SIEMENS

Power Transmission

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HVDC/FACTS - Highlights

Interview on the topic:

Renaissance of a classic – the synchronous condenser

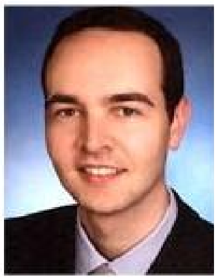
Over the past few decades power electronics have increasingly defined reactive-power compensation in alternating current systems in line with the motto “Fast and efficient.” But with the new trend in power generation towards ever more renewable energy sources feeding into the grid and with the simultaneous shutdown of conventional power plants, the existing network topology has changed. Speed alone is no longer enough. New challenges for stabilizing the networks of the future have led to the rediscovery of a conventional technology – the synchronous condenser. In this interview Volker Hild, Head of Global Sales FACTS, explains the synchronous condenser and the opportunities that arise for power transmission.

Herr Hild, the energy policy is undergoing change and the proportion of renewables in the power generation mix is growing. What does this mean for the transmission network?

Hild: A good way to explain that is to take the example of Germany. The power plants integrated in the network here are predominantly thermal plants with large turbines and generators. In the event of voltage dips these simply carry on running because of their inertia, feeding power into the grid.

The transition to a new energy mix in Germany has resulted in generators with 1000 or 1200 MW capacity being taken off the grid due to the shutdown of power plants, in our case nuclear power plants. However, these generators used to act as a rotating mass to provide stability. Renewable forms of energy cannot do this. Even wind turbines only have a small rotating mass and also switch off very quickly. With a conventional base load this leads to instability in extreme cases. An indicator for network stability is the short-circuit power. The higher this value, the more stable the network, or to put it another way: without short-circuit power no restart after a short-circuit. That’s why it is important to take countermeasures in such a case.

Volker Hild



Background

Since 2012 Volker Hild is Head of Global Sales for Flexible AC Transmission Systems (FACTS) being active in power transmission solutions for more than seven years.

Education

Hild graduated from University of Technology Darmstadt, Germany, in Business Administrations and Electrical Engineering.

Network stability can be adversely affected by changes in the energy mix. What impact does this have on power transmission and the consumer?

Hild: Basically, energy consumption and generation have to be kept in balance. Large fluctuations and reduction of network

stability lead to an increase in undesirable voltage dips.

Generally, consumers are not aware of short-time voltage dips caused by short-circuits. The problem, however, is that the voltage may not increase again automatically. This is where reactive-power compensation comes in. The transmitted power is split into active power and reactive power. Wherever electromagnetic alternating fields are created, reactive power arises, for example in any electric motor.

In other words, I need reactive power but this limits the transport of active power. The reactive power requirement therefore needs to be actively regulated. You can’t do without it entirely but you don’t want too much of it either, rather like the head on a good beer.

The purpose of reactive-power compensation is to provide network stability. What solution approaches are possible here?

Hild: Capacitor banks or electronic reactive-power compensation systems can regulate in the transient range (milliseconds). The window for adjustments of this type is relatively small. It varies between 0.9 and 1.1 pu (per unit), i.e. + / - 10%. This is not enough with low short-circuit power (e.g. due to changing network topologies). For example, a capacitor providing reactive power is discharged within 30 ms. This is where the synchronous condenser solution comes in.

Inertia can be an advantage

“The inertia of a synchronous generator provides network frequency stability and so prevents voltage dips in the network.”

Volker Hild

What is meant by a synchronous condenser solution?

Hild: The main component of this solution is a generator which does not, however, generate any real power but acts as a large rotating mass. If massive voltage dips occur it simply continues running due to its inertia and injects - depending on its size - several hundred MW of short-circuit power into the grid. This makes it possible to restore the network even after major interruptions.

The synchronous condenser is a conventional solution that was already used for regulating reactive power before there were any power electronics compensation systems. Over the past 25 years, the aim has been to completely replace synchronous condensers with highly dynamic, low-loss and low-maintenance power electronics. However, in the course of the global trend towards renewable energies, synchronous condenser solutions have been experiencing a renaissance since 2011. There are systems that are 40 - 50 years old and are still running or are partially replaced.

What prospects and application areas do you see for the synchronous condenser solution on the market?

Hild: I can see a requirement in Europe and North America. Both markets are characterized by growth in renewables while maintaining or reducing thermal power plant capacity.

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The Bjæverskov project in Denmark is a good example of this. Denmark is a pioneer in the integration of renewable wind energy with the familiar consequences. In the cold months of the year, thermal power plants continue to be operated and their waste heat is used for district heating. However, it's expensive for the network operator to pay the power producer to keep the power plant blocks running in the summer months in order to guarantee the short-circuit power needed to ensure network stability. A cheaper solution is to use a synchronous condenser as a replacement which is in the network operator's area of responsibility. Energy market political conditions also play a key role.

Site view of Bjæverskov substation in Denmark

Modular reactive-power compensation system

"We evaluate the technology objectively since Siemens offers the complete power electronics as well as synchronous condensers including generators from its own production."

Volker Hild

If power plants can be used for regulating reactive power, is it then possible to use their generators as synchronous condensers?

Hild: Yes indeed, that is an alternative. A conversion of this kind was implemented in the decommissioned Biblis nuclear power plant in Germany. For this purpose you need a new control system and the turbine train has to be decoupled. If the shaft train is permanently coupled to the turbine train, subsequent separation of the forged shaft is technically extremely challenging and is generally not cost-effective anyway.

Does that mean, Siemens also converts power plants?

Hild: We're the only company to cover the entire energy conversion chain from the generator to the consumer in our portfolio.

Siemens either converts a power plant or we offer the customer the entire range of reactive power compensation, delivering all components including the generators from our own production. We sell total solutions adapted to customers' needs. Our experts provide advice up front, since synchronous condenser technology and reactive-power compensation systems based on power electronics are not mutually interchangeable in every case. There is an overlapping area, and the technologies can be mixed. Power electronics can control the voltage in the millisecond range. On the other hand, the mechanics of the rotating mass compensates for longer voltage dips and frequency fluctuations.

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Synchronous generator in the factory

How does frequency regulation by the synchronous condenser function?

Hild: The generator, which is the main component of the synchronous condenser, is accelerated to network frequency for example by means of a pony motor and connected synchronously to the transmission network with a circuit-breaker and a transformer. This means that the generator with its rotating mass always acts against a variation of network frequency, thereby supports that this remains stable.

It also acts as a reactive-power compensator. If its magnetic field is under-excited, it absorbs reactive power like an inductor, and if it is overexcited it dissipates reactive power like a capacitor.

However, that also means the synchronous condenser, used as a motor, can provide short-circuit power and capacitive reactive power for restoration of the network. In the Black Sea Network Project in Georgia, 3 synchronous condensers were used with a capacity of 60 MVAr each. They ensure the necessary short-circuit power in the three-phase system and in this way support the operation of the HVDC (high voltage, direct current) back-to-back link between Georgia and Turkey.

Synchronous condensers at the Black Sea Network Project in Georgia

What information and technical data play an important role in the design of a synchronous condenser solution?

Hild: Apart from the network frequency and data about the ambient conditions, the most important values for the design of a synchronous condenser are the reactive power requirement and the short-circuit power needed. These basic data aside, the customer's operating philosophy is also crucial for the system configuration. For the design of the system you therefore have the choice between a pony motor or a frequency converter, a conventional excitation system or a brushless excitation system, as well as between various different cooling systems depending on the generator output and the ambient temperature.

What other influencing factors need to be taken into account in the system design?

Hild: The operating conditions must not be underestimated. Let's take the choice of the excitation system. Brushless excitation offers a low-maintenance, robust design and provides support during a generator-related fault. By comparison, the conventional static excitation system scores due to its faster reaction time, smaller space requirement on the generator shaft and better accessibility.

The principle with the cooling system is: "Keep it as simple as possible." Air-cooled systems are not only cost-effective but much easier to handle in terms of installation and maintenance effort compared to water- or hydrogen-cooled systems.

From what you say we can conclude that it's an advantage to consult with the customer when specifying a synchronous condenser solution. What is the expected planning and implementation period?

Hild: We can't speak for the customer with regards to their planning and decision making process, but for drawing up the quotation one should allow about 3 months. After a contract has been awarded, we can reckon on an implementation time of about 2 years. These figures are only approximate values and depend on the scale of the project.

Synchronous condenser solution – individually planned

"The customer's operating philosophy is important for us. We are glad to advise on the best possible 'return on investment'."

Volker Hild

What needs to be considered when analyzing the economic efficiency of investing in this reactive-power compensation system?

Hild: It's not possible to make a generalized statement in reply to your question. The procurement costs of a synchronous condenser solution are not the only factor to be considered in economic analyses. It's also necessary, for example, to take into account space requirements, maintenance efforts and electrical losses at required operating points, and the "no-load losses" of the selected solution. This may then lead to different buying decisions