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MATLAB/Simulink Simulation of Renewable Energy Distribution System Using MPPT

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Abstract: The conventional sources of energy are generally not replenished easily and are thus exhaustible in nature. This implies that they draw finite resources which would eventually diminish. As a result, there would be a scarcity of energy supplies if we continue to depend entirely on these non-renewable energy sources. In contrast, the renewable sources of energy, commonly known as the non-conventional sources such as the wind, geo-thermal, hydro as well as solar are non-exhaustible and can be replenished. The only drawback they face is their intermittent nature as well as high installation and maintenance cost. It is always of due concern regarding the consistent developing energy systems which involves that the final product requirements should be noted, hence this paper focuses on the storehouse in a renewable energy system. Basically, two sources of renewable energy namely, solar and wind are incorporated and their unpredictable nature leads to the use of battery as the source of energy. The energy is supplied in intervals from the two renewable sources with the provision of battery as backup source. MPPT is used to ensure maximum power output. The benefits related to environmental aspect of these energy resources are recognized widely and on a large scale. The renewable energy resources are not affected greatly from the monotonous long-term availability issues in regard to finite fuels location restriction, but at the same time include different problems such as the interdependence on flowing resources that are not constant.

Key words: Renewable energy, wind energy, solar energy.

Introduction

With the growing demand in energy in the various sections and the depletion of the affordable energy resources the prime focus for energy generation has now been shifted to renewable energy resources. The domination of the energy system worldwide is by the renewable sources. These sources generally include energy from the sun, wind, water, as well as fossil fuels (Singh et al., 2016). The effective distribution and generation of energy is necessary in view to be able to maintain at a particular level. Attention is focused on the problem of variability of electricity production from renewable. But, this applies only to an extent of renewables. These include solar photovoltaics system as well as wind. Consequently, their importance is dependent on a variety of categories mentioned below:

- The penetration of the concerning renewables
- The balance between plant and the system.
- The extensive connectivity of the system
- The flexibility on the side of demand

The growing penetration of intermittent renewable energy resources and the growing development of information that is advanced generally arise the pointers as in which way the loads that are responsive be

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managed to optimize the usage of the assets and the sources (Vahedipour et al., 2017). Our country is one of the developing countries and hence, to manage and support its growth to compete on the global level, the country needs option in the region of renewable sources in order to enhance the generation of power capacity for high growth (Bugaje, 2006). Technically speaking, the energy potential from the inexhaustible sources including wind, solar, hydro, geothermal is high (Saha et al., 2014). Accordingly the prices of the same fluctuate. The government of India should initiate and implement a model work which is technologically mature enough as well as carries the potential of resource.

Over the years, the renewable energy sources are the ones that have gained huge importance in terms of growth, which is quite comparable with the growing demand of coal and wood. In the year 2007, the production of renewable energy share was calculated as 19%. Although, 16% is mainly due to the electricity through water and hence, the wind and PV energy production is very promising. The renewable energy delivered to the plant should comprise certain characteristics. The primary being, minimum price of delivery to the consumer. Otherwise the cost of energy increases and affects various sectors, hence affecting the economy adversely (Singh et al., 2016).

The other characteristic being, reliability of energy. For sufficient and safe delivery of energy, the power infrastructure that includes the generation, transmission and distribution systems should have certain qualifications (Ruciński et al., 2016). An increasing need of electrical power and the reduction of the non-renewable energy sources (natural gas, coal) has emerged new studies in the field of non-exhaustible energy research and their utilization in urban as well as rural sectors. The non-accessible areas wherein the connection of grid is not feasible but the renewable aspects such as solar, hydro and wind in large ratio can thus be exploited for the usage as electricity generation (Spurrier et al., 2012). The solar and wind power have proven to be a great replacement alternative owing to their advantages in the generation and distribution. In this paper, simulation is carried out using MATLAB software. Two sources of renewable energy have been used to supply the plant. The sources include solar and wind. A battery backup has been provided since the non-conventional resources are intermittent in nature.

Methodology

In the recent years, there has been a significant role in the expansion of solar and wind resources as a source of electric power (Gow et al., 1999). Thus, these technologies strive to increase the reliability, consistency, unpredictable growth as well as cost efficiency. Solar and wind power generation have therefore been the fastest emerging section in the electricity market (Reichling et al., 2008). In our country, PV and the wind power generation has achieved a high level of gain and accessibility in contrast with the other available alternatives of energy.

Solar and wind power generation system has been used and simulated in the MATLAB. An additional source of battery has also been incorporated which acts as storage system and supplies the plant once the wind or solar energy is turned off. The division of energy distribution from the renewable sources is based on time duration.

The block diagram of the renewable energy distribution system incorporating the two sources of energy along with the battery back is depicted in Figure 1.

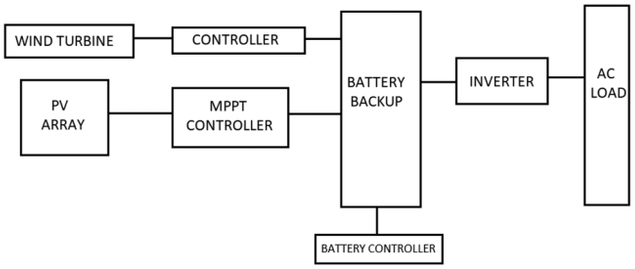

Figure 1: Renewable energy distribution system.

System Description and Modelling

Our model basically consists of three layers, namely:

- The layer of physical power.
- The control layer.
- The layer of application.

Modelling and Design of Photovoltaic Module

The mathematical equations involved in the study of a solar cell is: [10]

$$I_{pv} = I_{gc} - I_o\left[\exp^{\frac{eV_d}{KFT_c}} - 1\right] - \frac{V_d}{R_p} \qquad (1)$$

where I_{gc} is light generated current, I_o = dark saturation current dependent on temperature of the cell, e = electric charge: 1.6×10^{-19} Coulombs, K = Boltzmann's constant: 1.38×10^{-23} J/K, F = the cell idealizing factor, T_c = the cell's absolute temperature, V_d = diode voltage and R_p = the parallel resistance.

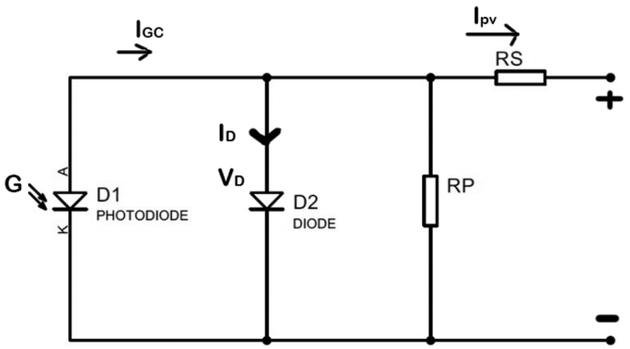

Figure 2: Single diode PV cell equivalent circuit.

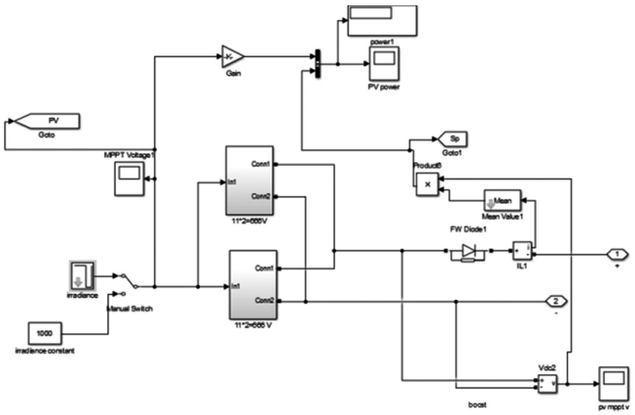

Figure 3: Subsystem implementation of PV module.

A PV model is built and verified using MATLAB/ Simulink. The proposed model is implemented and shown in Figure 3. Here, the inputs are solar irradiation and irradiance constant (= 1000 W/m^2).

The output characteristics of a solar system with varying irradiance is generally non-linear. Also, this irradiance is dependent on weather conditions which further makes the maximum power point of the module vary invariably. Hence, in view of this scenario the operation of PV system is carried out at its maximum power point using MPPT (Maximum Power Point Tracker). An MPPT controller is designed and implemented using MATLAB, to operate the module at its maximum power point.

Modelling and Design of Wind Turbine

The output of the wind turbine model is based on wind speed. The power is given by the equation 2:

$$P_m = C_p(\lambda, \beta)\frac{\rho A}{2}v^3 \qquad (2)$$

where P_m is mechanical output power of the turbine, C_p = performance coefficient of the turbine, λ = tip speed ratio of the rotor blade, β = blade pitch angle, ρ = air density, A = turbine swept area and V = wind speed.

In the proposed model, the input applied is the wind speed and pitch-angle, consequently the output is the torque applied to the generator shaft. The Permanent Magnet Synchronous Generator (PMSG) is used as a wind turbine generator owing to its property of eliminating the excitation loss due to the presence of permanent magnet. An MPPT controller is designed and implemented using MATLAB, to operate the module at its maximum power point as shown in Figure 5.

Modelling and Design of Battery and Inverter

Energy backup is provided by the battery. When the solar and wind systems generate energy according to their time division, they are also charging the battery in turn (Figure 6). The major aim of using the inverter

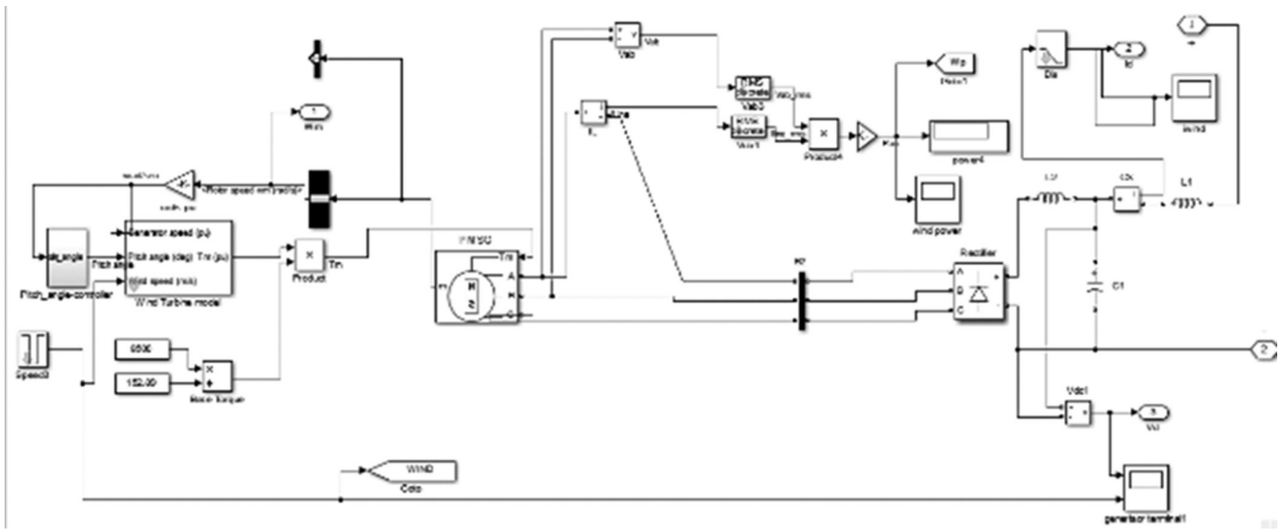

Figure 4: Subsystem implementation of wind turbine module.

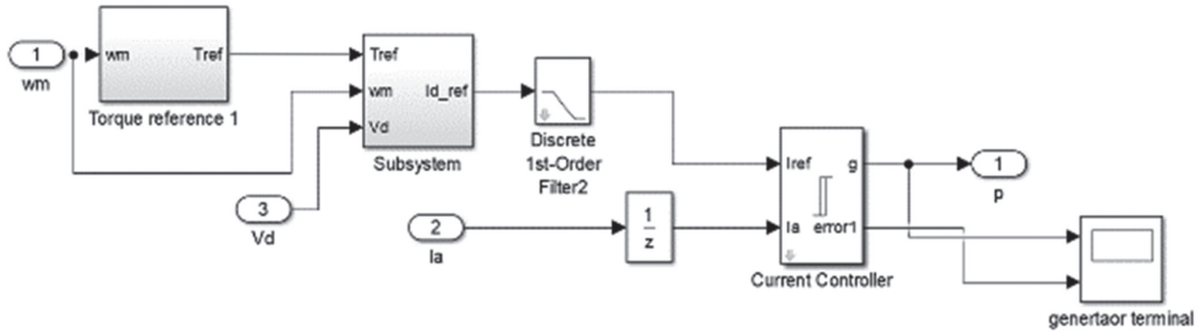

Figure 5: Subsystem implementation of the MPPT controller model.

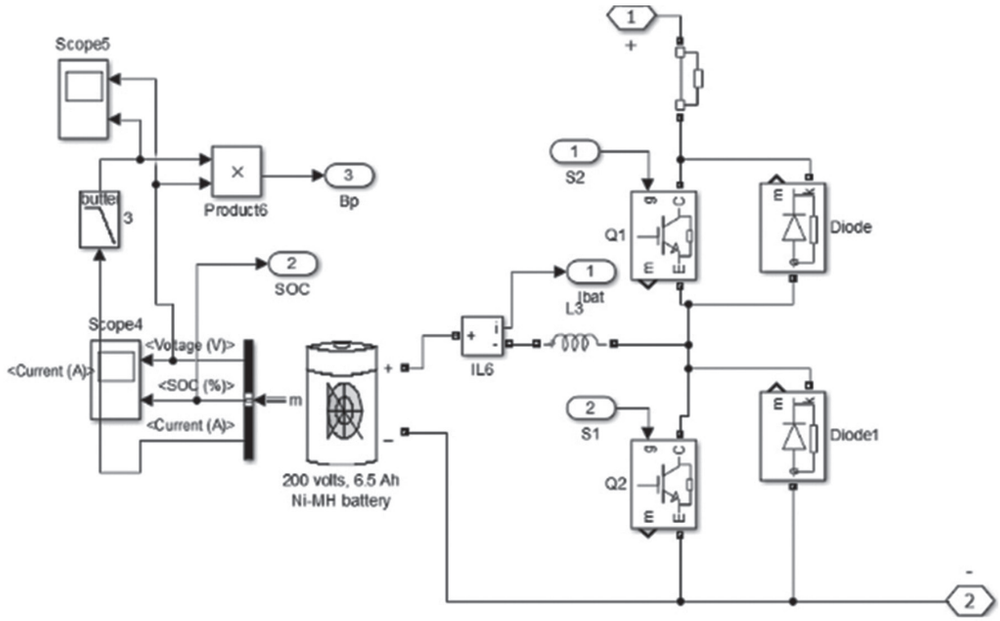

Figure 6: Subsystem implementation of the battery.

is for the conversion of dc power from the battery into 3-phase ac supply power (Figure 7). The load demands are met using this power under emergency conditions when there is either a shortage of generation from that of the wind or solar power.

Simulation Study

The model of the integrated wind/photovoltaic system and the control of power was simulated. The input for the solar panel is the solar irradiation and irradiance constant. The output power of the solar system is shown in Figure 8. Consequently, the output power using the MPPT controller is shown in Figure 9. The output power of wind turbine is dependent on the wind speed and pitch angle controller. It is shown in Figure 10. The power output employing the MPPT controller for wind turbine is shown in Figure 11.

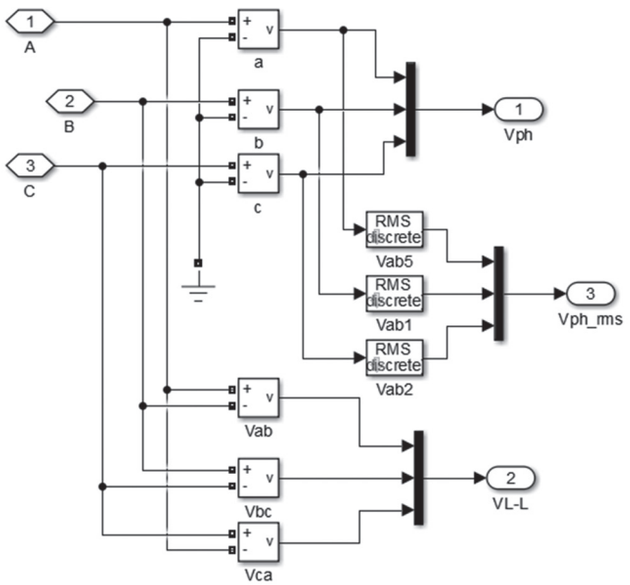

Figure 7: Subsystem implementation of inverter controller.

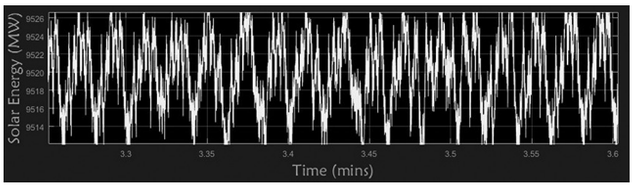

Figure 8: Solar output power.

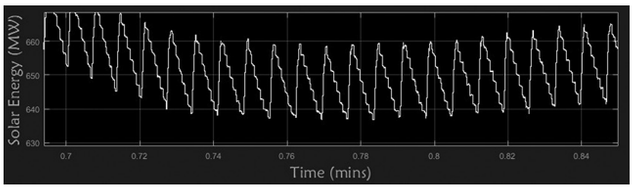

Figure 9: Solar MPPT output power.

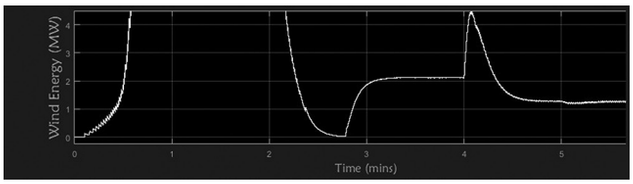

Figure 10: Wind output power.

The backup power is provided by the battery (Figure 12), hence in the time period when the solar or wind is generating power to the plant, the battery is also getting charged. Once, the renewable sources are shut down, the battery starts getting discharged by providing power to the load plant. The plot of the output power is given in Figure 11. The overall Simulink model and output

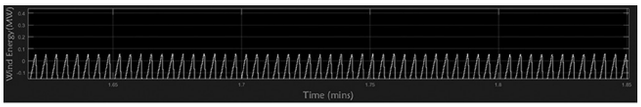

Figure 11: Wind MPPT output power.

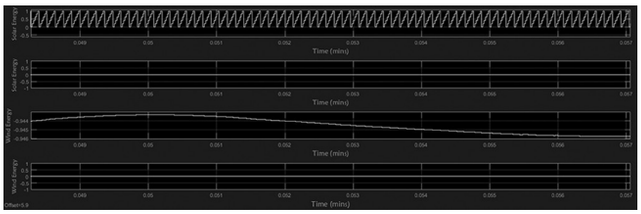

Figure 12: Battery output power.

plot from all the three sources—the wind, solar and battery—is depicted in Figures 13 and 14 respectively.

Conclusion

Presently, our country is encountering the crisis of power due to the constant depletion of non-renewable energy sources and the lack of technological development in the section of non-exhaustible sources. Human development and the related activity is empowering our atmosphere with carbon dioxide and the other harmful global warming emissions. Thus, the use of renewable energy sources have proved to provide little or no harmful emissions and thus, act as 'clean-energy life cycle'. The study for the generation of power is hence, getting inclined towards the renewable sources of energy.

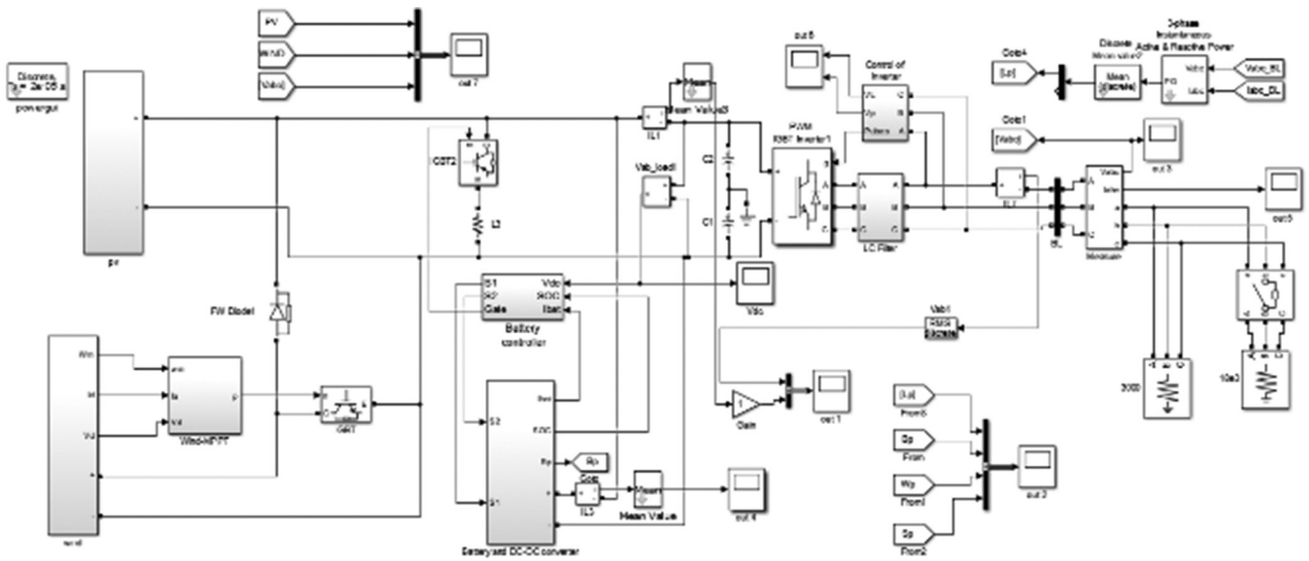

Figure 13: Simulink model.

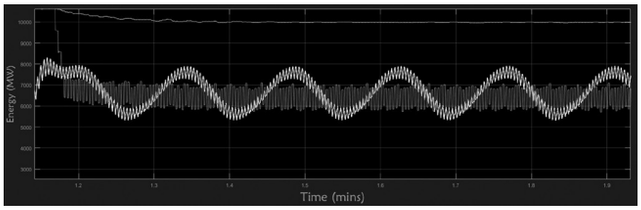

Figure 14: Renewable energy power generation.

In our paper, we have designed a hybrid power system using two renewable sources of energy, namely solar and wind and a backup battery. The system is modelled and has been implemented using MATLAB/Simulink package. The power which is available from PV as well as wind system is majorly dependent on radiation of Sun and speed of wind respectively. To overcome this drawback model was integrated with battery backup. The wind energy system, with wind turbine driven Permanent Magnet Synchronous Generator (PMSG) is simulated using MATLAB.

References

Bugaje, I.M. (2006). Renewable energy for sustainable development in Africa: A review. *Renewable and Sustainable Energy Reviews*, **10(6):** 603-612.

Gow, J.A. and C.D. Manning (1999). Development of a photovoltaic array model for use in power-electronics simulation studies. *IEE Proceedings - Electric Power Applications*, **146(2):** 193-200.

Koumboulis, F.N. and D.G. Fragkoulis (2017). Switching design for the observation of the biomass in alcoholic fermentation processes. *In:* Information, Communication and Automation Technologies (ICAT), 2017 XXVI International Conference. IEEE.

Reichling, J.P. and F.A. Kulacki (2008). Utility scale hybrid wind–solar thermal electrical generation: A case study for Minnesota. *Energy*, **33(4):** 626-638.

Ruciński, D. (2016). Neural-evolutionary modelling of polish electricity power exchange. *In:* Electric Power Networks (EPNet). IEEE.

Saha, S., Biswas, S. and S. Pal (2014). Survey analysis, scope and application of biomass energy in India. *In:* Non Conventional Energy (ICONCE), 2014 1st International Conference. IEEE.

Singh, B., Panigrahi, B.K. and G. Pathak (2016). Control of wind-solar microgrid for rural electrification. *In:* Power India International Conference (PIICON). IEEE.

Singh, S. and S.C. Kaushik (2016). Optimal sizing of grid integrated hybrid PV-biomass energy system using artificial bee colony algorithm. *IET Renewable Power Generation*, **10(5):** 642-650.

Spurrier, N. (2012). Looking forward ... looking back [heritage renewable energy]. *Engineering & Technology*, **7(12):** 82-84.

Vahedipour-Dahraie, M., Rashidizadeh-Kermani, H., Najafi, H.R., Anvari-Moghaddam, A. and J.M. Guerrero (2017). Stochastic security and risk-constrained scheduling for an autonomous microgrid with demand response and renewable energy resources. *IET Renewable Power Generation*, **11(14):** 1812-1821.