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Inductive Energy Harvesting for Monitoring Devices in Power Grid

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***Abstract*— Power grid is a network that delivers electricity from generating station to consumers. Grid efficiency and reliability can be increased by implementing real time monitoring of high voltage devices and transmission line. It helps in fault detection and hence avoids cascading failure initiated by a single fault. Real time monitoring is provided by low cost devices such as wireless sensor nodes. Wireless sensor nodes are battery operated devices and replacing theses batteries is one of the major drawback of it. These monitoring devices can be made self sustainable by harvesting varying magnetic field around high voltage devices and overhead transmission line. The amount of energy harvested by magnetic field harvester depends on magnetic core, field intensity, de-magnetization effect, and distance between harvester and magnetic field. This paper provides an overview of different magnetic field harvesting techniques employed in power grid.

***Keywords*—** Wireless sensor node, Smart grid, magnetic field harvesters, real time monitoring.

I. INTRODUCTION

Electric grid is a network of transmission lines, substations and distribution systems that delivers power from producer to consumers. Existing power grids are overstressed and burdened to meet ever increasing energy demand and they lack effective communications, monitoring and fault diagnostics. Power grid now provides unidirectional power flow and hence cannot identify fault in real time which results in power loss [1]. Hence real time monitoring is implemented on high voltage transmission lines, transformers and relays to ensure reliable power transmission to customers [2]. These power grids are distributed over wide geographical areas and monitoring them proves to be a challenging task. Hence monitoring of high voltage devices can be implemented using wireless sensor nodes as they are low cost and can continuously sense and transmit the data to control centre from diverse environment.

Wireless sensor nodes are battery powered devices and needs replacement regularly. Replacing the battery in the high power environment involves high risk and it is a time consuming task. In order to reduce maintenance work and to overcome replacement of battery, energy harvesting technique can be implemented. Energy harvesting is a process of scavenging residual energy and make sensors self sustainable. In power grid applications varying magnetic field is major source of energy along with electric field. Varying magnetic field is independent of environmental conditions and hence can be used as continuous source of energy. There are two types of magnetic field harvesting system in general.

i) Cable clamped energy harvesting system.
ii) Free standing magnetic field harvester [3].

Cable clamped energy harvesting device encloses current carrying conductors as shown in figure1 [4]. As the iron core encloses the power line, power density is relatively high.

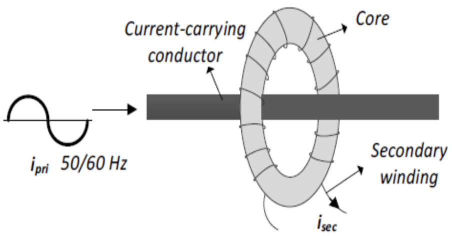

Figure1. Enclosed magnetic field harvester

Free standing energy harvesting device can be placed anywhere near the varying magnetic field. This provides greater flexibility compared to cable clamped harvesting device [3]. As it does not enclose current carrying conductors it prevents them from line sagging as shown in below figure2. [3]

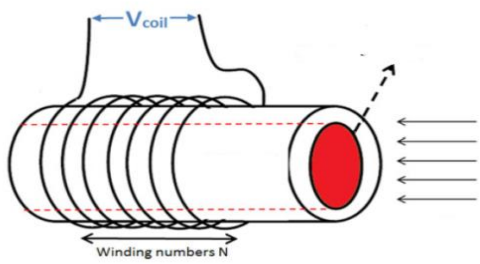

Figure2. Non-Enclosed magnetic field harvester

This paper provides the review on magnetic field harvesting system and their research challenges.

Section II gives details on clamped magnetic field harvesting systems. Section III deals with Free standing magnetic field harvesting system.

II. CABLE CLAMPED MAGNETIC FIELD HARVESTING SYSTEM

Following papers gives the review on clamped magnetic field harvesting system

Yuan Zhuang et al.[5] propose magnetic field harvesting which is clamped to overhead power lines. The paper addresses the issue of reduction in harvested energy due magnetic saturation in the core. To address this issue counter magnetic field is introduced using a control coil. Control coil harvests the energy required to generate the counter magnetic field and is stored in power management circuit. The harvested energy from the control coil is given as negative feedback to the harvester which produces counter magnetic field. The counter magnetic field reduces the overall magnetic flux and hence avoids core saturation. The paper proposes idea of implementing control coil to increases the harvested energy by 45%. The energy harvested by the harvester with control coil is 283mW.

Zheng Jun et al.[6] propose a technique to efficiently transfer the harvested energy to load by implementing adaptive power management circuit. Analogue control circuit and energy aware interface are the two main subsystems of power management circuit. Analogue control circuit provides efficient power transfer from harvester to storage device and energy aware interface provides maximum power transfer between storage device and load. The adaptive power management circuit has efficiency of 76.18% in transferring harvested energy to storage device. And has 96% efficiency in transferring energy from storage device to load.

The harvester used is piezoelectric which is excited by applying mechanical strain. And the harvester is made of low power consumption elements and hence it also self start without any external power. The proposed power management circuit can also be applied to magnetic field harvester.

Wei Wang et al.[7] proposes a magnetic field harvesting system. The harvesting device is clamped to the 110kV high voltage transmission line. It provides technique to transfer the harvested energy wirelessly to the load. According the study if the distance between transmitter and receiver is 1.1m the transmission efficiency is 10% to 20%.The proposed system delivers 20W to the load. The transmitted energy is received using a coil which is connected to wind generator. The wind generator rotates the receiving coil to increase the coverage area and also provides additional energy to the system. The proposed harvester is hybrid energy harvesting system as it consists of inductive energy harvesting and wind energy harvesting.

Y. Zhuang C et al.[8] propose a technique to reduce core saturation duration in magnetic field harvesting system. Due to the reduction in core saturation time the harvested power level is increased by 27%. This can be implemented by adding switch in parallel to the harvesting coil. The switch is closed when the core gets saturated. As the switch short circuits the magnetic core for short duration, magnetic flux density in the core falls below the saturation. Switch is open until the next saturation level. By adding switch the harvested power to the load is 792mW

Cable clamped harvesters generate more energy compared to free standing harvesters as they are very close to varying magnetic field. But the major drawbacks of cable clamped harvesters are core saturation and maintenance risk. Clamped harvesters also introduce line sag on the transmission line.

III. FREE STANDING MAGNETIC FIELD HARVESTING SYSTEM

Following papers discusses on non-clamped magnetic field harvesting system

Sheng Yuan et al.[3] propose a technique to design a core magnetic field harvester. Here the harvesters do not enclose current carrying conductors. The core is designed to improve path provided for the magnetic flux density and thereby increases the harvested power. The paper proposes ferromagnetic helical core. The experiment shows that with the above design the harvested energy is increased by four times compared to previous work. The proposed core can harvest 9.8 μW/cm3 if the coil has 2000 turns.

Awab A. Ali et al. [9] propose magnetic field harvester and support multiple sensor scenarios. The harvester placed under overhead transmission line with voltage of 375kV and 707A of current in it. The harvester are placed 2m away from the line. The paper also gives the relationship between the amount of energy harvested and change in current.
The energy harvested from the varying magnetic field is disturbed among sensors using two methods. The first method depends on user decision. User decides how the energy should be distributed among the sensors. The second method deals with energy allocation based on the requirement of the load, their capacity and priorities. The maximum power harvested is .137W.

Free standing harvesters provide greater flexibility compared to clamped harvesters. These harvesters do not enclose the current carrying conductors. But the amount of energy harvested in free standing harvesting is less compared to clamped harvester due to increase in the distance between magnetic coil and varying magnetic field.

IV. CONCLUSION AND FUTURE SCOPE

The above article gives a detailed review on types of magnetic field harvesting techniques and their contribution in making wireless sensor nodes self sustainable. Varying Magnetic field is selected over other energies due to its availability and non-dependency on environmental changes. Magnetic field harvesters face multiple issues like core saturation, low power density, demagnetizing of the core and core losses. If the above issues are addressed, these harvesters can be the source of energy for monitoring devices placed near high voltage equipments and over head transmission lines in the near future.

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Dr. RohiniDeshpande received her Ph. D degree in Electronics and Communication Engg.,fromGuru Gobind Singh Indraprasth University (GGSIPU)New Delhi, M. E degree in Electronics and Communication Engg., from the University of Delhi, with honors and bacholers degree in Electronics and CommunicationEngg., from Gulbarga,Univeristy. She is in academics for the last 32 years and involved in research and teaching UG and PG students. Her major areas of research are Signal Processing, Optical Networks, Mobile Computation etc.She has published more than 36 papers in journals and conferences of good impact factors. She has citation index of 45 and h-index of 3. She has given invited talk in various occasions including many international conferences. She also has administrative experience of around 10 years. She has delivered the responsibilities of head of ECE, IT, CSE and Mechatronics Engineering departments. She has research experience of 12 years and is guiding five scholars for their doctoral degrees. Presently she is professor and HOD designate of ECM department in school of ECE, REVA University, Bengaluru.