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HYBRID OPTIMIZATION OF PIEZOELECTRIC WIND TURBINE AND PHOTOVOLTAIC SYSTEM

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Abstract

The demand for electricity is increasing day by day and the natural reserves of non-renewable fuels are rapidly diminishing. To avoid these energy crises, alternate energy source market is unavoidable which includes the wind energy, solar energy as well as the energy from vibrations (Piezoelectricity). There are numerous ways to provide the required pressure/vibration to the piezoelectric material. This paper proposes a hybrid simulation model that uses two energy sources which are wind and solar energy. The output from the piezoelectric system is converted to DC by a DC-DC converter. The solar panel is employed with a Maximum Power Point Tracking (MPPT) technique which ensures the maximum output from solar energy at all times. The output from both the solar panel and the piezoelectric system is stored in a battery which provides to DC loads directly and to AC loads through an inverter.

Keywords : MPPT,DC-DC converter, PEWT, PV Energy.

1. Introduction

The hybrid systems of two or more non-conventional energy sources are a popular trend nowadays due to their advantage of continuity of supply, reliability, and capability to supply increased loads. The researchers have conducted numerous study on hybrid models consisting of different energy sources during recent years [I-X]. The popular among these energy sources are solar, wind and pressure or vibrations. Solar energy is used to generate electricity by photovoltaic cells or units. The vibrations which usually go wasted in so many forms (walking, transportation on roads, dynamic fluid flow, and windvibrations) can be utilized by using piezoelectric material which converts mechanical pressure into electricity. But the power output from such a piezoelectric system utilizing wind [IX] is usually very small and cannot power bigger loads. Similarly, the kinetic energy from wind is captured by a device called wind turbines which converts it to mechanical energy which is converted in electricity by a generator. But these arrangements for generating power [X] have the problems of huge size and heavyweights of windmills. The tower which supports the windmill/turbine and its associated structure is usually 100 meters high with the blade radius for windmills of nearly 60 meters, whereas, the area required for operation is huge. Also due to the heavy weight of components and tower height, transportation and installation cost is very high. With these limitations, researchers have been looking for alternative approaches to utilize wind energy instead of conventional windmill setup which has the issues of high cost and greater maintenance required. Considering the problems associated with these two energy sources, the alternative conclusion with possible solution is to combine these two sources. That is to say, if the linear vibrations from the windmill placed at a comparatively lower height are delivered to piezoelectric materials, an increased output can be obtained with the additional advantage of elimination of windmill supports which reduces the transportation cost and maintenance required by a great extent.

II. Literature Review

The authors in [XI] present a model which utilizes the dynamic fluid flow of wastewater with the aid of piezoelectric material to generate electricity. The flange coupling inside the pipes house the piezoelectric patches which are further connected to the electrical circuit. A water tank is used to store and supply water to the system and a motor is used to recirculate the flow of water. In [XII], a detailed review of sources is given which provide pressure for piezoelectric material to be converted in electrical energy. Pressure from sea waves, walking, transportation on roads, wind, from raindrops impact and dynamic fluid flow are studied as potential sources of input to the piezoelectric material. Different ways of generating electricity from vibrations and pressure on roadways, bridges, and railways using piezoelectric material in [XIII], [XIV] and [XV]. The authors in [I] proposed a hybrid model in which the output from a solar panel and wind turbine was controlled and stored in the battery from where it was provided to both AC and DC loads. The study in [X] aims to design a model for a piezoelectric wind turbine which uses a Savonius type rotor and bimorphs actuators for electromechanical energy conversion and is targeted to operate near ground level where wind speed is comparatively low. The simulation model in [2] is the hybrid system of solar and wind with

Maximum Power Point Tracking (MPPT) for solar panels which ensures maximum output from the panels at any time in the day. The research in [16] develops a practical piezoelectric wind turbine to harvest energy from wind which first converts the kinetic energy of wind into the rotational motion of shaft and then employs a Scotch yoke mechanism to convert the rotational motion into linear vibrations which they are utilized by two piezoelectricity-levers to generate electricity [I-III]. The comparative study of different modeling methods for piezoelectric wind energy harvester including single-degree-of-freedom (SDOF) model, the Euler-Bernoulli distributed parameter model using single mode and the Euler-Bernoulli distributed parameter model using multi-modes is presented with experimental results in [III, XVII] and the effects of load resistance, wind exposure area of the bluff body, mass of the bluff body and length of the piezoelectric sheets on the power output are also studied. The authors in [IX] used an alternate approach to utilize wind energy without using wind turbine or conventional windmill with piezo bimorphs. In [9], the experiment was carried out to convert wind vibrations directly into electrical energy by using large piezoelectric discs and across each disc was connected a supercapacitor with a very small charging time. The output from this discwas amplified and added and then stored to a 5V battery. On this, low scale power output was small but by using larger and greater num. of disc x1for large scale applications areas of high wind potential, power output will increase. The author in [XVIII] present design of a tree-shaped hybrid Nanogenerator (TSHG) which consists of leaves with thin films of piezoelectric and PV fixed on them in a way that these generators can simultaneously use both solar and wind energy to generate small amount of power which is enough to power a small electronic device which was not possible by using only piezoelectric films whose collective output was very small incapable of powering any device. The power output from piezoelectric films, regardless of its magnitude, is used to charge a capacitor through the rectifier. Similarly, the output from solar films is used to charge the same capacitor by-passing any rectifier. This capacitor is then discharged through a small load. The proposed work is inspired by [II].

III. Proposed Simulation Hybrid Model Of PEWT and PV System

Figure 1 shows the structure of hybrid piezoelectric wind turbine and PV panel. The power generated from a piezoelectric wind turbine is generally involved three steps. Firstly, the kinetic energy of the wind turbine is converted into rotational mechanical energy of wind turbine; secondly, the rotational motion is converted into linear vibration through the scotch mechanism of two piezoelectricity levers through springs, and then linear vibration is converted into electrical energy due to piezoelectric effect [II, XVI]. The PV system generates DC power which is feds into the maximum power point tracking system through the dc-dcconverter after this is fed to an inverter which converts dc into the ac supply which is further utilized by the AC loads. In this process, one parallel battery charging unit is used for charging the battery for dc loads. Table 1 shows the specifications of parameters used in modeling.

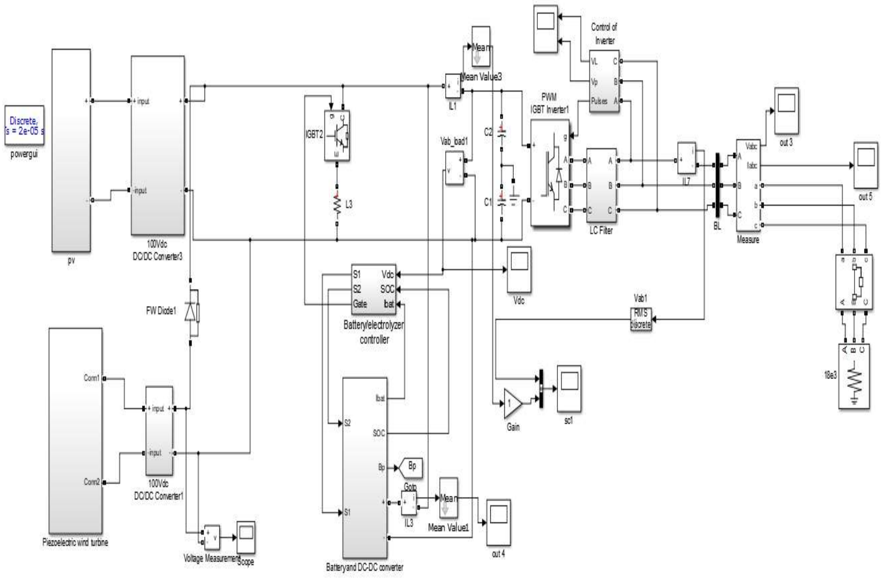

Figure. 1. Hybrid piezoelectric wind turbine and PV system

Table 1. Proposed hybrid power system parameters

s. no	Names of Parameter	Parameters specification
1.	Speed of wind	7.2 m/s
2.	Angular speed	50 rad/s
3.	Tip speed ratio (λ)	6.91
4.	Power coefficient (Cp)	0.44
5.	PEWT output power	3kW

6.	PV system output power	10kW`
7.	Battery	200V, 6.5Ah, NiMH battery
9.	Connected Load	10kW
10.	Line voltage	400V
11.	Frequency	50Hz
12	Inverter	Snubber Resistance=5 k Ω, Ron= 1m Ω

The mechanical power output of the turbine is given by [19]

$$Pw = \frac{1}{2}\rho A V^3 Cp(\lambda) \quad (1)$$

where V is the wind velocity, ρ is air density, A is swept area, and R is the blade length of the turbine

The value of power coefficient is not the static it varies with respect tip speed ratio λ, of the turbine and it is given by

$$\lambda = R\omega/V \quad (2)$$

The power produced by a piezoelectric wind turbine is calculated by using

$$P = \frac{\frac{1}{2}\sigma^2 k^2}{2c} \quad (3)$$

where is the applied stress through the scotch mechanism, k is coupling coefficient, c is elastic constant. (and k are the material properties).

IV. Simulation Results and Discussions

The aero-electromechanical energy conversion in a piezoelectric wind turbine depends on two factors: first; vibrational frequency or ultimately wind speed and second; numbers of bimorphs. The proposed equivalent circuit model of Hybrid piezo-electric wind turbine and PV panel is verified through Matlab/Simulink. The total installed capacity of the PV/PEWT/BESS hybrid system is 10kW. The results are shown separately.

(A). Voltages and current waveforms. Fig.2 and Fig.3 show the three-phase output voltage and current across the load terminal, from the results we can observe that there no harmonics are generated due to a proper connection.

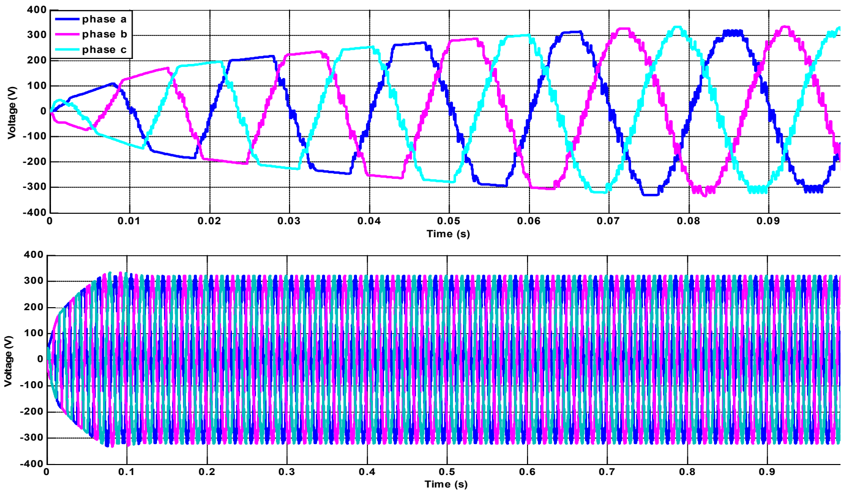

Figure. 2. Load voltages

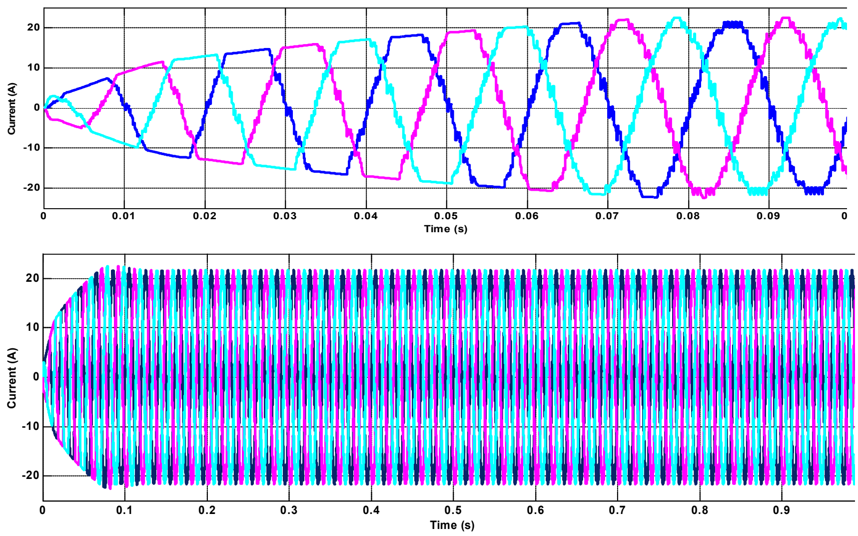

Figure. 3. Load current

(B). PV system parameters waveforms

Fig.4 and fig.5 shows the PV power with MPPT technique and output voltage

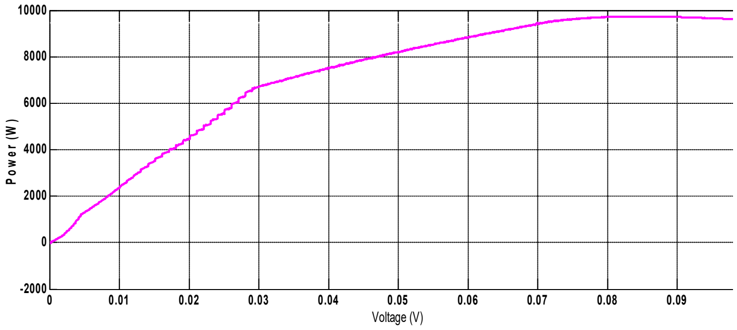

Figure. 4. Power and Voltage characteristics of the PV system

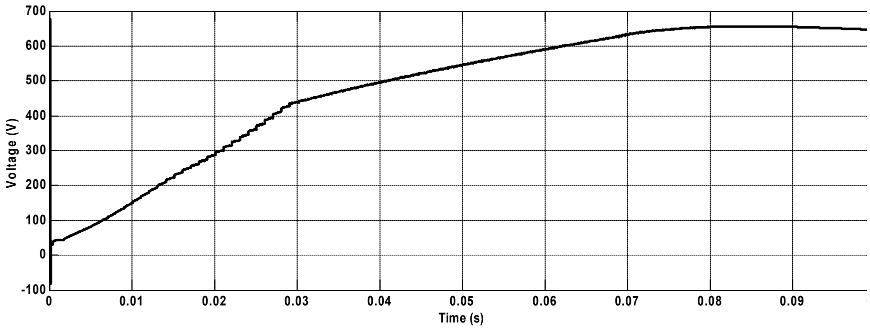

Figure. 5. Output voltage of PV system

(C). Piezoelectric wind turbine voltage

Fig.6 shows that output voltage from PEWT after the rectifier and dc-dc converter. The constant 88 volts are generated ongoing.

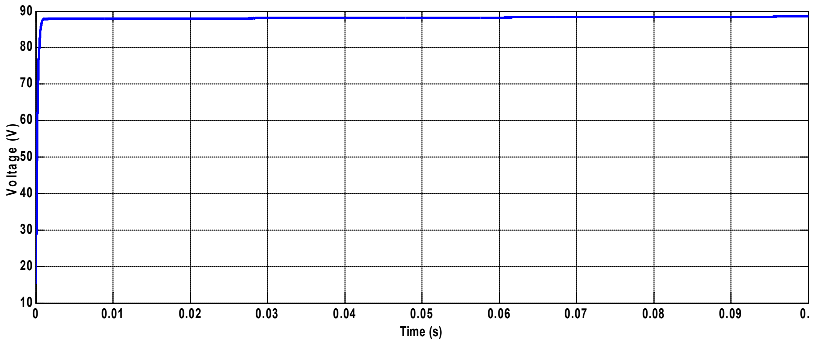

Figure 6. Output voltage of PEWT

(D). Battery Energy Storage System (BESS)

In Fig. 7 percentage state of charging (SOC) can be seen, which shows the charging and discharging behavior of the battery, and battery output voltage.

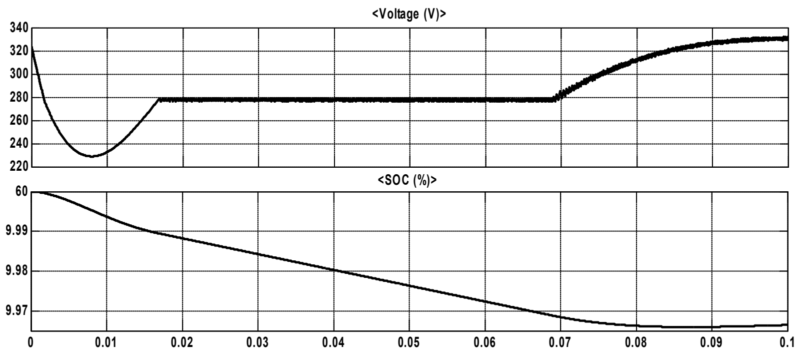

Figure 7. Battery out voltage and state of charge (SOC)

V. Conclusion

In this research, simulation of the hybrid piezoelectric wind turbine and PV system is presented. The modeling of the integrated power system with dc-dc converter, three phases PWM inverter, and LC filter are developed using Matlab/Simulink. The aim of the hybrid modeling is to increase the reliability in power to electrical network and to reduce the capital cost of generating power. The conventional wind turbines are designed to operate at lower effieceieny tha the rated, hence power output is less thatn the rated output. In the proposed model, the pizo electric wind turbine can be designed to oprertae at effieceiny closer to the rated effieceieny. Therefore, the uotput power will be near to the rated output.

VI. Future Scope

The future scope of this research will be arranged towards the optimization design of PEWT/PV/BESS in order to limit the sizing, cost and guarantee the framework stability. Further that, if the wind energy is additionally used as a separate energy source, the proposed model can give significant results.

VII. Acknowledgements

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