A NEW CONCEPTION OF BIG POWER LOAD REGULATION

At present one of actual task of power electronics is to regulate the power that releases in different loads of industrial automatics in many industry fields. By specialists of many world's companies specialized in power electronics are developed and produced monolithic thyristor modules that allow you to adjust the loads with operating current up to 250 A. An important feature of these modules is availability of inbuilt interface devices that allow the customers to connect such regulators to controllers with standard current and potential signals (4-20 mA, 0-5 V, 0-10 V).

Semiconductor optoelectronic modules of power regulators are for changing the voltage that connecting to the load – power regulating that transfer to the load from AC power.

Modules M25 are thyristor converters that is driven by the net where used the regulating phase method of AC regulation, in which the changing of AC load root-mean-square value is made by changing of open state duration of one of a switched off opposite-parallel thyristors during of net frequency half-cycle.

In the modules M25 have realized a principle of synchronous pulse-phase controlling in which is produced the managing pulses phase regulation (moment changing of unlock pulses supply to thyristors towards sinusoidally varying voltage curve).

The structural scheme and functional application of the assemblies of the module M25 shown in Figure 1.

A reference voltage generator RVG with a null-element NE represents a phase shifter PhSh of vertical-type control.

The RVG forms the ramp voltage synchronized with voltage. With NE the reference voltage is compared with the control signal C_α. When the reference voltage in increasing process (or decreasing) achieves the value C_α, at the output NE appears the pulse that enters the amplifier-shaper ASh. The ASh gives the switching pulse to controlled valves CV.

Ramp voltage of RVG and formed pulse synchronized in time with AC voltage. By changing the value C_α occurs a shift in time the output pulse and angle adjustment α, and hence and converter output voltage adjustment.

The functional scheme of the module M25 shown in Fig. 2, functional application of outputs shown in Table 1.

Galvanically isolated scheme of the voltage transfer through the zero indicator forms synchronized pulses t_0 with frequency, multiple frequency network, at a controlled voltage level less than 30 V. Voltage diagrams, for clarity are made not in a scale, shown in Fig. 3.

A phase regulator forms a signal of managed angle α that is counted from the beginning of voltage half-cycle and depending on a controlling signal value C_α.

The optoelectronic driver by control signal α forms and distributes the unlocking pulses on controlled electrodes of power thyristors.

Permissible value of repetitive pulse voltage in the closed position of power thyristors is 1200 V providing a reliable product when a surge, depending on the nature of the load.

A control signal converter converts the control signal of 4 types (0-5 V; 0-10 V; 4-20 mA, 0-5 mA) to the signal C_α for two types of control characteristics depending on an embodiment of the module. Angle dependence of thyrostor's conductivity (the time during which thyristors conduct current) of the relative value of the control signal is shown in the charts of Fig. 4.

When the root-mean-square value of the switching voltage is changed then happens the time changing of synchronizing pulses t_0 and, in hence, some decreasing of thyristor conductivity angle. Dependence of the conductivity angle of the switching voltage value is shown in Table 3.

A hybrid assembly of the module M25 is constructively made in a rectangular metal-plastic house having a hermetic construction. The power part of the modules is made on thyristor structures with maximum allowable voltage 1200 V that resistant to the rate of voltage increase not worse than 500 V/μs, to the rate of current increase – not worse than 160 A/μs and voltage decrease in open state not worse than 1.5 V. In depending on the rating the devices can adjust the power with operating current 20, 63, 100, 200, 250 A, while the pulse currents (10 ms) are 160, 600, 1250, 2500, 3000 A.

On the top surface of the house are vertical outputs for connecting the equipment wire. The device's house is isolated from power circuits (isolating voltage is not worse than AC 2500 V). Electric control contacts and power contacts are also isolated from each other.

The low metal surface of the house is radiating one. To ensure reliable operation of the module it's necessary to install a module's house on a heat sink (cooler or constructive element).

Coolers provide the power modules with operating current I that is determined from the relation

$$I=\frac{125-T_{env}}{\theta * U_{res}},$$

where T_{env} – environment temperature, U_{res} – decrease of voltage in circuit current flow, θ - thermal resistance of the cooler that determined from the charts for preset speed airflow. Dimensional drawings of coolers and drawings of transient thermal impedance are shown in Table 4.

The produced modules differ by type of operating characteristics, by type of controlling signal and rate current that corresponds to the long-term allowable rms current through the device.

Notation:

1. The name of the module:
   - M25 – power regulator module.
2. Characteristics of control:
   - A – 100% of the control signal correspond to the zero power;
   - B – 100% of the control signal correspond to the full power;
3. View of control signal:
   - 1 – 0-5 V;
   - 2 – 0-10 V;
   - 3 - 4-20 mA;
   - 4 – 0-5 mA.
4. Maximum switching current, rms:
   - 20-20 A;
   - 63-63 A;
   - 100-100 A;
   - 200-200 A;
   - 250-250 A.
5. Peak value of switching voltage:
   - 12-1200 V.

Recommendations for application of power regulation modules

Modules M25 are thyristor converter of alternating voltage that constructed by a synchronous principle. Normal operation of the modules is possible only if there is power mains supply that has multiple high load power.

Possible connecting schemes of the modules M25 to load circuit are shown in Fig. 5 and 6. Serial connection of synchronized circuit with load is allowed when the load power coefficient $\cos\varphi \geq 0{,}9$. A scheme with parallel connection of synchronizing circuit is more jam-resistant.

With strong interferences that come from the mains, synchronizing circuit connection should be made through the isolating transformer having $K_{tr} \approx 1$ and power not less than 2 W.

The installation is not allowed us to prevent the laying of power line wires and control circuits in a bundle or a common tube (house).

To avoid loops in the connecting wires of control and supply circuits. Connecting wires for providing jam-resistance should be made as a twisted pairs.

For modules M25 power thyristors protection against destructive effects in close proximity to modules' outputs is required to install the protection circuits. Possible protection circuits schemes are shown in Fig. 7 and 8.

For thyristor structure protection against overload is necessary to use the varistors of types CH2-1 and CH2-2 with coefficient of nonlinearity more than 30 and dissipation energy 10-114 J, classification voltage 680-750 V for net 380 V and 390-470 V for net 220 V. It should be noted that other conditions being equal the varistor voltage in time of overvoltage depends on the current. When commutating of large current the use of 12 class thyristors increases the reliability of the product but does not preclude the need for use of the varistors.

For voltage rise speed decrease (transients in commutative net or surges when the inductive character load net is open) is necessary to use the damping RC-circuit. The parameters of protective RC-circuit for limit switching currents are shown in Table 5.

For current rise speed decrease (initial stage of active and capacitive character circuit load switch) is necessary to use a delay reactor – an inductive coil in the magnetic core with high magnetic permeability and a rectangular hysteresis loop. The range of necessary inductivity value is L = 3...30 mH.

When connecting an inductive nature load of the risk of over-current due to the asymmetry of switching moments in the positive and negative half-cycles, which leads to the appearance of a permanent component of flowing current, as well as the coincidence of the sign of the residual magnetization and the current generated at the time of inclusion. The resulting inrush current can be tens of times higher than the rated current, and the case of switching at the time of the transition voltage phase through zero- the worst case. When connecting loads of capacitive type exists the danger of over-current in the power circuit and the effects on voltage thyristors, reaching twice the amplitude of the switched voltage, and the moment of switching at the time of the maximum voltage amplitude - the best case. Amplitude value of the voltage when switching the thyristors at full power is 30 V. Electrical surges appear in each half-cycle of switching voltage. When the capacitive load 100 µF and the absence of current-limiting element, the amplitude of such surges is 500-1500 A. They generate the significant electromagnetic interference - powerful high-frequency components in the spectrum of the load current. The last ones can cause overheating and breakdown of the capacitors.

For controlling of power in inductive character load circuit the primary switch of thyristors should make in a maximum point of net voltage, that is when the control signal is 50%. The full regulator shutdown must be performed at small conduction but not equal to unity degree as there is a possibility of appearance of switching asymmetry because of net instability frequency. It should avoid feeding of control signal with a value that corresponds to the total angle conductivity as it can lead to the mode of continuous current through the thyristors (because of phase shift between load current and voltage one of controlling pulse supplying moment will happen earlier than a switch off moment of other thyristor). Such mode occurs when the equality

$$\alpha_{crit} = \alpha_{contl} = \mathrm{arctg}(\omega L_H/R_H)$$

For power controlling in a load circuit of capacitive character the primary switch and full shutdown should perform at small value of voltage, that is at value of control signal that corresponds to the small conductivity.

Due to electrical losses in the module is released thermal energy. If an intensive cooling of the module is not provided then thyristors' heating can exceed the permissible value, and because of it the reliability of the device will be decreaseв and is even possible complete failure of the module.

The value of thermal resistance of coolers at different cooling air speed and the dependence of the required thermal resistance of the cooler on the value of switching current is shown in charts Fig. 9.