HIGH POWER COCKCROFT-WALTON GENERATOR

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Summary

To utilize the full current capability of the regular or symmetrical cascade generator, the conventional selenium rectifiers have to be replaced by a series-connection of silicon diodes which are rather sensitive to overvoltages and overcurrents. The problem of the application and protection of silicon diodes in high voltage generators had to be overcome in connection with the design of an air-insulated 770-kV dc power supply with a rated current of 180 mA dc for the ATOMIC ENERGY OF CANADA, LTD., Chalk River, Ontario and also for a 2 MV, 30 mA test facility.

General Design Considerations

The first high voltage dc generators with solid state rectifiers were constructed in 1952. Since that time, the conventional thermionic tubes for high voltage applications were more and more replaced by selenium and silicon rectifiers. A significant step towards high voltage dc power supplies with increased output current was the development of the symmetrical cascade generator. That new circuit has led to a universal tool, meeting a wide variety of requirements in nuclear research, electron microscopy and many industrial applications, such as electron beam irradiation. During the past 20 years a large number of high voltage dc power supplies using selenium rectifiers were built. This type of rectifiers has been preferred because of its well known capability to withstand high voltage and current surges. However, two effects limit the application of selenium diodes. The first of those limitations is the low current density which results in large outline dimensions for high current rectifiers. The second restriction lies in the operating frequency range which is limited to 20 kc/s.

In recent years growing interest in higher power has forced the manufacturers of high voltage equipment to develop new rectifier stacks, replacing selenium by silicon. Serious problems have been encountered in the design of short-circuit proof high voltage power supplies with silicon rectifiers. When a large number of silicon diodes is connected in series it is well known that each diode has to be protected by a passive network, consisting of a series resistor, a shunt resistor and a shunt capacitor, to limit the forward current and equalize the inverse voltage. However a high degree of protection must be paid for by a loss of power efficiency. The series resistor causes additional power losses in the rectifiers and the total shunt capacitance affects the performance of the Cockcroft-Walton generator like the stray capacitance between the dc and ac capacitor columns, thus creating additional ripple voltage and voltage drop. Nevertheless, the latter disadvantage can be eliminated to a great extent by high-Q compensating reactors, inserted between the ac columns of the symmetrical cascade generator. That technique admits a large shunt capacitance across each rectifier, thus providing improved protection against high voltage transients.

Applications

Figure 1 shows the 770-kV, 180 mA dc power supply for the ATOMIC ENERGY OF CANADA, LTD., Chalk River, Ontario. The 3-stage cascade generator with silicon rectifiers energizes a dc accelerator through a water cooled damping resistor, which protects the accelerating tube as well as the power supply from damage in the event of sparkover in the beam tube. One of the most remarkable features of that power supply is its capability of withstanding frequent discharges, thus allowing the use of an automatic restarting device which resets the output voltage with an accuracy of 0.1 percent within less than 25 seconds after each overcurrent trip. The frequency converter set and the high voltage transformers are overrated to allow the future extension of the rectifier stack to 1 Megavolt by adding one more stage. The high voltage dc power supply is operated at 10 kc/s to achieve a voltage stability and ripple of less than 1 part in 1000. The equipment was installed at Chalk River in 1970, and will be used as an injector or pre-accelerator power supply.

Cockcroft-Walton generators operating in atmospheric air are also used in high voltage dc test facilities. Figure 2 shows a 7-stage 2-MV cascade generator, which supplies 30 milliamperes into the test load. To demonstrate the high reliability of the newly designed silicon rectifiers that power supply has been operated at a voltage as high as 2.5 MV. The polarity of the output voltage can easily be reversed by an automatic device. Less than 17 seconds are required for the polarity reversal under full operating conditions.

In recent years another demand for high power dc sources has been created by the industrial electron beam irradiation. Considering the specific requirements of that application, a compact sized 600-keV electron accelerator has been constructed. The dc power supply in figure 3 is designed to generate an output current of 100 mA. The Cockcroft-Walton generator is insulated by 45 psi of sulfur hexafluoride. Due to the high field strength to which the components of the power supply are exposed particular attention had to be paid to the protection of the silicon rectifiers. A series of experiments has led to completely encapsulated modules which are rated at a peak inverse voltage of 50 kV. That technique allows to connect several modules in series for higher inverse voltages. Although each silicon diode is protected against overcurrent surges by a small series resistor a large current-limiting resistor is installed between the top of the cascade generator and the output terminal. The rated output power of 60 kW allows to energize simultaneously two or more electron accelerators, which are connected to the dc supply by shielded high voltage cables.

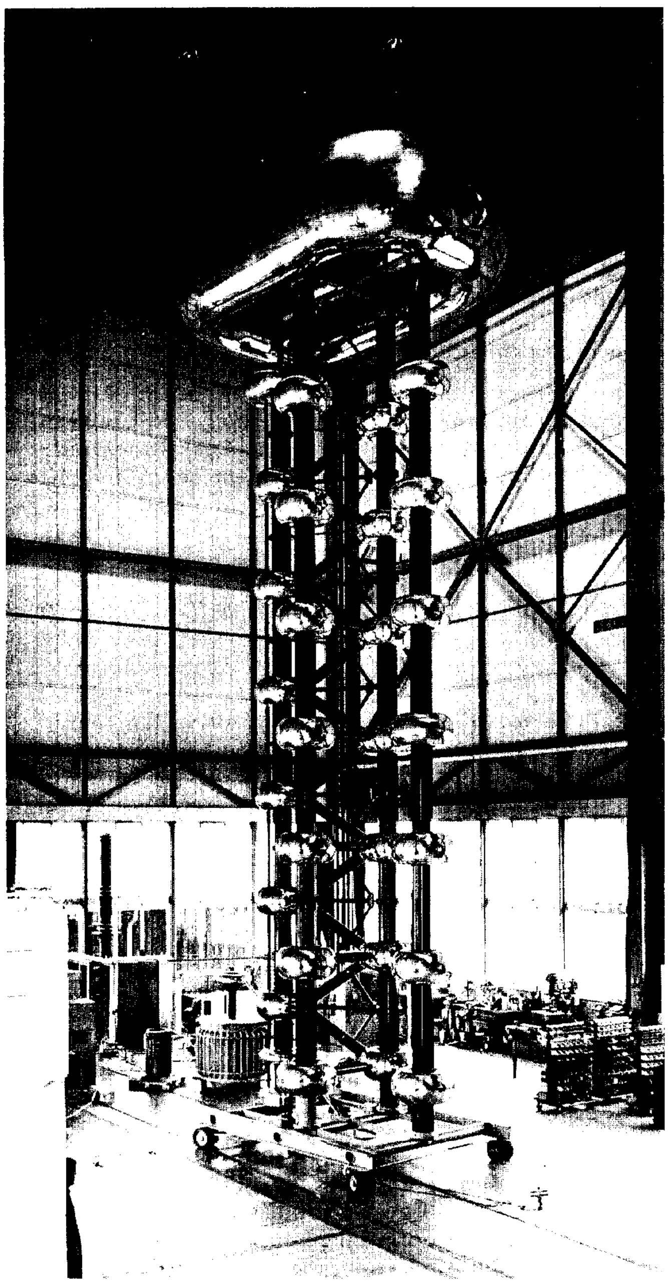

Fig. 2. 2 MV Test Facility

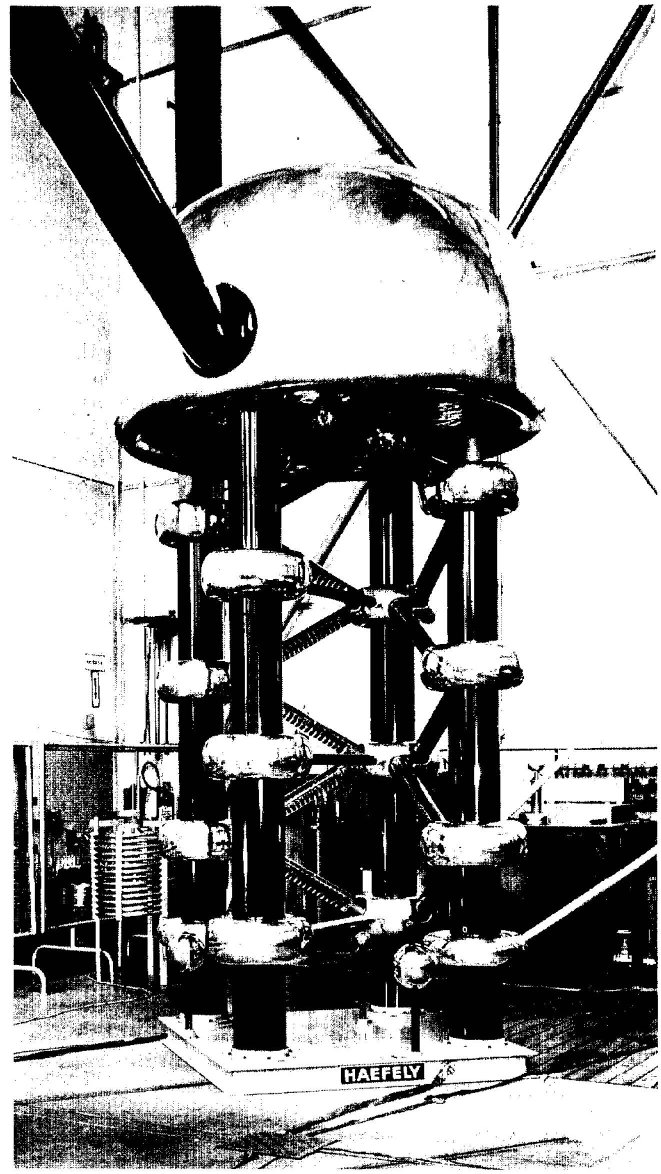

Fig. 1. 770 kV - 180 mA DC Power Supply

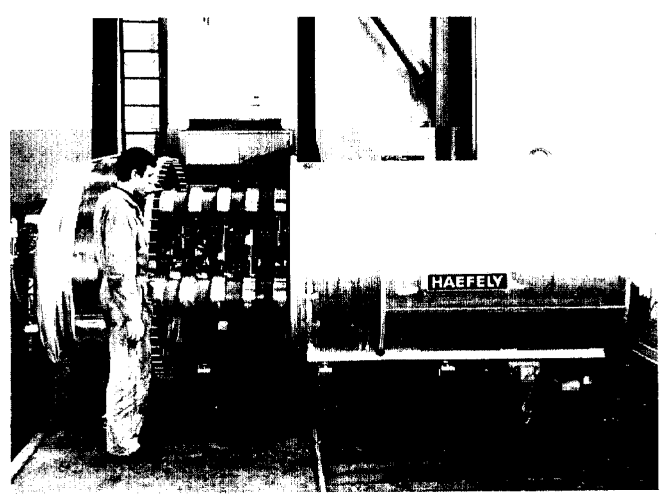

Fig. 3. 600 kV - 100 mA DC Power Supply