Spike Production Circuit for Electrical Appliance Testing

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Abstract: -This paper presents the design and implementation of a spike production circuit for testing the endurance and behavior of electrical appliances in fluctuations of their input supply voltage. The proposed spike production circuit produces voltage spikes up to 1KV with high slew rate. The spike production circuit uses an AC/DC converter that can produce variable voltage up to a maximum voltage level. This voltage charges a variable capacitance in a capacitor bank. An electronic relay circuit is responsible to switch the electrical appliance to the output of the Spike Production Circuit. The spike production circuit is interfaced with a PC where a control program was developed to set and control the spike production circuit. Experimental results are presented.

Keywords: - spike production circuit, electrical testing platform, appliance testing

1 Introduction

Power networks experience many abnormalities, which are unavoidable and most of the times are harmful and reduce the lifetime of the electric appliances. This paper presents the design of a spike production circuit which can be part of a testing platform, which has the ability to cause voluntary electrical distress on the appliances in a similar way with the power network and in a programmable and repeatable fashion.

Functional problems of the electric appliances caused by the abnormalities of the power network voltage depend on the nature of the appliance [1]. The spike production helps in the acquisition of the “know-how” around the behavior of each appliance on skipes in its power supply. Appliances can be designed to embody effective protection from spikes on the power network. The ability to classify the electrical appliances depending on their internal structure is offered. Finally, the classification of the requirements for each electric appliance group will be able to be performed. The problems that appear in the electrical appliances from abnormalities on the power network causing spikes are of different kinds and depend mainly from the type of the appliance.

The spike production circuit is designed to produce spikes with programmed voltage peak and energy. The spike production circuit is interfaced through a solid-state electronic relay to the other platform circuitry. This way a relatively high slew rate can be produced inexpensively and reliably. The design of the spike production circuit will be presented in section 2. The control of the spike production will be presented in section 3. The algorithms running on the processor for the spike production circuit follow in section 4. The experimental results are discussed in section 5. Conclusions are drawn in section 6.

2 Spike Production Circuit Architecture and Operation

The Architecture of the Spike Production system is shown in fig. 1.

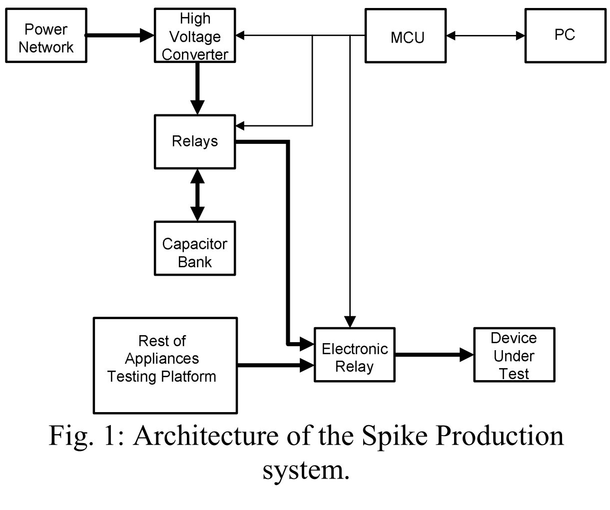

Fig. 1: Architecture of the Spike Production system.

The program running on the PC is able to send commands to the MCU to control the spike production circuit. The MCU processes the command and acknowledges the PC, or returns to the PC an error number, in the case that is not possible to process the command. The commands can preset the spike characteristics and request the spike production circuit to produce a spike. Error messages can be used for system diagnosis.

The spike production system's microcontroller, controls a number of relays and connects in parallel capacitors from a capacitor bank. This way the desirable capacitance is created. The microcontroller is also possible to set the voltage in a High Voltage Converter, to start it and stop it. This way the charging voltage of the desirable capacitance can be controlled and the maximum energy of the spike can be set. The electronic relay that switches the Device Under Test between the rest of the appliances testing platform and the spike production circuit is controlled from the microprocessor also. The rest of the appliance testing platform is based on an inverter [2-4] which is a High Bandwidth Pulse-Width Modulated Inverter [5].

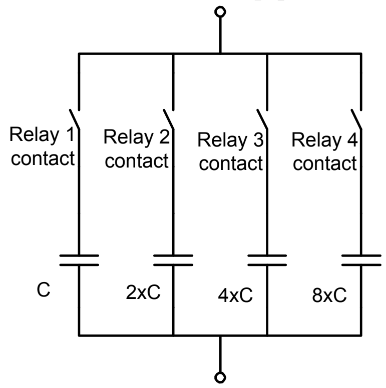

Fig. 2. Capacitor Bank connection.

A basic diagram of the Capacitor Bank is shown in Fig 2. If a number of "n" relays is used then the bank can create 2^n-1 different capacitance values. The created capacitance is charged by a High Voltage Converter the output voltage of which is controlled from a digital potentiometer in its feedback path. The Device Under Test is switched to the capacitance voltage through the Electronic Relay. The Electronic Relay and the connections around it are shown in Fig. 3. The electronic relay is formed from four switches. Each switch is consisted from two high voltage IGBTs (Insulated Gate Bipolar Transistors). The emitters and the gates of the two IGBTs are connected respectively. The two collectors are the switch terminals. An isolated DC/DC converter with current sink capability is placed between the connection of the emitters and the connection of the gates. When the isolated DC/DC converter applies voltage between the gates, then the switch goes to the "on" position and when absorbs current and discharge the emitter – gate capacitance of the IGBTs to zero volts, then the switch goes to the "off" position. The four switches form two groups with independent controls to give the ability to the control circuit to provide dead-time during the switching.

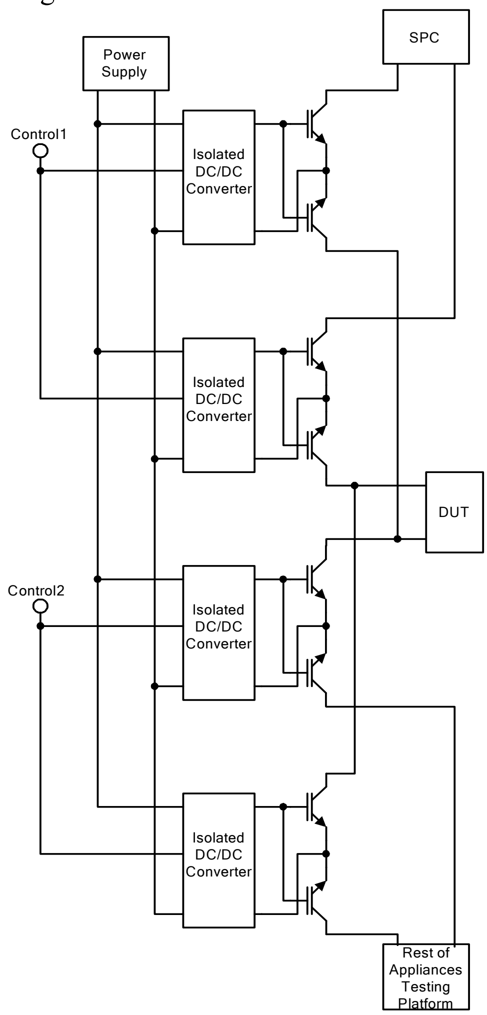

Fig. 3. The electronic relay.

The total energy that is stored in the created capacitance of the capacitor bank is given by Equation 1:

$$E_{stored} = \frac{1}{2} C_{created} \cdot V^2 \qquad (1)$$

where the V is the charging voltage that is produced from the High Voltage Converter. This is the maximum energy that the spike can transfer to the Device Under Test, if the capacitors fully discharge on the Device Under Test. The transferred energy in the case that the capacitors have not fully discharge are given by the Equation 2:

$$E_{stored} = \frac{1}{2} C_{created} \cdot (V_{initial}^2 - V_{final}^2) \qquad (2)$$

The spike duration is half period of the network frequency (10mSec for 50Hz network). Longer spikes may be supposed to carry DC component and may not be assumed as AC signal distortion. Lower duration spikes do not affect significantly the tested devices since their effect is reduced from the inductance or the input filters of the tested device.

3 Spike Production Control Program

A PC application program was developed to interface the Spike Production Circuit with a PC. The program is able to prepare a spike and also to ask the spike from the Spike Production Circuit with a command. This way, with the integration of the program in the Appliance Testing Platform control software, the Spike Production Circuit has the ability to cause spikes at the Device Under Test in a programmable and repeated fashion. The basic application program was initially developed in a DOS environment. The screen of this program that controls manually the Spike Production Circuit is shown in Fig. 4. The program user is able to control the Spike Production Circuit and test the circuit operation.

From this menu, it is possible to access the capacitance and voltage menu. The default values, that are the minimum, are shown. In this menu the user is able to define the created capacitance of the capacitor bank. The value is rounded to the closer possible created capacitance value that is finally displayed on the screen. From the same menu it is possible to defined the charging voltage of the created capacitance.

From the same screen the system can also be started or stopped. This means that the electronic relay connects the Device Under Test to the output of the rest platform circuitry, or turn all the switches to the "off" state and disconnect it respectively. The capacitors charging can be achieved from the same screen and this is the spike preparation. After this a spike production can be asked from the Spike Production Circuit.

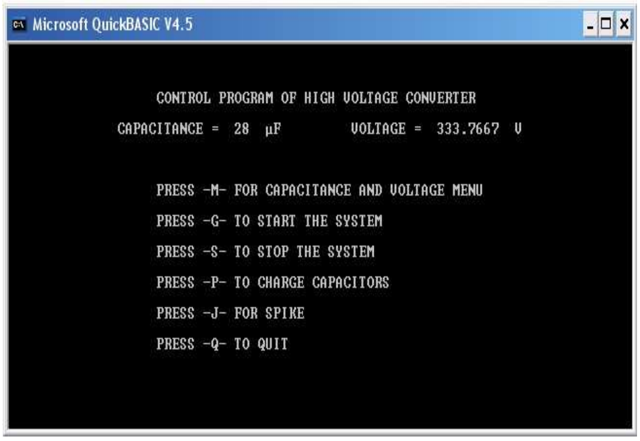

Fig. 4. The real time control screen of the application program.

The control program of the Spike Production Circuit was integrated in the real time control program of the Testing Platform [6]. The main screen of this program is shown in Fig. 5.

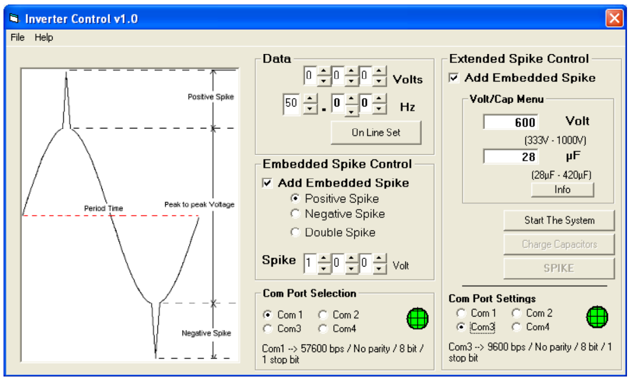

Fig. 5. The main screen of the Testing Platform control program.

4 The Processor Algorithm

A photograph of the constructed Spike Production Circuit is shown in Fig. 6. It is consisted of two printed circuit boards. All the power and high voltage circuitry is in the bigger board and the microcontroller and its support circuitry are in the electrically isolated smaller board.

Fig. 6. The constructed Spike Production Circuit.

The simplified flow-chart of the microcontroller's program is shown in Fig.7. During initialization of the microcontroller the digital potentiometer and capacitor bank are set in their minimum value, the High Voltage Converter is stopped and the Electronic Relay disconnects the Device Under Test. The microcontroller sets a communications buffer to temporarily keep the incoming command from the PC. The commands are coded from the PC to numbers. This way the microcontroller is able to fast compare and jump to the respective command routine.

After initialization the microcontroller examines continuously if the communications buffer is empty. At the moment that a number will be found in the communication buffer is compared with "1". "1" represents the command "START". If the number inside the communications buffer at this point of the algorithm, is not equal to "1," an error string is transmitted to the PC. This string is the word "ERROR" followed from an error number. The PC examines the string and if it contains an error prints on the bottom of the program screen a respective error message, in this case 'Unexpected Communication Number for Starting System'. If the command at this point is "START" then the microcontroller turns on the proper switches of the Electronic Relay in order to connect the Device Under Test to the output of the Testing Platform.

After starting the platform the microcontroller waits for the next command. The next command can be a number from a wide integer number range. The reason is that every High Voltage Converter output voltage and every Capacitor Bank created capacitance is represented with a different number. This way with a single command a state can be set or a procedure to be executed. The capacitor charging is not continuous and must be set before asking for a spike. If not, then an error message is produced. This way the operation of the platform is more efficient.

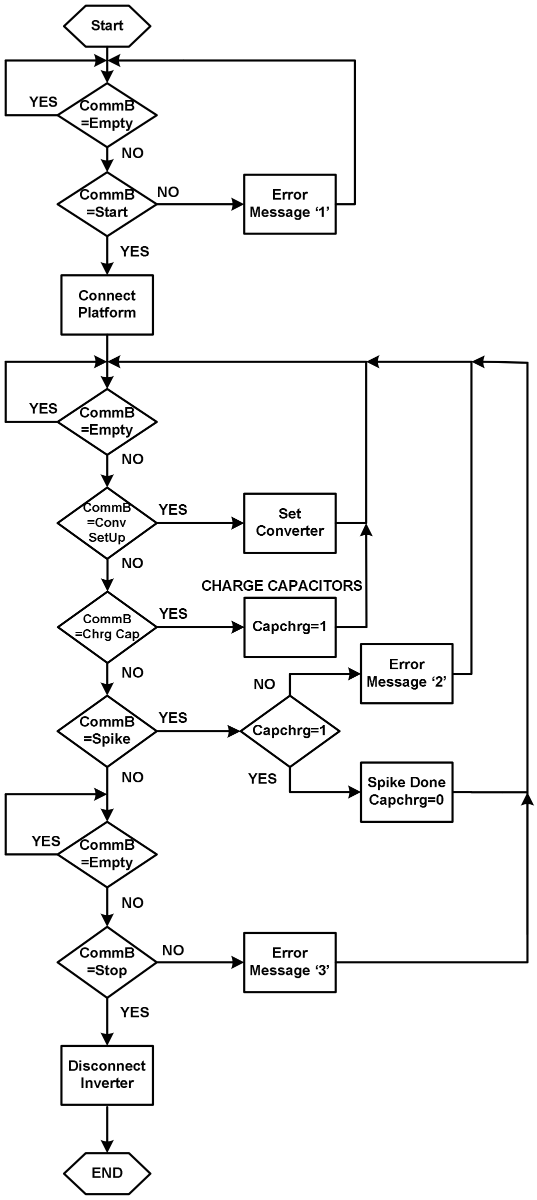

Fig. 7. Flow-chart of microprocessor

5 Experimental waveforms and results

Some experimental results that make clear the operation of the Spike Production Circuit are shown in this section. Two different spikes to the same load with different created capacitance of the Capacitors Bank are shown in Fig. 8 and Fig.9. The effect of the different discharge time is apparent.

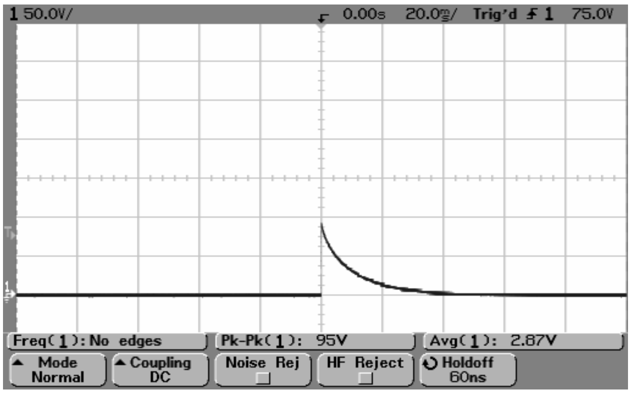

Fig. 8. Spike with 28μF created capacitance

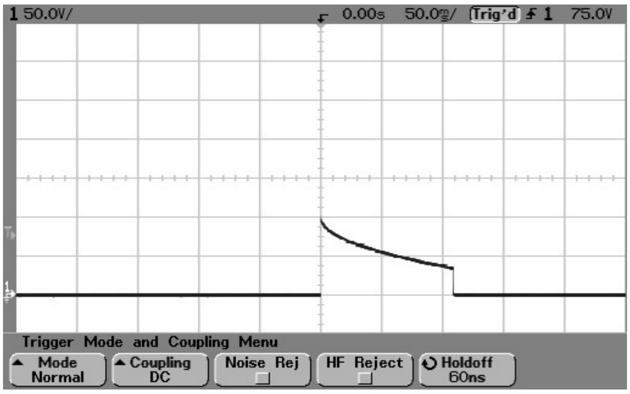

Fig. 9. Spike with 420μF created capacitance.

Three different spikes with the platform in operation are shown in Fig. 10, Fig. 11and Fig 12.

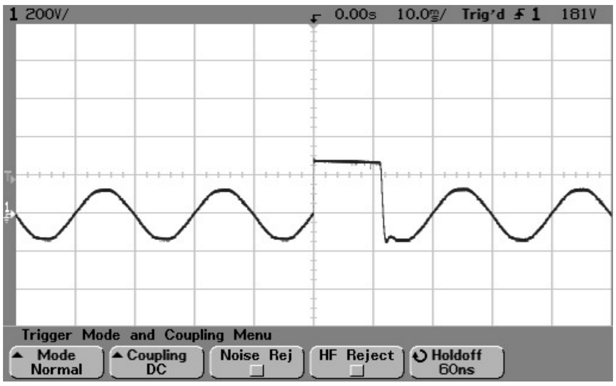

Fig. 10. Small spike during Brownout.

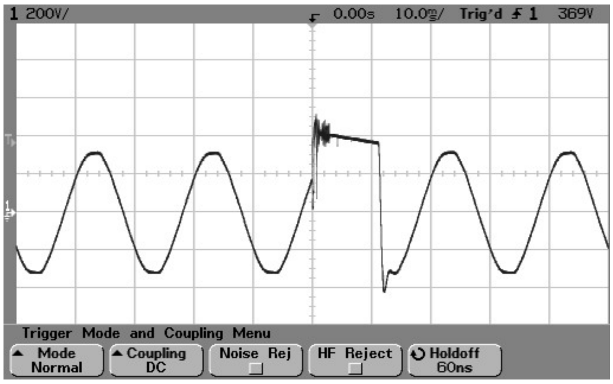

Fig. 11. First spike during appliance test.

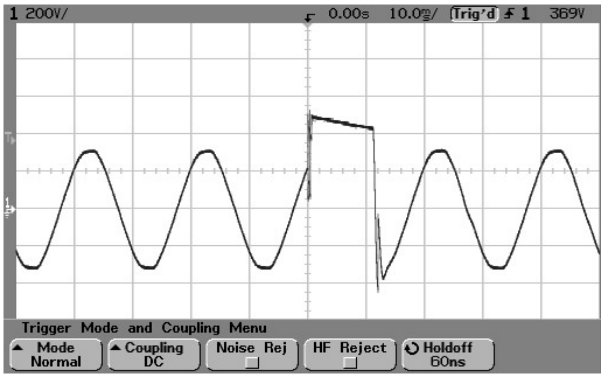

Fig. 12. Second spike during appliance test.

6 Conclusions

A Spike Production System was designed, constructed and tested in the laboratory that can be used for Electrical Appliance Testing. This System is able to produce most spike abnormalities, similar to the ones produced by the electric power network, and can be used to bring knowledge about the sensitivity of the appliances. Knowing the weak points of the appliances, more sufficient protection against the power network absnormalities can be utilized and people may have less problems with them. The circuitry of the spike production is designed in an efficient way, minimizing the occurance of faults in the circuitry. Fault minimization is very important on testing devices. The characteristics of the produced spike can be controlled through a PC. The spike production software can be extended to include many testing patterns. Also the patterns can be sequenced to make test series for testing the endurance and behavior of electrical appliances in fluctuations of their input voltage signal. The implementation of the spike production system makes the manufactures of electrical appliances to be able to easily test the endurance of their appliances under different tests in a repeatable fashion and for long time periods.

Acknowledgments
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