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Constant Voltage Output Energy Harvesting System

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Abstract: The research on electromagnetic energy harvesting has great impact on the other energy harvesting methods over the last few years. Sometimes the low power electronics devices required constant voltage supply for their stable and efficient operation. In this paper an electromagnetic energy harvesting system is designed using high permeability ferrite toroidal core consisting copper coil turns on it and power management circuit for the desired constant 5-volt DC output voltage. The variable resistance of 1 k ohm is connected as a load for energy harvesting circuit and the phase wire carrying 10 Amp AC current passed through the energy harvester. The variable resistance load 600 ohm to 1 k ohm was supplied by constant 5 Volt DC voltage. This method of energy harvesting is reliable and maintenance free.

Keywords — ***Energy harvester; high permeability core; magnetic field; Resistance; rectifiers; constant voltage.***

I. INTRODUCTION

In recent days, in low-power applications the Energy harvesting methods have turned out to be progressively mainstream as auxiliary options to batteries [1]. There are numerous sources for energy harvesting in the environment such as solar [2], thermal [3], electrostatic [4], piezoelectric [5]and electromagnetic [6]. In power condition monitoring system an energy harvesting is very significant to maintain certain amount of energy. the electromagnetic energy harvesting based on magnetic induction principal in adjacent to current carrying electrical cord is very reliable to power the monitoring sensors at remote locations, where time to time battery replacement and facility of reliable power is more difficult [6,7].as compared to the other energy harvesting sources the electromagnetic energy harvesting is very interesting due to its independency on outdoor weather circumstances such as sunlight or wind.

Utilization of electrical energy becomes very important part of human being life. Therefor while any appliance connected to the electrical supply magnetic field produce around the connecting cord depending on the value of current which can be easily harvested to power the energy management circuit in small electronic devices. Electromagnetic energy harvesting by this method is maintenance free and stable in operation. [8] Some electromagnetic energy harvester described in [9-15]. Generally, the output voltage from the harvester is in micro volt to milli volt but using current transformer-based energy harvester it is improvement in the generated voltage. This paper delivers design of energy harvester to generate the constant output voltage by passing 10 Amp AC current wire (phase or neutral) through the harvester.

II. ENERGY HARVESTING SYSTEM

In this paper the proposed energy harvester introduced in two steps for converting magnetic field around wire in 5-volt DC voltage as shown in Fig.1. First step is energy conversion in which the magnetic field around the conductor converted into electrical energy in ac form using induction based stray magnetic field harvester. Second step consist a power management circuit is used to supply constant 5 V DC output to the load.

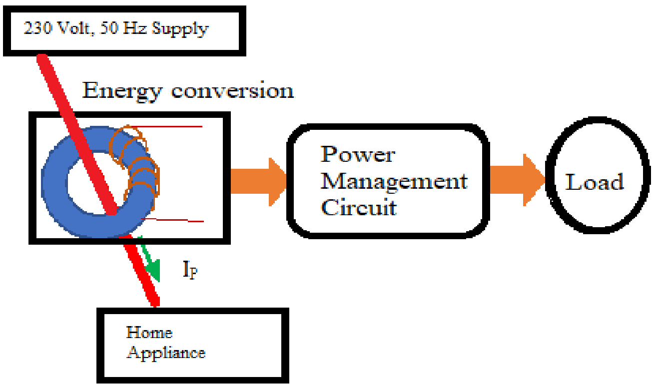

Figure.1. Energy harvesting system

Energy Conversion

When the current carrying cord passing through the round sized toroidal core comprising copper coil with feu turns wound on it ac voltage will be generated across the terminal of coil and ac current flows through coil in mA. Due to the current flowing through wire magnetic field strength H is developed around the conductor which causes to produce magnetic flux density ‘B’ in the toroidal core. The value of ‘H’ depends on the range of current flowing through the wire and distance between the conductor from the average MPL (magnetic path length). The harvesting output power is depending on high permeability of toroidal

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core and saturation flux density. The magnetic flux density B determined by the value of H.

The voltage induced 'Vs 'in the coil having Ns number of turns depending on the value of flux density and size of the core. The flux density and induced voltage is expressed as-

$$B = \mu H \qquad (1)$$

$$Vs = \frac{d\Phi}{dt} = \frac{d(B.A)}{dt} \qquad (2)$$

Table no. 1 shows the various values of H, B and Vs due to the variation in primary current obtained mathematically using electromagnetic theory [16].

Table 1. Variation of Flux density and Induced voltage

Primary current Ip (Amp)	Magnetic Flux Density in the core B(Tesla)	Magnetic Field intensity **H(A/m)**	Induced Voltage in secondary coil V_S (Volt)
1	**0.03**	**3**	0.78
2	**0.05**	**6**	1.56
3	**0.08**	**9**	2.34
4	**0.11**	**12**	3.12
5	**0.14**	**15**	3.90
6	**0.16**	**19**	4.69
7	**0.19**	**22**	5.47
8	**0.22**	**25**	6.25
9	**0.24**	**28**	7.03
10	**0.27**	**31**	7.81

The value of Magnetic field strength and flux density is minimum in the range of 3 A/m and 0.03 Tesla at the 1 ampere AC current in primary wire. Therefor the value of induced voltage is also a lesser amount of 0.78 Vrms. All the three values are increasing with increase in primary current. The highest value of induced voltage is 7.81 Vrms in secondary coil of harvester which is suitable for as input to IC 7805 after rectification.

Power management circuit

Induced voltage in the coil is not constant, due to the minor change in primary current value of induced voltage will be varied which cause to instability in output power to the load which is not suitable for efficient operation of low power device. Hence to regulate the output voltage at 5-volt DC, a regulator IC is used here in power management circuit. Using the full wave rectifier circuit induced ac voltage is converted into DC voltage. There are two types of full wave rectifiers, one is center tapped and other is bridge rectifier. After the rectification DC voltage Vdc is smoothed by the capacitor C1.IC LM7805 connected to regulate voltage at 5-volt DC. Capacitor C2 and C3 used to reduce the noise due to incentive current. A variable resistive load is connected to the DC circuit.

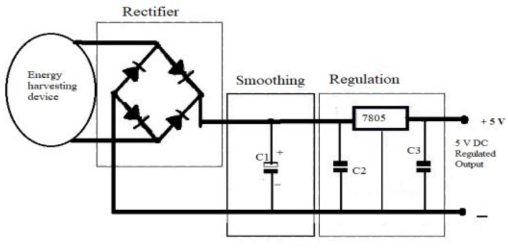

Figure. 2. Energy Harvesting circuit

III. EXECUTION OF SYSTEM

The testing setup is shown in Fig. 3. (Photo of experiment). The energy harvester of high permeability ferrite toroidal core is placed on the 10 Amp current carrying phase wire. The harvester was designed in such a way that it will produce 7 Volt at the input terminal of IC LM7805. A variable resistive load of 1 K ohm is connected to the management circuit.

In the Fig.4. It is shown that after connecting 1 K Ω variable resistance as load, at 200 Ω the DC value of voltage is 3.5 Volt and through IC 7805 it is 2.5 Whereas across 600 Ω AC voltage is 7.5 volt and it is increasing as increase in load resistance up to 1K Ω. The voltage induced in secondary coil using proposed method is higher as compared to the method used in [15]. Therefore, final output DC voltage is constant at 5 volts.

Figure .3. Testing Set-up

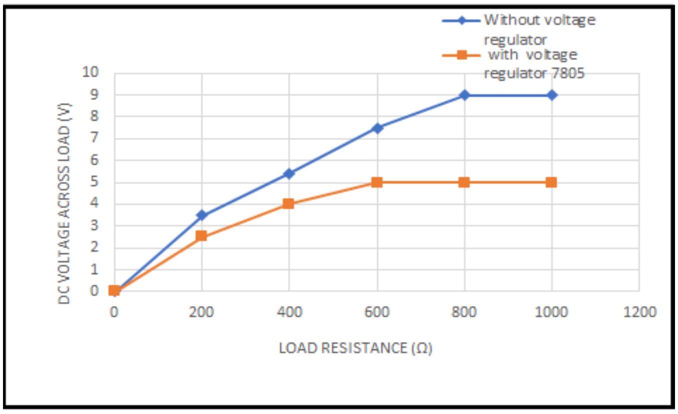

Figure 4. DC output voltage with and without voltage regulator

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IV. Conclusion

This paper introduced electromagnetic energy harvesting for constant 5-volt DC voltage. The energy harvester has been designed in such a way that it will generate 7-volt Ac. This energy harvester is appropriate for supplying the constant 5-volt DC to small portable device. It is also possible to store the energy in a rechargeable battery cell and supercapacitor for later utilization purpose. Here the ferrite toroidal core is used for energy harvesting because of its high permeability, low eddy current loss and high volume of resistivity.

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