STABILIZED HIGH VOLTAGE DC POWER SUPPLIES OF THE SHIELDED DESIGN

G. Reinhold, R. Minkner and K. Truempy
Accelerator Department, Emile Haefely & Co Ltd, Basel
Switzerland

This paper discribes recent progress in the design of the fully enclosed, stabilized High Voltage power supply.

The performance characteristics and operating life of a 600 kV power supply of this type are discussed.

High voltage dc power supplies are required for a wide variety of applications in the field of nuclear physics. Typical examples are : positive ion accelerators for nuclear research, electron accelerators for extra high voltage electron microscopy and for irradiation purposes, particle beam separators in large orbital accelerators, and test installations for the development of ion sources and accelerating tubes. Nearly all these applications require low ripple voltages, and most of them a high stability of dc output voltage. As these power supplies are considered to be auxiliary equipment only, they have to be compact in design and simple in operation. A first step towards the compactness was made when a type of dc power supply was built into one single cylinder of insulating material or porcelain. However, these power supplies were still of the so-called air-insulated design. Today completely shielded power supplies housed inside steel tanks are available from leading manufacturers in this field. As these units are enclosed in steel tanks, repairs connot be performed as easily as in the case of the open ones. Therefore, the entirely shielded units have to be designed for the highest degree of reliability and long life.

This paper deals with a dc high voltage power supply which is based upon the principle of the Cockcroft-Walton cascade rectifier [1,2]. The size of the main components, such as capacitors and transformers depends on the insulating properties of the material which is used for the filling and impregnation of the tank, and on the frequency at which the rectifier is operated. A high operating frequency will not only reduce the size of the components, but also considerably decrease the capacitance of the coupling and smoothing capacitors and thus the total stored energy.

High quality mineral oil was chosen for the filling of the rectifier tank. The same oil is used for the impregnation of the capacitors, transformers and rectifiers. For this reason, these components do not have to be individually enclosed. Mineral oil has excellent insulating properties, low losses and a much better thermal conductivity than compressed gases.

As already mentioned, the operating frequency plays a major part in the design of a cascade rectifier. Experiments have proven that the maximum operating frequency of selenium rectifiers is in the order of 20 kcps. Therefore, an operating frequency of 10 kcps was chosen which allows for a considerable reduction in the size of the components. As far as frequency response is concerned, silicon diodes are better than selenium rectifiers. It is well known, however, that silicon diodes are very sensitive to overvoltages and over-currents which may frequently occur during the operation of high voltage equipment. Moreover, silicon diodes cannot be simply connected in series in order to obtain higher peak inverse voltages. Additional shunt capacitors and series resistors have to be provided in order to protect the silicon diodes. Out of economic considerations, it can be proven that silicon diodes are preferable to selenium rectifiers in high voltage techniques if the rated dc current exceeds 50 mA [3].

The maximum output voltage of the dc power supply was rated at 600 kV, since this was the limit for the cables that were available. Today, 1000 kV cables are available, and future high voltage dc power supplies will be manufactured for this voltage. For most applications a relatively weak dc current of a few milliamps is sufficient and, therefore, the rated current was limited to 5 mA.

For the rated output power of 3 kW, the input frequency of 10 kcps can easily be electronically generated, thereby avoiding noisy and expensive rotating machines as frequency converters.

Figure 1 shows the block diagram of the complete high voltage power supply. The cascade rectifier is composed of 4 stages of 150 kV each. The ac input voltage is supplied from the secondary winding of a high voltage transformer. In case of external short-circuits the full dc voltage may appear across the secondary of the transformer. Normally, a spark gap in parallel with the secondary winding is used in order to protect the high voltage transformer. However, a spark gap under oil or insulating gas would create other problems. Therefore, the secondary winding is designed in such a way as to provide a large parallel capacitance which automatically short-circuits the surge voltages.

The top terminal of the smoothing column is connected to the built-in measuring potentiometer through a protective resistor. This damping resistor limits the dc current in case of external short-circuits and simultaneously acts as a filter resistor in combination with the capacitive part of the measuring potentiometer. Depending on the capacitances used for the capacitors of the rectifier stack and the measuring resistor, the residual ripple voltage is between 0.01 percent and 0.05 percent of the dc output voltage.

The assembly of the rectifier stack and metering potentiometer is surrounded by several cylindrical layers of insulating material acting as electrostatic shielding against the wall of the steel tank. The high voltage terminal of the measuring potentiometer is connected to a contact inside a socket made of insulating material which fits into the plug at one end of the high voltage cable. A bleeder chain is provided on the surface of the socket in order to obtain a uniform voltage distribution from one end to the other which is at ground potential. The small slit between the outer surface of the plug and the inner surface of the socket has to be filled with a special type of oil. This can be done in less than half an hour, while the disassembling of the plug from the socket takes only a few minutes. Figure 2 is a photograph of the high voltage dc power supply, showing the rectifier steel tank and the racks for the input voltage supply and stabilization.

It can be seen from this photograph that the surface of the steel tank is provided with cooling pipes for forced dissipation of the internal power losses. No water or fan cooling is necessary even under permanent operation at full load and maximum ambient summer temperatures.

Figure 1 also explains the block diagram of the electronic voltage supply and stabilization. The operating frequency of 10 kcps is generated by an rc oscillator. The oscillator voltage is amplified in a driver chain and applied to the primary winding of the high voltage transformer directly connected to the anodes of the power amplifier tubes and with its center tap to the anode voltage supply. The power amplifier of the driver chain and the rectifier for the plate voltage supply are rack mounted. The so-called stabilization rack contains the reference voltage source, the dc and ac amplifiers, the modulator of the stabilizing circuit as well as the control unit.

The reference voltage source is connected to a pair of helipots for coarse and fine control of the dc output voltage. The preset reference voltage is compared with the secondary voltage of the measuring potentiometer. Any deviations, i.e. error signals, are amplified by ac and dc amplifiers and finally applied to the grids of the power amplifier tubes.

The control unit is included in the stabilization-rack. The number of control switches and pilot lights has been minimized in the control and supervision of the complete installation. The power supply is provided with protective devices against over-voltages and over-currents. An "out of stability" indicator is also included which is very useful for the automatic operation of beam separators.

Under full load the stability of the dc voltage is 0.05 percent of the preset output voltage in the range between 100 kV and 600 kV. The long-term stability (drift) is better than 0.5 percent per hour.

A particular feature of this type of dc power supply is that it can be frequently and directly short-circuited without any harm to the cascade rectifier or the electronic tubes of the driver chain. Repetitive short-circuit tests at 600 kV have proven that the power supply will exceed the life-time of the high voltage cable which can be replaced in case of emergency within less than half an hour.

References

(1) Craggs and Meek : High Voltage Laboratory Technique. Butterworths Scientific Publications, London, 1954

(2) G. Reinhold, J. Seitz und R. Minkner : Die Weiterentwicklung des Kaskadengenerators, Zeitschr. F. Instrumentenkunde 67 (1959)

(3) R. Minkner und G. Reinhold : Ein Hochspannungsgleichrichter mit Siliziumdioden. Bulletin des Schweiz. Elektrotechn. Vereins No. 19 (1962)

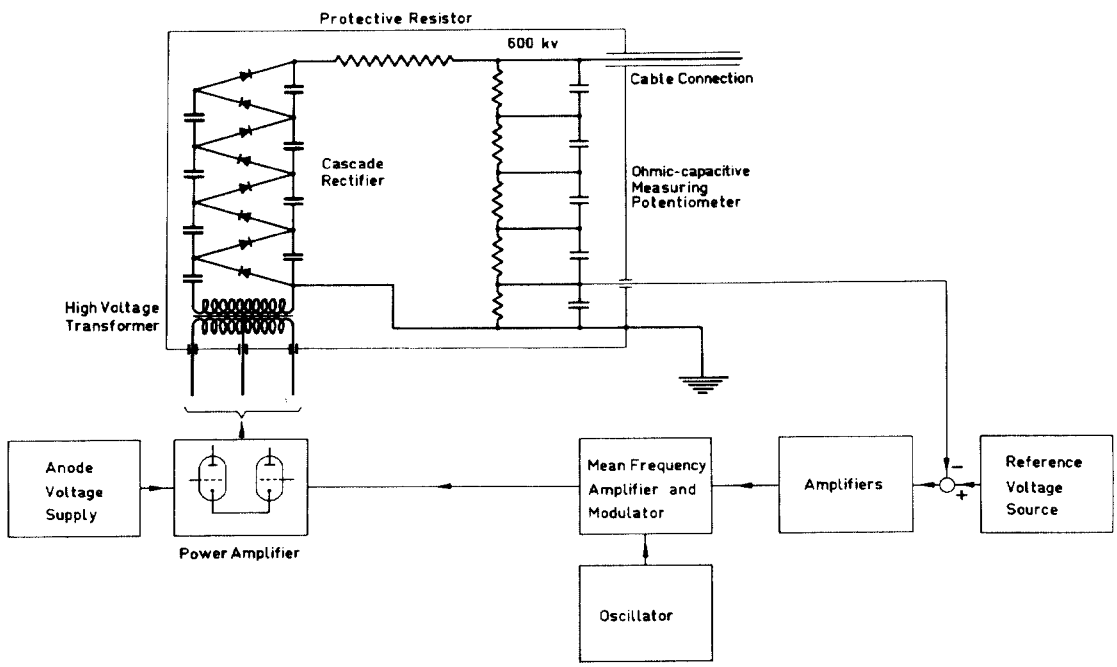

Fig. 1. Block diagram of a 600 kV dc power supply.

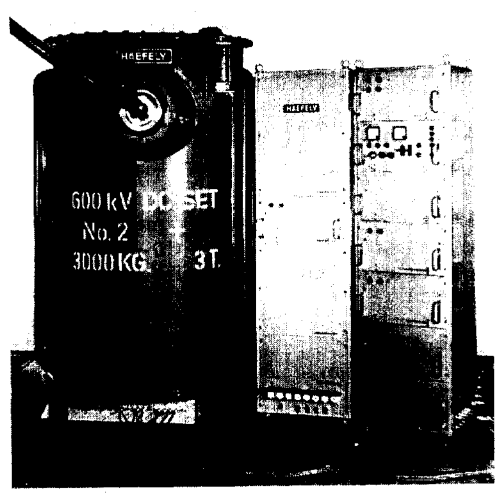

Fig. 2. 600 kV power supply with racks for the input voltage supply and stabilization.