International Journal of Engineering Works
https://www.ijew.io/
ISSN-p: 2521-2419
ISSN-e: 2409-2770
Vol. 10, Issue 03 PP. 16-21, March 2023
https://doi.org/10.34259/ijew.23.10031621

Design of Hybrid Power System using PV and Piezoelectric Energy Harvester

Sanan Afridi[1*] and Dr. Abdul Basit[2]
[1,2] Center for Advanced Studies in Energy (CAS-E), Department of Electrical Energy System, University of Engineering and Technology Peshawar, Pakistan
sananafridi50@gmail.com[1], abdul.basit@uetpeshawar.edu.pk[2]
Received: 24 February, Revised: 01 March, Accepted: 18 March

***Abstract*—** Now a day's modern power system gradually prefers renewable energy resources. Conventional energy resources involves issues related environmental pollution and its reserves are also diminishing whereas demand for energy is rising daily. Whereas share of renewable energy in power industry is increasing because they are affordable, reliable, clean and available in large quantity. Renewable energy resources are intermittent in nature. So, to make power system more reliable combination of both piezoelectric transducers and solar panel are used to generate sufficient energy. Solar panels output is first given to DC-DC Boost Converter through maximum power point tracking (MPPT) algorithm. Piezoelectric generator gives AC output so it is desired to rectify this output to get DC. Both sources are then connected in parallel which charges/discharges through a bi-directional DC-DC converter. Battery is connected with the system. The overall DC output is converted to AC through voltage source inverter (VSI) for grid connection and vice versa. The main purpose to design such kind of power system is to generate electricity from renewable energy resources which will be more reliable.

***Keywords*—** Solar panel, Piezoelectric transducer, Battery, Voltage source inverter, Grid.

I. INTRODUCTION

Energy is an essential element of human growth. Fossil fuels have been the primary sources of energy for more than two centuries, but as society and businesses evolve, the need for energy resources is expanding. It is predicted that within coming years, energy consumption will rise, leading to the depletion of fossil fuels.

However, in addition to being exhausted, fossil fuels also emit greenhouse gases that causes climate change to occur, which can have catastrophic and permanent repercussions for the ecosystem. Seeking clean, renewable energy sources is necessary as a result of the anticipated rise in energy consumption and the shortage of fossil fuels, which compels society to expedite the shift to a carbon-free economy. The most common and unlimited natural form of energy in the globe is energy from the sun. It is completely renewable because the sun will continue to shine for countless years. Solar panels generate quite large output but its output depends upon weather conditions. Most of the renewable energy sources are intermittent in nature so combination of photovoltaic (PV) and piezoelectric energy harvester are implemented to ensure continuous power generation that can meet load demand. Piezoelectric transducer converts mechanical energy such as vibration or mechanical stress into electrical energy. To achieve decent power generation from piezoelectric energy harvesters they are embedded beneath asphalt roads. Both PV and piezoelectric energy harvester are connected in parallel to accommodate grid.

II. LITERATURE REVIEW

Renewable energy sources are effectively used because it has approximately no issues related environmental pollution[1]. Renewable energy sources are preferred over non-renewable energy sources because it is cheap, clean and reliable source [2]. Other than this fossil fuels reserves are depleting, so renewable energy source is used as an alternative [3]. By the end of the century, the population of the planet is predicted to exceed 11000 million, and a recent mathematical model that took into account factors like wealth, population, and oil consumption predicted that within coming years, energy consumption will rise, leading to the depletion of fossil fuels. World energy consumption would need to rise by roughly 1700 million tons of oil equivalent per year to maintain the natural worldwide expansion of gross domestic product. This indicates that retaining a 33 percent oil energy share would necessitate an increase in existing oil supply of more than 10 million barrels daily [4].

A. Solar Energy

In the past few years solar energy is being used as the most common renewable energy source due to its easy installation and decent power generation [5]. NASA estimates, the Sun has

another 6.5 billion years of lifespan left, and each hour it sends more energy to Earth than is required to meet a year's worldwide consumption. The amount of solar radiation striking the Earth's crust is 120000000 gigawatts, or 20,000 times more energy than the globe as a whole needs [6]. In just two to three weeks of solar irradiation, the Earth is expected to receive energy equal to all of the world's fossil fuel reserves [7].

The two main angles needed to orient photovoltaic modules are azimuth angle and elevation angle at solar noon. To pinpoint the sun's direction, one must track the azimuth angle and as well the elevation angle throughout the day. These angles are determined by "Solar time". The declination angle is the difference in angle between the axis of the Earth and a line drawn through the centers of the Sun and the Earth. The declination angle therefore varies depending on the above-mentioned elements due to the Earth's revolution and orbit, varying from +23,45° on the summer solstice to -23,45° on the winter solstice, whereas this value approaches 0 ° on the equinoxes [8]. When sizing PV installations, these variations must be taken into consideration.

B. Solar PV Modules

PV cell is a thin slice of a semiconductor material made up of a top layer of negative region silicon and a bottom layer of positive region doped silicon. A p-n junction is formed between them. As a result, when sunlight strikes the cell, the absorbed photons flow through the material, rupturing bonds and ripping off electrons from semiconductor, forming holes in the stimulated elements. In the depletion area, holes and free electrons team together. However, the layer's driving force drives the electrons and holes out of the layer. As a result, under the influence of the electric field, free electrons and holes move in opposite directions. Due to significant abundance of holes in the positive region and free electrons in the negative region a potential difference is created. When a load is applied electrons will start to travel from negative to the positive region. Afterwards it will merge with the holes. Solar cells produce direct current consistently in this manner. In order to boost performance and widen the depletion region, solar cells often employ a thin, heavily doped negative region and a wide, mildly doped positive region [9].

To achieve increase in output, several solar cells are arranged and encased using bus bar connectors to create a PV module. Similarly PV modules are connected in series to create solar panels. Solar strings or arrays are further created by connecting panels together. The cells are shielded from water, dust, fumes, and other factors by this material, which is typically tempered glass with low iron content [10]. As a result, the cells are neither rusted nor damaged. Additionally, because the solar cells are tiny and sensitive, the front surface offers mechanical resistance, stiffness and durability, and also provides barrier that guards against electrical shocks for the user. The encapsulating layers would be the second part of the modules. The front and back surfaces of the module's front and rear surfaces, as well as the strings of solar cells, are held together by the encapsulate. The most popular substance is ethyl vinyl acetate [11]. At last, an aluminum body is attached to these group of components to connect them and prevent lateral dust and moisture or rain lodgment, extending the solar module's lifespan.

The amount of energy that penetrates a PV module is influenced by the elevation angle between the solar panel and the Sun as well as the strength of the sunbeams. When the panel is completely perpendicular to the sun, power density will be at its highest point. The output power per unit volume is never more than the incident one because of the Sun's erratic position and numerous sorts of losses. To get the most output power out of panels, the best tilt angle must be determined [12]. Fixed systems and tracking systems are the main categories for PV systems. The latitude of the area and the optimal elevation angle for a fixed panel are equal. Energy output is maximized during the winter when the elevation angle is enhanced. Otherwise, lowering it is advised for summer energy production. However, they are unable to alter their elevation angle or orientation. Solar tracking panels can be installed in order to enhance the power of a solar system under certain circumstances [13]. The most popular kinds of tracking systems often have one or two rotating axes, which causes their degrees of freedom to vary. Single-axis trackers are often positioned to track the Sun's movement by aligning with the north-south meridian. However, two-axis tracking systems can follow the Sun in any location in the sky and can adjust their tilt angle to account for changes in the Sun's seasonal height. These systems cost far more than fixed ones, but energy harvesting is renowned for being improved. Typically, 60 to 72 cells are placed in series on a module. When cells are arranged in series a module is formed. PV panel is formed by connecting modules in series. Solar array is created when numerous number of panels are connected together in parallel [10].

C. Algorithms for MPPT

Solar panels have a non-linear I-V characteristic, and its power generation is affected by factors including temperature and solar radiation. Maximum power point tracking (MPPT) is implemented to adjust the operating voltage of photovoltaic near maximum power point (MPP under different weather circumstances. In order to consistently gather the most electricity possible from the solar system, they need to remain functioning at its MPPT regardless of the irregular fluctuations in the weather conditions. The solar module produces the most power at a spot along the I-V curve where the product of the voltage and current is greatest. The MPP is the name of this point. The MPPT's objective is to make sure that the solar system draws the peak power possible [14]. For MPPT, several strategies have been proposed such as perturbation and observation technique, the incremental conductance technique, ripple correlation technique, short circuit current technique, and open circuit voltage technique [15].

D. Piezoelectric Transducer

The piezoelectric effect acts as the base core for a piezoelectric energy device. Piezen is a Greek word, which refers to compress or squeeze. The piezoelectric effect states that whenever mechanical action such as compression or force is applied to quartz crystal surfaces it will result in electrical output. A piezoelectric device convert mechanical energy into

electrical energy in order to detect alterations in stress, strain and temperature [16].

E. Applications of Piezoelectric Transducer

Piezoelectric energy harvesters are used in multiple applications. In microphones, the acoustic is turned into an electronic signal that is subsequently enhanced to produce a clear sound. Battery powered lighters for the stove also utilizes the piezoelectric sensing elements. When force is exerted on sensing element, an electric signal is generated, and it is this signal that ultimately causes the spark. Moreover, it is also utilized in marts, malls, boutiques, hotels, and airports in such a way that whenever a person approaches the entrance the door will instantly open. The theory behind this is that as the visitor reaches entrance door, their bodyweight exerts pressure on the transducers, causing an electric reaction that forces the door to open automatically [17].

F. Energy Generation

A piezoelectric energy harvester is designed to generate electrical energy through walking. Piezoelectric energy harvester is embedded within the shoes. While walking, the shoes absorb compression and strain which results in electrical energy generation [18]. Output is very low so that's why utilized at small scale only [19]. Piezo electric transducer output is very low. So, it is desired to design an energy harvester so that it can be utilized at large scales. Piezoelectric energy harvesters can be used to generate electrical energy from moving vehicles. Piezoelectric generators utilize strain due to moving vehicles over asphalt roads and harvests kinetic energy or vibration due to moving vehicles. The only cause of these vibrations coming from moving automobiles is an imbalance brought on by a tire's strain on a gravel road (asphalt road). A piezoelectric transducer is the ideal tool to capture and use such energy since these types of devices respond to "compression" by producing electric energy.

This mechanical energy source is subsequently transformed into electrical power output via the "piezoelectric generator". The "rectifier" subsequently rectifies the generated power into DC supply. Together, they make up the piezoelectric transducer stage. Rectified output of piezoelectric transducer is used to increase its output through boost converter. Power generated is supplied to the grid for onward transmission after passing through an "inverter". Implementation cost and payback period were calculated, confirming and forecasting the real-time economic impact. Competitive advantage of the piezoelectric energy harvester over other non-conventional sources of energy is then justified, supporting the provision of an affordable solution to reduce the world's carbon footprint. This is done through a comparison study with other non-conventional and sustainable energy sources based on levelized energy cost (LEC). Based on LEC, it is thought to be more economically advantageous than most of the commonly used sustainable energy sources such as wind energy or solar energy [20]. Approximately 35 mobile cells battery power can be generated using piezoelectric Technology under vehicles on the road. This output can be still improved [21].

G. Hybrid System

Piezoelectric transducers and PV panels can be connected together to form a hybrid system to get improved output. Generator is designed based on solar energy and piezoelectric transducer. A hybrid panel was designed which rotates with the help of servomotor. Moisture sensor and light dependent resistors (LDR) were used to sense rainfall and sunlight. During sunlight solar panel is faced up and during rainy day piezoelectric plate is faced up to ensure continuous generation of power [22]. Due to intermittent nature of renewable sources batteries are utilized to store energy [23].

PV and piezoelectric transducers are used in a hybrid power system coupled with a battery to provide a constant power source. The PV panel provides the primary power, while the piezoelectric modules' captured energy can be used to supplement it. A parallel-connected piezoelectric module system and an energy harvester are created for the application. Additionally, the buck-boost dc-dc converter for the solar system and piezoelectric energy harvesters are made to link two power inputs in parallel. The developed dc-dc converter runs with MPPT and the maximum current or voltage control mode for the battery, depending on the input power and battery state. The suggested buck-boost dc-dc converter is used in the proposed system to link the solar system and piezoelectric energy harvesters to the battery storage system and regulate input power as well as battery charging and discharging. In order to generate AC power for the grid line, the battery is also linked to the grid line through inverter [24]. In the event that there is sufficient power generation, the bi-directional DC-AC grid connected power converter sends power to the grid. Grid power can recharge the battery over the night for efficient power use [25].

III. Design and Analysis of Hybrid System

Hybrid system is basically combination of two or more than two sources. Hybrid system can provide a lot of positive impacts in contrast to those systems that depends upon single source only. So there is a substantial demand of hybrid system because if one source fails to deliver than other source can compensate for it. With the addition of batteries and on grid system, overall system becomes more reliable.

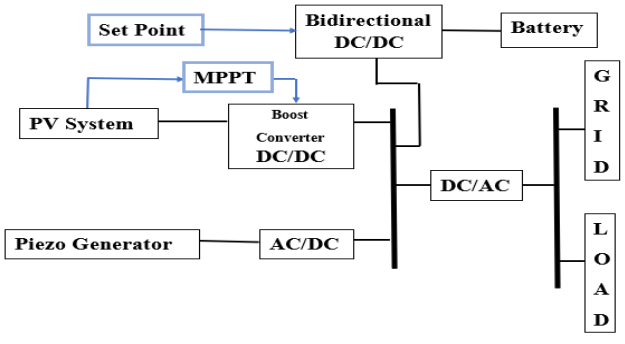

Figure 1. Block Diagram

Fig. 1 shows the block diagram of hybrid system. PV system along with MPPT algorithm is implemented and its output is boosted through a boost converter. Piezoelectric generates output is rectified through a rectifier. Both sources

outputs are then connected in parallel. Energy storage system is also implemented with a bi-directional DC-DC converter. When battery is charging (Buck Mode) and during discharging (Boost Mode). Battery charging/discharging depends upon power generation versus power consumption. All these outputs are connected to a grid through VSI.

A. Photovoltaic System

MATLAB program has been used to simulate the PV module as a benchmark. MSR 245W PV module with 12 parallel and 5 series solar units are used to make this solar system. It consists of 60*96=5760 number of solar cells.

Irradiance and temperature are considered as the input parameters. At $1000\frac{W}{m^2}$ irradiance and 40 ℃ temperature, output supply voltage is ~ 170V and current value is ~ 75A. Therefore, cumulatively its power can be calculated as P = V*I = 170*75 = 12.75KW. In cascaded structure addition of DC/DC Boost converter, an average model of Boost converter is used. Boost converter is used to boost up the voltage up to 300V, so that achieve a better performance in power management and distribution can be achieved. Low pass filter is set to remove the unwanted harmonics, so that it becomes smooth power supply source. Due to Inductive and Capacitive nature the storing and opposing capability of the voltage and current will be smoother. It will provide protection from surge currents.

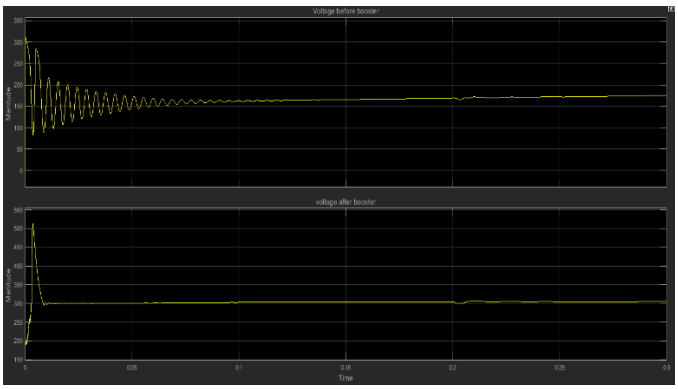

Figure 2. UN Boosted and Boosted PV Supply

B. Piezoelectric Generator

To establish a "continuously powered" system, a microgenerator that turns ambient energy into electric power is used as an alternative approach. Main emphasis is the conversion of mechanical stresses into electrical energy through piezoelectric energy harvesters.

1) Synchronous Machine as Micro Generator

The cantilever beam that makes up the vibration-based electromechanical generator under consideration has piezoelectric devices adhered to its surface. Such a system's model density is usually quite low. Hence, the initial bending mode and the other resonance frequencies may be easily distinguished. Since the strain is greatest at the clamped end in the initial bending mode, the piezoelectric components coupled there provides the optimal electromechanical conversion for a specific mechanical excitation. It accurately describes the performance of the structural body close to resonance, such as close to its initial bending mode. Due to this model's simple structure, both the mechanical and electrical quantities in the linearly elastic region can be calculated easily.

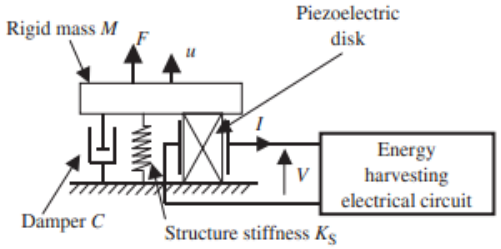

Figure 3. Piezo Road Plate Model

When moving mass will walk on the rigid mass M then beam will move downward by pressing the mechanical metallic steel spring in the donward dirction. This motion of spring will push the gear set in parallel fashion. The shaft of electromechanical generator is fixed with the gear set, as a result it will rotate in a megnatic field as shown in Fig. 4. Voltage induces by the movement of magnet, if a metalic coil moves in a magnetic field, an electromotive force will be induced.

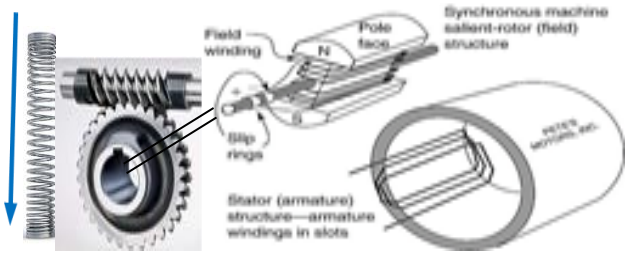

Figure 4. Parts of Mechanical Model

2) Piezo Energy Generation

Piezo energy generator is an electromechanical device which provides electrical energy. Basically two steps are involved that is first kinetic energy is turned into mechanical energy and further this energy is transformed into electric energy by following the laws of energy conservation and conversion or transformation. In this case a mini permanent magnate synchronous machine is used as a small power generator unit.

Piezo generator is generating about 0.6A current. For the current interface we performed test for general values with constant operational conditions. Since mechanical torque $\left(T_m = 1\frac{N}{m^2}\right)$, have stable and same input to the generator, that's why a constant power generation is achieved. Surge arrester resistance are applied so that system remain safe from surge currents and abrupt shoots of the heavy currents. Output receiving AC voltage is 280V and AC current is 0.06A or 60mA as depicted in Fig. 5.

Since the AC supply produced by piezo generator can't be used directly, so it is converted to DC. For this purpose, a rectifier is required to convert AC into DC. A DC source is

obtained which is connected to hybrid network having 27V and 0.055A as depicted in Fig. 6.

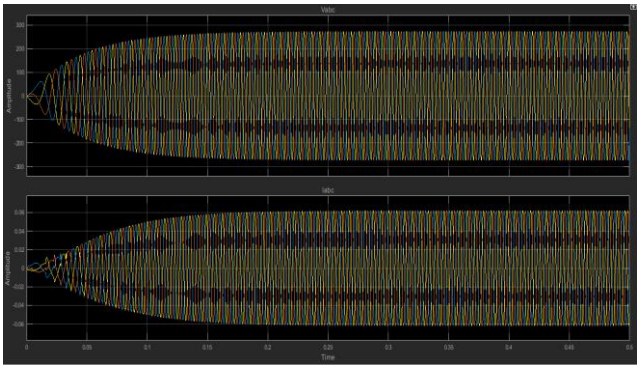

Figure 5. Piezo Generator AC Supply

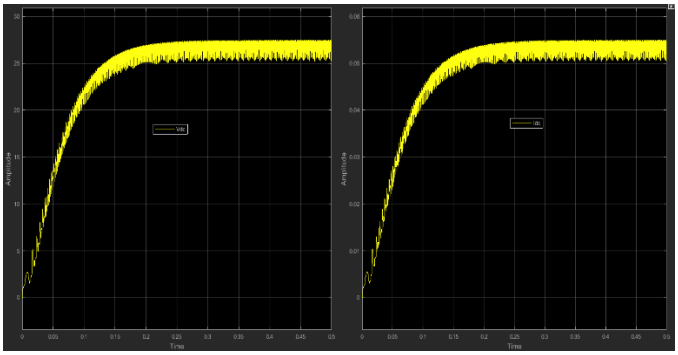

Figure 6. Piezo Generator DC Supply

IV. HYBRID SYSTEM SIMULATION RESULTS

A PV system installed in parallel with Piezo electric generator. Both of the sources may have unwanted distortions and irregularities, that's why a capacitor bank is integrated with them so that their combined supply may filtered out to reduce the distortions and unwanted peaks to make it a smooth and stable supply. PV and piezo provides a combined supply having voltage = 300V and Current = 0.64A without grid connection.

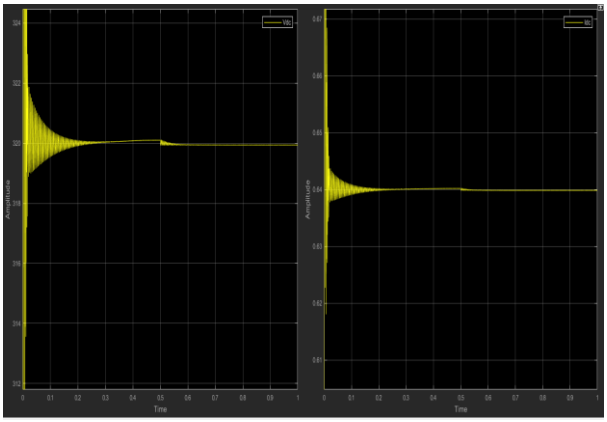

Figure 7. Hybrid System DC simulation witout Grid

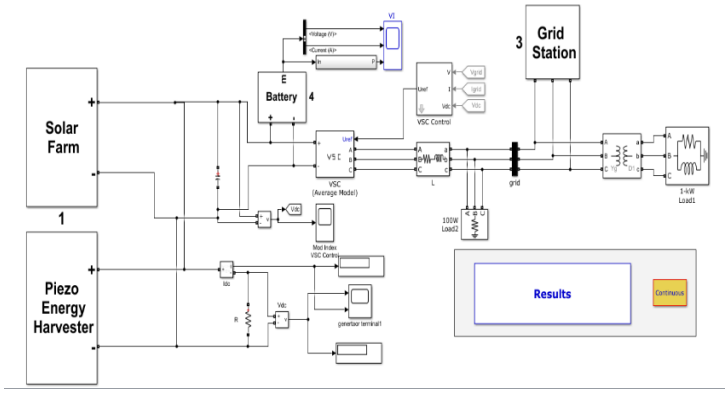

Figure 8. Hybrid Power System (MATLAB Design)

Hybrid power system consists of multiple sources connected with battery management storage system and grid station. Their mutual coordination empowers the mutual power sharing. It should provide a stable and smooth supply in the regular behavior. After an undesired small disturbance renewable energy sources are providing a combined supply of slightly more than 300V and 60A (generated power ≥18KW).

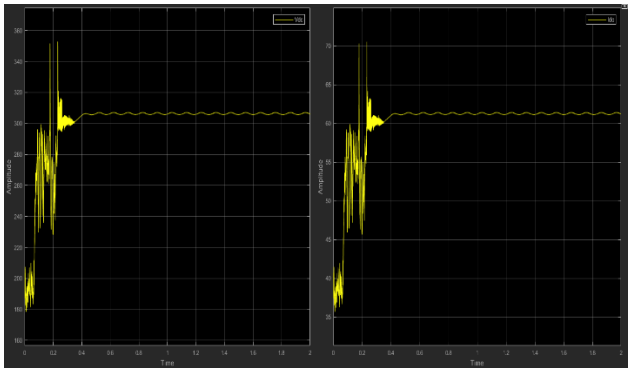

Figure 9. Hybrid System DC Supply with Grid

Battery has the capacity to store 300V supply in it. In hybrid system it is storing 0.9KW power. Initially battery is charging, but depends upon the load demand. VSI has the ability to convert DC supply taken from the DC bus and convert it into AC in order to supply it to the AC bus. On DC bus we have PV panels, piezo electric generator and battery as sources of DC supply. On AC bus VSI and grid acts as sources. The AC supply by the VSI is V_{AC}~$130V$ and I_{AC}~$25A$.

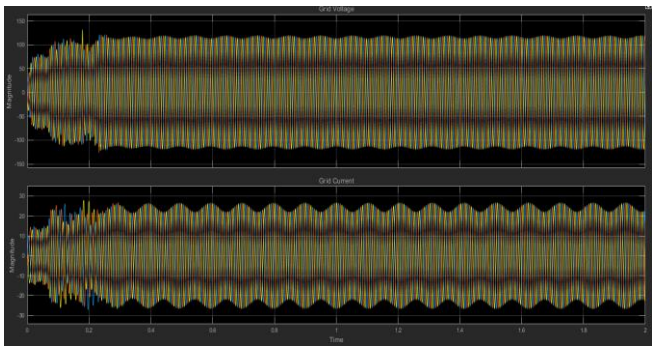

Figure 10. Hybrid System AC Supply with Grid

CONCUSLION

In this research work photovoltaic system has the capacity to generate 15KW power. Power generation can be further increased by using multiple number of units but it is intermittent in nature. That's why piezoelectric energy harvester is considered and it is connected in parallel with PV system to meet load demand. Piezoelectric energy harvesting technique is a modern technique used to generate power from the kinetic energy transferred by the moving bodies such as vehicles or human. Although it can generate limited energy, but this document justified this concept that how output power generated by piezo electric energy harvester is improved to a decent value. This document shows that 26 watts AC power is generated from a single piezo energy harvester unit. By implementing multiple units of piezo generators (depending upon load demand), power in large quantity can be easily generated. It is valuable to integrate power grid with renewable energy sources to generate 18KW power. This overall system is also integrated with battery management. DC supply of renewable energy sources is converted to AC and vice versa through VSI.

REFERENCES

[1] N. L. Panwar, S. C. Kaushik, and S. Kothari, "Role of renewable energy sources in environmental protection: A review," *Renewable and Sustainable Energy Reviews*, vol. 15, no. 3, pp. 1513–1524, Apr. 2011, doi: 10.1016/j.rser.2010.11.037.

[2] G. E. Halkos and E.-C. Gkampoura, "Reviewing Usage, Potentials, and Limitations of Renewable Energy Sources," *Energies*, vol. 13, no. 11, Art. no. 11, Jan. 2020, doi: 10.3390/en13112906.

[3] A. K. Akella, R. P. Saini, and M. P. Sharma, "Social, economical and environmental impacts of renewable energy systems," *Renewable Energy*, vol. 34, no. 2, pp. 390–396, Feb. 2009, doi: 10.1016/j.renene.2008.05.002.

[4] F. Meneguzzo, R. Ciriminna, L. Albanese, and M. Pagliaro, "The energy-population conundrum and its possible solution." arXiv, Oct. 24, 2016. doi: 10.48550/arXiv.1610.07298.

[5] I. G. Zurbriggen and M. Ordonez, "PV Energy Harvesting Under Extremely Fast Changing Irradiance: State-Plane Direct MPPT," *IEEE Transactions on Industrial Electronics*, vol. 66, no. 3, pp. 1852–1861, Mar. 2019, doi: 10.1109/TIE.2018.2838115.

[6] "Energías Renovables," *Energías Renovables*. https://www.energiasrenovablesinfo.com/ (accessed Oct. 03, 2022).

[7] "Union of Concerned Scientists." https://www.ucsusa.org/ (accessed Oct. 03, 2022).

[8] C.-J. Winter, R. L. Sizmann, and L. L. Vant-Hull, *Solar Power Plants: Fundamentals, Technology, Systems, Economics*. Springer Science & Business Media, 2012.

[9] T. R. Kuphaldt, "Lessons In Electric Circuits, Volume III – Semiconductors," p. 537.

[10] "PVEducation." https://www.pveducation.org/ (accessed Oct. 03, 2022).

[11] C. Wiesmeier, I. Haedrich, K.-A. Weiss, and I. Duerr, "Overview of PV module encapsulation materials," *Photovoltaics International*, vol. 19, pp. 85–92, Jan. 2013.

[12] E. A. Handoyo, D. Ichsani, and Prabowo, "The Optimal Tilt Angle of a Solar Collector," *Energy Procedia*, vol. 32, pp. 166–175, Jan. 2013, doi: 10.1016/j.egypro.2013.05.022.

[13] S. Aziz and S. Hassan, "On Improving the Efficiency of a Solar Panel Tracking System," *Procedia Manufacturing*, vol. 7, pp. 218–224, Jan. 2017, doi: 10.1016/j.promfg.2016.12.053.

[14] S. Saravanan and N. Ramesh Babu, "Maximum power point tracking algorithms for photovoltaic system – A review," *Renewable and Sustainable Energy Reviews*, vol. 57, pp. 192–204, May 2016, doi: 10.1016/j.rser.2015.12.105.

[15] M. Hlaili and H. Mechergui, "Comparison of Different MPPT Algorithms with a Proposed One Using a Power Estimator for Grid Connected PV Systems," *International Journal of Photoenergy*, vol. 2016, p. e1728398, Jun. 2016, doi: 10.1155/2016/1728398.

[16] J. Holterman and P. Groen, *An introduction to piezoelectric materials and applications*. Apeldoorn: Stichting Applied Piezo, 2013.

[17] "Piezoelectricity & Piezo Applications." https://www.americanpiezo.com/knowledge-center/piezo-theory/piezoelectricity.html (accessed Oct. 04, 2022).

[18] A. Gupta and A. Sharma, "Piezoelectric Energy Harvesting via Shoe Sole," vol. 1, no. 6, p. 5, 2015.

[19] J. Kymissis, C. Kendall, J. Paradiso, and N. Gershenfeld, "Parasitic power harvesting in shoes," in *Digest of Papers. Second International Symposium on Wearable Computers (Cat. No.98EX215)*, Oct. 1998, pp. 132–139. doi: 10.1109/ISWC.1998.729539.

[20] H. Najini and S. A. Muthukumaraswamy, "Piezoelectric Energy Generation from Vehicle Traffic with Technoeconomic Analysis," *Journal of Renewable Energy*, vol. 2017, p. e9643858, Feb. 2017, doi: 10.1155/2017/9643858.

[21] Y. Cao, A. Sha, Z. Liu, J. Li, and W. Jiang, "Energy output of piezoelectric transducers and pavements under simulated traffic load," *Journal of Cleaner Production*, vol. 279, p. 123508, Jan. 2021, doi: 10.1016/j.jclepro.2020.123508.

[22] K. Aneelkumar, M. Sridhar, D. S. Durgaram, P. Rahul, and G. S. Kumar, "DESIGN OF MULTI ELECTRICITY GENERATOR USING SOLAR AND PIEZO ELECTRIC TRANSDUCER," vol. 04, no. 07, p. 6.

[23] C. A. Hill, M. C. Such, D. Chen, J. Gonzalez, and W. M. Grady, "Battery Energy Storage for Enabling Integration of Distributed Solar Power Generation," *IEEE Transactions on Smart Grid*, vol. 3, no. 2, pp. 850–857, Jun. 2012, doi: 10.1109/TSG.2012.2190113.

[24] J. Park and D.-H. Lee, "Hybrid Power System using PV and Piezoelectric Modules," in *2019 22nd International Conference on Electrical Machines and Systems (ICEMS)*, Aug. 2019, pp. 1–6. doi: 10.1109/ICEMS.2019.8922091.

[25] J. Park and D.-H. Lee, "Design and Analysis of the Hybrid Power System using PV and Piezoelectric Modules," in *2019 International Conference on Clean Electrical Power (ICCEP)*, Jul. 2019, pp. 280–285. doi: 10.1109/ICCEP.2019.8890102.

How to cite this article:

Sanan Afridi and Dr. Abdul Basit "Design of Hybrid Power System using PV and Piezoelectric Energy Harvester" International Journal of Engineering Works, Vol. 10, Issue 03, PP. 16-21, March 2023. https://doi.org/10.34259/ijew.23.10031621.