



# DC-DC POWER CONVERTER FOR UNCONVENTIONAL SUPPLY VOLTAGES

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**Abstract:** During the last years, the generation of electric power by unconventional methods required the achievement of some modules for adapting the level of DC voltage, with galvanic insulation so that the output voltages are compatible with the industrial level. In this sense, the presented paper proposes the carrying out of a DC power converter, 6 kW having as level of the input voltage 50 Vdc - 120 Vdc, at the output a DC stabilized voltage 200 Vdc  $\pm$  10%. For reaching the proposed aim, the use of IGBT and magnetic cores made of amorphous materials is taken into account.

**Key Words:** DC/DC Converters, Design procedure.

## 1. INTRODUCTION

The Full-Bridge converter shown in Fig. 1 is a higher power version, and provides the highest output power level of any of the converters.

The maximum current ratings of the power transistors will eventually determine the upper limit of the output power of the Half-Bridge. These levels can be doubled by using the Full-Bridge, which is obtained by adding another two transistors and clamp diodes to the Half-Bridge arrangement. The transistors are driven alternately in pairs, T1 and T3, then T2 and T4.

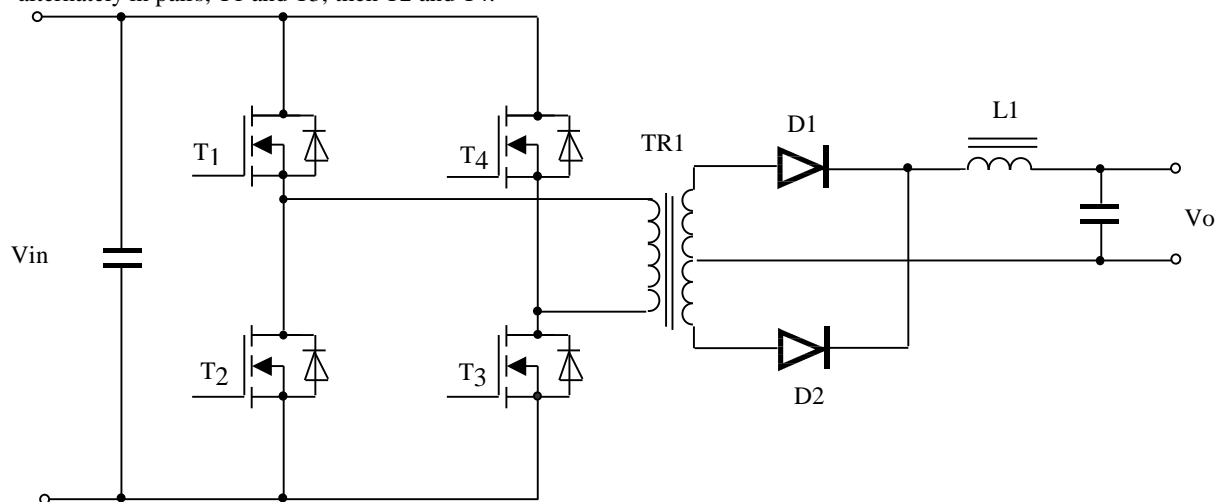


Fig. 1. - Full-Bridge converter

## 2. DESIGN PROCEDURE

**Design Output Inductor L1** (see Fig. 1)

**Determine the Choke Ripple Current, DI**

The transformer primary TR1 is now subjected to the full input voltage. The current levels flowing are halved compared to the Half-Bridge for a given power level.

Hence, the Full-Bridge will double the output power of the Half-Bridge using the same transistor types.

The practical achievement of a full bridge converter involves firstly the adequate choice of the four switching elements T1, T2, T3, T4. For high power with kW or tens of kW as order of magnitude, insulated gate transistors IGBT are preferred as switching elements. Unlike the power transistor MOS, the transistor IGBT have a high current capability (thousands of Amperes) for operating voltages of thousands of Volts and even higher than 1000 V, although they have a worse frequency behavior.

The new technologies allow to achieve the IGBT structures intended to carry out different switching configurations, having also included elements for simplifying an electronic control of these devices.

For continuous current conduction in the choke, the minimum dc current,  $I_{omin}$ , must be equal to, or greater, than half the choke ripple current  $\Delta I$ .

$$I_{omin} \geq DI/2; DI \leq 2I_{omin} \quad (1)$$

In the case where the minimum dc output current,  $I_{omin}$ , is not specified, typical value for  $\Delta I$  is to 10 to 20 percent of the maximum dc output current,  $I_{omax}$ .

$$DI = 0,1I_{omax} \quad (2)$$

**Determine the critical inductance, Lmin**

The minimum dc output current, and the minimum duty factor,  $D_{min}$ , of the converter main switch, are critical choke-design parameters in determining the critical inductance for uninterrupted choke current operation.

$$L_{min} = \frac{V_o(1 - D_{min})}{2 \times I_{O \ min} \times f} \quad (3)$$

were  $D_{min} = \frac{V_o}{V_o + V_{pk}}$  (4)

and  $t_{off \ max} = 1 - D_{min}$

The duty cycle, D, is derived as follows:

$$T = t_{on} + t_{off} = 1/f$$

were  $t_{on} = DT$ , and  $t_{off} = T - DT$

For the average volt-seconds across the inductor to equal zero

$$DT V_{pk} = V_o(T - DT) \quad (5)$$

Solving for D in equation (5)

$$D = \frac{V_o}{V_o + V_{pk}} \quad (6)$$

were  $V_o$  is the output dc voltage (volts)

$V_{pk}$  is the peak voltage across the inductor (volts)

$t_{off}$  is the off time of the converter main switch

$f$  is the frequency of operation (Hz). For Full-Bridge converter  $f \leftrightarrow 2f$

It is recommended that the designer plan on a design margin of about 10% to 20%. (Make  $L_{min}$  larger than the value calculated in equation (3) to account for percent change in the  $A_L$  value).

**Determine the required area product,  $W_a A_c$ , of the core.**

$$W_a A_c = \frac{2W}{B_{max} K J} \bullet 10^4 \ (cm^4) \quad (7)$$

were  $W_a$  is the window area of the core ( $cm^2$ )

$A_c$  is the cross-sectional area of the core ( $cm^2$ )

$W$  is the energy (watt-seconds)

$B_{max}$  is the maximum flux density (Teslas)

$K$  is the window fill factor

$J$  is the current density ( $A_{mps/cm^2}$ )

The relationship between the area product,  $W_a A_c$ , of a core and its capability for storing energy can be obtained by using Faraday's Law of Induction. When solving for  $W_a A_c$ , certain assumptions must be made about  $J$  and  $K$ . For the current density,  $J$  a reasonable value may range from 250 to 400  $A_{mps/cm^2}$  for a temperature rise of 35 to 50°C (in still air)  $J=400 A_{mps/cm^2}$ .

Although the core geometry provides a relatively large window area for the winding, only a limited portion

of this area can actually be filled with wire. The fill factor,  $K$ , may vary from 0,3 to 0,6 with a typical value being 0,4. The value used for  $B_{max}$  is based on the saturation induction,  $B_{sat}$ , of the magnetic material used. For POWERLITE C-Cores,  $B_{sat}$  is 1.4 Teslas. Once  $W_a A_c$  has been determined, the optimum core size can be selected from POWERLITE C-Cores. Choose the core with the next largest  $W_a A_c$  value and make note of  $A_c$  for future reference.

**Calculate the required number of turns and wire size**

$$N = \frac{L_{min} I_{pk} \bullet (10^4)}{B_{max} A_c} \quad Turns \quad (8)$$

where  $L_{min}$  is the minimum inductance required for continuous choke current operation.

The maximum copper fail width, is determined similarly with secondary conductor.

**Output Capacitance C13** (see Fig. 2)

In switching power supply power stages, the function of output capacitance is to store energy. The energy is stored in the capacitor's electric field due to the voltage applied. Thus, qualitatively, the function of a capacitor is to attempt to maintain a constant voltage.

The value of output capacitance is generally selected to limit output voltage ripple to the level required by the specification. Since the ripple current in the output inductor is usually already determined, the series impedance of the capacitor primarily determines the output voltage ripple.

For continuous inductor current mode operation, to determine the amount of capacitance needed as a function of inductor current ripple,  $\Delta I_L$ , switching frequency,  $f$ , and desired output voltage ripple,  $\Delta V_o$ , the following equation is used assuming all the output voltage ripple is due to the capacitor's capacitance.

$$C \approx \frac{\Delta I_L}{8 \bullet f \bullet \Delta V_o} \quad mF \quad (9)$$

where  $\Delta I_L$  is the inductor ripple current.

**Design of a high power/high frequency transformer TR1** (see Fig. 2)

To the SMPS designer, POWERLITE C-Cores provide a superior solution to core loss when compared to ferrites and Si-Fe steel cores. In addition, ultra-efficient POWERLITE C-Cores offer dramatic reduction in weight and volume (of up to 50%) and a substantially wider operating temperature range than ferrites.

**Calculate the number of primary and secondary turns**

**Primary**

Calculate the number of turns  $N_p$  required to support the primary volt-second product.

$$N_{pmin} \geq \frac{V_{ccmin} d_{max} (10^4)}{\Delta B_{max} A_{cmin} f_{sw}} \text{ Turns} \quad (10)$$

### Secondary

The turns ratio  $n$  is used to calculate  $N_s$ :

$$n = \frac{N_p}{N_s} = \frac{(V_{ccmin} - V_{trans(sat)}) d_{max}}{V_0 + V_{diode}} \quad (11)$$

$$\text{For Full Bridge } n = \frac{1}{2} \frac{N_p}{N_s}$$

$$N_s = \frac{N_p}{2n} = \frac{(V_{ccmin} - V_{trans(sat)}) d_{max}}{N_p (V_0 + V_{diode})} \text{ Turns} \quad (12)$$

$N_s$  should be rounded off to the next largest integer.  $N_s$  may have to be increased during design testing due to parasitic effects such as rise and fall times of transistors,  $I^2R$  losses in the circuit, leakage inductance effects, etc.

### Full Bridge designing (see Fig. 1)

In order to achieve the switching diagram in Full Bridge structure, we chose to use as power switching elements the intelligent power module IGBT.

For meeting these demands we chose the Intelligent Module IGBT manufactured by Mitsubishi, type PM300DSA060.

The module is characterized by the following main electrical and switching parameters:

- collector current  $I_c = 300 \text{ A}$ ;
- collector-emitter voltage  $V_{CE} = 600 \text{ V}$ ;
- operating frequency – 20 kHz max.

Mitsubishi Intelligent Power Modules are isolated base modules designed for power switching applications.

Built-in control circuits provide optimum gate drive and protection for the IGBT and free wheel-diode power devices.

### 3. CONCLUSION

In this paper, we presented the designing methodology applied at ICMET Craiova, for carrying out the DC-DC high power supply sources (2-6 kW). As a result of the performed experiments, the validity of the solutions used for the structure of full-bridge converter was proved.

### 4. REFERENCES

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