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A NEW APPROACH ON POWER GENERATION USING ACOUSTIC SIGNALS

Rohan Silvius Robey

Department of Electronics and Communication Engineering,
Gopalan College of Engineering and Management, Bangalore, Karnataka, India

ABSTRACT

In this paper, a quite rare form of energy is explored and studied, a form of energy so common and omnipresent, but due to its few limitations, it has been ignored to a very great extent in its potential to be used to as a source of power, thus a methodology for capturing acoustic energy or sound, converting it to its electric equivalent and storing this energy is primarily proposed here. Due to the weak and varying amplitudes of acoustic signals, amplifiers are used to step-up the amplitude of the electric equivalent of the incoming acoustic signals. The boosted electric signals are then rectified and stored, which is potential electric energy. Just as in the case of a battery, this stored energy can be used in its A.C equivalent by inverting it or in its stored D.C state for the innumerable purposes possible.

***Keywords** : Acoustic signals, Sound, Electric power, Acoustic energy, A.C voltage, D.C voltage, Super Capacitor.*

***Abbreviations** : A.C - Alternating current.*
D.C - Direct current.
V - Volts.
F - Farad.
A - Ampere.
W - Watt.

1. INTRODUCTION

Electric power generation as we know, primarily is a process of harnessing power or energy by manipulating any form of energy to its electric equivalent, such as hydro-electric or thermo-electric power generation. As implied by the law of conservation of energy, energy can neither be created nor destroyed, therefore energy can be *manipulated* for various purposes by converting it from one form to another.

As of today, 67% of the fundamental sources of the *electric energy* are dependent on natural and exhaustible forms of resources of our planet. Taking into consideration the rate at which these resources are depreciating, alternate forms of energy sources and their extraction have been implemented to a certain extent. These alternate sources of renewable energy amount to only 13% of the total electric power generated globally.

Sound or acoustic energy (used interchangeably) is present everywhere and is inevitably generated as a result of innumerable activities, from the sound of human speech to the sound of wind, it is a form of energy that is scattered and random in nature, that it fails to be considered a source of energy that can be used to generate usable energy. The merits of acoustic energy in this scope of work are that, it is a form of energy, it is present almost everywhere and it does not consume non renewable sources for its generation. The de-merit of acoustic energy or signals in this scope of work is it is random in nature, i.e. it does not have continuity to be used as a sustainable energy source to provide continuous and sustained power. The methodology used in this paper tries to bridge the gap between the merits and demerits of sound within this scope of work and proposes a way to capture, store and use the energy generated by sound to power electric devices, thus providing a basis for sound to be used as a potential source of electric power generation.

With respect to the previous research work performed in the field of harnessing sound energy to generate electric power, piezo-electric crystals were used as the type of transducer to convert acoustic energy to electric energy, and in turn generate considerably small electric power which limits the scope of application of the technologies proposed

Therefore an approach to generate electric power (domestic/commercial voltages) by using the fundamental concept of manipulating one form of energy to another, which in this case is *acoustic energy to electric energy* is the objective of this paper.

.2. METHODOLOGY

In the methodology implemented to achieve the objective mentioned above, two working models have been proposed:

1. Direct conversion system.

2. Storage system.

The direct conversion system proposes a methodology used to *manipulate* and convert *acoustic energy to electric power*. The storage system proposes a methodology that is used to store the extracted energy for later use.

2.1 Direct conversion system

Under laboratory test conditions, the direct conversion system was operated on two conditions.

1) Constant acoustic signals from a metal fan were given to the input of the system.
2) A 10.5W bulb was used as a load at the output of the inverter.

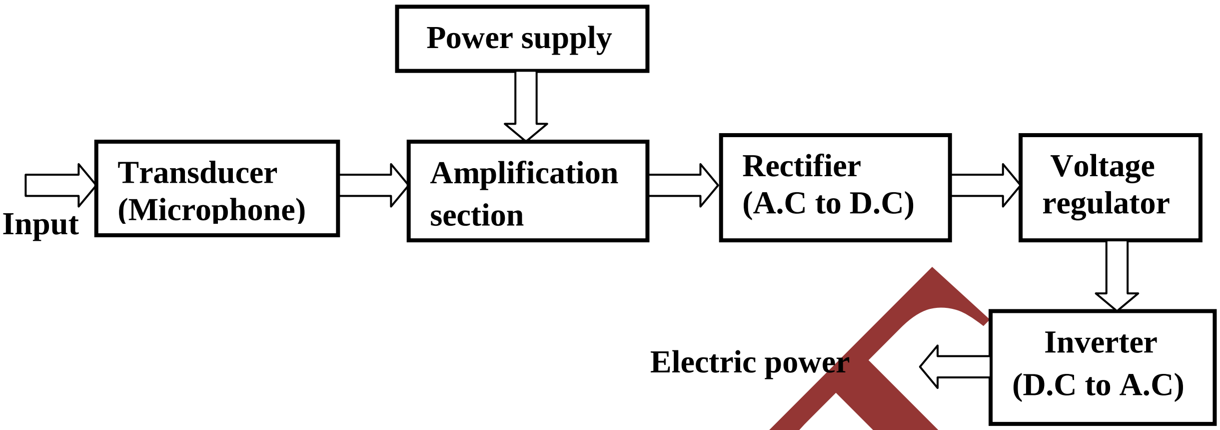

Figure 1. Direct conversion system.

The figure 1. sows the various stages of the system. As illustrated, at the input, the acoustic signals are directed towards the microphone. The electric equivalent of the acoustic signals which are generated at the output of the microphone are then applied as input to the amplification section (amplifier).

The *amplification* section is sub-divided into two sections, pre-amplifier and main amplifier. The pre-amplifier is used to boost the incoming signals to a suitable level for the main amplifier to operate on. The frequency range of the input acoustic signals accepted by pre-amplifier is set between 50Hz to 100KHz. The amplified signals generated at the output of the main amplifier is of a suitable signal amplitude to power up the further stages of the system. One of the underlying purposes for the use of a main amplifier is to strengthen the signals to a suitable amplitude level to compensate for the voltage drops (loss) caused by the use of heavier loads in the output section, as seen in table 1.

Sl.No.	**Distance (cm)**	**Voltage output of the rectifier(V)**	
		Without load	**With load**
1.	5	19.04	7.45
2.	30.48	16.59	6.82
3.	45.72	14.09	6.38

Table 1. Output of the rectifier with respect to distance of the microphone from the source of sound.

In the next stage, the amplified signals generated by the main amplifier are *rectified*, to convert the alternating output voltages of the main amplifier to their equivalent D.C voltage. The D.C voltage generated at the output of the rectifier then drives the voltage regulation section.

The output of the *rectifier* varies with respect to the intensity and amplitude of the incoming acoustic signals, as well as the distance between the source of sound and the microphone. The variations in the output voltage of the rectifier with and without the load with respect to the distance are tabulated in table 1,where the distance represents the distance between the source of sound and the microphone.

Due to the continuous variations of the D.C voltages which is caused by the variations of the input acoustic signals, the D.C input to drive the inverter has to be regulated to a fixed D.C value. This fixed D.C voltage value must be set to the voltage regulator as its required output. Since the variations in D.C voltages at the output of the rectifier can exceed or fall below this value, a *buck-boost* type D.C voltage regulator must be used so as to produce a constant D.C output to power the inverter stage.

The *inverter* which is powered by the fixed D.C voltage at its input, converts this D.C voltage to a any commercial alternating voltage (ex: 220V ,110V), depending on the design of the inverter for the various purposes required. The figure 2. (a), (b), (c), (d), (e), (f) show the A.C voltage generated at the output of the inverter from the corresponding input acoustic signal at different distances between the source of sound and microphone. The A.C voltages depicted in the given waveforms are when no load is attached to the output of the inverter.

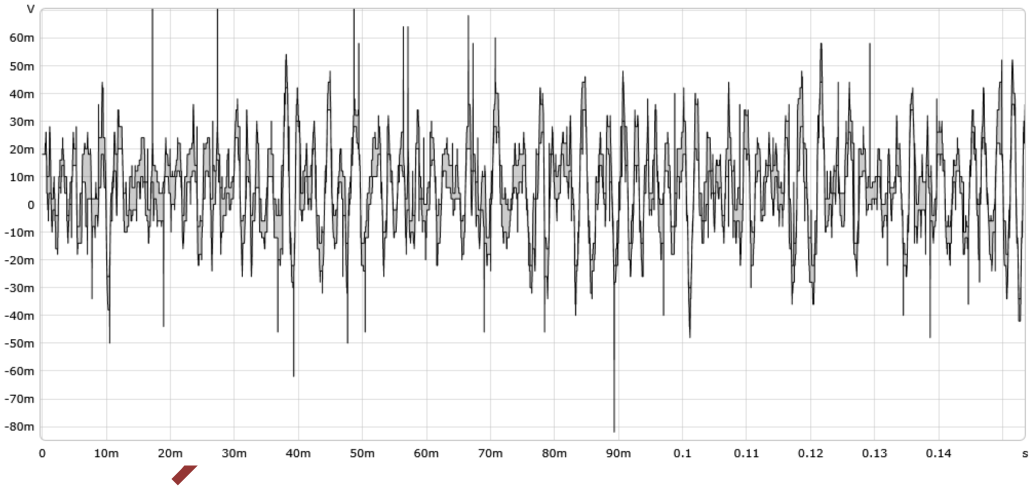

Figure 2. (a) Output signal from the microphone at 5cm from the source of sound

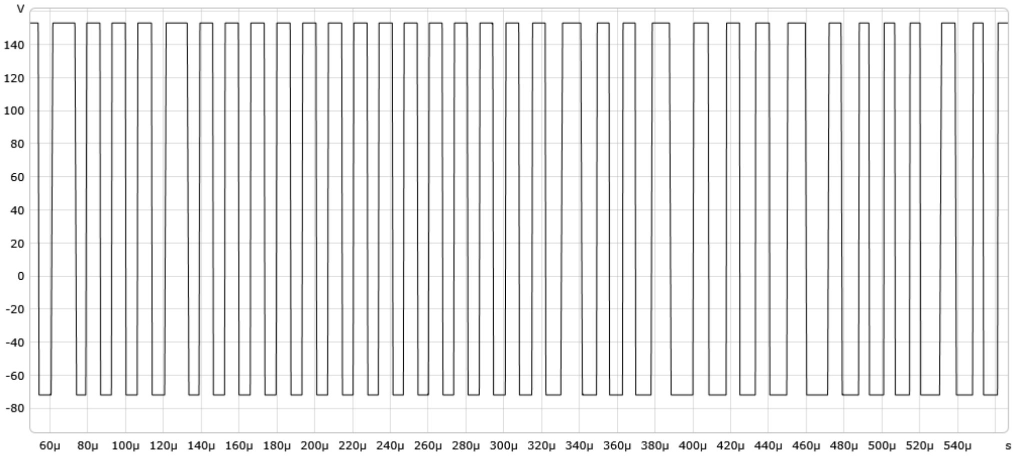

Figure 2. (b) Output A.C voltage from the inverter with the microphone at 5cm from the source of sound.

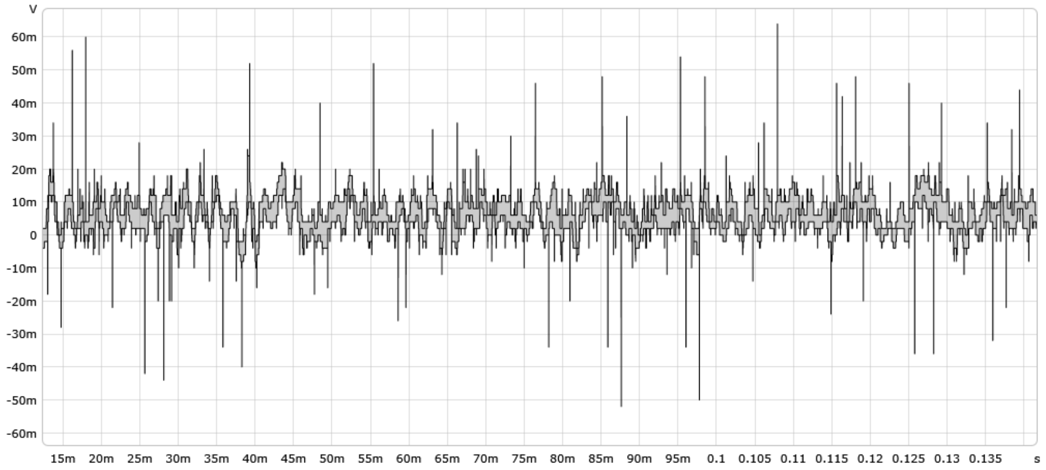

Figure 2. (c) Output signal from the microphone at 30.48cm from the source of sound.

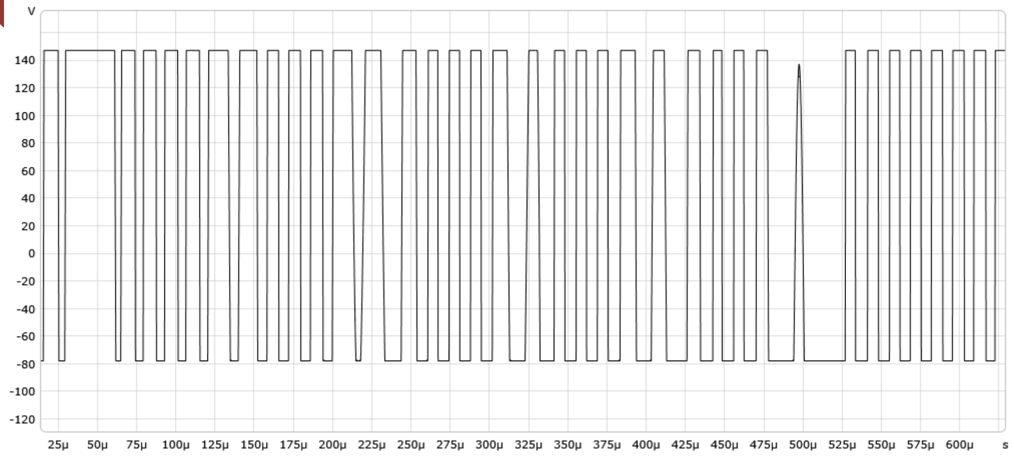

Figure 2.(d) Output A.C voltage from the inverter with the microphone at 30.48cm from the source of sound.

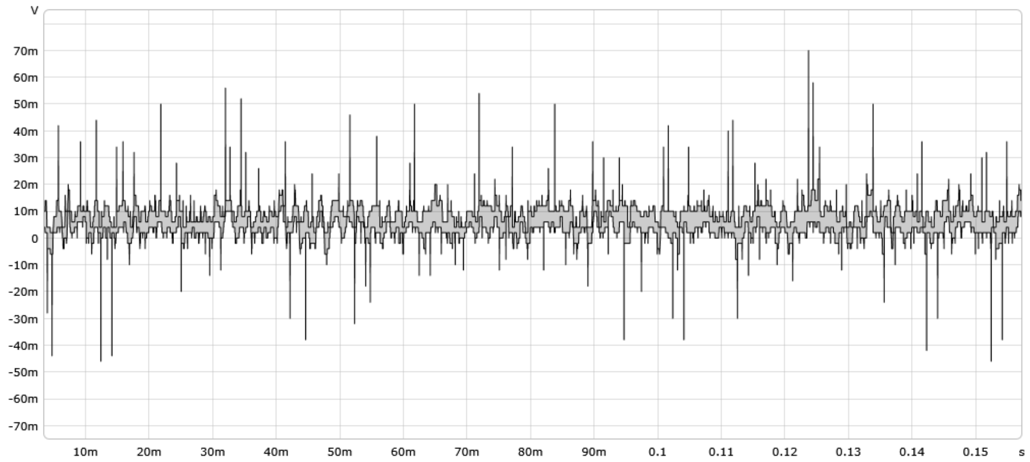

Figure 2. (e) Output signal from the microphone at 40.72cm from the source of sound.

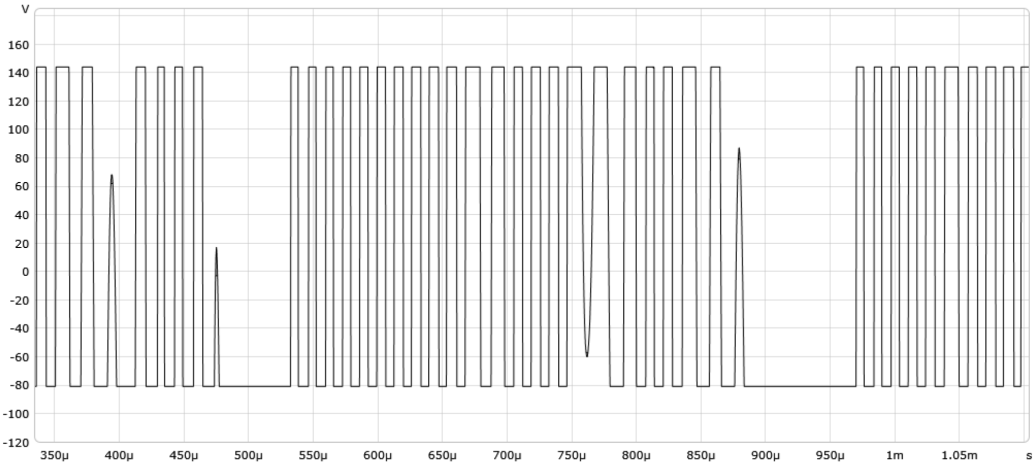

Figure 2. (f) Output A.C voltage from the inverter with the microphone at 40.72cm from the source of sound.

The direct conversion system proposes a method which instantaneously converts the incoming acoustic signals to electric power, as seen in the above waveforms, i.e. electric power is generated if and only if there are acoustic signals directed towards the input of the system continuously. Since continuously varying output power goes wasted, a way to make this form of power useful is to store it and later discharge it as a constant output, is the underlying functionality of the storage system.

From the waveforms given in fig 2. and from table 1. it can be inferred that with an increase in the distance between the source of sound and the microphone the commercial A.C voltage generated at the output shows diminishing variations and that there is a direct relation between the output of the inverter and the input acoustic signals. Hence the direct conversion system establishes and methodology and a process to convert acoustic signals to commercial A.C voltages, but considering the fact that the amplification section requires an overhead power for its specific operation, this puts a limitation on the systems with regards to the independency of the system being able to generate commercial A.C voltages solely from acoustic signals. This limitation is due to the drawback in the power required for the functioning (operation) of the microphone. Although the microphone has an advantage in generating greater voltages when compared to the piezo-electric crystals and their sensitivity, the drawback in using a microphone lies in its dependency of a minimum operating voltage.

Therefore in order to reduce the overhead required to power the system and to generate a more constant and a stable output and also considering the drawback of the microphone, the storage model poses as the solution where the variations in D.C voltages are stored (collected) over a period of time and then discharged as a constant output.

2.2 Storage system

The storage system is essentially the same as that of the direct conversion system as depicted in figure 3, the additional circuitry included are the charging and voltage regulation circuitry along with a storage unit that stores the D.C voltages from the output of the rectifier.

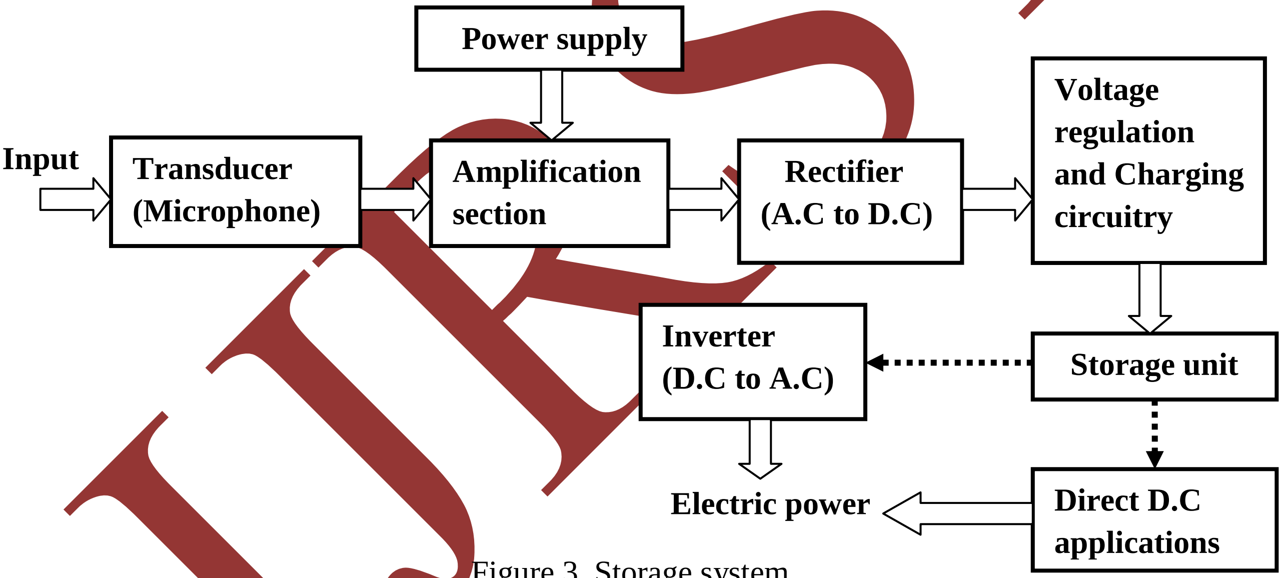

Figure 3. Storage system.

The most common device to store D.C voltage/current would be a battery, but in the practical scenarios with respect to the scope of this system, where acoustic signals are not constant and continuous, the D.C voltages generated have considerably large degrees of variation, which would even cause voltage regulation to fail in producing a constant D.C output to charge a battery (the battery considered in this scope of work would be of a specification required to drive inverters to power commercial electric loads such as a light bulb). Therefore to charge a battery with high voltage variations and a specific current drawn, would make it impractical for its application, also the time required to charge a battery as given by the equation 1,

$$T = Ah/A \qquad \ldots 1$$

would amount to a minimum of 9 to 12 hours for a 12V/1Ah battery with a constant D.C supply, where A=10% of Ah in most cases for a lead-acid battery.

Hence an alternative to batteries is a device that can be charged at relatively low voltages with variable current for charging, and requires much less time to charge to its maximum storage value are *super capacitors*.

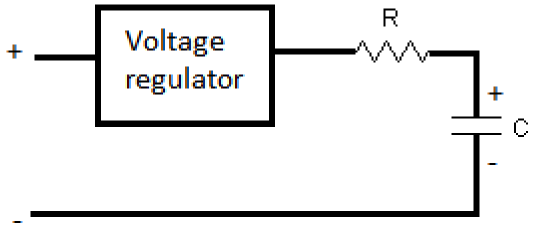

Figure 4. R-C circuit.

The simple R-C circuit along with a voltage regulator shown in fig 4. can be used to charge the super capacitor. The charging and discharging time of a capacitor is given by the equation 2.

$$\tau = R \times C \qquad \ldots 2$$

The time taken to charge a capacitor in most cases is five times the time constant τ, but with respect to this scope of work, the charging time of the super capacitor is also governed by two factors:

1) The degree of variation of the D.C voltage generated as a result of the varying input acoustic signals.
2) The resistance value selected to set the charging current of the super capacitor.

The voltage required to charge a capacitor is predominantly determined by the maximum rated voltage of it. Hence the charging voltage required for the super capacitor is set as the output voltage of the buck-boost regulator, followed by a resistance value that determines the charging current of the super capacitor. Therefore the time required to charge a super capacitor to its maximum potential is much less as opposed to the time required to charge a battery. A specific time period cannot be mentioned as the source of power is the acoustic signals, and due to the continuous variations of natural acoustic signals the charging time varies.

Under laboratory test conditions the voltage regulation and charging circuitry consisted of two 500F super capacitors rated at 3V each, which were placed in series and charged up to 5.8V using acoustic signals as the source of power .The capacitors were then discharged through an inverter having a 10.5W bulb as the load. The voltage drop rate was calculated to 0.024V/s at a discharge current of 2.3A, for one minute.

$$i = C \times dV/dt \qquad \ldots 3$$

Using the formula given in equation 3, it can be inferred that the rate of voltage drop during the time of discharge can be reduced by selecting higher value capacitances for the super capacitor, along with setting a constant discharge current using suitable resistance values. Using larger value super capacitors would in turn lead to an increase in the time required to charge a super capacitor, but much less time when compared to a battery.

In the storage model, the power consumed by the system is only during the time when the system is extracting the acoustic energy and charging up the storage unit. While the storage unit is discharging the stored power there is no power consumed by the system.

The power source used to power the amplification section in the working laboratory model were solar panels. The use of solar panels restrict the usage of the system to extract acoustic energy only if there is sufficient light to provide the required power, but the power supply can be replaced with any other power source with suitable specifications that can provide power according to the amplification sections power demand. Considering the power required for the functioning of the system, it is much less when compared to the power generated on discharge of the storage unit, thus causing the system to be considerably efficient.

3. RESULTS AND CONCLUSION

This paper thus proposes a theoretical interpretation of the working model of the direct conversion and storage type system, which has been built and verified in accordance with the operation and principles as described in the above sections. Considering the primary objective of this paper, i.e. to generate electric power from sound, this model proposes a way to extract and use the energy from sound (acoustic energy) and use that in generating electric power, this was achieved in the working model.

But to use that power on a commercial level of consumable electric power would require further research and work on the extraction methods of acoustic energy, as the limitation of both piezo-electric crystals and microphones as transducers with respect to the sensitivity and power required to power them impose a considerable overhead to the system. Also further improvement on storage devices and their efficiency of storage can bring in a very promising future to the implementation of this concept in real world energy conservation and extraction.

The extensions, applications and further improvement of the system are numerous. This system can be installed in areas where noise (acoustic energy) is generated in abundance and can be used as a source of power to power commercial electric devices or store the power generated for later use.

The system proposed here does not provide a complete solution to use sound as a source of power, it rather proposes a process and a method which can be used as a basis for further development in the field of non-conventional energy extraction.

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