Smart Appliances for Solar-Powere Homes Nano-Grid Power Management.

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ABSTRACT

The availability of electricity significantly affects daily life. Essential tasks include running various pieces of machinery, charging mobile devices, and illuminating dwellings that require electricity. Approximately 1 billion people globally lack access to this vital resource, and many of them live in poor countries, especially in remote areas. In addition, many isolated settlements lack utility grid connectivity, largely because it would be prohibitively expensive to bring the grid to these remote communities. This difficulty has led to the development of numerous micro grid-focused efforts to supply electricity to remote locations. According to its description, nano grids are "a single domain for voltage, price, reliability, quality, and administration." These nano grids, which are smaller versions of micro grids, are designed to provide electricity to remote, small buildings that have restricted electrical supplies. This paper offers an evaluation of current rural electrification projects in developing countries, focusing on isolated regions of India. It presents a collection of algorithms intended to manage the power consumption of different electrical devices and establish the pricing for residential electricity use. Smart devices, pricing for equipment and the Internet of Things (IoT) are all important topics as they play a vital role in the application and functioning of the proposed algorithms.

Keywords: Solar-Powered, Micro-Grid Power Management, Internet of Things (IOT).

1. Introduction

The United States produced more than 4,118 billion kWh of power in 2019. [1] The availability of reliable and clean illumination is one of electricity's main benefits. Artificial illumination prolongs daytime hours, allowing people to complete more chores and promoting social and economic growth.
[2]. Another advantage of electricity is that it may be used for refrigeration. Refrigeration improves the effectiveness of medicines, expands the range of foods humans may consume, and lowers the risk of catching food-borne illnesses. An electric grid system is necessary to enable the distribution of electrical electricity. An electric grid, often known as the utility grid, is defined

as “a system of transmission lines, substations, transformers, and other elements that deliver electricity from power plants to homes and businesses”. [2]. Electricity is delivered more easily because of its distribution network. Because of the large CO2 emissions that contribute to air pollution, the use of non-renewable energy sources presents serious environmental problems. Furthermore, the medical community has been investigating power-generating technologies, specifically in relation to the health consequences of using non-renewable energy as opposed to renewable options. A research study conducted undertaken by [5], the relationship between CO2 emissions and air pollution-related death rates was compared. The results showed that the risk of deaths from these pollutants is higher in underdeveloped countries. It was determined that the use of renewable energy sources that are not reliant on carbon will greatly benefit population health. Renewable energy-based grid solutions are becoming more and more popular. Particularly in areas like India with sizable rural populations and plenty of sunlight, solar energy has become a major power source. [6]. When compared to connections with the utility grid supply, ~~It~~ **it** has been demonstrated that these systems are less expensive to build and deploy, particularly in rural locations where people are disconnected from the grid. The outlying villages linked to the grid demonstrate how difficult and inefficient it is to maintain the electrical distribution infrastructure.[7]. Because the expenses of extending the utility infrastructure are expensive and outweigh the advantages of having power, isolated areas frequently lack access to it. Nonetheless, renewable energy currently costs the same as power from the traditional utility system. These communities demonstrate that standalone microgrid systems, such as the hybrid wind-solar microgrid constructed on Lençóis Island in Brazil, offer a workable and dependable alternative that generates power of a calibre comparable to that of larger grid-connected cities. [8]. The idea of Service Quality Level relates to electric utility companies' main goal, which is to provide a consistent supply for their clients. Providing top-notch service is part of this reliability. [9], The need ~~of~~ **for** electricity in our everyday lives is highlighted by its capacity to control air conditioning during different seasons and to keep freezers operating continuously for food preservation. An estimated 1 billion people worldwide are thought to be without access to this essential resource. [10].

It is essential to evaluate the total efficacy of power availability. Regardless of whether utility companies bill customers for their electricity usage, ~~A~~ **a** high degree of service must be offered by any grid system that supplies electricity to its consumers.

2. Concepts of Local Grids – Micro grids and Nano grids.

Regions that are not connected to the utility grid are known as local grids. These small networks can supply electricity to a single facility, such as a house, or to many buildings spread across a greater region. Microgrids and nanogrids are the two different types of local grids. WG6.22 defines microgrids as "electricity distribution systems that include loads and distributed energy resources, such as storage devices, distributed generators, or controllable loads, which can be operated in a controlled and coordinated manner, either while connected to the main power network or in an islanded mode." It is possible for these grids to function both as stand-alone systems and in tandem with the main grid. A broad illustration of the accompanying figure 1 shows a generic illustration of a microgrid.

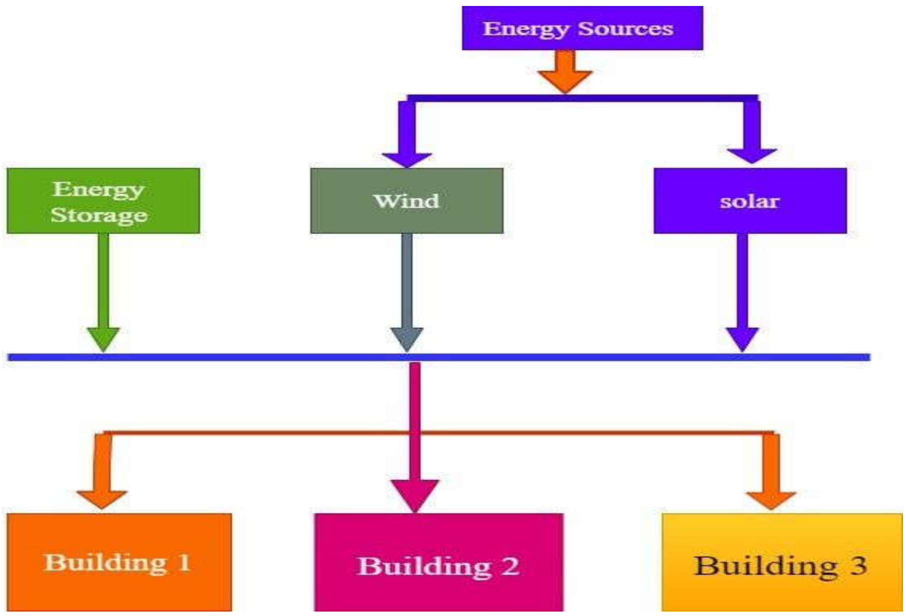

Fig. 1 Diagram of microgrid.

Often referred to as "a single domain for voltage, price, reliability, quality, and administration," a nanogrid is essentially a microgrid on a smaller scale.In contrast to microgrids, this type of grid facilitates power distribution to a limited number of loads or devices and is commonly employed in settings such as single buildings, small communities, and villages that have lower electricity demands. In contrast to a microgrid, a nanogrid runs separately from the primary utility grid. However, in order to provide electrical service to a larger population, nanogrids can link to other local grids. A nanogrid's design demonstrates its enormous potential in areas with limited access to power. The standard components of a nanogrid are illustrated in Figure 3.2. A controller, optional battery storage, electrical loads, links to other grids, and an energy sourc like solar panels or a wind turbine make up a nanogrid. This controller manages functions such as monitoring storage levels, enabling communication with other grids, supplying electricity to loads, and gaining energy from sources as well as managing all the parts. In a nanogrid, loads are any appliances or electrical gadgets that require electricity from the controller.

3. It should be mentioned that each structure in the illustration represents a separate house.

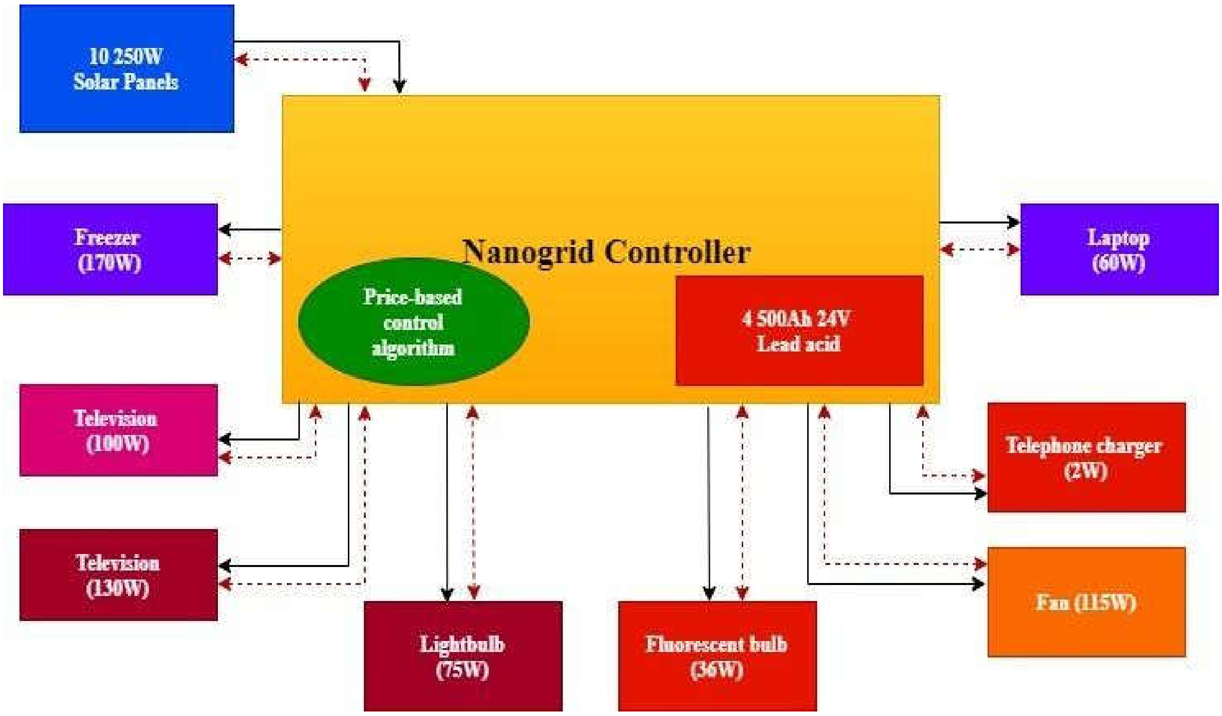

Figure .2 A nano grid with price-based control mechanism in a household.

The model of a price-based control mechanism installed in a Nanogrid system in a home in a developing Indian nation is shown in Figure 1. Based on the available energy supply, the minimum and maximum prices, the charge and discharge rates of the devices in relation to the solar panels, the specific time of day, and the weather forecast for the following day, the nanogrid controller's set of control algorithms provides the energy price in real time.

The nanogrid controller relays this real-time energy price to the devices, which, depending on user demand, turn off their power if the price is too high, reduce their power if the price is within a specific threshold, or use all of their power when the price is low. It is crucial to remember that in the system being studied, the freezer (high priority load) is effectively paying the highest amount possible in order to maintain optimal food storage. This tendency is caused by the freezer's impacts in comparison to those of the other devices; turning off the freezer's power has greater negative consequences than momentarily turning off the power to the other devices.

4. Residential DC Nanogrid.

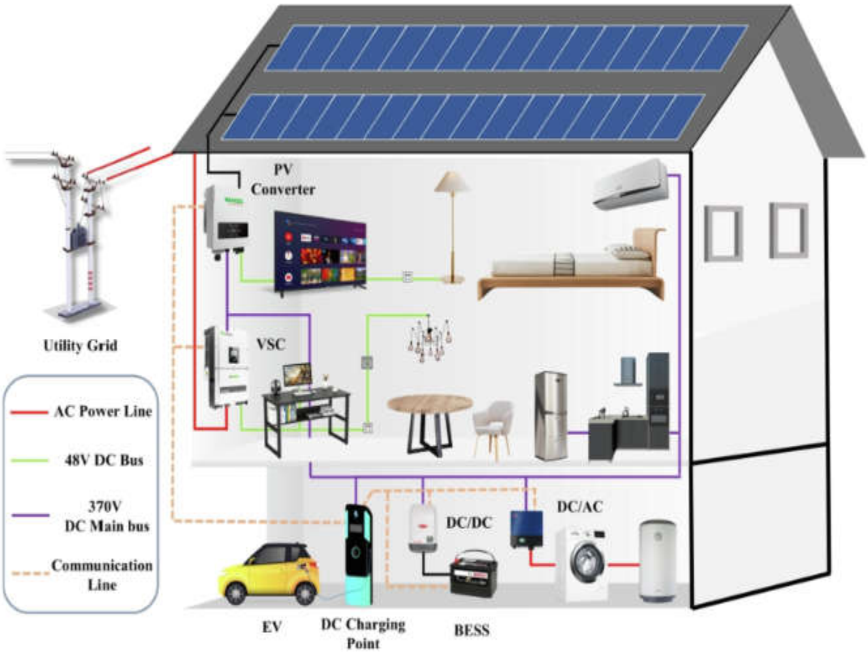

Fig: 3 Schematic diagram of typical residential DC nanogrid

The secondary level of the microgrid may be used to restore the voltage divergence caused by the primary control. Moreover, the possible existence of many power components would enable multi-agent cooperation. However, due to the integration of fewer components and the restricted functions of main level control, no equivalent control requests would exist in a nanogrid. System energy management is the microgrid's tertiary goal, which is in line with the nanogrid's objective. As seen in Fig. 2(a), direct component monitoring through specialized communication channels may also have an impact on microgrids at the tertiary level. In conclusion, because of the intricacy of the architecture, the control functions of the microgrid are more difficult than those of the nanogrid. Therefore, the classic hierarchical architecture is more suited for microgrids since it provides more control agents, levels, and communication availability. Another crucial factor to be evaluated is the architecture's cost. The microgrid can afford the more costly structure with several management layers, strong control agents, and many communication lines due to the larger system scale and investments. However, it would not work with the nanogrid, which prioritizes affordability, portability, and ease of use.

Characteristics of the household appliances.

Sl NO	Appliance	Operation periods	Power rating(W)
1	Refrigerator	24 h	150
2	Electric oven	1 h 15 min	2400
3	Kitchen ventilator	1 h	230
4	Electric iron	15 min	1500
5	Electric kettle	30 min	1500
6	Vacuum cleaner	1 h	2000
7	Lighting	5 h 30 min	100
8	Bedroom air conditioner	9 h 45 min	2200 x 2
9	Hair dryer	15 min	1800

10	Desktop computer	4 h 15 min	150
11	Dishwasher	1 h 15 min	2000
12	Laundry machine	2 h	1400
13	Central air conditioner	4 h 45 min	4000
14	Heater	2 h	2000
15	Rice cooker	1 h 30 min	700
16	Telephone	24 h	5
17	Electric kettle	30 min	1500
18	Other fixed loads	24 h	50

5. Real and predicted PV and conventional load curve.

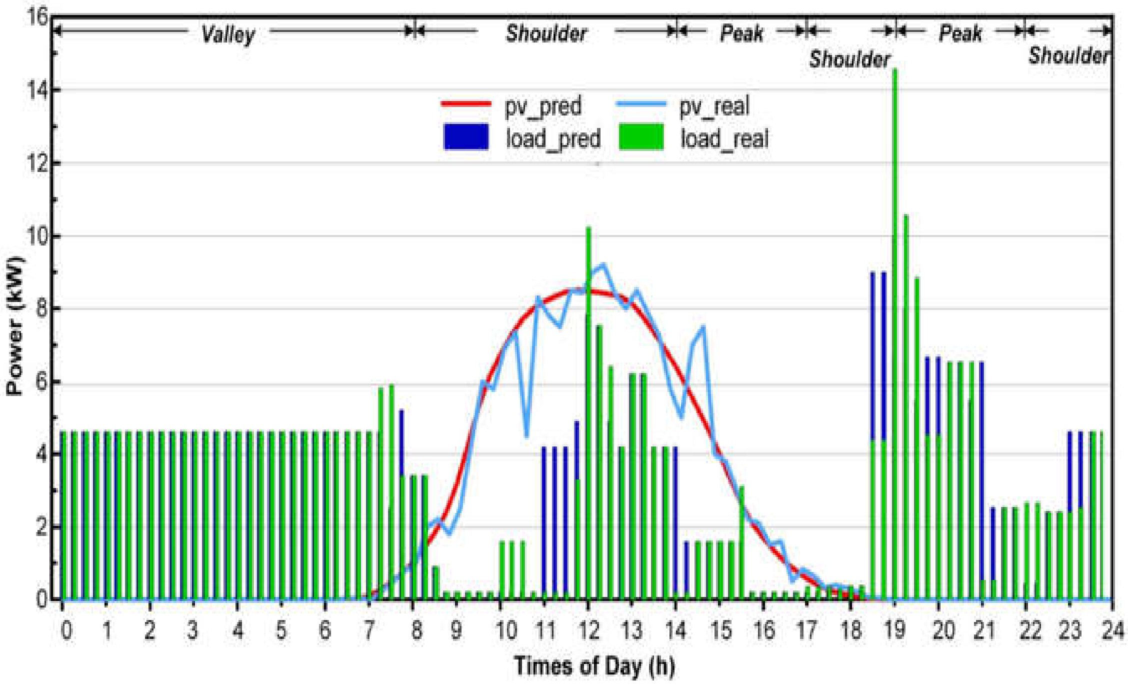

Fig.4. Real and predicted PV and conventional load curve.

Based on the actual specifications of PV and household appliances listed in the appendix, Fig. 11 displays the expected and actual PV and conventional load profiles with a 15-minute resolution with regard to the generation of PV and load data. Real PV production routinely varies from the projected PV output due to a variety of meteorological factors, including sudden variations in sun irradiation. Similarly, the actual load consumption will differ from the projection due to unexpected power demand or load cut-off. Analyzing common EV arrival and departure scenarios takes into account different EV charging and discharging procedures. The suggestions include EV conventional charging (ECC) mode, conventional autonomous V2G operation mode (ECC + droop), and suggested autonomous V2G operating mode (ECS + droop).

6. Results and Discussions

It is crucial to identify the pertinent components and their corresponding levels in order to evaluate the suggested control mechanism's efficiency and put it into practice. The control mechanism, seasonal fluctuations, battery capacity, battery level thresholds, device charge and discharge rates and thresholds for these rates, the list encompasses the time of day as well as the weather forecast for the following day.

6.1. Below is a summary of the factors and their corresponding levels.

Depending on whether the nanogrid system employs a price-based approach, the control mechanism presents two options: yes or no.

The four categories of season type—ideal, dry, intermediate, and rainy—reflect the yearly changes in the climate. Two predetermined levels, 1x and 2x, that determine the battery capacity by representing the energy needs depending on the amount of dark days the system must serve. Specifically, in Yaoundé, Cameroon, 1x accounts for 2.7 hours of dark days, and 2x accounts for 4.14 hours of black days. It's crucial to keep in mind that all battery sizes begin the season fully charged.

6.2. Battery Level Threshold: Specifies the two levels that make up the battery charge level.

1. The battery management system has both low and high threshold criteria for battery capacity.

2. The Charge and Discharge Rate Threshold illustrates the difference between the energy utilized by devices (discharging) and the energy supplied by solar panels (charging) at two distinct levels: negative and positive rates.

3. The Adjustment for Charge and Discharge Rates The term "threshold" describes the three degrees of adjustments performed in accordance with the charge and discharge rates: low, medium, and high.

4. Depending on whether it is morning or evening, the time of day component affects modifications.

5. The weather forecast for the following day provides an adjustment factor. Based on expected weather,

The Next Day Weather Forecast offers an adjustment factor. It has two levels: bright and overcast, which the user may change based on seasonal changes.

6.3 Program writing for coding variations power in micro grid

```
#include <stdio.h>

// Define constants based on the algorithm
#define ADJUST_CHARGE 1.1       // Adjustment factor when charge difference is positive
#define ADJUST_DISCHARGE 0.9    // Adjustment factor when charge difference is negative
#define ADJUST_MIDDLE 1.0       // Adjustment factor when charge difference is between
positive and negative thresholds
#define POSITIVE_RATE 10.0      // Threshold for positive charge difference
#define NEGATIVE_RATE -10.0     // Threshold for negative charge difference

// Variables for charge difference and energy price
```

```
float charge_difference;        // Current battery charge difference (in W)
float energy_price = 1.0;       // Initial energy price (in dollars per Wm)

int main() {
   // Infinite loop to simulate "do forever" in the algorithm
   while (1) {
      // Simulate updating charge_difference
      printf("Enter the current charge difference (in W): ");
      scanf("%f", &charge_difference);

      // Check if charge_difference is above the positive threshold
      if (charge_difference > POSITIVE_RATE) {
         energy_price *= ADJUST_CHARGE; // Increase energy price by adjustment factor
         printf("Charge difference is positive. Adjusting energy price by ADJUST_CHARGE
factor.\n");
      }
      // Check if charge_difference is below the negative threshold
      else if (charge_difference < NEGATIVE_RATE) {
         energy_price *= ADJUST_DISCHARGE; // Decrease energy price by adjustment factor
         printf("Charge difference is negative. Adjusting energy price by
ADJUST_DISCHARGE factor.\n");
      }
      // Charge difference is in the middle range
      else {
         energy_price *= ADJUST_MIDDLE; // Adjust energy price by middle factor
         printf("Charge difference is in the middle range. Adjusting energy price by
ADJUST_MIDDLE factor.\n");
      }

      // Send the updated energy price to the time-of-day algorithm (here, we simply print it)
      printf("Updated energy price: $%.2f per Wm\n\n", energy_price);

      // Wait for 1 minute before repeating (simulation in this program)
      // In a real program, you might use a delay function like sleep(60) to wait for 1 minute.
   }

   return 0;
}
```

6.4. Variation of the power

Enter the current charge difference (in W): .4
Charge difference is in the middle range. Adjusting energy price by ADJUST_MIDDLE factor.
Updated energy price: Rs113.92 per Wm

Enter the current charge difference (in W): 2.5
Charge difference is in the middle range. Adjusting energy price by ADJUST_MIDDLE factor.
Updated energy price: Rs113.92 per Wm

Enter the current charge difference (in W): 3
Charge difference is in the middle range. Adjusting energy price by ADJUST_MIDDLE factor.
Updated energy price: Rs113.92 per Wm

Enter the current charge difference (in W): 4
Charge difference is in the middle range. Adjusting energy price by ADJUST_MIDDLE factor.
Updated energy price: Rs113.92 per Wm

Enter the current charge difference (in W): 5
Charge difference is in the middle range. Adjusting energy price by ADJUST_MIDDLE factor.
Updated energy price: Rs113.92 per Wm

Enter the current charge difference (in W): 6
Charge difference is in the middle range. Adjusting energy price by ADJUST_MIDDLE factor.
Updated energy price: Rs113.92 per Wm

Enter the current charge difference (in W): 7
Charge difference is in the middle range. Adjusting energy price by ADJUST_MIDDLE factor.
Updated energy price: Rs113.92 per Wm nter the current charge difference (in W): .4
Charge difference is in the middle range. Adjusting energy price by ADJUST_MIDDLE factor.
Updated energy price: Rs113.92 per Wm

Adjustment factor for battery level-low=minimum price
Medium=adjusted price
High = maximum Price

Adjustment factor for charge and discharge rates –low = 0.4, medium=0.7, high=1.0
The element of time of day adjustment –morning=0.4, evening=0.9

• The next day's weather modification factor - Cloudy rate during the ideal season = 0.15, sunny rate = 0.1.
Cloudy rate during the dry season = 0.22, sunny rate = 0.21.
Cloudy rate in the intermediate season = 0.35,
sunny rate = 0.3. Rainy season: cloudy rate = 1.3, sunny rate = 0.78

6.5. Experiment with Battery Size.

The performance of the system in relation to various battery sizes is examined in this study. We examine total energy waste (kWh), power loss occurrences, user experience quality, and energy use for the 1x and 2x battery combinations. This battery size experiment enables comparison of the nanogrid system's efficiency with and without a control mechanism.

Table 1.1 summarizes the results of experiments for both controlled and uncontrolled nanogrid configurations that were carried out throughout the rainy season.

6.7. Season Effects Experiment.

An examination has been conducted on the energy consumption during the rainy season, optimal season, dry season, and intermediate season 55. This includes impacts from blackouts, quality issues, and total energy waste (kWh). Since electricity supply matches demand, devices will consistently operate at maximum power during the optimal season, which features clear, sunny days for the entire month.

6.8. Table 1.1 **e**xplains how the system is affected by the several seasons that are utilized for testing.

Table 1.1: Rainy-season battery size

Experiment Number	Control Mechanism	Season	Battery Size (fixed)
1	no	Rainy	1X=2Days.7 hours
2	yes	Rainy	1X=2Days.7 hours
3	no	Rainy	2X=4days.14 hours
4	no	Rainy	2X=4days.14 hours

Table 1.2 Season effects for ideal, dry, intermediate and rainy season.

Experiment number	Control Mechanism	Season	Battery size (fixed)
1	No	Ideal	1x=2Days.7 hours
2	Yes	Ideal	1x=2Days.7 hours
3	No	Dry	1x=2Days.7 hours
4	Yes	Dry	1x=2Days.7 hours
5	No	Intermediate	1x=2Days.7 hours
6	Yes	Intermediate	1x=2Days.7 hours
7	No	Rainy	1x=2Days.7 hours
8	Yes	Rainy	1x=2Days.7 hours

6.7. Energy Utilization.

Table 1.3 describes the energy consumption of the system based on battery size. The nanogrid without control consumes more energy than the nanogrid with the control mechanism engaged in the battery size experiment.shows the system's energy use according to the seasons. We find that throughout the dry, intermediate, and rainy seasons, the energy consumption of the nanogrid without control is greater than that of the nanogrid with control.

Table 1.3 Energy utilization from battery sizing experiment

Experiment number	Control Mechanism	Season	Battery size (fixed)	Energy Utilization
1	No	Rainy	1x	91%
2	Yes	Rainy	1x	89%
3	No	Rainy	2x	92%
4	Yes	Rainy	2x	90%

Table 6.4 Energy utilization from season effects experiment

Experiment number	Control Mechanism	Season	Battery size (fixed)	Energy Utilization
1	No	Ideal	1x	100%
2	Yes	Ideal	1x	100%
3	No	Dry	1x	98%
4	Yes	Dry	1x	96%
5	No	Intermediate	1x	92%
6	Yes	Intermediate	1x	88%
7	No	Rainy	1x	91%
8	Yes	Rainy	1x	89%

7. Conclusions.

A strategy for managing a nano grid system through pricing is discussed. It looks into the rates of both managed and unmanaged power outages, as well as the existence of control systems, while evaluating different off-grid initiatives. The suggested strategy sets energy pricing according to consumer preferences and their willingness to pay for the operation of devices. This approach proved effective in completely eliminating blackouts across all seasonal fluctuations throughout the year by simulating a household in a developing country. The proposed control method establishes a balance between the occurrence of power outages (blackouts) and reduced power usage from appliances (brownouts) during the day, considering the technological and financial constraints of standalone systems.

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