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Vibrational Power Generation on High Ways using Piezoelectric Crystal

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Abstract

The vehicle pressures are enormously wasted in the densely populated country like India and china. Piezoelectric crystal can change the vehicle pressure in to electrical power. The pressure obtained by the vehicle tyre is used for power generation even through, which is not constant some delay may occur due to time difference between each vehicle. Piezoelectric sensors are placed on the right track on the high ways. Pressure varies for each vehicle. In order to maintain the constant regulated voltage. We place Cuk converter and a battery backup. Cuk converter will provide a constant voltage. Which is fed to the three phase inverter act as the DC to AC converter? Utilize those powers for the government office, street lighting, traffic lighting, check post lighting, and pumps for gardening in high ways etc. Simulation work is done by using MATLAB. The three phase output is obtained by effective utilization of Cuk converter and inverter. Continuous conduction mode (CCM) can be obtained by using battery backup.

Keywords: Continuous Conduction Mode (CCM), Current Sensor, MATLAB, Piezoelectric Sensor, Pressure, Rechargeable Battery, Stress, Vibration, Voltage Sensor

1. Introduction

The solar and wind energy plays the vital role in renewable energy about 97% of energy is obtained from both solar and wind. Piezoelectric sensors are now a day's slowly increasing. Stress, pressure and vibration will produce the electric power with high output impedance. Wasted vehicle pressure can be utilized in the high ways by placing the piezo electric sensors on highways. About 1,15,400 KM length of Indian National High Ways. NH 44 is the longest road running major North-South National highways in India. About 45000–50000 vehicles crosses each toll plaza. Many high ways does not have sufficient lighting system. Due to the lack of sufficient lighting more accidents take place in high ways. Accidents can be avoided by using the piezoelectric power generation. Many types of piezoelectric crystal are widely used, in which barium titanate, Lead Zirconium Titanate (PZT), Aluminium Nitride (AIN) will produce high output voltage than other crystals.

Power generation by walking and running in the platform by human being and voltage booster is used for high voltage[1]. Lead zirconium titanate as a piezoelectric transducer (PZT) has high efficiency than barium titanate[2]. Aluminium nitride (AIN) is designed and able to produce power of about 1.388 mW at resonant frequency of 576.8 HZ[3]. Gear system, shaft crank, spur type gears are used for the power generation, which used to maximize the output efficiency[4]. Very thin flim of bulk PZT material less than 20 μm with thickness of about less than 50 μm[5]. With the help of the switching devices like MOSFET will improve the output more than the other switching devices like bipolar transistor. MOSFET can operate under high frequency[6]. The output voltage depends on the weight of human. If more weight more power is obtained[7]. Quartz crystal has high frequency response which can operate under high frequency. Quick transient response from initial to steady state response. Construction is extremely rugged and can be used in any environmental condition.

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2. Renewable Energy Systems

All most all the countries are aware about the availability of non-renewable resources. They turn their focus towards renewable energy resources. About 97% of energy is produced by both solar and wind. 61% of energy is produced by the hydro power plant. About 45% of energy from geothermal, 23% of energy from the heat pumps, 10% from piezo electric power. Latest forecast (Figure 1) says that piezoelectric power is increasing linearly and new type of crytals are combined to produced high power. Piezoelectric power is under research to produce high power.

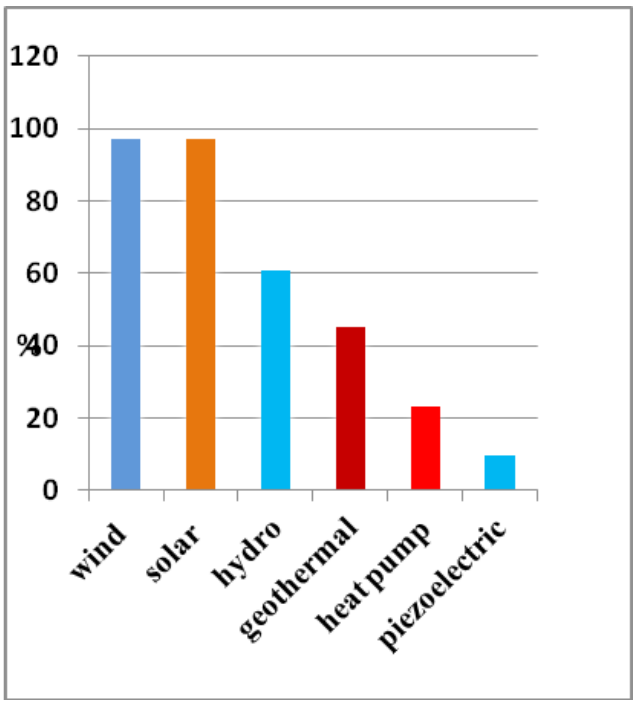

Figure 1. Renewable energy power generation system.

3. Block Diagram Description

Piezoelectric sensor which converts the vibration pressure in to the electrical power. Output power fed to the Cuk converter. When the output power is enormous it will act as the buck converter and reduces the output. When the output power is less than the reference value. It will act as the boost converter, output power will be boosted up to required power. This operation are carried out by feedback from the converter output a (as shown in Figure 2). The driver and control circuit will enegize from power supply circuit. Power supply circuit will provide 5V for controller and 12V for driver circuit. The driver will produce gate signal to the MOSFET by controller. The constant output is stored in the battery by the means of charging. Battery discharge the power to the 3ϕ inverter which convert DC to AC supply by 120 degree conduction. Output given to the three phase load.

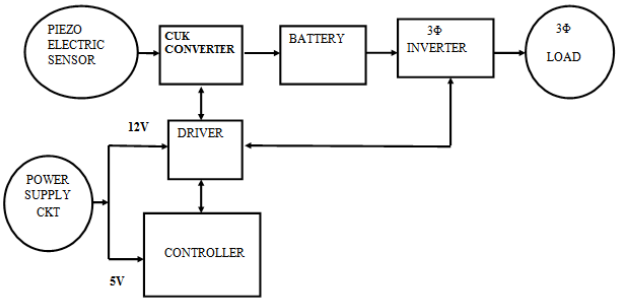

Figure 2. The control scheme block diagram of proposed method.

4. The Salient Feature of the Scheme

Mechanical stress is applied to the piezo electric transducer. It will generate electric potential by charging there dimension. Stress and force is applied to certain planes output voltage is minimum with high impedance. Amplifier circuit is used to amplify the output. Crystal will have high stability and high output humidity. It can operate under high frequency ranges from (certain KHz - certain MHz). It will have high transient response from initial state to the steady state value. Solid crystal extremely ruggedness in construction suitable for any type environmental condition. It will have certain disadvantages like output power is low with high impedance. Design and construction is more complex.

$$q = kf \quad (1)$$

k = piezo electric constant, c/N

k for quartz crystal = 2.3 pc/N

k for barium titanate = 140 pc/N

To find the output voltage V_0,

$$V_0 = q/c = kf/c = kf_x/\varepsilon_0\varepsilon_r A \quad (2)$$

for piezo electric sensor of 1-CM^2 area and 1-mm thickness with an applied force due to 10 -g weight the output voltage V is 0.23mv for quartz crystal and 14mv for barium tintanate crystal.

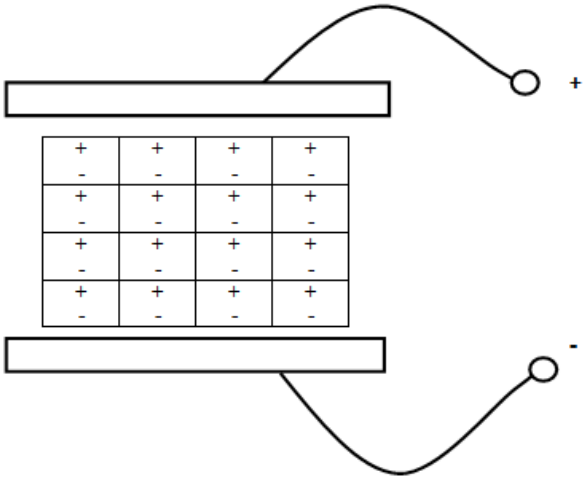

Figure 3. Block diagram of piezo electric sensor.

$$E = \frac{stress}{strain} = \left(\frac{F}{A}\right) * \frac{1}{\frac{\Delta T}{T}} \quad (3)$$

Electrical potentional E is given by

$$E = \frac{FT}{A\Delta T} \ N/M^2 \quad (4)$$

Area of the piezo electric crytal is given by

$$A = WL \quad (5)$$

Charge of thecrystal is given by

$$q = d33$$

The total voltage of the crystal

$$V = \frac{d\,33f}{e\,33A} \quad (6)$$

A - area of electrode, d - thickness
f - force, q - charge, v - voltage,
d 33,e33-piezo elctric constant.

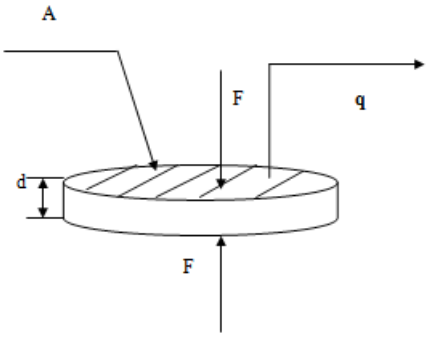

Figure 4. Block diagram of piezo electric sensor.

5. Proposed Circuit Diagram

5.1 Circuit Description

Piezoelectric output is of minimum range few volts. Then the output voltage is fed to the capacitor. Capacitor gets charged and release energy to the resistor and LED. The resistor is of minimum range. When the capacitor discharge the energy LED will glow and stores the energy to the battery.

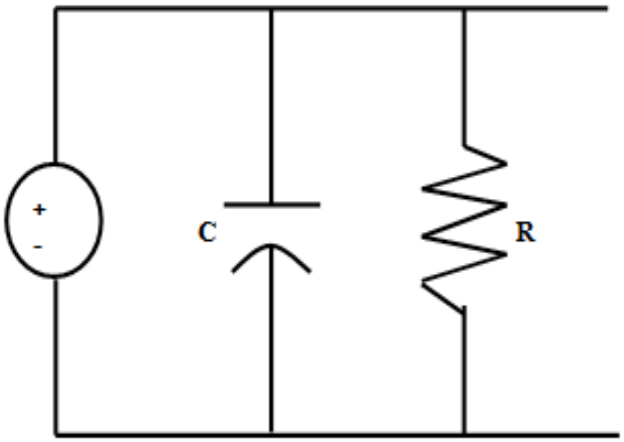

Figure 5. Circuit diagram of piezo electric sensor.

5.2 Open Loop Control of Cuk and Three Phase Inverter

Cuk regulator is similar to the buck boost regulator which delivers the output voltage more or less according to the input voltage. But the polarity of the output voltage will be alternate, According to the input voltage. When MOSFET is turned on L_1 charges. Voltage across capacitor C_1 reverse bias, diode D_1 turns off. The capacitor discharge energy to the load.

When MOSFET 1 is off capacitor C_1 charge from the source and inductor L_2 discharge to the inverter capacitor C_1 act as medium which transfer of energy from source to the inverter. Three phase inverter operated under 180^0 conduction mode. Two switches operated at a time. One from the upper leg and one from the lower leg. The output from the three phase inverter is a step waveform observed from the scope.

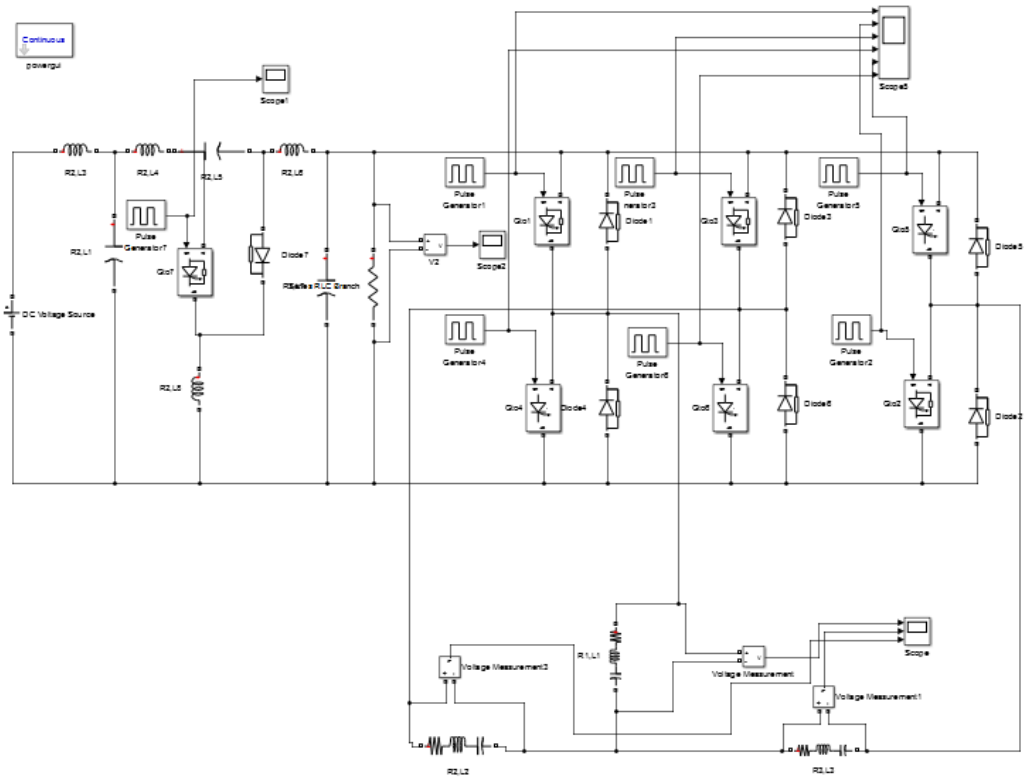

Figure 6. Simulink model Cuk converter and inverter with RLE load.

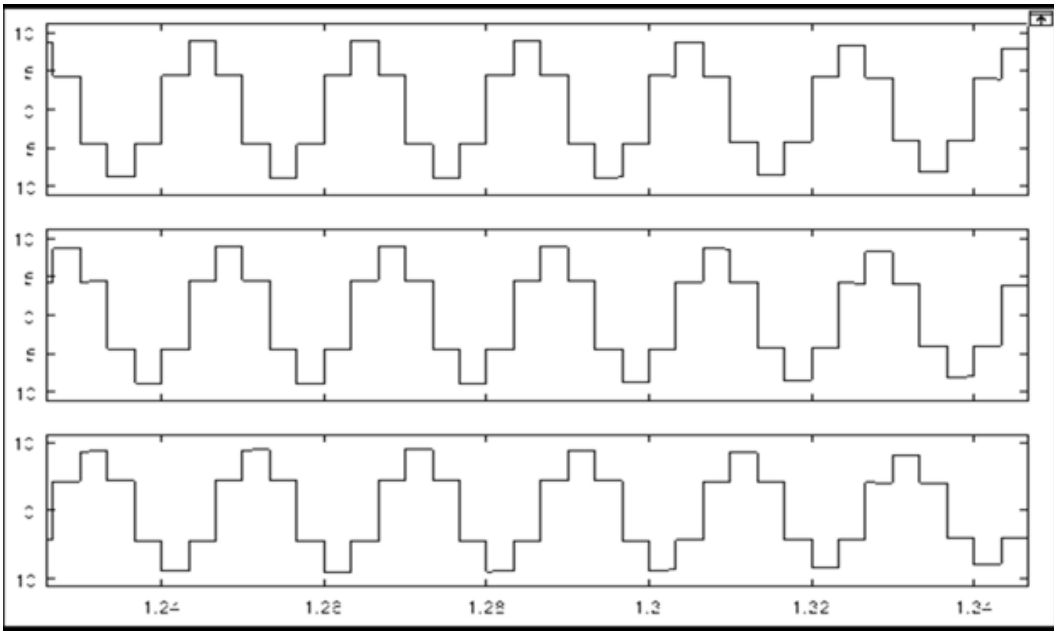

Figure 7. Output voltage of openloop wave form.

5.3 Closed Loop Control of Cuk and Three Phase Inverter

Similar operation is t carried out in closed loop. But in closed loop we can predict the output voltage by connecting the feedback from the cuk regulator. Output from the cuk regulator is compared with the reference voltage and given to the PI controller. PI controller will improve steady state error and transient response. It will reduce noise. Saturator will reduce the error up to 5V. Repeating sequence will repeat the signal with regular time interval. The relational operator will relate the two input signal and produce the output signal which is given to the gate of MOSFET. Desired output is obtained from the cuk regulator.

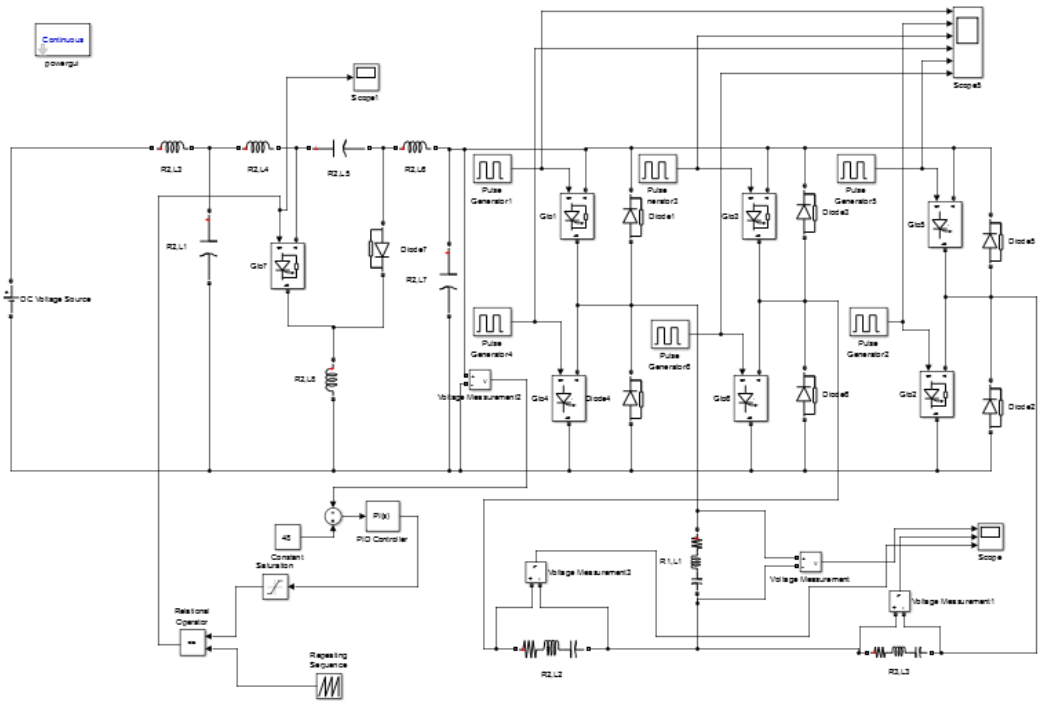

Figure 8. Closed loop of Cuk converter and inverter with Rle load.

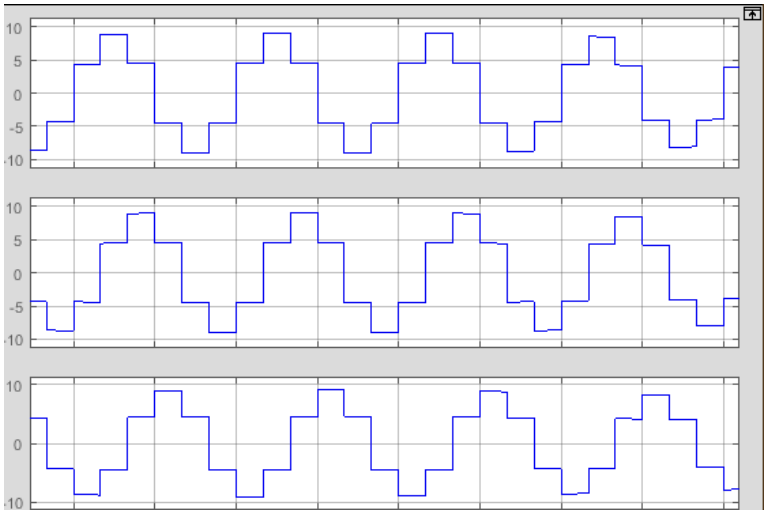

Figure 9. Output voltage of closed loop waveform.

6. Conclusion

In this paper compare the effect of various piezoelectric crystals. Buck-Boost converter and various gear arrangement are to produce high out voltage. In order to provide the constant output voltage due to fluctuation of pressure produce by the vehicle. The Buck-Boost converter is fed to the three phase inverter, which converter DC to three phase supply. The simulation work carried out both in open loop and closed loop and the performance is observed in MATLAB. Buck-boost converter and three phase inverter are fabricated for hardware circuit. The result is promising to expected level of output voltage.

7. References

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