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Isolated DC-DC UPS Based in a Fly back Converter Analysis and Design

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***Abstract*— This paper presents the analysis, design and simulation from a simple DC-UPS converter with integrated back-up and automatic transition. This converter makes automatic transition between the main AC and the battery when a failure occurs, and it delivers uninterrupted DC power to the load through two independent power sources of commercial input power and battery power. The converter has the following characteristics: automatic transition between the main and the battery, no additional control to detect failure in the main, single structure, galvanic isolation, multi output voltages capability and only one switch control for two operation modes normal and back-up. The analysis, design, simulation and experimental results for this converter are presented.**

***Index Terms*— Automatic transition, battery charger, DC-DC converter.**

I. INTRODUCTION

The use of DC-UPS has been increased in the last decades in the equipment of telecommunications and the portable electronic equipment [1]. This cause that every time improvements in their operation as in their structure for reduce size, weight, cost and dynamic response are made. Although several approaches for to solve above problems are made [2], only a few of them take into account the Automatic Transition in their structure. Traditional solution to design a DC-UPS is using two stages: the first include a battery charger and the second uses a dc-dc converter to regulate the output voltage (Figure 1). This structure provides a low efficiency since the total energy is processed twice before it is delivered to the load and in addition uses two control loops, one to regulate the battery voltage and the other to regulate the output voltage. This paper presents a DC-UPS based in a flyback converter in order to solve some of the problems that were mentioned before and including automatic transition between the main ac and the battery.

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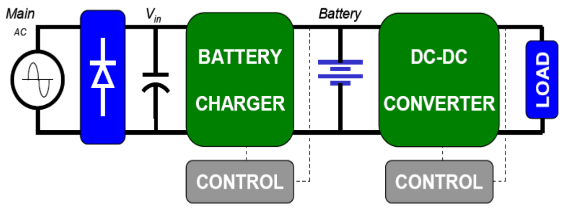

Figure 1.Traditional DC-UPS including rectifier, battery charger, battery, DC-DC converter, and two control loops

II. PROPOSED CONVERTER

The general structure of the proposed DC-UPS converter is known as CIBAT (Converters with Integrated Back-up and Automatic Transition) and it is presented in [2]. CIBAT is a family of four converters where each one consist of a transformer, main output, battery charger, two diodes (DN and DB) that make the automatic transition and two entrances, the input dc voltage from rectifiers Vin and the battery. Both entrances are connected in the primary winding of the transformer but the battery makes it through a centered tap with DB. Therefore both entrances share the same transformer, switch, and control loop obtaining in a simple circuit with only one stage (Figure 2).

CIBAT can adopt different topologies; it depends in how is transferred the energy to the load and how is charged the battery. The principal structure from CIBAT uses only one converter with two outputs of flyback one of them to feed the load and the other to charge the battery.

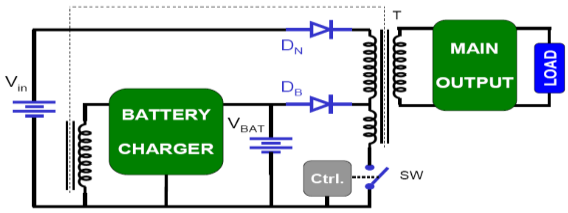

Figure 2. General structure of Converters with Integrated Back-up and Automatic Transition

A. CIBAT characteristics

Single structure: These arrays allow designing a DC-UPS with only one stage achieving high efficiency, small size and low cost.

Operation modes: These topologies have only two operation modes, normal plus battery charger and back-up mode. Both operation modes are in CCM and share same switch, control loop, and transformer.

Multi-output voltages: Additional windings can be placed in the transformer in order to obtain multi- outputs voltages (Figure 4); this is another characteristic that can be taken advantage of in the design of the converter.

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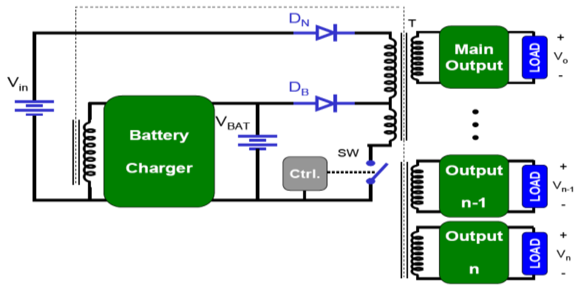

Figure 3. Additional windings to obtain multi-output voltages.

One switch: This is another important advantage of this kind of converters because all of them use only one switch, sharing the primary winding of the transformer, and uses only one control loop compensation for both operation modes. This makes the design of converter very simple and is other important characteristic to be considered in industrial applications.

Automatic Transition: This is possible under the idea to use two diodes to make this transition (DN and DB), when the converter is fed by the dc voltage entrance (Vin), DN conduce and automatically DB is blocked. When suddenly a problem occurs in the dc voltage entrance, automatically DB conduces allowing that the system be fed immediately from the battery. Since both entrances share the same transformer with a centered tap connection through DB the output voltage does not suffer any change in its value. This idea is important because it is not necessary to use any auxiliary circuit control to detect when a fail occurs, allowing fast dynamic response.

B. Circuit operation in different mode:

The circuit of the proposed integrated fly back converter is shown in Fig.4. The switch SW1 is used to select the mode of operation. When the main power input VAC is functioning properly, the switch SW1 will be closed and MOSFET Q2 turned off to operate the converter in normal mode. The equivalent circuit of the converter in normal mode is shown in Fig. 5(a). The battery voltage VB should be chosen to be higher than Vc1n2/n1 to prevent diode D2 from conducting when Q1 is turned on. Such choice will make the backup converter (VB, Q2, D2 and n2) idle, thus disappearing from the equivalent circuit during normal-mode operation. When input power failure is detected, MOSFET Q1 will be switched off and switch SW1 will be closed to operate the converter in backup mode. The equivalent circuit of the converter in backup mode is shown in Fig.5 (b).

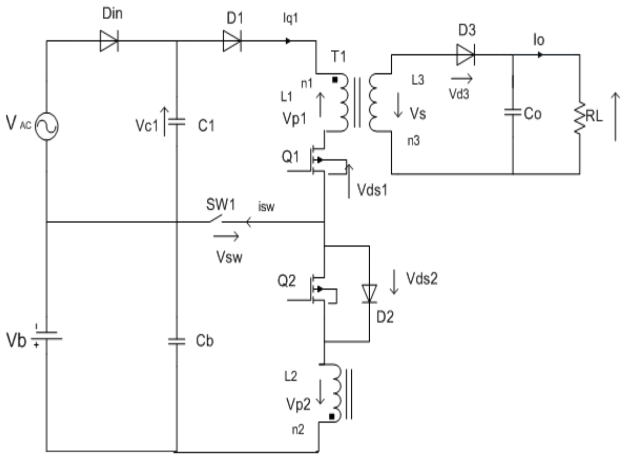

Figure 4. The proposed integrated fly-back converter

As the battery voltage VB is much lower than main input voltage V_{Cl}, the switch current iQ2 in backup will be much higher than the switch current iQ1 in mode normal mode. Therefore a low-voltage, low-R_{Ds}(on) MOSFET should be chosen for Q2. The number of turn's n2 in the primary of backup converter should be chosen to be much smaller than n1 in the main converter and with much higher current winding used.

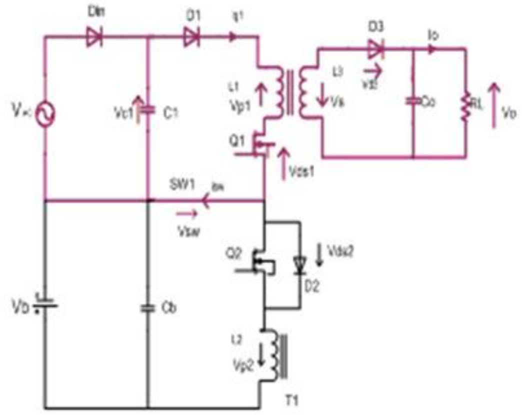

Figure 5(a) Normal Mode

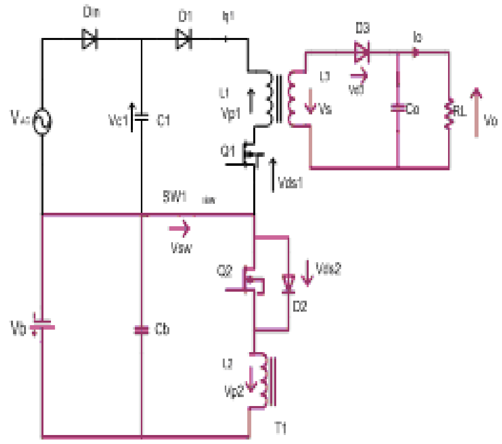

Figure 5(b) Back-up mode

When the main power input VAC is functioning properly, SW1 can be opened to operate the converter in the charging mode. The equivalent circuit of the converter in the charging mode is another flyback converter as shown in Fig.5(c). As the battery VB is in series with the main input VCl, the battery charging current -IB will be equal to the averaged input current IQ1 from VCl.

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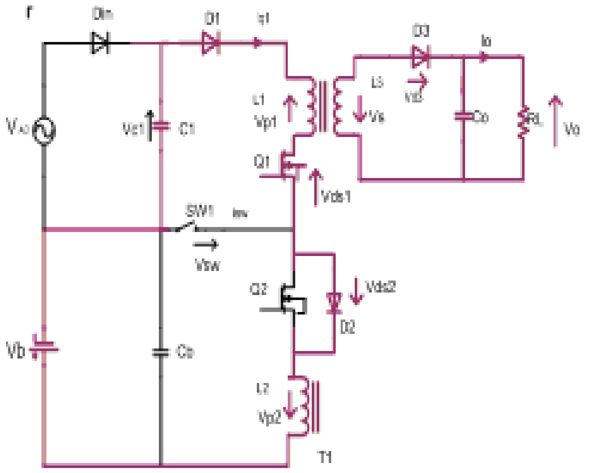

Figure.5(c) Charging mode

A disadvantage of the proposed converter is that the charging current is load-dependent and cannot be controlled independently. The converter thus cannot provide battery charging when there is no load. Battery charging is instead controlled by charging time, i.e. the duration the converter operates in charging mode.

C. Steady-State Analysis

The steady-state analysis of the converter is performed with the following assumptions.

- The converter operates in the continuous conduction.
- D1 and D2 have slow reverse recoveries.
- Power losses and stray capacitances and inductances are ignored.
- Capacitor voltages are constant within a switching cycle.

Referring to the equivalent circuits in Fig.5, the expressions for the steady-state waveforms of the converter in different modes of operation can be written as shown in Table-A.

As a design requirement, the duty cycles in different mode of operations are related by

$$D_2\ (\text{Backup}) < D_l(\text{Norma1}) < D_l(\text{Charging})$$

In order to keep the output voltage V0 constant.

The voltage stress shown in the table –A on Q2 during turn off in different operating modes can be related by

$$V_{DS2}(\text{Norma1}= V_{DS2}(\text{Backup}) > V_{DS2}(\text{Charging})$$

The voltage stress on D3 during turn off in different operating modes can be related by

$$V_{D3}(\text{Backup}) > V_{D3}(\text{Normal}) > V_{D3}(\text{Charging})$$

The voltage rating of D_3 should thus be chosen according to iD3PK. The peak MMF in transformer T_I is given by MMFPK = n3iD3PK together with the maximum value of the expressions is used to determine the air gap length of the transformer core of T1.

TABLE-A: CIRCUIT PARAMETERS UNDER DIFFERENT OPERATING MODES.

Parameter	Normal Mode :		Backup Mode :		Charging Mode :	
	$0 < t < D_1T$	$D_1T < t < T$	$0 < t < D_2T$	$D_2T < t < T$	$0 < t < D_1T$	$D_1T < t < T$
V_{p1}	V_{C1}	$-n1V_0/n_3$	n_1V_B/n_2	$-n_1V_0/n_3$	$n_1(V_{C1}-V_B)/(n_1-n_2)$	$-n_1V_0/n_3$
V_{p2}	n_2V_{C1}/n_1	$-n_2V_0/n_3$	V_B	$-n_2V_0/n_3$	$n_2(V_{C1}-V_B/(n_1-n_2)$	$-n_2V_0/n_3$
V_s	$n3V_{C1}/n_1$	$-V_0$	n_3V_B/n_2	$-V_0$	$(V_{C1}-V_B/(n_1-n_2)$	$-V_0$
V_{DS1}	0	$V_{C1} + n_1V_0/n_3$			0	$(V_{C1}-V_B)+(n_1-n_2)V_0/n_3$
V_{DS2}	$V_B - n_2V_{C1}/n_1$	$V_B + n_2V_0/n_3$	0	$V_B + n_2V_0/n_3$	0	0
V_{DS3}	$n_3V_{c1}/n_1 + V_0$	0	$n_3V_B/n_2 + V_0$	0	$n_3(V_{C1}-V_B)/(n_1-n_2) + V_O$	0
V_{D1}	0	0			0	0
V_{sw}	0	0	0	0	$(n_1V_B-n_2V_{C1})/(n_1-n_2)$	$V_B+n_2V_0/n_3$
V_0	$V_{C1}\ nD_1/n_1D_1'$		$V_B\ n_3D_2/n_2D_2'$		$(V_{C1}-V_B)n_3D_1/(n_1-n_2)D_1'$	
D_1	$n_1V_0/(n_1V_0+n_3V_{C1})$		0		$(n_1-n_2)V_0/[(n_1-n_2)V_0+n_3(V_{C1}-V_B)]$	
I_{Q1}	I_0n_3/n_1D_1'		0		$I_0n_3/[(n_1-n_2)D_1']$	
I_{Q2}	0		I_0n_3/n_2D_2'		$-I_0n_3/[(n_1-n_2)D1'$	
I_{D3}	I_0/D_1'		I_0/D_2'		I_0/D_1'	
I_B	0		$I_0(D_2/D_2')(n_3/n_2)$		$-I_0(D_1/D_1')[n_3/(n_1-n_2)]$	
I_{sw}	$I_0(D_1/D_1')(n_3/n_1)$		$I_0(D_2/D_2')(n_3/n_2)$		0	
i_{D3PK}	$(I_0/D_1')+(V_0D_1'T/2L_3)$		$(I_0/D_2')+(V_0D_2'T/2L_3)$		$(I_0/D_1')+(V_0D_1'T/2L_3)$	
Where $D' = 1 - D$.						

D. Design considerations

Design has to take into account the total relation among all the components and semiconductors in the converter as input voltage variation, output power and the possible relation turns in the transformer. Analysis and design of this converter only have to take into account restrictions in construction of the converter because it uses two topologies much known, sharing same transformer, switch and control. The desirable duty cycles in each operation mode, determine the possible turn ration in the transformer. One important consideration to guarantee the correct operation of the converter in normal operation mode is to ensure that cathode voltage in DB has to be higher for any rectifier input voltage (V_{in}). In order to accomplish this, equation (1) has to be satisfied.

$$V_{in}N_b/N_a > V_{BAT} \quad \text{…………….(1)}$$

III. SIMULINK MODEL OF PROPOSED INTEGRATED FLY BACK CONVERTER

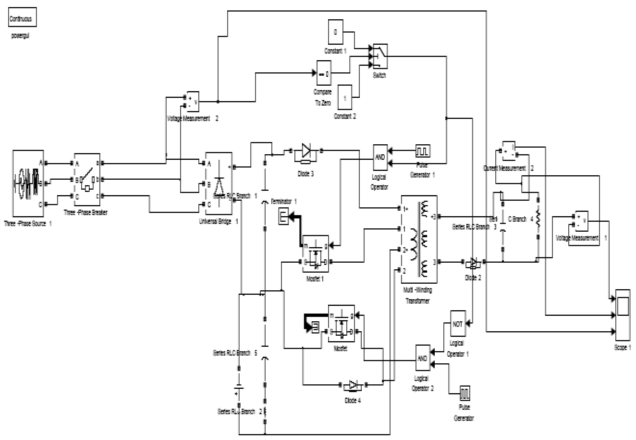

Figure 6. Integrated operation of Normal and Backup with control circuitry for automatic on-off operation of two MOSFET's with three phase circuit breaker

Fig 6 shows simulink model of integrated flyback converter for high frequency dc UPS operation. For demonstrating practical aspect we used circuit breaker to cut off the main supply for few cycle interruptions.

A. Simulation Results

Fig. 6.1 and Fig 6.2 shows the result of output current and output voltage under Normal and back up mode of simulink model shown in Fig 6.

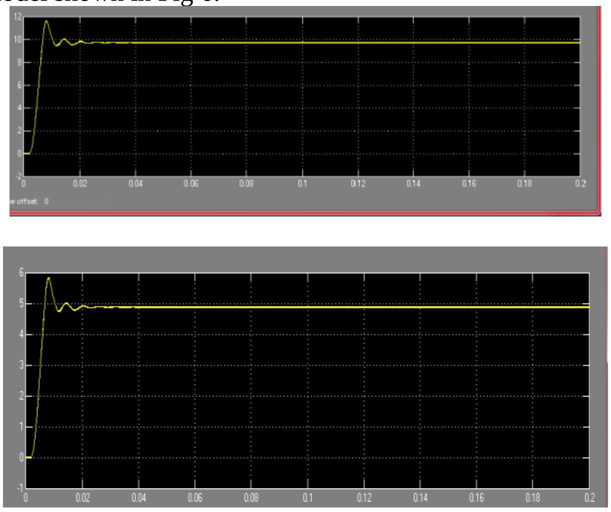

Figure 6.1 Load current and load voltage versus time in normal mode.

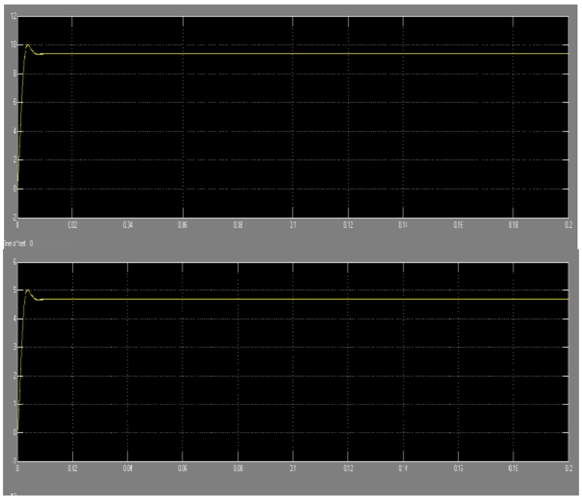

Figure 6.2 Load current and load voltage versus time in back up mode

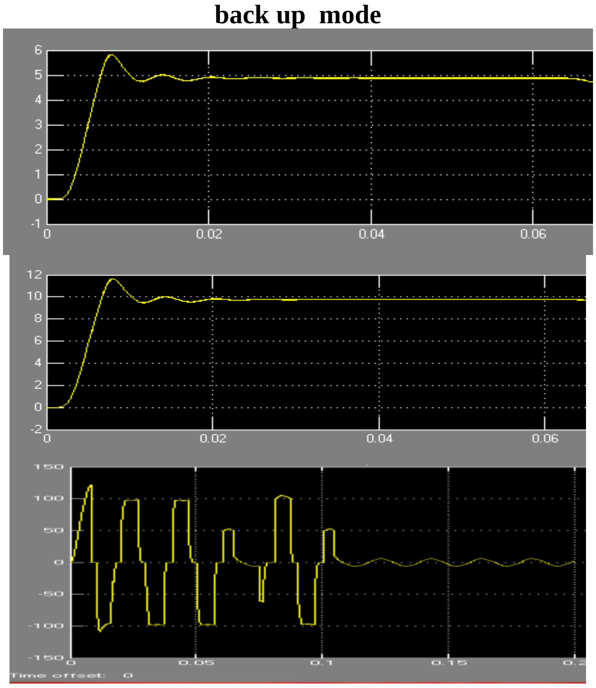

Figure 6.3 load voltage, load current, and main supply voltage versus time

IV. CONCLUSIONS

A single simple structure of converters has been developed to make Automatic Transition without fail detects circuit. Preliminary results of the converter shows that is an interesting propose from point of view operation, size, dynamic response and cost because it is a very simple structure based in a Flyback converter with two outputs. Simulation and results show that the converter shows a good operation. The answer of the circuit before failure of the main AC has been very fast and an output voltage has been obtained that as soon as it throughout varies the operation of the circuit. The transitions of operation in a one mode operation to another one do not suppose any change in the output voltage, as it were expected.

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