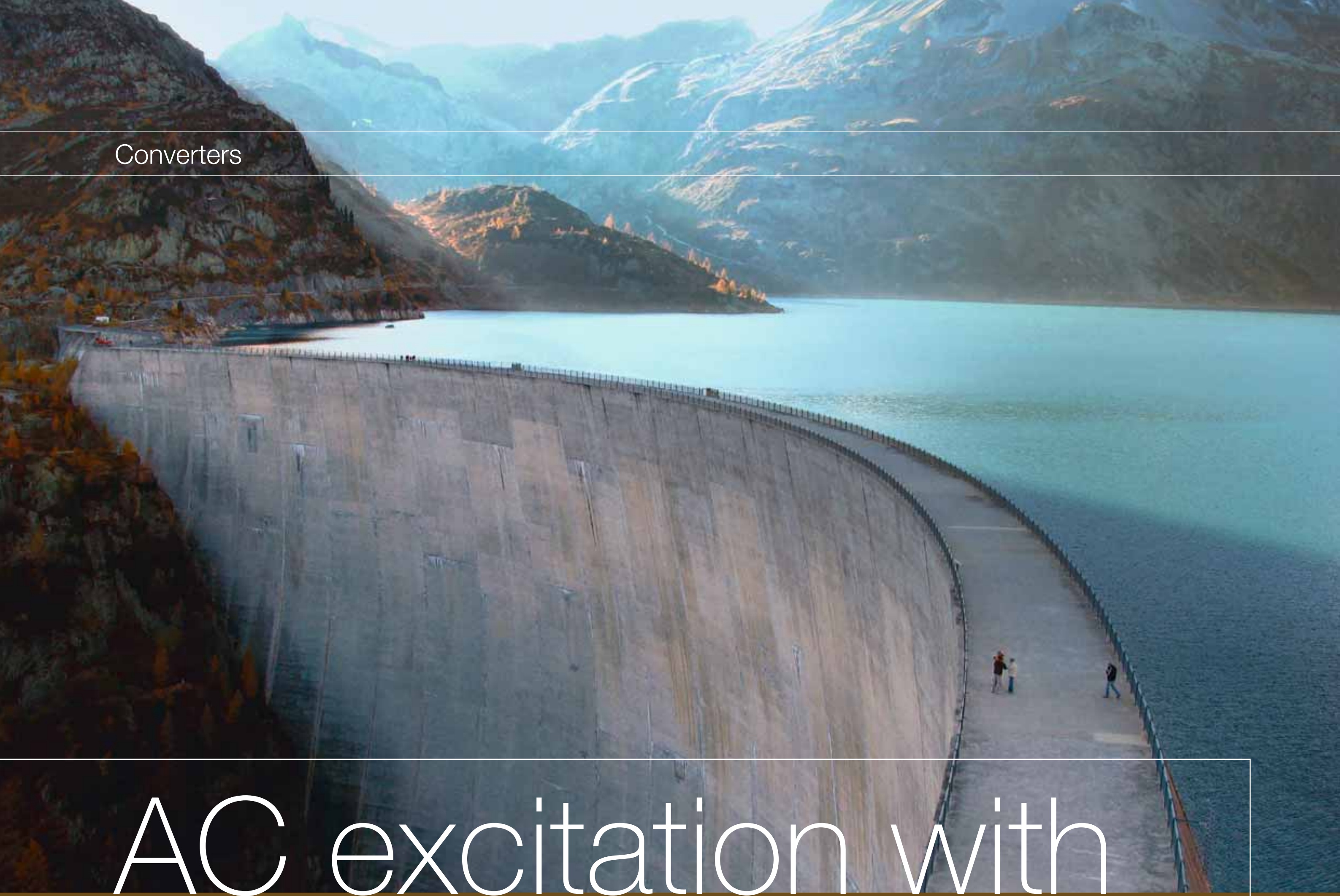


AC excitation with ANPC

ANPC converter technology tailored to the needs of AC excitation equipment for pump storage plants

Andreas Hämmerli, Bjørn Ødegård

The PCS8000 converter platform is a new modular converter system based on ANPC (active neutral point clamped) converter topology. Combined with a new generation of integrated gate-commutated thyristor (IGCT) power semiconductors, this new technology has increased the unit output power compared to the types presently in use. Additionally a superior DC current capability is achieved, thus providing additional advantages where DC current or low-frequency AC current is required.

The latter is the case in AC excitation equipment of Varspeed Systems, which are increasingly being used in modern pump storage power plants. Currently such an installation using the new PCS8000 converter platform is under construction for the Pump Storage Power Plant Avče of Soške Elektrarne Nova Gorica in Slovenia.

During the last 10 years, the IGCT power semiconductor has found widespread use in medium-voltage high-power applications in the industry and utility market. In most of these applications, the IGCT serves as the main switch in a three-level voltage source converter (3L-VSC). As the name suggests, the output voltage of the converter can be generated by means of the appropriate combination of three voltage levels as shown in 1. The converter has become popular in high-power applications as a high output voltage is obtained without direct serial connection of semiconductor devices and the relatively low output ripple current compared to a two level converter.

The three-level converter is also called the neutral point clamped (NPC) converter. This name comes from the two diodes connected in anti-parallel that are used to "clamp" the output voltage to the neutral point of the DC circuit when the zero-voltage level is required. The output current direction determines whether the neutral point current flows through the upper or the lower current path shown in 2.

ANPC converter technology

By adding two additional switches in the neutral point connection, an interesting alternative to the three-level NPC converter has been achieved 3. By means of an appropriate switching strategy of the additional neutral point switches S5 and S6, the output can be "actively" clamped to the neutral point of the DC circuit, with this new feature lending the name to the new converter technology: ANPC (active neutral point clamped) converter.

The flexibility provided by the additional switches S5 and S6 enable an advantageous distribution of conduction and switching losses within the converter. Two main advantages arising from this are:

Current sharing between neutral point current paths

The neutral point current paths of the NPC converter are unidirectional 2. The direction of the load current determines which current path is used. In the case of an ANPC converter, the upper or lower path can be chosen as desired 3. Even in DC operation, the current can be equally shared between the upper and lower path as desired. Half of the time the current is flowing through the upper neutral path and the other half through the lower.

A 33 percent increase in DC current capability is thus achieved compared to NPC technology.

Distribution of switching losses

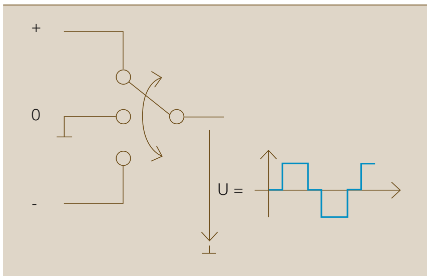
When switching the output back and forth between the positive and neutral point or between negative and neutral point, the devices carrying the switching losses in the NPC converter are determined by the direction of the output current 4. In 4 and 5, the path colored red shows current flow before switching takes place, and the blue color shows current flow after the switching transition. The red semiconductor device is being switched off and hence dissipating the associated switching losses, while the blue device is being switched on.

> The possibility of the ANPC converter to choose which neutral point current path should conduct the output current enables an advantageous distribution of switching losses within the converter.

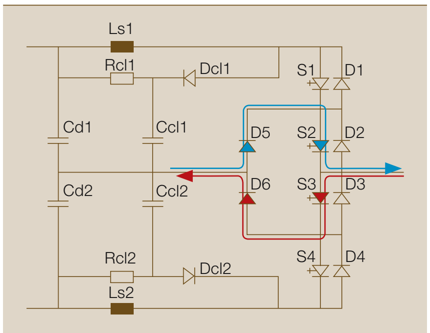
Once more, the possibility of the ANPC converter to choose which neutral point current path should conduct the output current enables an advantageous distribution of switching losses within the converter. 5 shows S1 dissipating switching losses when switching onto the upper neutral point current path whereas S2 dissipates switching losses when the lower current path is selected. Similar sharing of loss dissipation can also be shown for the other switching transitions of the switching scheme.

This effect contributes to a substantial increase in output power both in rec-

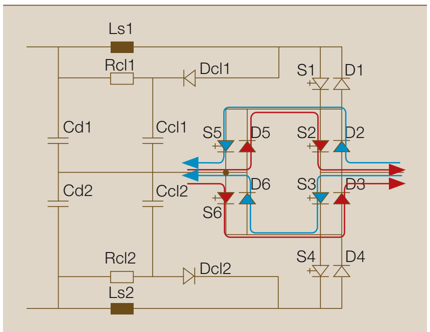
1 A three-level voltage source converter



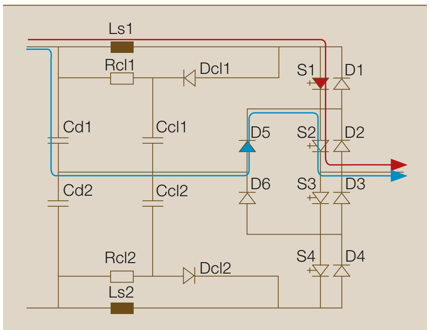
2 A neutral point clamped voltage source converter with unidirectional current paths between the phase output and neutral point



3 Active neutral point clamped voltage source converter with bidirectional current path between phase output and neutral point



4 NPC converter: S1 only can dissipate switching losses when switching from positive to neutral.



tifier and inverter operation compared to the NPC technology.

PCS8000 converter module

Based on the ANPC converter technology, a new ANPC PEBB (power electronic building block) has been developed. It comprises two phase legs as shown in 6, and is suitable for use in an H-bridge configuration. This new PEBB also features new IGCT semiconductor devices with increased turn-off capability and a du/dt snubber network for further increase of turn-off capability and reduction of switching losses.

The ANPC PEBB is integrated into the PCS8000 Power Module with ratings as follows:

Output voltage:	Un	= 3,600 VACrms
Output current:	In	= 2,600 AACrms
DC current capability:	Idc	= 2,750 A DC

7 shows an example of a PCS8000 static frequency converter comprising two PCS8000 power modules in the rectifier section (on the left), and three PCS8000 power modules in the inverter section (on the right). A very low inductance laminated DC bus bar can be seen behind the power modules. This connects the power modules to the intermediate DC link capacitor bank at the rear bottom of the converter frame.

Pump storage power plants for optimum coverage of peak power needs have an important role in public grids around the world.

Pump storage power plants

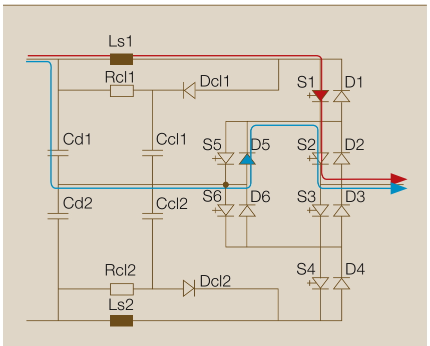
Pump storage power plants for optimum coverage of peak power needs have an important role in public grids around the world. Such plants not only feed hydropower into the electrical grid, but also pump water back into the reservoir, thus increasing the power availability for peak hours. A characteristic of such a system is that the speed at which the greatest pumping efficiency is obtained is greater in pumping mode than it is in generating mode. The optimum speed also varies with the load.

In systems with Francis turbines, Varspeed systems are increasingly being used to achieve the maximum efficiency throughout the operating range. As the name indicates, these systems are able to adjust the turbine speed within a limited range, thus enabling operation at maximum turbine efficiency independent of the load condition and operating mode. Induction machines with wound rotors are used instead of synchronous machines.

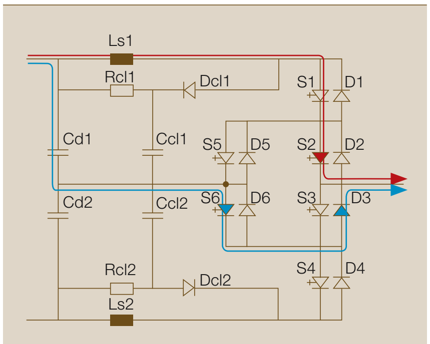
As a consequence, the rotor speed deviates from the synchronous speed given by the public grid frequency. This is made possible by means of the excitation equipment of the drive system, which is able to supply not only DC currents but also low frequency AC current (0 to ~5 Hz) to the rotor windings of the pump motor. Thus the rotor speed is not strictly tied to the frequency of the public grid, but can be controlled within the required lim-

5 ANPC converter: S1 or S2 can dissipate switching losses when switching from positive to neutral.

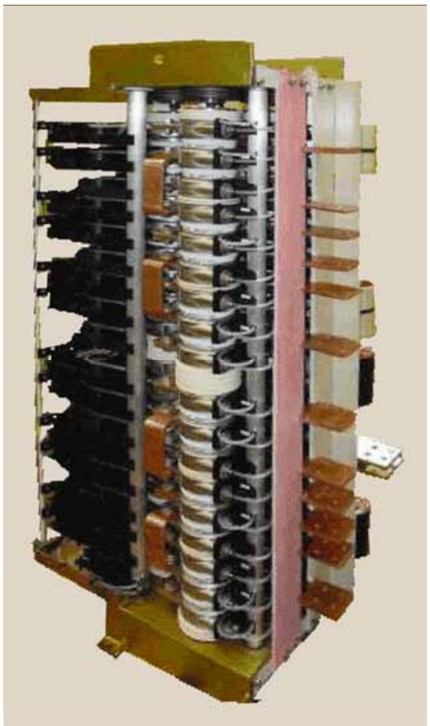
a S1 is switching off – output current flows through the upper neutral point path.



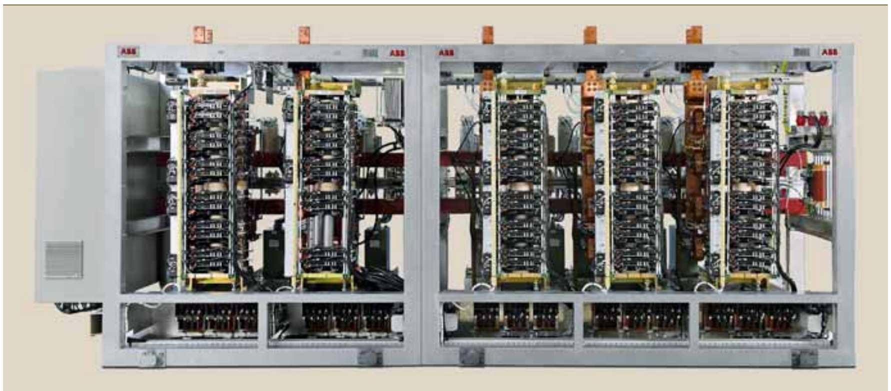
b S2 is switching off – output current flows through the lower neutral point path.



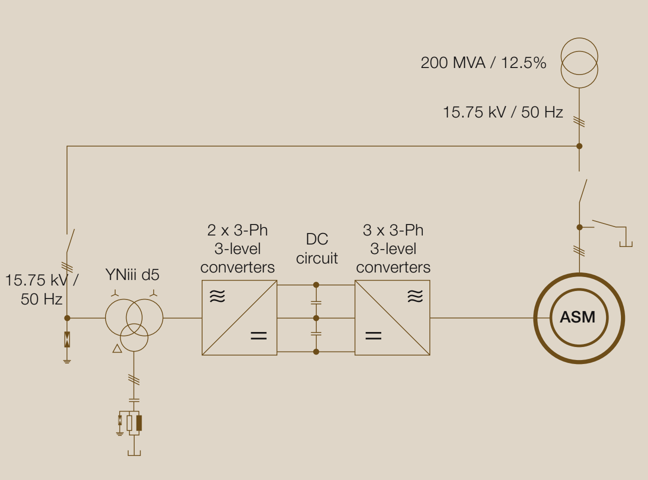
6 The ANPC PEBB is suitable for use in an H-bridge configuration.



7 A frequency converter built from five PCS8000 power modules



8 Single line diagram of a Varspeed Drive System with PCS8000 AC excitation system



Factbox Operational modes controlled by the PCS 8000 AC excitation system

Generator mode	Feeding electrical power to the 110kV Grid ■ Synchronisation with the grid (voltage, frequency) ■ Control of the reactive power
Pump mode	The plant pumps water from the river Soške to the upper reservoir which is located 500m above the plant ■ Soft start without load ■ Speed control in pump mode
Reactive power	Supply or absorption of reactive power, this mode does not require water

Additionally, the AC excitation system provides important functions to assure safe operation:
- Protection against rotor overvoltage in case of failures in the grid
- Protection against rotor overcurrents
- Protection against overtemperature of the windings

Additional functions are provided to protect the various modules of the system, the cooling and also to act as a watchdog of the control system itself.

ited speed range around the synchronous speed imposed by the grid frequency.

Additionally, the system has power/frequency control capability both in pump and turbine operation mode – providing incremental service business opportunities with transmission system operators. Conventionally pumped hydro storage plants can do this in turbine mode only.

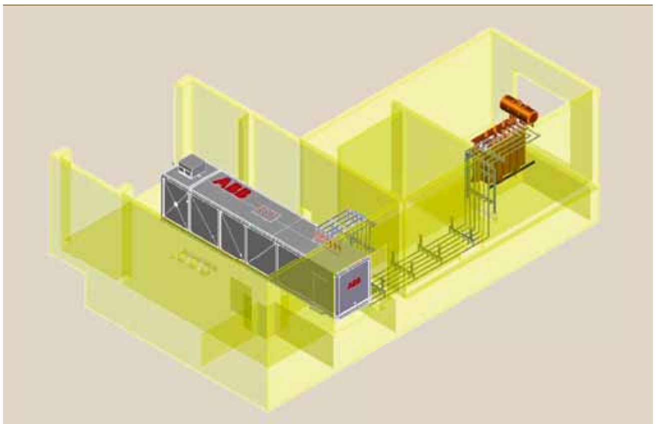
A single line diagram of such an excitation system is shown in 8. In this example the static frequency converter is connected to the rotor winding via slip rings.

The rotor speed is not strictly tied to the frequency of the public grid, but can be controlled within the required limited speed range.

The pump storage power plant Avče of Soške Elektrarne Nova Gorica in Slovenia, which is currently under construction, is an example of such an application using a PCS8000 AC excitation system.

The plant, which was designed for a power of around 180MVA, is being interconnected to a relatively weak 110 kV grid. It is a requirement that the new plant may not affect the voltage and frequency stability of the grid. Thus a modern double-fed asynchronous machine with variable speed will be installed and an ABB PCS 8000 converter will feed the power to its rotor Factbox.

9 3-D model showing the complete installation with an 11.6 MVA transformer, a container comprising converter, cooling unit and auxiliary systems.



AC excitation system for Avče

The AC excitation system is powered by an 11.6 MVA transformer fed from the 110 kV-Grid. The static converter consists of a rectifier and an inverter connected by the DC-link 9.

The static converter is located entirely in a container together with its control panel, the online control system as well as the powerful cooling system for the semiconductors. This modular structure shortens the assembly time, installation as well as commissioning as all functions can be checked and preset in the factory.

For more on ABB's IGCT product offerings, see "A tiny dot can change the world" on page 15 of this issue of *ABB Review*.

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