Real-time Control of the Defibrillation Waveform with Digital Signal Processor

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Department of Biomedical Systems of Moscow Institute of Electronic Technology works with real-time shaping technology of defibrillation waveforms since 1995. Our technology allows producing defibrillation pulse with fixed duration and energy, regardless of patient impedance, with sufficient defibrillation current even for high impedance patients. “Ural Optical & Mechanical Plant” company has released first defibrillator with our technology, named DFR-2, to production in 2003. Feedback loop has been done with analog components. Main limitations of the technology were limited accuracy and speed, complexity of the analog control loop.

With the current state of digital signal processing it looks possible to increase precision and speed of the control loop, along with significant simplification of analog part. Extensive PSpice simulations have been by authors to prove such possibility.

General view of defibrillation pulse-shaping unit with real-time control is presented on Fig. 1.

The unit contains several independently controlled power cells with reversible polarity, stacked in series to provide maximum voltage on the output up to 3600V, voltage and current sensors to measure patient voltage and current, smoothing inductor to prevent rapid current changes during regulation and digital signal processor (DSP) based control unit to control the power cells. Unlike the preceding technology, all feedback control actions can be calculated in digital domain.

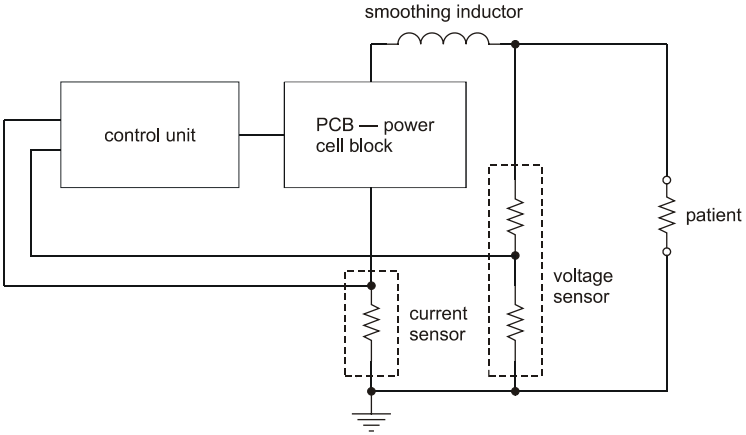

Fig. 1. Defibrillation pulse-shaping unit.

During the delivery of pulse control unit continuously samples the signals from current and voltage sensors and makes analog-to-digital conversion. Based on sampled values DSP calculates difference between the actual and reference waveforms and takes required control action to the power cells, by switching power cells on and off. Several control strategies can be implemented, including delivery of fixed energy and fixed current pulses. Shape of the waveform can be made insensitive to impedance changes during delivery of the pulse. Implementation of the control loop with DSP provides the increased noise immunity and decreased quantity of analog components.

Algorithms of defibrillation pulse-shaping control by means of DSP have been simulated on P-Spice-model. The sampling period of analog signals has been chosen equal 5μs, and time for analog signal conversion and data processing is set equal 2μs.

Results of simulation are shown on Fig. 2, 3 and on Fig. 4, 5 for for Gurvich-Venin defibrillation pulse and biphasic truncated exponential defibrillation pulse respectively, for patient impedances of 50Ω and 100Ω. Control strategy with predefined current shape has been used.

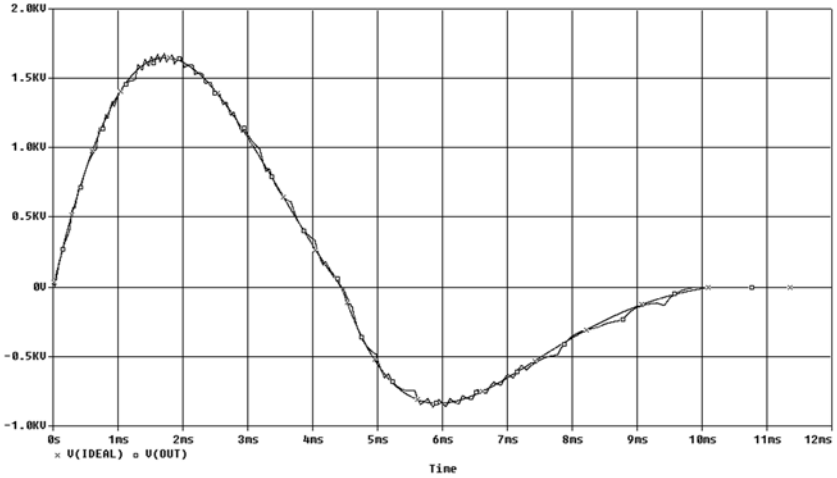

Fig. 2. Result of modeling for Gurvich-Venin pulse on 50Ω load (the amplitude of current of first phase is 33A).

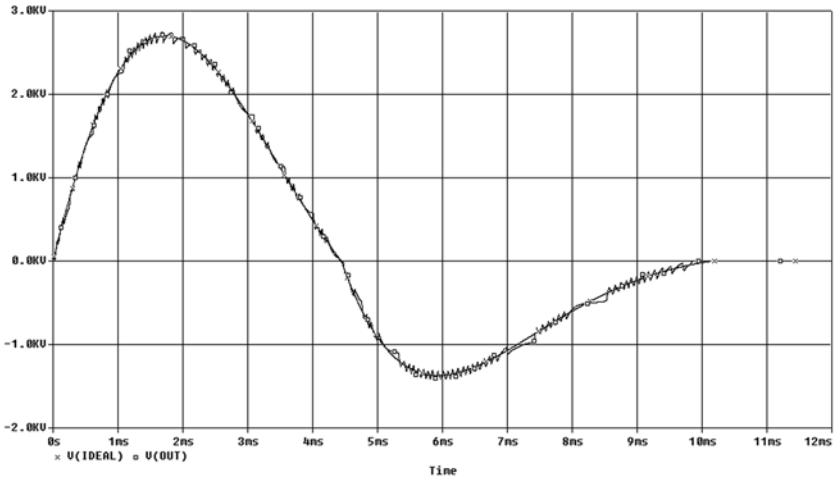

Fig. 3. Result of modeling for Gurvich-Venin pulse on 100Ω load (the amplitude of current of first phase is 27A).

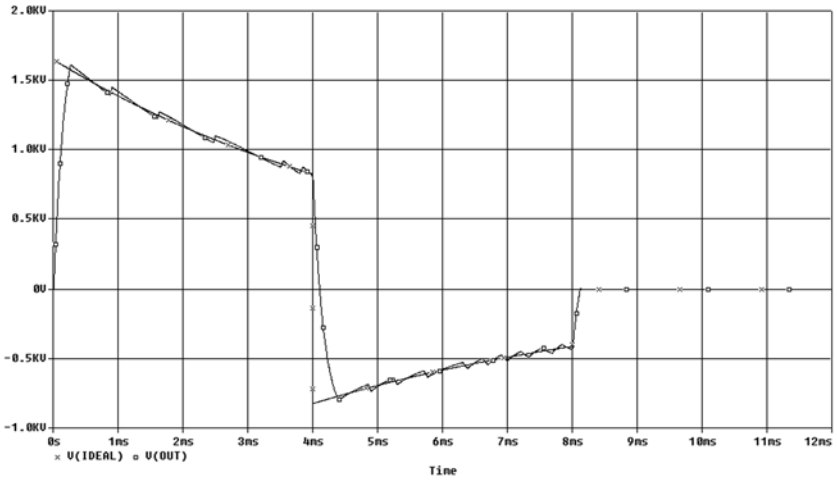

Fig. 4. Result of modeling for biphasic truncated exponential pulse on 50Ω load (the amplitude of current of first phase is 33A).

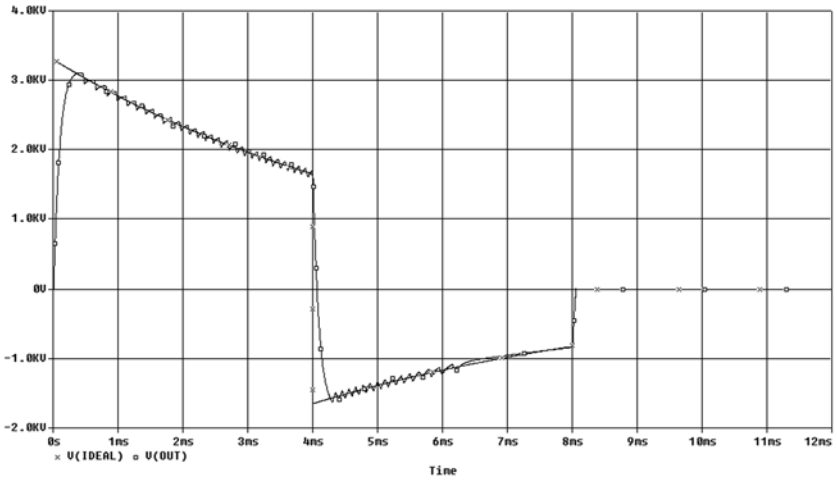

Fig. 5. Result of modeling for biphasic truncated exponential pulse on 100Ω load (the amplitude of current of first phase is 33A).

Based on the results of simulation we can conclude that implementation of defibrillation pulse-shaping unit with DSP feedback unit can be implemented.

The given work is executed at partial financial support of the Russian Fund of Basic Researches, project N 05-08-50300.