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Investigation of wireless power transfer applications with a focus on renewable energy

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ABSTRACT

With ever-increasing demands for energy and gradual climate changes, development and advancements of renewable energy have become a major priority of every country. The applications of renewable energy increase many folds when coupled with wireless power transfer (WPT) technology. About a century ago the advents of Tesla provided us with the principles of WPT. Since then a lot of research has been done in this field. Many efforts have been put to transmit power of renewable energy wirelessly. In this paper, the basic principles and various methods of WPT are reviewed and also discuss the recent developments in wireless transmission of renewable energy. An update for application and limitations of WPT has been presented. The possible systems produced with the coupling of WPT are also presented.

1. Introduction

In recent years, the demands for energy has been increasing at an alarming rate and is expected to increase in the coming years [1]. The rapid decrease in fossil fuel reserves, climate changes, environmental issues and ozone depletion is the most important concern of modern times. It is thus essential to increase the penetration of renewable energy into our grid system to meet the ever-increasing energy demands of the present world. Out of total 17,450 TW energy generated in 2005, the majority is generated by non-renewable energy sources. The availability of fossil fuels has decreased tremendously over the past few decades due to excessive usage of energy production. It has also given birth to tons of other environmental problems. Out of which greenhouse effect is one of the most important problems which need to be addressed. Nuclear power seems to be an answer for global warming, but concerns about terrorist attacks on Earth bound nuclear power plants have intensified environmentalist opposition to nuclear power.

Many new possibilities open up while interface the technology of WPT with existing renewable energy sources. Out of all the energy sources, solar energy is most commonly used for WPT application, since it is abundant, free of cost and non-polluting source of energy making it an ideal solution. SBSP is one of the most researched topics of the proposed system. The solar wireless charging station of Electric Vehicle and UAV is a significant outcome of the proposed interfacing. Two types of charging stations have been developed viz. Static and Dynamic.

Some of these possibilities with WPT include solar wireless charging station of Electric vehicles and UAV's, SBSP transfer and powering of wireless sensor nodes. It is particularly advantageous in the underwater applications where AUVs, ocean sensors etc. The most well known experiments on WPT was started by Nikola Tesla about a century ago [2]. Since then it has become a subject of intense investigation and experimentation. In recent years, Wireless power consortium has gathered a tremendous amount of momentum with over 180 member companies covering 16 countries.

After all these years of research, many methods of transferring the power wirelessly have been discovered. Depending on the mechanism of energy transfer, WPT is divided into two groups which are Radiative and non-Radiative. Both categories have their own merits and demerits. Solar energy is harnessed by sunlight or the heat obtained by it. It is classified as direct radiations or diffused radiation [3]

A renewable energy source plays a major in the reduction of global dependence on fossil fuels. New strategies are being developed to tap these ubiquitous sources of energy. Recent trends suggest a remarkable increase in sales and production of the electric vehicle. The only limitation of these vehicles is limited battery life, long charging times and infrastructure. To overcome such limitations researchers, as well as

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Nomenclature

IPTS	Inductive Power Transfer System
RPEV	Roadway Powered Electric Vehicles
EV	Electric Vehicle
WPT	Wireless Power Transfer
SBSP	Space Based Solar Power
SSPS	Space Solar Power System
UAV	Unmanned aerial vehicles
AUV	Autonomous underwater vehicles
EM	Electromagnetic
UHF	Ultra High Frequency
RF	Radio Frequency
MINIX	Microwave Ionosphere Nonlinear Interaction experiment
MPT	Microwave Power Transfer
JPL	Jet Propulsion Laboratory
SHARP	Stationary High Altitude Relay Platform
ISY-METS	International Space Year - Microwave Energy Transmission in Space
RFID	Radio Frequency Identification
WiPE	Wireless Power Transmission for Sustainable Electronics
GIS	Geographic Information Systems
DSSC	Dye-Sensitized Solar Cell
CIGS	Copper Indium Gallium Selenide
LASER	Light Amplification by Stimulated Emission of Radiation
ALPHA	Arbitrarily Large Phased Array
RLV	Reusable Launch Vehicle
HAP	Hybrid Access Point
OMEGA	Orb-shape Membrane Energy Gathering Array
CPTS	Capacitive Power Transfer System
CMRS	Coupled Magnetic Resonance System
ORNL	Oak Ridge National Laboratory
ICNIRP	International Commission on Non-Ionizing Radiation Protection
GEM	Global Electric Motorcar
OLEV	Online Electric Vehicles
MOD	Metal Object Detection
GEO	geosynchronous orbit
LEO	low earth orbit
MEO	medium earth orbit
EMR	Electronic Medical Record
JAXA	Japan Aerospace Exploration Agency
FY	Fiscal Year
MV	Mega Volt

manufacturers all around the world, are now looking into the possibilities of wireless charging technology.

The objective of this study is to investigate the applications of WPT in renewable energy and discuss about the latest development in this field. The concept and history of WPT and the problems related to solar energy are discussed. In addition, this paper provides an insight on various wireless power technologies and its characteristics are discussed. At the end of this study, the issues related to wireless power technologies are discussed. This paper provides an overview of the researches performed on WPT, which can help the researchers to detect significant gaps in the present approaches, as well as promising research directions. To the best of our knowledge, there is currently no methodical study providing a broad view about what has been investigated so far and what are the open concerns about this field.

Therefore in this paper, the investigation has been carried out for the WPT on Renewable energy. The paper is organized as follows. Section 2 describes the WPT. History of WPT has been discussed in Section 3. Problems associated with the solar energy have been presented in Section 4. Section 5 presents the Applications of WPT and the Issues with WPT has been discussed in Section 6 and conclusion has been presented in Section 7.

2. WPT

For a better understanding of the of existing WPT technologies, it has been classified on the basis of energy carrying medium. WPT can be classified as radiative and non-radiative.

Radiative power uses EM waves to send power over large distances (Km range). The power emitted from an antenna propagates through a vacuum or air medium. This type of WPT is omnidirectional in nature and thus provides very less efficiency. The other type of technology i.e. non-radiative WPT is applicable for short to medium range energy transfer. It is based on the principles of Nikola Tesla which uses either near-field inductive coupling or magnetic resonant coupling mechanism. As compared to two coils used in inductive coupling, Resonance-based WPT uses four coils. Use of four coils allows WPT for longer distances and improves quality factor coils. Thus the effects of low coupling coefficient between primary and secondary coil are reduced, and the efficiency of the system is improved. The efficiency profile is relatively is less sensitive to changes in distance. A four-coil energy transfer system can be optimized to provide maximum efficiency at a given operating distance. To further improve power transfer capability, inductive and resonant couplings are simultaneously used which reduces the leakage inductance.

After a thorough literature survey, the forecast on WPT has been carried out up to 2022. Major application of WPT is in consumer electronics goods such as laptops, tablets and smartphones. The major application of WPT is in solar power satellites. WPT is also used in fuel-free aircrafts, fuel-free electric automobiles, robots and fuel-free rockets.

The key drivers for the market area huge demand by the battery functioned devices globally and decrease in high tension on Head Cables. Market is anticipated to display a double digit growth rate in five years (2017–2022). The progression is majorly determined by need of technical advancement and new wireless power transmission applications such as solar-power satellites.

The inductive technology taken the major share of the wireless power transmission market. But, the magnetic resonance has a good benefit over the inductive technology as it provides long range power and multiple devices charging capabilities. Along with these technologies, far-field technologies such as microwave (RF) and laser/infrared-based power transmission would anticipate to transform the market for wireless power transmission in the near future. Microwave (RF) and laser/infrared-based power transmission is at the promising research and enlargement stage and anticipated to be commercialized in the next one or two years. The inductive technology is in the development stage, while the magnetic resonate technology is in the introductory phase. Still, the market for both is expected to grow in the future. The wireless power transmission technology market was valued at 2.50 billion in 2016, and it is estimated to grow at a Compound Annual Growth Rate (CAGR) of 23.15% between 2017 and 2022.

3. History of WPT

HC Oersted in 1819 discovered that electricity and magnetism are interrelated. This discovery is regarded as a milestone in the development of WPT. After this Amperes law in 1820, Biot Savart law in 1820 faradays law 1831 contributed towards a better understanding of electricity and magnetism as well as their mutual effects. In 1873 J C Maxwell unified the laws of electricity and magnetism and predicted the transport of energy through vacuum via electromagnetic waves. In 1884, John H. Poynting quantified the electromagnetic energy using