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Fault-Tolerant Power Supply for Aircraft-Store Interface

Harminder Singh Johar,[#,*] Abhijit Bhattacharya[$] and Srinivasa Rao S.[%]
[#]*DRDO - Research Centre Imarat, Hyderabad-500 069, India*
[$]*DRDO - Defence Research and Development Laboratory, Hyderabad – 500 058, India*
[%]*Electrical Engg. Deptt. NIT, Warangal, Telangana - 506 004, India*
[*]*E-mail: hsjohar@rcilab.in*

ABSTRACT

This paper brings out the design of a fault-tolerant power supply unit for the aircraft-store interface. This switched mode power supply provides multiple 30 V regulated and isolated DC outputs required for pre-launch preparations and auto-launch operations of avionic sub-systems in a store. 3Ø-115V-400Hz-AC supply as well as 27V-DC supply are available from a fighter aircraft for powering up of any store. Power (wattage) output from 27V/10A DC is inadequate to power up various onboard avionic sub-systems in guided stores involving seekers and other avionics. Hence, it is planned to convert available high power 3Ø-115V-400Hz-AC supply for applications requiring higher wattages (of the order of 500 watts or more). This power supply provides multiple output options of 30V regulated and isolated DC supply with multiple input supplies from Aircraft, viz. 3Ø-115V-400Hz-AC, 1Ø-115V-400Hz-AC and 27V DC. One of the outputs provided is with hold-up capacitors, to cater for any input power interruptions as per requirements of MIL-STD-704F and GOST-19705-89 standards. This power supply is a ready-to-connect device and essentially consists of housing, components of DC to DC conversions, EMI/EMC filters, solid state power controllers, control switches, and control circuitry for monitoring signals.

Keywords*:* Hold-up capacitor; MIL-STD-704F; GOST-19705-89; MIL-STD-461F; MIL-STD-810G

NOMENCLATURE

P	Output Power, watts
E	Energy stored in Capacitor, joules
C	Capacitance, μF
V	Voltage, volts
V_{max}	Max. Voltage, volts
V_{min}	Min. Voltage, volts
t	Capacitor energy storage time, msec
L1	Common mode inductance, milliHenry
L1R	R-Phase inductance
L1Y	Y-Phase inductance
L1B	B-Phase inductance
L2, L3, L4	Differential mode inductance, milliHenry
C1, C2, C3	Y capacitance, μF
Cos Ø	Power factor
η	Efficiency, %
T_{op}	Operating temperature, °C
T_{stor}	Storage temperature, °C
fc	Filter corner frequency, KHz

1. INTRODUCTION

Reliability of power supplies is an area of great interest, particularly for military and aerospace industries that are increasingly adopting power electronic devices to improve overall system efficiency and performance. Power supplies are mission critical mainly for aerospace applications such as Air to Surface, Air to Air and other Air launched stores. During pre-launch preparations and auto-launch operations, an air-launched store is powered ON with an aircraft power supply and health checks of all avionic sub-systems are carried out.

Reliability is of paramount importance and continuous operation of the system must be ensured. Modern Air-vehicle power system architectures are driven by redundancy and fault tolerance requirements (in particular the ability to supply uninterrupted power) as well as cost, weight, power quality, and electromagnetic compatibility (EMC)[3,5] requirements. As a result, parallel redundancy for fault tolerance is often employed for these systems, although at a higher system cost. The concept of fault tolerance focuses on the satisfactory and continuous operation of a particular system, even during faults. The term "satisfactory" implies a minimum level of performance after a fault and will therefore be heavily influenced by system requirements.

A fault-tolerant switched mode power supply with a 2000 watts rating, is designed and presented in this paper. To optimize the size and weight considerable amount of modeling, structural and thermal analysis is done before realizing this power supply. In aerospace applications, size and weight are a major concern since they affect the overall system efficiency. A major activity of the aviation industry is the reduction of emissions in combination with cost efficiency. On one hand, eco-friendly aircrafts save the industry more money because of forecasted rising fuel prices in the future; on the other hand, environmental pollution will become increasingly a problem for human society. The main part of development is focused on reducing weight and because of that directly reducing fuel consumption. Electrical systems use only 0.2 % of the whole

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engine power[7] at cruise, so savings in electrical consumption have only a small effect on aircraft fuel consumption. Weight savings on the other hand have a positive "snowball effect". For example, saving one kilogram on the equipment means also a possible weight reduction of the aircraft structure and the engine by an additional 600 g. A saving of 1.6 kg of the aircraft weight translates into lower fuel consumption and an extended performance[6].

There are many physical and operational differences between electrical machines which are used in industry and aviation[13]. The most notable difference is the voltage level. In industry, a 230/400 V-AC system at 50 or 60 Hz is used. In aviation, 115/200V-AC at 400 Hz or 230/400V-AC at a variable frequency and 28V-DC or ±270V DC are used[11,12]. The power supply discussed in this paper, provides multiple 30 V regulated and isolated DC outputs for pre-launch preparations and auto-launch operations of avionic sub-systems in a store, before launching from the aircraft. 3Ø-115V-400Hz-AC supply, as well as 27V-DC supply, is available from aircraft [8,9,12] for powering-up a store. The power output of 27V/10A DC from aircraft is not sufficient to power up various onboard avionic sub-systems in guided stores involving seekers and other avionics. Hence it is planned to convert available high power from the 3Ø-115V-400Hz-AC supply for applications requiring higher wattages (of the order of 500 watts or more). This power supply provides multiple output options of 30V regulated and isolated DC supply using multiple input supplies from the aircraft[8,9,12] as follows:

(a) 3Ø-115V-400Hz-AC,
(b) 1Ø-115V-400Hz-AC and
(c) 27V DC.

One of the power outputs provided is with hold-up capacitors, to cater for any input power interruptions as per requirements of MIL-STD-704F[1] and GOST-19705-89[2] standards. These power interruptions are anticipated during switching over from one engine of the aircraft to the other. MIL-STD-704F specifies this switching over time as 50 milliseconds (msec) and GOST-19705-89 specifies this time as 80 msec. However, to compensate for these power interruptions, hold-up capacitors are chosen such that they provide power backup for a minimum of 100 msec, suiting the requirements of both the above mentioned aircraft power supply standards.

This power supply is fault-tolerant since it provides regulated and isolated DC output, with AC input in the form of two power buses (PB-1 & PB-2). The power output of PB-1 is 1500 watts and of PB-2 is 500 watts. PB-2 incorporates hold-up capacitors for any input power interruptions as per MIL-STD-704F[1] and GOST-19705-89[2] standards. The power output of PB-1 and PB-2 employ redundancy at the converter level, hence fault-tolerant and uninterrupted power would be available continuously.

Further fault tolerance is built into this power supply since it takes another aircraft input of 27V DC supply in addition to 3Ø and 1Ø (115V-400Hz) AC input. If there is any problem with aircraft AC supply, this power supply will work with 27V aircraft DC supply as input and provide 30V regulated and isolated DC supply as output, with reduced wattage, i.e. of the order of 300 watts. Since there is built-in redundancy at the input as well as output levels, hence this power supply is referred to as fault tolerant.

This power supply unit is a Line Replaceable Unit (LRU) in the launcher platform of a fighter aircraft. It has a mission-critical role of converting AC input supply to DC multi-outputs for powering a weapon system (store). Multiple output DC voltages are generated from this unit. These voltage limits are as follows:

- Output-1: 30V DC/25A (PB-1)
- Output-2: 30V DC/25A (PB-1)
- Output-3: 30V DC/17 A (PB-2)
  (With hold-up of 30V DC/8A for 100 ms)
- Output-4: 30 VDC/10 A
- Trim output voltage Range: ± 5 %
  (Current remains constant)

Other specifications are as follows:

- AC Operating voltage: 108V – 125V P-N (1Ø and 3Ø)
- Operating frequency: 350Hz to 420Hz (1Ø and 3Ø)
- Cos Ø : ≥ 0.8
- Ripple content : < 150 mV
- Noise : < 250 mV
- Efficiency (η) : > 85 %
- Load/Line regulation : ± 1 %
- Input to Output Switching delay: <500 msec
- Isolation : >100MΩ at 500 VDC
  -Input to Chassis
  -Input to Output
  -Output to Chassis
- Remote ON/OFF & Sensing: Provided
- T_{op} : -40 °C to +71°C
- T_{stor} : -55 °C to +85 °C
- Shock & Vibration: Conforming to MIL-STD-810G[4]

2. PHYSICAL DESCRIPTION

This power supply is based on AC-DC converter & DC-DC Converter technology with rack-mountable mechanics for mounting on customized units. It is based on standard high-density, high-reliability power modules already developed for applications adopting modular technology, easy replacement, and the latest state-of-the-art engineered technology. This power supply is a ready-to-connect device and essentially consists of housing, components of DC to DC conversions, EMI/EMC filters, solid state power controllers, control switches, and control circuitry for monitoring signals.

The mechanical (Isometric) view of this power supply unit is shown in Fig. 1 Entire unit is housed in a compact metallic

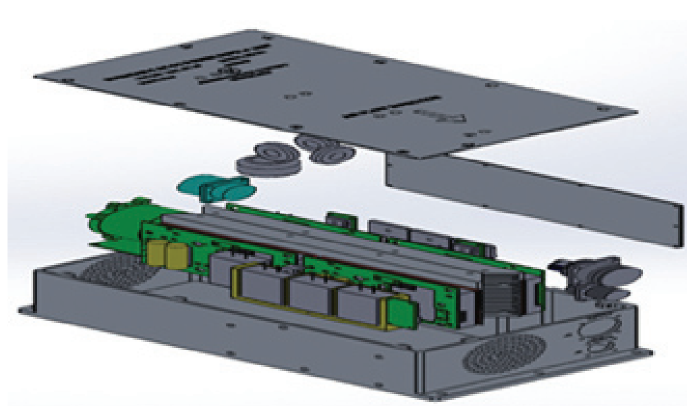

Figure 1. Mechanical (Isometric) view of power supply.

enclosure. Most of the electronic components are mounted on printed circuit boards and heat dissipating components and induction elements are placed in the metal housing for thermal management and prevention of mutual interference. The weight of this power supply unit is approximately 5 kg.

3. ELECTRICAL DETAILS

This power supply unit takes 1Ø & 3Ø, 115V AC, Phase – Neutral, 400 Hz & 27 V DC as power inputs from the aircraft through the J1 (Input) connector and converts it to isolated output voltages (Output-1, Output-2, Output-3) which are taken out through the J2 (Output) connector. Output-4, power supply OFF, and other debug interfaces are routed through the J3 connector. The internal block diagram of the complete unit is shown in Fig. 2.

This power supply unit is physically configured with 4 sections as follows:

- EMI/EMC section
- Rectifier section
- DC-DC converter section
- Output monitoring and protection section

Input 115V AC, 1Ø/3Ø, 400 Hz is taken through J1 connector, filtered, through Electro-magnetic Interference (EMI) filter and rectified using 1Ø bridge rectifiers, which gives a voltage of 160V DC and 270V DC at 115V AC, 1Ø, and 3Ø nominal voltage respectively. 270V DC output with 3Ø-115V AC input is selected since 270V

DC is gradually adopted as standard voltage level in future aircraft applications[5, 6, 10, 12]. This 160V/270V DC is fed to M1, M2, M3, and M4, 800W DC-DC converter modules through filters. These modules generate the required output voltage and power. Each DC-DC converters is isolated and has all necessary electrical controls, and protections/interlocks for safe shut-down of individual units in case of any malfunction. DC-DC Converters are very small and light because of their electronic components with a high power density. A DC-DC converter uses less number of electronic components which leads to the lowest average power density as compared to AC-AC, AC-DC, and DC-AC converters[6]. Hence weight optimization is achieved which is very important in aerospace applications since it affects overall system efficiency. There is restricted space on-board the aircraft, so the size of the components should be kept as small as possible. The selection of an electrical machine depends not only on its size and power but also on its weight. A very high power density of machines is necessary[11,14-15].

The primary functions of this power supply are reception, control, conversion, and distribution of DC voltage to the weapon system (store). Also, this power supply is well equipped with voltage, current, and temperature protections.

Its secondary function is to link with the host system

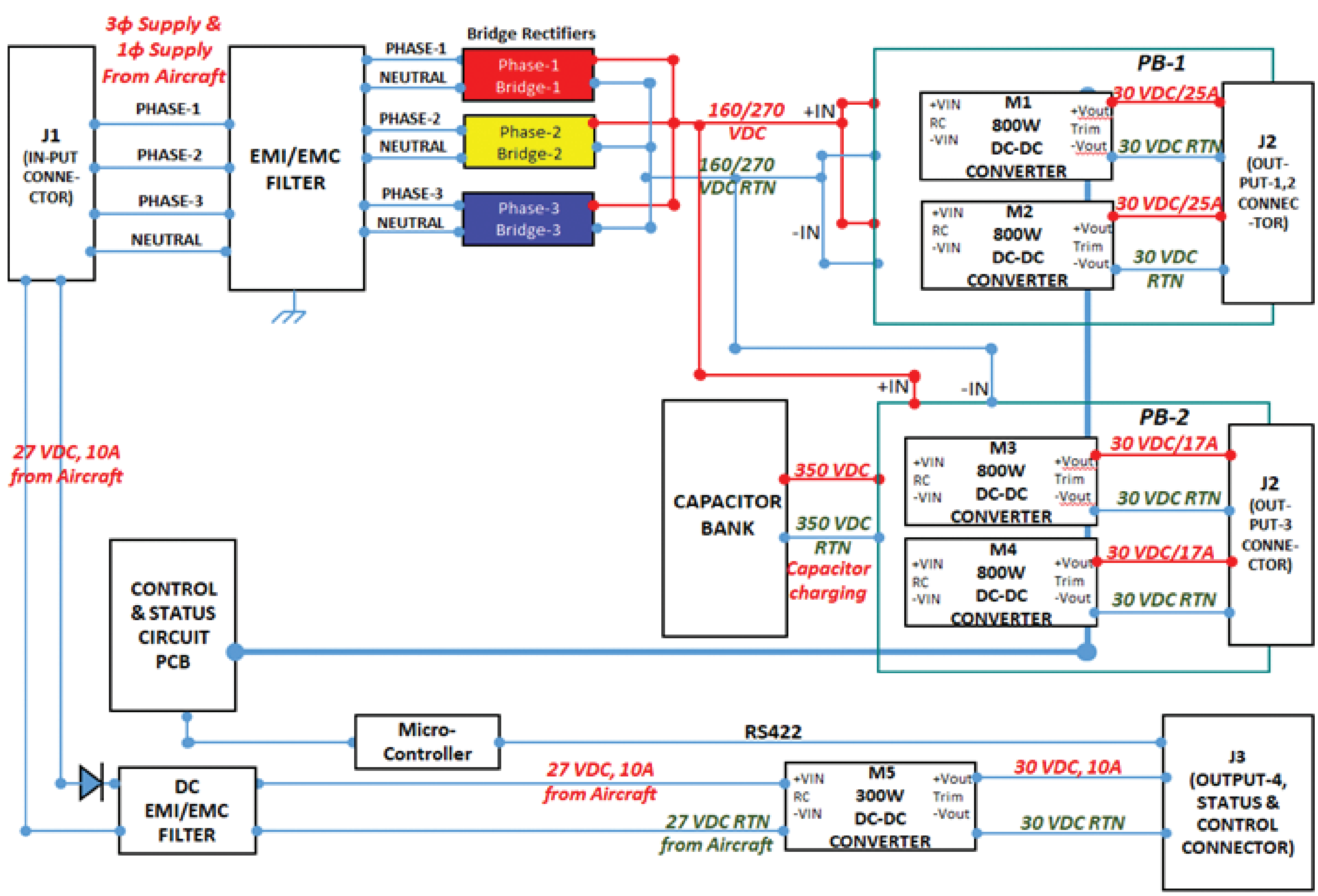

Figure 2. Internal Block Diagram.

for diagnostic and safety purposes and to link with the test Graphical User Interface (GUI) for debugging purposes. Within the power supply, power modules have the protection of output current limitation, over temperature shutdown, input under-voltage, and output over-voltage limit and can be programmed through the RS422 link.

Protection and necessary shut-down are accomplished through a micro-controller. This micro-controller constantly monitors the health status of DC-DC converters and temperatures inside each section and other circuits. It also controls other housekeeping circuits and displays these parameters on the GUI.

Microcontroller used is a 32-bit Arm Cortex micro-controller unit. It works on 3.3V DC, which is obtained by stepping down 30V DC to 3.3V DC using potential divider circuits. This potential divider circuit is also placed inside the power supply unit. The detailed functionality of this micro-controller is explained in Section 4 (monitoring section).

All modules are fastened directly to a heat sink to minimize thermal resistance between module & heat sink. A high-speed military-grade AC fan operating from 115V AC at a speed of 25000 rpm, 9 m/sec air flow rate is used for cooling in addition to conventional conduction cooling. This high-speed fan operates during AC input voltage only (1Ø or 3Ø) as maximum heat has to be dissipated during AC operation only.

During DC operation, only the M5 module is switched ON, hence power dissipation is very less and heat dissipation is achieved only by conduction cooling.

This unit is designed to meet MIL-STD-704F[1] & GOST-19705-89[2] defense standards. Also, it is designed to meet conducted and radiated emissions within specified limits as per requirements[3,5] for EMI/EMC.

One of the power outputs (150 watts) provided is with a hold-up capacitor bank, to cater for any input power interruptions. Capacitance values are calculated as follows:

$$P = 150/0.9 = 166,\ t = 100\,m\sec$$

$$V_{\max} = 350V$$

$$V_{\min} = 250V$$

$$E = \frac{1}{2}(CV^2)$$

$$C = \frac{(2*P*t)}{V_{\max}^2 - V_{\min}^2}$$

$$C = \frac{(2*166*0.1)}{350_{\max}^2 - 250_{\min}^2}$$

$$C = \frac{33.2}{60000};\ C = 553\,\mu F$$

Hence the capacitance value required is 553 μF.

Flat pack Aluminum electrolytic capacitors with ratings of 220 μF/450 V are chosen based on the size/space available in the unit. Three capacitors are configured in parallel, thereby giving a capacitance value of 660μF/450V These capacitors are rated for operating temperatures of -55 °C to +85 °C and altitudes of 92000 feet (28 km). These capacitors suit the requirements since fighter aircrafts are permitted to carry weapons up to a maximum altitude of 49000 feet (15 km).

Overall efficiency calculations:
Total output power = 2000 W
Total input power (max.) = 2200 W
Overall efficiency of the unit = (2000/2200)*100
= 90.09 % (min)

4. MONITORING SECTIONS

This power supply has the following sections for monitoring various parameters required for protection:

4.1 Voltage Monitoring Section

A micro-controller measures the output voltage from each DC-DC converter circuitry and displays these voltages in GUI. Users can set upper and lower threshold values of power modules in the GUI (18 to 36 V). Protection circuitry trips the respective power modules upon crossing these set values. Mains input to be recycled to restore normal operation.

4.2 Current Monitoring Section

Current is monitored from each DC-DC converter module for each output voltage derived from these modules. This sensed data is sent to the microcontroller, which displays it in GUI. Users can set upper and lower threshold values of currents in GUI based on the requirement (1A to rated value). Protection circuitry trips the respective power module upon crossing these set values. Mains input to be recycled to restore normal operation. Over-current settings for this power supply unit are programmed to minimum of 130% of the rated load and are as follows:

- Output-1 (+30V DC/27A): 34 A
- Output-2 (+30V DC/27A): 34 A
- Output-3 (+30V DC/17 A): 24 A
- Output-4 (+30V DC/10 A): 13.5 A

4.3 Temperature Sensing Section

Temperature sensors are placed at key hot spots in the power supply for sensing local temperatures. If any of these sensors detects an over-temperature (>105 °C) i.e. if temperature fault is detected by the microcontroller, all the outputs of the power supply will be switched OFF. Shutdown recovery is programmed at 98°C, which means that after temperatures are sensed less than 98 °C, the power supply switches ON again.

5. EMI FILTER DESIGN

It is appropriate to consider some of the critical air-vehicle Electromagnetic Effect (EME) issues for any new system or component which would be integrated into the aircraft/launcher. EME may be broadly categorized as external and internal. Those requirements that the aircraft environment imposes on the installed component are termed as external effects, whereas the intra-system requirements that impose constraints on how components may be affected due to other aircraft equipment, are termed as internal effects[5]. EMI filters are designed to reduce Conducted Emissions (CE) less than the limit line of CE102 as per MIL-STD-461F[3]. It also attenuates surges/spikes to Conducted Susceptibility limits as per CS101, CS114, CS115, and CS116 standards so that the equipment does not malfunction.

Filter design consists of three stages: Input filter, in-rush current limiter and bridge rectifier filter, and output filter.

5.1 Input Filter Design

EMI filter is placed immediately after the input connector which attenuates both common mode and differential mode noise. Its cut-off frequency restricts common mode noise i.e. noise generated for both power lines.

The plot of conducted emissions verses frequency, obtained for this power supply is as shown in Fig. 3. The plot obtained for this power supply is shown in blue and is well within the limit line of CE102[3] which is shown in red.

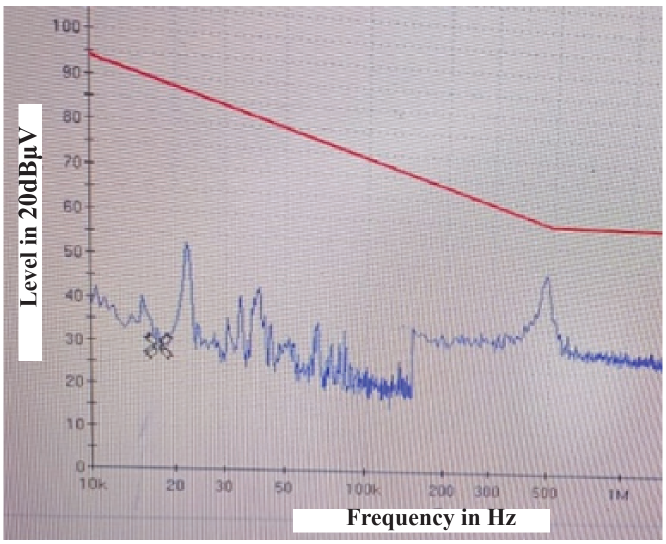

Figure 3. Conducted emissions v/s. Frequency as per CE102.

Input EMI Filter provides almost 40 dB attenuation above 1 MHz. Any common mode noise which is around 70 dBµV is limited to less than 20 dBµV meeting the CE102[3] requirement (as shown in Fig. 3). It also provides 40 dB differential mode attenuation. Input filter immediately before each power module will have a cut-off frequency of 8 KHz. It will provide attenuation of 52 dB shielding internally generated radiated emissions and also attenuating emissions generated outside the box or through cables (as shown in Figure-3).

Emissions generated are both conducted and radiated emissions and are generated by both magnetic and electric fields. Emissions generated by magnetic fields are suppressed to their maximum extent by power module enclosures. Electric fields are suppressed by the following:

- Power supply box enclosure, which absorbs all electric fields to the maximum, except through connector openings.
- Shielding all internal cables, control grounds are isolated from power line grounds and enclosure is also grounded.
- Conducted Emission filters, which reduce currents and in turn reduce radiations.
- Joining metal parts by suitable EMI gaskets to avoid any leakage of the radiated emissions from inside the enclosure and vice versa.

5.2 In-rush Current Limiter and Bridge Rectifiers

The in-rush current limiter is used to limit in-rush current using Negative Temperature Coefficient (NTC) thermistor on each line and 1Ø bridge rectifiers are used to rectify the single phase sinusoidal waveform and convert it into raw DC. 1 set of NTC thermistor and bridge rectifier is used for total power (as shown in Fig. 4). Also microcontroller is designed to switch ON power to individual modules by soft switching to limit inrush current.

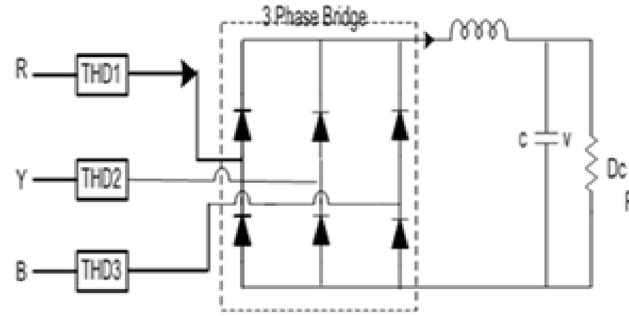

Figure 4. In-rush current limiter and bridge rectifier.

In-rush current calculations:

Referring to Fig. 4, 20 ohms NTC Thermistors (THD1, THD2 & THD3) are used in each line, so that maximum inrush current is limited to:

$$I = (\frac{270V}{20\Omega}) = 13.5A$$

5.3 Output Filter Design

It is required to filter conducted Electromagnetic Interferences (EMI), generated by DC-DC converters. Also, it will smoothen the DC output voltage, reduce the AC line harmonics and improve the power factor.

As shown in Fig. 5: L1 – Common mode choke; L2, L3, L4 – Differential mode chokes; C1, C2, C3- Y capacitors. An output filter is required to attenuate the common mode and differential mode noise generated by DC-DC converters and harmonics from the 3Ø full wave rectifier.

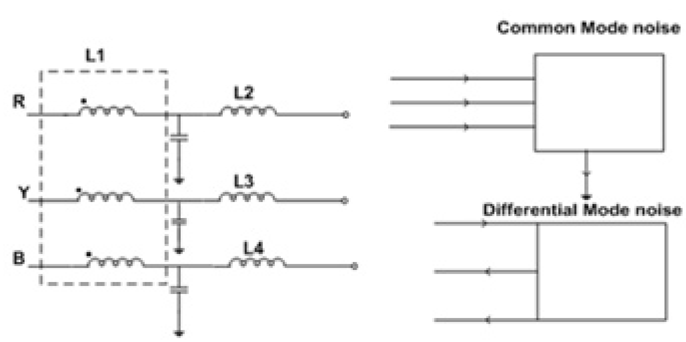

Figure 5. EMI filter design.

5.3.1 *Common Mode Filter*

Common mode noise generated in the DC-DC converters is from 8 MHz to 32 MHz having amplitudes greater than 60 dBµV conducted noise. An LC filter will give an attenuation of 20 dB/decade and the filter corner frequency is selected at

8 KHz. This will give 60 dB attenuation at the input wires.

As per MIL-STD-461F, line to ground capacitance shall not exceed 0.02μF for AC input equipment rated for 400Hz.

$$L = \frac{1}{(4\pi^2 * f^2{}_c * C)} \quad (C = C_1 + C_2 + C_3)$$

$$L = 6mH \quad for\ C = 0.066\mu F\,(630V)$$

$$(L = L_1R + L_1Y + L_1B)$$

5.3.2 *Differential Mode Filter*

Differential mode filter at the input of each DC-DC converter module is shown in the block diagram as in Fig. 5. Also harmonic LC filter used immediately after bridge rectifier with corner frequency 1.29 KHz gives almost 60 dB attenuation for differential mode noise. Small differential chokes L2, L3, and L4 filter the differential mode noise induced in each line.

6. STANDARDIZATION OF DESIGN

Standardization of design is achieved by using MIL-COTS (Military grade Commercial off the shelf) highly reliable, DC-DC converter modules. Standardized DC-DC converter modules are matured in design and are often used in various custom-built power supplies. During production, each power module is screened to levels specified in Military standards or to specifications laid down by Quality Assurance Agencies for screening these power modules. As these are screened modules and matured in design their Quality Factor is very low and reliability is high.

The requirement of high power, high reliability, and multi-output power supply can generally be met by using MIL-COTS DC-DC converter modules. These modules are encapsulated in thermally conductive material to enable heat dissipation generated by those components which do not directly interface with the base plate. Encapsulate materials have the following properties:

- Low-temperature Co-efficient of Expansion (TCE)
- High insulation resistance
- High tensile strength
- Low dissipation factor
- Good adhesion with the components
- Non-flammable
- Moisture and fungus resistant
- Can with-stand high temperatures at least twice the operating temperature.

These power modules are switched with a synchronized fixed frequency, to improve the narrow band noise of the system. The physical layout of these modules is planned such that interconnection with external circuits is through cables having adequate shielding. This shielding prevents EMI's radiating from individual modules to other modules, from cable to cable coupling, and EMI's radiating from the box to outside, either through joints or through cables. These modules are fixed to the cold plates through another plate that has high flatness and the interface material between the module and plate has a low thermal resistance (Less than 0.02 ºC / W / in^2).

These power modules are designed based on double-ended active clamp mode two transistor forward technologies. Electrical isolation & tight output regulation is achieved through optically coupled feedback. Voltage feed-forward with duty factor limiting provides good line regulation; the internal current load loop provides good load regulation. Single stage output filter typically reduces ripple to less than 50 mV at all load conditions. In case of over-current/short circuit/output over-voltage, the power module trips the output. Output is restored after input is recycled for 1 sec.

Switching ON/OFF any module can be controlled by an external logic signal. Each power supply module withstands a storage temperature of -55 °C to 125 °C & operating temperature of -55 °C to +110 °C (provided base plate temperature is maintained below 110 °C). These modules can be synchronized from 350 KHz to 450 KHz frequency by an external source with a duty cycle from 10 % to 50 %. Indigenously produced, screened and qualified DC-DC converter modules are used with the main functions as follows:

- Provides constant 30V DC output voltage for all load variations
- Low ripple content
- Good transient response
- Fixed switching frequency (Synchronized with external signal)
- Provides output voltage electrically isolated from the input.

7. WORKING AND OPERATION

This fault tolerant power supply unit with all output voltages will be switched ON as soon as AC or DC input supply is made available from the aircraft. This unit can be switched OFF by an active low signal from the store with or without the microcontroller. This power supply can be made ON/OFF by microcontroller through RS422 or from aircraft 27V OFF command. Both these signals are given by a common relay implementing diode steering. A relay is connected between the remote ON/OFF pin and ON/OFF return.

All power modules are positive logic. (If the ON/OFF pin is open with ON/OFF return then the output voltage is enabled and if this pin is shorted then the output voltage is disabled). An active low command is used for ON/OFF from the weapon with reference to any positive line of output. The active low command from weapon is taken to opto-coupler for isolation and then given to the micro-controller. A 3.3V DC supply is required for the control section which is generated by a DC-DC converter with an auxiliary supply of 30V DC as input, which in turn is generated after diode steering of 30 V DC generated using aircraft AC supply input and aircraft DC supply input.

Protection and necessary shut-down of individual DC-DC converter modules based on the inputs of the current monitoring section, voltage monitoring section, and temperature sensing section is accomplished through the micro-controller.

This unit has an in-built and efficient thermal cooling mechanism, provided by a military-grade fan operating on 115V AC, single phase, 400 Hz. During AC input this unit is cooled by forced air cooling internal fan and during DC input it is cooled by conduction cooling.

8. TEST RESULTS

Various tests have been carried out on the proto unit of this power supply. Test results obtained are satisfactory and are as follows:

1. Full Load test carried out on all three busses (Output-1, Output-2, and Output-3) with 3ϕ-115V-400Hz-AC input supply. The output voltage of power supply remains of the order of 30V DC for all busses when subjected to various loads up to full load.
2. Full Load test carried out on all three busses (Output-1, Output-2, and Output-3) with input 1ϕ-115V-400Hz-AC input supply. The output voltage of power supply remains of the order of 30V DC for all busses when subjected to various loads up to full load.
3. Load test carried out on all three busses (Output-1, Output-2, and Output-3) at various ranges of input voltage 3ϕ, 115V ± 30V AC. The output voltage from the power supply remains of the order of 30V DC.
4. Load test carried out on all three busses (Output-1, Output-2, and Output-3) at various ranges of input frequency 3ϕ, 400Hz ± 50 Hz. The output voltage from the power supply remains of the order of 30V DC.
5. For DC Bus (Output-4), Input voltage fluctuation from 18V DC-36V DC is tested; output is maintained at 30V DC. Cut-off happened when input voltage was reduced to 17V DC and also when increased to 37V DC.
6. Line regulation test carried out and values obtained are less than 1%.
7. Ripple Test: Ripple voltage recorded as 108 mV for Output-1 & Output-2 and 90 mV for Output-3.
8. Power hold-up test for Output-3:

1ϕ	Hold-up time recorded 112 msec. at 8 A, Output V=29.8V DC
3ϕ	Hold-up time recorded 112 msec. at 8 A, Output V=30.3V DC

The above test indicates that the hold-up time available is greater than the specified value of 100 msec.

9. An isolation test was carried out between output connector high lines to chassis, low lines to chassis, and input lines to output lines, and values were > 120 MΩ at 500V DC.
10. Endurance test up to 10 hours at ambient temperature was carried out on full load for all outputs
11. Input to Output time delay test carried out and delay time recorded was 300 msec which is well within the specified limit of 500 msec.

9. CONCLUSION

A 2000 watts, multi-input multi-output, fault-tolerant power supply unit, based on standard high density, high reliability power modules, adopting state-of-the-art technology, easy replacement and the latest modular engineering has been developed.

This power supply unit is designed to take care of all input line variations and transients as per MIL-STD-704F & GOST- 19705-89 military standards. Also, it is designed to meet conducted and radiated emissions within specified limits as per MIL-STD-461F for EMI/EMC.

This power supply unit operates with 3Ø, 115V, 400Hz, (Phase-Neutral) and 1Ø, 115V, 400Hz, (Phase-Neutral) and generates different output DC voltages.

These voltage limits are as follows:

- Output-1: 30V DC/25A
- Output-2: 30V DC/25A
- Output-3: 30V DC/17A (with hold-up of 30V DC/8A for 100 ms)
- Output-4: 30V DC/10A

This power supply unit also operates with 27V DC / 10A aircraft supply as input and converts it into 30VDC /10A. There is no hold-up for this section. This power supply can operate on inputs in the range of 18V DC to 36V DC. It will work on continuous duty as per required specifications.

Hence a compact and efficient fault-tolerant power supply is developed for the aircraft-store interface, which will enable and simplify the launch of an air-launched store from a fighter aircraft. This power supply is capable of generating a 30V regulated and isolated DC supply with higher wattage, thereby catering to high power requirements of onboard avionic systems such as seekers, on-board computers, servo-controllers, navigation systems, etc. This power supply is fault-tolerant since it provides multiple DC outputs, is compact and lightweight since it uses small MIL-COTS DC-DC converters, and takes into account requirements of the latest military standards. It complies with the power standards of MIL-STD-704F[1] and GOST-19705-89[2] and the EMI/EMC standards of MIL-STD-461F[3]. It is tested as per requirements of MIL-STD-810G[4] environmental standards for fitment into launcher units of a fighter aircraft, thereby extending isolated and regulated power supply for pre-launch preparations and auto-launch operations of avionic sub-systems in a store.

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CONTRIBUTORS

Mr Harminder Singh Johar completed MTech in Power Electronics and Power Systems from the Indian Institute of Technology Bombay, in 2008. He is working as a Scientist in Research Centre Imarat, RCI-DRDO-Hyderabad, and pursuing his PhD (part-time) from the National Institute of Technology (NIT), Warangal. Presently, he is working on research and development of Air-Launched Missile Systems (ALMs). His specializations include electrical integration and checkout of air launched and air defense missile systems, design and realization of electrical interfaces for on-board avionic systems as well as electrical interfacing of missiles/stores with various launch platforms such as ground launchers and fighter aircraft. He has carried out conceptualization of the problem, design, realization of proto-type unit, and testing of this unit.
He has written the draft manuscript.

Dr Abhijit Bhattaryya obtained MTech & PhD from IIT, Madras in Control Systems in the years 1991 and 1997 respectively. He is currently working as Technology Director, Directorate of Systems, DRDL, and Project Director (Mission) of Programme AD. His specialization is in Missile Guidance, Control, Estimation, and Modeling of Seekers. His research interests include Advanced Guidance, Control, and Estimation Design for Aerospace Applications.
In the present work, he has provided interface details of various air launched stores required for interfacing to a fighter aircraft and guided in identifying the power supply and control requirements of a store.

Prof. Srinivasa Rao S. received MTech from Regional Engineering College, Calicut, India in 1994. He obtained his PhD from the National Institute of Technology (NIT), Warangal in 2007. Since 1996 he is working as a faculty member at NIT, Warangal, India. His research interests include Power Electronic Drives, Switch Mode Power Converters, DSP controlled drives, and Renewable Energy Systems.
In the present work, he has guided the analysis of critical results and reviewed the manuscript.