1 Research of characteristics of power semiconductor devices

The main intension of the work is to give hands on experience for students with the classification system of power semiconductor devices (SPD), methods of testing and experimental study of the characteristics of a thyristor.

1.1 Lab Description

The laboratory setup consists of two power sources for the power circuit of the SPD for drawing their current-voltage characteristics in open and closed states, a direct current source for powering the control circuit tested SP and protection and blocking circuits.

The lab is turned on by the switch $S1$ (fig. 1), and the preparation of the junction of one of two sources power supply circuit power supply – by connection the $XP1$ plug connector in the socket $XS1$ or $XS2$ and turn switch $S4$ to the appropriate position. The SPD under review (thyristor VS1) is connected to terminals $X1 - X4$.

The voltage and current of the power circuit of the SPP are regulated by the T1 autotransformer. SPD control current adjustment carried out by potentiometer $R1$ (roughly) and rheostat $R2$ (accurately). Values control current and voltage are determined by a voltmeter PV and an ammeter $PA3$.

The power supply circuit of the SPD under the studying of its characteristics in the open state is carried out through transformer TK. To do this, $XP1$ is connected to $XS2$, and switch $S4$ is set to the lower position. The half-wave form of voltage and current of the SPD, necessary for characterization, is provided by the $VD5$ diode and the sinusoidality of the current curve is achieved by the diodes $VD6$, $VD7$ (creating a circuit for the flow of current in the second (non-working) half-period of the transformer voltage $T3$ and excluding due to this bias of its core by direct current) and inductance of the inductor L, (limiting the value and improving the current transformer shape). The average values of voltage and current of the SPD are determined by a $PV2$ voltmeter and ammeter $PA2$. To observe the curves of the anode voltage and current, the input of the oscilloscope is connected to terminals $X8 - X9$ and $X8 - X10$, respectively.

When examining the characteristics of the SPD in the closed state, $XP1$ is connected to $XS1$, and switch $SS4$ is installed in the upper position, in which the power circuit of the SPD is supplied through transformer $T2$. The average values of the voltage and current of SPD are measured with a

PVI voltmeter and a PAI ammeter. The polarity of the input voltage is determined by the position of the switch $S3$. Classification characteristics is observed with the switch $S2$ open. In this case, to the SPD through the diodes $VD1$, $VD2$, VD is supplied half-wave voltage from the secondary winding of the transformer $T2$. The $VD4$ diode sharply reduces the value negative half-wave voltage applied to the diode $VD3$ and SPD, which ensures the flow of current through SPD in only one direction. To observe the shape of the curves of the anode voltage and current input the oscilloscope is connected to terminals $X6 - X5$ and $X6 - X7$, respectively.

To observe the static current-voltage characteristics of the SPD in the closed state, the $S2$ switch connects filter capacitor C, which provides power to the DC power circuit with a constant voltage.

To turn on the power supplies of the power circuit of the SPD it is necessary:

- set switch $S4$ and plug connector $SP1$ to the desired position (upper or lower);
- set the autotransformer $T1$ to the lower position;
- turn on the switch $S1$ and the power supply of the control circuit;
- by pressing the SB button, turn on the relay $K2$, the contacts of which close the power supply circuit of the SPD.

The voltage relay $K3$ prevents the relay $K2$ from turning on when there is voltage at the output of the autotransformer $T1$. The sensitive current relay $K1$ traps the relay K2 in case of a dangerous increase in the leakage current of the SPD preventing it damage. When the connector $SP1$ is switched, the power supply circuit of relay coil $K2$ opens, therefore After switching the connector, you must repeat its inclusion with the SB button.

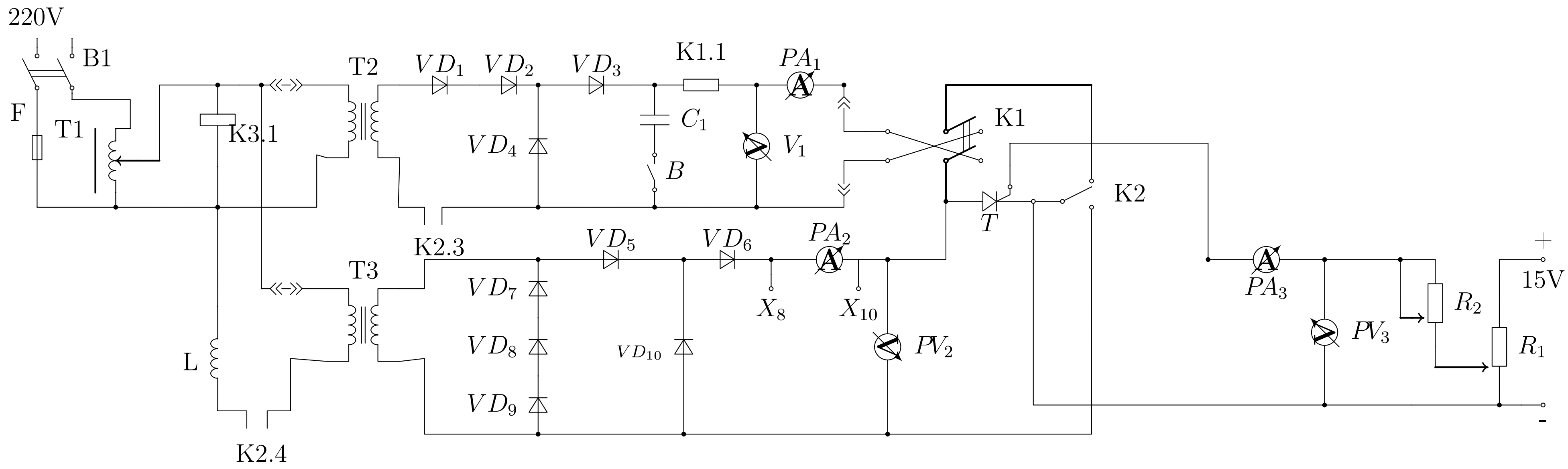

Figure 1: Laboratory arrangement

1.2 Task 1

Study of thyristor characteristics

1. Connect the test thyristor $VS1$ to terminals $X1 - X4$.

2. Observe and draw the static current-voltage characteristic of the thyristor control circuit $I_{ctrl} = f(U_{ctrl})$.

3. Determine the values of the control unlocking current $I_{ctrl.}$ and the unlocking control voltage $U_{ctrl.o}$.

4. Observe and draw a direct branch of the classification current-voltage characteristic of the thyristor $I_a = f(U_a)$ in the open state.

   Sketch from the oscilloscope screen a direct branch of the dynamic current-voltage characteristic of the thyristor in the open state $I_a = f(U_a)$ and the curves of the anode current $I_a = f(\omega t)$ and voltage $U_a = f(\omega t)$ at maximum anode current.

5. Determine the pulse voltage in the open state, the value of the threshold voltage U_0 and differential resistance Rd.

6. observe and draw the direct and inverse branches of the classification $I_{a.av} = f(U_{a\,max})$ and static $I_{a.st} = f(U_{a.st})$ current-voltage characteristics of the thyristor in the closed state at the following current values control: $I_{ctrl} = 0$; $I_{ctrl} = 0.9 I_{ctrl\,o}$; $I_{ctrl} = 2.0 I_{ctrl\,o}$.

   In the classification scheme, draw from the oscilloscope screen a form of voltage curves $U_a = f(\omega t)$, forward and reverse leakage currents $I_a = f(\omega t)$ at $I_{ctrl} = 0.9 I_{ctrl\,o}$ and the maximum possible values of the anode voltage.

7. Determine the thyristor class and the values of the direct ($I_{direct\ leak}$) and reverse ($I_{reverse\ leak}$) leakage currents.

8. Determine the value of the holding current of the thyristor I_{hold}.

1.3 Methodological instructions to accoplish the task

1. The static current-voltage characteristic of the control circuit of the SPD is observed on a direct current in the absence of the main (anode) voltage.

2. The values of the unlocking current and unlocking voltage control are determined in the circuit of the SPD in the open state.

   For this, it is necessary to set the average value at zero value of the control current. the main (anode) voltage ($PV2$) 1.5 V and, gradually increasing the current and control voltage, fix their values at the moment of the appearance of the main (anode) current (according to $PA2$).

3. Classification current-voltage characteristics of the power circuit of the SPD are observed at average values half-wave voltage and current according to the readings of $PV2$ and $PA2$ devices at a control current equal to 1.2 $I_{ctrl\ o}$. Since the rated (classification) current of the tested SPD under natural cooling equal to 6 A, the observing characteristics from 6 to 10 A in order to avoid overheating of the semiconductor structure need to produce fast.

4. The observation of the direct branch of the dynamic current-voltage characteristics of the SPD in a state of high conductivity produced from the screen of the oscilloscope when a signal is fed "vertically" to the input of the oscilloscope amplifier, proportional to the current of the SPD and to the amplifier input "horizontally" - a signal proportional to the voltage on the thyristor. To do this, turn off the oscilloscope sweep generator, connect a common point amplifiers to terminal $X10$, and the inputs of amplifiers to terminals $X9$ and $X8$, respectively. Since the amplitude sinusoidal half-wave current ($I_{a\,max}$) is in π times more than its average value, the greatest deviation of the current curve on the oscilloscope screen corresponds to an instantaneous value equal to $I_{a\ max} = \pi I_{PA2}$, where I_{PA2} is the current value measured by the $PA2$ ammeter. The scale of the voltage curve is determined using external source. The curves drawn from the screen onto the tracing paper must be transferred to the graphs taking into account their corresponding quadrants and scales.

   Differential resistance and threshold voltage are determined by the dynamic current-voltage characterization of open-loop SPD by approximation by its broken line, consisting of a horizontal segment and an inclined beam crossing the characteristic at points $0.5I_{m\ nom}$ and $1.5I_{m\ nom}$, where $I_{m\ nom} = 6\ A$ is the amplitude of the rated current STP.

5. To avoid damaging of the device when taking the current-voltage characteristics in the closed state the applied voltage is increased smoothly, carefully fixing the increment of the leakage current and stopping further increase in voltage, as soon as at a certain value of U_{zigzag} a sharp increase in current begins.

When plotting the classification characteristics of the SPD in the closed state, the average value voltage ($U_{a\ av}$), observed by the voltmeter $PV1$, is converted into the amplitude ($U_{a\ max}$) and characteristics are constructed in the form of dependences $I_{a\ av} = f(U_{a\ max})$. Since the voltage has a half-wave sinusoidal shape, conversion factor is π. Taking into account the same coefficient, the scale of the curves is determined by the voltmeter $PV1$ voltage $U_a = f(\omega t)$ observed when the oscilloscope is connected to terminals $X6 - X5$. The scale of the current curves is $i_a = f(\omega t)$, observed when connecting the oscilloscope to terminals $X6 - X7$, is determined using the ammeter $PA1$ by the deviation beam in the circuit for taking static characteristics, i.e. when $S2$ is on. Curve taking $U_a = f(\omega t)$ and $I_a = f(\omega t)$ is produced at voltages close to U_{zigzag}.

6. The rated voltage of the SPD is determined as follows:

   (a) according to the current-voltage characteristic in the low conductivity state taken at $I_{ctrl} = 0$, the amplitude voltage values $\pm U_{zigzag}$;

   (b) the smaller of the stresses / + Usag / and / -Usag / Multiplied by the safety factor, the numerical value of which usually around 0.75;

   (c) the obtained voltage value is divided by 100, and the result is rounded down to the nearest integer, which is the class of a given valve, i.e., its rated voltage, expressed in hundreds of volts.

   If the class turns out to be less than the third, for a more complete use of devices, division into classes produced in 0.5.

7. The holding current of the SPD is determined in the circuit designed for observing the direct branch of the static volt-ampere characteristics in a state of low conductivity. For this, at zero anode voltage the control current is set equal to $1.5 I_{ctrl\ o}$; by adjusting the autotransformer $T1$, the anode current is set at the maximum mark of the ammeter scale $PA1$, after which the control current decreases to zero and with a smooth reducing the anode current by adjusting $T1$, its value ($I_{ctrl\ d}$) is fixed at the moment of switching off the SPD.

1.4 Report content

The report should include:

1. laboratory setup and its brief description;

2. graphs and oscillograms specified in the task;
3. the conclusions based on research results.