Switch-Mode Success

By Mel Berman

Onsite and on-demand production of disinfectants, biocides and water purification chemicals including sodium hypochlorite and chlorine dioxide has been substantially improved via the use of advanced switch-mode power supplies that provide the power for automated electrochemical generators.

Advances in power supplies for automated electrochemical mini-plants

Many municipal water, food processing and wastewater treatment plants are switching over from the use of chlorine disinfectants and biocides to safer and more environmentally friendly point-of-use and on-demand generated chemicals. The primary reasons for these changes are that conventional chlorine agents require transport by tankers on accident-prone highways and railroads, the ever-increasing safety and environmental regulations regarding toxic gases and chemical spills and required bulk storage of these hazardous materials at the sites where they are used.

Safer, and in many cases, more effective chemicals have been developed that can replace chlorine. For example, after many trial-and-error attempts to find a way to effectively control Legionnaires' disease, it was found that chlorine dioxide (ClO_2) was one of the few chemical agents that could consistently and safely disinfect Legionella bacteria. Add to this the ability to manufacture these safer chemicals at the locations that use them—and only when needed—and the advantages in total become obvious.

ZUP programmable power supplies.

Photo courtesy of PureLine Treatment Systems.

The PureCIO_2 HP-100 electrochemical chlorine dioxide generator can produce up to 100 lb of chlorine dioxide per day from sodium chlorite.

Two popular substitute chemicals for chlorine are CIO_2 and sodium hypochlorite (NaOCI)—both of which can be manufactured via mini-plants, or generators, that are delivered to the end-user's site as a complete package and provide the disinfectants on demand and as needed. In many cases, these mini-plants operate automatically and can be employed in unmanned locations such as municipal water treatment sites.

Electrolysis

These electrochemical generators use the process of electrolysis as the basis for producing these disinfecting and biocide chemicals. Recalling past science classes, electrolysis is a common method of separating bonded elements and compounds by passing an electric current through them. It involves applying a voltage between two electrodes (anode and cathode) that are submerged in a conductive solution (electrolyte). When a voltage is applied to the electrodes, electric current flows and breaks down the molecules within the solution into its components (Figure 1).

Instead of a static vessel as shown in Figure 1, modern electrochemical generators pump the electrolyte solution continuously through one or more tubes that have the electrodes mounted within them. As the electrolytic solution flows through these tubes (electrolytic cells), the electrolysis process continuously separates the molecular components. In some instances, the solution is run through the dual-electrode electrolytic cells more than once to further refine and separate the resulting chemicals (Figure 2).

Historically, the power supplies that provide the driving force for electrochemical generators have evolved from basic transformer and diode rectifiers to transformer and silicon-controlled-rectifier (SCR) power sources, then to modern and more sophisticated power sources. The development of the switch-mode power supply greatly reduced the size and substantially improved the efficiency of these power sources. In addition, switch-mode power supplies have the ability to provide electronic signals for status information (i.e., volts, amps, temperature), remote control and communications to and from a programmable logic controller or a local/remote computerized controller.

The vast majority of switch-mode power supplies are designed to operate as regulated voltage power sources. These supplies regulate the output voltage very precisely regardless of the amount of current drawn from the supply, up to its design limit. A 1,500-watt supply, for example, can provide a 12-volt output while providing 0 to 125 amps of current. Once the maximum current of 125 amps is reached, the supply is designed to go into a current-limit mode, where the output voltage is automatically reduced or the supply shuts down.

It has been found in many electrochemical processes, including the production of disinfecting agents, that standard voltage-regulated power supplies do not always provide the ideal power profile for these processes. In fact, in many instances, the power supplies are forced to operate at a fixed voltage and at their maximum current rating. If these operating conditions are maintained for long periods of time, the supply will internally heat up and prematurely fail, thus shutting down the production of the disinfecting agents.

Constant-Current Mode

Why does this happen and how can it be avoided? As described above, during the electrochemical process, in order to keep up with the continuous electrolysis process with constantly flowing electrolyte solutions, the power supply must provide a high enough voltage to overcome the impedance between the two electrodes and the solution surrounding them and more importantly, to provide a high enough current density (amps) to effectively separate the molecules during the short time (determined by the flow rate) that the solution comes in contact with the electrodes.

By using a switch-mode power supply that is designed to operate in a constant-current mode (instead of constant-voltage, as is the norm), the electrochemical process has been found to produce chemicals more quickly with a consistent high quality and without forcing the power supply into an overload state.

There are a number of ways of providing current-mode power supplies for enhanced electrochemical applications. One method is to use programmable power supplies. These supplies are designed to be manually or remotely programmed to operate in a voltage mode or a current mode at a specific voltage and current range, along with other specified parameters. As an added bonus, these supplies usually include a serial digital communications port that allows them to "talk" to local or remote computer controllers.

Additionally, these supplies can be connected in parallel to the electrodes or to groups of electrodes when an electrochemical process requires more current than one supply can provide. For example, Lambda Americas' ZUP10-80/U programmable power supplies are adjustable from 0 to 10 volts with 0 to 80 amps

Figure 1: Basic electrolysis.

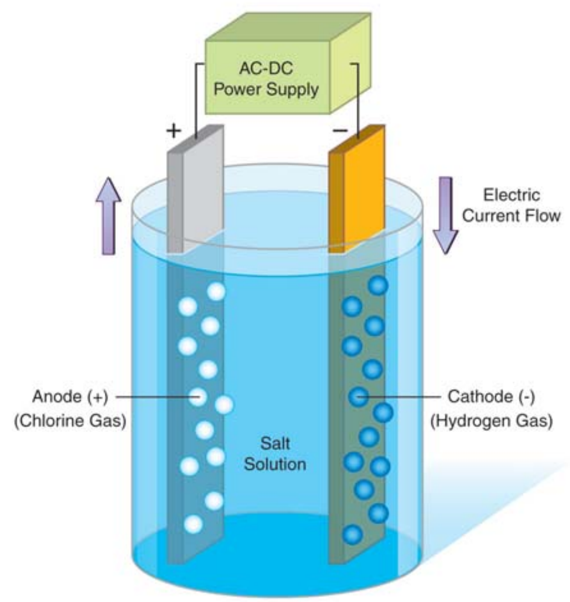
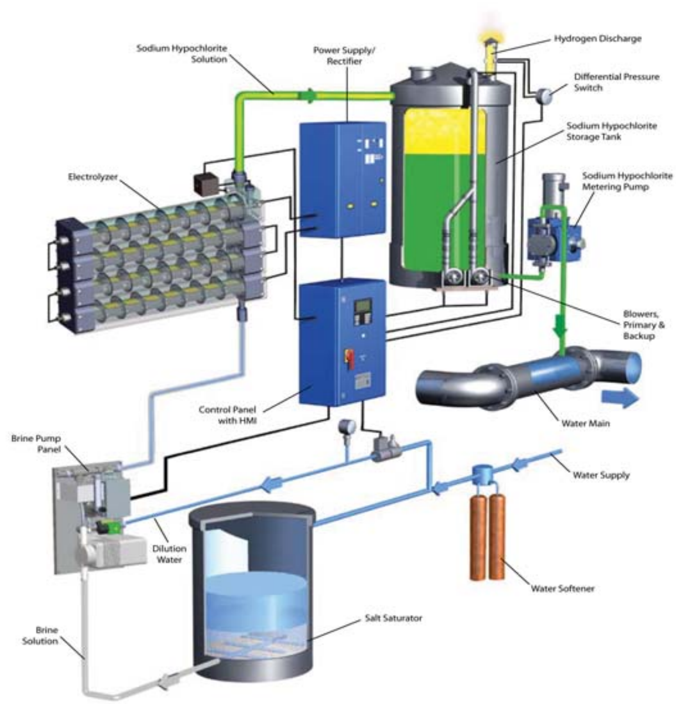


Figure 2: Dual-electrode electrolytic cells.



Graphics are courtesy of Siemens Water Technologies.

(800 watts total). This type of supply is being used in its constant-current mode to efficiently produce disinfectant and biocide chemicals at many unmanned and non-air-conditioned municipal water treatment sites. In some applications, two or more ZUP supplies are connected in parallel to provide the necessary amount of current for the electrochemical process.

Another method of providing a constant-current mode power supply is to modify the design of a voltage-regulated supply; adding circuits that monitor the supply's output current will prevent an overload yet maintain a constant-current profile from the supply. Lambda Americas' modified versions of its HWS-CC 1500-watt supply do this. In electrochemical applications that produce disinfectant and biocide chemicals, a number of these current-mode supplies are connected to different sets of electrodes, or in parallel, to support different output current requirements for various models of electrochemical generators. Generators that produce higher output rates of chemicals require higher current levels.

Switch-Mode Summarized

This paper has focused on the techniques and benefits related to advanced switch-mode power supplies for mini-electrochemical generators (self-contained plants) that produce disinfecting and biocide chemicals on site. It should be noted that electrolysis processes are used extensively in many other chemical and industrial areas, some of which include:

- Producing aluminum, copper and sodium;
- Anodizing;
- Producing hydrogen (e.g., for the cars and fuel cells of the future);
- Electroplating and polishing; and
- Factory and power plant cooling towers—recirculating water treatments.

Many of these electrochemical processes require power levels that far exceed the range of the switch-mode power supplies described above. These high-power rectifier systems, ranging from 300 kW to 10 mW, are very specialized, large and heavy, and are usually comprised of huge transformers, rectifiers, thyristors, SCRs, capacitors, regulating controllers and water-cooling systems. Some of these high-power sources are as large as a typical kitchen or even a house. There is no doubt that as technologies advance, these huge power sources will see reductions in size and improvements in efficiencies.

In summary, the application of modern switch-mode power supplies operating in a constant-current mode has been shown to provide significant improvements in electrochemical self-contained mini-plant generators that are used to produce disinfecting and biocide chemicals. These benefits include:

- Improved current-density control for consistent electrolysis;
- Enhanced quality of the resulting chemicals;
- Higher efficiencies and improved regulation of the power sources;
- Reduced space and weight;
- Compliance with international safety and power factor correction standards;
- Availability of digital communications, remote control and status signals; and
- Substantial reduction of downtime. WWD

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