Solutions for Power Quality and Productivity
As in many other sectors of society, the power business environment is undergoing dramatic change.

All round the world, previously passive Electricity Consumers are becoming active Power Customers, a trend which is particularly evident in newly deregulated power markets.

Ever increasing competition, in both power utility and industrial markets, is putting the focus onto the importance of Power Quality in the power supply.
Increasingly, industrialists are realising that electricity should be viewed as one among many commodities vital for their business. As such it should be subject to the same demands concerning quality control, reliability of supply, etc., as any other commodity.

For industry, Power Quality is all about assured productivity and cost control.

For utilities, Power Quality is all about Power Customer preference when choosing supplier.

With this increased awareness, previously hidden costs of poor quality supply are surfacing. For instance:

The interruption of an industrial process due to a power outage or voltage dip can result in very substantial additional costs to the operation. These include lost productivity, labour costs for cleaning and restart, damaged or poor quality products, delays in delivery, reduced customer satisfaction, and possibly even damage to production equipment. The industrial power consumer and grid owner can expect to enter into negotiations concerning responsibilities and liabilities in the near future.
Power Quality – a concern for everybody

Where power quality is lacking, disturbances such as voltage flicker and harmonics may cause problems for both domestic and industrial consumers, far from the source of the problem. Ultimately, the offending equipment will become a concern for many consumers and not just for the owner of the equipment or grid.

Problems and impact
The quality of a power supply is largely synonymous with the voltage quality. The voltage provided at a given connection point should be as close to the nominal value as possible, and the wave form a pure sine form, free from harmonics and other disturbances.

On a network, variations normally occur in voltage level, due to varying load conditions. This variation is kept within certain limits, and equipment connected to the network can handle this without problems.

Lightning strikes or grounding faults, caused by trees falling onto power lines for example, can however, lead to a drop in voltage outside the tolerance band for short or extended periods. Even though the cause is local, the resultant voltage drops and sags can affect consumers hundreds of kilometers away. And complex or sensitive industrial processes like paper, plastics, or semiconductor manufacturing can be disrupted, even by quite limited voltage disturbances.

Electric arc furnaces (EAFs) are used by steel makers all over the world. As heavy users of power, steel works are important customers for grid owners and power producers.

An uncompensated EAF in operation draws large amounts of reactive power from the grid.

For the steel maker this leads to unnecessary loss of efficiency and productivity.

For the grid owner, an uncompensated EAF is a major source of disturbance, such as voltage fluctuations, harmonics, and phase unbalance, which may cause problems for other customers on the grid. What’s more, the reactive power drawn by the uncompensated furnace leads to
power losses and limits the flow of useful, revenue bringing, active power in the network.

On weaker networks, large motors can cause such large voltage depressions when switched on, that the motor itself may not be able to operate.

Harmonics, caused by non-linear loads like rectifiers in power electronics or arc furnaces, lead to unnecessary losses and call for expensive modifications to equipment. In serious cases, high levels of harmonics can even disrupt control systems and electronic equipment.

Fortunately, the problem of poor or insufficient power quality, as highlighted above, can be dealt with.

ABB Power Systems offers a portfolio of solutions to power quality problems, which are presented in this brochure. In addition to solving power quality problems, our solutions often help improve the industrial process and increase your productivity and, with it, your competitiveness.
Minicap

In systems where relatively large loads are connected close to the remote end of a radial feeder, severe voltage drops and voltage fluctuations can occur at varying load levels. In some instances, large rotating machines on weak feeders cause such large voltage depressions during start-up, that it becomes impossible for the machine itself to reach operating speed. This can be the problem in remote mines, crushers, or mills, for example.

Applying series capacitor technology can be an economically attractive solution to these kinds of problem.

ABB Power Systems product range includes a pole-mounted series capacitor specially adapted to distribution lines:
- Minicap, designed to support power supply up to 36 kV

Both types of equipment use a combination of reactors, capacitors, and thyristor valves, to provide controlled reactive power output. Since most of the undesired voltage variations are normally caused by reactive power, the SVC and Minicomp are extremely effective in combating voltage variations caused by the normal operation of equipment.

SVC-Q and Minicomp

Loads where the demand for reactive power rapidly varies, such as rolling mills, mine hoists, cranes, welding machines, and arc furnaces, cause rapid voltage fluctuations. If the effects are sufficiently large, production or operational disturbances, such as relays being tripped by voltage depressions, can occur. The best way of counteracting this type of voltage variations is controlled reactive power compensation.

ABB Power Systems offers two solutions to this type of problem:
- Static Var Compensators, tailored to suit the needs of large loads (typically > 10 MVA up to several 100 MVA)
- Minicomp, aimed at medium power loads, which have reactive power demand from 1 to 20 Mvar

Minicap helps to minimise undervoltage conditions resulting from heavy loads, mitigate over-voltage conditions due to sudden load rejection, and reduce reactive power consumption. By continuous and instantaneous voltage control, Minicap fulfils the same stringent demands for precision and operational reliability as any other form of modern distribution equipment.
**What is flicker?**

Voltage variations give rise to fluctuations in intensity of lighting sources in homes, offices, and other buildings. At certain frequencies, even tiny light variations can be experienced as highly irritating by many people. Such disturbances are referred to as flicker. Flicker as a Power Quality issue has attracted a great deal of media attention. Around the world, lower tolerance limits on flicker are gradually being implemented.

Electric arc furnaces found in the steel industry, are a significant source of flicker. Other sources include welding machines and wind power generators. The violent forces released in the arc furnace process impose a wide band of disturbances of a truly stochastic nature on the power grid.

The only way to reduce such disturbances successfully is to continuously measure and correctly counteract rapid changes by extremely fast compensation.

**SVC Light – A Real Flicker Terminator**

The SVC Light is ABB Power Systems’ innovative solution to the problem of flicker. The SVC Light uses a voltage source converter to provide the necessary reactive power. The converter is equipped with IGBTs which enable it to have a switching frequency in the kHz range, and a response time of less than one millisecond. This speed makes the SVC Light much more efficient - typically by a factor of 2-3, compared with conventional solutions - in combating flicker. The SVC Light is similar in principle to a STATCOM.

The SVC Light stabilises the voltage on the furnace bus. From a production perspective, this means more power can be used in the furnace, which in turn can be used to increase productivity.

Additional benefits include reduced electrode consumption, reduced energy consumption per melt and less erosion of the furnace refractory lining.
A voltage sag is a rapid decrease in RMS voltage magnitude, typically lasting between 10 ms and 1 second, and usually caused by a remote fault somewhere on the power system. Voltage sags are a very important power quality problem facing many process industries. Equipment used in modern industrial plants such as process controllers and adjustable speed drives is becoming increasingly sensitive to voltage sags as the complexity of the process and equipment increases.

These events, random in character, are mainly caused by weather conditions affecting the transmission grid such as lightning strikes as well as the impact from wind and ice, which in turn interfere with industrial distribution systems. Contamination of insulators and accidents involving construction or transportation activities also cause faults.

Faults resulting in voltage sags can occur on the utility system or within the plant. The large majority of faults on a utility system are single line-to-ground faults. Three phase faults are more severe, but less common. The voltage sag condition lasts until the fault is cleared by a protective device. Although utilities go to great lengths to prevent faults on their systems, they cannot be eliminated altogether. Since faults (and, therefore, voltage sags) are inevitable, it is important for customers to make sure that critical equipment sensitive to voltage sags is adequately protected. This is where DVR (Dynamic Voltage Restorer) comes in.

Despite the local nature of the cause, voltage dips and sags can be felt hundreds of kilometers away. Even a relatively modest reduction in voltage of, say, down to 70 per cent of nominal in one phase, may trip entire paper machines. Other types of industries affected include semiconductor manufacturing, textile, pulp, and plants having critical hydraulic installations.

Compensating voltage variations over time periods ranging from minutes up to hours by changing taps on transformers has been standard practice in power systems for many years. For compensating voltage dips and sags on a millisecond time scale, however, conventional tap changers are far too slow.

ABB offers DVR as solution to dips and sags problems.
DVR – Dynamic Voltage Restorer
The function of the DVR is illustrated above. In the event of a voltage dip, the power electronic converter injects the appropriate voltage required into the supply bus to compensate for the sag. It effectively acts as a buffer to the load and prevents unacceptable disturbances. The rapid control cycles and millisecond switching speed of the converter afford fast and accurate control of the voltage experienced by the load. This can be critical in processes like semiconductor manufacturing, where a single voltage sag may cause the loss of production, and with it, very high costs.

A DVR would typically have sufficient energy storage capacity to compensate a 50 per cent three-phase voltage dip for up to 10 cycles, the period normally required for fault clearance. Capacitors serve as the energy storage device. For coping with longer dips, an energy storage of larger capacity can be added to the DVR. ABB’s DVR covers a power range from 3 MVA up to 50 MVA.

Although a DVR may be rated to compensate up to a 90 per cent voltage dip, it does not support complete outages. For the load to ride through a complete outage, a shunt connected variation of the DVR can be installed, – a DUPS, Dynamic Uninterruptable Power Supply.

System Analysis
Before design of a DVR is undertaken, a system analysis should be performed. Important issues to define are:
- Type of faults against which the critical load (single phase to ground, phase to phase or three phase faults) has to be protected and where faults occur.
- Size and duration of the voltage dips.
- Size and power factor of the critical load.
- Possibilities to separate feeders with important loads.
- Voltage correction requirements at the critical load (percent of the voltage and response time).
- Transformer connections (Y/y, Y/d, type of grounding, etc.).

With the information above, design of the most suitable and cost effective DVR can be carried out.
Harmonic filters

In the ideal case, the voltage and current waveforms follow perfect sine curves. In real networks, non-linear loads such as drive systems, electric arc furnaces, rectifiers, and increasingly, home and office appliances, cause harmonics and non-sinusoidal wave forms. The harmonics give rise to losses in, for instance, transformer cores and motors. They can also cause other, more serious problems, however, when interfering with control systems and electronic equipment.

Harmonics can be reduced by filtering. For large, easily identifiable sources of harmonics, conventional filters designed to meet the demands of the actual application, are the most cost efficient means of eliminating harmonics and remaining within stipulated limits. These filters consist of capacitor banks with suitable tuning reactors and damping resistors. For small and medium size loads, active filters, based on power electronic converters with high switching frequency, may be a more attractive solution.

Unbalance

For several reasons, it is preferable for the load to be shared equally by all three phases of the AC system. However, large single phase loads and unequal loading due to other reasons, cause unbalance in the system. Too much unbalance may have a disturbing or even damaging effect on generators, rotating machines and other equipment.

Depending on whether the unbalance is fixed or dynamic, appropriate compensation should be applied.

SVC is widely used for dynamic load balancing in conjunction with railway feeding.

If the load unbalance is fixed and known, fixed compensation can be designed using a combination of capacitors and reactors.
Studies
Standard products can be used in applications with limited power demands. For higher power, it is often more cost effective to optimise the solution to the specific system. It is also important to investigate the effects on system resonances caused by the introduction of new equipment. Modern computer simulation is an indispensable aid for this. An additional benefit of computer simulation is the facility to investigate the what-if effects of different faults and contingencies on the system, without putting the live system at risk. ABB Power Systems has extensive experience of applying computer simulation to solve Power Quality problems, using both standard commercial software packages and special programs developed in-house. Simulation results are regularly validated against measurements in full scale applications and cases.

Capabilities
ABB Power Systems has delivered Power Quality solutions and systems for over thirty years. This experience is borne by a dedicated organisation, employing some 100 people, with the project management, engineering, procurement, shipping, and all other know-how resources necessary for effective project performance. ABB Power Systems implements projects all round the world, often to demanding deadlines. Project installations include turn-key deliveries, as well as other divisions of responsibility, according to the specific wishes of each customer. A special Customer Support department takes care of customer needs for service contracts, service visits, and spare parts. Naturally, ABB Power Systems has quality certification to ISO 9001 standard.