



iJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 Issue: VI Month of publication: June 2021

DOI: <https://doi.org/10.22214/ijraset.2021.35978>

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A High Power Density Converter with a Continuous Input Current Waveform for Satellite Power Applications

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Abstract: Conventional Active Clamp-Forward topology is studied for a satellite converter owing to its comparatively simple structure, minimum number of components and fine clamping capability concerning its switch voltage stress. However, it has a high switch voltage stress, a high di/dt level and has pulsating input current shape. These are disadvantageous with respect to the EMI filter size and high input voltage converter applications. To get the better of these drawbacks, a new ACF topology with a continuous input current waveform is proposed. By this proposed waveform, the voltage stresses on the main switches are relieved. This is crucial reliability of satellite FET switches, by utilizing a two series connected structure. These conditions will allow the proposed converter to serve as a high input voltage, high power density satellite converter.

Keywords: ACF, FET, EMI, SWITCH VOLTAGE STRESS, HIGH POWER DENSITY CONVERTER

I. INTRODUCTION

In satellites, the most important requirements for dc/dc converter systems are high reliability, and a light weight design. These requirements have limited satellite converter topologies to the conventional single-switch-forward (ssf) type given its simple isolated structure and lowest number of part. In satellite applications, reliability is more important than the efficiency, such as bridge type converter topologies. Many high efficiency topologies can't be easily applied to satellite applications due to low reliability.

A. Objective

The basic objective is to reduce switch voltage stress and current ripples, and provide continuous input current waveform for satellite applications, and simulate using MATLAB. Modelling the ACF topology with some modifications to increase output power with high reliability is the primary objective.

II. PROPOSED SYSTEM

The dc blocking capacitor C_b behaves as a constant voltage source with a level equal to V_{in} . Because C_b is connected in series via the auxiliary winding, the ac component of the input current is divided into the primary and auxiliary winding components. When the primary-side leakage inductance L_{k1} becomes larger than the auxiliary-side leakage inductance L_{k3} , more of the ac component of i_{in} flows into the auxiliary winding. Hence, when L_{k1} is sufficiently larger than L_{k3} , the ac component of i_{in} flows only into the auxiliary winding. The input current ripple is one of the most important design factors. In addition, a two-series connected switch structure is utilized for the main switch stage to relieve the voltage stress of the switches for high reliability and lower switching losses. With a simple turn-off delay method, the voltages of the main switches are clamped to V_{in} and V_{cl} regardless of changes in the switch turn-off characteristics.

III. WORKING

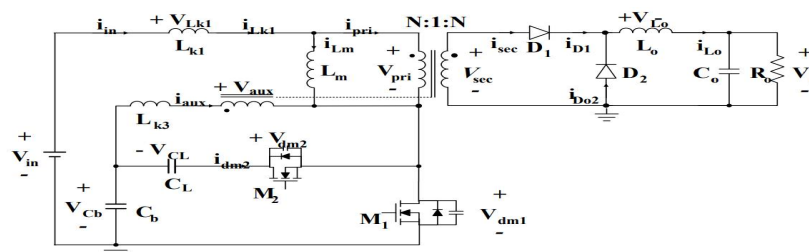


Fig 1: circuit diagram of the proposed ACF converter with reference direction of voltage and current

The new circuit that is used here is shown below and in this we use two Mosfet's these two mosfet's are P channel Mosfet thus these two mosfet's are having same parameters. Before going to operation like many other power electronics circuits we also make some assumptions .They are:

- 1) The primary winding and auxiliary windings are having same number of turns and secondary winding is having the multiples of primary turns
- 2) Leakage inductance of second inductance is greater than first inductance
- 3) Diodes are ideal
- 4) The capacitors are having large enough values
- 5) Here the input voltage is same as voltage on capacitor in primary side
- 6) Current input is always constant

A. Modes of Operation

Here by using the above assumptions we make the circuit to run . In this for full cycle of current we gonna have 6 modes. They all are classified based of time of operations for a full cycle .

- 1) *Mode 1: (t_0-t_1)* : Here in this mode the circuit gonna run normally as we expected initially when there is an power supply to the circuit the M1 is in on state and M2 is in off state and by the transformer the secondary winding of transformer gets flux inside of it and thus the current start to flow throught the secondary circuit and this makes the diode D1 to run in on state and diode D2 in off state due to reverse biased so the load gets power to it .Here while M1 is in on state then the current starts to flow in primary side the voltage across capacitor and primary winding becomes same as input voltages and thus the input current starts to increase linearly. The voltage remains constant and current starts to increase linearly and the voltage across the load remains constant and current across the load increase linearly. According to Kirchhoff's current law (KCL) and the sum of the transformer primary and auxiliary currents $i_{pri} + i_{aux}$ is equal to $i_{sec}/N = i_{L1}/N$, The current across the diode and the secondary current across inductor are same this mode ends when the M1 turns off. This voltage and current goes normally until and unless M1 gets turns off. The real problem comes when the M1 gets turn off. At this time the inductors that are present gonna change their polarity because they doesn't allow sudden change in currents and thus to maintain the constant voltage to the load there will be changes in currents so we have 5 types of modes here.
- 2) *Mode 2 : (t_1-t_2)*: As soon as the M1 turns off mode 2 begins we know that voltages across the capacitors of Mosfet M1 is less than the M2 . Due to the inductors present the inductors now changes their polarities and they start to charge the load and maintains the diode D1 to be in on state still and the voltages of primary and secondary are in positive .So all the current through inductor on secondary side goes to diode D1 and because there is no way to go because of blockage of diode D2. By using kitchhoff's current law we can get the current through auxiliary . The Mosfets M1 and M2 are identical so we can get the value of current through Mosfet M1 as there is no way to go current . The voltage through the mosfet are obtained which is increasing linearly upto input voltage and the voltage across the Mosfet M2 decreases to its series capacitor voltage. This mode thus ends at t_2 .
- 3) *Mode 3 : (t_2-t_3)*: As soon as the mode 2 ends mode 3 begins with the M2 voltage with input voltage and M2 with the voltage of the capacitor which is connect in series to it.As the windings of transformer are nothing but the inductors so the polarities of auxiliary winding and secondary winding changes so the diode D1 gets reversed biased and the diode D2 gets forward biased and turns on and the primary winding current is reverse of auxiliary current and this makes the Mosfet M1 and M2 are to be having voltages of sum of voltage input and voltage through capacitor M2 to decrease upto 0V. This mode ends at this stage and goes to Mode 4 . Before going to Mode 4 we need to know about ZVS(Zero Voltage Switching) in ZVS or also can be known as conventional PWM Power conversion during the Mosfet turn on time but with resonant switching transitions.The main use of this ZVS is to make the the use of inductance energy efficiently and return to faster switching frequently at higher input voltage and voltage drop .
- 4) *Mode 4 : (t_3-t_4)* : In this the diode D2 starts to conduct due to reverse in polarity of secondary winding and the M2 capacitor is fully drained to 0 and at this time the Mosfet M2 start to turn on under ZVS condition .When M2 start to conduct under ZVS condition the the auxiliary voltage and primary voltage are to be having same and nearly equal to capacitor voltage which is connected in series to it and the current through the inductor is linearly decreasing. Because of the diode D1 in off condition and diode D2 in on condition the inductor voltage is negative and the current is linearly decreasing in diode D2 and in the inductance. By using KCL the currents through the primary winding and the secondary winding are obtained and the the current through the Mosfet M2 is obtained .This mode ends when the Mosfet M2 is turned off and no current through M2 flows.

- 5) *Mode 5 : (t_4 - t_5):* This mode starts as soon as the Mosfet M2 gets turned off and the because of the voltage at Mosfet is lower than the voltages at capacitor ,at the primary and secondary winding due to the reversed in polarity at the secondary winding .This makes the Diode D2 to get turn on because of the reverse polarity and the diode D2 is made to turn off state . The current at the secondary winding is zero so this makes the primary current to be the negative of the auxiliary winding current and are of same magnitude with different directions. So at this condition the inductor which is present at the primary side starts to charge the capacitors of both mosfet's and hence the inductor starts to loose all of its energy and continous to charge the capacitors upto it reaches its half of the value of its energy it stored in it.This discharge of energy through the inductor happens linearly so this can be in a straight line in the graph between the voltage and current. This mode ends when the Mosfet M1 voltage increases upto the input voltage on primary side and the Mosfet M2 voltage decreases upto the value of the capacitor voltage in its series.Thus this mode ends at t_5 .
- 6) *Mode 6 : (t_5 - t_6):* This mode is the last mode and this mode starts when the voltage of Mosfet M1 is reaches to input voltage and the voltage of the Mosfet M2 reaches upto the capacitor voltage in its series.at this stage the voltages through the primary ,secondary and auxiliary are at zero due to this the current through the auxiliary becomes the reversed of the input current.At this stage the current through the inductor on secondary side remains constant and we know from the circuit that the current through the primary and the current through the auxiliary sum is equal to the transformer ratio on secondary side .This mode ends when the Mosfet M1 gets turn on. This modes are to be repeated for every full cycle from t_0 to t_6 .For half cycle the mode 1 is operated and for another half cycle the mode 2 to mode 6 are operated .By using this extra circuit we can obtain the continous input voltage and the reduction of voltage stress on input side .The ripples are reduced to maximum side hence this can be used for higher voltage applications.

IV.SIMULATION LINK MODEL

In this MATLAB model the another mosfet,inductor and transformer winding is added to ACF topolgy, to improve the output with reliability. That is the motor reaches to synchronous speed at a faster rate as modulation index reaches to 1 within less time when compared with PI controller. Here we take error and change in error as inputs and get speed control as output.

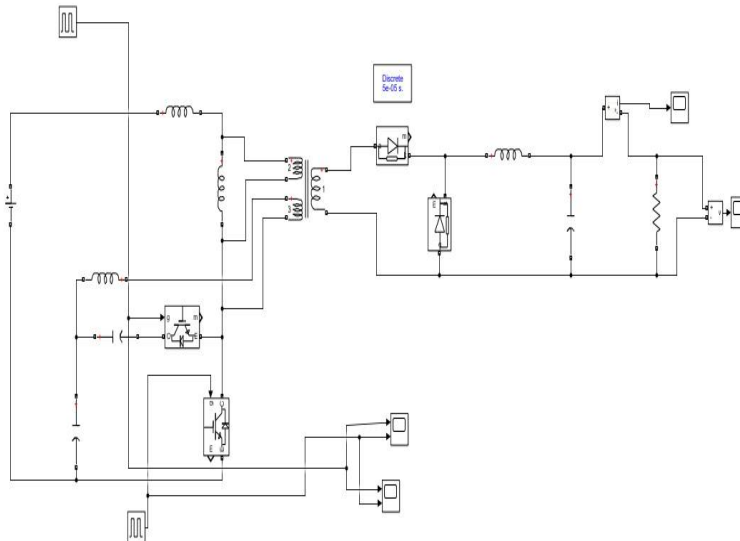


Fig 2:simulink circuit of the proposed system

It consists of 2 MOSFET's, 4 inductors, 2 diodes , 3 capacitors and 1 resistor and 1 load resistor .voltage waveform is obtained from voltage measurement model in simulink .similarly current waveform is obtained with current measurement model.

V. SIMULATION RESULTS

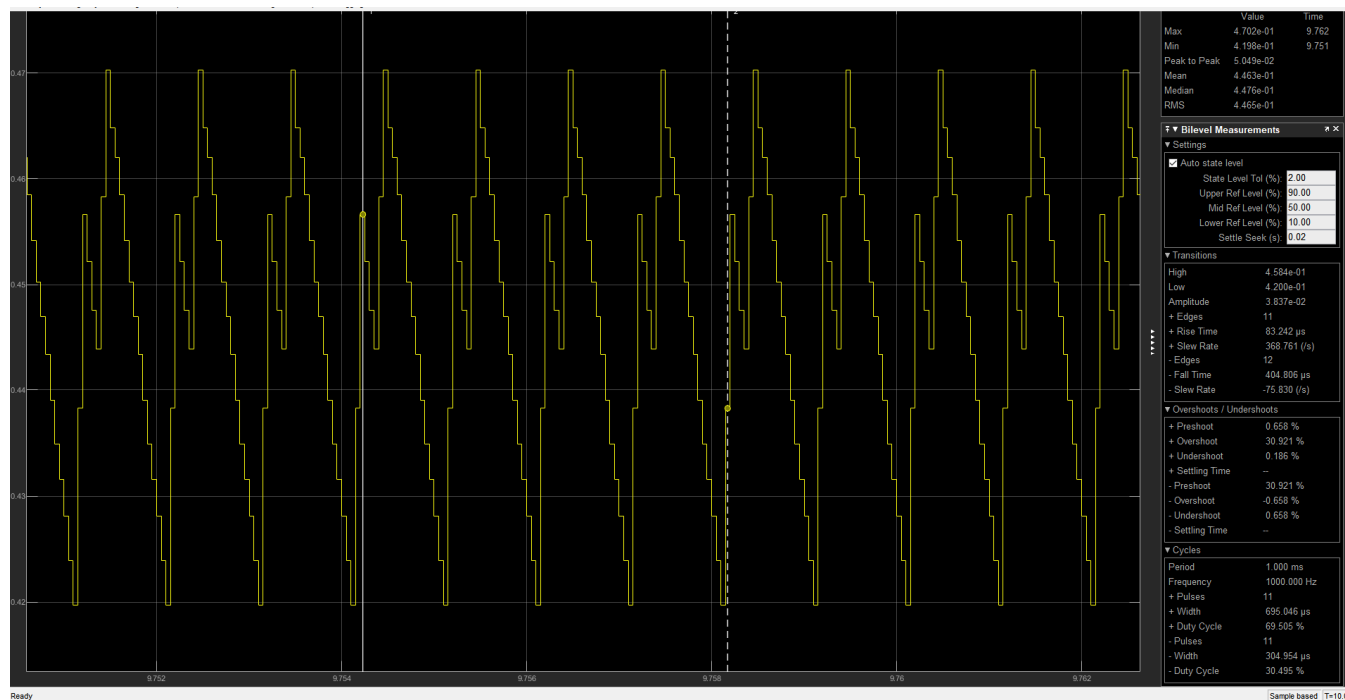


Fig 3:output current waveform for the proposed system

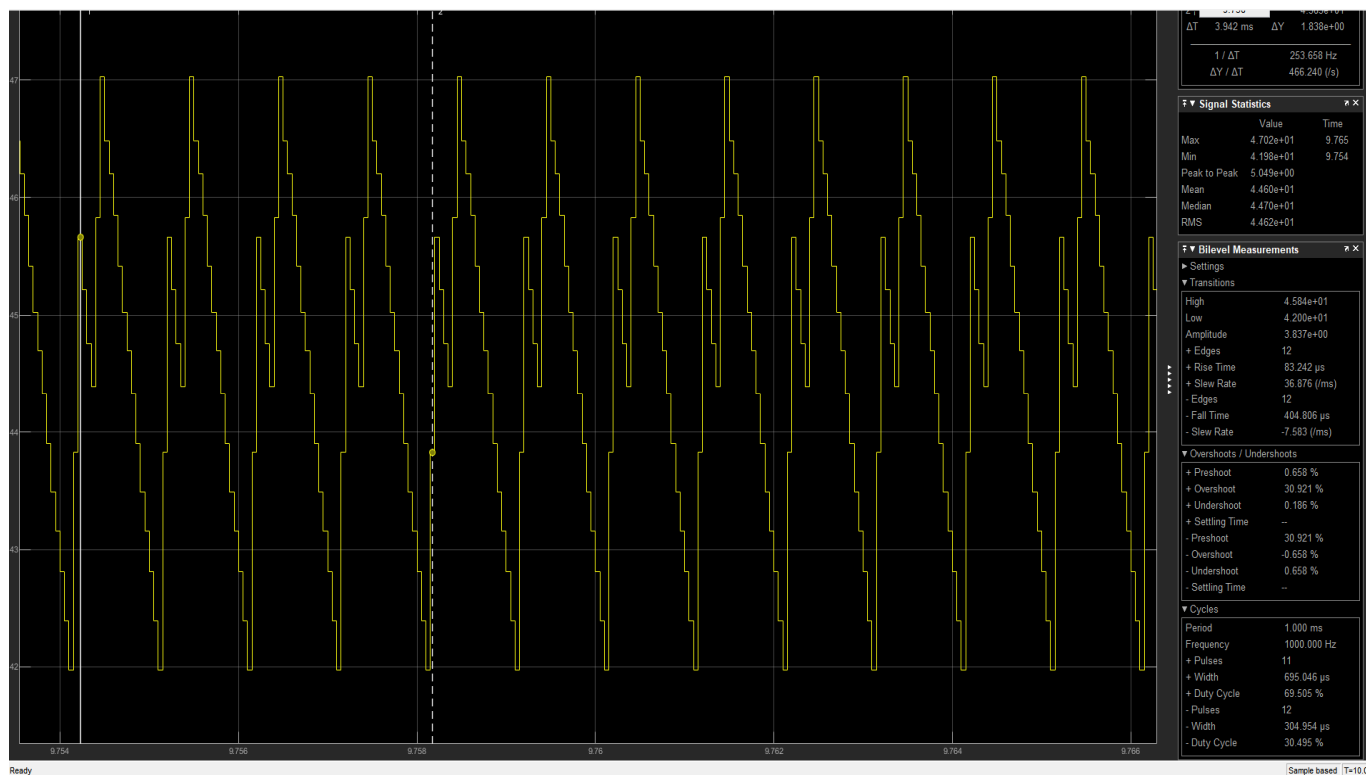


Fig 4: output voltage waveform of the proposed system

We can adjust the output of the proposed system ,by adjusting the pulse width modulation(PWM).The output ranges from around 5watts to 20watts with change of PWM from 20% to 90% ,Respectively.

VI.CONCLUSIONS

In this paper, the new ACF which is proposed by attaching two new circuits to the existing circuit makes more useful for use of high voltage device . By using existing system there are pulsating input currents which makes the system to get damage so easily and there is also some voltage stress on the main switches which is an another problem by adding there two circuits and a transformer winding(Auxiliary winding) reduces the voltage stress on main switches and avoids the damage for main switches and reduce ripples in the input current and produce continuous input current makes more efficient to use and have long life and avoids battery damage occurrence.

VII.ACKNOWLEDGMENT

We would like to express our sincere thanks to our project supervisor Asst. Prof. G. Sravanthi, Department of Electrical Engineering, Sreenidhi Institute of science and Technology for her constant support, timely help, guidance, sincere co-operation during the entire period of our work. We are grateful to her for providing all the necessary facilities during the course of project work, for the help provided during various stages of the project.

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