

Bidirectional DC–DC Converter for Aircraft Electric Energy Storage System

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Abstract:

Modern aircraft electrical systems require efficient power management to meet dynamic load requirements such as actuators and avionics. This paper presents the design and analysis of a bidirectional DC–DC converter used in an aircraft electric energy storage system. The proposed system utilizes a Dual Active Bridge converter topology enabling bidirectional power flow and galvanic isolation. Simulation analysis and hardware implementation using a PIC16F877A microcontroller-based driver circuit are discussed. Results demonstrate efficient operation in both forward and reverse power flow modes.

Keywords — Bidirectional DC–DC Converter, Aircraft Electrical System, Energy Storage System, Dual Active Bridge Converter

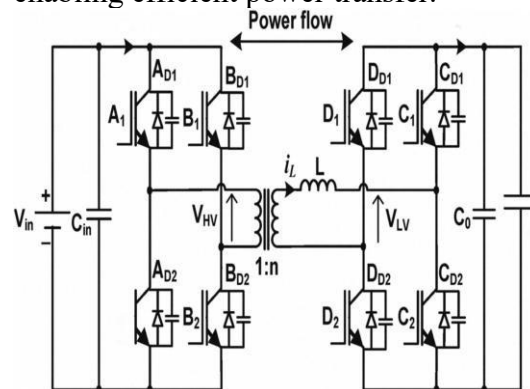
1. INTRODUCTION

The development of more electric aircraft has increased the demand for efficient electrical power systems. Aircraft loads such as actuators, avionics, and control systems require reliable power sources with fast dynamic response. Energy storage systems such as ultracapacitors help support peak load demands and improve power stability. Bidirectional DC–DC converters allow energy to flow between the power source and the storage system in both directions, making them suitable for modern aircraft electrical systems.

2. SYSTEM ARCHITECTURE

The proposed system consists of a rectifier circuit, isolation transformer, bidirectional DC–DC converter, driver circuit, ultracapacitor energy storage unit, and a microcontroller-based control system. The isolation transformer provides galvanic

isolation between the source and the load while enabling efficient power transfer.

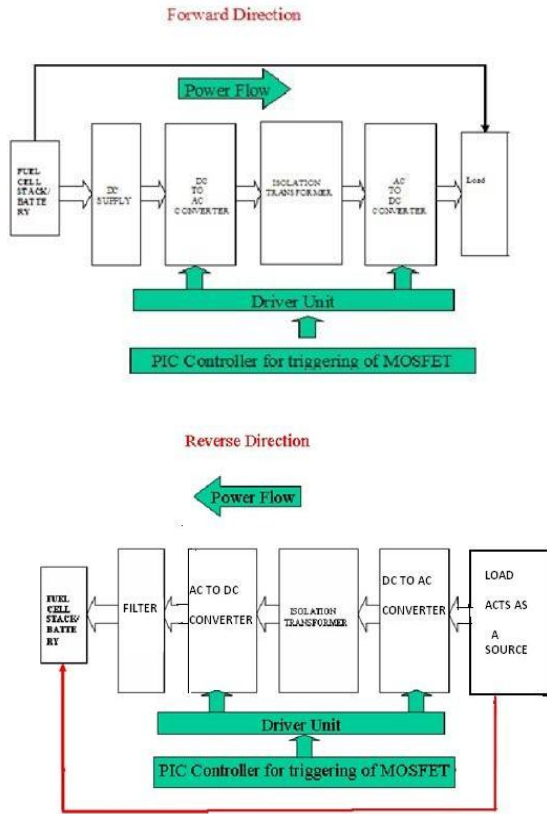


3. BIDIRECTIONAL CONVERTER OPERATION

The converter operates in two modes. In forward mode, energy flows from the main power source to the energy storage system. In reverse mode, stored energy from the ultracapacitor is delivered back to the load during peak demand conditions. The dual

active bridge topology ensures high efficiency and reduced switching losses.

N_1 = primary turns
 N_2 = secondary turns



4. MATHEMATICAL ANALYSIS OF DAB CONVERTER

The transferred power in a DAB converter is given by:

$$P = \frac{1}{2} \cdot \phi^2 \cdot (1 - \cos \alpha)$$

Where:

- P = transferred power
- V_1 = primary side voltage
- V_2 = secondary side voltage
- ω = angular switching frequency
- L = leakage inductance of transformer
- ϕ = phase shift angle between bridges

Current Equation

$$I = \frac{V_1 - V_2}{L \omega}$$

Output Voltage Relation

$$V_2 = \frac{N_2}{N_1} V_1$$

Where:

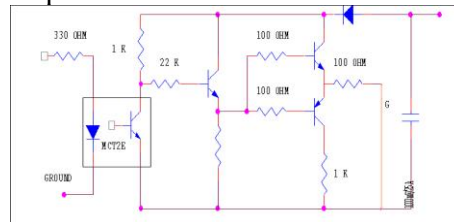
5. HARDWARE IMPLEMENTATION

The hardware includes a rectifier circuit, gate driver unit, optocoupler isolation circuit, buffer IC, and PIC16F877A microcontroller. The microcontroller generates switching pulses that control MOSFET switching in the converter. Optocouplers provide electrical isolation between the control circuit and the power circuit.

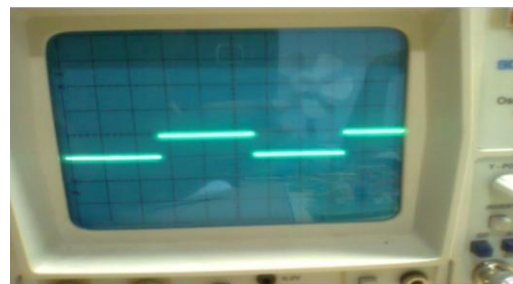


A. DRIVER UNIT

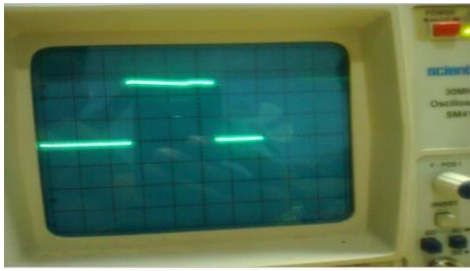
Microcontroller's Output from the respective ports are fed to this gate driver Eight such circuits are used to provide Gate pulse for eight MOSFET respectively. The driver circuit forms the most important part of the hardware unit because it acts as the backbone of the inverter because it gives the triggering pulse to the switches in the proper sequence.



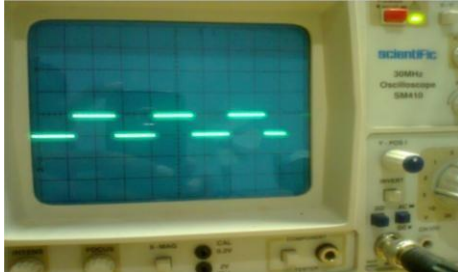
HARDWARE RESULTS



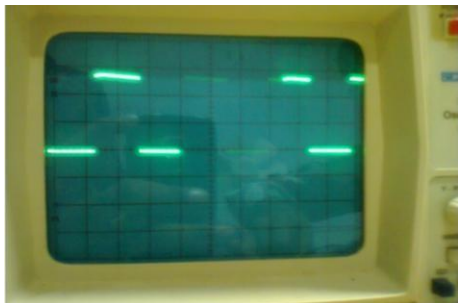
FORWARD MODE



FORWARD SWITCHING PULSE

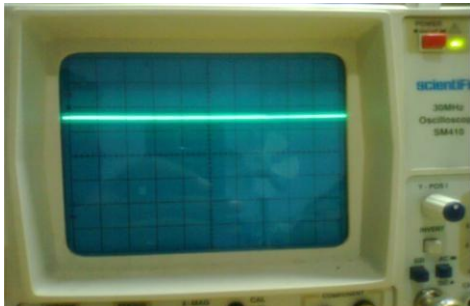


REVERSE MODE

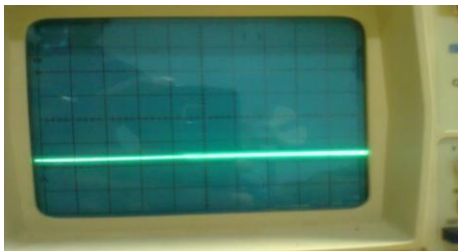


REVERSE SWITCHING PULSE

7. OUTPUT VOLTAGE



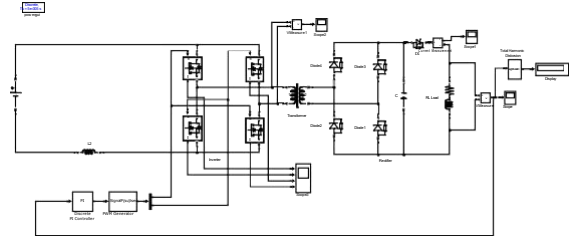
FORWARD MODE OUTPUT VOLTAGE



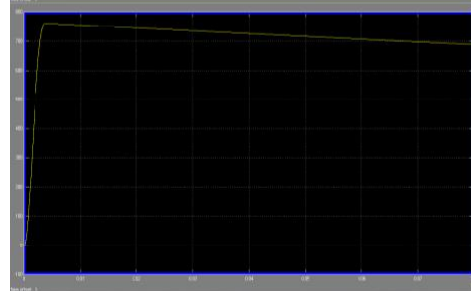
REVERSE MODE OUTPUT VOLTAGE

8. SIMULATION RESULTS

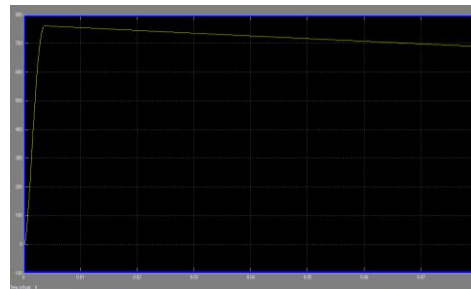
Simulation studies were performed to verify the converter operation in both forward and reverse modes. The results show stable voltage output and proper switching characteristics. The bidirectional converter demonstrates reliable performance and efficient power transfer.



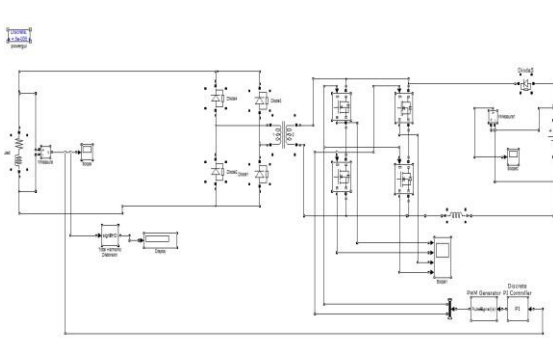
FORWARD MODE



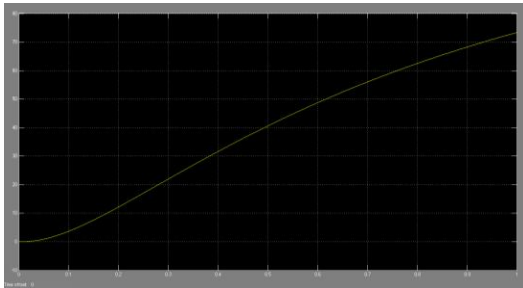
INPUT VOLTAGE



OUTPUT VOLTAGE



REVERSE MODE



OUTPUT VOLTAGE

9. PERFORMANCE RESULTS

Table 1: Simulation Parameters

Parameter	Value
Input Voltage	230 V
Output Voltage	12 V
Switching Frequency	20 kHz
Transformer Ratio	1:1
Filter Capacitor	1000 μ F

Table 2: Converter Performance

Mode	Input Voltage	Output Voltage	Efficiency
Forward	230 V	12 V	93%
Reverse	12 V	230 V	91%

10. ADVANTAGES

The proposed system provides high conversion efficiency, reduced switching losses, fast dynamic response, and bidirectional power transfer capability suitable for aircraft energy storage applications.

11. CONCLUSION

This paper presented a bidirectional DC-DC converter for aircraft electric energy storage systems. The Dual Active Bridge topology provides efficient bidirectional power transfer with galvanic isolation.

Simulation results confirm stable operation in both forward and reverse modes. The proposed system effectively supports aircraft power systems by supplying peak load demand and absorbing regenerative energy.

Future work will focus on hardware implementation and advanced control strategies to further improve efficiency and reliability.

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