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Design and Implementation of Modified Multiplier Circuit of DC High Voltage Generator for Electric Vehicle

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***Abstract*—The voltage multiplier is a different type of diode rectifier circuit, which produces an output voltage many times greater than the applied input voltage depending on the number of stages in the voltage multiplier circuit. Voltage multipliers can be used to generate a small volt to millions of volts for particular purposes. In this paper, the Quadrupler and Cockcroft-Walton voltage multiplier circuit having five Stages withthe proposed 12 pulse rectifier transformer methodology are designed and simulated using MATLAB/Simulink software. The proposed work results in faster control response of the system whichresults in good voltage stability which is fed to the battery of an Electric vehicle.**

***Index Terms*— Voltage Multiplier Circuit, 12 Pulse RectifierTransformer, MATLAB/Simulink.**

I. Introduction

A voltage multiplier is a combination of capacitor and diode network which converts an ac input voltage vi(t) = E sin(wt) intoa dc output voltage V_{out} = nE for n greater than 2. Some commonly used voltage multiplier circuit configurations for n = 2,3,4 are Voltage Doubler, Tripler, Quadrupler circuit. Voltage multipliers are broadly used in the high power voltage supply of TV sets and in the other applications requiring an ac to dc conversion [1][2]. The Cockcroft-walton circuit is made up of capacitors and diodes to give the required output. In this circuit, byusing a capacitor and diode, the output can be obtained to very high values from relatively low input voltages [3]. A voltage transformer is normally used in electronic circuit to increase a voltage, but in high voltage applications eventually, a required step-up transformer and insulated transformer may not be present. The voltage can be stepped up using a diode voltage multiplier without using a transformer. These multipliers are rectifiers that converts AC voltages to DC for various applications in electrical and electronic circuits, such as X-Raysystems, lasers, electrostatic systems, cathode ray tubes, photomultiplier tubes, etc. where it is indispensable to consume essential a very highDC voltageproduced from a comparatively low AC supply.

This paper deals with an approach to generate the high voltage DC using twelve-pulse rectifier transformer

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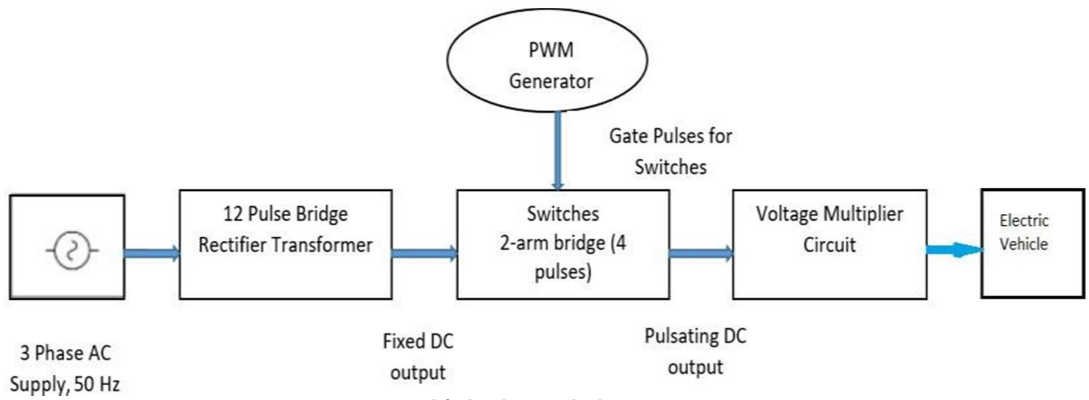
voltage multiplier system to achieve its voltage stability with faster control response of the system by considering Quadrupler and Cockcroft-walton voltage multiplier circuit.

II. METHODOLOGY

A. Block diagram of Proposed Methodology



Modified Voltage Multiplier Circuit

Fig. 1. Block diagram of Proposed Methodology

The Fig. 1. shows the block diagram of modified multiplier circuit which consists of the three-phase supply, twelve pulse bridgerectifier transformer, PWM generator with power switching devices and voltage multipliers circuit blocks.

A twelve pulse bridge rectifier transformer allows supplied AC signal into DC output which improves the rectification efficiency and ripple factor. The PWM generator is used to convert static DC input voltage to the inverter's controlled AC output voltage by setting the on and off periods of the inverter units. The voltage multiplier circuit blocks were used to give high voltages and low current. For the input voltage, as per requirement of the system, the output voltage of voltage multiplier circuits will be several times greater.

A twelve pulse system performs well in terms of rectification efficiency and ripple content in case of bothfrequency and amplitude compared to a six pulse bridge configuration. Without affecting the performance of the rectifier, the three-phase bridge can use indifferent delta or Ysecondary connections which makes it possible to build twelve pulse structures avoiding complex transformer configurations.

Pulse width Modulated(PWM) voltage inverter is widely performed in the industry. Nowadays, in many new industrial applications, PWM is based on variable speed drives are mostly practiced and require superior performance [4].

The need for new global energy has led to changes in the industrial environments. Cost reduction, pollution restrictions and increasing demand for energy have been shifted to the efficiency requirements of electric drives and energy conversion systems. The PWM circuit is sinusoidal PWM(SPWM) is feasible sine wave as the control voltage, whose average voltage differs sinusoidally [6].

III. SIMULINK MODELS

A. Simulink model of Quadrupler voltage multiplier circuit

The Single phase AC supply voltage of 230 V was supplied atthe transformer primary side and for comparison purpose, 331 V was obtained at the transformer secondary side which was input to the Quadrupler voltage multiplier circuit which is shown in Fig.2.

TABLE I: COMPONENTS USED

AC voltage source	Peak amplitude of 230 V
Linear transformer	125 VA
Diode	Resistance of 0.001 ohms
Forward voltage(V_f)	0.8 V
Capacitor	470 micro farad

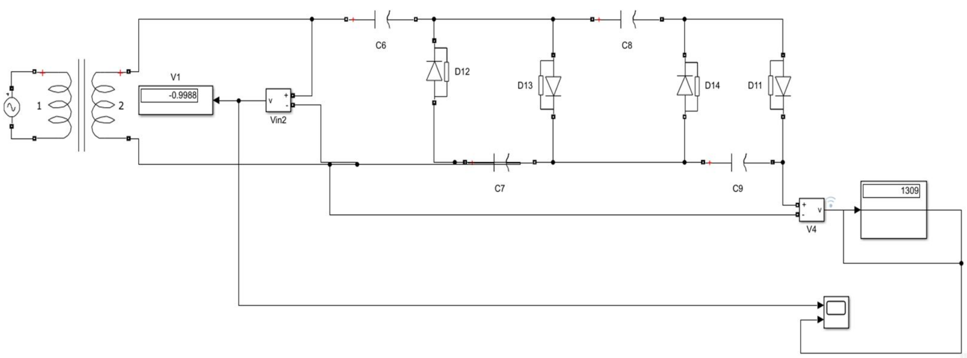


Fig.2. Simulink model of Quadrupler voltage multiplier Circuit

B. Simulink model of Modified Quadrupler voltage multiplier circuit.

The 3-phase AC supply voltage of 300 V was supplied atthe input of 12 pulse bridge rectifier configuration, theoutput of the 12 pulse bridge rectifier configuration was 331 V. As the output of the rectifier circuit was pure DC, a PWM generator was used to convert it to pulsating DC which canbe called as AC voltage. This AC voltage of 331 V was supplied at the modified Quadrupler voltage multiplier circuit which is shown in Fig.3.

TABLE II: COMPONENTS USED

AC voltage source	Peak amplitude of 300 V
Three phase 12 bridgerectifier transformer	250 KVA
Diode	Resistance of 0.001 ohms
Forward voltage(Vf)	0.8 V
Capacitor	470 micro farad

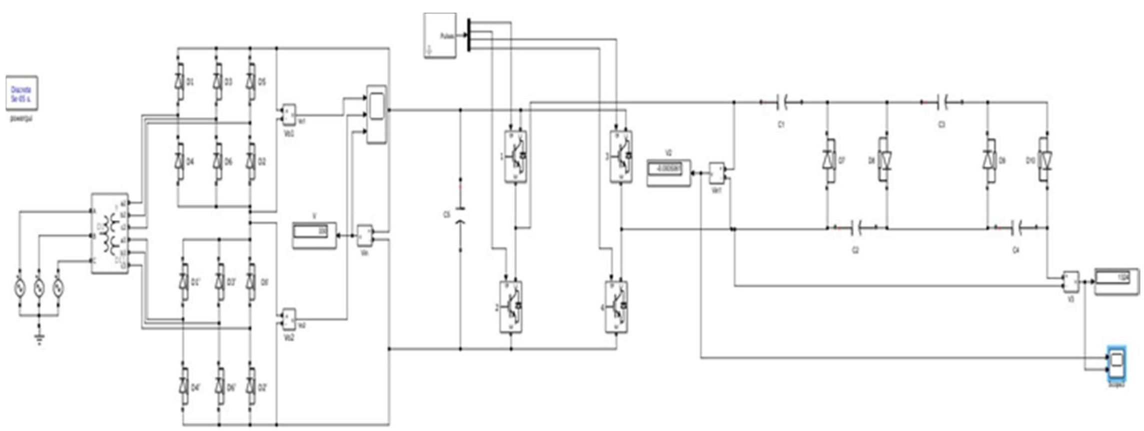


Fig.3. Simulink model of Modified Quadrupler voltage multiplier Circuit

C. Simulink model of Cockcroft-Walton 5 stages voltage multiplier circuit

The single-phase AC supply voltage of 230 V was supplied at the transformer primary side and for comparison purpose, 331 V wasobtained at the transformer secondary side which was input to the Cockcroft-walton voltage multiplier circuit which is shown in Fig.4.

TABLE III: COMPONENTS USED

AC voltage source	Peak amplitude of 230 V
Linear transformer	125 VA
Diode	Resistance of 0.001 ohms
Forward voltage(Vf)	0.8 V
Capacitor	470 micro farad

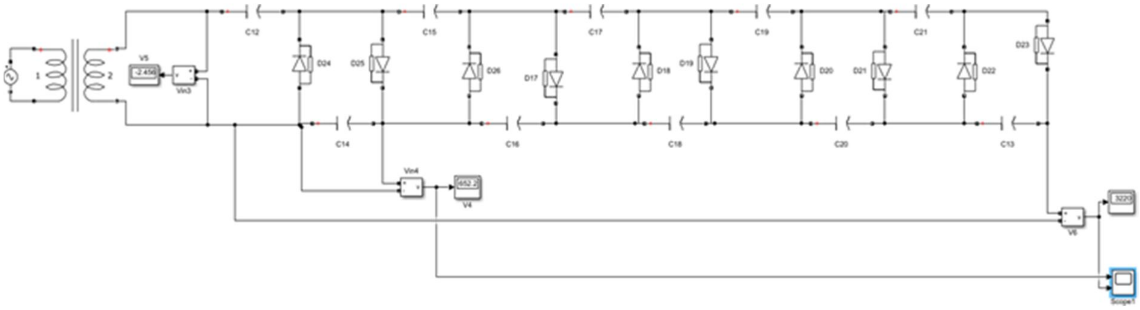


Fig.4. Simulink model of Cockcroft-Walton 5 stages voltage multiplier circuit

D. Simulink model of Modified Cockcroft-Walton 5 stages voltage multiplier circuit.

The 3-phase AC supply voltage of 300 V was supplied atthe input of 12 pulse bridge rectifier configuration, theoutput of the 12 pulse bridge rectifier configuration was 331 V. As the output of the rectifier circuit was pure DC, a PWM generator was used to convert it to pulsating DC which canbe called as AC voltage. This AC voltage of 331 V was supplied at the Cockcroft-walton voltage multiplier circuit which is shown in Fig.5.

TABLE IV: COMPONENTS USED

AC voltage source	Peak amplitude of 300 V
Three phase 12 bridgerectifier transformer	250 KVA
Diode	Resistance of 0.001 ohms
Forward voltage(V_f)	0.8 V
Capacitor	470 micro farad

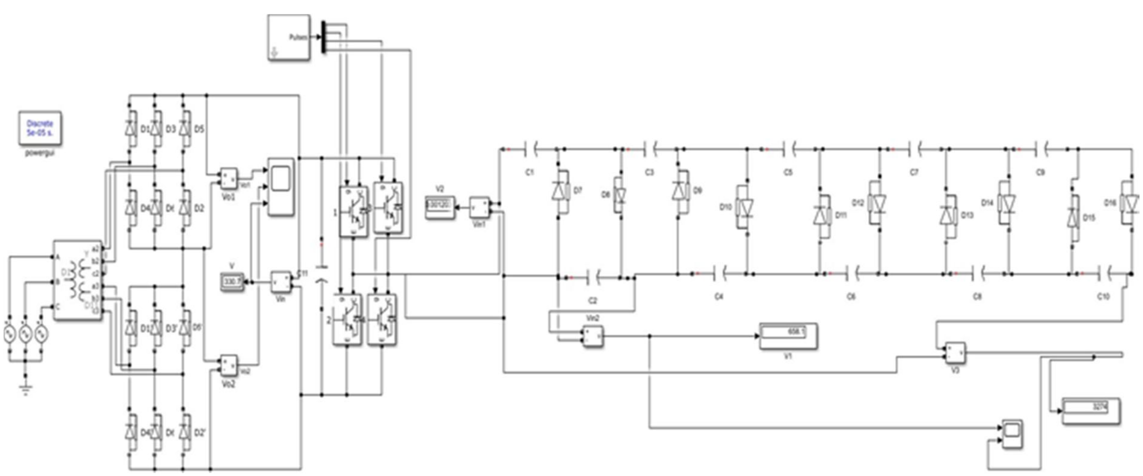


Fig.5. Simulink model of Modified Cockcroft-Walton 5 stages voltage multiplier circuit

IV. SIMULATION RESULTS AND DISCUSSIONS

A. Simulation result of Quadrupler voltage multiplier circuit

For the Simulink model shown in above Fig. 2. was provided with AC Supply of peak amplitude 230 V, 50Hz, gets rectified and resultedin the voltage multiplication of DC Voltage to 1309 V from the multiplier circuit is shown in thebelow Fig. 6. with a settling time of 2s is observed.

B. Simulation result of Modified Quadrupler voltage multiplier circuit

The 3-phase AC supply voltage of 300 V was supplied to the input of 12 pulse bridge rectifier configuration, with a rectified output voltage of 330.6 V. Since the output of the rectifier circuit was pure DC, a PWM

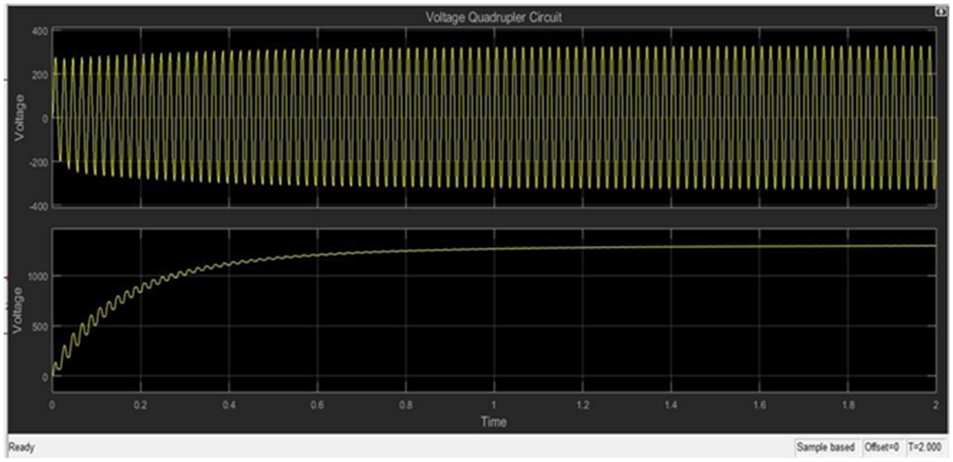


Fig.6. Simulation results of input AC sinusoidal voltage waveform and DC output voltage of the circuit settling at 2s

generator converted it to pulsating DC. This AC voltage was fed to the Quadruplervoltage multiplier Circuit, output voltage of the Quadrupler voltage multiplier circuit was 1324 V. From the below Fig. 7. it can be observed that the sinusoidal PWM voltage waveform as input to the Modified Quadrupler voltage multiplier circuit and at themodified Quadrupler voltage multiplier circuit, the voltage is settlingat 0.8s.

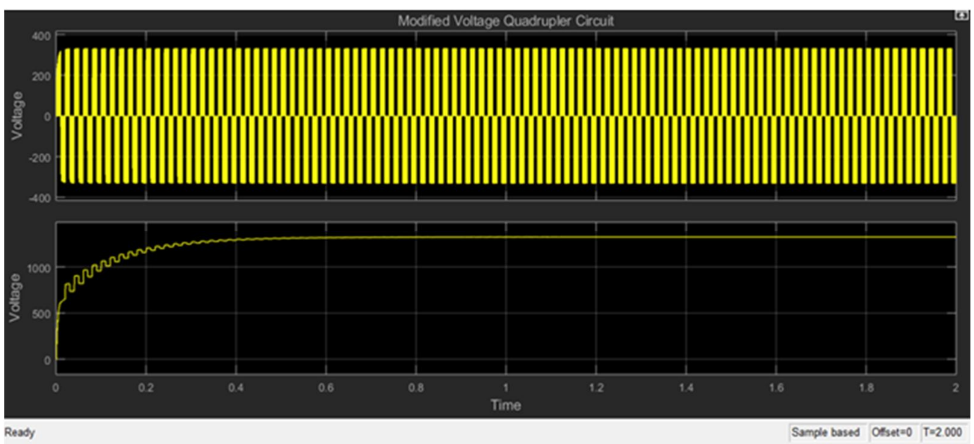


Fig .7. Simulation results of sinusoidal PWM voltage waveform and DC output voltage of the circuit settling at 0.8s

From these two observations, it can be observed that, settling time of the Quadrupler output voltage is less in caseof the proposed 12 pulserectifier transformer. The lesser the settling time faster will be the system response which results in good voltage stabilization of the system.

C. Simulation result of Cockcroft-Walton 5 stages voltage multiplier circuit

For the Simulink model shown in above Fig. 4. wasprovided with AC Supply of peak amplitude 230 V, 50Hz, gets rectified and resulted in the voltage multiplication of DC Voltage to 3220 V from the multiplier circuit is shown in the below Fig. 8. with a settling time of 7s is observed.

D. Simulation result of Modified Cockcroft-Walton 5stages voltage multiplier circuit

The 3-phase AC supply voltage of 300 V was supplied tothe input of 12 pulse bridge rectifier configuration, with a rectified output voltage of 330.6 V. Since the output of the rectifier circuit was pure DC, a PWM generator converted itto pulsating DC. This AC voltage was fed to the Cockcroft-walton voltage multiplier circuit, and output voltage is 3274 V.

From the below Fig. 9. it can be observed that, thesinusoidal PWM voltage waveform as input to the Modified Cockcroft-walton voltage multiplier circuit and the voltage is settling at 4s.

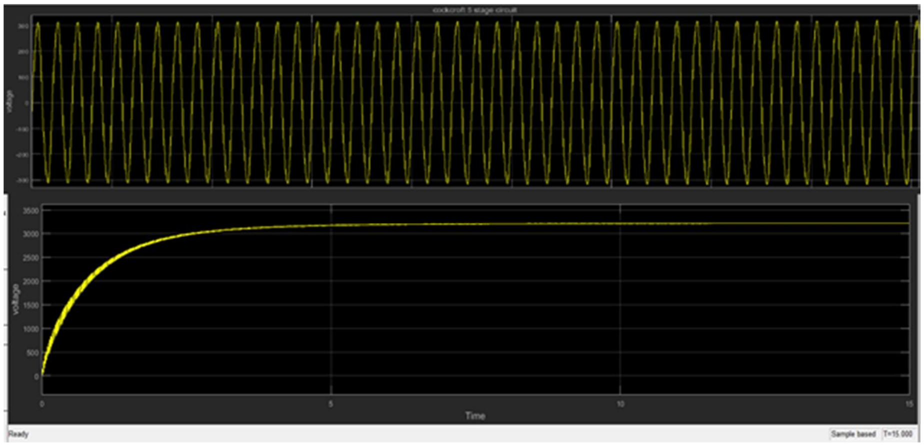


Fig.8. Simulation results of input AC sinusoidal voltage waveform and DC output voltage of the circuit settling at 7s

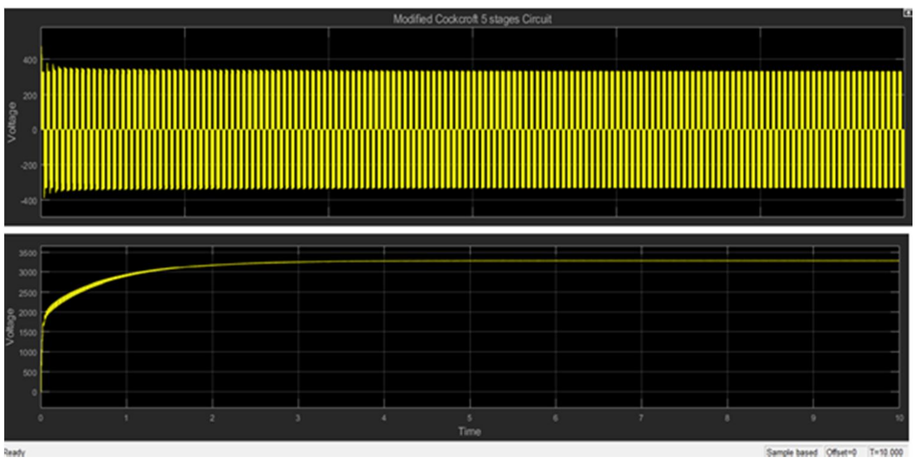


Fig .9. Simulation results of sinusoidal PWM voltage waveform and DC output voltage of the circuit settling at 4s

From these two observations it can be detected that the settling time of the Cockcroft-walton output voltage is less in case of the proposed 12 pulse rectifier transformer. The lesser the settling time faster will be the system response which results in good voltage stabilization of the system.

V. CONCLUSION

The objective of this paper was to evaluate the performance of twelve pulse rectifier transformer voltage multiplier circuit with a conventional voltage multiplier circuit. Regarding this, the Simulink models of twelve pulse rectifier transformer voltage multiplier with conventional voltage multiplier are designed. It is observed that the settling time is less in proposed methodology which results in faster control response of the system and good voltage stability which is fed to the battery of an Electric vehicle.

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