High Power Pulse Generators for Plasma Application

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Abstract: A new generation of its FID and DRD power switches with nanosecond and picosecond transition time featuring operating voltages from tens to hundreds of kV with peak current from tens of amperes to tens of kA, capable of operation up to hundreds of kHz with peak power of tens of MW and average power of tens of kW.
New switches became a basis for development of a wide range of pulse generators for accelerators, lasers, opto-electronics, medical and biological and ecological applications.

Keywords: pulse generator, pulsers, nanosecond, picosecond.

1. Introduction

FID GmbH has developed a new generation of its FID and DRD power switches with nanosecond and picosecond transition time. The main advantage of the new switches is a range of high operating voltages from tens to hundreds of kilovolts with peak current from tens of amperes to tens of kiloamperes. At the same time the switches feature high efficiency and are capable of operation up to hundreds of kilohertz with peak power of tens of megawatts and average power of tens of kilowatts. A new development level has been reached by using of new materials and implementation of new processing technologies.

A new generation of FID and DRD switches has become a basis for development of a wide range of nano and picosecond pulse generators for accelerators, lasers, opto-electronics, medical and biological and ecological applications.

2. Series of pulse generators

Use of power nanosecond generators for forming plasma in various gases in a wide range of pressure and different configurations of plasma reactors has become one of the most popular applications.

Various modifications of nanosecond pulsers based on the new FID and DRD switches can be classified into several series depending on their key technical parameters.

Series of pulse generators with amplitude of 100-1000 kV, peak current of 100-1000 kA, energy in pulse from 10 to 1000 J has pulse duration from 10 to 1000 ns and pulse repetition rate of 1-100Hz.

Series of industrial pulse generators has amplitudes of 10-100 kV, peak current of 100-1000 A, pulse width of 0,1-1 J, repetition frequency of up to 100 kHz and average power of up to 10 kW.

Series of high frequency pulsers with amplitude of 20-30 kV, peak current up to 1kA, energy in pulse of 10-100 milli Joules have pulse repetition rates of up to 1 MHz and average power of up to 10 kW

Series of multichannel pulsers with number of synchronous channels from 2 to several tens and each channel having amplitude of 10-50 kV, peak current of up to 1kA, energy in pulse of up to 10 J, pulse repetition rate up to 100 kHz. Average power of multichannel pulsers can reach tens of kilowatts with a synchronization accuracy better than 1 ns.

In some cases pulse generators were built with an adjustable pulse duration from 10 to 1000 ns with an amplitude from 1 to 100 kV, with a possibility of burst mode operation at 5-10 MHz or with adjustment of rise time in range from 100 to 1000 ns. Many other specifications were customized for specific research or industrial projects.

3. Operating parameters

In this paper we present investigation of operating parameters and modes with plasma loads of a most popular generator FPG 30-50NM10. This pulser has an output amplitude of up to 30 kV into 500-1000 Ohm load with a pulse duration of about 10 ns and maximum operating frequency of 50 kHz.

At the first stage of the experiment measurement of operating parameters of voltage pulses has been performed into a 75 Ohm load. This corresponds to impedance of connection coaxial cables going to load. For measurements a high voltage attenuator ATF 50 produced by FID GmbH has been used. It has a bandwidth of about 1 GHz. As the second, lower voltage stage, attenuators manufactured by Barth Electronics Inc. and Aeroflex Weinschel were used. Fig. 1 shows an oscillogram of the output pulse captured using Tektronix DPO 4104 oscilloscope. Rise time can be estimated as 2.5 ns, pulse duration at 90% level of amplitude is about 9.5 ns.

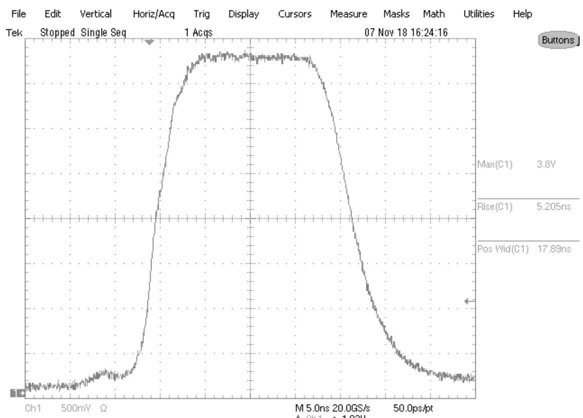

Fig. 1 – Pulse shape of FPG 30-50NM10

Amplitude of pulse is 19.5 kV. Measurement of the input power of the pulser's pulse power block and the output power of high voltage pulse has shown efficiency of about 70%. Maximum energy of output voltage pulse has been 53 mJ, and maximum average power to load at the PRF of 50 kHz 1515 W. Taking into an account measured efficiency of the pulse power module it is possible to calculate maximum dissipated power inside module as about 600 W. Cooling of pulse power module is provided by pumping water via an external heatsink with a flow rate of 5-7 liters per minute with ambient temperature of 20-25˚ C. Measurement of temperature of pulse power module operating at maximum output power has shown the temperature of 39-40˚ C into a matched load of 75 Ohm. When the load has been increased to 200 Ohm there appear reflections of high voltage pulses from unmatched load and the temperature of pulse power module increased to 45-47˚ C. In all experiments the load has been connected by 5 m of high voltage coaxial cable with impedance of 75 Ohm.

For tests with a gas discharge we have use a chamber with atmospheric pressure, the gap of 5-7 mm and capacitance of about 5 pF. At maximum amplitude and pulse repetition frequency of 50 kHz the temperature of pulse power module reached 51-53˚ C within 15 minutes. In some of experiments chamber electrodes have been destroyed after 15-20 minutes of operation at full power. To protect pulse power module from overheating a special control circuit has been implemented which automatically turns off the pulser at critical temperature which has been set to 60˚ C.

Tests into 3 types of loads mentioned above have shown that at PRF of up to 5 kHz it is possible to safely operate the pulser even without pumping water via an external heat-sink.

At high power plasma pulsers can be connected to a single load in parallel. In such case the synchronization accuracy of several generators is very important. Measurements have shown a delay of the output high voltage pulse relative to triggering as 375 ns.

Jitter measurements performed at PRF from 1 to 50 kHz have shown values of not more than 0.5 ns. At the same time it has been determined that the triggering to output delay time had been changing with the increase of temperature of pulse power module. Maximum increase of delay from the initial value of 375 ns at 25˚ C to 377,5 ns has been measured at temperature of 53-54˚ C. With increase of amplitude from 25˚ C to 40˚ C the delay increased by 0,9 ns. Further measurements have shown the maximum change of delay time relative to temperature were within 2-3 ns.

Measurement of amplitude stability of output voltage pulses from pulse to pulse have shown values of ± 0.3-0.5% which approximately corresponds to amplitude stability of a power supply of the pulse power module. At maximum output power at 50 kHz amplitude of the output pulse has decreased for 3-4% which is connected to the drop of amplitude of power supply and frequency dependence of commutation specifications of the main DRD switches.

4. Conclusion

A large volume of test experiments of pulsers designed for plasma applications has shown their reliable operation in a wide range of peak and average power values. High stability of parameters permits to increase output power in many times using parallel connection of several pulse generators to a single load. At the same time it is necessary to seek for maximum possible matching of impedance of pulser and load to improve the temperature operating mode of pulse generator.