Using a stepper motor as a low-power, low-rotation DC generator for renewable energy harvesting

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Abstract. Currently, the need for renewable energy is getting bigger; studying renewable energy generation requires a small-scale or miniature generator with a low rotation that can produce power for lamp loads. The selection of generators is not as appropriate as using DC motors with high rpm, as generators still produce a small voltage (<12V) and a small current. The use of DC motors equipped with gears requires a large torque to rotate the rotor. The solution offered to overcome this problem is the use of stepper motors as a DC generator with low rotation. The stepper motor has a multi-pole coil and permanent magnet that qualify it as a generator. This study uses the nema23 stepper motor as a DC generator. The stepper motor used is a 6-wire stepper motor (two pairs of coils), a half-wave rectifier, and a capacitor to buffer the voltage. The load is a 12VDC lamp. The results obtained indicate that the stepper motor generator can turn on the lights with a manual hand rotation.

1 Introduction

The need for renewable energy in Indonesia is increasing along with the increasing population and increasing energy consumption. Indonesia has great potential for renewable energy, such as solar, hydro, wind, geothermal, and bioenergy. However, the level of utilization of renewable energy in Indonesia is still low, including in Yogyakarta, which only reached 5 percent of the total energy demand in 2018 [1]. One of the problems in learning about renewable energy is the selection of generators. Generators that are widely used in renewable energy research are DC motors. DC motors can be used as generators because of the voltage-regenerative principle. One of the drawbacks of DC motors without gear reduction is that they require a large rotation to generate voltage.

Research related to renewable energy generators: Lesmana [2] used a bicycle dynamo as a renewable energy generator with a yield of 31V and a speed of 1362 rpm. Ramdany et al. [3] used a modified BLDC as a generator with an output of 855 VA at 1300 rpm. Semenov [4] researched modeling low-speed wind generators using Matlab. The model consists of two sine voltage sources and a full wave rectifier circuit. Kaphungkui [5] studied energy harvesting using stepper motors. The results obtained by a stepper motor without a load can

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produce a voltage of 35V, whereas when a 2k2 resistor is installed, it can produce a current of 10mA. Wargula [6] Wargula [6] studied the dynamic characteristics of stepper motors to find applications for periodic rotation generators.

Another alternative for generating renewable energy is using a stepper motor. Stepper motors can be used as generators because they comply with the principle of regenerative voltage, which has a permanent magnet coil and rotor.

This paper will discuss the use of stepper motors as low-speed generators for renewable energy.

2 2. Experimental methodology

Faraday law for voltage induced as shown in eq. 1.

$$Emf = -\frac{d\Phi}{dt} \quad (1)$$

Where emf is an electromotive force in volts, Φ is magnetic flux in Weber.
For a constant coil area and rotating magnetic field, the magnetic flux that occurs is as shown in Eqs. 2 and 3.

$$\Phi \; = BA\,cos(\theta) \quad (2)$$

Where angle θ is a product of angular velocity and time.

$$\Phi \; = BA\,cos(\omega\, t) \quad (3)$$

Eq.1 becomes Eq. 4.

$$Emf = -\frac{dBA\cos(\omega t)}{dt} = A.B.\omega\sin{(\omega t)} \quad (4)$$

Stepper motor experiments as generators of renewable energy require the following equipment: stepper motor, full-wave rectifier circuit, storage capacitor, and load R, as shown in Figs. 1 and 2.

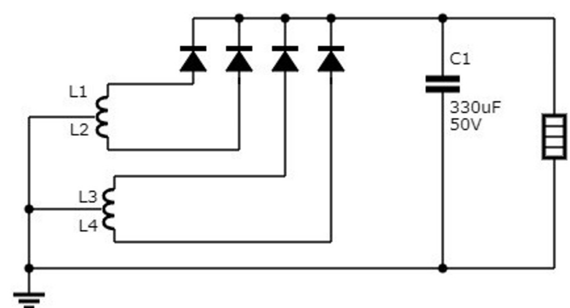

Fig. 1. Motor stepper as DC generator and half-wave rectifier circuit.

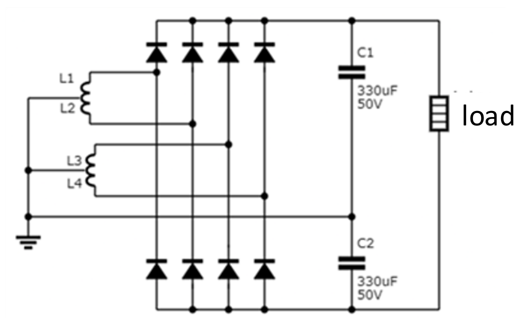

Fig. 2. Motor stepper as DC generator and full-wave rectifier circuit.

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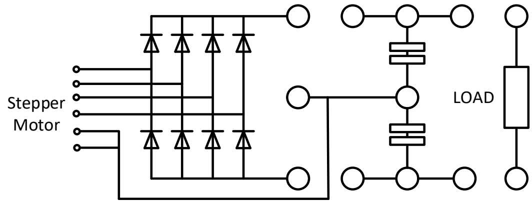

Fig. 3. Layout Motor Stepper as DC generator and full-wave rectifier circuit.

3 Results and discussion

The waveform of one of the stepper motor phases as a generator is shown in the following Fig 4. The waveform at a certain speed will produce a wave that resembles a sine or triangular wave.

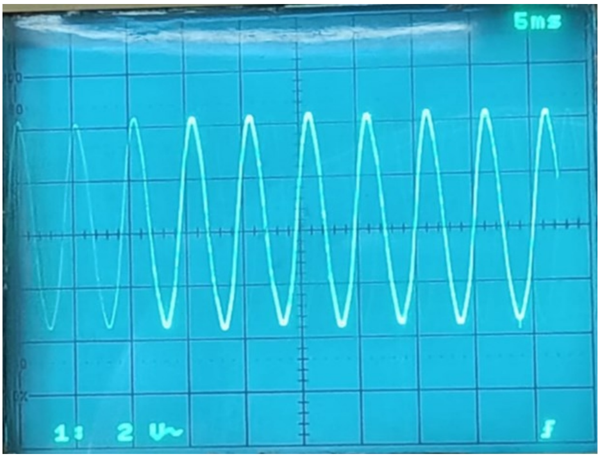

Fig. 4. The stepper motor output waveform as a generator.

Testing the characteristics of the rotating speed of the generator vs. generator voltage is shown in Fig.5 below.

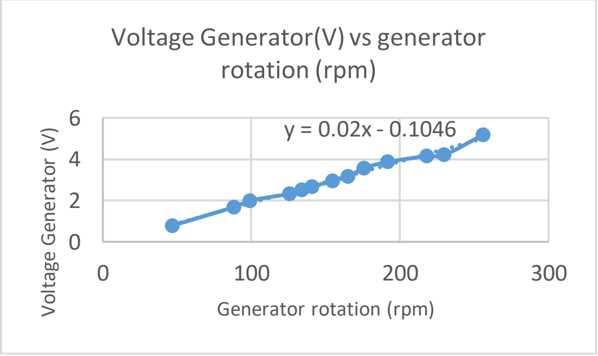

Fig. 5. Generator voltage characteristics and generator speed.

From the graph showing the relationship between generator rotation and generator voltage, the generator voltage emf is directly proportional to the generator rotation according to the following Eq. 5.

$$emf = K\_e \ \omega \tag{5}$$

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Where Ke is the generator constant, Ke = 0.02V/rpm
The generator model equation is shown in the following Eq. 6.

$$GenV = 0.02\,rpm - 0.1046 \tag{6}$$

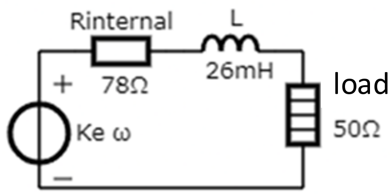

Fig. 6. Motor stepper model.

The value of the inductance and internal resistance of the stepper motor as a generator is shown in Table 3.

Table 3. Internal resistance and induction value

Coil	Internal resistance	Inductance
L1	78,4 Ω	25,6 mH
L2	82,4 Ω	25,6 mH
L3	79,2 Ω	26,3 mH
L4	77,3 Ω	26,4 mH

The time constant of the coil with internal R = 78.4 Ω and L = 25.6 mH is equal to

$$\tau = L/R = 25.6\ mH/78.4\ \Omega = 0.326\ ms$$

The time constant affects the switching speed. The maximum frequency for the coil with a time constant of 0.3 ms is

$$f = \frac{1}{10 \times \tau} = 333\,Hz$$

Rotation testing up to 240 rpm (4 Hz) is necessary for the generator to still work properly.
The output of the stepper motor is in the form of a 4-phase pulse voltage; a rectifier diode is needed to become a DC voltage, and the voltage generated from the rectifier diode has decreased by 2 times the diode voltage.
The following table 3 compares the use of silicon diodes with Schottky diodes.

Table 3. Comparison between silicon diodes and Schottky diodes.

Silicon Diode	Schottky Diode
V diode = 0,6 up to 0,7V	V diode = 0,2 V up to 0,45 V
Recovery time: 30 μs	Recovery time: 50 ns
Suitable for 50-60 Hz rectifiers	Suitable for large switching frequencies

The use of rectifier diodes in stepper motor generators is more suitable for using Schottky diodes because the forward voltage of Schottky diodes is 0.2V to 0.45V compared to silicon

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diodes which reach 0.6V to 0.7V. The rectifier diode will reduce the voltage from the generator by 2 times the diode voltage.

4 Conclusion

Based on the information found, the following conclusions. The stepper motor can be used as a generator to generate electricity. When the stepper motor is rotated mechanically, it will produce an output voltage that can be used as a power source. The constant Ke of the stepper motor, which is 0.02 V/rpm, indicates that each revolution per minute (rpm) made by the stepper motor will produce an output voltage of 0.02 volts. A Schottky diode is used to convert the AC voltage generated by the stepper motor into a usable DC voltage. The Schottky diode was chosen because it has a low forward voltage, so it can reduce the voltage loss in the rectifier circuit.

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