Static Loss Measurement Methods for Quality Improvement

Steady increase of power for electric converter units leads to the constant enhancement of characteristics and load capacity of power semiconductors. Thus, requirements to the maximum current load of power thyristors and diodes, limited by heat-release losses in a semiconductor element and the intensity of heat removal from the die, are also increasing. Power semiconductor manufacturers do their best to the maximum reduction of conducting losses and preserving all the remaining characteristics at the required level by precise measurement of forward voltage drop. **Alexey Poleshchuk, Automation Lab Engineer, Proton-Electrotex, Orel, Russia**

Sufficiently small spread of parameters within 10-15% range can have a key influence on comparative load capacity of semiconductors due to the restrictions of maximum heat removal from the die. On the other side, it's often necessary to commute the currents higher than current-carrying capacity of large diameters dies (90 mm and more). In this case it's necessary to connect power semiconductors in parallel in a single unit where the devices should be precisely selected according to their characteristics in order to provide symmetric semiconductor load and annealing of heat release.

The above-mentioned tasks determine the necessity of maximum precise measurements of semiconductor characteristics, responsible for the static losses of conductivity (in this case - peak on-stage voltage (V_{TM}), for their correct classification and selection in groups for parallel connection. In order to measure V_{TM} at the operating currents in semiconductors with large diameters it's necessary to have the equipment able to form current pulses of desired amplitude and form with high accuracy and frequency. Thus not only current pulse amplitude is significant for characteristics measurement, but also its length, form and further treatment of the received data are important as well.

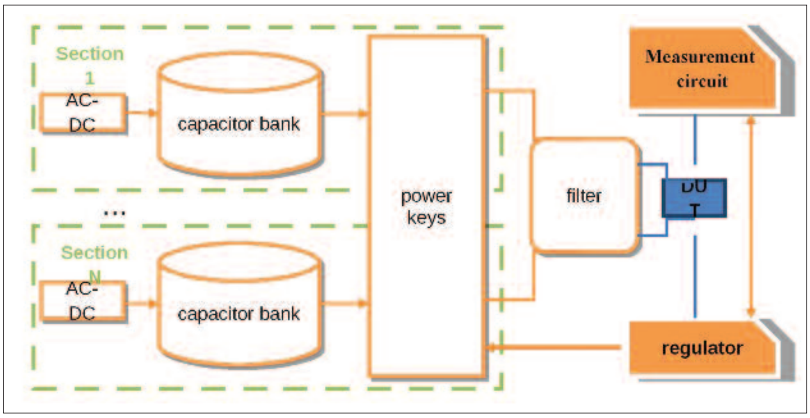

Figure1: **Functional scheme of measuring module**

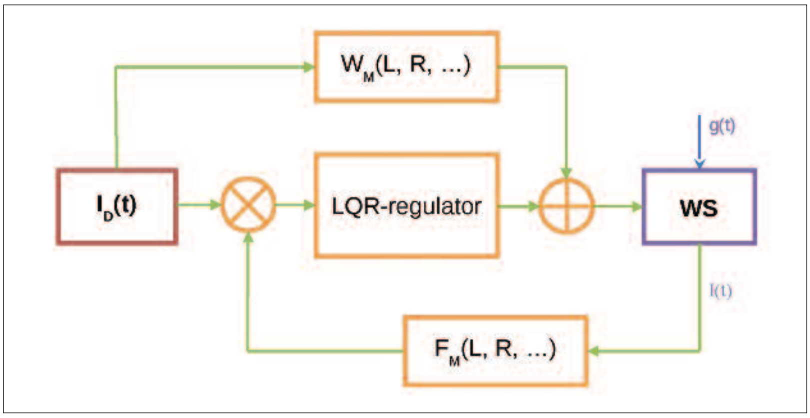

Figure 2: **Simplified schematic of current regulator**

Current pulse formation

The developed equipment uses the parallel buck-converter topology operating as a current supply to form a current pulse with variable form. A set of capacitor banks (batteries) commuted by high-speed IGBT modules serves as the energy supply for the pulse and is aimed to form current pulse with the desired form and amplitude after filtering. Module construction with parallel connection of cells allows sizing unit power within broad limits of 1 to 9 kA and maintaining independent automatic diagnostics of the condition of each battery.

By using the adaptive circuit of signal digitalization and digital control of power keys it's possible to obtain almost any form of current pulse, including trapezoidal, half sinusoidal, step trapezoidal and S-shaped.

The main requirement to the control circuit is the maximum precise generation of the desired current pulse with length small enough, as well as provision of its repeatability within the series of tests.

Moreover, the characteristics of the circuit runs are rather stable and do not change during the measurements. This allows realizing current regulator that performs current control in the circuit on the base of previously formed mathematical model (model following control). The scheme in Figure 2 consists of

* $I_D(t)$ - desired form of current pulse;
* W_M - model of the object controlled, current circuit;
* F_M - filter of measured current value;
* I(t) - actual current value in a circuit;
* g(t) - external perturbation;
* LQR-regulator - regulator, minimizing an error of current pulse formation.

With the more or less identified system model it's possible not only to increase the processing speed of the desired signal, but to sensitize optimal filter and regulator to increase stability of the control circuit towards external clutter and noises. The latter is extremely important taking into consideration rather high level of electromagnetic noise, generated by the power keys.

Automatic identification of the circuit characteristics is based on determination of such parameters as ohmic resistance (R) of circuit, inductivity (L), effective capacitance of energy storage units (C) by providing the series of test pulses and aftertreatment of results for the system self-adjustment according to the present circuit characteristics. Besides, diagnostics of the capacitors batteries condition is performed to exclude their ageing effect and further system unbalance.

The above-mentioned opportunities provide deviation of actual current from the desired in dynamics less than 2-3% and repeatability of measurement results at the level of 0,6 - 0,9% (Figures 3, 4).

Treatment of digital measurement results

Main aim of the performed measurements is to receive more adequate V_{TM} (F_M) results of bipolar power semiconductors at the desired value of current and pulse form. Actual value of current fluctuates around target value during the measurements due to the pulse method of current regulation that provides a certain scatter into the measured values which appears to be the noised external disturbances. In order to get a more exact voltage value it's necessary to make an additional mathematical treatment of the measurement results. The known equation approximates the type of voltage-current characteristics of the power unit [1]:

$$V = A + B \cdot i_T + C \cdot \ln(i_T + 1) + D \cdot \sqrt{i_T}$$

While small deviations from the measurement point the formula can be

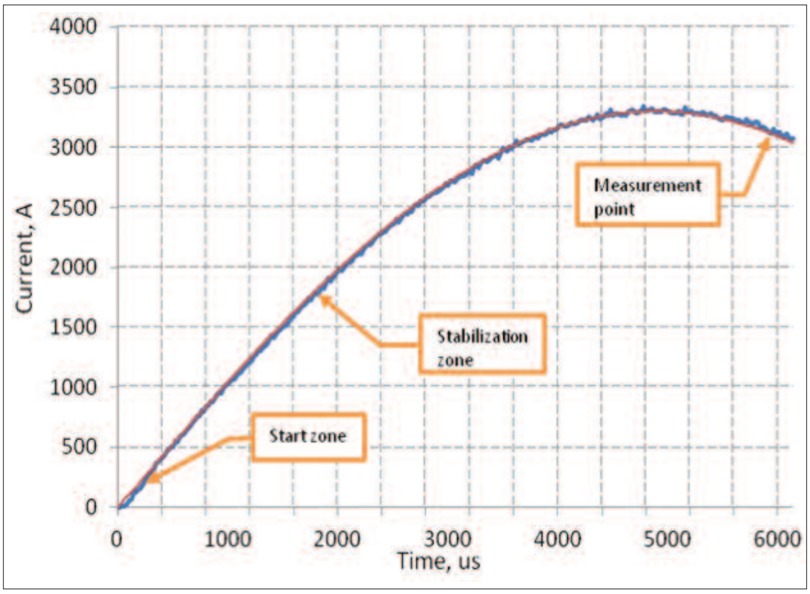

Figure 3: Sinusoidal pulse 3.3 kA max

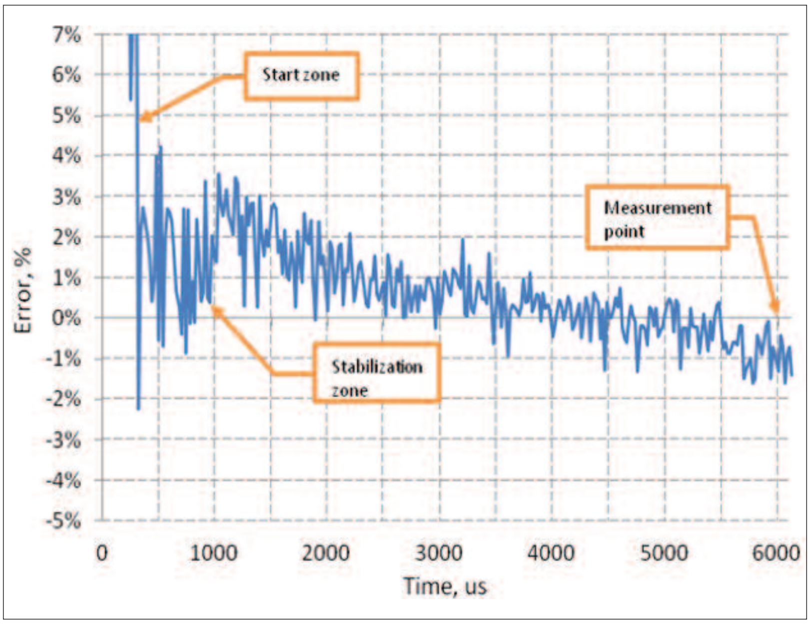

Figure 4: Deviation between measured and desired results

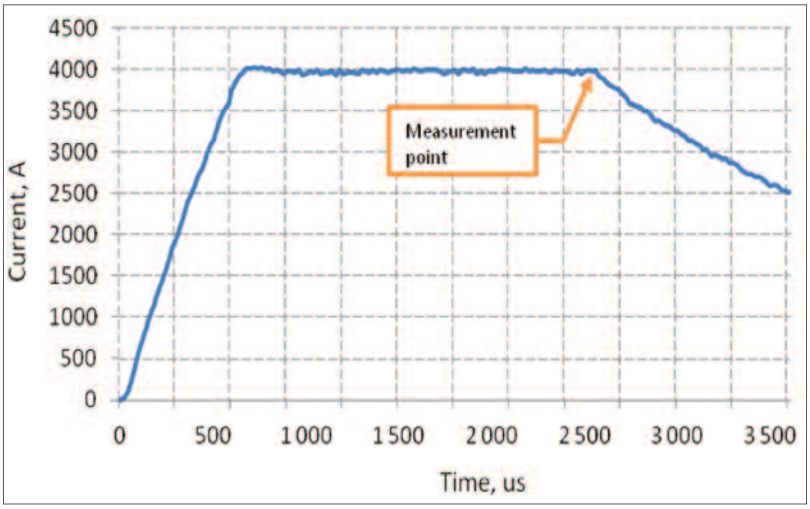

Figure 5: Trapezoidal pulse duration of 2000 microseconds

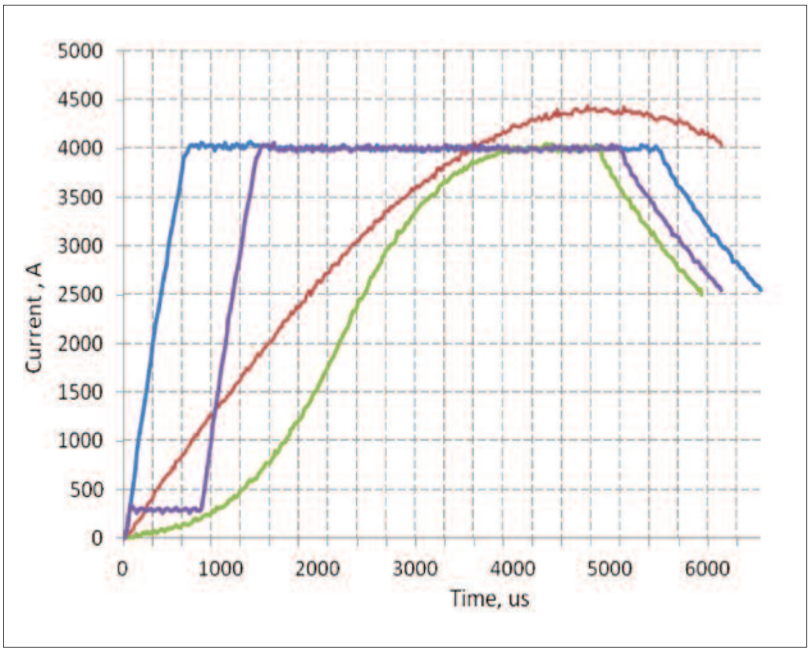

Figure 6: Different pulse forms for V_{TM} measurement at I_{TM} 4 kA

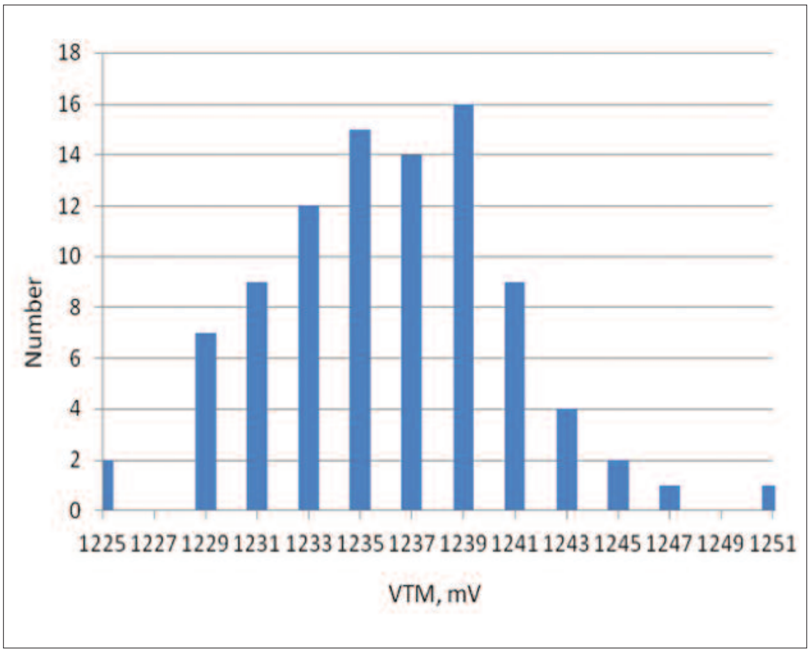

Figure 7: Scatter of measurement results for one device at I_{TM} = 1570A, 25°C. Average value of selection is M = 1235.53 mV, σ = 4.74 mV, that makes less than 0.7 % of the measured value

successfully linearized. Method of the smallest squires can be further used to the received sum of measurement results in order to obtain the most reliable estimate of the measured parameter. Measurement is performed not less than in 10-20 points of the neighborhood of the desired current value for the successful realization of the described method.

Measurement at different forms of test pulses

V_{TM} value may vary depending on the current pulse form due to the different heating-up of a semiconductor element as well as due to dynamic processes in the device. Main task is to provide equal complete opening of a power semiconductor for the running current, together with the minimization of its characteristics variation due to the heating by the running current. That's why it may be reasonable to use different test pulses forms: from sine-shaped to S-shaped (Figures 6 and 7).

Conclusion

Measurement of power semiconductor conducting losses allows for assembling of parallel stacks that have advanced operational reliability and more symmetric load of each device. For large diameter elements that have rather large turn-on time, the mentioned equipment allows to select optimal test mode that will minimize self-heating of an element together with provision of complete turn-on of a die into the conducting state across the surface.

The described measuring unit is a part of the complex for semiconductor static characteristics measurements. The complex ensures testing of thyristor and diode elements produced by JSC "Proton-Electrotex". Further developments will target at test equipment for large currents (20-30 kA) and test equipment for IGBT modules.

Literature

[1] Thyristors. Information material of ABB Semiconductors AG. - ABB Semiconductors AG, 1999