ISSN 2347 - 3983
Volume 8. No. 5, May 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter67852020.pdf
https://doi.org/10.30534/ijeter/2020/67852020

A Hybrid Photovoltaic-Wind Electricity Generation for Street Lighting

Agus Ulinuha[1], Gunawan Ariyanto[2], Septian Dhimas Prasetyo[3]
[1]Dept. of Electrical Egineering, Universitas Muhammadiyah Surakarta, Indonesia, Agus.Ulinuha@ums.ac.id
[2] Dept. of Informatics, Universitas Muhammadiyah Surakarta, Indonesia, Gunawan.Ariyanto@ums.ac.id
[3] Dept. of Electrical Egineering, Universitas Muhammadiyah Surakarta, Indonesia, septian.dhimas17@gmail.com

ABSTRACT

Electricity has become essential need of human being. The generation of electricity is primarily based on electromechanical energy conversion that so far uses fossil-based resources. The increase demand of electricity forces extensive exploration of fossil fuels causing significant reduction of fuel deposit. Another effect of burning a lot of fossil fuels for electricity generation is environmental problem in the form of pollution. It is therefore necessary to substitute electricity generation using renewable energy resources. Renewable energy is extensively available and has not been intensively utilized for electricity generation. Electricity generation using renewable energy resources is still in the beginning stage and has not taken dominant part on electricity supply. However, the quality of electricity generated using renewable energy resources may not be fully acceptable for grid connection. Therefore, for some cases, they are operated as stand-alone unit to supply a specific load. This paper presents a small-scale hybrid photovoltaic-wind power generation to supply a LED lamp for street lighting. A 50 WP solar panel is combined with a wind driven modified synchronous generator to supply a battery. A controller is utilized to assure that power flows charging the battery and blocks power flowing back or circulating current. This combination enables to light up a 10 Watt LED lamp along the night. Compared with the only wind driven generator, this combination enables supply the light longer. This prototype may be extensively used for street lighting and its massive using is expected to reduce electricity demand in a regional level.

Key words: Hybrid System, Modified Synchronous Generator, Photovoltaic Panel, Stand-alone, Street Lighting, Wind Generation

1. INTRODUCTION

Electricity is one of the most important energy needed by human being. The activity of people currently might not be separated from the use of electricity. In a more extensive perspective, the electricity supports development for a country, since it is used in industries and other sectors that support the country development. For this reason, the use of electricity tends to increase, and this increment needs to be fulfilled by either intensifying the existing generation units or establishing new power plants. Since the power plants normally use fossil fuels to operate, increasing the generation capacity or building new power plant will increase the consumption of fuels. As a result, this will significantly reduce the fuels deposit that may cause limited fuel left for the next generation.

There is awareness of some countries to use alternative energy to generate electricity. Alternative energy is normally in the form of renewable energy. This is the resources that are naturally replenished. Even though generating electricity using renewable energy has not taken significant part in supplying electricity demand, massively using these resources will contribute some reduction of fossil fuel consumption. The extensive availability of renewable energy resources in one hand, and the increasing awareness of utilizing it, on the other hand, will simultaneously improve the situation in supplying electricity demand using renewable energy resources.

It is broadly accepted that electricity generation using renewable energy is the key for sustainable energy supply since it is either inexhaustible or nonpolluting. Some technologies for exploring renewable energy for electricity generation are now available, such as wind power, photovoltaic, solar thermal systems, biomass, and various forms of hydraulic power. According to the report of REN21 2014, renewable resources contributed 19 % of worldwide energy demand and 22 % of electricity generation in 2012 and 2013, respectively [1]. The trend of using renewable resources for electricity generation seems to increase in the future.

However, a number of problems may be encountered of using renewable energy generation. Some factors such as capacity, supply continuity, as well as uncertainty are the problems that may arise of using renewable energy for electricity generation. The capacity of renewable power plant is normally smaller than that of conventional fossil fuel power plant. Furthermore the continuity of supplying the demand and the uncertainty of power quality will be the other problems [2]. Another challenge to overcome of using power from renewable energy generation is how to perfectly synchronize the output power to the electricity network [3]. The aforesaid problems are due mainly to the characteristic of renewable energy generator, which depends on the availability of resources. In a power system with high contribution of renewable energy source, uncertainty and continuity are the main concerns of system planning and operation [4].

Considering the abovementioned difficulties, some strategies may be proposed. This may be in the form of employing renewable energy generation as a stand-alone generation unit supplying specific load(s). Since the availability and quantity of the resources is different, combining different resources to expand the capacity will elongate the supply [5]. The next improvement of the scheme is power conditioning of renewable energy generation output to be acceptable for grid connected system [6]. Power electronic devices will be used to customize the generated power such that it may be synchronized to the existing grid and contribute supplying the common load. Nevertheless, it should be noted that employing power electronic devices will cause system distortion in the form of harmonic pollution [7].

In Indonesia, electricity demand is fulfilled by power plants mainly using non-renewable resources and partly using hydropower. The current situation may be described where the generated power is sometimes insufficient to supply all the demand leading to disconnection of electricity supply to some customers. This is called as load shedding and this decision is carried out to avoid system black out because of persistent frequency decrease [8]. Looking ahead the situation where, in one hand, the inadequacy of power generation capacity to supply the load, and, in other hand, the high cost of generating power using fuel power plant due to the constantly increasing oil price, the use of renewable energy generation is expected to take more place.

This paper presents the design and implementation of Hybrid Photovoltaic-Wind power generation to supply the street lighting. This is stand-alone renewable energy generation to provide power for a specific load. The hybrid system is selected to enable longer energy supply; solar energy is unavailable in the evening while the intensity of wind power is normally unstable [9]. This combination is expected to complement each other in generating higher power more continuously. Lighting for the street is about a problem in Indonesia. Since the power is not really sufficient during the peak time at night, the lighting for the street may not be of high priority. On the other hand, the traffic during the night is still high in Indonesia. The low illumination intensity in a heavy traffic may lead to frequent traffic accidents. The real system has been constructed and tested indicating the capability to provide the lighting along the night.

2. LITERATURE REVIEW

The fuel price that tends to increase has motivated people to consider using different type of energy for their life. Another reason is that intensive exploitation of fossil-based resources may lead to fast reduction of fuel deposit and gives nothing left for the future generation. Electric power will be the alternative choice of energy that people use more to substitute the fuel-based energy source.

This will lead the demand of electricity to increase and requires power plant to generate more power in satisfying the demand. If the electric power generation still depends on fossil fuels then there is no significant benefit of changing from fossil fuels to electric power since the additional electric power demand requires more fuels to generate and, therefore, the fuel consumption at national level will not be lower. On the other hand, taking more fossil fuels for electric power generation does not support natural conservation. It is required to generate power using different type of resources preferably renewable resources so that the electricity demand can be fulfilled with less cost with better environment preservation.

This is a growing concern on employing renewable energy resources to answer the aforementioned reasons. However, the use of renewable energy for electricity generation has not taken a major part in the world. While the accurate data may not be available; it may be recognized a global trend to use more renewable energy for electricity generation. The estimation of using renewable energy in 2040 will be nearly 25% [10], [11]. Indonesia is very rich with renewable energy resources yet have not been used optimally. The government policy on renewable energy states that by 2025 about 17 % of energy demand must be supplied by renewable energy resources [12].

Renewable Energy Generation (REG) is a well-researched topic. The research on this area focuses on two perspectives: theoretical analyses of REG and real implementation of REG units. Theoretical discourse of REG may include analyses of equipment employed for generating electricity powered by renewable energy sources, stochastic analyses of REG, inclusion of REG to the conventional power system, combination of different REG types, and the influence of REG inclusion on system control and improvement.

Some models of wind power generation are already available, including how the wind driven generator is included in power flow calculation [13]. Some models are presented, and the detail mathematical formulations are included. Another study about the wind power is the impact of wind speed on bus terminal voltage for different wind power model [14]. The inclusion of stochastic behavior of wind power generation and how it is taken into calculation has also been discussed [15]–[17]. Another study is about the impact of wind power inclusion on system operating condition [18]. Integrating wind power generation in the existing system by determining the optimal number and location is analyzed with the objective of achieving maximum benefit on social welfare [19].

Application of renewable energy generation is normally performed in a big scale project [20] or it is developed in a country level [21]. In some countries, a home scale electricity generation using PV starts to be common [22], [23]. The house is normally equipped with two-way meter (net meter) that indicates the net power consumed by the household, which is the different between the power taken from the grid and the PV generated power supplied to the grid. Another type of energy measurement is bi-directional meter consisting of two non-communicating meters that respectively measure the incoming power from the utility and PV generated power sent to the grid.

Another scheme to accommodate renewable energy generation to contribute the wider energy demand is microgrid [24]. It is a local and independent power system that generates, distributes, stores and controls the electric power flow. It is basically a smaller-scale version of the main grid and can operate either in combination with the larger system, or in "islanded mode." Where necessary and practical it can also be switched between the two. Like it's larger system, a microgrid can also draw power from non-renewables and renewable sources or a combination of the two. The more this microgrid is optimized for the use of renewable inputs, the lower its environmental impact and long-term costs of operation become.

While the aforementioned situations indicate a good future in satisfying electricity demand more economically and environmentally friendly, the capability of every country to progress accordingly seems to be different. On the other hand, the availability of renewable energy resources varies in some countries. It is therefore necessary to start utilizing the resources for electricity generation even for small and isolated load. This paper presents the combination of PV and wind power generation for supplying the street lighting load. While the generated power may be used for different load type, the choice of street lighting is based on consideration that some streets and roads in Indonesia are not equipped with proper lighting. This is may be due to the lack of electricity at the peak time at the evening and, as a result, the electricity is more dedicated to priority loads. Whereas, in some streets the activity is still heavy in the night, and less lighting may lead to more frequent traffic accident. This work is expected to practically contribute the fulfillment of electricity need for important load.

3. DESIGN OF HYBRID PHOTOVOLTAIC-WIND POWER GENERATION

Indonesia is tropical country where geographically has sufficient sunlight and wind power. These two natural resources may be used to generate electricity using different type of power generator. The hybrid PV-wind power generation includes two type of power generator, i.e. wind power generator and solar power converter. The combination of these power generation units is aimed to improve the supply sustainability and to increase supply capacity. The combination of the two generations may be presented the diagram of figure 1.

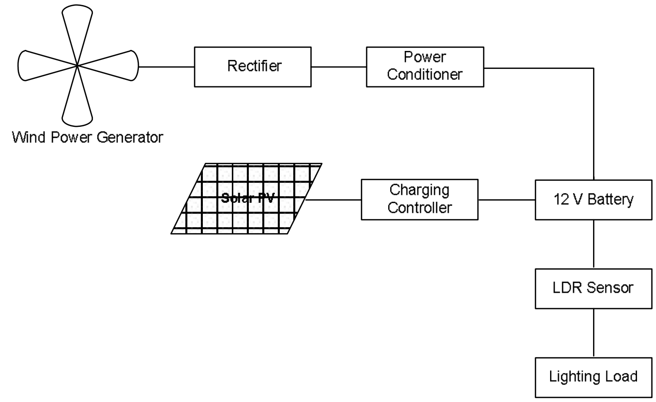

Figure 1: The hybrid scheme of Wind-Solar PV

The combination of Wind Generator and Solar PV enables the system supplying the load longer compared with that employing only one type of power generator. This is due to the complement mechanism of the two power generations. Solar PV will supply the storage at daylight when the intensity of sunlight is sufficient. The generated power tends to be more stable, since the sunlight intensity is about constant. However, PV may not supply the power when the light is unavailable, mainly during the night. On the other hand, wind generator may produce power as long as wind flow is available. However, the wind speed characteristic is normally stochastic causing the power output is not constant. This combination enables the power supply higher and more sustainable.

Different with solar PV equipped with charging controller that may assure voltage and current flowing to the storage more stable and acceptable, wind power with stochastic characteristic suffers from voltage variability. Therefore, wind power generator is equipped with rectifier and power conditioner. The rectifier converts the generated ac voltage into dc voltage. It uses 2 diodes and a capacitor. The magnitude of voltage is then customized to ensure the current can flow from generator to the storage. The power conditioner uses IC7812 and capacitors for customizing the variable voltage into the regulated 12 V. Moreover, the rectifier is designed to enable blocking the reverse current from the battery to the generator. The design of rectifier and power regulator is given in figure 2 and figure 3, respectively.

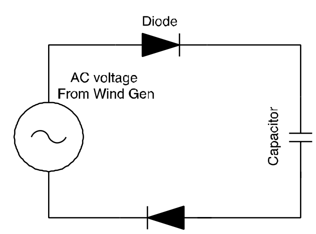

Figure 2: Rectifier used in this system voltage controller

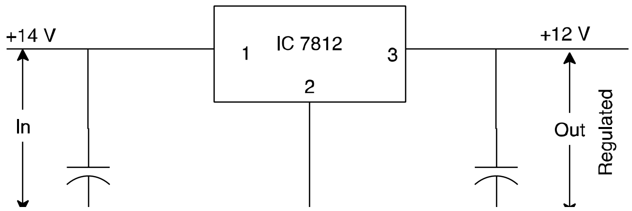

Figure 3: Voltage controller used in this system

For the developed hybrid system, the wind generating system uses a modified synchronous generator. The generator is built form induction motor with modification on permanent magnet and number of winding so that it enables to generate maximum power of 25 W, 1.0 Amp. The solar PV has the capacity of 50 WP equipped with 12 V charging controller ensuring the voltage magnitude that enables power flowing to the storage[25]. The capacity of the battery is 5 Ah with the nominal voltage of 12 V. This battery is used to supply the 10-Watt DC LED light through an LDR sensor to switch the light on in the dark situation. To drive the synchronous generator, a wind propeller with 4 blades is used. The system is mechanically supported with a 3-dm metal, with the high of 4.5 m. The system costs very low and is suitable for massive production and application. For measurement purpose, some equipments are used, including multimeter, anemometer and luxmeter. The implementation of design is shown in figure4.

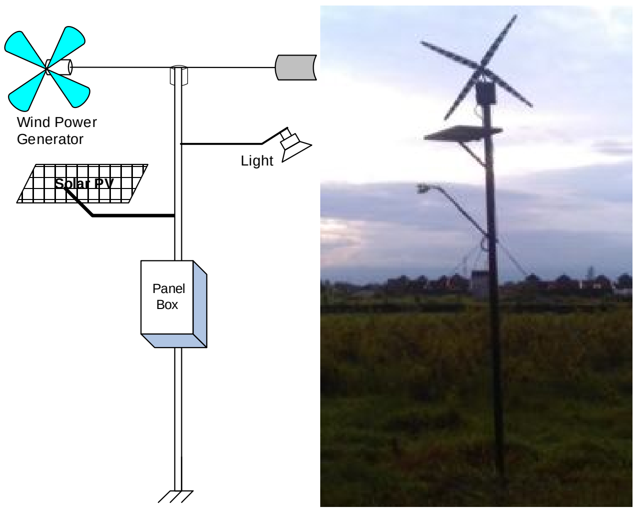

Figure 4: The hybrid scheme of Wind-Solar PV

4. RESULTS AND DISCUSSION

The system as shown in figure 4 is tested for the real environment. The measurements were carried out during 10 am – 3 pm considering that the sunlight intensity is enough, and the wind speed is capable to rotate the wind blades. Please be noted that power generation takes place along the day. The Solar PV generates power as long as sunlight with sufficient capacity is available and the Wind Power Generator will generate power when the wind speed is enough for 24 hours. They both supply the power to the battery and the saved energy will be used by the light to be on during the night. The duration of the light "on" was also observed.

The measurement is separately taken for Solar PV and Wind Power Generator. The data from Solar PV is given in Table 1 and the relation between the results is shown in Figure 5. Since the data is presented in the different scale, to show the trend, the data are plotted in stacked lines. It might be the most suitable way to indicate how the data are correlated each other. It may be seen from the figure that the light intensity determines the voltage. The voltage is sufficient to enable power flowing from the panel to the battery. For the given battery capacity, the current magnitude during the measurement period indicates significant contribution from the panel in supplying energy to be saved in the battery.

Table 1: Data from Solar PV measurements

Hour	Light Intensity (Lux)	Voltage (Volt)	Current (Amp)	Power (Watt)
10:00	49.404	19	1.2	21.8
11:00	49.702	20	1.4	27.3
12:00	50.000	21	1.5	31.2
13:00	49.404	19	1.2	21.8
14:00	42.510	19	0.8	14.5
15:00	27.591	18	0.4	6.8

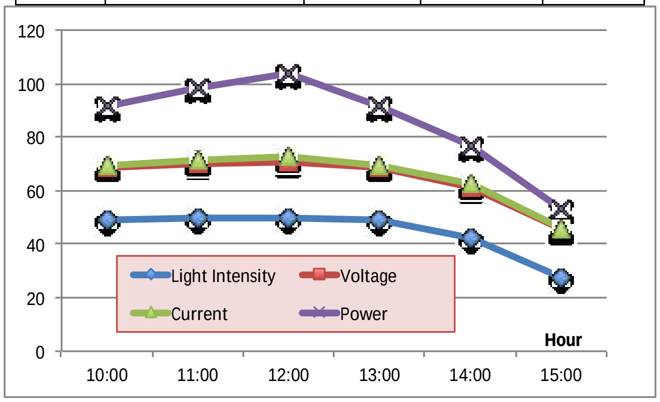

Figure 5:. Light intensity and the generated voltage/current

The measurement of wind power generation is taken for the same period and the results are presented in Table 2. The graphic indicating the relation between the wind speed and other variables is shown in Figure 6. It may be observed from the table and figure that wind power generation is more stochastic than solar PV. Furthermore, the capacity of the generator is smaller than that of solar PV. However, the voltage generated by the generator is sufficient to make the current flowing from the machine to the battery. On the other hand, the capacity may easily be enlarged by constructing the bigger generator dimension. In this research, the machine was constructed from the unused (broken) induction motor of fan and was built for experiment purpose.

Table 2: Data from wind generator measurements

Hour	Wind Speed ($m.sec^{-1}$)	Voltage (Volt)	Current (Amp)	Power (Watt)
10:00	0.4	18	0.08	1.24
11:00	1.0	25	0.20	4.22
12:00	1.8	32	0.51	14.02
13:00	2.4	28	0.43	9.40
14:00	2.6	35	0.60	18.46
15:00	0.8	22	0.10	1.95

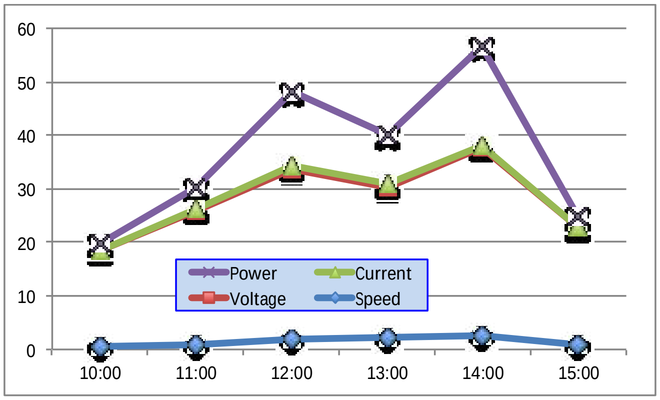

Figure 6: Wind speed and the generated voltage/current

The system is currently still operating well, when this paper is composed. The length of the light to be "on" is observed and it indicates that the light is on along the night. The experiment period to operate the system has taken more than one year and the system is able to run properly. It verifies that the energy supplied to the battery is enough to provide the energy for light to be "on" along the night. This system is suitable to be developed and installed in remote streets where the electricity network has not reached the place. The system is inexpensive and stable for long time operation. This system is expected to be the answer of problem in providing street lighting at the remotes areas. This effort will also contribute to suppress the number of traffic accident.

5.CONCLUSION

The design of hybrid renewable energy system has been implemented in the form of Solar PV – Wind Power generation for supplying street lighting load. The conclusions from the work are:

1. Combination of two different generation system may enable providing more energy leading to longer load operation,
2. The output power from solar PV is more stable in term of voltage magnitude yet the duration of generation is limited by the availability of sufficient sunlight intensity,
3. The stochastic characteristic of voltage generated by wind generation requires more difficult power conditioning to assure that the power flows from the generator to the storage,
4. The load may operate in more sustainable period confirming that the system is suitable for remote street where the electricity has not reached the area.

ACKNOWLEDGEMENT

The Authors would like to acknowledge that this research is financially supported by The Directorate of Research and Community Service (DRPM), The Ministry of Research and Higher Education (Kemenristekdikti) under the scheme of International Research Collaboration and Scientific Publication for the Funding Year of 2017. The official contract number is 211.17/A.3-III/LPPM/V/2017.

REFERENCES

1. REN21, **Renewables 2014: Global Status Report.** 2014.
2. Y. M. Atwa, E. F. El-Saadany, M. M. A. Salama, and R. Seethapathy, **Optimal Renewable Resources Mix for Distribution System Energy Loss Minimization**, *Power Systems, IEEE Transactions on*, vol. 25, no. 1, pp. 360–370, 2010, doi:10.1109/TPWRS.2009.2030276.
3. H. Van Pham, J. L. Rueda, and I. Erlich, **Probabilistic evaluation of voltage and reactive power control methods of wind generators in distribution networks**, *IET Renewable Power Generation*, vol. 9, no. 3, pp. 195–206, 2015, doi: 10.1049/iet-rpg.2014.0028.
4. P. Wang, Z. Gao, and L. Bertling, **Operational adequacy studies of power systems with wind farms and energy storages**, *IEEE Transactions on Power Systems*, vol. 27, no. 4, pp. 2377–2384, 2012, doi: 10.1109/TPWRS.2012.2201181.
5. P. Yang and A. Nehorai, **Joint Optimization of Hybrid Energy Storage and Generation Capacity WithRenewable Energy**,*IEEE Transactions on Smart Grid*, vol. 5, no. 4, pp. 1566–1574, Jul. 2014, doi:10.1109/TSG.2014.2313724.
6. L. Cao, K. H. Loo, and Y. M. Lai, **Frequency-Adaptive Filtering of Low-Frequency Harmonic Current in Fuel Cell Power Conditioning Systems**,*IEEE Transactions on Power Electronics*, vol. 30, no. 4, pp. 1966–1978, Apr. 2015, doi:10.1109/TPEL.2014.2323398.
7. A. Elrayyah, A. Safayet, Y. Sozer, I. Husain, and M. Elbuluk, **Efficient Harmonic and Phase Estimator for Single-Phase Grid-Connected Renewable Energy Systems**, *IEEE Transactions on Industry Applications*, vol. 50, no. 1, pp. 620–630, Jan. 2014, doi: 10.1109/TIA.2013.2266392.
8. L. Gelažanskas, A. Baranauskas, K. A. A. Gamage, and M. Ažubalis, **Hybrid wind power balance control strategy using thermal power, hydro power and flow batteries**, *International Journal of Electrical Power & Energy Systems*, vol. 74, pp. 310–321, Jan. 2016, doi: http://doi.org/10.1016/j.ijepes.2015.08.002.
9. B. S. Shalavadi, R. Vankina, and U. R. Yaragatti, **Modelling and Analysis of a Standalone PV/Micro Turbine/ Ultra Capacitor Hybrid System**, *International Journal of Renewable Energy Research (IJRER)*, vol. 6, no. 3, pp. 847–855, 2016.
10. IEA, **Renewable Energy Report**, 2015.
11. S. Hiremath and M. Tech, **Designing of the Interleaved Flyback Inverter for PV Applications**, *IJETER*, vol. 7, no. 6, p. 4, 2019.
12. Kementrian ESDM, "**PotensiEnergiBaruTerbarukan (EBT) Indonesia**(*Potency of New and Renewable Energy in Indonesia*), 2015.
13. P. S. Divya, K.C.,Nagendra Rao, **Models for wind turbine generating systems and their application in load flow studies**, *Electric Power Systems Research*, vol. 76, pp. 844–856, 2006. https://doi.org/10.1016/j.epsr.2005.10.012

14. K. C. Divya and P. S. N. Rao, **Models for wind turbine generating systems and their application in load flow studies**, *Electric Power Systems Research*, vol. 76, no. 9–10, pp. 844–856, Jun. 2006, doi:10.1016/J.EPSR.2005.10.012.
15. H. Wu, P. Dong, and M. Liu, **Random fuzzy power flow of distribution network with uncertain wind turbine, PV generation, and load based on random fuzzy theory**,*IET Renewable Power Generation*, vol. 12, no. 10, pp. 1180–1188, Jul. 2018, doi: 10.1049/iet-rpg.2017.0696.
16. Vlachogiannis John G., **Probabilistic Constrained Load Flow Considering Integration of Wind Power Generation and Electric Vehicles**, *IEEE Transactions on Power Systems*, vol. 24, no. 4, pp. 1808–1817, 2009, doi: 10.1109/TPWRS.2009.2030420.
17. T. R. Ayodele, A. Jimoh, J. L. Munda, and A. J. Tehile, **Challenges of Grid Integration of Wind Power on Power System Grid Integrity: A Review**, *International Journal of Renewable Energy Research (IJRER)*, vol. 2, no. 4, pp. 618–626, 2012.
18. slimanesouag and F. Benhamida, "**A Dynamic Power System Economic Dispatch Enhancement by Wind Integration Considering Ramping Constraint - Application to Algerian Power System**, *International Journal of Renewable Energy Research (IJRER)*, vol. 5, no. 3, pp. 794–805, 2015.
19. P. S. GeevMokryani, **Strategic placement of distribution network operator owned wind turbines by using market-based optimal power flow**, *IET Generation, Transmission & Distribution*, vol. 8, no. 2, pp. 281–289, 2014, doi: 10.1049/iet-gtd.2013.0288.
20. Y.-H. Wan, **Wind Power Plant Monitoring Project Annual Report**, 2001.
21. ADB, **Wind Power Generation Project: Social Safeguard Monitoring Report (January-June 2018) | Asian Development Bank**, 2018.
22. New England Clean Energy, **Different Types of Utility Meter for Solar | The Energy Miser**,*E-Newsletter*, 2017.https://newenglandcleanenergy.com/energymiser/2017/02/15/different-types-of-utility-meters-for-solar/.
23. Canadian Solar, **Solar Power for Home: Residential Solutions**, *Energy Solution*, 2018. https://www.canadiansolar.com/energy-solutions/for-home.html.
24. CanadianSolar, **Microgrid Solutions for Your Project**, *Energy Solution*, 2018. https://www.canadiansolar.com/energy-solutions/microgrid-solutions.html.
25. S. A. Meshram, S. A. Kapade, A. D. Choudhari, R. S. Kakade, A. V. Mhala, and K. B. Nagane, **Solar PV System for Electric Traction Application with Battery Backup**,*IJETER*, vol. 7, no. 1, p. 4, 2019.