Performance through the roof

The 20-kV GIS switching station recently installed by Opel Austria Powertrain in their factory near Vienna is the largest of its kind in Austria and one of the highest-rated in the European automobile industry. It replaces the original BBC air-insulated switchgear installed many years ago in this Fiat-GM Powertrain group location.

Such switchgear is usually quite noticeable, but at the Opel installation, you could search long and hard before finding it – it is on the roof!

The reason for choosing such an unusual location is simple: space. The large roof area can easily accommodate capacity upgrades and the power can be delivered through the roof to the factory floor below.

In the years after the original installation, one unexpected problem came to light: the factory ventilation outlet was also located on the roof and, over time, trace amounts of oil in the expelled air penetrated the switchgear, forming a thin film on the switch-disconnectors and the busbars, thus increasing the risk of current leakage or arcing.

"You could sometimes actually see arcing on the insulation," remembers Roman Szegner, in charge of electrical systems planning at the Opel plant. Not surprisingly, frequent inspections were necessary.

The new switchgear on the roof of the Opel factory

Uprated switchgear reflects plant expansion

This was not the only reason for replacing the switchgear: The original equipment could easily cover the initial 16 MW power budget, but in the meantime demand at the plant, currently producing 466,000 engines and 858,000 gearboxes annually, has risen to 27 MW and will continue to grow - spurred on in no small part by the imminent introduction of a new six-speed gearbox production line, which will be ramped up to three-shift working in 2004. (The 800,000 gearboxes which will be produced annually will be used in GM and Fiat automobiles.) Even today, the plant takes 150 GWh from the local utility (Wienstrom), making it one of their biggest customers.

"Over the years, cooperation with

The 66 gas-insulated 20-kV cubicles of type ZX 1.2

ABB has been excellent, and that's why we've decided to go with them for the new switchgear", explains Roman Szegner. The multimillion-dollar order encompasses the installation of gas-insulated switchgear (66 cubicles) and a new control system.

Lorenz Göttfried, the ABB project manager responsible, describes the project: "To eliminate the contamination we chose gas-insulated switchgear and have also introduced a slight overpressure in some areas. Thanks to the new control system, we can manage the apparatus from the control room. Previously, we were confined to switch status display and emergency switch-off."

Roman Szegner takes up the story: "Until now, we didn't get much data from the switchgear, but now we can track long-term energy consumption; this allows us to take optimization measures. Another immediate benefit is the reduced maintenance effort."

Cable terminations

Switch-over had to be carefully planned

The first of two commissioning stages was completed in August to take advantage of the holiday period. Switching over to the new system was a complex operation which had to be very carefully planned and executed. "For example," explains Göttfried, "every phase of the heaviest conductors needs three cables, each with a 300-mm² cross-section, making nine cables in all. Each cable has to be separately sleeved. This is done by placing the stripped ends of the cables in a copper tube, which is then crimped. A copper screen is then manually woven around the joint and the whole thing covered with a heat-shrink sleeve. In addition, all control, interlock and display data transmission had to be assured, in some cases to old control equipment."

Electricity store

A quiet corner of south-east England is attracting an unusual amount of attention from the power community these days. The reason is a new type of energy storage plant with the potential to revolutionize the industry. Called Regenesys™, it is based on regenerative fuel cell technology originally developed by UK utility National Power. *Innogy Technology Ventures Limited*, a new company formed during the de-merger of National Power, has built the 19-MVA/15 MW facility alongside its 680-MW combined cycle power station at Little Barford, Cambridgeshire. ABB Industry in Switzerland supplied the facility's state-of-the-art power conversion system, which features innovative IGCT-based power electronics and advanced control. With a storage capacity of 120 MWh – enough to keep 10,000 consumers supplied with electricity for a full day – the plant is the largest of its kind anywhere in the world.

Little Barford's new energy storage facility will primarily supply electrical power to black-start the adjacent combined cycle plant and be used for peak shaving on the connected grid (by storing surplus generated energy and discharging it during load peaks) as well as provide reactive power.

The world's power community is showing a keen interest in the demonstration facility. Following an exhaustive study, Tennessee Valley Authority (TVA), the largest public power provider in the USA, has agreed to install an almost identical plant to reinforce its power system in an area of weak distribution. ABB is also supplying the complete power conversion system for this project.

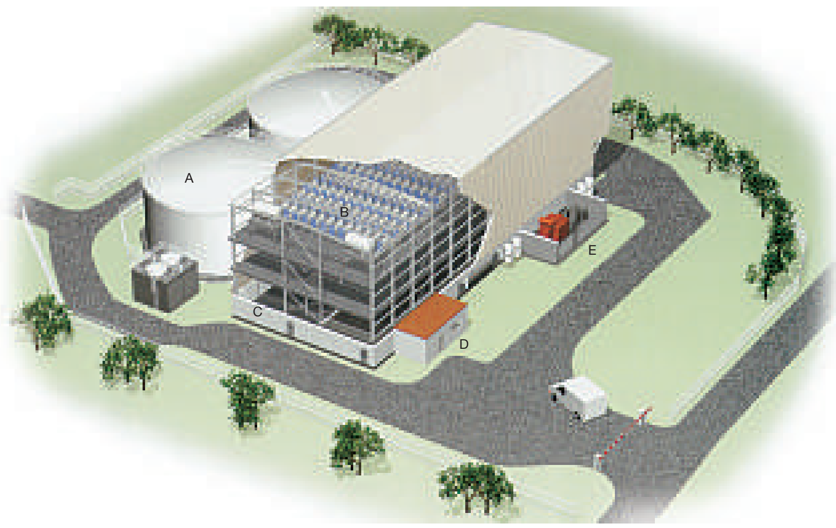
Why store electrical energy?

Electricity is the major commodity of the 21st century but, unlike water, steel, grain or other commodities, it is difficult to store. This is why electricity supply systems are built and operated the way they are – so that production matches demand at any moment. Storage has the obvious advantage that production can be decoupled from demand.

Scientists and engineers have worked for many years on developing cost-efficient technologies that would allow electricity to be stored on a large scale. One such technology, pumped storage, uses connected upper and lower water reservoirs to provide peak energy. Water is pumped into the upper reservoir when electricity is plentiful and then released to turn turbines that produce electricity when it is needed. However, this technology relies on the reservoirs being at different heights, which restricts its usefulness to mountainous regions.

Various types of rechargeable batteries have also been used to store electricity in the form of chemical energy. Known generically as battery energy storage systems, or BESS, they tend to be used mostly on a smaller scale.

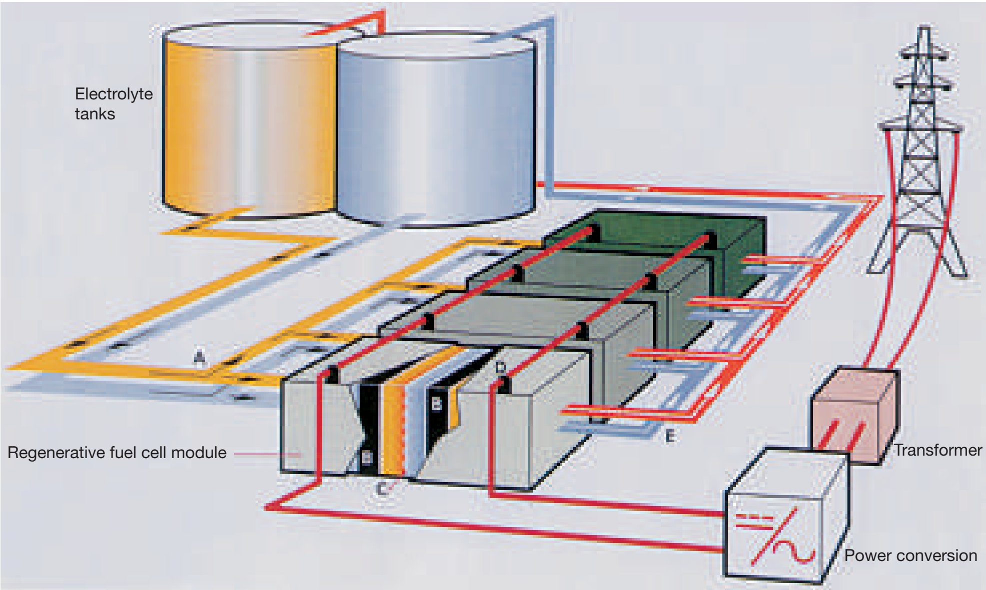
Storage technologies based on compressed air, flywheels (FESS), super capacitors or superconducting electromagnetic storage (SMES), have also been developed, but they all suffer from drawbacks – either technical, environmental, safety or cost – that hamper full



Courtesy of Regenesys Technologies

Artist's impression of the new Regenesys™ plant now being commissioned at Little Barford power station

A *Electrolyte storage tanks*
B *Regenesys modules*
C *Power conversion system*
D *Control room*
E *Transformer*



Courtesy of Regenesys Technologies

How the Regenesys plant works. More like a small chemical processing plant than a traditional power station, it makes use of high-grade polymer pipes, fittings and pumps rather than large rotating electrical machines.

A *Electrolyte inlet manifolds*
B *Bipolar electrodes*
C *Ion-selective membrane*
D *Electrical connection*
E *Electrolyte outlet manifolds*

commercial development at the present time.

Regenesys™ – an alternative approach

The Regenesys system is based on regenerative fuel cell technology (sometimes known as redox flow cell technology). Electrical energy is converted into chemical potential energy by 'charging' two liquid, water-based electrolyte solutions and subsequently releasing the stored energy on discharge. The efficient conversion of electrical to stored chemical energy and back again can be repeated indefinitely. In common with all DC battery and fuel cell systems, a converter and suitable transformer are required to connect the system to an AC network. The technology is environmentally benign; there are no emissions.

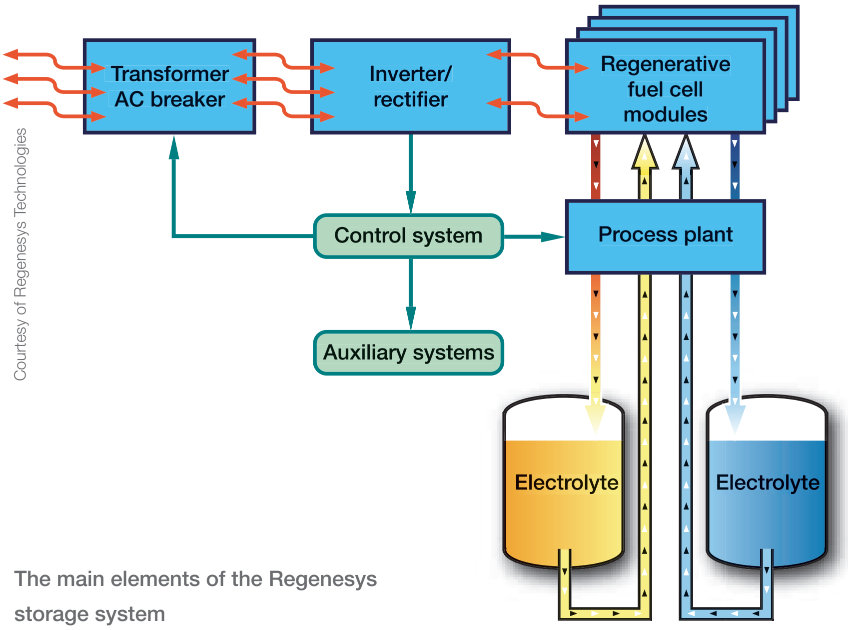
What, then, are the differences between conventional storage batteries and Regenesys? The defining difference is that in the former the power output cannot be decoupled from the actual stored energy. This is because the energy is stored through chemical changes on the surface of the electrodes. Therefore, to store large amounts of energy, large numbers of battery cells are needed, even if the (short-time) power requirement can be met with considerably fewer cells. 'Flow batteries' work differently: here, the energy is stored via chemical changes to the liquid electrolytes. The energy is discharged and charged in so-called reactor modules; the liquid electrolytes are stored in tanks. Thus, the power output and actual stored energy are clearly separated from one another. The number of reactor modules required is determined by the maximum amount of power to be discharged/charged, whereas the tank size defines the amount of energy that can be stored. Since the tanks cost much less than reactor modules or battery cells, the specific first-time costs for the new technology are comparatively low.

Following successful pilot tests, *Innogy* decided to build, on a site next to its Little Barford combined cycle power plant, a commercial-scale demonstration facility capable of storing 120 MWh of energy and of discharging 15 MW. Its most important task will be to provide the 680-MW main station with the power needed to re-start after a grid failure. The plant will also act as an energy 'buffer', storing 'cheap' off-peak night-time energy which it can then supply 'off the shelf' during the day, when demand is greatest and tariffs are highest.

When commissioned, the plant will have the ability to start up in less than 10 minutes or, if held in standby mode, in less than 2 minutes. During operation, it will be fully connected to the grid, capable of turning from a state of fully charging to fully discharging or any state in between in about 0.02 seconds.

The Regenesys facility comprises four main sections:

■ *Storage tanks:* These hold the two electrolytes that are pumped to and from the regenerative fuel cells when the plant is charging or discharging.



Courtesy of Regenesys Technologies

The main elements of the Regenesys storage system

- *Regenerative fuel cells* (RFC) into which the two electrolytes flow. The electrolytes react through an ion-selective membrane during charging and discharging, and are pumped back into the tanks again afterwards.
- *Converter/chopper/rectifier:* This provides the electrical interface between the grid and the voltage characteristics when charging and discharging the RFC. During discharges it converts the DC voltage from the RFC into AC voltage, and during charging the grid voltage into a DC voltage.
- *Transformer:* During RFC discharges this transforms the converter output voltage to the grid voltage, and during charging steps the grid voltage down to the voltage required for the converter.

Power conversion system and process control

A key component of any battery or fuel cell system is the Power Conversion System (PCS). The PCS provides the interface between the AC grid supply voltage and the variable operating voltage of the DC modules. The terminal voltage of the RFC varies considerably, being dependent on the flow direction and magnitude of the power.

The PCS consists of two functionally separate and autonomous converter systems as well as the chopper unit (a DC/DC converter) that provides the link to the variable voltage of the Regenesys modules and the DC/AC inverter unit. To ensure the black-start capability of the system, self-commutating voltage source type converters are used. The resulting system is a four-quadrant converter designed to transfer both reactive and real power simultaneously and independently of each other.

Both the chopper and voltage source converter use the same hardware platform – the very compact IGCT stack design also used by ABB in various other applications.

System control for many operating modes

The normal operating mode would be to follow a pre-defined schedule of current/voltage/time profiles during charging and discharging, including startup and shutdown of the system. The schedule is updated on a daily basis to define the operation for the next 24 hours.

The main system control inputs are conditioned signals for the system frequency and voltage (supplied by the PCS control) and the various control mode orders received from the owner's dispatch center via a remote communication link.

The main outputs from the RFC plant are the setpoints for active and reactive power.

The following functions are implemented in the programmable high-speed controller's software:

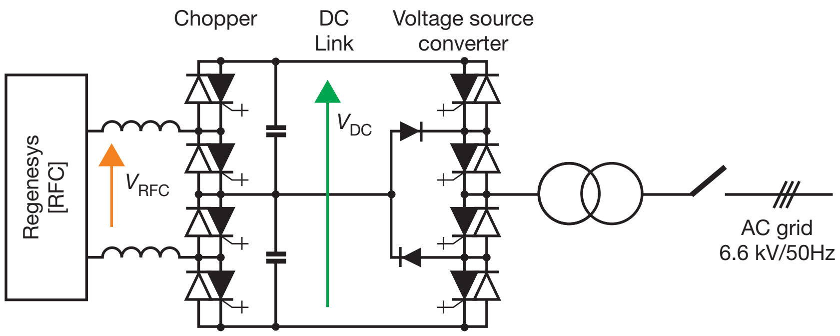
- *Voltage control:* Responds to fluctuations in the AC grid, providing voltage regulation under steady-state as well as transient operating conditions.
- *Frequency regulation:* Starts as soon as the system frequency drops or changes too fast, such as when spinning reserves are connected into the grid circuit.
- *Power system stabilization:* Damps power system oscillations by monitoring frequency fluctuations and controlling the RFC import/export.
- *Auto generation control:* Varies the plant output to match load increases/decreases.
- *Constant AC power:* Ensures that the system charges/discharges at a constant AC power.

■ *Constant var mode:* Ensures the system provides reactive power at a constant rate.

If required, a self-commutated PCS and storage system could be configured to operate as a UPS, supporting part of a distribution system or a large consumer without any need for rotating plant to keep the frequency stable, or to provide black-start capability for conventional generating plant.

A promising future

The commercial and operational potential of Regenesys has already been recognized by a number of major electricity companies and large industrial users.



Schematic of the power conversion system

Thanks to the exceptional adaptability of the power electronics systems used, there would seem to be no limits to the applications for this technology.

So what does the future hold?

■ Fewer power plants may be needed: power system planners could plan for average instead of peak demand, the peaks being covered by releasing stored energy.

■ Generating capacity could be operated more efficiently as the output would not have to change constantly to respond to demand fluctuations.

■ Transmission lines and distribution equipment could be operated at higher load factors, reducing the need for new or upgraded lines.

■ Renewable energy, such as wind, solar and wave power, could be harnessed more efficiently, being stored and then sold during peak periods.

A drawback of mechanical energy storage systems is that there is some delay in response time and in their ability to switch rapidly from charge to discharge. Advanced power electronics and high-speed control endow redox flow cell technology with an excellent response time, allowing full power to be delivered in a fraction of a second, ie exactly when it is needed. And it can be installed almost anywhere in the power system.

The great interest being shown in this new technology points to a promising future. It is no exaggeration to say that it will strongly influence the way in which power grids are built and operated in the years to come.

Current/voltage characteristic of the regenerative fuel cell

The DC link voltage of the voltage source converter is kept at a nominal constant value; the RFC terminal voltage varies as a function of the flow direction and magnitude of the power (ie, direction and magnitude of the DC current). Power is transferred between these two voltage levels by the bi-directional chopper, which acts as a stepless variable DC transformer. Rated at about 15 MW, the chopper is one of the largest ever built.