Improved Grid Connected Power Supply for Drivers in Power Electronic Converters

Vencislav C. Valchev[1], Dimitar Bozalakov[1] and Angel St. Marinov[1]

Abstract – **The paper presents a specialized power supply for drivers in power electronic converters. The proposed topology can be directly interfaced to the electric grid without the need of a rectifier or high voltage filter capacitor. Advantages of the presented circuit are: reduced complexity, size, weight and price. The suggested device supplies power and galvanic separation of the driver stages of high power electronic converters. The scheme was tested and validated experimentally.**

Keywords – **Switch mode power supply, Power electronics, MOSFET/IGBT drivers, Insulated Power Supply**

I. Introduction

The paper presents a specialized power supply for drivers in power electronic converters. The suggested device is meant to provide power supply and galvanic separation of the driver stages of high power electronic converters. Figure 1 shows a classical driver topology, presented for one power leg. Utilizing it in a 3-phase system requires high number of power supplies with galvanic separation: one power supply for each high side transistor plus one for all the low side transistors. Using this type of driving topologies however improves the safety and reliability, as well as the EMC characteristics of the power electronic converter. Anyhow using it leads to some certain disadvantages, due to the influence of the overall complexity of the whole scheme, which increases the gross price, weigh and size.

The paper introduces a topology that can be directly interfaced to the electric grid without the need of a rectifier or high voltage filter capacitor. This in terms will reduce the circuits complexity, improving the parameters stated in the previews paragraph. The introduced circuit in its specifics can be described as a switch-mode AC/AC converter that uses high frequency transformer to obtain the required voltage transfer ratio and number of insolated outputs. Only a small capacitor in the output is required in order to filter the output voltage.

Using a separate connection to the AC grid makes the power supply independent from the power converter. This provides a stable power source for converter, which DC line cannot be used for driver supply, for example converters controlling energy generation.

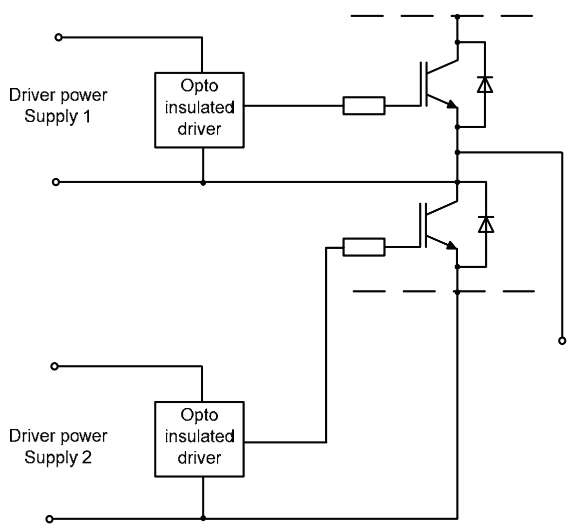

Fig. 1. Drivers with galvanic separated power supply

II. Presented Topology Operation

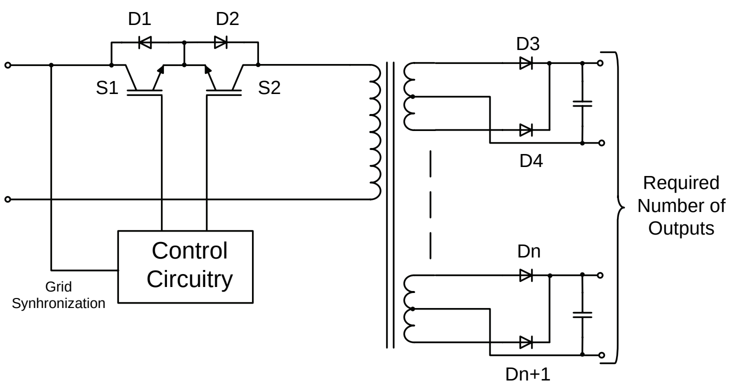

Fig. 2. Proposed Power Supply topology using AC voltage

A. Description of the presented circuit

The suggested topology is given at figure 2. In its essentials the circuit is a modified AC/AC converter formed by transistors S1, S2 and their corresponding anti-parallel diodes D1, D2. In the developed modification the transistors are

[1]Vencislav C. Valchev, Dimitar Bozalakov and Angel St. Marinov are with the Faculty of Electronics, Technical University of Varna, 9010 Varna, Bulgaria, E-mail: vencivalchev@hotmail.com, igdrazil@abv.bg

directly interfaced to the AC grid. The input voltage is transferred to the primary winding of a pulse transformer, as S1, D2 and S2, D1 respectively conduct the positive and negative half-wave. During each half-wave only one transistor is controlled, the other is off. The corresponding wave is being chopped by the corresponding transistor - creating a high frequency (30kHz to 50kHz) square pulse voltage applyied to the primary winding of the transformer. The amplitude of each pulse is determined by the instant value of the input sine wave voltage. This voltage is then transferred to the required number of outputs with the necessary voltage transfer ratio. The voltage from the secondary windings is rectified and filtered by the output circuitry. Thus, for each half-wave the circuit behaves as a flyback converter. For example during the positive half-wave S1, D2 and D3 form the 'first' flyback converter. During the negative half-wave S2, D1 and D4 form the 'second' flyback converter. Thus the low frequency sine wave voltage can be transferred to the secondary windings and then rectified and filtered. Due the nature of the chopped sin wave input voltage, the output voltage will have higher level of pulsations then when using a regular flyback working with rectified DC voltage, this however will not affect neither the supplied drivers – considering a sufficient output voltage, nor the other components of the circuit – the pulse transformer or the power transistors.

B. DC and AC input interfacing

As described, the circuit can be directly interfaced either to an AC or to DC line, depending on the available voltage source. When connected to a DC line the circuit can operate as normal flyback converter utilizing only one of the transistors –S1 and one half of the output winding. This gives the circuit significant flexibility as a pre-prepared circuit can be used for wide range of applications.

C. Output interfacing

The circuit can posses a high number of output windings, thus providing a sufficient number of output voltages with galvanic separation necessary for supling the required number of drivers. For example for a three phase inverter, the circuit can provide four power supplies with galvanic separation needed to supply drivers and drive the transistors (three power supplies for the high side transistors and one power supply for the low side transistors). Since drivers can sometimes act as open circuit (when the controlled transistors is been kept off for prolonged durations of time) a special protection circuit – zener diode D1 and resistor R1 is added. The circuit provides alternative path for the transferred energy during open circuit mode and protects the capacitor against overvoltages. (figure 3) The zener diode should be selected with a stabilization voltage higher than the required output.

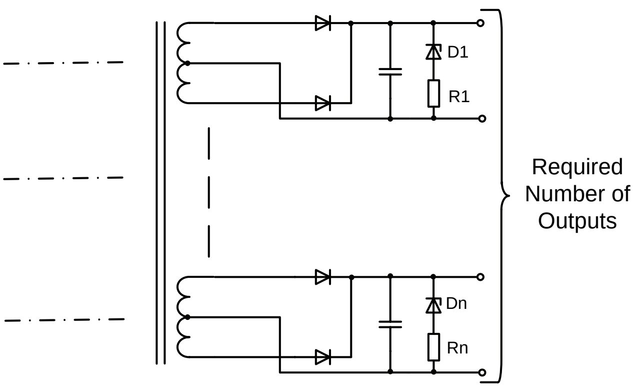

Fig. 3. Output Interface

D. Advantages and Disadvantages of the presented topology

The suggested topology has several main advantages because of the reduced number of components compared to the classic flyback circuits. The presented circuit avoids a separate rectifying and filter circuit which reduces the overall complexity of the circuit and allows the fallowing advantages:

1. Reduced size and weight since no high voltage input capacitor is used
2. Reduced gross price, determined by the difference of the value of one extra IGBT compared to the high voltage capacitor and rectifier.
3. Flexibility – the circuit can be interfaced to both DC and AC lines with different voltage. Thus it can be used as a laboratory supply for drivers or pre-prepared circuits can be connected directly to the available source.
4. Spin-off technologies – the circuit can be introduced in different fields where power supplies with large number of outputs with galvanic separation are necessary.

III. Experimental Results

The suggested circuit was tested for functionality and it proved to be operational, working without notable drawback. Due to safety issues the circuit was tested using reduced galvanic separated AC voltage, where only the positive half-wave was utilize. Complete tests utilizing the whole AC voltage will be shown at the paper's presentation.

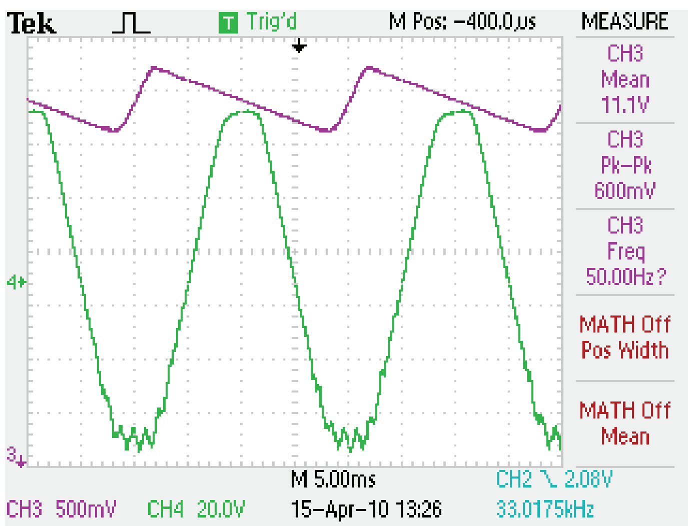

Fig. 4. Waveform of the input and output voltage

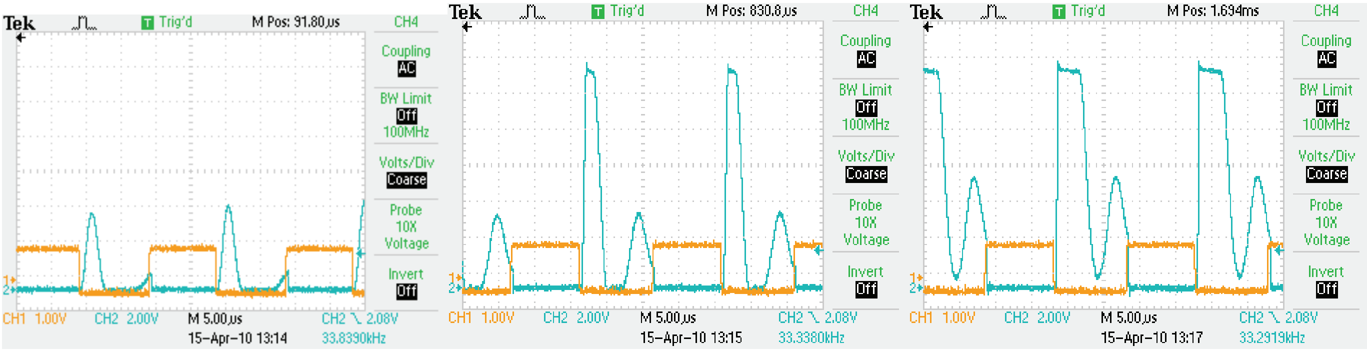

Fig. 5. Waveforms of the collector emitter voltage, and control voltage (gate-emitter) at the moments of 4ms and 5ms after zero crossing

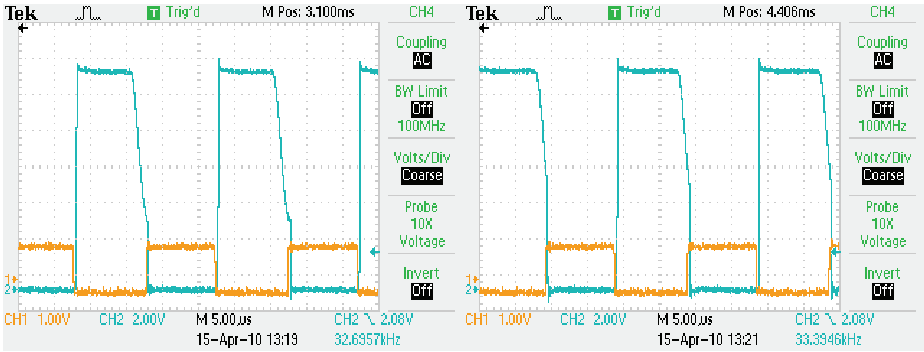

Fig. 6 Waveforms of the collector emitter voltage, and control voltage (gate-emitter) at the moments of 4ms and 5ms after zero crossing

Figure 4 shows the waveforms of the output versus the input voltage, where:

Channel 4 (green) is the input voltage

Channel 3 (purple) - output voltage

It can be seen that the output voltage has small ripple with gird frequency due to the sinewave component. This ripple however will not affect the proper operation of supplied driver circuits.

Figure 5 presents the Collector Emitter (CE) voltage on the transistor and its control pulses. The different waveforms are taken in different moments of the input sine-wave, as it follows 0,5ms, 2ms and 3ms after zero crossing of the input voltage. It can be seen that there is a certain transition period in the CE voltage of the transistor due to the discontinuous mode of operation of the transformer. This transition process can be additionally used to improve the circuit efficiency, obtaining soft switching of the transistor.

The waveforms of the Figure are:

Channel 2 (blue) is the CE voltage of the transistor

Channel 1 (yellow) - control pulses on the transistor

Figure 6 has the same depictions as figure 5 but for time periods 4ms and 6ms after the zero crossing of the input sinewave. It can be seen that for high voltages the transformer begins operating in continuous mode as the transition process are diminishing. Wave placement on the diagrams repeats that of figure 5.

Figure 7 presents the waveforms of the control pulses, the output voltage and the voltage on the primary winding of the transformer. The figure gives a visual explanation of the principle of operation of the suggested circuit.

The waveforms of the Figure are:

Channel 3 (purple) is the output voltage

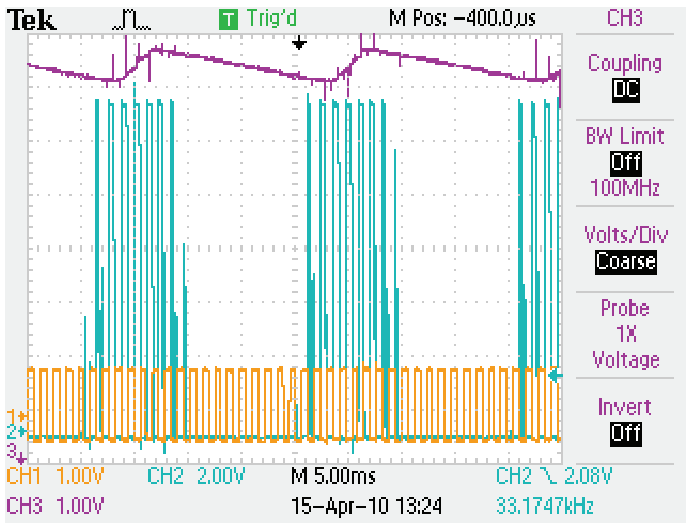

Fig. 7. Waveform of the positive half-wave on the primary winding of the transformer, the control pulses and the output voltage

Channel 2 (blue) – Voltage on the primary winding of the transformer

Channel 1 (yellow) - control pulses on the transistor

IV. CONCLUSION

The presented circuit provides notable advantages over the standard driver power supplies, as it offers reduced complexity which benefits size weight, and prize. The circuit was experimentally tested and validated. The results show possibilities that the circuit can be utilized in different applications and that its efficiency can be further improved.

ACKNOWLEDGEMENT

The paper is developed in the frames of the project ‘Development of specialized scientific infrastructure for investigation of wind and solar energy potential’, № DO02-48/10.12.2008, Ministry of Education, Youth and Science, Fund ‘Scientific Research’, Bulgaria.

REFERENCES

[1] Smith K. et. al., ‘A Comparison of Voltage-Mode Soft-Switching Methods for PWM Converters’, IEEE Transactions on Power Electronics, vol.12, No2, March 1997, pp.376-386.

[2] [Zhang J. M., et. Al., ‘Comparison Study of Phase-Shifted Full Bridge ZVS Converters’, 2004, 35th Annual IEEE PESC, Aachen, Germany, 2004, cd-rom.

[3] Vencislav Valchev et al, ‘Design Considerations and Loss Anylasis of ZVS Boost Converter,’ IEE Electric Power Applications, vol.148, No1, January, 2001, pp.29-33.

[4] Chang-Sun Kim, et. al., ‘Alternately Zero Voltage Switched Forward, Flyback Multi Resonant Converter Topology’, IEEE IES, Sevilla, November 5-8, 2002, cd-rom.

[5] Farrington R, F. Lee, M. Jovanovic, ‘Constant frequency zero-voltage multi-resonant converters: topologies, analysis and experiments’, IEEE PESC, 1991, pp. 33-40.

[6] Gradinarov N., N. Hinov, D. Arnaudov, “Analisys and Design of Resonant Inverters with Improved Output Characteristics, Zero-Current Switching’, PCIM’03, Germany, 05.2003, pp. 423-427.