Dynamic energy storage

Rolf Grünbaum, ABB

SUMMARY

The ever increasing demand for power, and the need of reducing CO_2 emissions at the same time, requires the integration of more renewable power into the system. For intermittent power sources like wind and solar, the challenge is to connect and integrate them without compromising the required reliability, particularly at a low reserve capacity level. This requires viable solutions of electrical energy storage both for distributed and bulk power applications.

DynaPeaQ® is a dynamic energy storage system based on Li-ion batteries combined with SVC Light®. State of the art IGBTs (Insulated Gate Bipolar Transistors) are utilized as switching devices. DynaPeaQ enables dynamic control of active as well as reactive power in power systems, independently of each other. By control of reactive power, grid voltage and stability are maintained with high dynamic response. By control of active power, back-up for intermittent power is enabled, as well as other, related services, such as capacity firming and area frequency control.

SOMMAIRE

La demande sans cesse croissante de puissance, concomitante à la nécessité de réduire les émissions de CO_2 exige l'intégration au système électrique de plus de sources à énergie renouvelable. Pour les sources à production intermittente, comme celles exploitant l'énergie solaire ou l'énergie éolienne, le défi est de les connecter et de les intégrer au système sans compromettre la sûreté de ce dernier, particulièrement à bas niveau de capacité de réserve. Cela requiert des solutions fiables de stockage de l'énergie électrique pour les applications distribuées et de masse.

DynaPeaQ est un système dynamique de stockage d'énergie basé sur des batteries Li-ion combinées avec un SVC Light. Les IGBT (Insulate Gate Bipolar Transistosr) de dernière génération sont utilisées comme composants de commutation. Ce système permet à la fois un contrôle dynamique indépendant des puissances active et réactive du système électrique de puissance. Par le contrôle de la puissance réactive, la tension du réseau et sa stabilité sont maintenues avec une réponse très rapide. Le contrôle de la puissance active permet aussi bien la compensation des puissances intermittentes que la réalisation d'autres services correspondants, comme le maintien de la capacité de production que le contrôle de la fréquence de la zone concernée.

SAMENVATTING

De toenemende vermogenvraag samen met de noodzaak om de CO2-uitstoot te reduceren brengt mee dat steeds meer hernieuwbare energiebronnen in het elektrisch systeem moeten geïntegreerd worden. Het is een uitdaging de intermitterende bronnen, zoals deze op basis van zonne-energie en windenergie, aan te sluiten en te integreren in het elektrisch systeem zonder de veiligheid van dit laatste in het gedrang te brengen, vooral wanneer de reservecapaciteit beperkt is. Dit vergt betrouwbare oplossingen om zowel op kleine als op grote schaal elektrische energie te stockeren.

DynaPeaQ is een dynamisch energieopslagsysteem gebaseerd op Li-ion batterijen gecombineerd met een SVC light. Moderne IGBTs (Insulated Gate Bipolar Transistors) worden gebruikt als schakelcomponenten. Het systeem laat toe in vermogennetten zowel het actief als het reactief vermogen te regelen en dit onafhankelijk van elkaar. Bij het regelen van het reactief vermogen worden de netspanning en de stabiliteit in stand gehouden met een hoge dynamische respons. Het regelen van het actief vermogen maakt het mogelijk het intermitterend productievermogen te compenseren evenals andere ondersteunende diensten te leveren zoals de frequentie-vermogen-regeling in de regelzone.

The integration of dynamic energy storage into transmission and distribution systems has the potential to provide significant benefits to the supply chain. Until now, grids have been characterized by centralized power generation and one directional power flow. Tomorrow's grids will to a higher degree be characterized by centralized and distributed generation, intermittent renewable power generation, and multi-directional power flow where consumers become also producers. The ever increasing demand for power, and the need of reducing CO2 emissions at the same time, requires the integration of more renewable power and more distributed energy supply into the system. A future electric system is needed that can handle those challenges in a sustainable, reliable and economic way.

For intermittent power sources like wind and solar, the challenge is to connect and integrate them without compromising the required grid stability and reliability, particularly at a low reserve capacity level. This requires viable solutions of electrical energy storage both for distributed and bulk power applications. Dynamic energy storage will play a vital role in this field.

DynaPeaQ®

DynaPeaQ is a dynamic energy storage system based on Li-ion battery storage combined with SVC Light®, ABB's STATCOM concept, to be connected to the grid at transmission as well as sub-transmission and distribution levels. State of the art IGBTs (Insulated Gate Bipolar Transistors) are utilized as switching devices. ABB is aiming for industry, distribution and transmission level energy storage applications. Especially the focus is on applications where the combined use of continuous reactive power control and short time active power support is needed.

DynaPeaQ enables dynamic control of active as well as reactive power in a power system, independently of each other. By control of reactive power, grid voltage and stability are controlled with high dynamic response. By control of active power, new services based on dynamic energy storage are introduced, such as:

– black start support of grids;
– first minute emergency power supply until emergency generation is on line;
– provide power to support frequency regulation (primary and secondary frequency support);
– capacity firming for wind/solar generation to generate higher forecasted levels of renewable production (having a stochastic behavior);
– ramping support, to avoid power system disturbance, when renewable generation is quickly dispatched;
– storing power as alternatives to T&D investments for peak load support;
– reducing peak power to gain on tariffs, for instance for fast charging EV (Electric Vehicles) and industrial loads.

With all these benefits, DynaPeaQ is coming out as a qualified enabler of Smart Grid.

DynaPeaQ's ability to store energy is highly scalable. At present, rated power and storing capacity are typically in the range 20 MW during tens of minutes, but up to 50 MW during 60 minutes and beyond is possible. In some perspective, as battery prices go down, applications requiring larger battery storage will become viable, such as multi-hour storing of renewable power during low demand for release into the grid during higher demand.

Basic mechanisms

DynaPeaQ is connected to the grid at the Point of Common Coupling (PCC) through a phase reactor and a power transformer (Fig. 1). Having both capacitors and batteries, it can control both reactive power (Q), as an ordinary SVC Light, as well as active power (P) thanks to the batteries.

SVC Light is based on Voltage Source Converters (VSC) connected in shunt to the grid at transmission as well as sub-transmission and distribution levels. The grid voltage and the VSC current set the apparent power of the VSC, whereas the energy storage requirements decide the battery size. As a consequence, the peak active power of the battery may be smaller than the apparent power of the VSC: for instance, 10 MW battery power for an SVC

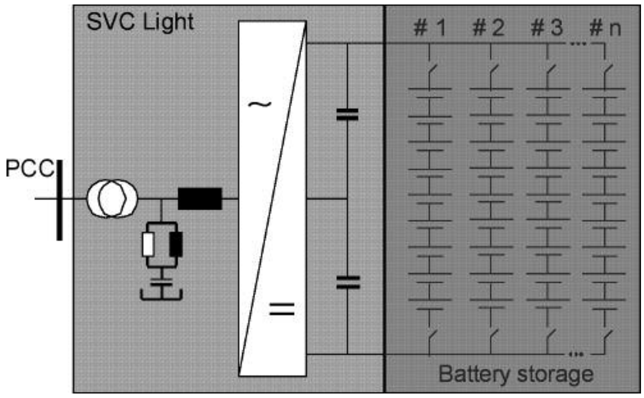

Fig. 1: DynaPeaQ: basic scheme

Fig. 2: VSC valve

Light of ± 30 Mvar. To support the grid during contingencies, as well as for ancillary services, it is enough to have the necessary amount of power available during a relatively short time. An energy storage system can then provide the necessary surplus of active power and after that be recharged from the grid during normal conditions.

The VSC is built up of IGBT and diode semiconductors (Fig. 2). To handle the required valve voltage, the semiconductors are connected in series. Water cooling is utilized for the VSC, giving a compact converter design and high current handling capability. Each IGBT and diode component is built up in a modular housing comprising a number of sub-modules, each containing a number of semiconductor chips (ABB StakPakTM).

Battery system

Since SVC Light is designed for high power applications and series connected IGBTs are used to adapt the voltage

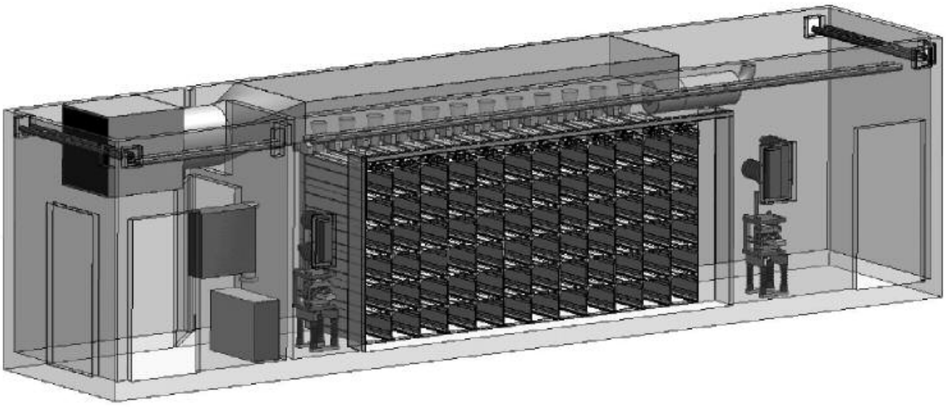

Fig. 3: Battery room

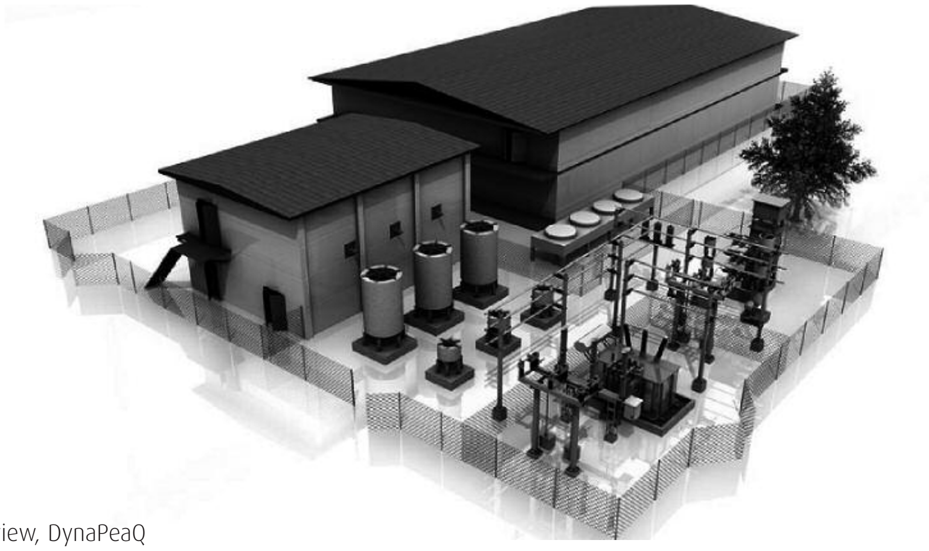

Fig. 4: Artist's view, DynaPeaQ

level, the pole-to-pole voltage is high. Therefore, a number of batteries must be connected in series to build up the required voltage level in a battery string. To obtain higher power and energy, a number of parallel battery strings may be added.

The battery system comprises rack-mounted Li-ion modules. An array of battery modules will provide the necessary rated DC voltage as well as storage capacity for each given case. The Li-ion batteries have undergone thorough testing for the application in question. A battery room is shown in Fig. 3.

The Li-ion battery technology selected for DynaPeaQ benefits from a number of features:

- high energy density;
- very short response time;
- high power capability both in charge and discharge;
- excellent cycling capability;
- strongly evolving technology;
- high round trip efficiency;
- high charge retention;
- maintenance free design.

An artist's view of a DynaPeaQ installation is shown in Fig. 4. A typical rating of ± 30 Mvar, 20 MW during 15 minutes will have a footprint around 50 x 60 m.

Fig. 5: Dynamic energy storage

A pilot case

A dynamic energy storage pilot installation is coming on line in 2011 in an 11 kV distribution grid in the UK (Fig. 5 and 6). Its purpose is to test the functionality of the concept in conjunction with a small wind farm and try out various applications such as levelling out short time power fluctuations from the wind farm and storing energy during low demand, to be released into the grid during high demand.

Fig. 6: Li-ion battery cubicles

The author

Rolf Grünbaum received his M.Sc. degree in Electrical Engineering from Chalmers University of Technology in Gothenburg, Sweden. He is currently working for ABB AB within its FACTS Division, where he is Senior Marketing Manager of FACTS and Reactive Power Compensation Systems. Mr. Grünbaum has been active in ABB and previously in Asea for a number of years. Before that, he was employed by DISA Elektronik in Skovlunde, Denmark, where he was involved in marketing of scientific equipment for fluid flow research. He has also held positions as Scientific Counsellor in the Swedish Foreign Service. Mr. Grünbaum is a Member of Cigré, Senior Member of IEEE, and the author of numerous FACTS papers.