A Novel Approach of Synchronization of the Sustainable Grid with an Intelligent Local Hybrid Renewable Energy Control

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Abstract: Energy management, emission reductions, and sustainable development are directly linked. The use of renewable energy and intelligent control systems serves two goals: sustainable development and energy supply. In this paper, we propose an improved intelligent hybrid renewable energy management system to utilize local renewable energy. The penetration of renewable energy in this study starts from 20% and 50% and reaches 100%. The innovation of this research is the use of a dynamic decision algorithm in an intelligent system microcontroller that can determine the maximum possibility of hybridization of local solar and wind energy sources and optimize the electricity demand of the residential unit. The results show that the proposed control strategy in the first scenario, with average daily fuel consumption of 1.11 liters, the total energy produced by the hybrid renewable energy conversion system is equal to 1697 kWh/yr, and the NPV is $ 553.68 and the IRR is 49.9. 21% with a payback period of 15.71 years. In the second scenario, with average daily fuel consumption of 0.694 liters, the energy production is equivalent to 1652 kWh/yr. The NPV is equal to $ 341.47 and IRR is equal to 19.5% with a ROI of 17.61 years. In the third scenario, the energy production of the system was equal to 1933 kWh/yr with NPV equal to -372.9 dollars and IRR equal to 15.08%. The intelligent power control system received the electricity generated by the renewable energy subsystems and provides the electricity needed by the green cottage based on the proposed decision algorithm.

Keywords: Sustainable Energy; Energy Efficiency; Microgrid; Renewable Energy; Control Strategy; Green Cottage.

Nomenclature			
Symbols			
P	Power	*ADC*	Analog to Digital
T	Temperature	*ANN*	Artificial Neural Networks
Q	Irradiance	*BESS*	Battery Energy Storage System
V,F	Wind Speed	*COE*	Cost of Electricity
Subscript		*FL*	Fuzzy Logic
min	Minimum	*GA*	Genetic Algorithms
DG	Diesel Generator	*IEC*	International Electrotechnical Commission
max	Maximum	*IRR*	Internal Rate of Return
PV	Photovoltaic	*NPV*	Net Present Value
RSq	R-Squared	*PBP*	Payback Period

WT	Wind Turbine	*PWM*	Pulse Width Modulation
Acronyms		*ROI*	Return on Investment
HRES	Hybrid Renewable Energy System	*STC*	Standard Test Conditions

1. Introduction

While renewable energy is becoming more essential for utility companies, end users, and governments, the issues associated with renewable energy use must be addressed, given the unpredictability, intermittency, and low energy density of a single renewable energy source. Microgrids based on renewable resources have been intensively researched to reduce global warming and greenhouse gas emissions. A direct current microgrid includes photovoltaic control systems, wind and battery-based renewable energy systems, and super capacitor based energy storage systems. The maximum power points for photovoltaics and wind, respectively, are determined using a neural network and optimal torque control. There is a nonlinear sliding mode controller for power supplies. Off-grid energy storage technologies are the emphasis of research, rather than the application and development of control systems. Hybrid Renewable Energy Systems (HRES) are regarded as one of the most promising and reliable alternatives to the main power grid for electrifying rural customers, since they contribute to climate change mitigation and fossil fuel consumption reduction[1]. The iterative technique involves a series of mathematical simulations that result in a succession of approximately approximated solutions to the investigation's issue. The simulations are carried out on a computer up to the point at which the specified conditions are satisfied[2]. Three segments comprise the energy value chain: generation, transmission and distribution, and end-user application. With rising power consumption and an urgent need for decarburization, resilience, and access to electricity, a shift in the energy value chain is occurring. On the generating side, distributed hybrid renewable energy systems are becoming more prevalent in order to optimize the usage of dispersed and locally distributed renewable energy[3]. The evolutionary algorithm (or heuristic approach) is a development of the more well-known iterative technique. Despite the shortcomings that result in a local rather than a global optimal system, the evolutionary algorithm is unaffected by the number of decision variables; its expansion is proportional to an exponential increase in simulation time. Linear Programming[4,5], Dynamic Programming[6–8], and Multi-objective optimization are all iterative techniques[9]. A 2021 study in the field of intelligent control offered a fuzzy logic control system with an independent photovoltaic system and battery storage[10]. Another research published in 2021 showed that an electrolyzed control mechanism may be used to create a self-contained photovoltaic system with direct connectivity[11]. Recent research, on the other hand, has concentrated on networked hybrid systems and real-time algorithms. For instance, in 2021, mariz and sungwoo used a real-time digital simulator to design a grid-connected solar photovoltaic system[12]. Additionally, in 2018, Lee et al.

investigated the performance of a solar-plus-battery system in grid-connected households in Japan to boost consumption and improve correction[13]. To be more exact, iterative approaches are used to modify the values supplied to HRES decision variables linearly, effectively scanning all potential configurations of the generating units. In this light, the computation of the system's power reliability is discovered via testing each design, along with the optimal configuration[14]. Through statistical tools, probabilistic procedures are developed as a description of the design of each variable, awarding random values based on the imported data. Hourly or daily simulations are undertaken[15,16]. Petrols et al. and more researchers investigated coordinated control for the solar array, battery storage, and capacitor network integration in 2018[17]. These researchers examined the clustering of inventions and the development of solar batteries. To balance load generation, an energy management system based on fuzzy logic was built, and controllers were simulated using software such as MATLAB and compared to one another. These systems are integrated into the control loop through hardware to do experimental validation and to verify and validate the intended system's performance[18–21]. Today's wind turbine controllers incorporate information from hundreds of sensors to regulate rotor speed, blade step angle, generator torque, and voltage and power conversion phases[22]. The controller is also responsible for important safety decisions such as shutting down the turbine in the event of an adverse situation[23,24]. The turbines operate at variable speeds and adjust the rotor speed control system to achieve maximum efficiency and maximum power and torque in oscillating winds by constantly updating the rotor speed and loading the generator[25,26]. In a study, a stochastic control model was designed for renewable energy microgrid public lighting systems. In the control system, controllable and non-controllable parts were separated and controlled by a switching unit with linear input, and feedback was recorded. Iqbal's results confirmed the use of local renewable energy sources[27]. In another system, the control model was designed based on the predictions of the dynamic DC / DC converter. Controlled automatic current operation by relay by the development of multi-port DC / DC converter. The results show that the determination of the best mode of operation depends on the input source and the energy is optimized[28]. The strategies in this category might be thought of as metaheuristic optimization methods. Artificial Neural Networks (ANN), Fuzzy Logic (FL), and Genetic Algorithms (GA) are subsets of evolutionary algorithms that function as global search heuristics[9]. The integration of renewable energy sources into hybridization systems will create voltages with different frequencies. In order to maintain the performance and stability of the consumer network, the network side converter must be synchronized[29]. the situation will be critical when there is a distortion in the output voltage. On the other hand, load demand and resource availability are analyzed as deterministic parameters with known time series change; this is how deterministic approaches work[30]. Intelligent control systems will continue to fail in this situation. the excessive DC link voltage, loss of grid voltage synchronization, and high AC current[31]. The criteria of power quality cannot be met in any other way. With a large penetration of RES into the system, the many tiny generators linked to the grid, as well as the unpredictable and time-varying nature of RES (particularly wind and solar), contribute to power quality concerns[32]. As a result, the system's nominal frequency variation may be caused by an imbalanced connection between demand and supply. If total production exceeds demand as a result of RES excess electricity exported to the grid, the frequency will be raised, and vice versa. This frequency variation has the potential to ruin the mechanical system of spinning machines and produce other difficulties that may compromise the power system's stability[33,34]. Thus, to minimize control difficulties and power outages, the frequency of the power grid should be kept within allowed limits[35]. Numerous grid codes (e.g., IEEE Std. 1588–2008, IEEE Std. 1547) have been established to solve this problem[36,37]. These standards provide restrictions for frequency, voltage, harmonics, and power rating. Frequency monitoring and estimate are consequently critical for synchronizing and safeguarding the power grid, as well as for ensuring the quality and dependability of its electricity[1,38]. Apart from the grid variables mentioned above, detecting probable harmonic components generated by the power converter is garnering more attention these days, since harmonic components may cause control mistakes and increase equipment loss[39].

The intelligent control system for hybrid renewable energy was developed in 2021. The system was powered to achieve maximum performance with minimal operating costs. The system has not been built and evaluated, however, the control scenario was based on environmental conditions. The hybrid energy system analyzed environmental conditions and modeled load balancing for the maximum benefit[40,41]. In 2021, Pastore et al. Reliably controlled the renewable energy hybrid AC system[42]. In 2020, Pravin et al. Developed a response planning and control framework for the integration of energy resources[43]. In 2021, Koh et al designed the control of a renewable energy hybrid system with battery backup using a switching systems strategy[44]. In 2020, Tedesco and Cassavela developed a load and frequency control system using the reference governor method[45]. In 2021, feist et al implemented a control system for optimizing residential hybrid renewable energy by particle optimization method[46]. In 2019, Guillaume et al. Sought to increase the penetration of renewable energy sources over time with an intelligent control system[47]. Esmaeili Shayan et al. have previously used the genetic algorithm in the hybrid system for linear integration in 2021[48]. Also, Bashir et al. optimized wind speed and solar irradiance in the power model[49]. In 2022, wang et al. Used a multi-objective algorithm based on particle swarm optimization in a wind-solar hybrid system[50]. The results are validated by the non-dominant sorting genetic algorithm (NAGA-II). After extensive studies in the control system, Esmaeili Shayan et al. In 2021 examined the optimal size of a hybrid system based on a genetic algorithm[11]. In further research[51–53], Homer software has been used to optimally measure the technical and economic efficiency of renewable hybrid systems. Homer's optimization algorithms and detailed analysis allowed the user to evaluate the economic and technical assumptions of a large number of Architect and to calculate uncertainty. Additionally, innovations in renewable electricity hybridization have been investigated. In [54,55], a novel approach for synchronizing the phase and frequency of microgrids with the distribution network was developed based on the combined use of several phase automated frequency tuning systems. The authors in [56] addressed another issue that has been overlooked or disregarded in previous research, namely the fact that during synchronization, communication links may have temporal delays; as a result, it must be included in the design of synchronizers and load sharing controllers. The main gap in existing researches is that no economic size for hybrid renewable energy systems has been determined, nor has a technical and economic model based on sustainable development been developed.

The objectives of this work is to develop an intelligent renewable energy management hybrid system that will optimize the use of generated renewable energy. With the assistance of a diesel generator support subsystem and a smart battery bank, this system investigates the cost of energy supply for a green cottage under three different scenarios: technical, economic, and environmental. Renewable energy penetration ranges between 20% and 50% in this research and approaches 100%. The novelty in this study is the use of a dynamic decision algorithm in an intelligent system microcontroller to calculate the greatest number of local solar and wind energy that can be hybridized and to optimize the residential unit's power demand.

2. Materials and Methods

A hybrid renewable energy conversion system is developed and built to coordinate, manage and control solar and wind renewable energy sources in real-time. A battery energy storage subsystem including two 100 amp-hour batteries and a diesel generator support unit is connected to the main system. Diesel generators can be renewable or non-renewable energy sources depending on the fuel consumed. This resource is included in the technical and economic calculations as the backbone of the off-grid system. The control system intervention and hybridization process has a voltage-based intervention approach with the PIC16F877A microcontroller and integrates to predict the increase or decrease of regulated output voltages or climate change between solar and wind renewable energy sources. Figure 1 The hybrid renewable energy conversion system shows an environmental test. The components of the dynamic hybrid renewable energy converter are as follows: green cottages, electronic circuits, flexible solar panels, charging controller, battery bank, temperature sensor, humidity sensor, wind speed sensor, voltage and power sensor, battery fuses, digital to analog converters, analog to digital converters, voltage divider, voltage intervention circuits, relay switch circuits, DC to DC and data logger and computer.

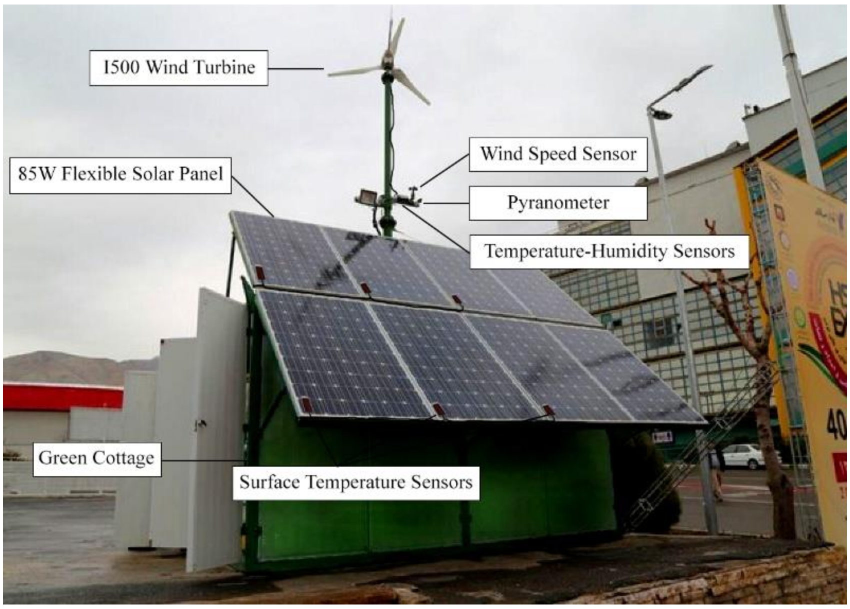

Figure 1. Renewable energy system installed on the green cottage.

Modeling and simulation of hardware system in real-time using MATLAB-State Flow software. Simulation in Simulink MATLAB software is the input of optimization analysis of intelligent renewable energy conversion system. Dynamic decision making, on the other hand, is programmed to continually understand the current state of each subsystem and to make any changes in the event of a felt and measured change. Thus, the electronic database and dynamic decision control subsystems have been integrated to monitor the performance of the DC direct current combinatorial renewable energy conversion system. DC to DC to increase the output voltages set from 7 to 12 volts, solar and wind renewable energy sources are used to the desired output voltage. The power supply is also connected to the AC load via DC to AC inverter or charging the battery energy storage system. The inverter is integrated to adjust the output voltage from 12 to 15 volts from renewable energy sources and the battery energy storage system to one voltage. Convert AC. DC to AC inverter operation is controlled using a PWM signal.

The project for a period of 20 years, assuming a discount rate of 16.7, a feed-in tariff of $ 0.05, a gasoline price of $ 0.12, and average inflation of energy carriers of 10%. The first scenario examines the situation in which the supply of greenhouse electricity is for "economic" purposes. In this scenario, wind energy source (because it is not economical) is not used and the penetration rate of renewable energy is 23.8% and non-renewable energy with 407 liters of gasoline fuel is 76.2%. Scenario 2 looks at situations where the goal is "renewable and economical." In this scenario, the penetration rate of renewable energy sources (solar and wind) is 54% and the penetration of non-renewable energy is 46%. The third scenario seeks to supply greenhouse energy through renewable energy sources. In this scenario, the consumption of fossil fuels is zero and it has been tried to meet the electricity demand of the greenhouse from solar and wind energy sources and the use of battery energy storage backup.

Development and simulation of control circuits and decision-making of renewable energy conversion systems have been done using Proteus software. At this step, C programming were used to develop the decision algorithm and finally installed on the microcontroller. The electronic circuit of the PIC16F877A microcontroller was modeled and designed in Proteus software. Electronic circuits include the following units. Voltage control units, PIC16F877A microcontroller unit, switching units, converters units, and inverter unit. The switching units have been divided into two parts:

- Switching units and control subsystems that are self-intervening between output voltages set from renewable energy sources of the sun and wind.
- Charging or discharging switching circuits are used for self-interference during the charging or discharging process.

The location of the systems in Tehran is on latitude 35°70′ N and longitude 51°15′ E. Meteorology of the test area through the control system measured in an annual period and through USB4711 at the time interval every 1 hour to a total of 8760 hours from the date of 2020-01-01 and the time 00:00:00 to date 2020-12-30 and time 23:00:00 in LabVIEW and then recorded in Excel[57]. Figure 2 shows a schematic of the subsystem connections. The energy generated by the wind turbine reaches the power line by passing through the wind turbine converter, and the voltage of the flexible solar panels reaches the power line directly. The battery bank consists of battery A and battery B connected to the DC line. HRES is powered by a dynamic decision-making algorithm that receives environmental meteorological data via USB4711A and uses TG2500DC backup to power the hybrid, supplying the greenhouse and connecting the surplus to the mains. The main source of electricity is a renewable green cottage, and if renewable energy resources are first referred to batteries and then to the generator diesel.

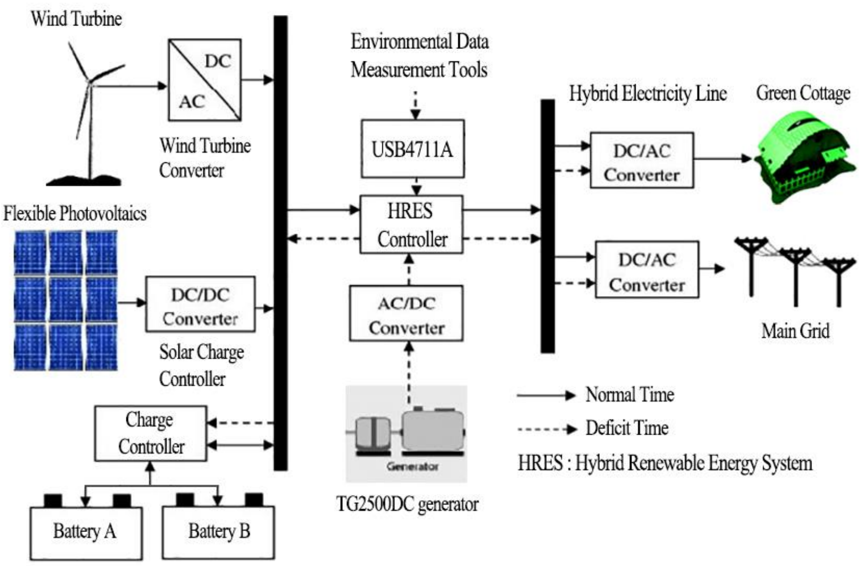

Figure 2. Schematic of hybrid system subsystems.

The hybrid renewable energy system control structure is divided into three main blocks. Figure 3 shows monitoring blocks, control, and renewable energy hybrid. Blocks perform concentration, distribution, and hybridization activities. These blocks are connected to a smart controller so that the decision algorithm is implemented through electrical circuits and optimized electrical energy performance.

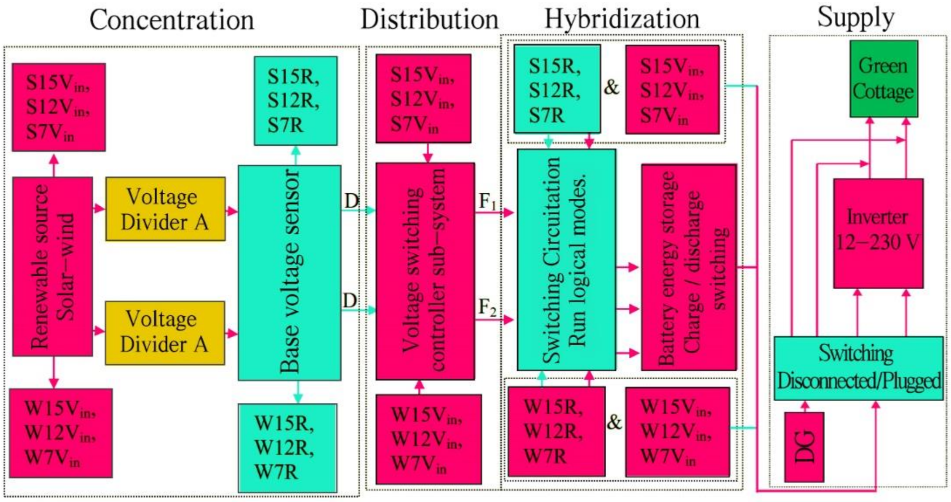

Figure 3. Green cottage control structure.

The dynamic decision algorithm depicted in Figure 4 is used to monitor, manage, and control the renewable energy conversion system. The hybrid renewable energy converter system's decision algorithm has nine states and proportional states for nine logical tasks. At each stage, the intelligent control system provides a task. Each recipe on the PIC16F877A microcontroller receives an active signal that is used to turn on or off the modules' control relays, circuit switches, or discharge switches. Switching modules and relay controllers are activated and deactivated to supply the load power supply connected to the intermittent current or charge/discharge process in the battery power supply.

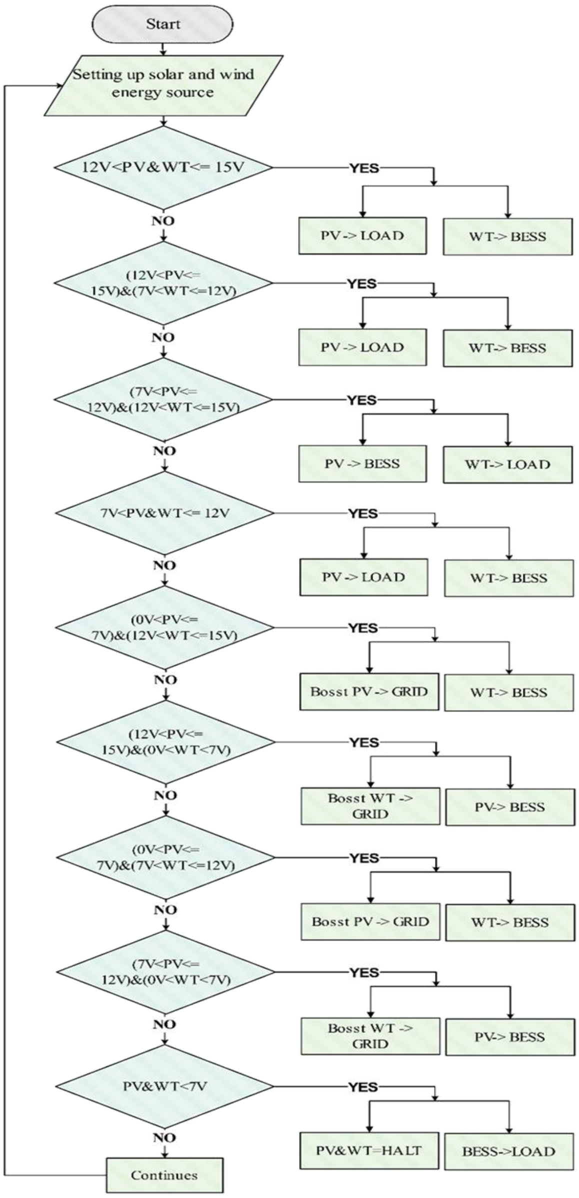

Figure 4. A decision algorithm for the hybrid renewable energy converter system.

The solar power source's adjusted voltage is set between 7 and 12 volts, and the renewable energy source's output voltage is set between 0 and 7 volts. In this case, the ADC0 reference voltage is between 0 and 2.33 volts, while the ADC1 reference voltage is between 2.33 and 4 volts. The crucial job is engaged when the renewable energy source's voltage is between 7 and 12 volts and the source's output voltage is between 0 and 7 volts. The RC6 microcontroller port transmits an active signal to the NPN transistor base, in this case, activating the relay coil. The relay is switched from NO to NC when the relay coil is activated. The renewable energy source switch circuit's output voltage of 7 to 12 volts is generated by passing the DC voltage converter through DC Boost if necessary. If the battery source energy is less than 40% and is replenished, the Microcontroller RD7 port transmits a signal for switching NO to NC relay. In this case, the system will initiate the start of the diesel generator through smart start. The green cottage's electric customers are listed in Table 1. Figure 5 depicts the annual power usage profile of the green cottages. The load factor of the green cottage is 22%, and the average daily usage is 4.10 kWh.

Table 1. Green cottage electric consumers[58].

Section	Consumption (W)	Current (A)	ON (Hours)	Ampere Hourly (Ah)
Cooking[1]	40-800	8.33	1	8.33
Entertainment	17-100	2.5	2	5
Lighting	5-10	2.28	5	11.45
Computer	50	4.16	8	33.28
Maintenance	20-100	3.33	24	79.9
Total	132-1060	20.6	-	137.96

[1] Use of electrical energy for the cooking section.

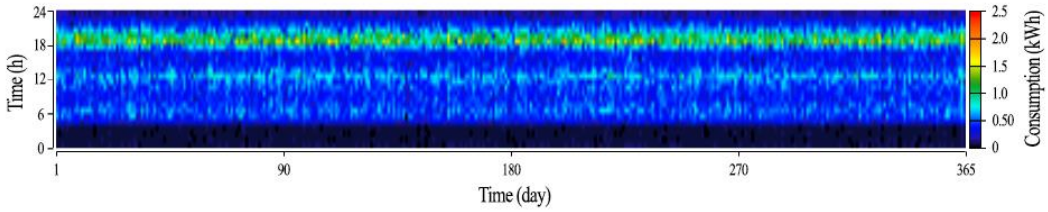

Figure 5. Green cottages electricity consumption profile.

The green cottage consumes the most power due to its lighting and cooking equipment operating at sunset. When the critical state power consumption is 247 watts and the batteries are fully discharged, the battery support time is 408.10 minutes. These situations exist when renewable energy sources are unavailable and the system's diesel generator is not connected. If the control algorithm is unable to preserve 40% of battery power, the backup system will be activated. The instrument used to measure the environmental test variables is listed in Table 2. Each device's measurement and accuracy have been reported. Systems are evaluated in real environments. Under standard test conditions (STC), the performance of an outdoor solar cell may be recorded. The IEC 61853-4: 2018 standard was utilized to determine the solar system's performance in this study[59]. For the evaluation of wind energy systems, IEC 61400-5: 2020 and IEC 61400-12-1: 2017 RLV were used, as well as for the assessment of electrical power under the wind system[39], IEC 61400-12-1: 2017 RLV[60]. The greenhouse gases equivalencies calculator is used to transform saving kilowatt-hours to reduce carbon dioxide emissions using the CO_2 margin release rate and the ANSI average weight. Finally, ISO 14067 and ISO / IEC 17029 standards were utilized to calculate the environmental impacts of the green cottage, which is supplied by a renewable energy conversion system[61].

Table 2. Measuring instrument.

Device	Variable	Unit	Range	Precision/Error
DT-8833	temperature	°C	-50-800	0.1
Pvm 210	Irradiance	W/m^2	0-2000	0.1
Cimo VT 210	Wind speed	m/s	0-35	0.1
VT 210	Humidity	RH[1]	5-95	0.1
UT203	Power	W	0-24000	1%

[1] Measurement of relative humidity percentage.

The Taguchi test and Pareto distribution will be a criterion for choosing effective components on the performance of the renewable energy system. The proposed system is based on the balance between power management and the minimum fossil fuel. Economic events through engineering economics criteria: Net present value (NPV), Payback period (PBP), Internal rate of return (IRR), and with the use of COMFAR software. Finally, after examining the dynamic response due to the dynamics of the control device and recording the power of the hybrid renewable energy conversion system, HOMER software has been used to simulate the solar-wind and diesel generator system and battery energy source. Using this analysis, different design options were compared with technical and economic principles. Also, with this method, the possibility of changes and uncertainties in the inputs was provided.

The aim function is considered to be the highest power and efficiency, as well as the efficiency of electricity production costs. In the analytical connection part, regression analysis is utilized to compare sensor data and establish the theoretical model's correctness. Minitab software was used to examine the data. A full factorial test was used to construct the Taguchi orthogonal array test. After the model is complete, it is assessed using constraints and directed functions on each subsystem. As seen in Table 3, the matrix was a useful tool for deriving interactions between subsystems and external factors, as well as output variables from one subsystem to another.

Table 3. Matrix testing levels of variables.

Variables	Range	Level 1	Level 2	Level 3	Level 4
Irradiance (W/m^2)	0-1200	0-300	300-600	600-900	900-1200
Temperature (°C)	-5-+100	-5-+20	20-50	50-80	80-110
Wind speed (m/s)	0-15	0-4	4-8	8-12	12-15
Power[1] (W)	0-1000	-	-	-	-

[1] The term "power" refers to an independent variable.

Maximum performance (electrical power generation) in watts is selected as statistical analysis. Also, to achieve this goal, "the biggest is better" was used. In this study, changes in controllable and uncontrolled variables are assessed for each contact level and then compared using the Taguchi technique of optimum system analysis.

3. Results

In order to optimize the life cycle cost of the hybrid renewable energy conversion system, several green cottage power supply strategies were studied. For modest renewable energy generating systems, particularly those that use intermittent renewable energy sources, the one-hour step model estimates renewable energy and scales it. Figure 6 displays the system cost dependent on subsystem selection.

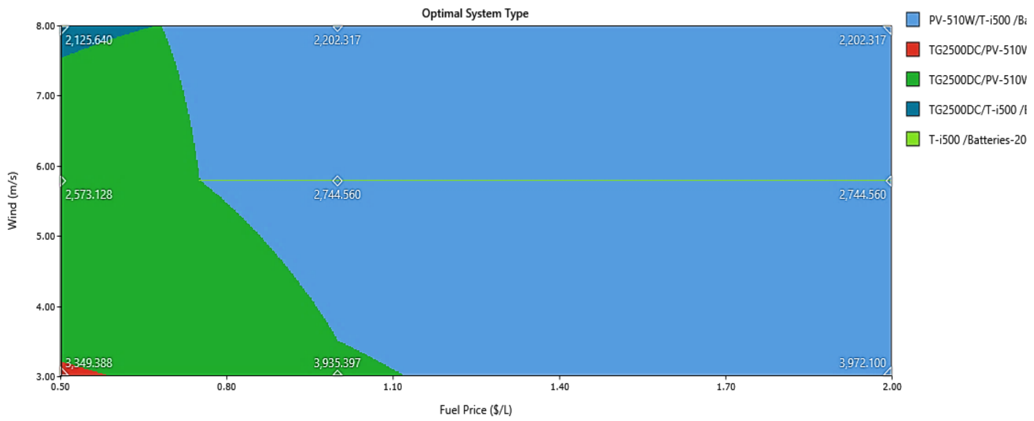

Figure 6. Selection map of the hybrid renewable system based on initial start-up cost.

If the goal is to power the Green Cottage through the use of solar, wind (with an average wind speed of 7.97 m/s), and batteries without the use of a diesel generator, the initial start-up cost will be approximately $ 2,210. If the wind speed is at a point close to the minimum 3 m/s, the same system arrangement to supply electricity will require an initial cost of $ 3961. For the arrangement of the subsystems, we will have 13 logic modes with sensitivity analysis, combinations using diesel generators and fuel consumption, and combinations with 100% renewable energy penetration. A combination that uses all the subsystems and the levelized cost of energy (COE) of $ 0.396 per kilowatt has 0.205 kW of solar subsystems (initial cost $ 410) with 1 wind turbine Model i500 (initial cost $ 1000) and diesel generator (electric motor) model TG2500DC with a nominal capacity of 0.890 kW and 2 batteries of 100 amps. This system has a penetration of 54% of renewable energy and has 253 liters of gasoline consumption during one year of operation. Also, the electric motor works in this arrangement for 1345 hours to produce 675 kWh of energy. The battery can be recharged in this arrangement for 7.03 hours and the total annual transient energy from the battery energy storage source is 499 kWh. In the simulation process, all possible scenarios are simulated to select the optimal arrangement, the ones with the lowest net present cost are introduced. Also, the summary of the annual production results of the model shows that the annual production of the solar subsystem with a penetration of 20% is equal to 331 kWh/yr and the wind subsystem with a penetration of 40.8% equal to 675 kWh/yr and diesel generators with a penetration of 39.2% is equal to 647 kWh/yr. The total energy produced by the model system is equal to 1652 kWh/yr. The AC load produced by the system for the green cottage was calculated at 1468 kWh/yr.

Wind speed factor has a direct and positive effect on the performance of the hybrid renewable energy system. The wind subsystem will reach the desired level of power generation by a wind turbine in the range of 4 to 8 m/s. Increasing the wind speed from 8 to 12 m/s will have a positive effect with a lower slope on the power and will continue up to a level of 15 m/s. The optimum wind speed for the use of small-scale wind turbines (400 watts) is recorded at more than 4 m/s and in the range of 8 m/s. Also, increasing the temperature of solar cells to more than 80 °C is undesirable and will have a significant effect on reducing the power of the system. Radiation will have the greatest effect on the production of solar subsystem power and wind speed will have the greatest effect on wind subsystem power. The combined effect of radiation and solar cell temperature is very close to each other and positive in power generation. The most combined effect in system power generation is related to the interaction of wind speed and radiation intensity. In the radiation range of 300 W/m^2, the effect of temperature is significant and can reduce the power of the system below 400 watts. In the radiation range of 600 W/m^2, the effect of temperature has a negative impact on power, this value will pass with a greater slope after 80 °C. To achieve the desired wind subsystem power, the wind speed must be more than 4 m/s. The optimum power output of the wind subsystem is more than 4 m/s and in the range of more than 8 m/s. The environmental conditions for the optimal power generation of the system are predicted in Figure 7. The system has shown the best power performance in the range of 900 W/m^2 to 1200 W/m^2 and wind speed of 12 to 15 m/s.

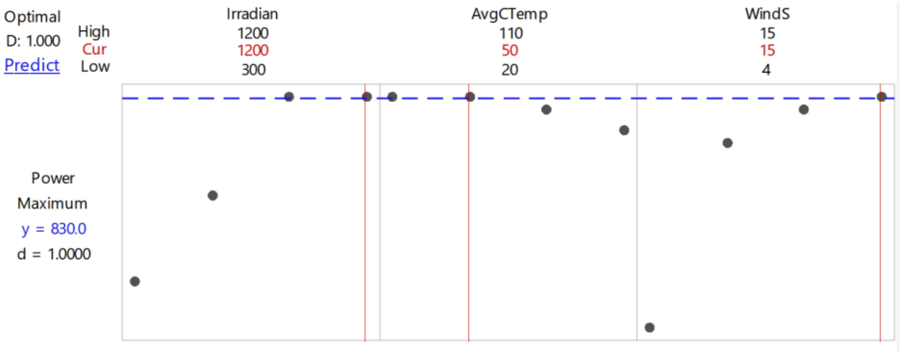

Figure 7. Green cottages optimal system power.

Figure 8 shows the Pareto analysis of the green cottage hybrid energy conversion system. The study of the average effects of environmental variables showed that the greatest effect in generating the power of the green cottage hybrid renewable energy conversion system is related to the effect of solar radiation and then wind speed. The third priority is the combined effect of solar radiation intensity and the effect of temperature on the surface of the solar panels. If the variables of irradiance and wind speed are uncontrollable, the reduction of losses due to temperature increase can have a significant effect on the electrical power of the system.

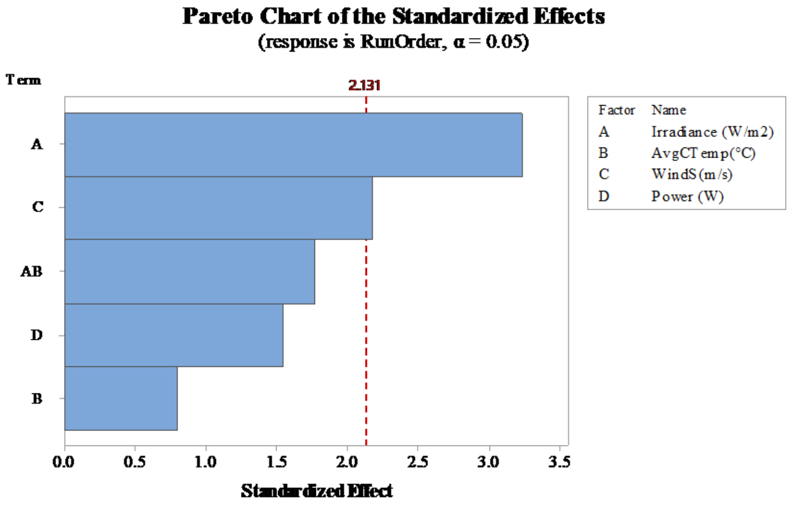

Figure 8. Average effects of environmental variables on system power generation

The analysis of variance of the means is shown in Table 4. This research demonstrates that wind speed, irradiance, and the surface temperature of solar cells all have an impact on the system's electrical output.

Table 4. Analysis of Variance for Means.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Q (W/m^2)	3	676480	676480	225493	99.78	0.000
T (°C)	3	51492	51492	17164	7.60	0.001
F (m/s)	3	1096442	1096442	365481	161.72	0.000
Q (W/m^2)*T (°C)	9	33764	33764	3752	1.66	0.148
Q (W/m^2)*F (m/s)	9	43814	43814	4868	2.15	0.060
T(°C)*F (m/s)	9	23702	23702	2634	1.17	0.355
Residual Error	27	61017	61017	2260		
Total	63	1986711				

Equation 1 shows the power of a hybrid renewable energy conversion system in outdoor conditions. The system power equation has R_{Sq} equal to 96.93% and the variables Q is Irradiance (W/m^2) and T is solar panel surface temperature (°C) and F is wind speed (m/s) are considered.

$$P(W) = 0.00047Q - 0.001155T + 0.0463F + 5.656 \quad (1)$$

Scenario 1 uses 407 liters of gasoline per year to power its diesel generators. The annual pollution emissions from each scenario are shown in Figure 9. This calculation may be effective for explaining your greenhouse gas reduction strategy, objectives, or other greenhouse gas reduction actions. Scenario 1 with a 23 % renewable energy penetration emitted 1065 kg of carbon dioxide per year. While scenario 2, with a higher penetration of renewable energy, accounted for 53% of the yearly carbon dioxide emissions of 633 kg. The vertical axis shows the amount of greenhouse gas emissions in kilograms per year and the horizontal axis shows for types of gas. Scenario 3 has a 100% renewable energy penetration and does not use fossil fuel sources. Therefore, in Figure 8, the column for emissions of Scenario 3 shows the equivalent without the value.

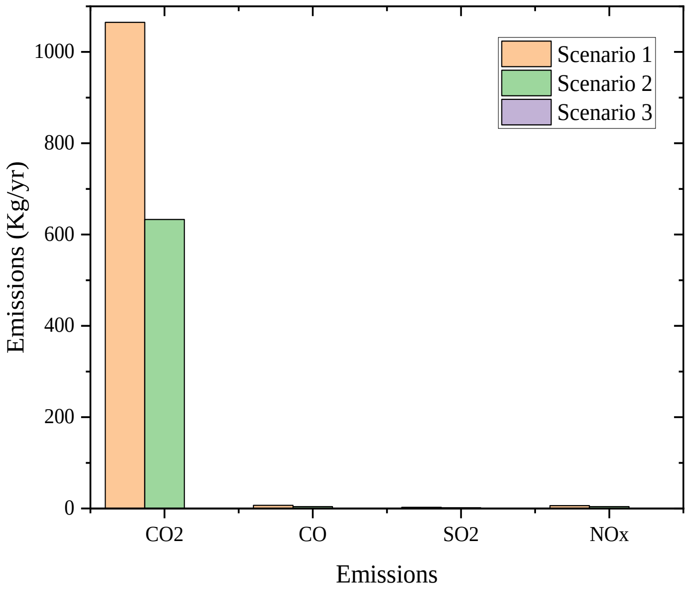

Figure 9. Emissions released in each scenario.

4. Discussion and Conclusions

The intelligent controller optimized the input and output ports of the integrated renewable energy conversion system. In certain cases, the hybrid renewable energy system will be unable to fulfill the green cottage load. A diesel generator or a local grid connection supplies the intermittent load. The study showed that the greatest effect on the electric power generation of the green cottage hybrid system is related to solar radiation and wind speed. In the first scenario, with average daily fuel consumption of 1.11 liters, the total energy produced by the hybrid renewable energy conversion system is equal to 1697 kWh/yr, and the NPV is $ 553.68 and the IRR is 21% with a payback period of 15.71 years. In the second scenario, with average daily fuel consumption of 0.694 liters, the total energy production is equivalent to 1652 kWh/yr and NPV is equal to $ 341.47 and IRR is equal to 19.5% with a return on investment of 17.61 years. In the third scenario, the energy production of the system was equal to 1933 kWh/yr with NPV equal to -372.9 dollars and IRR equal to 15.08%. Therefore, scenario 1 with renewable energy penetration of 23.8% is the most economical, scenario 2 has economic justification with a renewable energy penetration rate of 54% and implementation of scenario 3 with renewable energy penetration of 100% is not suitable for investment in countries with a discount rate of more than 10%. Increasing renewable energy feed-in tariffs is the most critical component in project economics, followed by lowering operational costs. The least effective is connected to fixed asset growth. The environmental pollutants of the first scenario are equivalent to 1065 kg of carbon dioxide per year and the second scenario is 633 kg/yr. Scenario 3 is completely renewable and has no environmental pollution. To execute scenario 3, the system needs a 400 watts of solar subsystem and two 400 watt turbines, 4 batteries of 100 ampere-hours with an average cost of $ 3378. It has a production capacity of 1933 kWh of electrical power.

In comparison, the advanced set of rules the usage of the taguchi method appears to provide substantial outputs for the battery performance, at the same time as measuring the battery performance score at 85%[32]. Study [29] proposes a modeled configuration of a small power system that integrates into an energy management strategy. Accessed the energy output of some power generation units and the inputs/outputs of charging stations or grids. The proposed model aims to minimize the operating costs of the system. The power management control intelligently controls the suitable operation of DC to DC Converter unidirectional and bi-directionally according to different conditions or solar and battery storage[25]. The study conducted in [42] explains that the artificial intelligence approach is also suitable for implementing energy management strategies. in research [56] proposed and developed a grid-connected PV system integrated with battery storage to provide an uninterruptible power supply for DC load. Reviewing applied optimization strategies in references, artificial neural networks [9], fuzzy logic [3], and genetic algorithms [32] were most used in hybridization of energy sources. However, the dynamic decision algorithm method was able to determine the economic size of the subsystems and by integrating the subsystems and with minimal investment to develop the power supply path of a house with the penetration of renewable energy.

To provide continuous power supply for load demand, it is critical to control energy flow properly throughout the proposed hybrid system. As a result, control techniques play a critical role in increasing a plant's system efficiency and energy output. In other words, by selecting the appropriate control strategy throughout the system design process, it is possible to optimize the power available from an HRES efficiently. As a result, power flow control is critical in HRES to ensuring uninterrupted energy transfer between system components. This is also necessary to extend the life of the HRES and to guarantee the energy flow is of high quality. The main limitation of the study on the investigation is the uncertainty associated with systems and models. As a consequence, the model must be updated in response to each situation. Additionally, climate might promote one form of hybrid system over another. For instance, photovoltaic hybrid systems (Photovoltaic–Diesel–Battery) are optimal in warm climates.

The main benefit of HRES is that it improves the efficiency of renewable energy generation technologies compared to a single power source. It may also address fuel flexibility, efficiency, reliability, pollution, and economics. Many things must be addressed while using hybrid energy systems to generate power. Two of these considerations are dependability and cost; hybrid generating systems are frequently more reliable and less costly than single-source systems. However, some features might be stressed to speed up the development of HRES. For example, in addition to cost and system dependability, many other practical considerations such as social, environmental, and political concerns have received little attention and need more study to give realistic and useful decision assistance. The many-to-many and system-of-systems thinking structures may provide a more holistic approach to HRES design than the simple sizing recommended in most system design research.

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