ENERGY HARVESTING TECHNOLOGY APPLICABLE TO DISTRIBUTION LINE

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ABSTRACT

To ensure stable power supply and prevent faults, protective devices and IoT sensors for status monitoring are installed in the distribution line. These devices are powered by batteries and external power sources. There is an energy source that can be harvested in various fields such as electric wire which constant current flows, vibration of a transformer, pressure of a manhole, etc. Distribution lines composed of a working or an underground. We will examine various methods and R & D cases for high-quality power supply by installing the harvesting device to harvest waste energy.

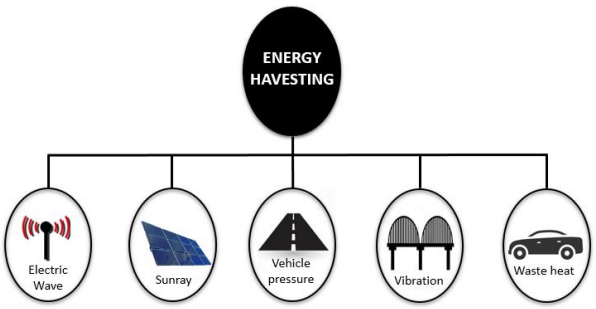
INTRODUCTION

With the advancement of various IT technologies, power is required for almost every things used in everyday life, and the power quality level required by electric power consumers is getting higher day by day. In order to meet the increasing demand of consumers, the number of automation devices such as Switchgear and Recloser installed in distribution system, various communication devices such as RTU, DCU, and advanced IoT sensors are increasing more and more, The energy used by these devices is also negligible. Furthermore, most of these devices are powered by batteries, which means that the device cannot function when the battery is defective, such as discharge or aging.
In this paper, we propose a solution to solve the problem of power supply to various devices of the distribution system which is increasing in quantity.

MAIN CONTENTS

1. Types of energy harvesting

Energy harvesting technology is a technology to reproduce energy by harvesting or using abandoned energy. It is not only converting natural energy such as wind, water, heat, sun into electric energy, but also human step, vibration due to vibration of transformer Energy, and other sources of energy.



[Fig1. Energy Harvesting]

The energy flow of energy harvesting can be divided into energy generation, energy conversion, energy storage and energy consumption.

Energy generation	Physical / Vibration / Heat / Gravity / Positon / Light / Electromagnetic Energy
Energy conversion	○ Piezoelectric : Utilizing piezoelectric elements by vibration or pressure ○ Thermoelectric : Utilizing residual heat or waste heat of human body and machine ○ Photoelectricity : Convert light energy into electricity ○ Electromagnetism : Collect electromagnetic waves and convert them into electricity
Energy storage	Batteries with elements capable of accumulating and preserving energy and with little leakage of electricity
Energy consumption	Devices that consume energy produced by energy generation / conversion / storage

[Fig2. Harvesting's energy flow]

In this paper, we will only deal with the following techniques of harvesting that can be linked to distribution lines in various energy harvesting.
① Piezoelectric energy harvesting: The mechanical energy is applied to the outside to affect the dielectric properties of the piezoelectric element, and the generated voltage is used as an energy source.
② Magnetic energy harvesting: When a current flows in a conductor, a magnetic field is generated around the conductor, and a coil can be installed around the conductor to produce electric power by a magnetic field.
③ Harvesting using a magnetostrictive element: It generates electrical energy through a magnetic field generated by a transmission line, a subway, a transformer, or the like by combining a metal material that grows or shrinks due to a minute magnetic field change and a piezoelectric material that generates electrical energy when deformation occurs

2. Characteristics of distribution line and prevention of failure

2.1 Features of Distribution Line

Distribution lines supply power to widely dispersed customers, so the loads are scattered sporadically and the facilities are also diverse.

In addition, the transformer, switchgear and other equipment are attached to the support to supply a small amount of power. In addition, electrical failures occur frequently and sporadically due to external exposure of supports, various types of loads such as general houses, shopping malls, large capacity factories, and various electric works. The causes of the failure are various such as equipment failure, vehicle collision, excavation, bird contact, and tree contact. In order to provide a stable power supply, there is a need for an optimal fault prevention method in consideration of these factors, and a technique for quickly recovering the fault if failure can not be prevented.

2.2 Prevention of Power Failure

Recently, researches using IoT sensing technology have been actively carried out to prevent power outage in distribution lines. A technology for monitoring and remotely monitoring the state (heat, vibration, contact, temperature, etc.) of a power facility through a sensor is being continuously studied.

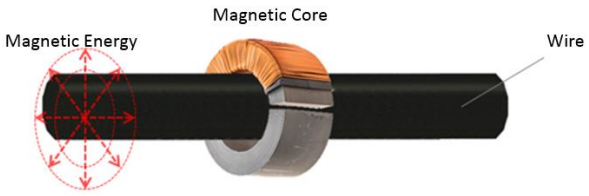
In order to prevent power outages or recover power outages, an external power source (transformer) is used to operate these devices, or a battery is used to operate various devices such as switchgear, recloser and other communication devices such as RTU and DCU have. However, in case of battery discharge, obsolescence, battery failure, or external power supply (transformer failure), it is necessary to take countermeasures against the problem that the protective devices are not functioned properly.

3. Harvesting using magnetic development

3.1 Harvesting using magnetic fields

It is possible to utilize extra high voltage current flowing in the processing power line to supply the protection device such as switchgear, recloser, or IoT sensor.

A constant current flows through the distribution line, and a magnetic field is generated on the line. Therefore, a coil or the like can be installed around the conductor to generate electric power using a magnetic field.

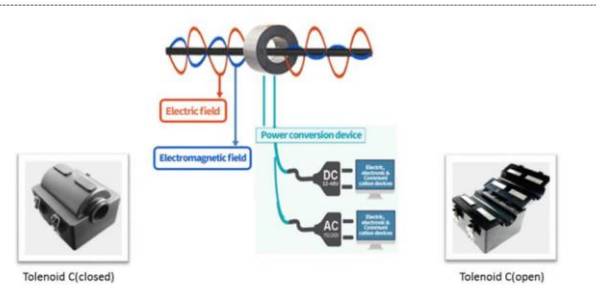


[Fig3. Generate electrical energy from magnetic fields]

The following technologies were developed as a result of this research.

① Non-contact power supply unit Tolenoid C (Ferraris power)

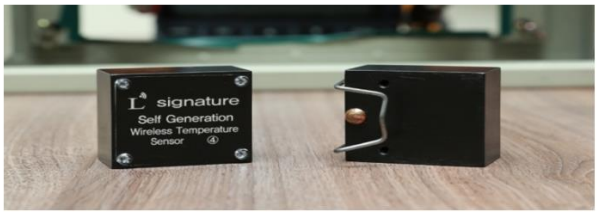
It is a device that induces a magnetic field of a wire to convert it into electric energy and supplies electric power to the electronic device (passive way magnetic induction method). The core is a magnetic field induction technology and it is attached to a power line without power line change or other facilities. Since it is a non-contact type that can be detachable, it is convenient to replace before.



[Fig4. High efficiency wireless charging and noncontact power supply]

② Non-power wireless temperature diagnosis technology for electric power equipment

The Korea Electrotechnology Research Institute (KIER) has more advantages such as semi-permanent use through magnetic energy harvesting, real-time temperature monitoring using 2.4GHz wireless communication, and a highly elastic clamp structure that can be easily attached and detached. And it is not necessary to replace the battery because the leakage magnetic field generated around the conductors or wires of the switchgear is collected through the 'integrated magnetic energy harvesting' coil and used as the driving power for the temperature sensor and the radio transmitter.



[Fig5. Self-generated powerless wireless temperature for power equipment]

③ Harvesting to convert magnetic field noise into energy
The Korea Institute of Machinery & Materials has developed magnetic field energy harvesting composites and power generation materials that can convert magnetic field noise into electrical energy.

In general, there are magnetic field noises of less than 10G (Gauss) with a frequency of 60Hz in transmission lines, subways, high-speed railways, factory machines, etc. The team has developed a smart composite material that converts such fine magnetic noise into electrical energy. Using this, we succeeded in producing energy harvesting device and driving wireless sensor network without external power source separately.

This new concept of compact energy harvesting device vibrates when a small magnetic field change is detected. This vibration is transmitted to the piezoelectric material, and the change of the magnetic field is converted into electric energy. The generated power can turn on dozens of LEDs or drive the wireless sensor.

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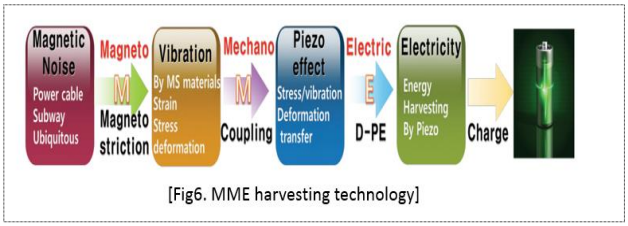
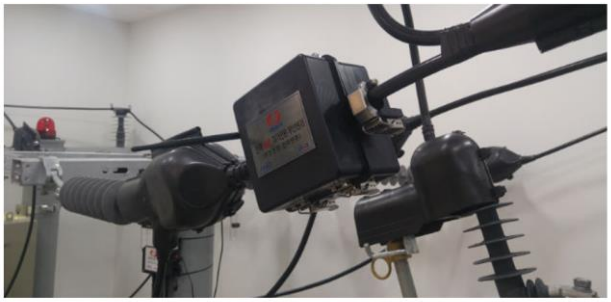


[Fig6. MME harvesting technology]

④ Energy harvesting power supply for IoT wireless sensor
The Korea Electric Power Research Institute (KEPCO) has developed a wireless sensor for the internet for managing distribution facilities and a device capable of supplying power without using an external power line or a battery.
The energy harvesting power supply for IoT wireless sensor converts the electric field generated from the distribution wire to electric power and supplies it to the IoT sensor to remove the battery of the IoT sensor and increase the wireless communication distance with sufficient power supply, Can be enlarged.

Like the current transformer, it uses the flowing current in the distribution wire and uses the principle of producing the electric power required for the IoT wireless sensor, and it is directly installed in the distribution wire by applying the penetration type, vibration, waterproof and dustproof design.

It is designed to supply power of 5W and 30W capacity from the electric current of distribution line which varies up to 250 amperes depending on the power consumption of the consumer connected to the distribution line, and it is possible to supply power required by IoT equipment such as wireless sensor and communication gateway.



[Fig7. Energy harvesting power supply for IoT wireless sensor]

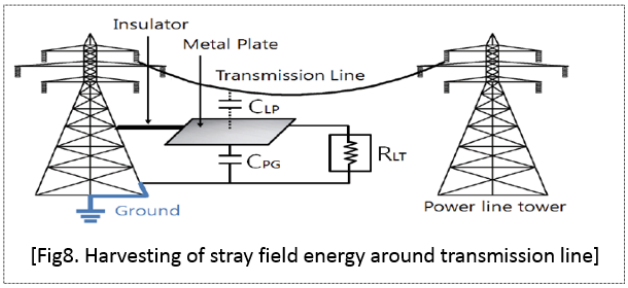
3.2 Stray Field Energy Harvesting Technology

The magnetic field energy harvesting technology is a technology to operate the wireless sensor module by collecting the magnetic field energy generated when the electric current flows in the transmission line. However, when the electric current flowing through the transmission line is not constant and the electric current does not flow extremely. There is a disadvantage that the wireless sensor module cannot be operated.

However, unlike conventional environmental energy, stray field energy harvesting has the advantage of constantly collecting energy when voltage is applied to the transmission line. That is, the transmission line surveillance system can be operated stably unless the transmission line is cut off or the power supply is interrupted.

In the analysis of stray field energy harvesting for transmission line monitoring, stray field energy is collected using the stray capacitance generated between the metal plate and the transmission line after the metal plate is installed in the transmission tower so that stray field energy is collected without direct contact with the transmission line Is expected.

According to the results of the study, when the voltage of the transmission line is 765kV and 345kV, the power delivered to the load is 38.7W and 37.4W respectively. For 154kV, the maximum voltage is 13.2V and the output is 8.62W. Therefore, it is necessary to design the area of the metal plate, the winding ratio of the transformer, etc. in order to obtain the required output.



[Fig8. Harvesting of stray field energy around transmission line]

4. Piezoelectric energy harvesting

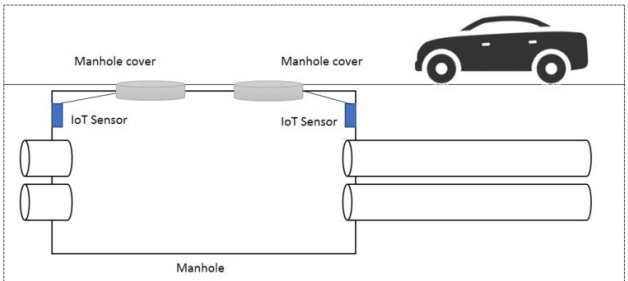
4.1 Technical Overview

Since the discovery of piezoelectric effects by Jacques Curie and Pierre Curie in 1880, commercialization has progressed through research and development of devices and process technologies. Recently, the use of flexible materials, such as micro fiber composites, Research and development are being actively pursued. Piezoelectric energy receives external mechanical energy and affects the dielectric properties of the piezoelectric element, so that the generated voltage is used as an energy source. The quality factor of PZT, PVFD, and Quick Pack are the most important factors for the piezoelectric element. The higher the quality factor, the more energy is generated. In the case of MFC (micro fiber composite) can be generated by energy.

4.2 Piezoelectric Harvesting in a Distribution Line

The method of using piezo-electric energy in a distribution line can see energy by direct pressure or vibration. Direct pressure can be applied to manholes exposed to roads or sidewalks, and in the case of vibrations, energy can be harvested through the vibration of the working / underground transformer.

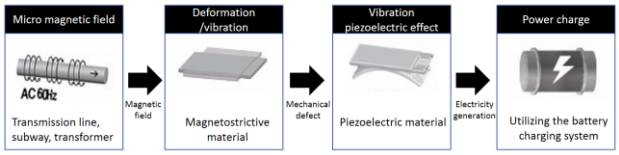
A schematic diagram of the technique for energy harvesting through manhole pressure is given below.



[Fig9. IoT Sensor and Harvesting for underground facilities]

4.3 Harvesting using a magnetostrictive device

It is possible to harvest energy directly through magnetic energy, but if it is deformed due to a slight change in magnetic field, a piezoelectric material that generates electric energy can be combined to produce electricity through a magnetic field generated by power lines, subways, and transformers.



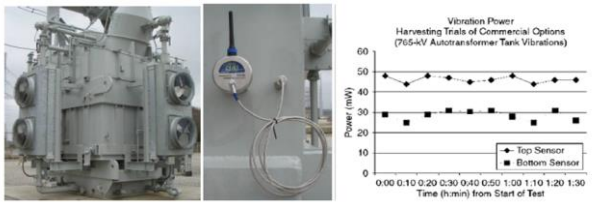
[Fig10. Concept of magnetic field electrical energy transformation]

4.4 Vibrational Energy Harvesting

Power equipment uses a transformer to boost / lower voltage. Transformers are used for underground lines as well as for machining lines. Vibrations occur due to the nature of the transformer, and vibration energy can be converted to electrical energy through piezoelectric elements.

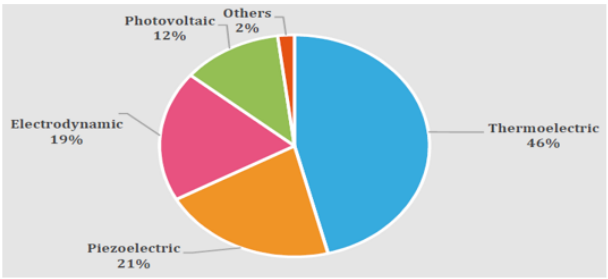
An example of this is as follows.

Figure 11 shows the available energy sample vibration profiles collected from a vibrating harvesting device and a 765kV-class autotransformer for about 2 hours. EPRI published a report in 2011 on EPRI's Power Harvesting for Sensors in Electric Power Utility Applications, Information is used to develop power harvesting sensors for transformers.



[Fig11. Vibrating harvesting module and harvested power graph]

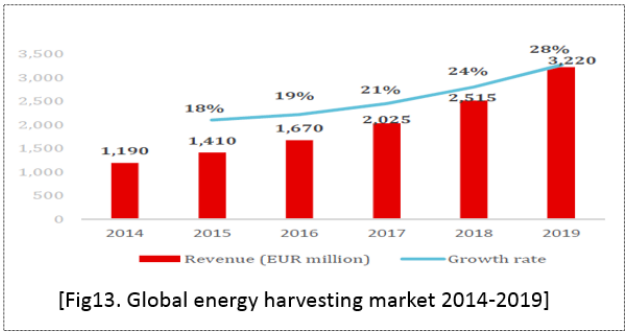
5. Energy Harvesting Market Trends



[Fig12. Global energy harvesting market by technology, 2014]

As of 2014, Thermoelectric has the largest market share of 46%, followed by Piezoelectric (21%), Electrodynamic (19%), Photovoltaic (12%) and others 2% of the total.

The market share of energy harvesting technology using magnetic fields is expected to be included in other fields, and overall market formation seems not to be significant.



[Fig13. Global energy harvesting market 2014-2019]

The global energy harvesting market is estimated to be EUR 1.2 billion in 2014 and several studies by the Energy Harvesting Journal or Winter Green Research show that by 2020 it will reach EUR 2.66 billion (EUR 2.63 billion) Respectively.

In 2015, Technovia Insights expects the energy harvesting market to reach 3.24 billion euros (EUR 3.24 billion) by 2019.

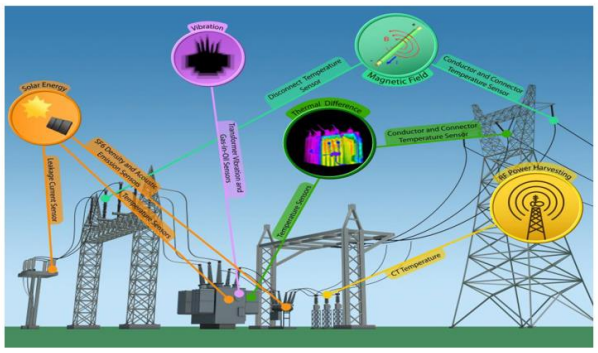
Looking at the energy harvesting market, it is expected to grow to 21.9% between 2015 and 2019, and to 28% by 2019.

CONCLUSION

Energy harvesting research is becoming more and more active. However, most of the techniques are based on piezoelectric and thermoelectric materials. Harvesting using magnetic phenomena is poorly performed in the market, patent, and dissertation despite its high utilization potential.

The problem with this is that the current flowing in the power line can vary depending on the size of the load and the thickness is not the same. Since the strength of the magnetic field is larger and closer to the near distance, further development such as applying the harvesting device differently according to the thickness of the wire is necessary.

In addition, there is a need to utilize harvesting technology in distribution lines through additional research and development such as application of backup devices such as batteries for low current or overcurrent, or parallel operation with other harvesting power supplies.



[Fig14. Energy harvesting of IoT sensor applied to Electrical equipment]

REFERENCES

[1] 2011, Power Harvesting for Sensors in Electric Power Utility Application, EPRI,

[2] 2017, Energy harvesting to power the rise of the Internet of Thing, Article

[3] SungMin Gong, 2014,"Analysis of stray electric field energy harvesting for transmission line monitoring", The Korean Institute of Electrical Engineers, p1219

[4] http://ferrarispower.co.kr, website

[5] http://news.hankyung.com/article/2015061746301, Article

[6] http://www.todayenergy.kr/news/articleView.html?idxno=209546, Article