Variable Electronic Power Supplies

RED Elektronik AG

V02/08

HighTech aus Deutschland

Introduction

The electronic conversion of energy provides an efficient means of varying the voltage and frequency of electricity provided by the public electricity supply, a DC battery, or renewable energy sources such as wind turbines. The fast response times of power electronics, enables the output to be held fairly stable despite variable conditions, such as the increase/decrease of a load or fluctuations in the supply.

Conventional thyristors have the highest ratings of all power electronic devices, they are robust, have low conduction losses, are relatively inexpensive but they have slow turn-on and cannot be turned off other than by stopping the flow of load current. For applications that require control of public supply voltages at frequencies of 50 and 60Hz they are the first choice, and in particular because of their ability to withstand high forward and reverse voltages.

However, if the requirement is to produce alternating voltage from DC such as in the case of frequency inverters or switched-mode power supplies, then devices with faster switching rates are more desirable. In such cases the choice is between bipolar power transistors, insulated gate bipolar transistors (IGBTs), MOSFETs or gate turn-off thyristors. When switching rates of greater than 100kHz are required, MOSFETs (metal oxide semiconductor field-effect transistors) are the only possibility, whereas up to 100kHz bipolar transistors and IGBTs are more price effective, have lower conduction losses but suffer from higher switching losses.

Most electronic power supplies use a microprocessor system for controlling firing pulses and the spare capacity of the microprocessor can be used to run displays, provide fault-finding diagnostics and to store settings. For more sophisticated applications they can be programmed to give specific functions such as acceleration and braking times, soft-starting, loss minimisation and closed-loop control. They can also provide interfacing with computers and PLCs for remote enable and set-point control as well as status monitoring. A large number of controllers can be co-ordinated in a process by using a field bus communication network.

Electronic power controllers can be designed so that they always operate safely despite harmful, external fault conditions such as short-circuits or overloads, although this is easier to achieve with thyristor based units.

This guide describes the various types of electronic power control systems that are manufactured by REO ELEKTRONIK AG with application examples and explanations of why a particular circuit design or device was chosen in each case.

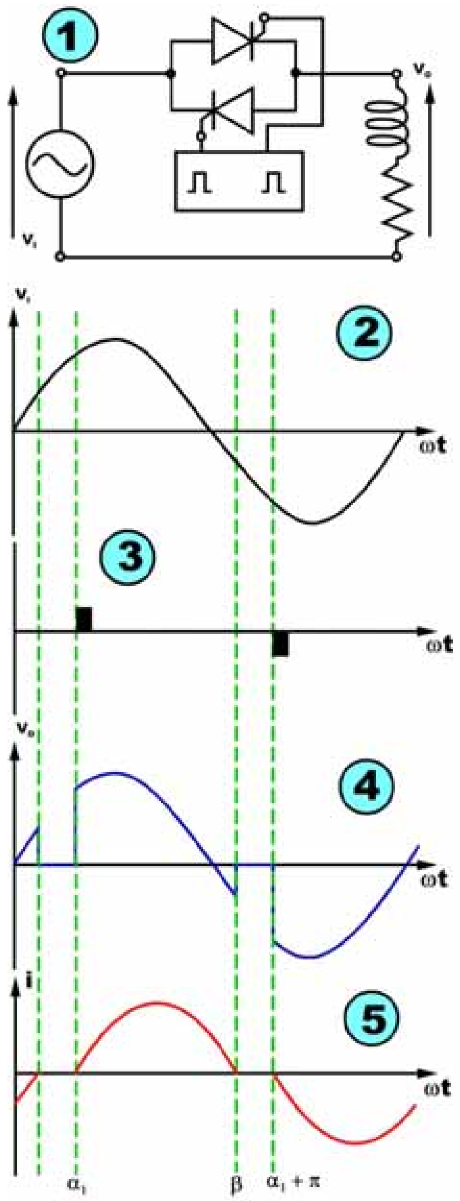
Power Switching

Using thyristors instead of contacts is a good way of switching power on and off and one good example is in the case of power factor correction where the capacitive reactance has to be adjusted to maintain a power factor of between 0.95 and 1. This is achieved by monitoring the power factor and switching banks of large capacitors in and out of circuit – typically in 25 kVAR units.

The picture shows the REO RP Controller with a capacitor bank.

AC to AC Conversion – Phase-angle control

Where simple control of the voltage amplitude is required then phase-angle controlled thyristor rectifiers are often used, and are often the only viable devices at very high powers, providing the cost of harmonic mitigation can be met. The thyristor is a semiconductor which has a gate and only allows current flow in one direction (from anode to cathode). When a small voltage is applied to the gate this induces current to flow through the power circuit and it will continue to flow until the current falls to a threshold level, determined by the characteristics of the component and usually just above zero amps.



1) The circuit diagram at the top shows a pair of thyristors in anti-parallel connection used as a phase-angle controlled switch to regulate the voltage supplied to a single-phase load.

2) A trace of the mains supply voltage shows that this is a sine-wave.

3) Firing pulses are generated by the control system and these initiate the flow of current at any point in the appropriate half-cycle of the mains supply sine-wave.

4) The output voltage trace shows how the conduction of each thyristor is initiated by the firing pulses at any point in the appropriate half-cycle and how it controls the effective output voltage value. With an inductive load, which is often the case, conduction will continue part way into the following half-cycle.

5) The current trace at the bottom shows how the current flows when voltage is applied. The current continues to flow until the current level passes through the zero crossing point, where it ceases to flow according to the physical properties of the thyristor.

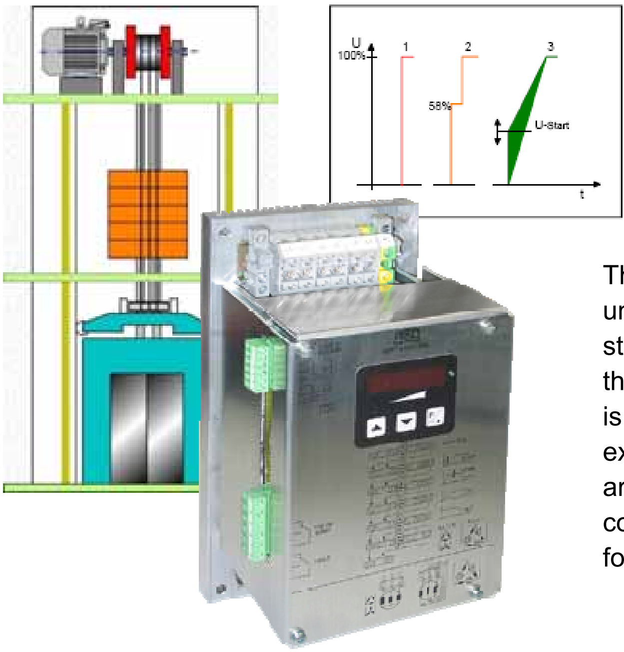
The phase-angle α can be at any angle between 0 and 180° for each positive and negative half-wave, with 0° being full conduction or maximum voltage amplitude. The output voltage and current traces are not true sine-waves but this will be suitable for most loads. The non-linear switching of the thyristors does generate harmonics on the mains supply and so some form of harmonic filtering is usually required (such as the REO CNW 854).

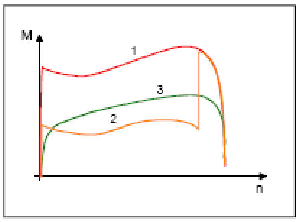
Typical applications for phase-angle controllers

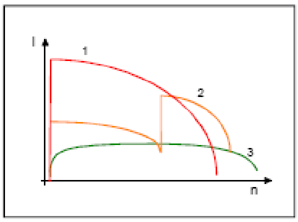
Phase-angle controllers are ideal for when a quick response is required, for example in fan, pump or lighting control systems or an application where there is changing load impedance between hot and cold conditions such as with heating elements.

A typical use of a phase-angle controller is for soft starting, where the initial torque required to provide initial movement of a mechanical load, such as a fan or elevator, causes a high-current to be drawn from the mains, which can be up to ten times the normal running current. The start-up current is reduced considerably by increasing the voltage gradually until the full voltage is applied.

Lift Application





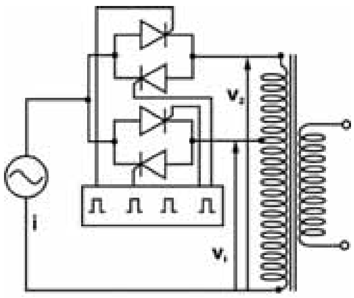


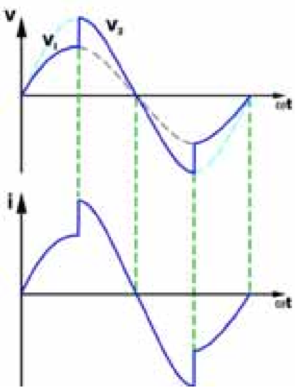
The SAG M 300 is a microprocessor controlled soft-start unit with current limiting, which provides a very efficient start-up technique because at all stages of the procedure the maximum amount of voltage can be applied since this is controlled by the current limitation which cannot be exceeded. Like all REO soft-start units all three phases are controlled. There is also a choice of 3 or 6 wire connections to the motor. The digital control panel is used for setting up the unit and displaying fault diagnostics.

Two-stage control – High Current AC

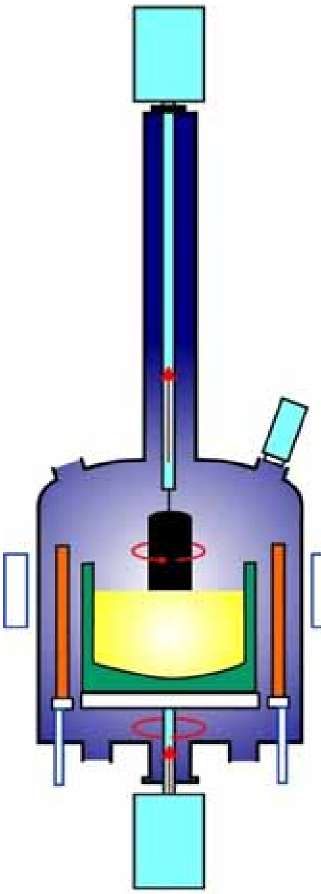
Reduction of harmonic distortion is becoming more important consideration because of stricter controls being imposed by electricity network operators, and by national EMC standards – both for very good reasons. One technique that REO uses for reducing harmonic is described below.

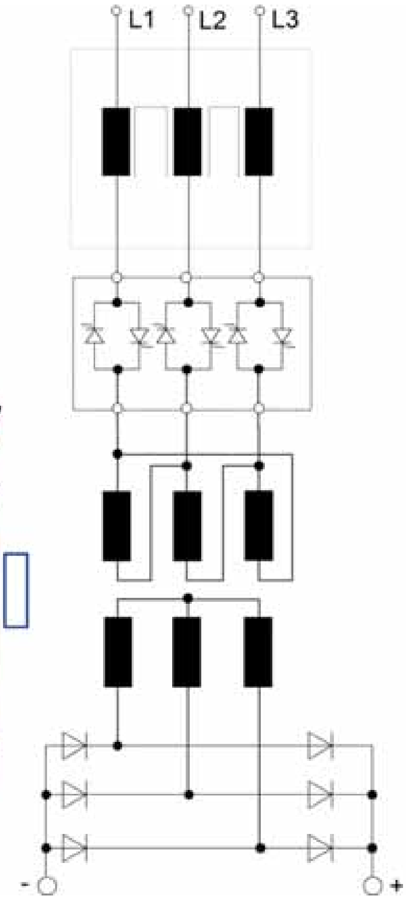
By sharing the load, for example by using a transformer and a 2-stage thyristor controller, the adjustment range can be divided into two levels, whereby only one stage works under partial load conditions. The 2nd stage only operates under phase-angle control in the upper part of the power range, so that the current curve corresponds more to a sine-wave than the one using just one stage.





High-Current DC – Silicon Crystal Growing



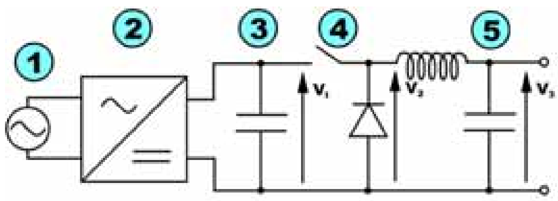


One of the most common methods used for producing silicon monocrystals which are used for manufacturing semi-conductors and photovoltaic cells is the Czochralski process.
This involves placing raw polycrystalline material in a rotating crucible in a vacuum chamber and then purging with argon, whilst melting the silicon using a resistance heating system.

After the temperature of the silicon has stabilised a seed crystal is dipped into the molten liquid and rotated. The temperature of the crucible is then gradually lowered whilst the crystal is withdrawn from the melt, encouraging new material to grow onto itself.

A regulated high-current power supply required for this process was specially developed by REO ELEKTRONIK AG and this comprises a three-phase thyristor controller, a water-cooled, high-current transformer and a rectifier – as can be seen in the circuit diagram.

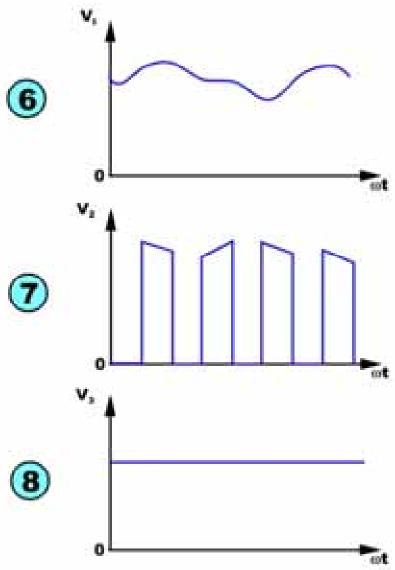
Switch-mode Power Supplies



Fast-switching semiconductors such as MOSFETs and IGBTs are very attractive to power supply designers because they enable the output voltage waveform and frequency can be determined by the switching topology, irrespective of the supply frequency.

Often the output is required to be DC with negligible AC ripple and for these applications a circuit similar to the one on the right is used. The main components are:

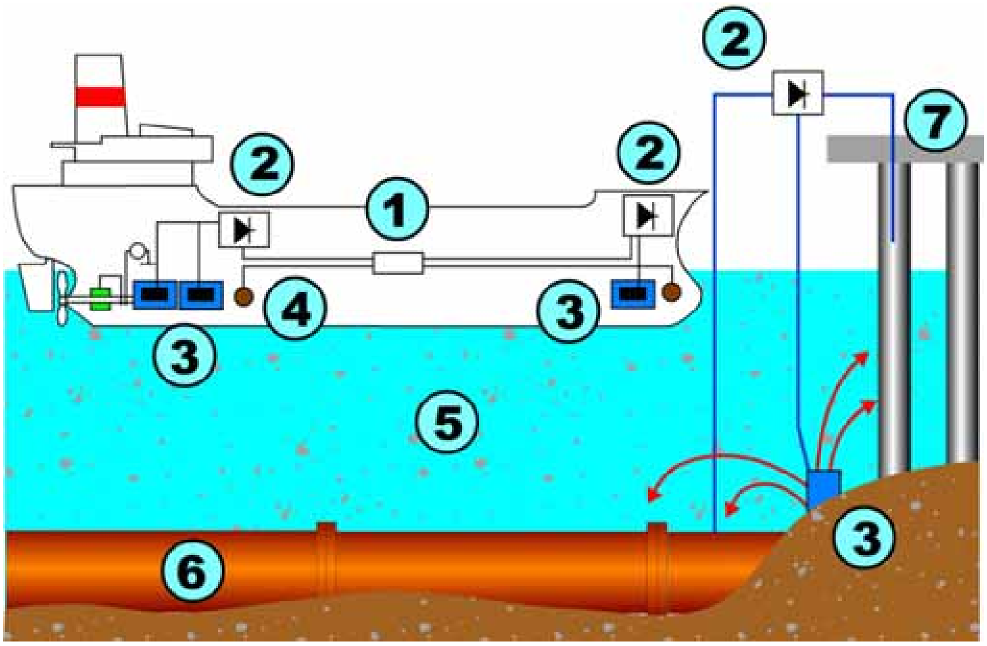
1) AC power from the mains supply
2) Uncontrolled rectifier
3) Capacitor to partially smooth the uncontrolled DC as it is being switched by the power semiconductor
4) Switching device such as an IGBT or MOSFET which can be turned on and off rapidly
5) LC network for filtering



By switching the rectifier output (6) very rapidly (7) between source level and zero control of the DC output is obtained and the voltage level is determined by the on/off ratio.

Low-voltage DC – Cathodic Protection

Variable DC power supplies are widely used for the protection of metal and concrete structures from corrosion. The presence of an electrolyte such as sea water or soil causes a spontaneous electrochemical process in which a metal reacts with its environment to form an oxide or some other compound. Effectively the metal surface becomes cathodic in some areas and anodic in others, caused by differences in the metal itself, variations in its protective coating or changes in the surrounding electrolyte. Protective coatings do provide a degree of protection but these have to be carefully applied and regularly maintained, therefore it is often better to combine this with a form of cathodic protection, especially in adverse environmental conditions such as in a salt-laden atmosphere or high-investment structures.



By using artificial anodes and impressing a current between these and the structure to be protected it is possible to inhibit corrosion. The diagram shows three examples of how this is achieved.

1) Often a central system is used to control several low-voltage DC power supplies.
2) The DC power supplies require low ripple and minimum leakage voltages. Often isolation from the mains power supply is an important requirement.
3) Long-life anodes are located near to but not touching the metal structure.
4) Reference electrodes are used by the central control system for monitoring the potential.
In this instance the electrolyte (5) is seawater and the structures to be protected are a tanker, pipeline (6) and a shore-side concrete structure (7) such as a jetty.

The picture shows a tandem switched-mode DC power supply type SMP 15-220 designed and manufactured by REO ELEKTRONIK AG for use in cathodic protection applications. These are just one example of a whole range of units built for different applications such as hypochlorite generation, electroplating, electro-chemical machining and ultra-violet water sterilisation.

Multiple DC Power Supply

For accurate, co-ordinated control of power using a large number of load elements, such as in a heating process, it is possible to combine many switched-mode power supplies in one enclosure, as can be seen in the picture below.

A field bus interface provided in each power supply is used for the remote adjustment of the voltage, current or power set-point and for enabling units as required. Internal parameters can also be set to match the application and continuously monitored by the supervisory system. Diagnostic displays are provided to assist with fault finding and to increase "up-time".

A summary of applications which use REO Power Controllers

- Electroplating
- Metal coating of plastic film
- Controlling vibratory conveyors
- Sodium Hypochlorite generation
- Crystal growing
- Cathodic protection
- Air conditioning equipment
- Power Factor Control systems
- Lifts and escalators
- Induction furnace heating
- Welding plant

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