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Energy Generation through Multiple Renewable Sources for Low Power Gadgets

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Abstract
As time progresses, the demand for energy continues to rise, leading to the exploration of various energy sources. The global population is growing exponentially, resulting in a substantial energy requirement. Consequently, the world has been shifting towards renewable energy resources, as non-renewable resources are expected to be depleted in the near future. Our research focuses on designing a Simulink model for energy harvesting, utilizing multiple renewable energy sources. This model can be tailored to meet the energy harvesting needs of both large and small grids. Our Simulink model integrates wind energy, solar energy, piezoelectricity, and thermoelectricity as renewable energy resources. With these resources, we can ensure that at least one energy source will be available for harvesting. Furthermore, we anticipate that in the future, a radio frequency energy resource model could be integrated to enhance the system's robustness.
Keywords: Solar Energy, Wind Energy, Energy Harvesting, Medical Equipment’s, Thermal Energy, Piezoelectric Energy

1. Introduction

Due to recent advancements in wireless technology and low-power electronics, the development of wireless sensors for various applications is underway. Power harvesting has witnessed substantial growth in the past few years due to the increasing demand for portable and wireless electronics with extended battery life [1-2]. The need for energy, particularly electrical energy, is constantly present, as it constitutes a significant portion of global energy consumption. With the passage of time, the consumption of electrical energy has been growing exponentially, leading to a doubling of demand in recent years [3]. Projections suggest that the demand could increase by up to 76% by 2030. Conventional electric power generation systems rely on hydro power, nuclear power, and fossil fuels. However, nuclear and fossil fuel resources are non-renewable and will eventually deplete as the global population continues to grow exponentially [4-5]. When considering hydropower, there are several challenges, such as limited available sites that are often located far from areas where power is needed. Energy harvesting (EH) presents a solution by offering "endless energy" throughout the lifespan of electronic devices. In many cases, energy harvesting can eliminate the need for batteries in wireless devices, serving as a practical and cost-effective substitute for batteries that are difficult, expensive, or hazardous to replace.

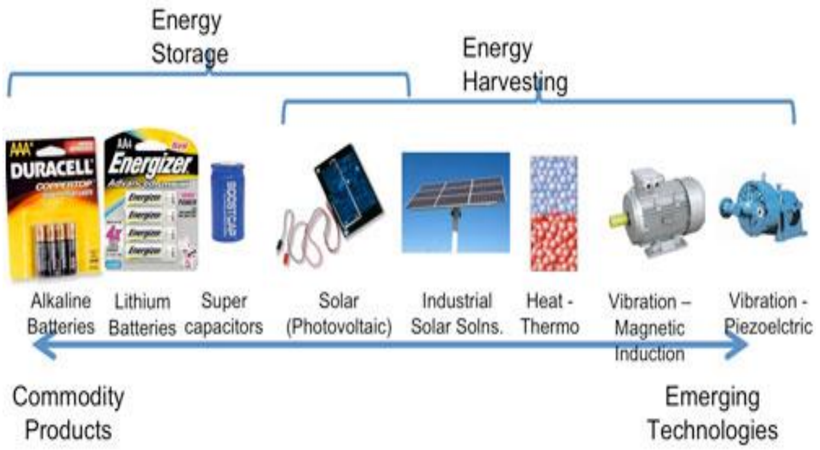

Fig.1: Hierarchy of main energy harvesting technologies

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Conversely, obtaining power through conventional means has detrimental effects on the environment. The extensive combustion of hydrocarbon-rich fossil fuels leads to the release of a substantial number of harmful particles into the atmosphere, including carbon dioxide and carbon monoxide, which contribute to global warming [11]. There exist a variety of energy resources, which can be classified into two categories:

- Renewable Energy Resources
- Non-Renewable Energy Resources

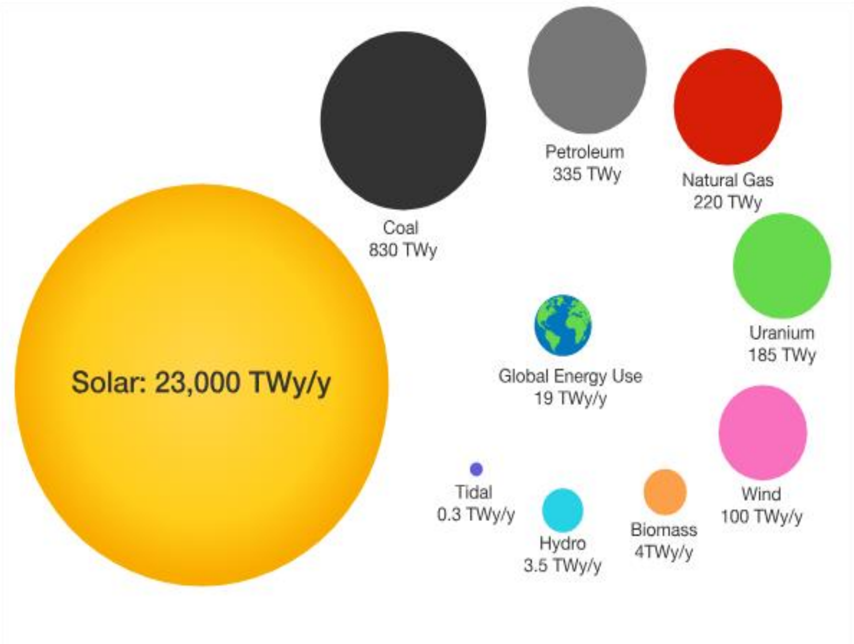

Fig. 2: Sources of energy

Moreover, within the realm of renewable energy resources, there exist numerous sources that hold significant importance for our future well-being, particularly considering the depletion of non-renewable resources. Fossil fuels, in particular, have a detrimental impact on the environment and human health, primarily due to the release of harmful gases into the atmosphere.

2. Literature Survey

Johan J. Estrada-López et al., the authors discuss the continuous development of the Internet of Things (IoT) paradigm and its advancements resulting from collaborative efforts between the industrial and academic communities. The paper begins by presenting a generalized structure for IoT end-nodes and highlighting the main characteristics of Power Management Units (PMUs) for energy harvesting. Subsequently, the authors provide an overview of existing published works on multisource power harvesting, examining their key advantages, disadvantages, and performance comparisons. The paper concludes by identifying open areas of research in the field of multisource harvesting [6].

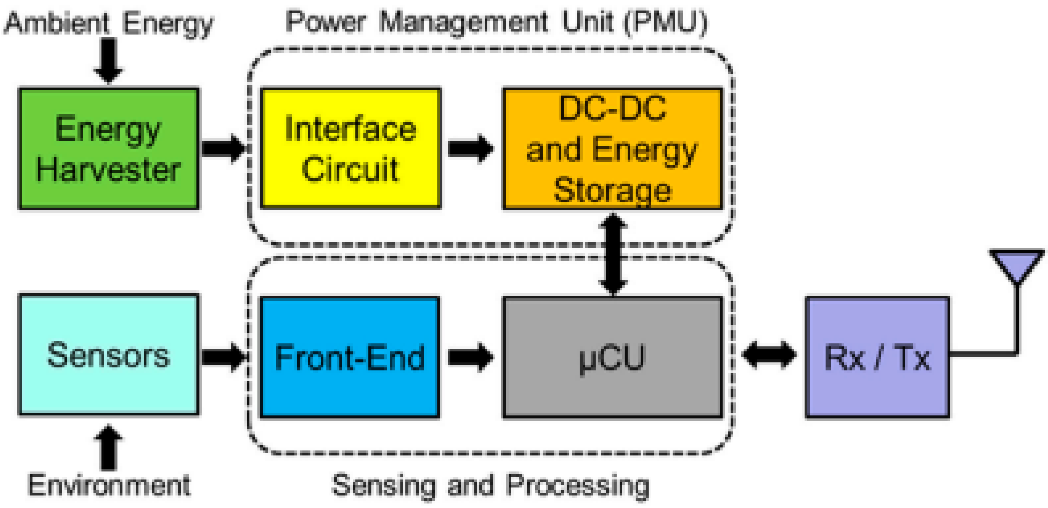

Fig.3: Block diagram of an IoT end-node

Huan-Liang Tsai et al. conducted a study that focuses on the implementation and verification of models for thermo-electric cooler and generator modules using MATLAB/Simulink. Their proposed models are designed with user-friendly icons and dialog boxes, similar to Simulink block libraries, which enhance their usability for simulation, analysis, and optimization in various applications [10].

Hiba Najini et al: In this research paper, a technical simulation-based system is introduced to support the concept of harnessing energy from road traffic using piezoelectric materials. The proposed system design structure takes into account the principles of material sciences for piezoelectric generator modeling and the field of power electronics for incorporating additional components to achieve realistic outcomes. Moreover, the system ensures seamless integration with vehicle performance, as it utilizes the kinetic energy released from vehicles and converts it into electrical power. This energy is harnessed by capturing the strain generated by vehicles traveling over asphalt road surfaces [7].

Anjali Prabhakaran et al: The tracking of the maximum power point in a photovoltaic (PV) system poses challenges due to the nonlinearity of the I-V characteristics, which are influenced by temperature and irradiation conditions. To address this issue, this research paper introduces the application of sliding mode control for controlling the photovoltaic system. Specifically, an open circuit voltage maximum power point tracking (MPPT) technique is employed. The system comprises a PV panel, a DC/DC boost converter, a load, and a control unit that generates a pulse width modulation (PWM) signal for the boost converter. The open circuit voltage-based MPPT method utilizes the open circuit voltage to determine the maximum power output voltage. The method offers several advantages, including high efficiency, accurate tracking, fast convergence speed, and robustness against changes in weather conditions [8].

Aryuanto Soetedj et al: In this research paper, the authors present a MATLAB Simulink-based model for wind energy systems. The model incorporates the maximum power point tracking (MPPT) technique to optimize power extraction from wind energy, considering the non-linear characteristics of wind turbines. The model comprises a wind generation model, converter model, and MPPT controller. Notably, the paper's main contribution lies in the detailed modeling of the DC-DC converter (specifically, a buck converter). This comprehensive modeling allows the MPPT controller to adjust the converter's input voltage, effectively tracking the wind generator's maximum power point. Simulation results demonstrate the model's compliance with theoretical expectations. Additionally, the MPPT control mechanism exhibits higher power output compared to the system without MPPT, highlighting its efficacy [9].

3. Methodology

3.1 Piezoelectric Model: Piezoelectric energy generation involves harnessing the strain induced by vehicles traveling over asphalt road surfaces, which is caused by gravity and the kinetic energy of moving vehicles. The vibrations generated by moving vehicles result from the imbalance caused by the tire strain on gravel roads [11].

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To capture and utilize this energy, piezoelectric transducers are well-suited as they can convert compression forces into electrical output. Piezoelectric materials exhibit the property of producing electrical energy when subjected to compression, making them an ideal choice for such applications.

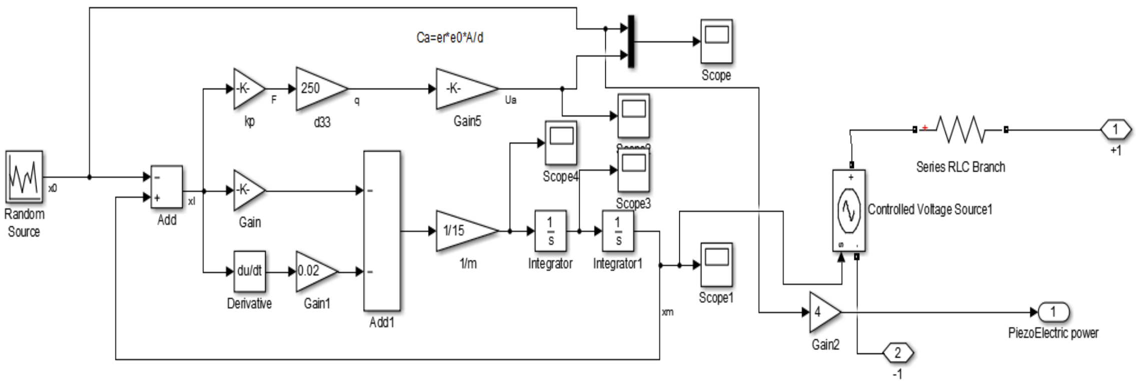

Fig.4: Simulink model for piezoelectric

The Random Source block generates a random signal with either a uniform or Gaussian distribution. The output repeatability of the block can be set to three different options: Non-repeatable, Repeatable, or Specify seed. In the Non-repeatable mode, the block selects a new initial seed randomly each time the simulation starts. This means that the output of the block will be different for each simulation run. In the Repeatable mode, the block selects an initial seed randomly once and then uses the same seed for every simulation run. As a result, the output of the block will be the same for each simulation run. Alternatively, in the Specify seed mode, the block uses a specified initial seed every time the simulation starts, ensuring repeatable output.

3.2 Wind Turbine using MPPT: In recent times, the demand for renewable energy resources has experienced a substantial increase. Among the most popular options are wind energy and solar energy resources. Both of these sources offer numerous advantages, including their free and clean nature. However, it is worth noting that wind energy generally boasts a lower installation cost in comparison to solar energy. In a wind energy system, wind energy is harnessed and converted into electrical energy. The power output of a wind energy system is dependent on the wind speed, resulting in variability. Maintaining the maximum power output of the wind turbine under different wind speed conditions is a challenging task due to the nonlinearity of the wind turbine's characteristics [4]. Many research studies have been conducted to develop approaches for tracking the maximum power point of the wind turbine, which is known as MPPT (Maximum Power Point Tracking) control.

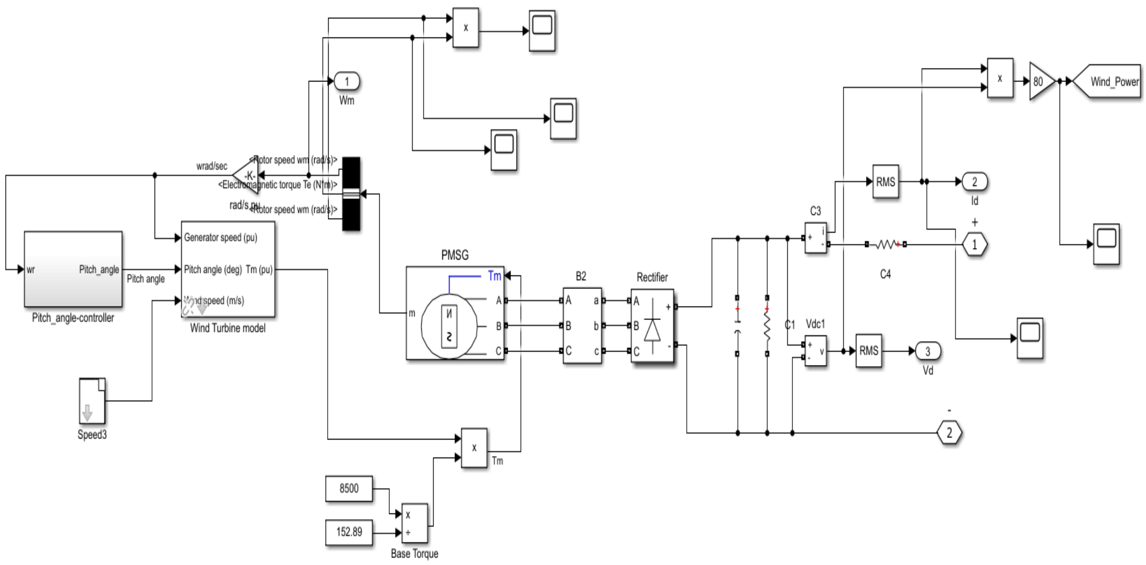

Fig.5: Simulink model for wind turbine model using MPPT

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Permanent Magnet Synchronous Machine (PMSM): The Permanent Magnet Synchronous Machine (PMSM) utilizes a wye-connected stator winding that is connected to an internal neutral point. The rotor configuration for a sinusoidal machine can vary, with options such as salient pole or round rotors. Various predetermined models are available for sinusoidal back electromotive force (EMF) devices.

3.3 Solar PV Panel Model: Photovoltaic generators exhibit a non-linear voltage-current characteristic with a distinct Maximum Power Point (MPP), which is influenced by temperature and irradiance conditions. As these conditions change, the operating point and MPP of the photovoltaic system also change [13], [15]. Hence, it is essential to employ a Maximum Power Point Tracking (MPPT) control method to ensure that the system operates at the maximum available power from the solar panel. The MPPT control technique enables the photovoltaic system to continuously track and adjust its operating point to optimize power output, maximizing energy harvest from the panel [18].

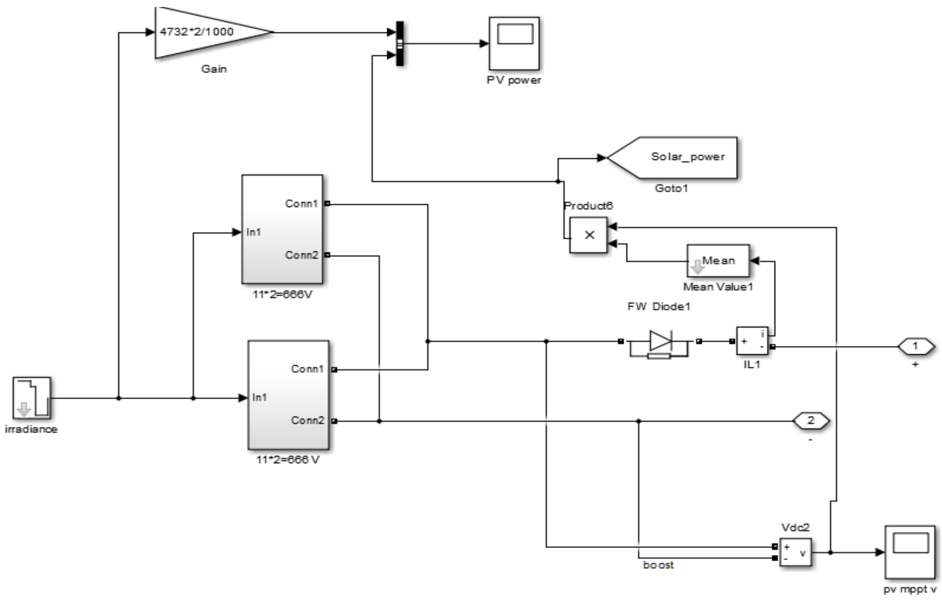

Fig.6: Simulink model for solar PV panel

3.4 Thermo Electric Model: Thermoelectric power generators have gained significant attention as a promising and sustainable green technology, thanks to their unique advantages. These generators provide a potential solution for the direct conversion of waste-heat energy into electrical power [20].

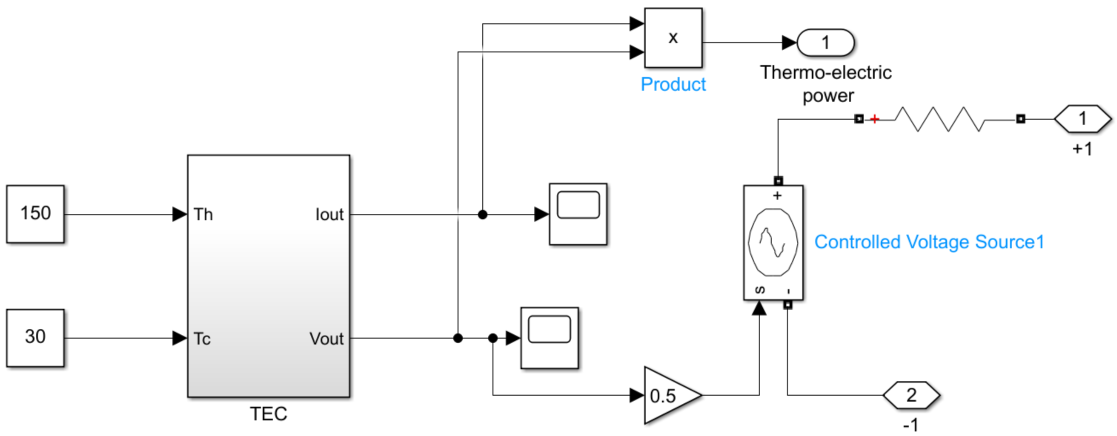

Fig.7: Simulink model for thermo electric system

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One of the key advantages of thermoelectric power generation is that it allows for the utilization of waste heat without the need to factor in the cost of the thermal energy input. This capability opens up new possibilities for efficient and cost-effective energy harvesting from various industrial and environmental sources, making thermoelectric power generation an attractive option in the pursuit of renewable and sustainable energy solutions.

4. Result and Discussion

SOFTWARE: MATLAB 2022b: The MATLAB software was chosen as the tool for designing our model due to its powerful capabilities in numerical computation and graphical output visualization. MATLAB provides a versatile environment that allows for work in various domains, including graphical user interface (GUI) development, fuzzy logic implementation, Simulink modeling, and scripting. This software provides a comprehensive set of tools and functions that facilitate the implementation of complex mathematical and computational tasks while offering intuitive graphical representations of the output.

Piezoelectric Model: The utilization of piezoelectric harvesters for ambient vibration-based energy harvesting has garnered significant attention among researchers, particularly for low-power wireless and self-sufficient applications.

Table 1 Piezoelectric based System Configuration

Sr. No	Parameters	Value
1	Stiffness of the piezoelectric material of the sensor (k)	2.21168122812721 5e+03
2	Electromechanical Coupling Factor	0.65
3	Elastic modulus of the piezoelectric element (Kp)	110
4	Piezoelectric coefficient of the piezoelectric element (D33)	250
5	Equivalent capacitance of the piezoelectric element (Ca)	1/2.412743157956961e+04
6	Gain1	0.02
7	Gain2	20

Table 1 represents the parameters taken care while designing MATLAB based Piezoelectric System for low power devices. In this system range of generated power is found 140-200 W

Solar PV Panel Model

Table 2 Power v/s Irradiance

Sr. No	Irradiance (w/m2)	Power (W)
1	**1000**	**115**
2	**950**	**110**
3	**900**	**100**
4	**850**	**90**
5	**800**	**80**

Wind Turbine using MPPT

Table 3 Wind Speed v/s Power

Sr. No	Wind Speed (m/s)	Power (W)
1	12	120-150
2	11	110-140
3	10	90-135
4	9	60-100
5	8	25-75

Table 2 represents the output in term of Power vs Irradiance for the designed solar system at various irradiance level and Table 3 represents the output in term of wind speed (m/s) vs Power (w) for the designed wind turbine system using maximum power point tracking at various speed (8-12 m/s).

Thermo Electric Model:

Table 4 Temperature at hot junction and cold junction v/s Power

Sr. No	Temperature at Hot Junction	Temperature at Hot Junction	Difference Temperature	Power
1	150	30	120	292
2	140	40	100	206
3	140	50	90	164
4	120	60	60	75.5
5	120	70	50	51.2

Table 4 represents the output in term of temperature difference vs Power (w) for the designed thermo electric system using see back effect at various temperature at hot and cold junction.

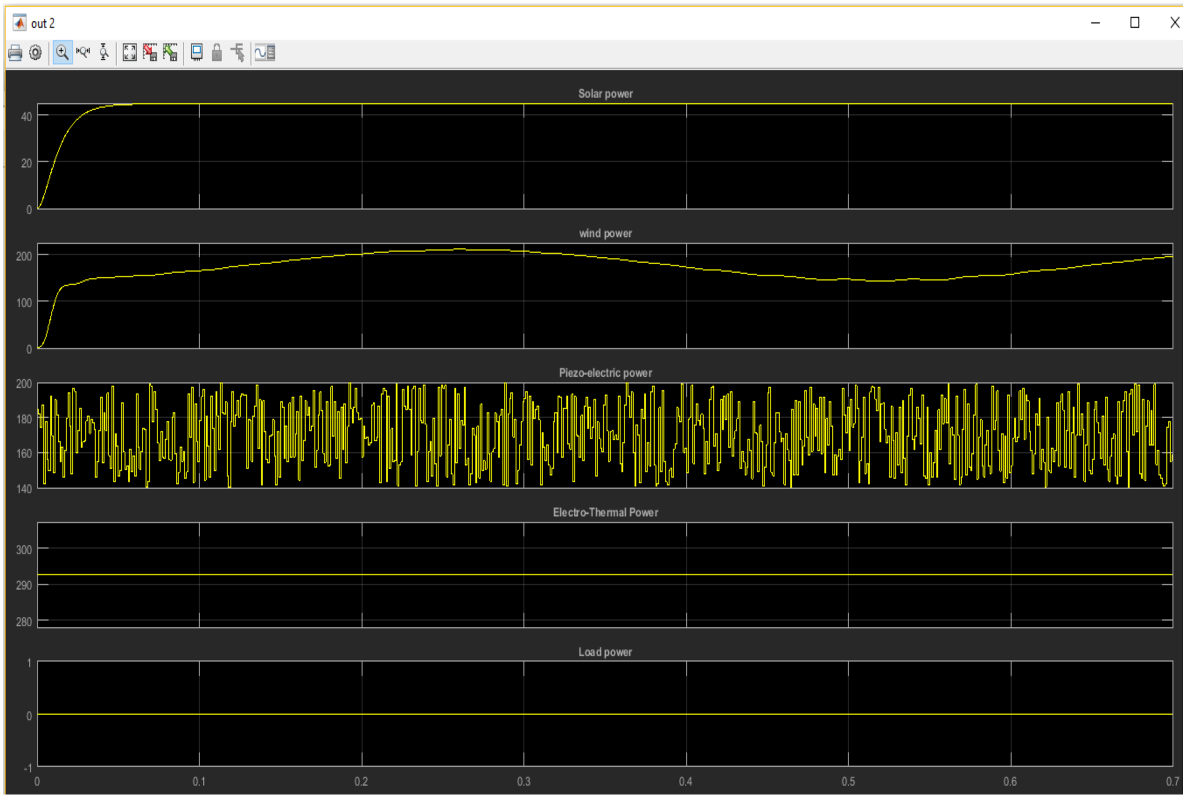

Fig.8: Simulation output for solar power, wind power, piezoelectric power, thermo electric power and load power

5. Conclusion

There is a wide range of energy sources classified as renewable and non-renewable. In recent times, the world has been increasingly focusing on renewable energy resources due to their numerous advantages. Two main types of energy systems are the on-grid and off-grid systems. In off-grid systems, energy harvesting plays a crucial role. Energy harvesting is an economically viable option, although the initial installation costs may be higher. It offers long-term cost-effectiveness. However, one of the major challenges is ensuring a consistent output since renewable energy resources may not be available or reliable at a specific location. In this research paper, an integrated approach is taken by utilizing multiple renewable energy resources, including solar energy, thermo-electric energy, piezoelectric energy, and wind energy. By combining these resources, a constant output can be achieved as at least one of the renewable energy sources remains active at all times. The entire system is designed and simulated using MATLAB Simulink. According to the design specifications, the harvested energy can be transferred to both large and small grids. The Simulink model has been successfully developed, and the harvested energy is capable of powering low-power devices. For future developments, there is a potential to integrate a radio frequency model into the system. Radio frequency energy is available continuously, which can further enhance the continuous output generation capabilities of the system.

References

[1.] Oh IH, Park E, Chang ST, Lim S, “Foldable RF Energy Harvesting System Based on Vertically Layered Metal Electrodes within a Single Sheet of Paper”, Advanced Materials. 2023 Mar 12:2300197.

[2.] Shuvo, M.M.H., Titirsha, T., Amin, N. and Islam, S.K, “Energy harvesting in implantable and wearable medical devices for enduring precision healthcare”, Energies, 2022, 15(20), p.7495.

[3.] Rajput, Shailendra, Moshe Averbukh, and Noel Rodriguez, "Energy harvesting and energy storage systems", Electronics 11, no. 7 (2022): 984.

[4.] Zheng, P., Qi, L., Sun, M., Luo, D. and Zhang, Z, “A novel wind energy harvesting system with hybrid mechanism for self-powered applications in subway tunnels”, Energy, 227, p.120446, (2022).

[5.] Ghandriz, Y., Noorbakhsh, S.M.Z., Gavagsaz-Ghoachani, R. and Phattanasak, M, “Effect of wide observation of nature in renewable energy engineering education”, In 2021 Research, Invention, and Innovation Congress: Innovation Electricals and Electronics (RI2C) (pp. 193-198). IEEE.

[6.] Sah, D.K. and Amgoth, T., 2020. Renewable energy harvesting schemes in wireless sensor networks: A survey. Information Fusion, 63, pp.223-247.

[7.] de Fazio R, Cafagna D, Marcuccio G, Minerba A, Visconti P. A multi-source harvesting system applied to sensor-based smart garments for monitoring workers’ bio-physical parameters in harsh environments. Energies. 2020 May 1;13(9):2161.

[8.] Eid A. Gouda, Mohamed. F. Kotb, and Dina A. Elalfy, “Modelling and Performance Analysis for a PV System Based MPPT Using Advanced Techniques”, EJECE, European Journal of Electrical and Computer Engineering Vol. 3, No. 1, January 2019

[9.] Johan J. Estrada-López, Amr Abuellil, Zizhen Zeng and Edgar Sánchez-Sinencio, “Multiple Input Energy Harvesting Systems for Autonomous IoT End-Nodes”, Journal of Low Power Electronics and Applications, 2018, 8, 6; doi:10.3390/jlpea8010006

[10.] Johan J. Estrada-López, Amr Abuellil, Zizhen Zeng and Edgar Sánchez-Sinencio, “Multiple Input Energy Harvesting Systems for Autonomous IoT End-Nodes”, Journal of Low Power Electronics and Applications, 2018, 8, 6; doi:10.3390/jlpea8010006

[11.] Hiba Najini and Senthil Arumugam Muthukumaraswamy, “Piezoelectric Energy Generation from Vehicle Traffic with Technoeconomic Analysis”, Hindawi, Journal of Renewable nergy Volume 2017, Article ID 9643858, 16 pages, https://doi.org/10.1155/2017/9643858

[12.] Hiba Najini and Senthil Arumugam Muthukumaraswamy, “Piezoelectric Energy Generation from Vehicle Traffic with Technoeconomic Analysis”, Hindawi, Journal of Renewable Energy Volume 2017, Article ID 9643858, 16 pages, https://doi.org/10.1155/2017/9643858

[13.] Kakarla Deepti, Dr. P. Srihari, Dr. Manjunadh Achari, “Design Analysis and Implementation of MPPT based Controlling Mechanism for improving the efficiency of Solar Photovoltaic based operated system”, 2017 11th International Conference on Intelligent Systems and Control (ISCQ)

[14.] Anjali Prabhakaran, Arun S Mathew, “Sliding Mode MPPT Based Control For a Solar Photovoltaic system”, International Research Journal of Engineering and Technology (IRJET), Volume: 03 Issue: 06 | June-2016

[15.] Md. Rokonuzzaman and Md Hossam-E-Haider, "Design and Implementation of Maximum Power Point Tracking Solar Charge Controller", 2016 IEEE iCEEiCT 2016

[16.] Anjali Prabhakaran, Arun S Mathew, "Sliding Mode MPPT Based Control for a Solar Photovoltaic system", International Research Journal of Engineering and Technology (IRJET), Volume: 03 Issue: 06 | June-2016

[17.] K. Sundareswaran, V. Vignesh kumar, S. Palani, "Application of a combined particle swarm optimization and perturb and observe method for MPPT in PV systems under partial shading conditions", Renewable Energy 75 (2015) 308e317, Elsevier Ltd.

[18.] M. Abdulkadir, A. H. M. Yatim, and S. T. Yusuf "An Improved PSO-Based MPPT Control Strategy for Photovoltaic Systems", Hindawi Publishing Corporation International Journal of Photo energy Volume 2014, Article ID 818232, 11 pages

[19.] Aryuanto Soetedj, Abraham Lomi, Widodo Puji Mulayanto, "Modeling of Wind Energy System with MPPT Control", 2011 International Conference on Electrical Engineering and Informatics, 17-19 July 2011, Bandung, Indonesia

[20.] Huan-Liang Tsai, Jium-Ming Lin, "Model Building and Simulation of Thermoelectric Module Using Matlab/Simulink", Journal of Electronic Materials, ISSN 0361-5235, Volume 39, Number 9, September 2010