Design and analysis of high frequency switched full-bridge dc-dc converter for ups in telecommunication applications

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***Abstract*— This paper describes the design and implementation of high frequency switched full-bridge DC-DC converter using analog control techniques. The major aim of this paper is to provide constant DC voltage to each of the switching equipment of the telephone exchange. In general, all the telephone exchanges are having switching equipment to trace out the route or the communication path to the destination. The voltage to be fed to the switching equipment is obtained from the series connected batteries and is delivered to the DC-DC converter. The DC-DC converter consists of a ferrite transformer. The voltage from the battery is being stepped down by the ferrite transformer according to the requirement. Filters are employed to suppress the harmonics and noise contents in the output voltage. The voltage obtained from the DC-DC converter is controlled by the regulating pulse width modulator using PWM technique.**

***Keywords*- DC-DC converter, regulating pulse width modulator, switching equipment, PWM technique.**

I. INTRODUCTION

According to the requirement of the telephone exchange, the voltage from the battery is fed to the DC-DC converter and is stepped down to the desired voltage by transformer. This voltage should be maintained constant to trigger the switching equipment at a high frequency. The DC-DC converter consists of a full-bridge inverter, a ferrite transformer, and a diode-bridge rectifier. The DC-DC converter performs two-stage conversion operation. The DC input voltage is obtained from the series connected batteries. This voltage is converted into AC by the full-bridge inverter. The ferrite transformer accepts this voltage as its input and performs the step down operation. As desired, the voltage that is stepped down is again converted into AC voltage by means of uncontrolled full-bridge rectifier. Finally the output voltage obtained has to be filtered out from harmonics. So a combination of inductor and capacitor is used to filter the output voltage from ripples and noise. The output voltage is necessarily maintained to be constant irrespective of input and load variations. With the use of analog devices like voltage regulators, The output voltage is controlled by PWM scheme. As a result, the constant controlled voltage is utilized for triggering the switching equipment. The electric automobiles are likely to use choppers for speed control and braking. Chopper systems offer smooth control, high efficiency, fast response and regeneration.

Some of the major advantages of DC-DC converters are,

1. Fast dynamic response
2. High energy efficiency
3. Flexibility in control
4. Fewer ripples in the armature current
5. Ability to control at low speeds

The full-bridge DC-DC converter is proposed in the paper to achieve the required specifications. The two-stage DC-DC converter is used to convert the 220V input supplyfrom the series connected batteries into 48V output voltage. The output from the DC converter will not be pure and constant. As the DC-DC converter systems are being operated at high frequencies, the size of the transformer becomes more compact.

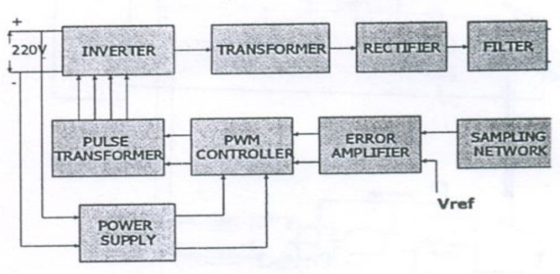

Fig.1 shows the entire functional block diagram of the proposed high frequecy switched full-bridge DC-DC converter with filter.Analaog control circuit are provided for the efficient control of the output voltage from the DC-DC converter. The voltage of about 220V DC input is converted into 48V DC output, which is used to trigger the switching equipment of the telephone exchange and other telecommunication applications.

II. MODELING OF DC-DC CONVERTER

According to the emerging technologies, there is a growing need for high switching frequencies and small size DC-DC power converters. The metal oxide semiconductor field effect transistors (MOSFETs) used in DC-DC converter has high switching speeds and its frequency ranges from 400 KHz to few MHz provides high efficiency. High frequency switching allows reducing proportionally the size of filtering elements like inductors and capacitors and thus, to perform a quick control of DC output voltage. The output voltage can be controlled by controlling the duty cycle or by adjusting the pulse width. The DC-DC converters are used to provide noise isolation, power bus regulation,

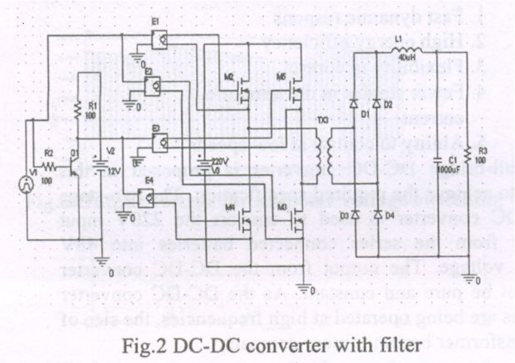

Fig.2 DC-DC converter with filter

The Fig.2 shows the DC-DC converter circuit associated with an LC filter MOSFET is mainly employed in full-bridge topology because MOSFETs are preferred to higher switching frequencies. These MOSFETs,employed in the full-bridge inverter are used to convert the 220V DC into the same in AC. The ferrite core setup transformer is used which makes the size of the transformer as more compact and capable of operating at high switching frequency.The output of the transformer is given to the uncontrolledfull-bridge rectifier whose output is 48V DC. Inorder to smoothen the output voltage of the uncontrolled full-bridge rectifier, the filter is suitably designed. The combination of inductor and capacitor is used to filter out undesirable harmonics at the output voltage of rectifier.

The inductance offers high impedance to harmonic voltage, higher the harmonic number, higher will be the impedance and lower will be the magnitude of the harmonic at the output.

The capacitance offers a shunt path for the harmonics current. The higher the frequency,the lower will be the capacitive impedance and more harmonic current will be by-passed.

III. DESIGN OF STEP DOWN TRANSFORMER

The voltage from the battery is stepped down by a high frecuency transformer whose core is made of ceramic ferromagnetic material. The output voltage of the transformer mainly depends on its inductance and secondary winding. The inductance, number of turns for primary and secondary windings is designed to obtain desired output voltage.

1. CALCULATION OF PRIMARY AND SECONDARY TURNS

SPECIFICATIONS

Input voltage =180V to 225V

Output voltage =48V

Current =50A(+5A overload)

Efficiency =88%

To select core size of a transformer

$A_eA_c = (0.68*P_{out}*D*10\text{^}3)/(f*B_{max})cm\text{^}4$

Where,

A_e is the core effective area, cm^2.

A_c is the boobin winding area, cm^2.

Maximum flux density is given by,

$B_{max} = (V_p*10\text{^}8)/(K*f*N_p*A_e)$

Where,

V_p is impressed by voltage

K= 4.44 (for sine waves)

Number of primary turns can be calculated from,

$N_p=(V_p*10\text{^}8)/(K*f*B_{max}*A_e)$

$P_{out}=1.16*B_{max}*f*d*A_eA_c*10\text{^}-9$

Where,

P_{out} is the power handling capacity of the core d is the current density of the wires, A/m^2.

A_e=3.54cm^2

$N_p=(V_p*10\text{^}8)/(K*f*B_{max}*A_e)$

Number of secondary turns can be determined by,

$N_p/N_s=(K_t*V_{in})/(2*V_{out}+V_{diode})$

$N_s=N_p/1.4$

2. CALCULATION OF PRIMARY AND SECONDARY WINDING INDUCTANCES

Primary inductance is obtained by,

$A_L = L_p/N_p$^2

$L_p = A_L * N_p$^2

Secondary inductance is calculated by,

$L_s = A_L * N_s$^2

3. DESIGN OF FILTER

The filter at the output side consist of inductor and capacitor in combination.The values are so designed for both the inductor and the capacitor to filter out the harmonics from the constant output voltage.The filter can be designed as given below.

Switching frequency F=100 KHz

Time period T=10µS

Assume 85% of duty cycle,T_{off}=1.55µS

V_L=51V

I_L =55A

20% of I_L = 11A

The inductance value is obtained from,

$L = V_L * dt/dI$

The value of capacitor is calculated from,

$C = (\Delta I * dt)/\Delta V_o$

IV. ANALOG CONTROL OF DC-DC CONVERTER

The output DC voltage from the DC-DC converter is controlled by an analog controller namely a voltage regulator.The power semiconductor switches of the inverter are triggered at finite intervals of time period in order to maintain output voltage of the device to be a constant . The pulses to trigger the switches of the inverter are generated by the voltage regulator using pulse width modulation scheme.By adjusting the width of the pulse,the output voltage of the converter can be varied accordingly and is controlled as per the requirement.

V. DESCRIPTION OF REGULATING PULSE WIDTH MODULATOR

The SG 1524B is a pulse width modulator for switching power supplies which features improved performance over industrial standards like the SG 1524 . It combines advanced processing techniques and circuit design to provide improved reference accuracy, and extended common mode range at the error amplifier and current limit inputs. A DC coupled flip-flop eliminates triggering and glitch problems, and a PWM data latch prevents edge oscillations.The circuit incorporates true digital shut down for high speed response, while an under voltage lock out prevents spurious outputs when the supply voltage is too low for stable operation.

Full double-pulse suppression logic insures alternating output pulses when the shut down pin is used for pulse-by-pulse current limiting . The SG 1524B is specified for operation over the full military ambient temperature range of -55˚C to 125˚C. The SG2524B is characterized for the industrial range of -25˚C to 85˚C, and the SG 3524B is designed for the commercial range of 0˚C to 70˚C.

The layout of the analog voltage control device is illustrated in fig.3.The voltage regulator, in general , consists of an oscillator, an error amplifier, a current sensor,a comparator, and a T-flip flop.The components of regulator have been discussed in detail in the fore coming sections.The oscillator, in general , is used to generate clock pulses to trigger the power electronic devices.The oscillator within the voltage regulator generates clock signal to initiate the operation of PWM latch, universal logic gates, flips flops. The error amplifier which is in built in the voltage regulator compares the output voltage from the DC-DC converter with the reference voltage and generates an error signal as its output voltage.

The current sensor senses the current every time and terminates the function of the voltage regulator whenever it detects any over current in the system.The comparator present in the voltage regulator compares the ramp signal with the error signal obtained from the error amplifier to generate the pulses to trigger the switches of the inverter . Depending upon the variations in the output voltage , the pulse width gets adjusted and the time period of switching also is varied accordingly. Thus the voltage is controlled effectively as desired by the pulse width modulation technique.

VI .FEATURES OF VOLTAGE REGULATOR

- 7V to 40V operation
- 5V referrence trimmed to±1%
- 100Hz to 400KHz oscillator range
- Excellent external sync capability
- Dual 100mA output transistors
- Wide current limit common mode range
- DC-coupled toggle flip-flop
- PWM data latch

- Under voltage lock out
- Full double –pulse suppression logic
- 60V output collectors

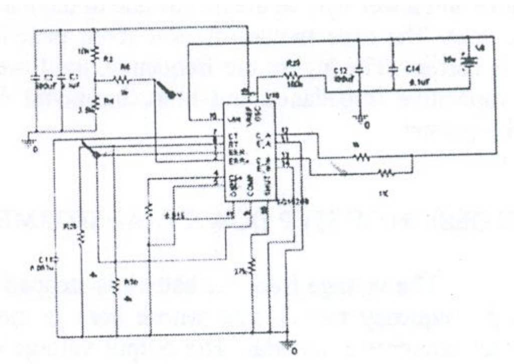

Fig.3 Voltage Regulator Circuit

The fig.3 shows the analog control circuit for the DC-DC converter.With the PWM technique the voltage is efficiently controlled.

VII. EXPERIMENTAL RESULTS

The hardware system has been developed and tested. The high frequency switched DC-DC converter for 220V DC to 48V DC has been designed and implemented.The analog control circuit is also developed to improve the control of DC-DC converter's output voltage. An LC filter is coupled to the output side of DC-DC converter to suppress the noise and ripples in output voltage. The entire system is effectively simulated and tested for various load conditions using the OrCADPSPICE simulation tool

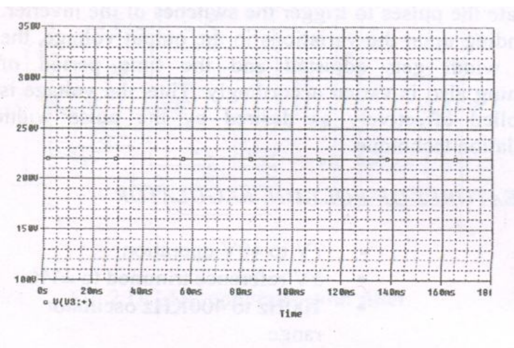

Fig .5 Input Voltage Waveform of Inverter

The Fig.5 shows the wave form of input voltage fed to the inverter . The single phase full-bridge inverter is brought into conduction by supplying a DC voltage of about 220V from the series connected batteries.

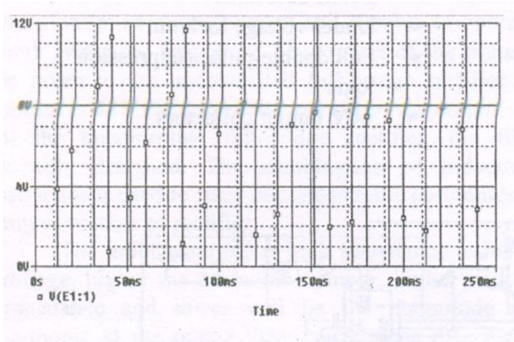

Fig .6 Pulses to MOSFET 1, 2

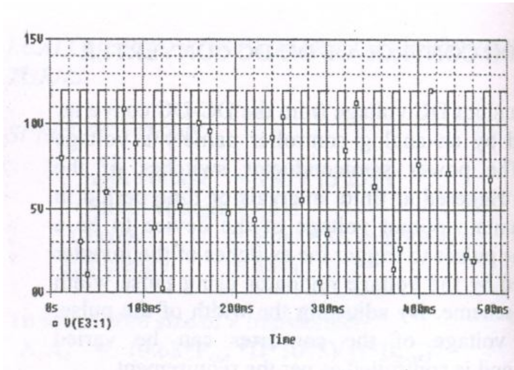

Fig .6 Input Pulses to MOSFET 3, 4

The Fig.5 and Fig.6 shows the triggering pulses to the MOSFETs 1,2 and 3,4 of the inverter . The MOSFETs from each leg of the inverter are triggered by the pulse obtained from the regulating pulse width modulator.

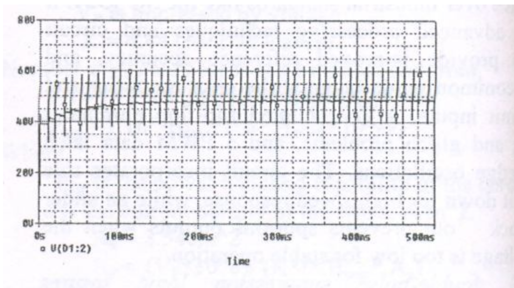

Fig .7 Waveform of DC-DC converter output voltage

The desired output voltage from the DC-DC converter is 48V but the waveform in Fig.7 consists of voltage spikes which may affect the performance of the system. The ripples present in the output voltage must necessarily by filtered out.

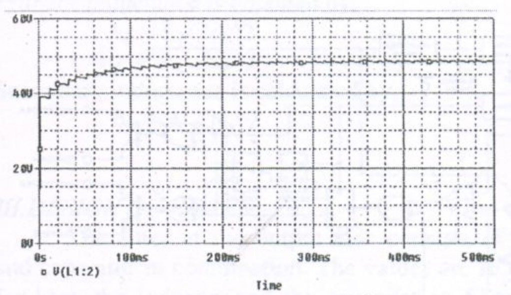

Fig .8 Waveform of filter output

The Fig.8 shows the waveform for output voltage of filter. The voltage spikes in the DC-DC converter output is suppressed by an LC filter. The inductance offers high impedance to harmonic voltage and the capacitance provides a shunt path for the harmonic current.

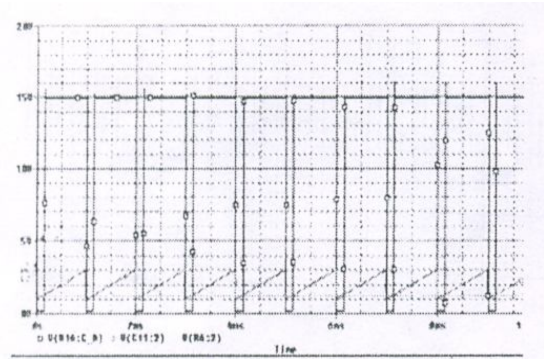

Fig.9 Pulse Width Variation for Reference voltage of 1.3V

For a reference voltage of 1.3V, the corresponding pulse width variation is shown in Fig.9.The ramp signal of magnitude 3V is compared with a 1.3V error signal to get a pulse of modulated width

VII. CONCLUSION

In this paper, modeling and simulation of DC-DC converter with control circuits implemented for telecommunication applications. The control unit consists of analog device namely voltage regulator.The components like error amplifier, comparator , flip flop, logic gates, and current sensors are all present in a single regulator chip.This reduces the number of external devices and is cost effective.The LC filter associated with the DC-DC converter suppresses the undesirable harmonics, ripples , and noise at the output voltage. This paper finds applications in the telephone exchange to provide a pure constant DC voltage to trigger the switching equipment.This paper offers a better solutions with the implementation of analog controller and was discussed briefly.As shown , not only the single-chip solution simplifies the entire hardware implementation, but also the programmability of the microcontroller chip facilitates excellent of output voltage.The simulation results verify the effectiveness of the single-chip voltage

Regulator implementation.

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