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Real Time Energy Data Monitoring Model for Integrated Renewable Energy System with other Collaborative Energy Supply

[1]Engr. Kufre Esenowo Jack* ORCID: 0000-0003-2422-5442, [2]Prof. Abel Usoro ORCID: 0000-0002-9640-7598, [3]Mr. Emaediong Sylvanus Udofa and [4]Mr. Linus Anthony Johnson

[1]Department of Mechatronics Engineering, School of Electrical Engineering & Technology, Federal University of Technology Minna, Niger State, Nigeria.*
[2]Department of Mathematics/ Computer Science, Ritman University, Ikot Ekpene, Akwa Ibom State, Nigeria.
[3]Department of Electrical/Electronic Engineering, School of Engineering Technology , Akwa Ibom State Polytechnic Ikot Osurua, Ikot Ekpene, Akwa Ibom State, Nigeria.
[4]Jalinus Engineering Works, Abak, Akwa Ibom State, Nigeria.

Corresponding Author's name and email address: Engr. Kufre Esenowo Jack; kufre@futminna.edu.ng

Abstract
The concept of integrated renewable energy has been a necessity for our fast-growing economies. However, most of the experimented integrated systems are facing large data management problems and this necessitates the need for smart configuration with Internet of Things (IOT). On an estate with houses that operate independent power systems, this research designed and implemented a 24-hour simulation of an integrated system that employed big data techniques for monitoring and controlling real time energy data from collaborative supplies with load priority selection options. It used Proteus software, Arduino uno, android app designed with HTML, CSS and JavaScript, and the web-based designed with PHP, MongoDB and JavaScript. Within a 3-hour schedule, the system underwent energy and load priority check to select preferred supply and suitable load. The operational level was displayed on both a mobile device and a hardware panel. Further research will be physical implementation.

***Keywords**: Real Time, Energy Data, Model, Integration Renewable Energy, Collaborated Supply*

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I. Introduction

The high demand for energy supply due to rapid population increase leads to the consideration of other sources of energy for human optimal operation. The concept of decarbonizing the economy through clean and renewable energy supply before 2050 is achievable [1]. However, most of the already experimented integrated systems are now facing large data management problems, and this necessitates the use of smart configuration with IoT. The technological advancement in the energy sector recently would pave the way for clean and renewable energy resources to thrive alongside with the IoT to mitigate this complexity [2].

This design would be demonstrated with five detachable household buildings in a semi-estate, the buildings make use of the single generating set (power generator), configured hybrid solar (clean energy) setup and public power supply. The design considers developing a scheme for the generators, clean energy and public supply smart integration into a common bus with energy priority concept. The generating set in the semi-estate will be synchronized for intelligent starting and stoppage, and the renewable energy setups in the semi-estate will be hybridized and optimized for intelligent operation as well, and the public power supply would be connected to a common tie (bus). Then the three-bus system will be developed to handle each of the multiple supplies with prioritization mode such that if power is available in the three energy sources, the intelligent system would initiate and allow only the public power supply for the mini-estate usage. In case of the public supply-outage, the intelligent system, with its sensing devices, initiates and allows the hybridized renewable energy supply to load the semi-estate, and when the public supply and the hybridized renewable energy supply are not available, automatically the intelligent system initiates a generator start-up scheme to load the estate. When the public power supply is restored, the self-prioritized system stops the generating set from operation and switches back the public power supply for the mini-estate use without visible notification of the energy transfer. The five-households in the mini-estate would assess and monitor all the energy operations on real time basis from their Android app but can only initiate an energy control function into their individual building from the mobile application. A real time energy data monitoring model for an integrated renewable energy system with other collaborative supplies can serve as an advanced step in meeting these targets.

Our flourishing renewable energy potential would salvage the present energy problem if harvested and harnessed but the high rate of energy demand has created data handling challenges in the energy sector globally. The generated and consumed data gathered from renewable energy and its collaborative sources are becoming big every day. Consequently, monitoring of these integrated energy schemes requires IoT for its real time data handling. Several households now depend on renewable energy systems alongside other energy sources for their domestic operation, thereby mitigating the problem of energy wastage, but the growing energy information still remains an issue which requires an IoT enabled system for data management. The IoT system would provide information on each building consumption and information tariff for each building thereby eliminating any disputes by the beneficiaries. With the incorporated prepaid tariff system, beneficiaries get the energy once they pay and when they do not pay, the system isolates itself automatically. This research proposed a real time energy data monitoring model for integrated renewable energy system and other available power supply for contributory energy scheme.

The aim of this paper is to design a real time energy data monitoring model for an integrated renewable energy system and its collaborative supplies concept. The objectives are to design energy monitoring and a control model with load priority check; real time energy data analysis from collaborated generating and consumption scheme and energy web-based for data collection, handling, analysis and evaluation. This proposed design would provide information for the development of a large renewable energy network data management system and encourage a collaborative energy supply scheme for miniature applications from this demonstration.

II. Literature Review

To attain a renewable energy smart-grid interconnectivity, IoT provides a basis for a variety of household applications that would facilitate sustainable energy delivery. IoT encompasses cloud computing and android devices for real time energy monitoring and control [2]. The challenges in determining the quantity of renewable energy produced has recently led to the development of the virtual power operating center to supply energy producers and decision makers in the energy market. However, adaptive models have been used to provide more reliable predictions algorithm [3].

Large data management is becoming a problem in buildings, this large data emanates from smart metering systems, sensing and other devices associated with IoT. [4] developed a building data exchange model with an algorithm from artificial intelligence to ease the data handling. [5] validates that renewable energy requires an adequate management system as it would require a data process to aid control activities. [1] explain that the universal energy demand by 2050 would be met from renewable energy supply sources, these predictions were made from the renewable energy dataset which shows that two-thirds of the renewable energy would contribute to the bulk of energy and thus, they would help to reduce the emissions from the greenhouse gas. [6] explored the potential of renewable energy for large integration systems and provided a guide for its integration such that it becomes the largest producer of energy for consumption.

[7] exploited the potential of renewable energy and explained that for it to be the leading sustainable energy source, smart-grid integration should be encouraged. [8][9]'s investigation reveals that the control issue associated with renewable energy systems is the integration which threatened the power system stability in the microgrid. Their research reveals that connecting the renewable energy sources to the grid was one of the major challenges and suggested from a developed single phase microgrid model that the electric grid must be made to adapt to the generation units before its integration. [10] established that a control scheme could be developed with a Dc microgrid through a simulation model for the autonomous control operation under various load conditions. The emerging electricity market would be interested in the deployment of a large quantity of renewable energy resources into the microgrid with flexible, controllable and efficient operation. [11] attempted to monitor and control an integrated renewable energy system on a real time basis, but discovered that the intermittent and random nature of renewable energy resources is the major challenge hampering the reliability of the system, thus they proposed a new off-line optimization approach to devise the online algorithm. [12]'s research indicated that energy cooperation (microgrids configuration) is the key to sustainable energy demand attainment given that the irregular nature of the renewable resources hindered the reliable operation of system. They proposed two cooperative microgrids systems with an online algorithm for real-time energy management as a suitable way to attain system reliability which this design seeks to demonstrate.

To mitigate the shortcoming of these renewable energy intermittent and randomly fluctuating nature, energy integration is required, and their design was developed with an intermittency mitigation technique for optimal system reliability [13]. [14] affirm that renewable energy intermittently and randomly fluctuates and proposed a fuzzy system-based management approach to overcome the challenges. [15] developed a residential feeder of Low voltage microgrid benchmark model for the integration of multiple sources and loads in the grid as the measures to face out the renewable energy intermittency and load uncertainty challenges. [16] explored the concept of blockchain in community energy management for smart grid systems where several self-renewable generating users share the energy into the community microgrid alongside with others for optional company utility. In these cases, every participant applies the best strategy to minimize their energy consumption cost with the internet of things and smart metering system.

[17] validated that in order to attain a complete transition from conventional energy source to renewable energy system successfully, small-scale integration and internet of things should be the first step. However, many renewable energy sources were presented in a modelled form, optimized and their integration was virtually demonstrated. This paper proposes a real time energy data monitoring model for integrated renewable energy systems and their collaborative supply concept. The novelty in this research work is the development of the central energy system for cohabited households to reduce cost of individual energy tariff and cope with energy wastages. This system proposed a centralized energy system for the five detachable households with real energy monitoring and control using IoT and the generated and consumption energy data are documented to ascertained individual energy dispensary level with mobile devices.

III. Methodology

3.1 System Design

A simulation is designed on a semi-estate with five detachable buildings. Each building has a single generating set, a solar hybrid setup and a public power supply. A generator set, clean energy and public supply smart integration scheme (common bus) is developed with a load energy priority concept. Priority is given to lighting load, followed by power load before heating load. The lighting load is for 5-10amp appliances; power load is for 13amp appliances, whereas the heating loads are for 15amp appliances such as a water heater, a pumping machine and air conditioners. Each of these loads generates its own data during energy usage, the data emanating from both the power supply and the domestic load are captured, collected, documented and analysed to ascertain the size of the data generated and consumed from this small model experiment.

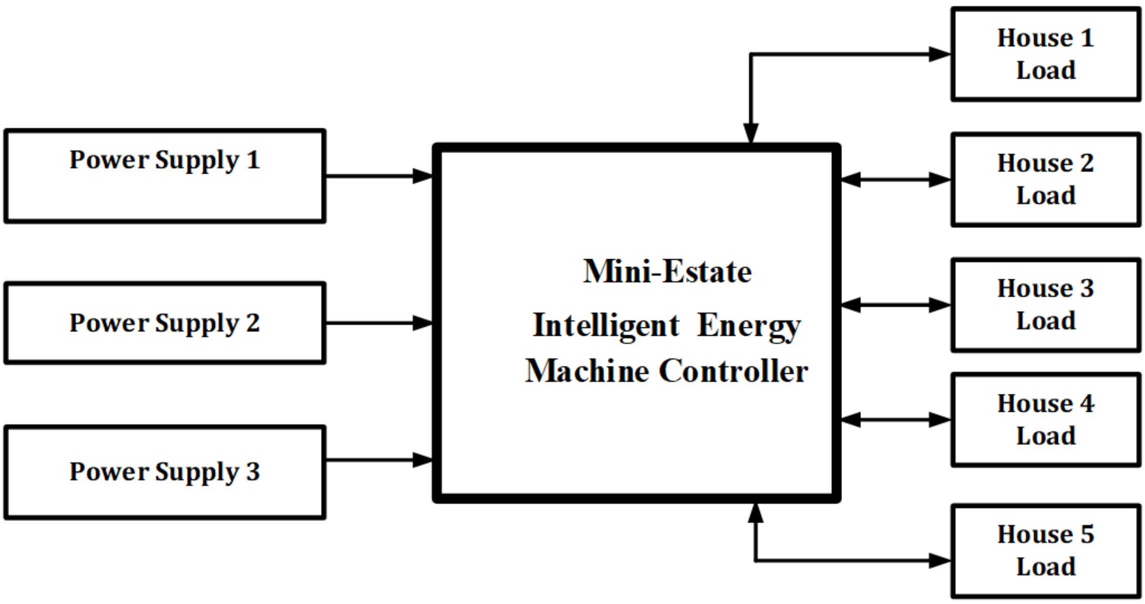

Figure 1: The Integrated Renewable Energy System with Other Collaborative Supply Models

Figure 1 shows the Power supply from the three sources with public supply, renewable energy and alternative generator supply. It also shows the mini-estate intelligent energy machine controller (microcontroller, GSM module, generator starting system, energy integration bus, switches and relays) and individual house service load with feedback system.

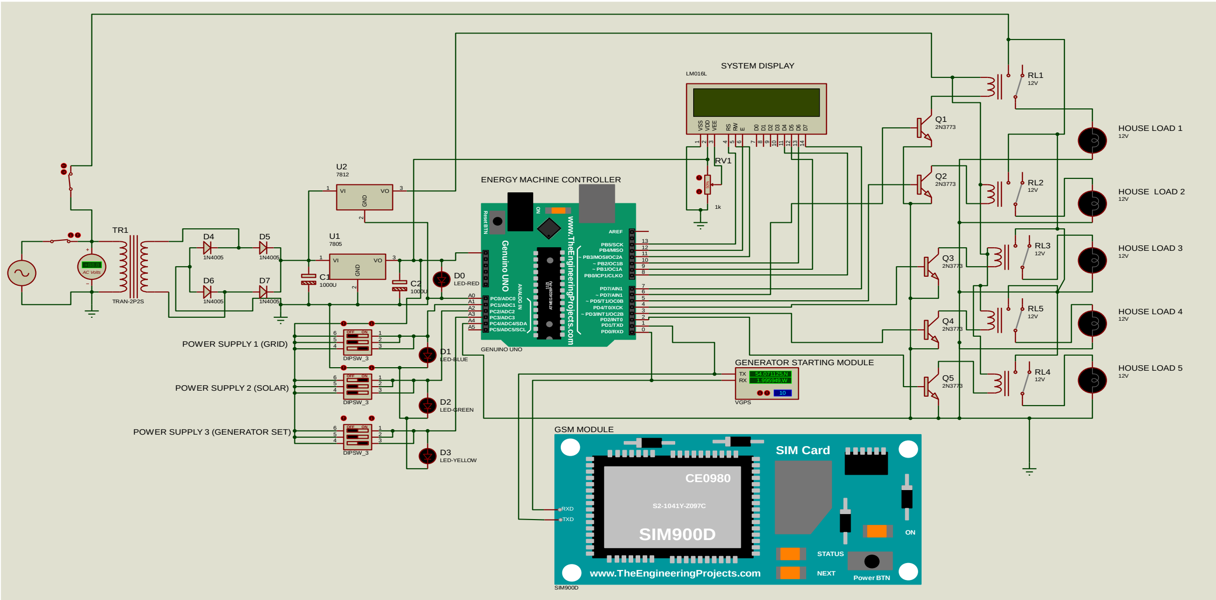

Figure 2: Proposed Mini-estate Intelligent Energy Machine Controller with Other Collaborative Supply Model

Figure 2 shows the proposed mini-estate intelligent energy machine controller with collaborative supply model, the power supply from the three sources: Public supply (grid system), renewable energy system (solar) and alternative Support (generator) supply. The system has supply priority selection capability and load supply priority selection. In the first instance, the system gives priority to the supply from the grid to serve the load demand for the five households. If the public supply energy is not available, the system automatically initiates the renewable system supply to the mini-estate and if the public power supply and the renewable energy are not available, the system smartly initiates the generator supply by automatically starting it. The three energy sources are integrated into the three-bus system via the energy machine controller. There is a feedback path from the individual load center which enables the controller to select the load depending on the source that is available for use. The available supply source is displayed on both the LCD and the mobile app with the wattage delivered to the bus; similarly, the individual energy consumption is also shown. The real energy data collection, documentation and display are made possible with interaction of the hardware and the GSM module via the internet.

IV. Results and Discussion

The system was simulated for 24 hours, with 3 hours' intermittent checks. The result shows when the grid, solar and generating set energy was available and their respective loads that were applied.

Table 1: The Mini-estate Power Supply within 24 Hours' Demonstration Period

Energy Supply (W) and Time Duration (3Hrs)	Grid	Solar	Generator set	Total Available Power
6am-9am	300	0	0	**300**
9am-12pm	0	180	0	**180**
12pm-3pm	0	220	0	**220**
3pm-6pm	250	0	0	**250**
6pm-9pm	0	0	340	**340**
9pm-12am	450	0	0	**450**
12am-3am	0	0	475	**475**
3am-6am	0	0	360	**360**

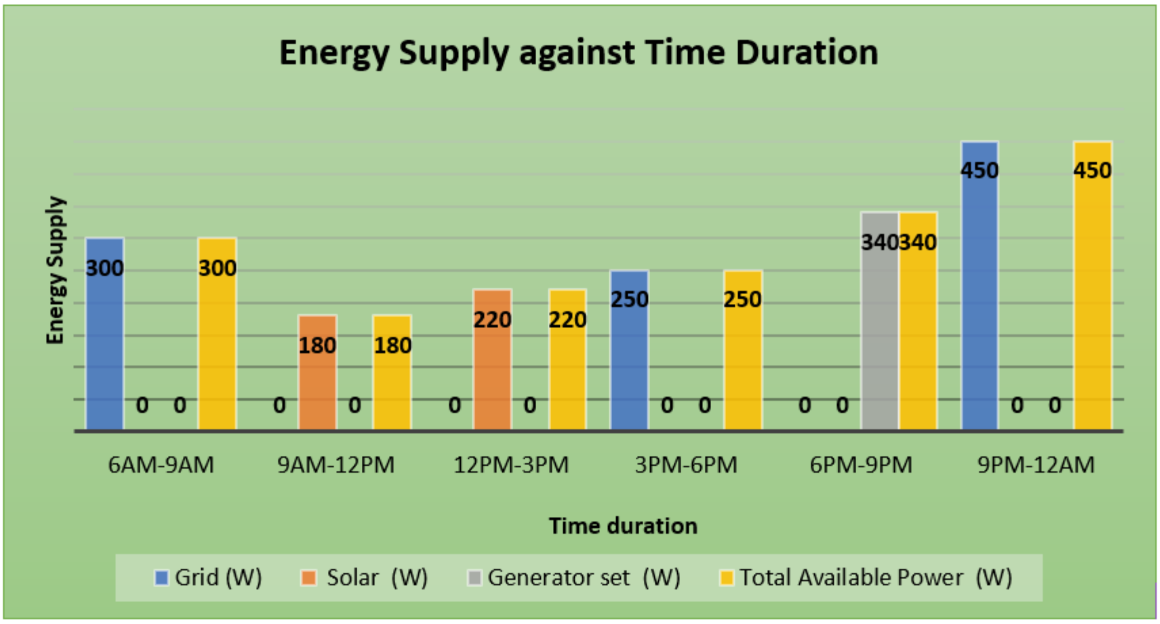

Figure 3: The Result of the Mini-estate Power Supply Within 24 Hours' Demonstration Period

Table 1 and figure 3 show the 3 hours' energy generated for the mini-estate consumption. The design is made such that only one source of energy operates within the designed 3-hour schedule. During the first 3 hours (6 am to 9 am) the public power supply was available and it supplied 300W; the solar energy was stored during this period. By 9 am the public power supply went off; then, the stored solar energy took over and delivered 180W to the mini-estate until 3 pm. The public power supply was restored by 3 pm and it produced a power supply of 250W, thereby relieving the solar energy supply smartly. By 6 pm there was an outage in the public power supply and the smart mini-estate energy controller scanned the power sources and solar energy was not available for use. Therefore, it initiated the generator, starting to load the mini-estate with 340W. The sequence of operation continued. The data were collected and deposited on the cloud. These energy changes were viewed from the developed panel on the hardware basis as well as on a mobile device. The design followed the prioritized sequence: the energy sensor first actuates the public power supply, followed by the solar energy supply and lastly the generating set supply.

Table 2: The consumed power in mini-estate within 24-hour demonstration Period

Households and Time Durations (3Hrs)	**House Load 1 (W)**	**House Load 2 (W)**	**House Load 3 (W)**	**House Load 4 (W)**	**House Load 5 (W)**	**Total Load (W)**
6am-9am	60	50	40	80	70	**300**
9am-12pm	30	60	40	0	50	**180**
12pm-3pm	35	40	45	50	50	**220**
3pm-6pm	50	50	50	50	50	**250**
6pm-9pm	70	80	75	45	70	**340**
9pm-12am	85	95	85	97	88	**450**
12am-3am	95	100	90	100	90	**475**
3am-6am	85	50	60	75	90	**360**

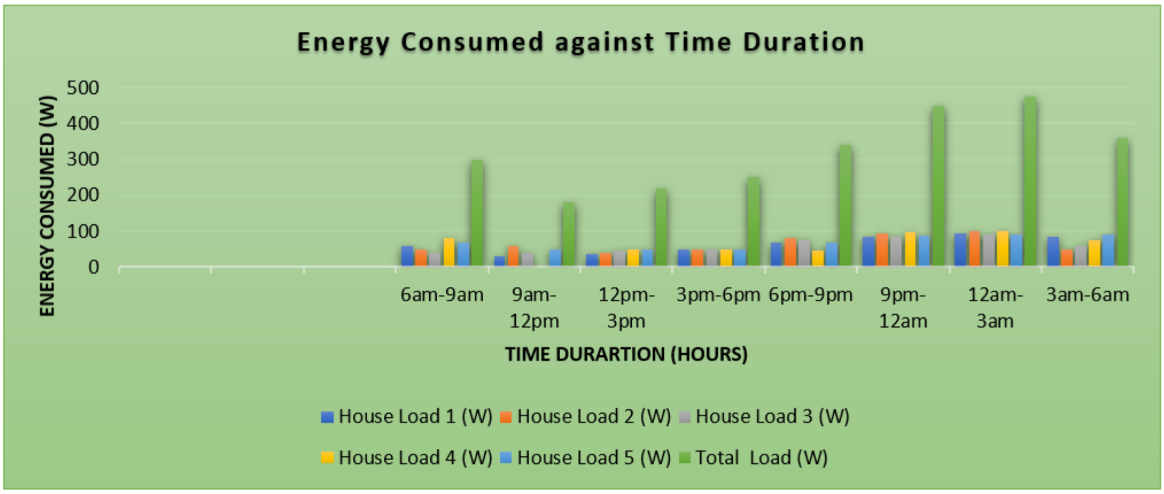

Figure 4: The result of the mini-estate power consumption within 24-hour demonstration Period

Table 2 and figure 4 show the 3-hour energy consumed for the mini-estate from energy generated. The design is made such that only one source of energy operates within the designed 3-hour schedule and this available source prioritized its load, such that within 6am and 9am, 60W was allocated to building 1, 50W was allocated to building 2, 40W was allocated to building 3, 80W was allocated to building 4, and 70W was allocated to building 5. In their load priority concept, the lighting appliances for the five buildings in the mini-estate were first put to use, which facilitated the collections of the lighting data and deposition to the cloud. The power appliances were also initiated for the five buildings, and their data were documented. The remaining power was used for the heating devices in the mini-estate.

The Database size estimation

$$Number\ of\ character\ in\ each\ field\ (field\ sizes) = x$$

$$Number\ of\ fields\ per\ record = y$$

$$Number\ of\ records\ in\ each\ table = z$$

$$Estimated\ \ size\ of\ each\ table\ = \frac{x \times y \times z}{1024}$$

From table 1,

$$Number\ of\ character\ in\ each\ field\ (field\ sizes) = x = 3$$

$$Number\ of\ fields\ per\ record = y = 5$$

$$Number\ of\ records\ in\ each\ table = z = 8$$

$$Estimated\ size\ of\ each\ table\ = \frac{(3 \times 5 \times 8)}{1024} = \frac{(120)}{1024} = \mathbf{0.12}\boldsymbol{kb}$$

From table 2,

$$Number\ of\ character\ in\ each\ field\ (field\ sizes) = x = 3$$

$$Number\ of\ fields\ per\ record = y = 7$$

$$Number\ of\ records\ in\ each\ table = z = 8$$

$$Estimated\ size\ of\ each\ table\ = \frac{(3 \times 7 \times 8)}{1024} = \frac{(168)}{1024} = \mathbf{0.16}\boldsymbol{kb}$$

$$Estimated\ size\ from\ table\ 1\ and\ table\ 2\ = [0.12 + 0.16] = 0.28\boldsymbol{kb}$$

Table 3: Estimated Daily data trend for 10 days

Days	Hours in days	Data(KB)
1	24	0.28
2	48	0.56
3	72	0.84
4	96	1.12
5	120	1.4
6	144	1.68
7	168	1.96
8	192	2.24
9	216	2.52
10	240	2.8

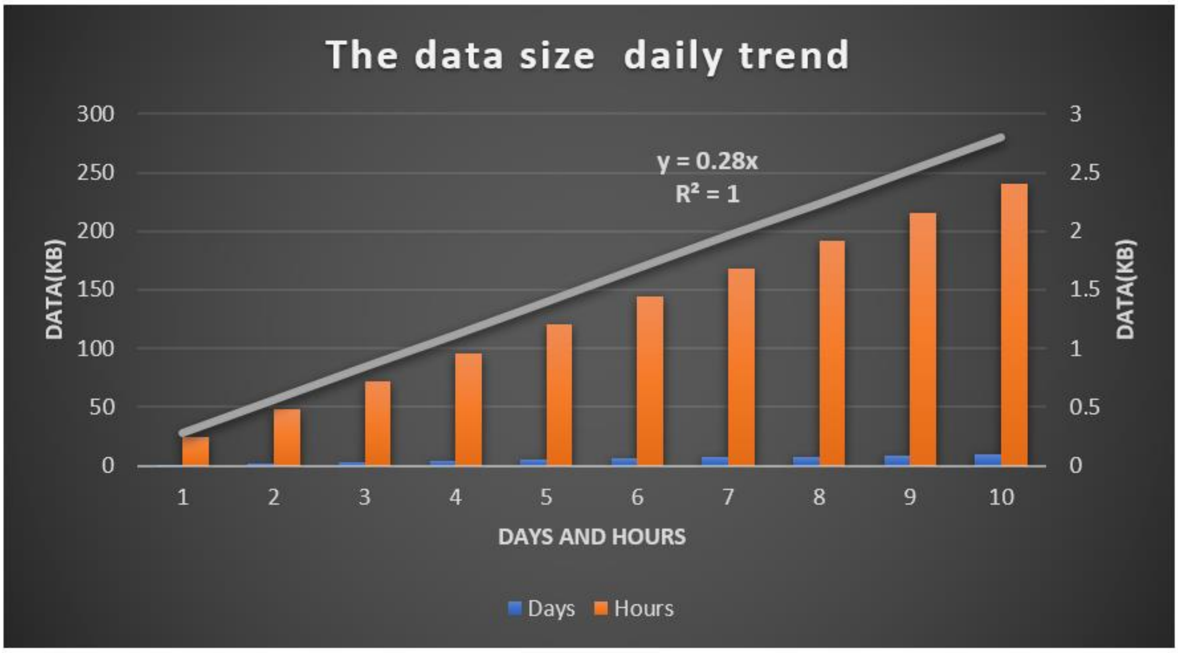

Figure 5: Daily Data estimate for the real time energy data monitoring model from integrated renewable energy system

Figure 5 shows data trend for one day of 24 hours during which time the data size increased to as much as 0.28kb. The projection for ten days, as shown in the figure is about 2.8kb. This demonstrates that the data size will significantly increase as the energy market grows.

The generated and individual consumed energy in the mini-estate shows that their data were becoming large, hence, some of the consumers reduced their energy usage from their building by isolating some of the energy devices remotely. The data gathered from this experiment from the five cohabited estate dwellers shows that big data handling by cloud computing was possible.

V. Conclusion

The collaborative supply and consumed data were daily increasing, thus the need for monitoring of its integrated energy scheme with IoT for its real time data management. Big data technique was deployed for energy data monitoring and control. In this design, the real time energy data monitoring model from an integrated renewable energy scheme and other collaborative supplies with load priority selection options were developed. The design was done using Proteus 8.0 software. Arduino uno microcontroller was used to control the system with programme code written in Arduino IDE and the web-based application was developed with mongoDB, PHP and JavaScript. The result from the 24-hour demonstration shows that it is possible to monitor the integrated renewable energy system with other collaborated supply energy data on a real time basis. The analysis of simulation data reveals that after every 3 hours of the 24-hour schedule, the system underwent generated energy and load priority check to determine the preferred supply and suitable load for the mini-estate from the energy machine controller action. The operational level is displayed on both a mobile device and a hardware panel. Energy provided and consumed were accessed by all the households in the mini-estate and their individual tariffs were displayed for payment without argument. The generated and individual consumed energy in the mini-estate shows that their data were becoming large, hence, some of the consumers reduced their energy usage from their building by isolating some of the energy devices remotely. The data gathered from this experiment from the five cohabited estate dwellers shows that big data handling by cloud computing was possible. The physical implementation will be the next line of action.

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