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Models for Determination of Maximum Power in Compatible Management of Hybrid Energy Sources

I. Kh. Siddikov
Professor of department of "Electricity and renewable energy sources" of logo "Tashkent institute of Irrigation and agricultural mechanization engineers" national research university

Kh. E. Khujamatov
Associate professor of department of "Data communication networks and systems" of Tashkent University of Information Technologies named after Mukhammad al-Kwarizmi

A. A. Temirov
PhD student of Namangan state university

Annotation: In this paper, the process of evaluating the flexible management efficiency of hybrid power supply sources and the magnitude of the impact circle aimed at achieving maximum power are mathematically modeled. To this end, control devices and software have been developed as solutions to the problems of energy production, energy consumption, energy consumption accounting, and resource management, minimization of electricity costs, uninterrupted supply and cleanliness of the environment.

Keywords: Energy saving, environmental pollution, electricity meters, energy sources, industrial waste.

1. Introduction

The use of alternative energy sources has been around since history, and renewable energy is ubiquitous, free, non-polluting. However, these energy sources are based on weather conditions and arise from the laws of nature, which impedes uninterrupted power supply [1,8]. Combining renewable energy sources is one of the possible solutions to address these shortcomings.

Hybrid power supply smart grid consists of elements such as control unit, power line, renewable energy sources, centralized power supply, IoT components, GSM, WiFi, ZigBee modules, server for database, sensors. In this case, the information collected on the server through a web page, SMS message, mobile application is presented in the desired format [2]. The architecture of this system is shown in Figure 1.

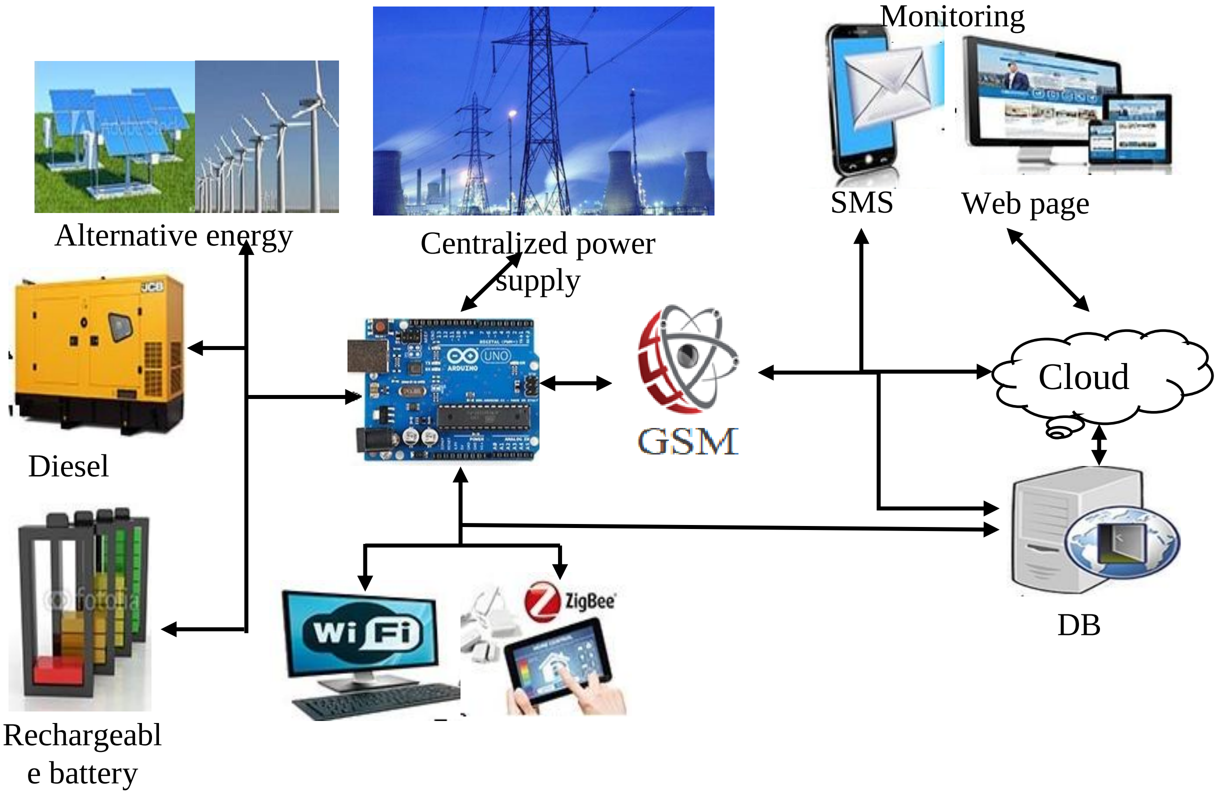

Figure 1. Hybrid power supply management monitoring architecture for smart homes

Centralized power supply leads to an increase in efficiency with the increase in power generation capacity, the specific consumption of energy consuming materials and a decrease in energy value. High energy infrastructure will destroy the revenues of powerful power plants and increase the cost of environmental protection measures [3]. The concept of introducing alternative energy sources does not mean abandoning centralized energy supply, but in some cases, it means that there is a reasonable alternative to it and fills the system. It is defined as a stable, secure, reliable, durable, stable and efficient electricity system that uses electricity generation, transmission, communication technologies and computing intelligence [4-6]. The smart grid allows for a high level of inflow of stochastic and intermittent renewable energy to reduce pollution and provides many additional benefits. Through two-way energy flows, consumers can not only consume energy, but also sell it. Market activation is another important feature of smart grids for efficient use of energy and increasing economic prosperity. These new features of smart networks are shown in Figure 2.

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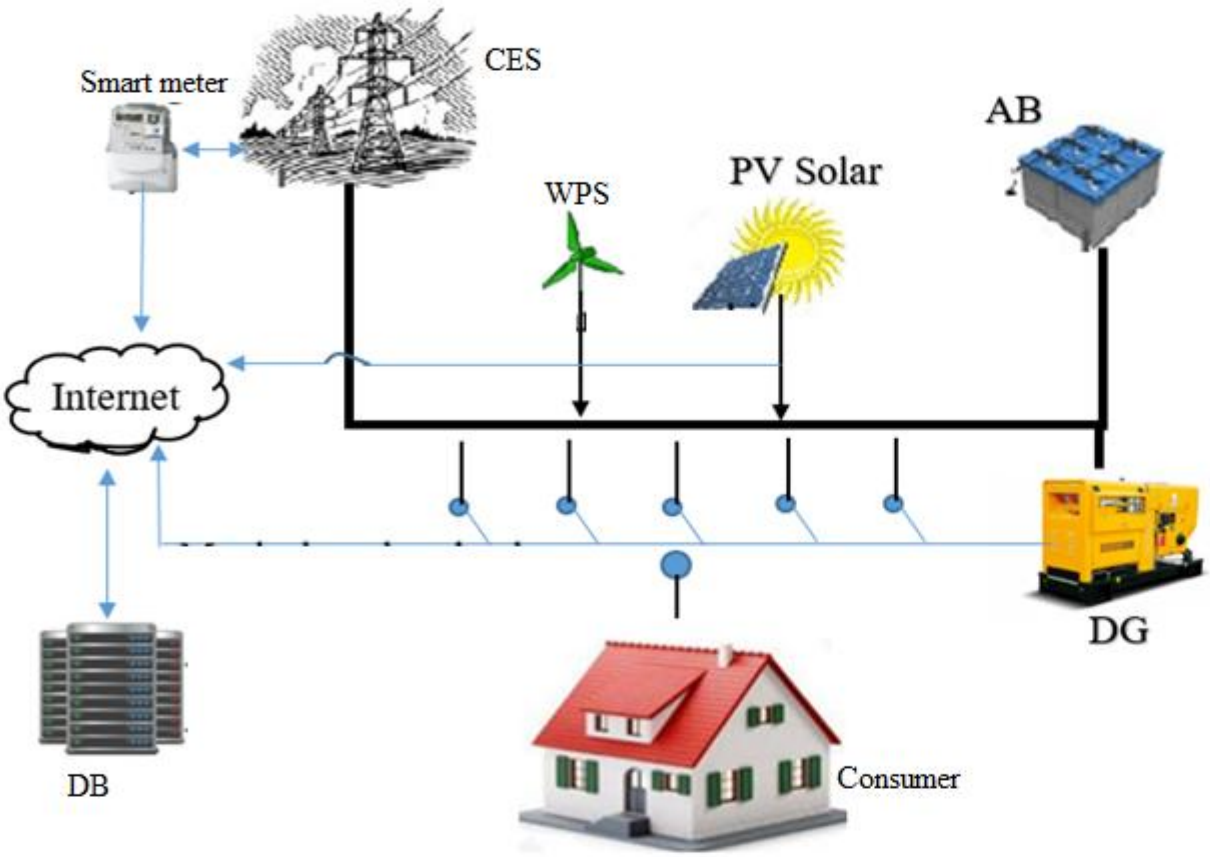

Figure 2. Hybrid power supply structure

The optimal dimensions of a renewable energy system depend on the mathematical model of the system components. In this study, renewable energy systems were mathematically modeled using PV solar energy, wind energy, a diesel generator, and a storage battery[4,6-9]. Due to its nonlinear power characteristics, wind power and PV solar systems require specifications to achieve maximum power. A hybrid system has a complex control system by combining two or more different power sources [10]. The complexity of the system increases with the maximum power control methods used in the subsystems. Mathematical modeling of various technical means for renewable energy systems. In a hybrid power supply system, we can see the types of errors and omissions listed in Figure 3.

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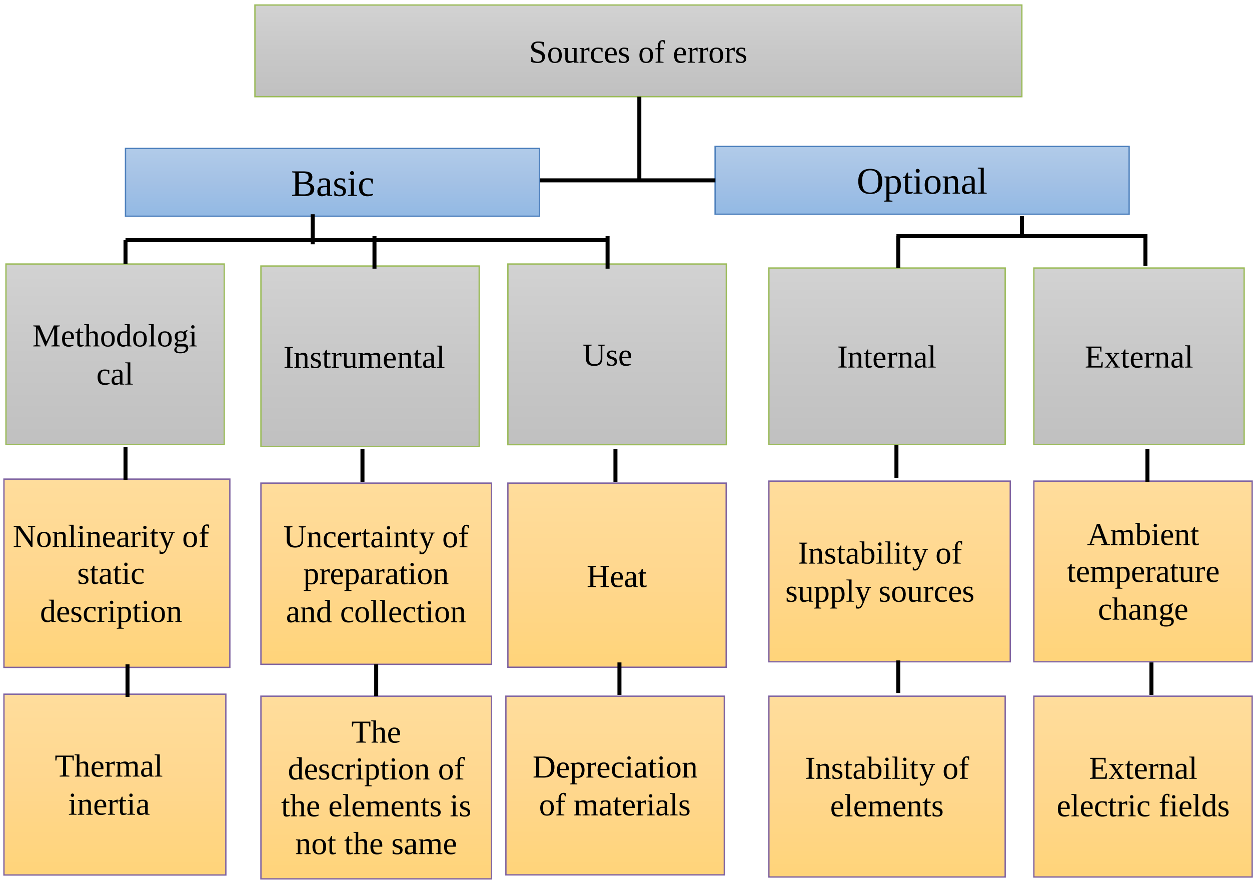

Figure 3.Sources of error of converters

Combining two or more forms of energy sources can create a hybrid energy system that fills the gaps in energy sources. The goals of the smart grid design are to minimize the cost of generating electricity, minimize the purchase of electricity from the grid (if it is connected to the grid), reduce emissions, and increase power reliability. Separate systems must be large enough to accommodate production, storage, and capacity [11,13-15]. However, when connected to the mains, appropriate power electronic control devices are required to control voltage, frequency, harmonic rules and load distribution. Flexible control can be tracked on the smart grid. Figure 4 shows a model of a smart grid [5,22-24].

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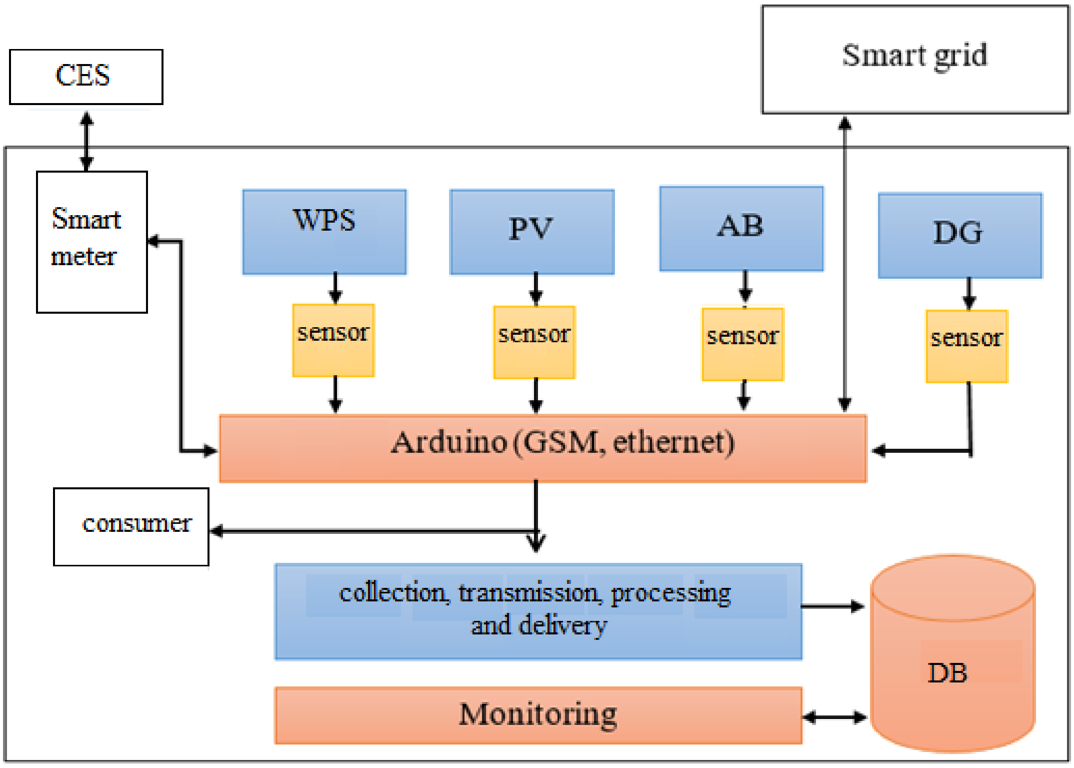

Figure 4. A model of hybrid power supplies created using smart grid technology

Hybrid energy sources can include wind power, solar energy, renewable energy conversion components, such as traditional non-renewable diesel generators, and storage devices such as batteries[12,16]. The first step in choosing the right components and subsystems for optimal measurement of the entire system is to model the individual components. The modeling process helps to determine the properties of the components and the decision-making properties [17-19]. The details of the modeling are reflected in the accurate prediction of its performance, but it can be very complex or time consuming to develop a perfect model [19]. A successful model must have a distinction between complexity and precision. The performance of an individual component is modeled using deterministic and probabilistic approaches.

2. Mathematical modeling of sources

2.1. Parametric indicators of sources

For flexible management of hybrid power supply sources, power output may vary depending on weather conditions when it comes to power generation at the source [20, 22-23]. Each source has its own characteristics and all of them have the highest power in different conditions. The monitoring system allows you to turn on and off solar panels and wind generators, monitor their condition and replace them if necessary [21]. Based on the above, the main parameters of an autonomous solar-wind power plant are:

- capacity produced by solar panels;
- level of solar radiation;
- ambient temperature;
- humidity of the environment;
- voltage at the output of the tester;

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- current at the output of the controller;
- regulator temperature;
- battery voltage;
- battery current;
- battery temperature;
- % battery charge;
- load voltage;
- loading current;
- loading power;
- voltage generated by the wind generator;
- current generated by the wind generator;
- wind speed.

2.2. Mathematical modeling of solar energy source

Modeling of solar power generation system. The solar radiation, which is the solar power generation unit, is interconnected in series in a parallel configuration to create P-N type semiconductor PV panels adapted to generate electricity mainly due to the photoelectric effect. Because N_s in series and N_p in parallel for connected panels may depend on the array voltage in the current [14].

$$I = N_P\left[I_{ph} - I_{rs}\left[[\exp(\frac{q(V+IR_s)}{AKTN_s} - 1)\right]\right] \quad (1)$$

Here I_{rs}

$$I_{rs} = I_{rr}\left(\frac{T}{T}\right)^3 \exp\left[\frac{E_G}{AK}\left(\frac{1}{T_r} - \frac{1}{T}\right)\right] \quad (2)$$

where q – is the electron charge (1.6×10^{-9}C), K – is the Boltzmann constant, A – is the ideal factor of the diode, and T –is the panel temperature (K). I_{rs}– is the reverse saturation current in the panel, T_r– is the temperature at the panel, I_{rr}– is the reverse saturation current, and E_G – is the band gap energy of the semiconductor used in the panel.

Solar cells are typically modeled as a single diode as shown in Figure 5.A and an electronic circuit with a diode as shown in Figure 5.B [14]

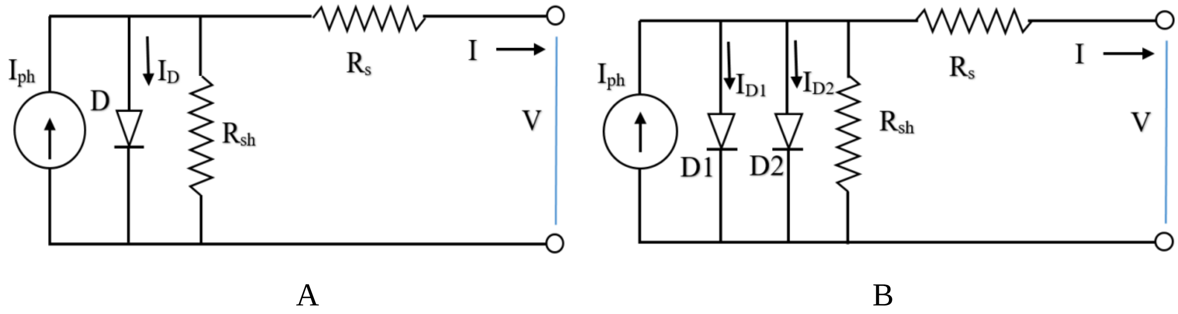

Figure 5. Single and double diode PV-panel model

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The single-diode model uses an additional shunt resistor in parallel with the ideal shunt diode model. The I-V properties of the PV panel can be obtained using a single-diode model as follows

Mathematical model for estimating the potential power of PV Solar. The production of electricity from a solar source varies depending on sunlight and ambient temperature. Calculates the power output in this model [14].

$$P_{pv} = \eta_{pvg} \cdot A_{pvg} \cdot G_t \qquad (3)$$

where η_{pvg}– is the PV production efficiency, A_{pvg}–is the PV generator area (m^2), G_t –is the modulus plane (W/m^2) of solar radiation.η_{pvg}–is defined as follows [14].

Given its simplicity and diffusion, the total radiation in a solar cell can be estimated as follows [14].

$$I_T = I_b \cdot R_b + I_d \cdot R_d + (I_b + R_b)R_r \qquad (6)$$

The characteristics of a solar cell depend on the insulation, temperature, and mass voltage. Thus, in order to bring the operating voltage closer to the maximum power point in a changing atmosphere, it is necessary to implement a maximum power search system [14, 21-25].

Finding the maximum power in the sun is important because it reduces the cost of using the solar system by reducing the number of solar panels needed to get the desired result. V-I descriptions of the solar array ignoring the internal shunting resistance are given here [14, 32-36].

$$I_0 = I_g - I_{sat}\left\{\exp\left[\frac{q(V_0 + I_0 R_5)}{AKT}\right] - 1\right\} \qquad (7)$$

Here A– is the dimensionless factor.

The output characteristics of the PV array are shown in Figure 6. It shows maximum power output in changing weather conditions [14].

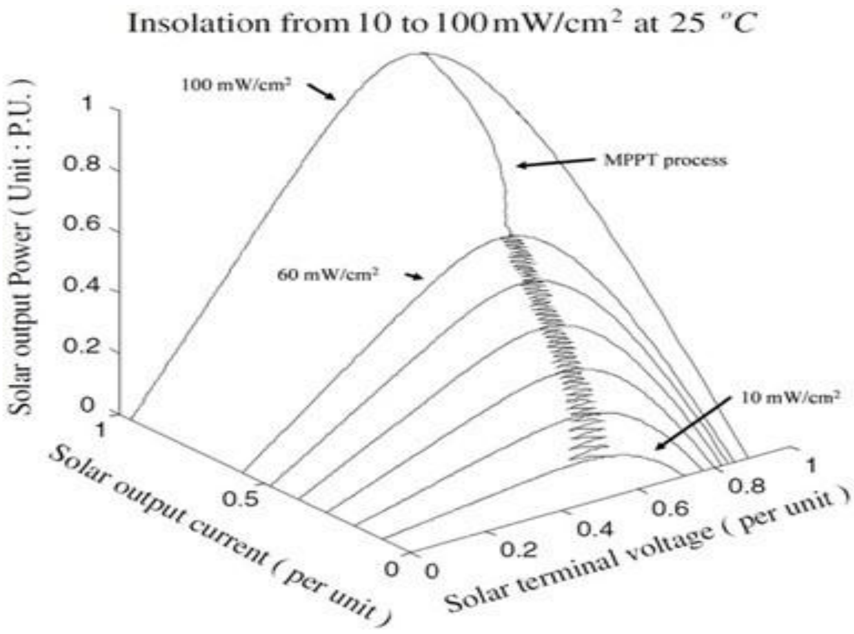

Figure 6. Maximum power control when insulation changes

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2.3. Mathematical modeling of wind energy source

In estimating the wind energy potential, a fundamental equation is given to control the mechanical power of the wind turbine [14]

$$P_w = \frac{1}{2} C_p(\lambda, \beta)\rho A V^3 \quad (8)$$

where r is the air density (kg/m^3), C_p– is the power factor, A – is the cross-sectional area of the rotor blades (m^2), V – is the average wind speed (m/s), and λ– is the speed ratio. The theoretical maximum value of the power factor is 0.593 and is expressed as the Betz coefficient.

The flight speed ratio for a wind turbine is defined as the ratio of the rotational speed to the wind speed for the wings.

$$\lambda = \frac{R\omega}{V} \quad (9)$$

where R – is the radius of the turbine (m), ω– is the angular velocity (rad/s), and V – is the average wind speed (m/s).

The parameters for obtaining wind energy are defined as follows.

$$Q_w = P \times (Time)[kWh] \quad (10)$$

Sometimes, due to various factors, it is not possible to determine the wind speed directly at any altitude. In this case, data at any suitable altitude can be interpolated or extrapolated to find the wind speed at the desired altitude [14, 37-39]. Wind speeds are measured at low altitudes and can cause errors due to vegetation, shadows and surrounding obstacles.

$$v(z)\ln\left(\frac{z_r}{z_0}\right) = v(z_r)\ln\left(\frac{z}{z_0}\right) \quad (11)$$

where Z_r– is the reference height (m), Z – is the height at which the wind speed is to be determined, Z_0– is the surface roughness (0.1-0.25 for cutting), and v(z) – is the wind speed (m/s). v (z_r) – wind speed at altitude (m/s).

The cutting speed is a very low wind speed at which the turbine starts rotating for the first time and produces power. Cutting speed is a high wind speed, in which the forces in the turbine structure are high, resulting in the risk of damage to the rotor. A brake system is used to stop the rotor to prevent damage [40]. Nominal output speed is the wind speed between the cutting speed and the shutdown speed, where the power output reaches the maximum level of the power generator and is called the nominal power output [14, 41-43]. In terms of wind speed, the power output can be calculated using the formula below

Built into a given power grid to maximize the potential charging infrastructure within it, it needs to be optimized not only for power generation, but also for accounting for any limitations that may occur in the system at any level [14, 31].

$$\omega_{opt} = \frac{\lambda_{opt}}{R} V_{wn} \quad (12)$$

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From this formula

$$V_{\omega n} = \frac{R\omega_{opt}}{\lambda_{opt}} \qquad (13)$$

where ω_{opt}– is the angular velocity of the rotor in (rad/second), λ_{opt}– is the optimal speed, R – is the radius of the turbine in meters, V_{wns}– is the wind speed in m/s

Wind Turbine Rotation Model. The wind turbine transmits high aerodynamic torque on the rotor through the gearbox to the generator's low-speed shaft. Some generators are connected directly to the rotor to reduce complexity, so they do not need to model this part.

The wind turbine can be modeled using one or two mass models. Details can be found elsewhere. A mathematical model based on a rotating polygon dynamic model is constructed as follows [14, 37].

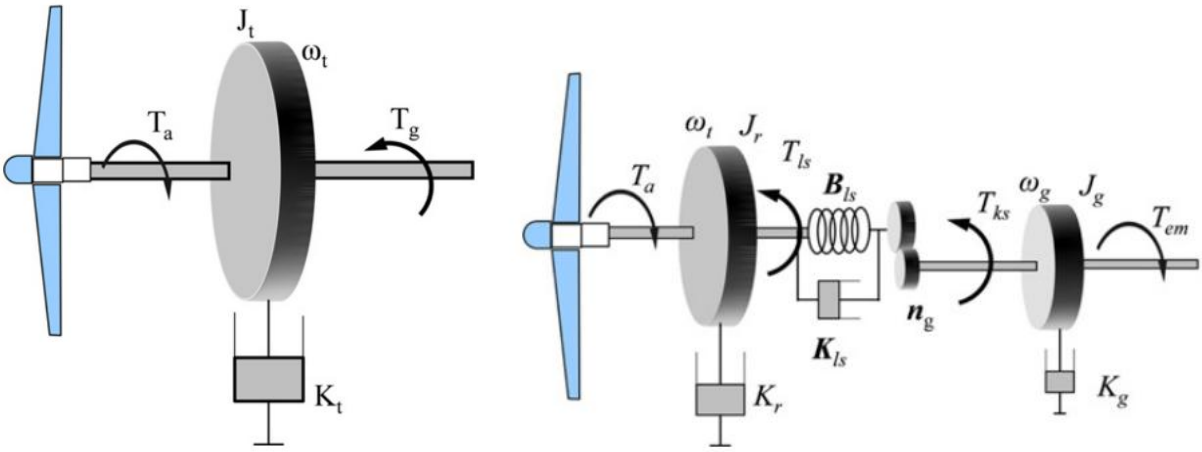

Figure 7. A single mass model of a wind turbine system; B Two mass models of a wind turbine system.

sHere

$$K_{ls} = IG / L_{ls}$$

$$D_{ls} = \xi D_s$$

$$\xi = \sqrt{1 - \left(\frac{\omega}{\omega_n}\right)^2} \qquad (14)$$

$$D_s = 2\sqrt{K_{ls} m} \qquad (15)$$

where ω/ω_n– *is* the ratio of the oscillation frequency to the unobtrusive natural frequency of the oscillation, m – is the mass of the wing, L_{is}– is the length of the shaft, G – is the modulus of stiffness, D_s– is the critical demampulation of the shaft, ξ – *is* the degree of demampage of the wing.

Monitor the potential power of the wind. The wind turbine can operate in two modes: constant turbine speed and variable speed. A fixed-speed turbine generator can be connected directly to a

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grid or load, while a variable-speed turbine power plant is used to convert variable frequency, variable power to constant frequency and power. The use of variable speed wind turbines has allowed the wind turbine rotation speed to be adjusted continuously to the wind speed in a way that reduces the turbulence of the turbine with high efficiency [29, 32]. Figure 8 shows the velocity ratio (λ) of the work factor (C_p). As can be seen from the figure, when the turbine speed changes, C_p reaches the maximum power, which is the corresponding maximum power. The main function of maximum power in the wind is to find the maximum C_p state when the wind speed changes [14, 19,31-34].

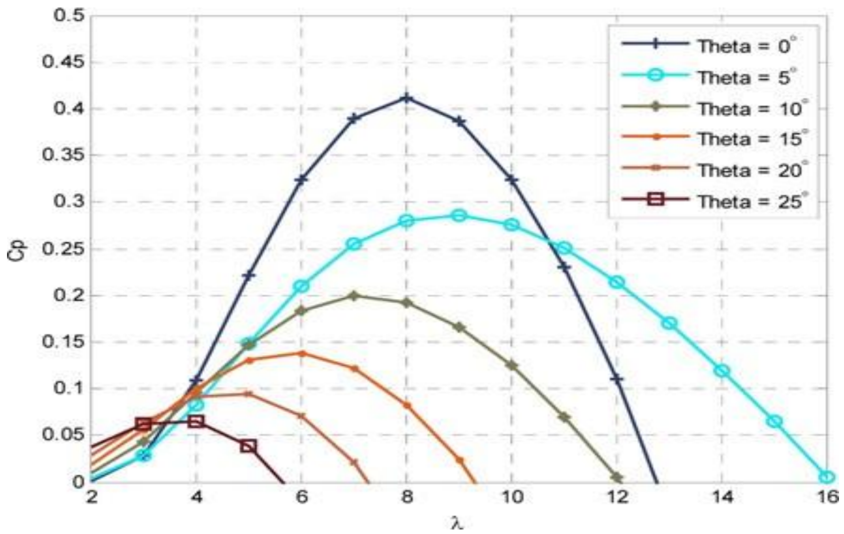

Figure 8. Graph for determining maximum wind power.

The maximum power point can keep the oscillation value at an acceptable value in a variable speed generation system at variable wind speeds. It is difficult to maintain the maximum power of a wind turbine under all conditions of wind speed, as this is not a characteristic of wind speed [42]. Thus, there are different control strategies to monitor the maximum power of wind turbine systems. Some techniques track the maximum power by observing the change in power produced, some techniques need mechanical sensors that measure wind speed to calculate the value of the generator speed, which forces it to operate at the maximum power point, so they can eliminate uncertainties. sensitive in modeling and some cases [14,33].

Check and monitor or search for parameters at high power output. These algorithms are an interactive method of obtaining maximum power, constantly searching for the maximum point of constant power in the conditions of vibration without previous static properties. In this method, the rotor speed is changed in small steps and the corresponding power output is observed. The next change in rotor speed depends on the previous power output reading. If an increase in output power is observed as the rotor speed is increased, the direction of the pertussis signal will not change. If a decrease in output power is observed while increasing the rotor speed, the direction of the test signal is reversed [17,34].

Measuring wind speed at an additional cost is one of the most important barriers to this control system. A customized control is required for the individual turbine. It can vary significantly depending on atmospheric conditions. Factors such as freezing, technical deterioration, and wear reduce the efficiency of the turbine rotor, which is not covered by the FSR control algorithm. [34]

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The optimal FSR is similar to the optimal control of the FSR, which ensures maximum use of available wind energy, as this method sets the maximum power torque at a given wind speed relative to the maximum adaptive torque of the wind turbine [14].

$$P_{opt} = \frac{1}{2}\rho\pi R^5 \frac{C_{p\max}}{\lambda_{opt}^3}\omega^3 = K_{opt}\omega^3 \quad (16)$$

Power defined formulas

P = ωT (17)

Using equations (31) and (32)

$$T_{opt} = \frac{1}{2}\rho\pi R^5 \frac{C_{p\max}}{\lambda_{opt}^3}\omega^2 = K_{opt}\omega^2 \quad (18)$$

The analytical value obtained by the above equation is presented as the torque directed to the wind turbine. This method is simple, fast, and efficient, but its efficiency is much lower compared to FSR control because it does not directly measure wind speed. Thus, changes in wind speed are not immediately reflected in the reference signal. Figure 9 shows a schematic of the most optimal torque control technique [14].

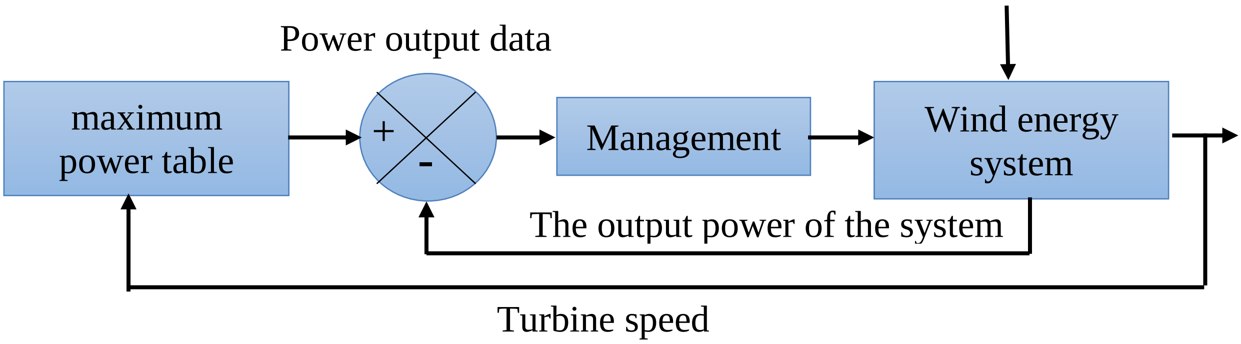

Figure 9. Maximum power management scheme

2.4. Battery modeling

Batteries play an important role in the energy management network of smart homes and have a large share in the cost of the system installation process. Batteries are used as a backup option to conserve power when power generation exceeds demand. Battery power is required during peak hours when demand for electricity is higher than production. In some models of batteries it is used as a storage buffer and is supplied by all electric batteries.

Batteries have different performance characteristics compared to batteries used in traditional applications and electric vehicles. Due to the stochastic nature of renewable energy sources, the battery can often experience deep cycles and erratic charging modes. Also, due to seasonal differences, the battery may have a low charge for a long time. Incompatibility in charging and discharging will result in a decrease in battery charge. Decreased battery power has a significant impact on the conversion of hybrid energy sources.

Battery life depends on the power consumption rate of the system. The easiest way to increase battery life is to reduce battery power consumption, which is not always practical in a hybrid

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system mode. During periods of high consumption, the efficiency of the battery decreases and therefore its service life decreases. When not in use, the battery can regain some of its lost power. Peukert's law is widely used to estimate battery discharge, given the nonlinear properties of the battery. Mathematician

The open contact voltage is a nonlinear function of battery temperature (T), discharge current (I_B), and energy from the battery (E_{cd}). This model uses battery initial current (I_B) to estimate maximum power. The remaining battery capacity and charging status are calculated dynamically by taking the initial energy. The scheme for determining the state of $V_{oc}$and charge is shown in Figure 10 [14, 36].

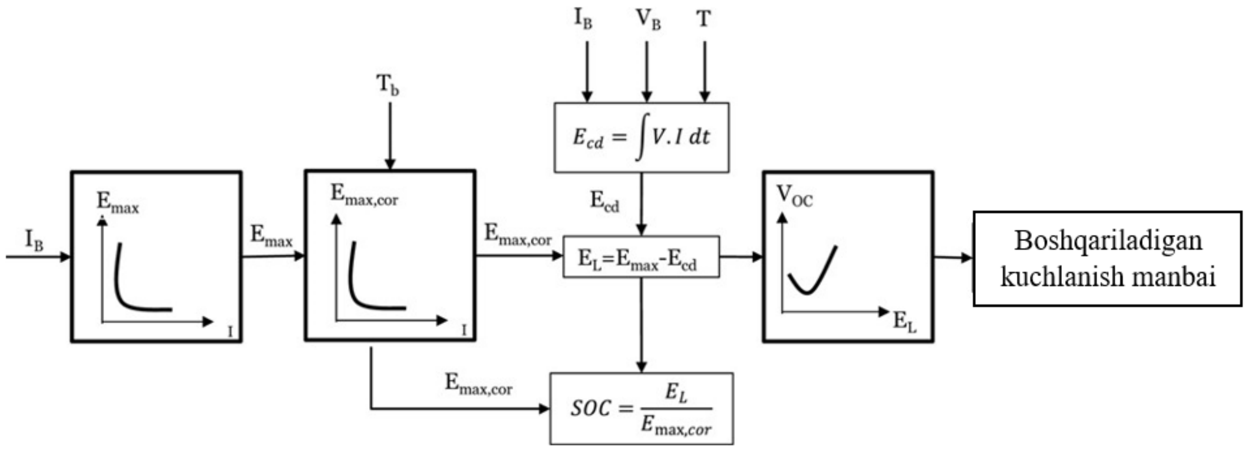

Figure 10. Diagram to determine the state of V_{oc} and charge

Compares power and demand generated by wind and solar to determine charge and storage capacity. In their system, wind power is sent directly to the boot via UPS. Unlike the sun, which only exists during the day, there is wind during the day. S_o, there are three possible scenarios:

a. Only wind can meet the demand for electricity, that is. P_{wg} (t) ≥ P_{load} (t). Excess power, if available, can be used to charge the battery. The storage volume (t) at any given time is expressed as follows

$$C_{bat}(t) = C_{bat}(t-1) + (P_{pv}(t) + P_{pv}(t) - P_{load}(t)\eta_{cad})\Delta t\eta_{cha} \qquad (19)$$

3. Hybrid power system management

Dynamic interactions between the electronic interfaces of renewable energy sources cause system stability and power quality problems, making it difficult to manage a hybrid system. The hybrid power system can be stand-alone or networked.

Independent systems must have a production and storage capacity that can handle the load, and in a network-connected system, the storage device can be relatively small because it can draw the missing power from the mains. A hybrid connected to the grid can power both the load and the utility network. However, when connected to the mains, appropriate power electronic control devices are required to control voltage, frequency, harmonic rules and load distribution [15,26]. The power balance equation used in a hybrid power supply is defined as follows.

$$P_{MET}(t) + P_{QET}(t) + P_{SHAS}(t) + P_{DG}(t) + P_{AB}(t) = P_Y(t) \qquad (20)$$

where P_{MET} (t) –is the current power value produced by the centralized power system; P_{QET} (t) – is the current power value produced by energy systems based on solar energy sources; P_{SHET} (t) – is

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the current power value produced by wind energy based power systems; P_{DG} (t) – is the current power value produced by power systems based on diesel generators; P_{AB} (t) – is the current value of the charge (discharge) of the electric accumulators; P_y (t) – is the current power value of the load. (t) – is the current power value of the load.

During operation, the hybrid wind-solar system is subject to the requirements of oscillating wind speeds and solar insulation, as well as variable loads. This means that it is very important to determine how much energy the controller receives from each component and how much should be used from it. The performance policy of an autonomous wind-solar hybrid system is to use the available energy from the wind turbine and the solar panel in each cycle to use the first and excess energy stored in the batteries. If the renewable energy is not enough to deliver the load for a certain period of time, the energy comes first from the battery reserve and then from the diesel generator. In existing systems with a diesel generator, the batteries serve as a fuel saver because the batteries are used before the diesel engine [15,28].

The maximum power from the PV and wind system can be obtained by observing the maximum power point in each of them. Because the variability for wind and PV systems is different, it is necessary to introduce an individual monitoring system for each system. Observing the maximum power point not only increases the efficiency of the system, it also reduces the cost.

Conclusions

In conclusion, the developed system provides a platform for continuous, efficient and reliable energy production, delivery and use. The new features of the smart grid have made its stability features much more complex than in the past. In this article, a mathematical model was created in which hybrid energy sources were analyzed, in particular PV soloar and wind energy sources. The described intelligent power management system provided the necessary tools for efficient energy management and monitoring. The smart grid made it possible to combine data from different sources. Implementing multidimensional modeling makes it easy to gather all the necessary levels of data related to energy consumption.

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