СЕКЦІЯ 4. ІНФОРМАЦІЙНО-ВИМІРЮВАЛЬНІ ТЕХНОЛОГІЇ І СИСТЕМИ

DEVELOPMENT OF ELECTRONIC LOAD FOR SOLAR CELL TESTING BASED ON FIELD-EFFECT TRANSISTOR

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The electronic loads, which are available on the market, combine excellent accuracy with complex control interfaces and, as a rule, capable of operating at very high currents at high power. Different models are usually available, each of them is corresponding to a different voltage, power and current range, the lowest achievable resistance is about 5 mOhm, and the current can reach 80 A.

However, despite these technical characteristics, the overall efficiency of the load array is fundamentally limited by its electrical connection to the tested power supply source. Copper and aluminum conductors with a cross section of 40 mm^2 or more are used for the connection requirements and this connection length imposes significant resistive losses between the tested power supply source and the load modules. This additional resistance affects the load voltage, and the parasitic inductance L_p in the conductors limits the maximum speed of transients:

$$\frac{dI}{dt_{max}} \leq \frac{Vd}{L_p}$$

Also, for testing more powerful power supply sources, it is possible to combine several of these load modules in parallel (it is possible to achieve an effective resistance below 2,7 mOhm). Moreover, when more and more individual loads that are connected in parallel, the installation becomes larger, and, accordingly, the more resistance busbars and inductive losses on the connection busbar. Obviously, to achieve the highest speed of transients and the lowest total resistance requires a more specialized solution of electronic load.

To simulate the behavior of a powered semiconductor device, we need an electronic load with the following characteristics: the highest possible rate of load current increase (dI/dt) (at best the rate of increase is also regulated); regulated load current; high scattering power, both peak and continuous; ability to control the load current with high accuracy and wide bandwidth.

To test low voltage power supply sources at very high current levels (eg. solar modules) [1], the electronic load must have an ultra-low minimum resistance. Finally, the electronic load must be designed for connecting to the test source with minimal resistance and inductance, otherwise the overall efficiency will be limited by the connection itself.

The simplest load that can be offered is a power resistor. If its size and cooling are correct, it can meet the requirement for high power dissipation, and the current can be controlled directly (by measuring the voltage on a known resistor). Sequentially adding a switch allows you to generate a transient load. However, the load will be either fully on or off, and the current will depend on the voltage being tested. The velocity of current change is not controlled or regulated. Obviously, this is not a flexible solution that can be adapted to a wide range of testing requirements.

For providing changeable load and adjustable current reduction velocity (velocity which impect on the load current increases and decreases), it is necessary to build an active circuit based on an operational amplifier. The operational amplifier activates the gate of the power MOSFET transistor to set the controlled voltage on the sensor resistor [2]. It results in a controlled load current flowing from the outlet to the MOSFET source and through the sensor resistor to ground. The power of the MOSFET adds current amplification, but does not add voltage amplification because it works as a current amplifier (source - follower).

This circuit can be implemented with an n-channel MOSFET with a sensor resistor on the lower side or with a p-channel MOSFET with a sensor resistor on the upper side. Anyway, the sensor resistor adds negative reverse connection because it is plugged to a MOSFET source, subtracting the voltage from the gate voltage as the current increases, and vice versa by adding the gate voltage as the current decreases, which promotes stability.

The load current, according to the proposed scheme, is proportional to the voltage and the shape of the control signal, while the coefficient of amplification is set by ratio input resistances and reverse connection of resistances [3].

An active electronic load circuit has many advantages over a simple switching resistor. Unlike simple resistance, active resistance can generate alternating load current from zero to maximum current. Besides, when the load current is controlled by an operational amplifier in a closed loop, the current accurately tracks the control signal. Therefore, the active electronic load can control the rate of decrease of current. Finally, since the circuit has a resistive element with a fixed value, accurate measurement of the load current of the high bandwidth is relatively simple.

Based on the considered physical and circuit solutions for the implementation of the electronic load unit, the electrical circuit shown in Figure 9 was developed. These transistors are controlled by four unipolar operational amplifiers integrated in the LM324 chip. The control of the electronic load unit is realized by controlling the voltage at the positive feedback terminals, which is additionally stabilized by the TL431 chip. The unit is powered by a source of direct stabilized current with a voltage of 12 V (provides additional filtering from voltage fluctuations).

References:

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