Smart and Economical Scheme for Electrical Power Generation

Ahmed A. Hafez[1], Abed Alrzaq S. Alshqirate[2*], Ahmed Y. Hatata[3], Khaled S. Alharbi[4], Mohammed Alotabi[5], Abdurhman S. Alotabi[6], Khalf M. Alotabi[7], Mohammed A. Almutari[8], Munif S. Almutari[9]

[1,3-9]Elect. Eng. Dept., College of Eng., Shaqra University, Kingdom of Saudi Arabia
[*2]Mech. Eng. Dept., College of Eng., Shaqra University, Kingdom of Saudi Arabia
[*2]Al-Balqa Applied University, Al-Salt, 19117, Jordan

Abstract— *This article advises a simple and innovative scheme for generating electricity from human activities. A simple and robust approach is proposed for converting human walking into valuable electricity source. The proposed scheme could be sufficient for powering small portable devices and providing independent power supply. Matlab and Simulink dynamic platform are used for stimulating the systems under concern. The prototype results validate the simulation results. The proposed scheme proofed to be valuable, economical and reliable power supply*.

Keywords— Pressure, Energy converter, Electricity, Boost converter, Portable.

I. INTRODUCTION

The electricity demand is increasing very rapidly, which requires building more fossil fuel power plants to supply such load. However, fossil fuel plants suffer from numerous drawbacks. They are main source of pollution. Tons of greenhouse gases as CO_2 are released, which causes global warming, desertion and flooding. Moreover, traditional power plants have high running and maintenance costs [1,2]. Furthermore, the limited reserve of fossil fuels motives the search for alternative energy sources.

The researchers are searching for eco-friendly and sustainable power source. Solar and wind energies are investigated. However, the stochastic nature and weather dependency reduce the advantages of these sources. Moreover, wind energy involves complex and costly system for generating electricity [3].

This article proposes a new scheme for generating electricity from human footsteps. A simple and efficient mechanical device is proposed that converts the footstep pressure into energy. An efficient and simple electronic circuit is advised for harvesting the generated power. A prototype was built to test the functionality of the proposed scheme. Matlab and its dynamic platform Simulink are used for stimulating the proposed systems. The practical and simulation results are introduced to validate the proposed generation method.

II. SYSTEM LAYOUT

The proposed system consists of energy converter, generator, diode rectifier, DC boost converter, battery and load as shown in Figure 1.

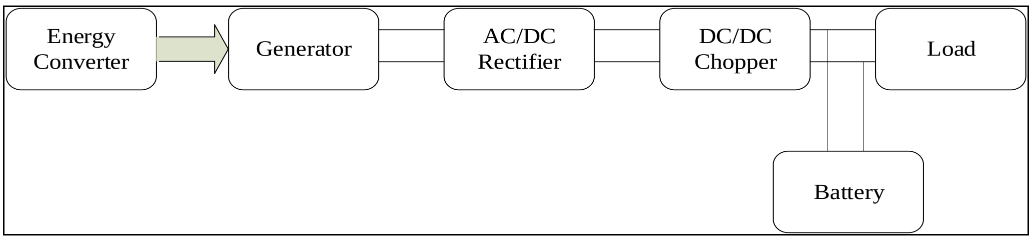

FIGURE 1. Block diagram of the proposed system

The battery is added to the proposed system to store the generated electricity. The power could be supplied to the load directly or stored in the battery depending on the load specification. Then, the battery feeds the load.

2.1. Energy converter

A mechanical device is used to converter the step into a mechanical energy. Figure 2 shows the energy converter. This device is designed to be simple and integrated easily on the structures involving human activities.

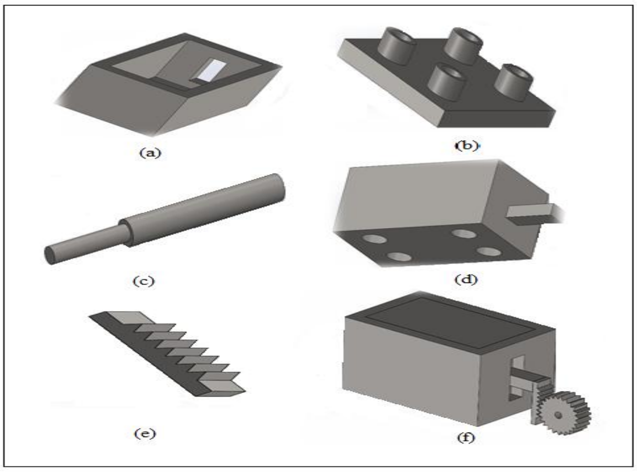

FIGURE 2. The mechanical parts of the designed prime mover

The main parts of the prime mover shown in Figure 2 are:

1. Part (a) is iron box with some holes and installation places inside it.
2. Part (b) is placed in part (a), it contains springs inside each slot to be controlled by the coming down and step surface height.
3. Part (c) is a rotating shaft, where the generator rotor is mounted.
4. Part (d) is installed above part (b) and it is free to move up and down.
5. Part (e) is installed with part (d) and it free to move up and down within part (d).
6. Part (f) is the container, where all the parts are installed.

The pressure on the upper part of the mechanical converter would result in freely up/down movement. The force would be produced due to the pressure, as given by,

$$F = P \times A \tag{1}$$

Where P is the pressure (N/m^2), A(m^2)

This force would produce motion; the linear velocity is related to the force by,

$$v = \frac{1}{m} \int F dt \tag{2}$$

Where, m is the mass of pressed, the output energy is given by

$$w = \frac{F}{m} \int F dt \tag{3}$$

2.2. DC Generator

A Permanent Magnet PMDC generator is used for converting mechanical energy in to electrical energy. This DC generator has simple structure due to existence of permanent field excitation [4]. The equivalent circuit that depicts the operation principle of the DC generator is shown in Figure 3.

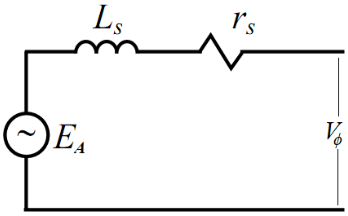

FIGURE 3. Equivalent circuit of PMDC

The operation of the PMDC for generation could be depicted by a 1st order differential and swing equations as given by [4],

$$\frac{di_a}{dt} = \frac{1}{L_a}\left(\omega_r \varphi - V_a - r_a i_a\right) \tag{4}$$

$$T_e = k_T \varphi i_a \tag{5}$$

$$T_m - T_e = J\frac{d\omega_r}{d} \tag{6}$$

Where, i_a, L_a, r_a and V_a are armature current, self-inductance, resistance and voltage respectively. ω_r , φ , T_e, T_m are angular velocity, flux, generator torque and prime mover torque respectively.

2.3. Diode rectifier

Mechanical mover , Figure 1, moves up and down; therefore the direction of rotation of the DC generator reverses with varaible amplitude. A full bridge diode recrtifier is applied to rectify the generator output voltage. Very low voltage drop diodes are chosen for implementing the diode rectifier [5-8].

2.4. DC Boost Converter

A boost converter is used to ensure constant output voltage and produce acceptable level for batteries. The boost circuit has two statuses: on and off-states. The dynamic performance model of the boost converter could be depicted from these states topology. Averaging over a switching cycle, the dynamic performance of the boost chopper could be given by [9-13],

$$L\frac{di_L}{dt} = V_{dc} - V_o(1-D) \tag{7}$$

$$C_o\frac{dV_o}{dt} = -\frac{V_o}{R_L} + i_L(1-D) \tag{8}$$

A Proportional Integral (PI) controller is used to ensure constant output voltage, V_o. The PI compensator is tuned via Nichols-Ziegler reaction time empirical method [14]. The parameters of the PI controller are given in Table1

TABLE 1
PARAMETERS OF PI CONTROLLER

Proportional gain k_p	0.1
Integral gain k_i	2

III. RESULTS AND DISCUSSIONS

Matlab dynamic platform, Simulink, is used for stimulating the system under consideration. Figures 4-6 shows the input force of the footstep, generated voltage, the diode dc voltage and the boost converter output voltage.

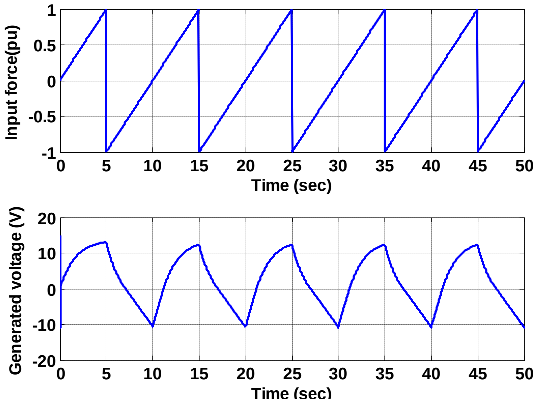

FIGURE 4. Input force (pu) top graph, generator output voltage (V) bottom graph

Figure 4 shows waveform of the force, which is exerted on the energy converter. This force is due to the pressed footstep and the spring in the energy converter itself. The generated voltage has bidirectional nature.

Figure 5 shows that the H-bridge diode rectifier converts the bidirectional generated voltage into useable DC voltage. However, the voltage level is still below the required. Therefore, a boost converter is employed for boosting the DC voltage into acceptable level

Figure 6 shows that boost converter increases the H-bridge rectifier voltage from 2.8V to around 9.8V. The boost operates with around 71% duty cycle, where the input voltage is boosted around 350%.

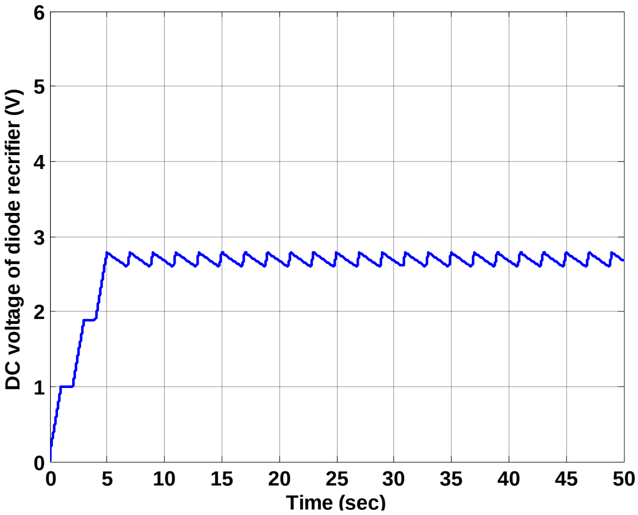

FIGURE 5: DC voltage of the diode rectifier

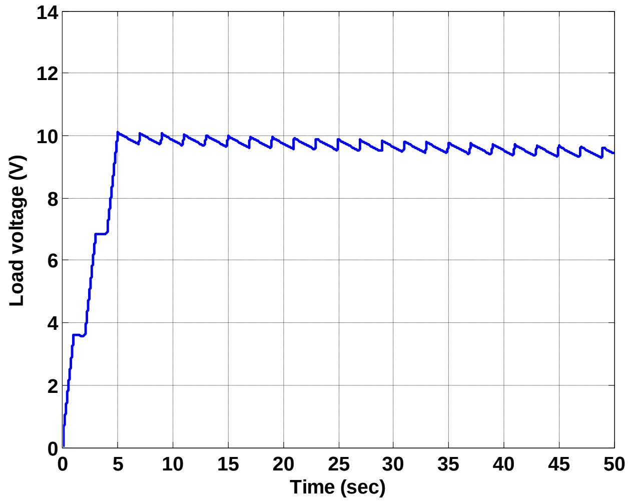

FIGURE 6: the boost converter output voltage

IV. PROTOTYPE OF THE PROPOSED GENERATION SYSTEM

A prototype was built as shown in Figure 7.

The output voltage of generator, diode rectifier and the boost converters are shown in Figures 8, 9 and 10 respectively.

Figure 8 shows that generated output voltage from the proto-type is bidirectional, this complies with figure 4. However, the difference due to the assumption and ideal components used in the simulation.

Figure 9 shows that the H-bridge diode rectifier converts the bidirectional voltage into DC voltage. Figure 9 shows that the DC voltage is almost ripple free, which is attributed to the capacitor size.

Figure 10 shows that the boost converter boosts the output voltage of the rectifier to the desired level.

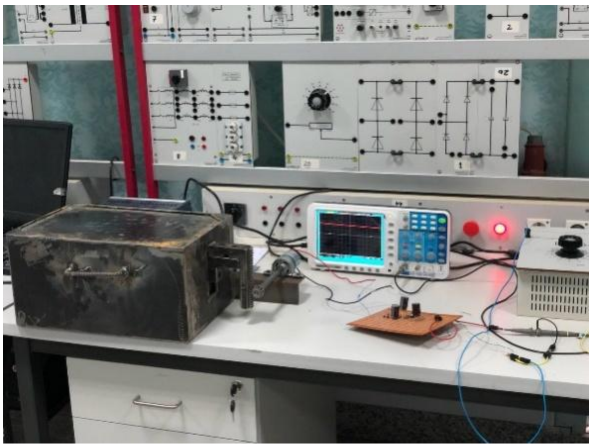

FIGURE 7. A prototype of the footstep electrical power generation

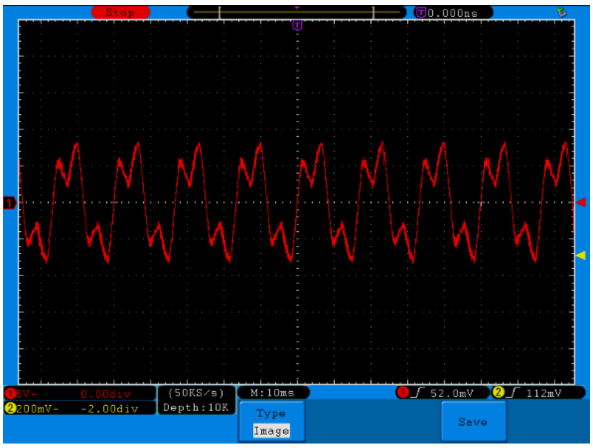

FIGURE 8. Generator output voltage

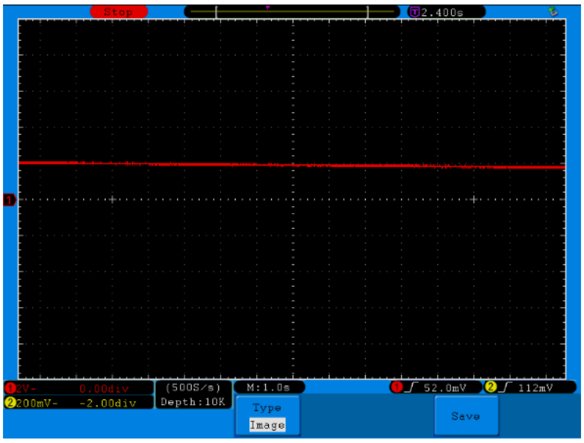

FIGURE 9. Diode rectifier output voltage

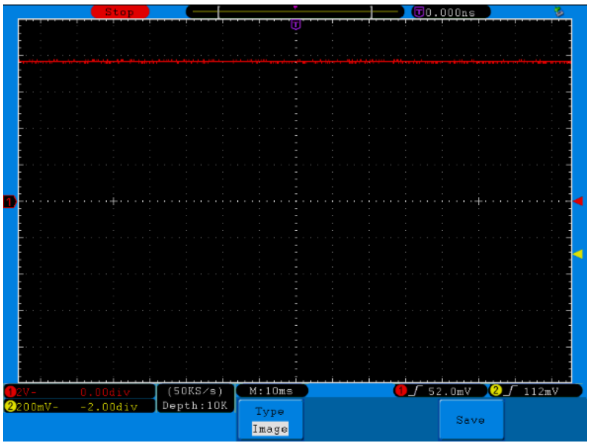

FIGURE 10: Boost converter output voltage

The feasibility of the proposed scheme proved by Figures 8-10, that itt could be valuable source for lighting

1- Figure 8 shows that the generated voltage is bidirectional, which is attributed to the mechanism of prime mover movement.

2- Figure 9 shows that the rectifier converter the bidirectional form of the generator output voltage into DC voltage. The DC voltage is shown to have small ripple content; this is due to the application of large DC capacitor.

3- Figure 10 shows that the boost converter boosts the output voltage of the rectifier to the desired level.

These figures confirm the functionality of the proposed idea. It is worth to mention that the output power is likely not enough to supply high power load.

V. CONCLUSION

Innovative scheme for generating electricity from main human activity, which is walking advised in this article. Simple and elaborate design for the energy converter convert human footstep into mechanical energy designed and implemented. This energy converter could be integrated with structures as stairs. PMDC generator, diode rectifier and boost converter are attached to the prime mover. The rectifier is used to rectify the output voltage as it fluctuates due to the mechanism of shaft rotation. The produced power is sufficient for charging portable devices. The practical setup validates simulation results, which proves the feasibility of this approach.

It is worth to mention that this scheme is notable for producing a power level required for a reasonable load. Moreover, this arrangement requires high flow of the people to generate electricity.

REFERENCES

[1] F. Shahnia, "Stability of a sustainable remote area microgrid," *2016 IEEE Region 10 Conference (TENCON)*, Singapore, 2016, pp. 1220-1223.

[2] A. K. Nayak, P. Sarangi, R. Santra and A. K. Kotini, "Economic generation mix for commercial building," *2014 14th International Conference on Environment and Electrical Engineering*, Krakow, 2014, pp. 249-253.

[3] N. Nikmehr and S. Najafi Ravadanegh, "A heuristic load flow algorithm for active distribution grids," *2013 Smart Grid Conference (SGC)*, Tehran, 2013, pp. 31-35.

[4] O.Wasynczuk, P. C. Krause, Scott D. Sudhoff, and Steven Pekarek" Analysis of Electric Machinery and drive systems" 3rd editon, IEEE press, Wiley, 2002.

[5] H. Shin and J. I. Ha, "Active DC-link circuit for single-phase diode rectifier system with small capacitance," *2014 International Power Electronics and Application Conference and Exposition*, Shanghai, 2014, pp. 875-880.

[6] Y. Son and J. I. Ha, "Efficiency improvement in motor drive system with single phase diode rectifier and small DC-link capacitor," *2014 IEEE Energy Conversion Congress and Exposition (ECCE)*, Pittsburgh, PA, 2014, pp. 3171-3178.

[7] T. Sakkos and V. Sarv, "A new high power factor single-phase diode rectifier with optimum ripple-power conversion," *2006 International Biennial Baltic Electronics Conference*, Tallinn, 2006, pp. 1-4.

[8] Y. Ji and F. Wang, "Single-phase diode rectifier with novel passive filter," in *IEE Proceedings - Circuits, Devices and Systems*, vol. 145, no. 4, pp. 254-259, Aug 1998.

[9] Mattos, A. M. S. S. Andrade, G. V. Hollweg, J. Renes Pinheiro and M. Lucio da Silva Martins, "A REVIEW OF BOOST CONVERTER ANALYSIS AND DESIGN IN AEROSPACE APPLICATIONS," in *IEEE Latin America Transactions*, vol. 16, no. 2, pp. 305-313, Feb. 2018.

[10] J. Arrozy, J. H. F. Rajagukguk, A. Rizqiawan and P. A. Dahono, "Performance evaluation of large ratio dc-dc boost converter," *2017 4th International Conference on Electric Vehicular Technology (ICEVT)*, Bali, Indonesia, 2017, pp. 55-60.

[11] M. Veerachary, "Third-order boost converter," in *IET Power Electronics*, vol. 11, no. 3, pp. 566-575, 3 20 2018.

[12] W. Jiang, S. H. Chincholkar and C. Y. Chan, "Comparative study of adaptive current-mode controllers for a hybrid-type high-order boost converter," in *IET Power Electronics*, vol. 11, no. 3, pp. 524-530, 3 20 2018.

[13] H. Han, R. Tan, J. Yang, H. Wang, S. Ning and M. Shen, "A novel efficient tri-state boost converter," *2017 IEEE Electrical Power and Energy Conference (EPEC)*, Saskatoon, SK, 2017, pp. 1-6.

[14] R. S. Burns" Advanced Control Engineering" 1st edition, Butterworth-Heinemann, 2001.