Ambient Radio Frequency Energy Harvesting: A Review

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Abstract **- RF energy is a collective term for electromagnetic energy emitted by all sorts of waves on the electromagnetic spectrum, which mainly include Radio waves and Microwaves. In this paper, we will discuss different methods of harvesting Radio Frequency energy. Also, in the next section we will see the advantages of Radio Frequency energy over other energy harvesting methods. We will be discussing some disadvantages of it too. In this particular review, we have come across some methods to increase the efficiency of Radio Frequency energy that is being harvested. This study will help further researchers to garner knowledge about RF energy harvesting in a brevity manner.**

Index Terms **- Ambient RF energy, Radiofrequency energy harvesting, Energy Harvesting.**

I.INTRODUCTION

In this paper, we will be putting some light on ambient RF (RF= Radio Frequency) energy harvesting. As we all know we are running low on fossil fuels and it would be a matter of time till these fossil fuels get exhausted and we will be left with nothing other than alternative energy sources like solar energy, wind energy, kinetic energy, thermal energy, and Ambient RF energy; all these energies are readily available to be used. It takes just some sensors and electric circuits to convert these energies to a more usable form (Direct Current power). In the first part of the paper, we will be looking at the advantages that RF energy holds over other energy sources and what are some of its disadvantages. In the second part of the paper, we will be looking at some ways to maximize the use of energy that is being harvested.

II. BASIC FEATURES AND ADVANTAGES OF ENERGY HARVESTING

As we all know battery has a limited life span which can be increased by reducing power consumption and by recycling energy such as in the Microelectromechanical system. Rechargeable batteries for laptops and mobiles can be easily charged by connecting into an electric supply, But the real problem arises when we have to charge sensors it becomes really hard when the number of devices is high and devices are spread in a wide area, and sometimes these devices or sensors are in inhospitable environments. To solve this problem, we use Wireless Power transmission (WPT) which consists of power transmission through microwaves and radio waves. Energy transmission is a field where researchers have worked for ages. This technology has been proposed for Helicopter Power, Solar Power satellites, SHARP (SHARP=Safety and Health Achievement Recognition Program) system, RFID (RFID= Radio Frequency Identification) [1].

III. DIFFERENT ENERGY HARVESTING METHODS

There are different methods available for energy harvesting, most familiar ambient energy sources are solar energy, wind energy, thermal energy, acoustic energy, kinetic energy, and electromagnetic energy.

Solar energy-It is widely used as it has some major advantages over other energy harvesting sources that is, it is cost-effective, size effective, durable, provides the output as DC power and it is widely used in shipping yards, the Agricultural sector, in outdoor security, etc. But it is not perfect, and it has some disadvantages i.e. it does not work well in indoors, it is time-dependent which means it works well in daylight but its efficiency decreases during night time. Also, it is weather dependent i.e. it does work well in a bright and sunny day but its efficiency decreases on a cloudy day. Hence, it cannot be used in an embedded system.

Thermal energy-It is an excellent source of energy harvesting, it works on the principle of the seed back effect. The advantage this type of technology provide

is that, it can work well even in harsh environments where batteries cannot work. It is active only when the source is active, therefore saves power. It is widely used for monitoring of industrial exhaust, furnaces, and Power train. Its major disadvantages include, it requires large thermal gradience to work, and also requires a bulky sink, to that it produces only a few micro-watts of energy.

Kinetic energy-It can work where energy exists in the form of vibration or as ambient random displacement of forces. It is converted using a transducer like a Piezo-electric transducer or an electromagnet. It is used in machine tools monitoring, pump monitoring. It has some disadvantages too i.e. it is really expensive. Though it produces a large potential difference for energy (~10V) still its efficiency is pretty low [2].

Ambient RF energy- One of the major advantages of this energy is that it is Ubiquitous; means it is widely available almost everywhere and anywhere. Electromagnetic waves are present in abundance. Where-ever we go we come across RF in some way or the other, whether it is transmitted from a TV broadcasting channel, GSM, radios, Wireless internet. We can easily use these RF signals and harvest them using a receiver, which is nothing more than an antenna, and by using some matching circuits which consist of Resistors, Capacitors, Inductors, and a rectifier to convert RF signals to DC power, which is a more usable form of energy and we can connect it directly to a load or a battery and then later connect it to a load. In the study of reference [5], A matching circuit can be designed using a combination of resistors, Inductor, and capacitor. Using various techniques such as the quarter wavelength technique which uses a transformer to match the antenna.

The comparison between some energy sources with their advantages, disadvantages, and applications is shown in Table-1.

Major advantages of RF energy are [3]

- RF can be used as an alternative source for electricity, it is renewable energy, it is present in an abundant amount, but current technology restricts its full advantage.
- It is ubiquitous, meaning it is readily available everywhere and anywhere. In an urban hospitable environment as well as in a hostile environment like forest.
- RF can also be used as an alternative for batteries, as batteries have a low life span and have to be replaced periodically; using RF signals and waves will save time. It can be used very well in Embedded systems. Unlike solar and thermal energy, it is not dependent on the time of the day and climate.
- It can be used in small places where other sources cannot be used.

Despite its numerous advantages over other energy harvesting methods, it has some major limitations too like:

- It converts very less energy (i.e., it gives very less output). Radio waves are widely spread and to capture it with current technology it becomes very difficult as the system has to be very near to the transmission, it generates less power i.e., its efficiency is very low because of current technologies.
- It is harmful to humans; therefore, high frequencies are being regulated due to health concerns.
- The transmitting antenna and the receiving antenna should have the same size, for the best possible results.

IV. SOME WAYS TO OVERCOME LIMITATIONS OF RF ENERGY HARVESTING

- We should use a spiral unipolar antenna. It provides maximum power transfer as shown in [1], it has several benefits some of them are – unipolar is convenient as feed point for diode connection, it has possible dual-polarization, it is a Broadband antenna, it has omnidirectional radiation and receiving pattern. All of this conclusion has been simulated by the HFFS tool [6]
- We can also minimize the use of wire for transmitting electrical signals, as wire leads to losses, not only that wire also leads to skin effect which is a tendency of AC to gather around the surface of the wire, which leads to current distribution within the current.
- Mismatch loss- It is due to improper matching of two consecutive stages of the waveform.

Matching circuits can be designed by using R, L, C., where R is the resistor of the active part, and L and C are the Inductor and Capacitor of the reactive part respectively. Only using resistance in matching circuits leads to Power loss; in this case only real (active) part of Impedance is matched. We use a Quarter wave-length transformer technique that uses a λ/4 transformer matching antenna. To increase the efficiency of the antenna, the antenna must be kept as high as possible, if the impedance of the antenna and rectifier are matched very well, then efficiency will be maximum [5].

- We should use high quality and sensitive Schottky diode in the rectification of the current.
- For storing, we should use a hybrid of Super Capacitor and regular battery. As a Super capacitor provides acts as a great energy-storing source for short term application, whereas batteries act a good source when the duration is long. Hence, we should use a hybrid.
- We can also use the E-WEHP Antenna design [4].

V. CONCLUSION

This article makes an effort to provide an overview of Ambient RF Energy Harvesting and its advantages and disadvantages. This comparative study provides the reader an overview on RF energy harvesting, with comparisons to other major renewable energy sources. The author believes that we shall use every possible method to increase the efficiency of RF energy harvesting not only that we should also combine various energy harvesting methods like solar-RF, kinetic-acoustic, and various other combinations if possible, this will lead to absorption and full advantages of not only Ambient RF signals but other energy sources too.

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