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UNINTERRUPTABLE POWER SUPPLY DESIGN USING FLOAT AND BOOST TECHNOLOGY

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Abstract - *In Military and Defence applications, Power supplies are of most important component. Usually, Uninterruptable power sources (UPS) with constant output voltage is required for continuous operation. In the recent years, UPS is designed using a new technology called Float cum Boost Charger (FCBC). FCBC is basically an UPS for ULSB MK-III devices which operates on 48V DC. In the present work, FCBC is used for delivering regulated output voltage of 48V DC at 4 Amps when loaded fully. Alternatively, a battery backup is also provided wherein, the battery is charged when AC mains is present. Even when the 230V Power supply is OFF, charged battery backup of 24V 6Amps is sufficient to deliver the required output voltage. Therefore, the entire system operates continuously with a constant voltage of 48V DC. The efficiency of the FCBC module was also well within the specified limits which indicated that use of FCBC is a good alternate for the conventional UPS systems.*

***Key Words*: Battery, Float Cum Boost Charger, Unit Level Switch Board, Uninterruptable Power Supply.**

1. INTRODUCTION

Power supply units are a must for functioning of any electrical equipment. To reduce the risk of power supply distortion, Uninterruptible Power Supply (UPS) systems are often incorporated in electrical equipment [1]. An UPS is designed to provide a battery-based source of AC power, such that under mains fail conditions the load can be supported for a specified period of time [2]. In military and defence applications, AC supplies are not preferred because continuous power supply is of Utmost importance. Therefore, this problem is overcome by using DC power supplies. For this Purpose, Float Cum Boost Charger (FCBC power supply module) is used [1, 2]. This work focuses on providing a regulated output voltage through the design, functionality and practical performance of FCBC. In this work efficiency, is the main parameter under consideration.

1.1 Float mode of operation

In Float mode, FCBC supplies DC voltage required to drive the load continuously and it also trickle charges the battery. This charged battery acts as a backup to drive the load when AC mains are OFF. As the battery gets charged, its charging current reduces gradually. The float charger senses the reduction in charging current and reduces the charging voltage. If the battery gets drained, the float charger will again increase the charging voltage and the process continues [3].

1.2 Boost mode of operation

Boost charging involves a high current for short period of time to charge the battery. It is generally used if the battery has been discharged heavily. Boost charging enables the quick charging of the depleted batteries [3].

2. SPECIFICATIONS OF POWER UNIT

Input voltage variation	: 150V AC to 300V AC
Lower voltage cutoff	: ≤150V AC
Upper voltage cutoff	: ≥300V AC
Output voltage	: 48±2V DC
Output rated current	: 4±1 Amps
Efficiency in Battery mode	: 75% (approximately)
Efficiency in AC mode	: 50% (approximately)

3. WORKING PRINCIPLE OF FCBC

Float Cum Boost Charger (FCBC) is a switched mode module capable of delivering regulated voltage of 48V at 4Amps when loaded fully. ULSB MK-III equipment operates at 48V DC. As the equipment is required to provide uninterrupted service to the subscribers, the FCBC provides 48V DC to the ULSB MK-III from an AC mains of 150V to 300V, 50Hz and in case of mains power failure the FCBC provides 48V DC to the equipment using battery bank of 24V connected to the FCBC. The change over from AC to DC is automatically done in case of power failure condition. The block diagram of FCBC is shown in Fig 1.

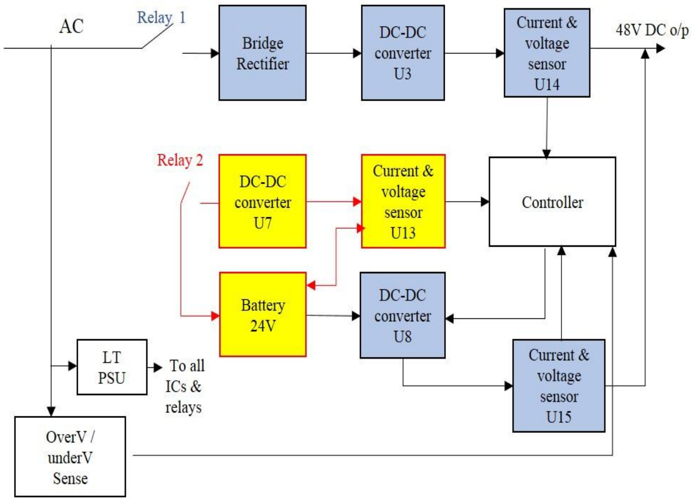

Fig -1: Block diagram of FCBC

A secondary transformer of two independent windings is connected directly after the fuse of AC mains supply. It outputs a nominal DC voltage of 21V from 220V AC through the bridge rectifiers. The input AC is applied to FCBC through EMI filters to bridge rectifier which converts 300VAC to 300V DC. The rectified DC is fed to DC-DC converter (U3) and a ripple filter. The output of ripple filter is passed to output via current sensor for purpose of over voltage and load current protection. During operation on AC mains supply, this current sensor protects the unit against overvoltage, excessive load current. If battery is connected when AC mains supply is ON, the rectified 300V DC is applied to DC-DC Converter (U7) for converting to 24V and is fed to battery to charge it. Relay RL1 is used to enable charging circuit whenever the battery potential is below 20V [4]. In the absence of AC mains, 24V battery voltage is applied to DC-DC Converter (U8) for conversion of 24V to 48V. This voltage is passed through current sensor. The current sensor gets activated and provides protection against overload and short-circuits. One output of the secondary winding is used to sense the input mains variation during AC mains operation. The output of this winding follows the variation on the mains supply. The FCBC is designed to operate from AC mains of 150V to 300V. Below 150 and above 300V, the unit gets automatically changed to battery mode after cutting off the mains supply for AC operation mode. In case of non-availability of AC mains and complete discharge of the battery, the entire unit automatically shuts down to protect it against under and over voltage variations. This protection is provided through Relay RL2. FCBC is equipped with a PIC microcontroller (PIC16F877A) to sense, control and indicate the status of the FCBC during operation [4].

3.1 Modes of operation

There are two modes of operation of FCBC. They are

I) AC/Battery Mode
II) Battery charging Mode

The block diagram of AC/Battery Mode is shown in Fig2.

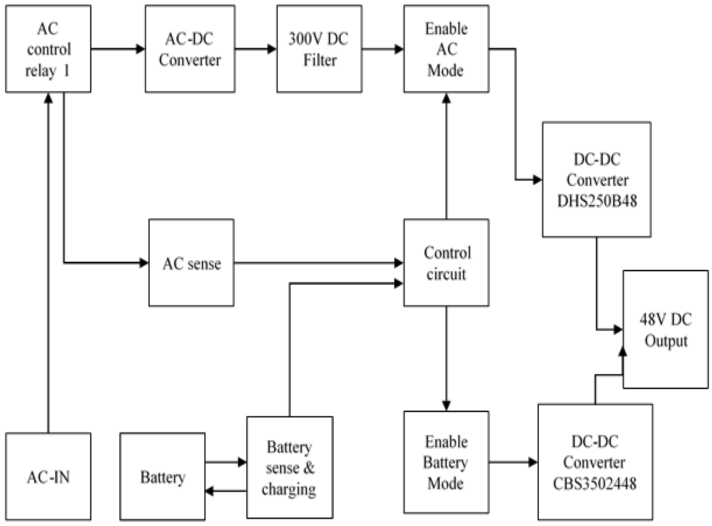

Fig -2: Block diagram of AC/Battery Mode

During the AC operation, the unit gets the supply from AC input connector. A rectifier, along with a DC-DC converter enables the required 48V output across pins of output connector for the operation of ULSB MK-III. During the operation in AC mode, the unit in addition to delivering 48V DC to ULSB MK-III, outputs a charging voltage to the 24V batteries through the charging circuit comprising a DC-DC converter and a relay [4].

The block diagram of battery charging mode is as shown in Fig 3. When the AC mains is ON, the battery gets charged which functions as a source of load when AC mains is OFF. When the FCBC is operating in AC mode, in addition to delivering a DC supply of 48V for the operation of ULSB MK-III, a DC supply required for the charging the battery is also generated. This charging voltage varies from 18 volts to 28 volts approximately depending on the charge already available in the battery. The maximum current drawn by the battery from the charging circuit is about 6 Amps.

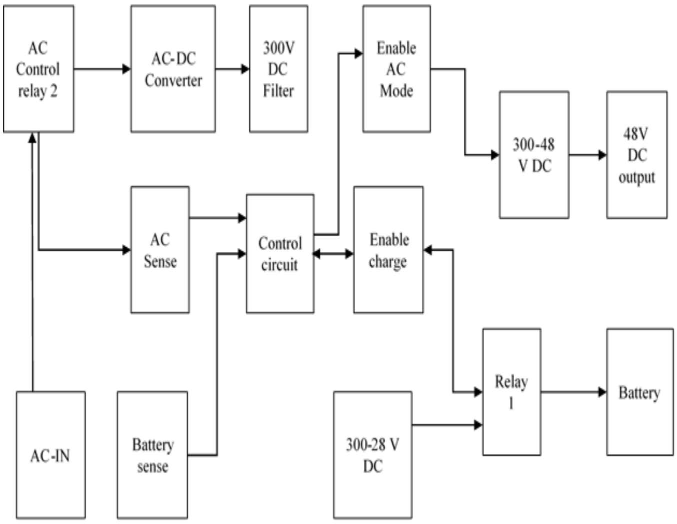

Fig -3: Block diagram of Battery charging Mode

4. PCB LAYOUT OF FCBC

The PCB layout of entire setup is as shown in Fig 4.

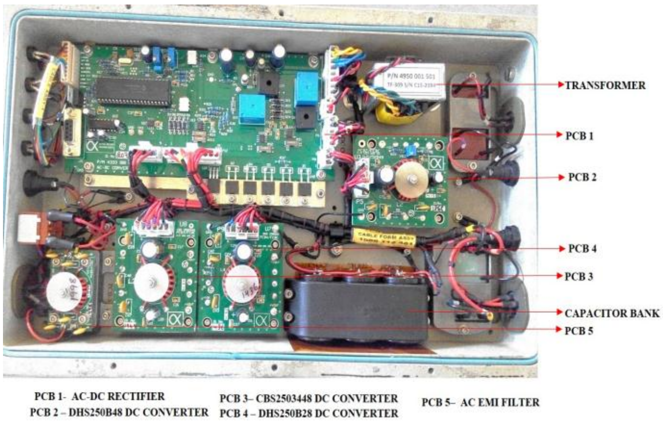

Fig -4: PCB Layout of FCBC

PCB 1 (AC-DC Rectifier):
The main purpose of PCB 1 is to convert the 300V AC to 300V DC via a bridge rectifier and is supplied to the converters for delivering load to the output.
The sensor INA271A measures the voltage drop and senses the current within the limits.
The PIC16F877A Controller controls the functions of all IC's such as UV, OV, Trim voltage, etc…
The DAC MCP4921 delivers the trim voltage to PCB 4 depending on the battery condition.
The regulator 7805 is used to obtain a constant voltage of 5V to supply power to IC's.

PCB 2 (300-48)V DC-DC Converter:
The input to the converter is 300V DC and the output from the converter is 48V DC and is delivered to the output load.

PCB 3 (24-48)V DC-DC Converter:
This DC-DC converter works in battery mode when mains are OFF. The input is 24V DC and the output is 48V DC and is delivered to load

PCB 4 (300-28)V DC-DC Converter:
The input is 24V DC and the output is 48V DC and is delivered to load.
The rectified 300V DC output voltage is given as input to the PCB4 to convert to 28V DC to charge the battery in AC mode.
Depending on the condition of battery, this voltage is controlled by the trim voltage from the DAC (MCP4921).

PCB 5 (AC EMI Filter):
The main purpose of AC EMI filter is to filter the harmonics and ripple in the circuit.

5. HARDWARE IMPLEMENTATION & RESULTS

The hardware implementation of FCBC is as shown in Fig 5. The parameters that are to be measured on FCBC is Efficiency.
Efficiency is defined as the ratio of output power to the input power. The formula of efficiency is shown in Equation 1.

$$\%\,efficiency = \frac{Pout}{Pin} * 100 \quad \text{.............. (1)}$$

AC Mode:

$$P_{out} = (V_{out} * I_{out}) + (V_{bat} * I_{bat}) \quad \text{............... (2)}$$

$$P_{in} = 230 * I_{in} * 0.7 \quad \text{...................................... (3)}$$

DC Mode:

$$P_{out} = (V_{out} * I_{out}) \quad \text{....................................... (4)}$$

$$P_{in} = (V_{in} * I_{in}) \quad \text{.. (5) [4]}$$

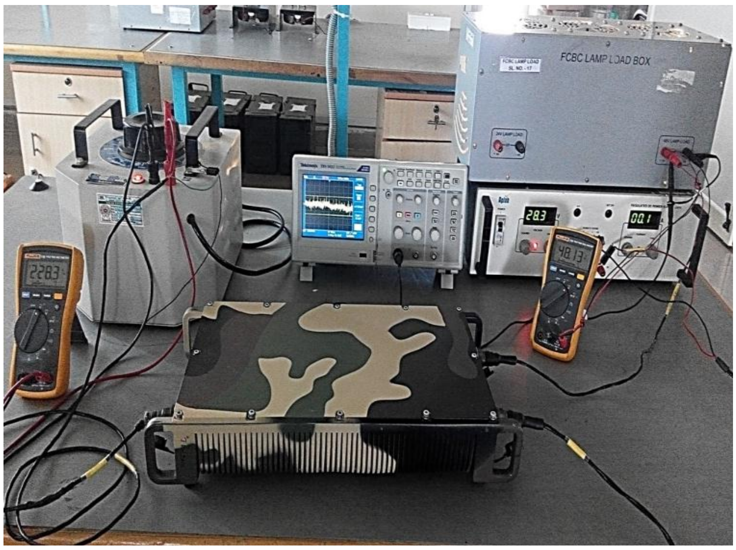

Fig -5: Hardware implementation of FCBC

Calculations:

Efficiency for AC and Battery mode operation is calculated using the following specifications as per requirement.

a) Input voltage: V_{in} =230V AC

b) Input current: I_{in} = 2.5Amps

c) Output voltage: V_{out}= 47.85V DC

d) Output current: I_{out} = 3.9Amps

e) Battery voltage: V_{bat}= 24V DC

f) Battery current: I_{bat} = 5Amps

Efficiency in AC mode:

$$P_{out} = (V_{out} * I_{out}) + (V_{bat} * I_{bat})$$

= (47.85*3.9) + (24*5)

=306.615 W

$$P_{in} = 230 * I_{in} * 0.7$$

= 230*2.5*0.7

= 402.5 W

$$\% \ efficiency = \frac{P_{out}}{P_{in}} * 100$$

$$= \frac{306.615}{402.5} * 100$$

= **76.177% (> 65%)**

Efficiency in Battery mode:

$$P_{out} = (V_{out} * I_{out})$$

= (47.85*3.9)

= 189.36 W

$$P_{in} = (V_{in} * I_{in})$$

= (230*2.5)

= 216 W

$$\% \ efficiency = \frac{P_{out}}{P_{in}} * 100$$

$$= \frac{189.36}{216} * 100$$

= **87.66 % (> 75 %)**

The efficiency in AC mode is less compared to DC mode as the AC mode has more ripple compared to DC (Battery) mode.

6. CONCLUSION

Regulated power output is a very important criteria to be considered in military applications for its continuous operation. The use of FCBC in ULSB MK-III resulted in better efficiency. The hardware implementation and practical testing of FCBC is discussed and the results obtained are within the specification limits and satisfactory.

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