transit magnets and achieve high magnetic flux gradient in the improved Halbach arrays.

2. Improved Halbach-Array System

The improved Halbach array, energy harvest system eliminates the low flux density and magnetic field and less energy. In this technique the magnets are arranged in specific manner that concentrates the magnetic field on one side of the array and the other side of the magnetic field becomes zero. This technique is implemented using the software "LabVIEW" and the simulation results are compared with the performance of the normal magnet.

2.1 Hardware Implementation Halbach Array Arrangement of Magnets for Energy Harvesting

The block diagram of the developed system is shown in Fig.2.1.The circuit consists of IC 555 connected to driver circuit through buffer MCT 2E and IGBT. The solenoid valve (Linear actuator) which is controlled by IGBT is connected to the Halbach array along with the load. For visual notification of output, multimeter is connected to the capacitor. The IC 555 act as the timer circuit for the linear actuator.

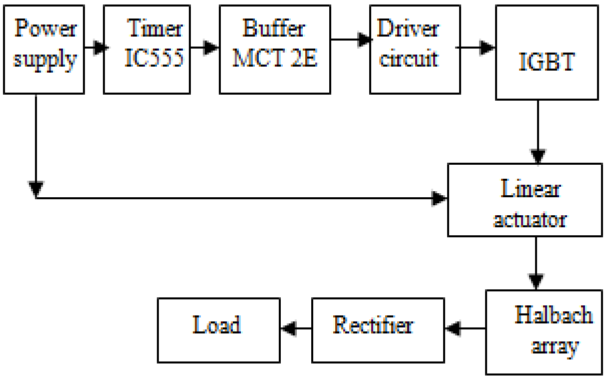

Figure 2.1: Block diagram of developed system

2.2 Working of the Improved Halbach Array System

Figure.2.2 shows the circuit diagram of Improved Halbach array system. The circuit is powered by the transformer which is 12 volt 1 amp power supply. The output of the transformer is connected to a full-wave bridge rectifier. It converts Ac to Dc, and then it passes to the voltage regulator and voltage is regulated by a voltage regulator IC 7805 which is constant 5volt.

A heat sinker is installed, which is used to eliminate the heat from transformer. A LED is fixed, in order to ensure accurate supply of voltage. The positive from the voltage regulator is given directly to linear actuator. The IC 555 Timer circuit is fixed to generate frequency, and it also includes to reset the circuit if the process hangs up.

To vary the frequency two 1KΩ variable resistors are used. This timer circuit is directly connected to the 12v power supply so there is less noise produced during the process. The frequency signal passes from timer circuit to driver circuit

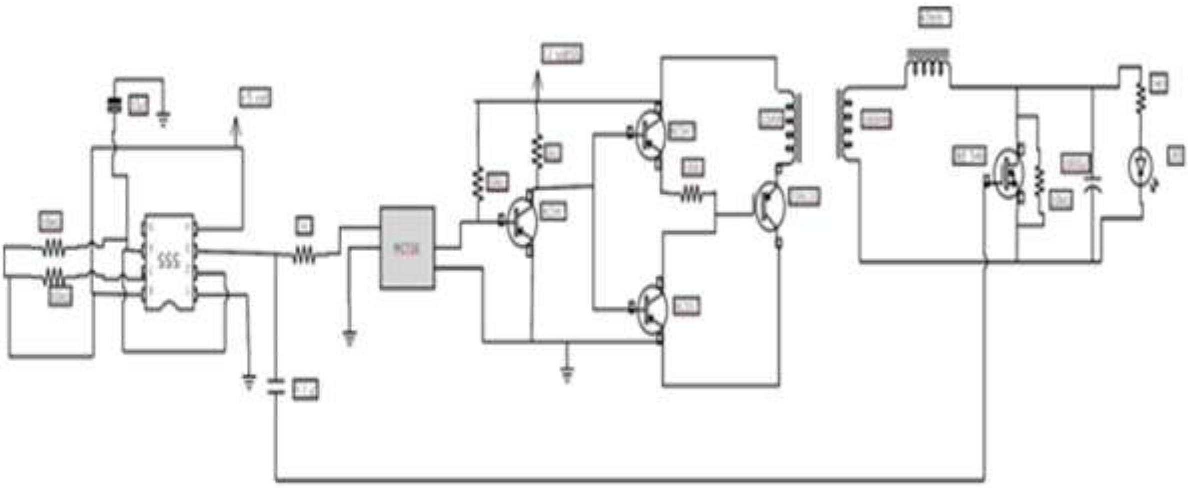

Figure 2.2: Circuit Diagram of Improved HalbachArray System

The resistor is used to resist very high voltage from the 12V supply. To restrict the reverse biasing process, a diode used. In driver circuit, optocoupler is a combination of auto transmitter and LED. The input frequency is given to the optocoupler which is received by the LED portions of it. Two NPN and one PNP transmitter are used, in which NPN gives positive supply and PNP with negative voltage supply.

IGBT is used for switching activity. When the positive 12volts is received, the switch attains ON condition, which does not automatically shuts OFF, unless the negative 12volts is supplied. The negative supply from the IGBT is given to the linear actuator. From the Table.1 Switching activity, when the switching signal is passed, the iron rod of linear actuator attains a straight line motion up to 3cm. One end of the Halbach array is connected to linear end while the other is connected to the spring, which is use give a stretch.

Table 1: Switching activity

LED	Switch (s0)	Switch (s1)	Switch (s2)	Switch (s3)	Output supply
OFF	OFF	ON	OFF	ON	-Ve
ON	ON	OFF	ON	OFF	+Ve

The magnet coil is wounded beneath the Halbach array. When the iron rod acquires the motion due to the switching activity, vibration is produced in the Halbach array, the vibration speed is varied by change the frequency in variable resistor. Magnetic flux is induced by vibration, this magnetic flux is cut by the coil, and hence an emf is induced. This emf is given to bridge rectifier. Then it is converted from AC to DC and it is stored in capacitor. The voltage is measured by multimeter and LED light glow by harvested energy.

3. Virtual Program for Halbach Array Arrangement of Magnets

Figure.3.1 shows the block diagram panel of virtual program for the improved Halbach array system. In this VI program for loop is used along with formula node.

The voltage response of magnet is used to vary the milli-volt range by adjusting the frequency from Low to High. These operations are done in front panel and the block diagram. The Front Panel is used to operate the function manually, here the amplitude and number of steps are given to formula node by the numerical input. The high frequency act as a Halbach array and low frequency is known as normal magnet.

The for-loop consists of two content, 'N' as top corner and 'I' as bottom. Four Number of Inputs are shown in blocks, which are Amplitude, Number of steps, High frequency and Low frequency

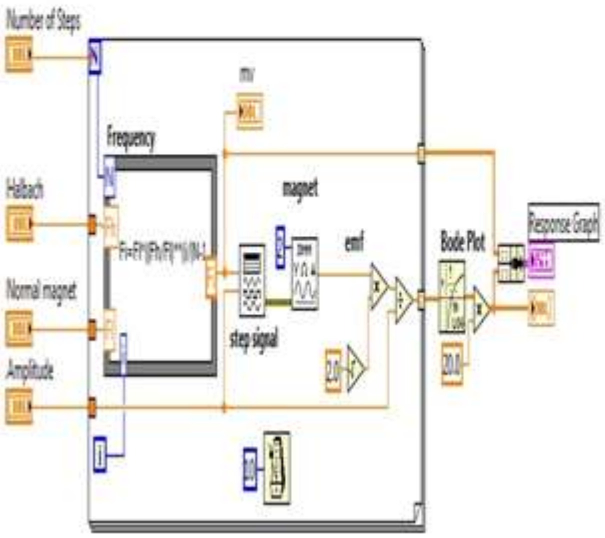

Figure 3.1: Virtual program block diagram for halbach array system

Amplitude is the objective measurements of the degree of change (positive or negative) in a atmospheric pressure caused by sound waves. Sound with greater amplitude is produce the changes in atmospheric pressure from high to low pressure. According to change of steps the variation can be changed the output voltage. The pointer speed can be increased or decreased by varying the number of steps.

Formula node Fi is used to the milli volts, which is used to indicate range of frequency. Formula node input N is connected with for loop (loop count), and frequency inputs are also connected with the for loop connected with for loop (loop count), and frequency inputs are also connected with the for loop.

Formula for operation of loop content is given by

Fi=Fl*((Fh/fl)**(i/(N-1)));

Where,

F_i = input frequency of the circuit

f_l = frequency of normal magnet

F_h= frequency of Halbach array

F_l= input variable.

The hardware tool consists of two tools namely stimulate UUT (Unit Under Test) and convert from RMS. The stimulate UUT input of frequency is given to the formula node f_i. The stimulate UUT of amplitude input is connected to the low frequency. The input convert from RMS is obtained from the output of stimulate UUT. There are three arithmetic functions used in for loop. Such as multiplication, division and square root. The multiplication and division functions are used as two inputs and one output.

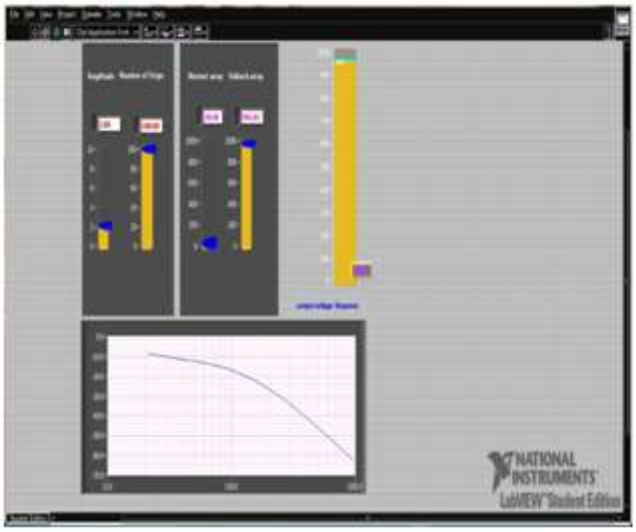

Figure 3.2: Front Panel of the Halbach Array System

In multiplication function first input is obtained from the output of convert from RMS. The root value of input is given as another input of multiplication function. Then, the output of multiplication is given as first input to the division and another input is taken from stimulate UUT of low frequency.

The output of division is given to the for loop content. The output from for loop is given as input to the bode plot. The output of bode plot is given as first input of multiplication and the number of steps is given as another input.The output from multiplication function is given as input to the bundle function and the output of bundle function is connected to bode plot. The response of output voltage is shown in figure.3.2.

4. Results and Discussion

The figure.4.1 refers the front panel of normal magnet, it consists of five thermometers, among them four thermometers are used for giving the inputs namely amplitude, number of steps, frequency of normal magnet and Halbach array magnet. The other thermometer is used to represent the output voltage in milli volt. A bode plot is used to indicate the voltage response.

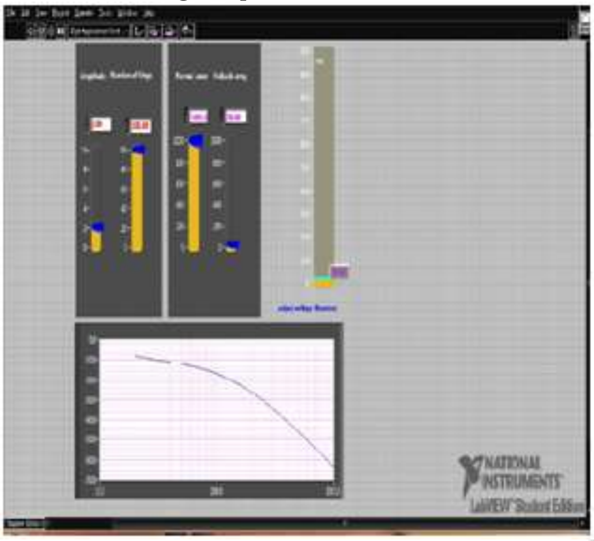

Figure 4.1: Output voltage response of normal magnet

In amplitude, input is set as 2, the number of steps is set to 100, set the normal array magnet to 1000 and Halbach array magnet is set to 0. The output voltage value is in very small range (i.e., 20mv).

Figure.4.2 refers the output voltage response of Halbach array magnet, when an amplitude is given as two with the number of steps as 100, the Halbach array magnet is set to 1000; it is a very high output voltage (i.e., 1000mv).

From the table.2 for a normal magnet with the amplitude of 1 milli volt and input frequency of 1000 Hz, it produces the output voltage as 20 mv. For the same input values, Halbach array magnet produces output voltage as 1000 mv.

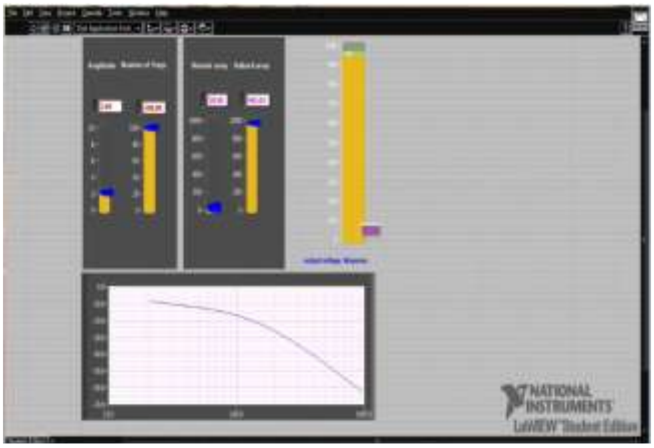

Figure 4.2: Output voltage response of Halbach array magnet

Table 2: Performance comparison of magnets

MAGNET	Amplitude (mv)	Input frequency(Hz)	Output Voltage(mv)
Normal magnet	1	1000	20
Halbach array	1	1000	1000

The main objective of this work is to design LabVIEW based energy harvest and control system for simulating the magnetic response of normal magnet and Halbach array magnet which is implemented successfully. The result shows that the LabVIEW based controller is easy to design and also produces better output than conventional controllers.

5. Conclusion

Based on analysis of the energy harvester with a normal magnet, the result shows that although the Halbach array magnet has higher magnetic field density compared to normal magnet layouts, its magnetic flux gradient is not necessarily high due to the existence of transit magnets. Thus, an output power of energy harvester with the single Halbach array is not always greater than those with normal magnet layouts. An improved Halbach array magnet, in this energy harvest work successfully minimizes the effect of the transit magnets in the Halbach array and thus increases the magnetic flux gradient. When compared to the normal magnet, it is found that the energy harvester with the improved Halbach array increases the output power.

References

[1] Beeby, S. P. and Tudor M. J. (2010) 'Energy harvesting vibration sources for microsystems applications Measurement Science and Technology', 17 pp.

[2] Cao X, Chiang W.J, King Y.-C. and Lee Y.(2007) 'Electromagnetic Energy Harvesting Circuit With Feed forward and Feedback DC–DC PWM Boost Converter for Vibration Power Generator System'- IEEE Transactions on Power Electronics, 22 pp.

[3] Beeby, S. and Tudor M. J. P.(2010) 'Strategies for Increasing the Operating Bandwidth of Vibration Energy Harvesters'-A Review Measurement Science and Technology, 29pp.

[4] Harris N.,TudorJ.and Zhu D., 2012 Vibration energy harvesting using the Halbach array Smart Mater. Struct,11pp.

[5] Beeby S. P, Tudor M. J. and White N. M.(2006) 'Energy harvesting vibration sources for microsystems applications Measurement Science and Technology', 17 pp.

[6] Beeby S, Harris N, Tudor J. and Zhu D.(2012) 'Vibration energy harvesting using the Halbach array Smart Mater'- Struct,11pp.

References

C. N. Divya received her B.E., Electronics and Instrumentation, from Mahendra Engineering College in 2013. Currently she's pursuing M.E., Control and Instrumentation in Valliammai Engineering College. Her area of interests includes Control system, Circuit Theory, Robotics

C. Praveen Kumar received his B.E., Electronics and Instrumentation, from Annamalai University in 2013. Currently he's pursuing M.E., Control and Instrumentation in Valliammai Engineering College. He has delivered many seminars on his YouTube channel. His area of interests includes Process control, Industrial Instrumentation and Control system.