Vol. 14. No. 01, Januari 2023: 52-55
http://publikasi.mercubuana.ac.id/index.php/jte
p-ISSN: 2086-9479 e-ISSN: 2621-8534

Soil Energy Harvester for Batteryless Wireless Sensor Network Node using Redox Method

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***Abstract*—The Wireless Sensor Network technologies has great advantage that provide us with cheap solution to deal with telecommunication infrastructure problem that don't exist in extreme and isolated area. However, the biggest problem exist within wireless sensor network was WSN node limited power. In this paper we try to provide battery less power sources for Wireless Sensor Network Node using Redox method. Using 9 combinations of electrodes circuits, it can provide 6.53 volt and turn on Arduino Mini Pro microcontroller. However, the second it turns on Arduino Mini Pro the voltage drops to 1.73 Volts. Hence this energy harvester can provide power to the Arduino Mini Pro microcontroller with unstable power supply.**

***Keywords*—Wireless Sensor Network, Battery less, Redox, soil energy harvester.**

DOI: 10.22441/jte.2023.v14i1.009

I. INTRODUCTION

The WSN or Wireless Sensor Network has been classified as the next generation network in 2010 by International Telecom Union [1]. This WSN contains wireless sensor nodes that interconnect with each other. The nodes also transmit and receive sensed data from other nodes in the network, using wireless technologies such as LoRa [2], ZigBee [3], and many others [4]. The WSN are using node to node communication (ad hoc network), therefore the WSN doesn't need an existing and a costly telecommunication infrastructure network just to send data measurement from each monitoring node to gateway before forwarding those monitoring data to the internet server. Because of this the WSN has a great advantage such as very low cost for network deployment and for operation [5]. Although the Wireless Sensor Network has this advantage, the main problem of Wireless Sensor Network still exists, which is limited power problem that caused by small battery capacity.

Wireless sensor networks are used in remote and isolated areas and make it very difficult to reach. Those remote and isolated area also means there were none existing telecommunication and power infrastructures. This make deployment of wireless sensor networks was very challenging. Thus, in areas where no power source available, an alternative power source or renewable energy sources other than batteries are needed to enhance WSN node lifetime. In this paper we would like to propose prototype for soil energy harvesting to be use for WSN node.

II. LITERATURE REVIEW

There are several researchers that propose soil energy harvester. Prasad [6] and Mulyadi [7] are using microbe to build bio electrochemical device that generates direct current. Another researcher such as Huang et al [8] and Pulwitt et al are using soil temperature difference in order to generate electricity using thermoelectric generator. However, if we compare their methods and its result, the electrochemical method provides more generate power compared with thermoelectric generator. The electrochemical are capable to provide 14 mW power compared with thermoelectric generator with just only 3.7 mW power. Therefore, in this paper we would like to propose prototype for soil energy harvesting to be use for WSN node using electrochemical method.

III. METHOD AND MATERIAL

A. Method

Ying and Dayou stated that hypothetically, energy harvester-based plant was based on redox electrochemistry method [9]. Redox is a chemical reaction that happens because electrons transfer between chemical elements [10]. There are 2 types of redox reaction, a reducing agent that donates electrons, and an oxidizing agent that gains or accepts electrons [11]. For redox method work, we need to use 2 different types of electrodes. On both electrodes an electro chemical reaction takes place. Ion molecules (such as water vapor) will be distorted in the electrodes surface, causing electrons to be released from the electrodes surface. This event is causing potential differences for both electrodes. Therefore, a conductive path the electrons need to be establishing to flown out electron, causing electrical current [12]. The total potential cell for redox chemical reaction would be:

$$E^o \text{ cell} = E^o \text{ Reduction} + E^o \text{ Oxidation} \quad (1)$$

B. Electrodes

The material that will be used in this research was an electrode that works as an energy harvester. Ying and Dayou in their research are used as an zinc and copper electrodes to generate electricity [9].

Figure 1. Electrode that use in this research. (left) Copper and (right) Zinc

C. *Microcontroller Arduino Mini Pro*

The microcontroller for energy harvester works as validation or to see whether this energy harvester can be used for wireless sensor network application. To do validation we propose to use Arduino Mini Pro that based on microcontroller ATMEGA328P. It has low power consumption, processor clock speed 8 MHz, and deep sleep feature [13] making it popular for fast prototyping wireless sensor network nodal [14].

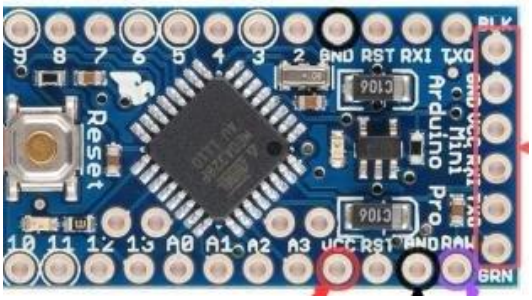

Figure 2. Microcontroller Arduino Mini Pro [15].

IV. Result and Analysis

A. *Measurement on Dry Soil*

We are doing data collection that will be measure power harvested with dry soil as we can see from table 1.

Table 1. Measurement Result on dry soil

Soil Measurement				
No. Pot	Time Measurement (Minute)			
	0		40	
	mV	mA	mV	mA
Pot 1	734	0,91	744	0,77
Pot 2	643	0,78	720	0,56
Pot 3	637	1,08	686	0,73
Pot 4	719	1,42	740	0,77
Pot 5	645	1,45	734	0,87
Pot 6	701	1,01	767	0,79
Pot 7	749	0,82	790	0,61
Pot 8	636	1,14	712	0,82
Pot 9	721	1,21	763	0,5

B. *Series and Paralel Power Generate Electrode on soil*

Based on measurement on table 1, the single pair or electrodes cannot supply the energy needed for microcontroller to operate. Therefore, to be able to operate Arduino Mini Pro microcontroller we need an array of zinc and copper electrodes to raise the electricity in terms of voltage and current. To do this we propose to do series and parallel zinc and copper electrodes.

In this experiment we will conduct a series circuit on a pot embedded with copper and zinc electrodes with a wet soil condition using mineral water. Where it is expected that the output voltage from the electrode will be able to rise. The following is a schematic of the series circuit on the electrode.

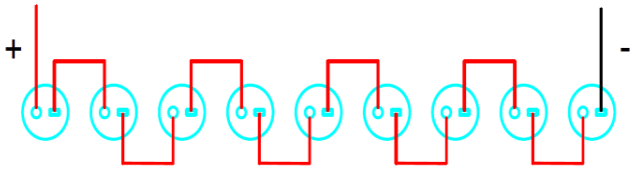

Figure 3. Series schematic.

Table 2. Series Measurement Result

Schematic	Volt (V)	Current (mA)
1 Series	0,87	1,12
2 Series	1,52	1,24
3 Series	2,38	1,2
4 Series	3,01	1,35
5 Series	3,76	1,22
6 Series	4,45	1,33
7 Series	5,16	1,32
8 Series	5,75	1,22
9 Series	6,53	1,13

In this experiment we will conduct a parallel circuit on a pot embedded with copper and zinc electrodes with a wet soil condition using mineral water. Where it is expected that the output current from the electrode will be able to rise. The following is a schematic of the parallel circuit on the electrode.

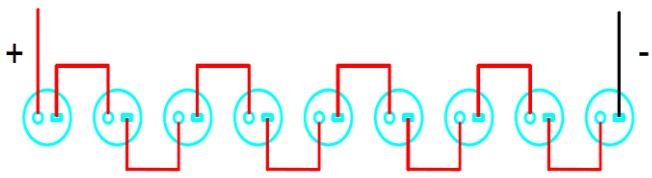

Figure 4. Parallel schematic.

Table 3. Parallel Measurement Result

Schematic	Volt (V)	Current (mA)
1 parallel	0,87	1,13
2 parallel	0,76	1,88
3 parallel	0,8	2,6
4 parallel	0,73	3,6
5 parallel	0,74	4,26
6 parallel	0,73	4,85
7 parallel	0,71	5,3
8 parallel	0,7	5,85
9 parallel	0,7	6,3

C. Power Generate Effect on Microcontroller

Based on table 2 and 3 we can see that the most promising energy harvester candidate in array of electrodes would be in series configuration. With this in mind, we would like to connect 9 series of electrodes energy harvester with Arduino Mini Pro microcontroller. According to the datasheet ATMEGA328P the microcontroller needs 1.8 Volt with 0.2 mA electricity to be able to operate [13]. This configuration theoretically can turn on Arduino Mini Pro successfully. After we connect Arduino Mini Pro with 9 series of electrodes energy harvester, Arduino Mini Pro can successfully turn on. However, after we connect the Arduino Mini Pro with 9 series of electrodes energy harvester, Arduino Mini Pro indicator light was dim. This was indicator that there are lacks power generation from 9 series of electrodes energy harvester. To validate this, we do measurement and found out that the output voltage of the power supply drops from 6.53 Volts to 1.73 Volts.

Figure 5. Arduino Mini Pro connect with energy harvester

V. CONCLUSION

In this paper we try to provide an alternate power supply using soil energy harvester. Measurement was done using copper and zinc electrodes with several conditions and producing different voltages and electric currents. On dry soil conditions it can produce an average voltage of 743.9 mV and an average electric current of 1.62 mA. To increase power, we are experimenting with 9 combinations of zinc and copper electrodes circuits connected to the Arduino Mini Pro. Using 9 series of zinc and copper electrodes, we successfully turn on Arduino Mini Pro but with dim indicator light. The 9 series of zinc and copper electrodes produce output voltage at 6.31 Volts and after being connected to the Arduino Mini Pro it drops to 1.73 Volts. This energy harvester configuration has been proved can provides power to the Arduino Mini Pro microcontroller. However, for a practical application and for a stable power supply including other functions in Wireless Sensor Node, it needs more array zinc and copper electrodes combine with boost converter that equip with super capacitor.

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