New power supply unit improves control response of electrostatic precipitators

ABB is one of the leading suppliers of control systems for electrostatic precipitators. For example, more than 9,000 voltage control units of type EPIC have been sold worldwide. ABB now offers a new, innovative power supply unit for electrostatic precipitators based on the very latest know-how in the areas of flue-gas cleaning, power electronics and high-voltage technology. Advantages over conventional units include better control response, a perfectly smooth output voltage, a reduction in weight of about 88 percent, and a design which makes the new unit much easier to install.

ABB introduced the first model of the new high-voltage supply unit for electrostatic precipitators to the market already in 1994. Other sizes soon followed, and today ABB offers units with power outputs of 20 to 60 kW for different power system voltage ranges.

The new high-voltage supply unit is named SIR, for Switched Integrated Rectifier. Based on advanced power electronics devices, it offers improved controllability as well as a considerable reduction in weight. A feature of the new unit is that the control circuitry for one chamber of an electrostatic precipitator has been combined in a single unit, which is mounted on the roof **1**. This significantly reduces the cost of installation.

A SIR unit consists of a three-phase recitifer, an inverter for the voltage regulation, a transformer, a high-voltage rectifier, a control computer and a number of contactors **2**.

In the new unit, the conventional thyristor bridge is replaced by a three-phase rectifier. In series with this rectifier is an IGBT inverter. Its operating frequency of up to 50 kHz means that the high-voltage transformer works with a much higher frequency than the normal 50/60 Hz. This enables the weight and size of the unit to be considerably reduced. Together, the transformer and HV rectifier of a 60-kW SIR unit weigh only about 65 kg, including the insulating oil, whereas a conventional transformer/rectifier unit weighs approximately 1,200 kg.

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The complete system weighs only 180 kg, including the control cabinet and transformer, compared with 1,400 kg for a conventional 60-kW unit.

Development steps

In recent years, switched mode power supplies have fully replaced the 50/60-Hz transformers used in computers, telefaxes, etc, mainly because of their much lower weight and smaller size. The new supply units normally work with a voltage of 110–240 VAC, an output voltage of 5–24 VDC and a power output of up to 1 kW. At the time ABB decided to develop a new technology for electrostatic precipitator power supplies, solutions first had to be found to the following problems:

- Electrostatic precipitators require powers of between 20 and 150 kW. Switched mode power supplies in this power class did not exist at the time.
- Output voltages of up to 100 kV had to be possible. It had to be determined if the equipment could be made smaller by reducing the size of the circuitry, while guaranteeing a large enough insulating clearance in the high-voltage circuit.
- Electrical sparkover occurs often in electrostatic precipitators and have the same effect as load-side short circuits. A completely new unit capable of withstanding up to five short circuits per second therefore had to be built.

To be able to handle the required commutation frequency without causing unacceptably high losses in the power semiconductors, a resonance inverter has to used. Several prototypes were built in the early 1990s, but the power output was limited at first by the fact that

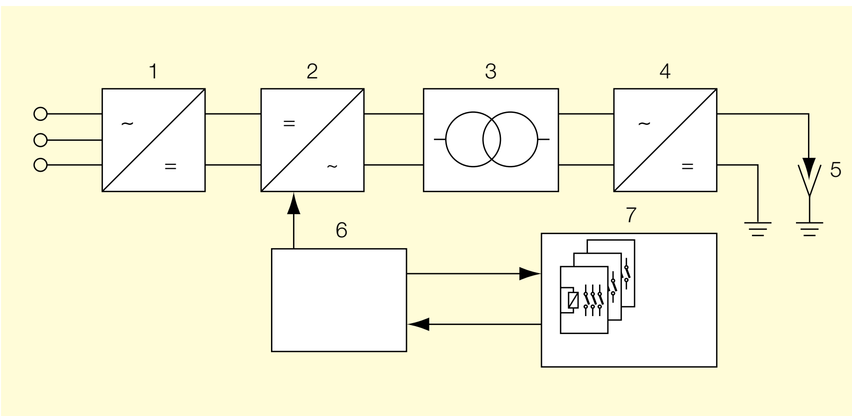
Two SIR units on the roof of an electrostatic precipitator. Due to their low weight, the units can be mounted directly on the tubular encapsulation around the high-voltage feeder. **1**

semiconductor devices of the required calibre were not yet available. At the time, only MOSFET-type transistors could be used as switches. It was not until the insulated gate bipolar transistor (IGBT) came onto the scene that it became possible to build inverters with much higher power ratings, and that these did not depend only on the power semiconductors.

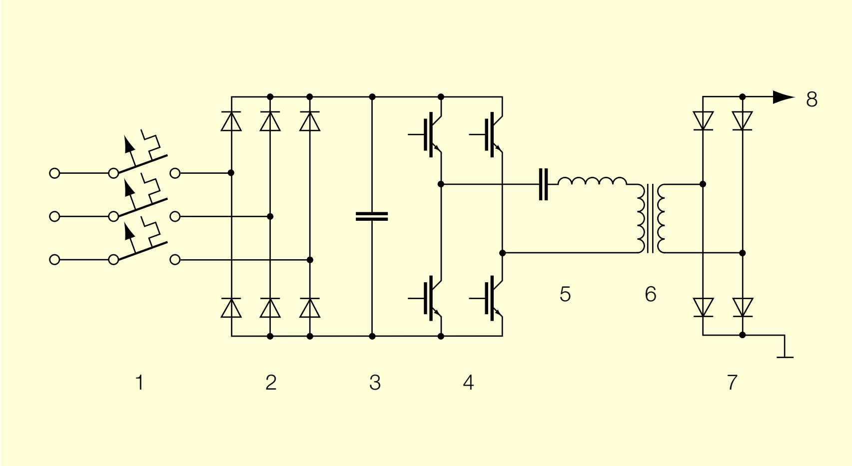
The next problem was soon identified. This was the transformer, which had to be able to handle high frequencies in addition to high powers and voltages. Parasitics, such as leakage inductance and capacitive coupling between the windings, have to be matched exactly to the inverter and load characteristics. This problem could be solved by paying close attention to the mechanical design of the magnetic circuit. ABB's extensive experience in transformer construction allowed an optimum solution to be found to this problem **3**.

Basic design of an SIR unit **2**

1 *Three-phase recitifier*
2 *Inverter for voltage regulation*
3 *Transformer*
4 *High-voltage rectifier*
5 *Precipitator*
6 *Computer*
7 *Auxiliary systems*



SIR units are currently available for outputs of up to 60 kW, with much larger units already at the development stage.



Circuit diagram of an SIR unit **3**

1 *Circuit-breaker*
2 *Rectifier bridge*
3 *DC link capacitor*
4 *IGBT-based inverter*
5 *Resonant circuit*
6 *Transformer*
7 *High-voltage rectifier*
8 *To precipitator*

Advantages for the precipitation process

SIR units make it easier to set the optimum operating point and thereby improve the efficiency of the precipitator. This allows smaller precipitators to be used in new installations, and in the case of existing precipitators reduces the pollutant emissions.

The most important advantages of SIR units are the smoothing of the high voltage, which eliminates even residual ripple, and the fact that they allow unrestricted control of the pulse cycle and pulse length.

Smoothed high voltage

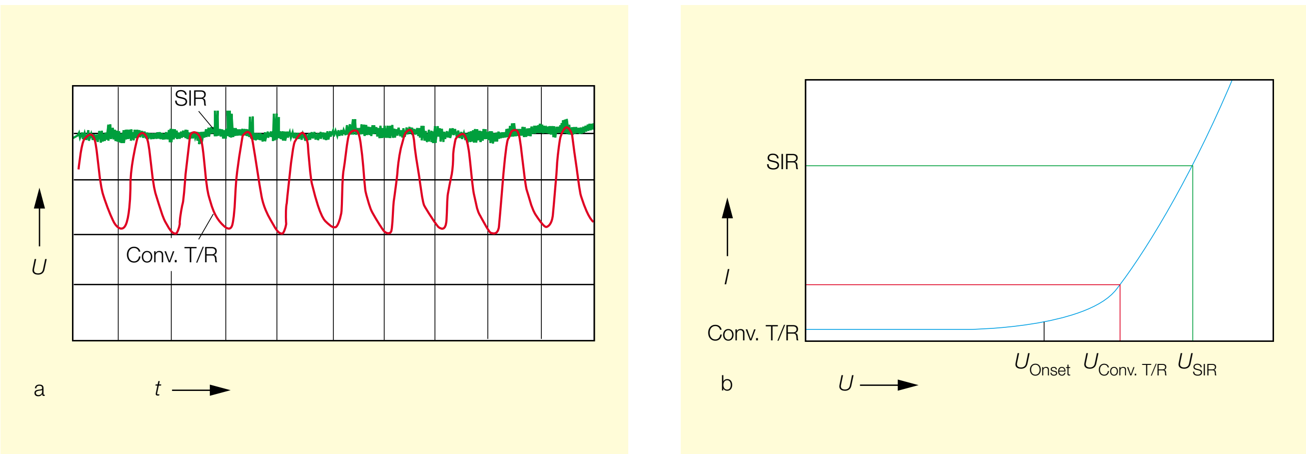
The precipitation process requires the mean voltage to be held at a constantly high level, so that a high corona discharge current is produced. A limiting factor in conventional rectifiers, is the significant ripple in the high voltage. The voltage peaks are not allowed to exceed the value at which sparkover occurs between the corona electrodes and the plate electrodes on which the precipitation occurs. Thus, the mean voltage lies considerably lower than the sparkover limit. The SIR unit produces a perfectly smooth high voltage. The mean voltage and the peak voltage therefore have the same value and can lie close to the sparkover voltage **4**.

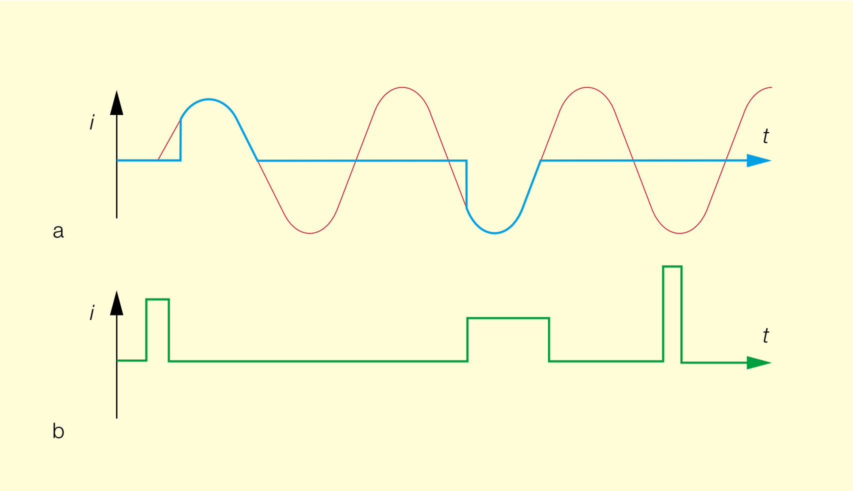
Current pulsation

Dust particles with a low electrical conductivity - the type produced, for example, when coal with a low sulphur content is burnt are difficult to separate in electrostatic precipitators. This is because the high-resistance particles form a thick layer on the plate electrodes, and the electrical field strength in this layer rises to a point where the particles are

Output voltages (a) and currents (b) of a conventional power supply unit and an SIR unit **4**

I *Precipitator current*
U_{Onset} *Voltage at onset of corona discharge*
$U_{Conv.\ T/R}$ *Voltage, conventional power supply unit*
U_{SIR} *Voltage, SIR unit*





Pulses generated by a conventional unit (a) in which the pulse length and cycle are controlled by the power system frequency, and by an SIR unit (b), with which the pulse cycle, amplitude and length can be freely chosen. **5**

New electrostatic precipitator from ABB in the 20-years old Karlshamn oil-fired power plant, Sweden. The precipitator began operating in 1997. **6**

repulsed by the electrode plates. To avoid this, the operating current of the filter is chopped into short pulses with a repetition frequency of 1–30 Hz. As a result, the dust layer discharges during the intervals between the pulses.

In order to optimize the current pulsation for installations of different designs and for a variety of fuels, ABB developed some years ago software with the type designation EPOQ for conventional power supply units.

With the SIR units, even better results can be achieved. In conventional precipitator control systems the thyristors are turned on only once every half-cycle, and to create a pulse gap it is necessary to skip several half-cycles. The pulse frequency is therefore tied to sub-harmonics of the power system frequency **5**. With the SIR unit the pulse length and pulse gap are continuously controllable from about 50 μs upwards, enabling the process to be optimized.

Electrostatic precipitators and environmental protection

Electrostatic precipitators are used to clean flue gas, eg from power stations, and the gases given off by blast furnaces. The precipitator intercepts the dust particles that would otherwise escape with the gas emitted by the stack into the atmosphere. Electrostatic precipitators therefore make a major contribution to environmental protection by reducing the emission of pollutants. In addition, they are useful for recovering valuable chemicals or metals from the flue gas.

Electrostatic precipitators are installed in the output stage of most incineration plants, including coal-fired power plants, the rotary kilns used to produce cement, and steam boilers. The amount of dust carried by the gas in these applications can be very large: for example, electrostatic precipitators downstream of a coal-fired 600-MW boiler commonly separate some 30 t of flyash per hour **6**.

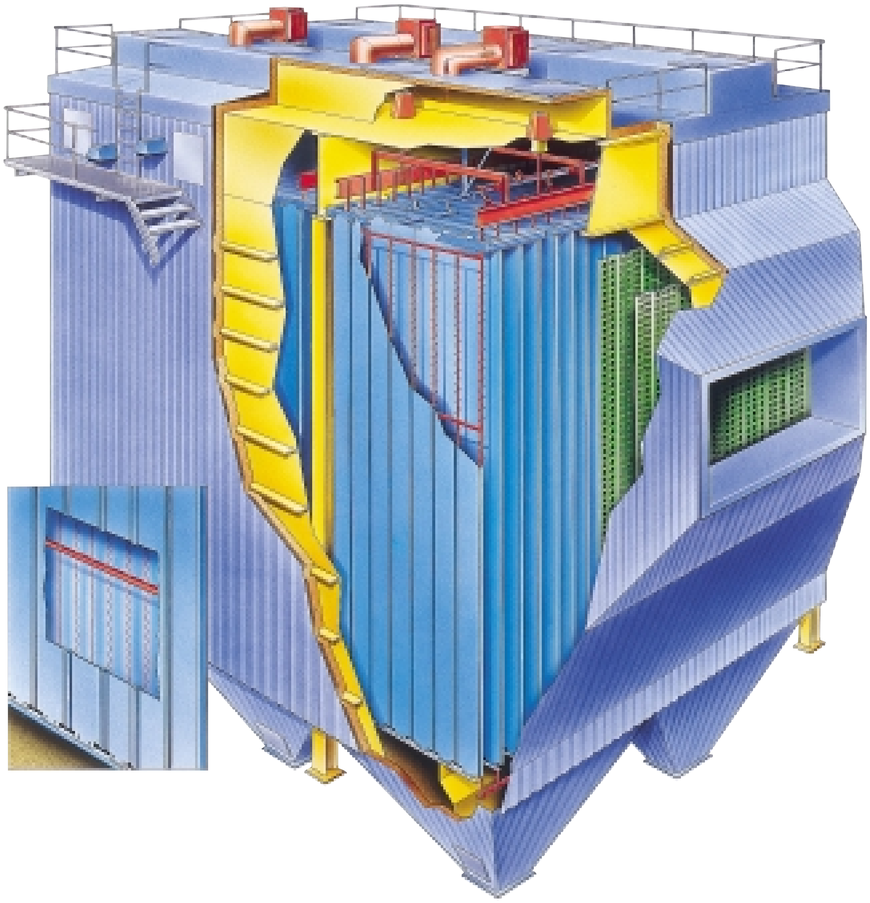
The electrostatic precipitator is installed between the boiler and the stack. Inside it there are large plate electrodes, spaced about 250 to 400 mm apart, on which the dust is precipitated. In a precipitator for a large, coal-fired boiler, the total surface area of the plate electrodes is about 60,000 m^2. Between the plate electrodes there are thin wires that act as corona discharge electrodes. The plates are grounded, whereas the wire electrodes are at a negative DC voltage of 50–110 kV, referred to ground potential.

A corona discharge current begins to flow as soon as the voltage in the precipitator has reached the required level. Electrons escape from the corona electrodes and migrate in the direction of the plate electrodes, clinging to suspended dust particles on the way. As a result, the particles become negatively charged and likewise migrate towards the plate electrodes, to which they adhere **7**.

To achieve a high precipitator efficiency, as many electrons as possible must cling to the dust particles. In other words, the corona discharge current has to be as high as possible. However, this means that the precipitator voltage must lie as close as possible to the voltage which sparkover between the discharge electrodes and plate electrodes takes place.

To identify the point at which this happens, the automatic voltage regulator increases the voltage steadily until sparkover occurs. Afterwards, the voltage drops by some percent, and the regulator takes it up again to the sparkover limit. The sparkover frequency lies in the range of 0.1–5 Hz and depends on the type of precipitator used.

The plate electrodes are vibrated at intervals which can be set between several minutes to several hours. This causes the dust particles to fall to the floor of the precipitator hopper, from where they can be removed for disposal.



Cutaway drawing of an electrostatic precipitator from ABB, showing the plate electrodes (blue) and corona discharge electrodes (red) **7**

References

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