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Development of an IoT-Enabled-Dynamic Master Controller Model for the Integrated Afikpo Metropolitan Power Monitoring and Control System

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***Abstract*-This research focused on the design and implementation of Internet of things enabled dynamic master controller model for the monitoring and control of integrated hybridized energy sources. Five neighboring communities that constitute Ehugbo metropolis in Afikpo with hybridized energy sources were integrated as a miniaturized micro-grid system. The design was equipped with an automatic switching control that allows self- synchronization and disengagement of individual sources to and from the central network. Proetus 8.0 software was used for model simulation. Implementation was achieved using hardware component, web-design was done using MonogoDB whereas the interaction between hardware device and the internet was achieved using Cordova. The results obtained show that the dynamic master controller regulated and monitored the hybridized integrated system with priority scan and the incorporated automated generator starting system functioned accordingly to maintain power supply level within demand at all times.**

***Index Terms*-Automatic Generator Starting Scheme, Dynamic Master Controller, Hybridized Energy System, IoT-enabled Scheme, Power Pool System**

I. Introduction

This research proposed an integrated metropolitan energy monitoring and control platform. This integrated energy monitoring and control uses an already existing grid system; hybridized clean energy system and a synchronized generator energy system for its operation. Energy monitoring and Control techniques change as the energy demand increases. These increases require an advanced technological approach to meet up with the challenging demand. As the changes occur, real-time and dynamic system becomes the suitable device with its varying operational sequence [1],[2]. Dynamic master controller is an automated intelligent computer-based controller developed to monitor and control several energy sources with a priority scan enablement. With this, preference is given to first energy source before another priority scan is initiated intelligently to ascertain which energy source is available so as to decide when is appropriate to switch ON/OFF the alternative energy source [3],[4]. Remote and real-time monitoring and control of the system status is as a result of the interaction created through the internet of things. The miniaturized grid and the operators' action are simultaneously viewed and regulated [5].

[6], evaluated the standalone system and emphasized the need for all the standalone systems to be hybridized and integrated into the micro-grid system for sustainable and continuous energy supply in Afikpo Metropolis. In this research, it is necessary to develop a platform that enables the integration of multiple interfaces such as the hard and soft touch devices showing the status of the system. In this power pooling system configuration, the components to be inter-connected are various sources of energy available in Afikpo. This includes standby power sources, grid source and renewable energy sources. With these, it requires the android mobile application for the accommodation of various interfaces and sources connection points via internet of thing where remote monitoring and control will be adopted.

[7] opined that introducing the IoT to the system will not only facilitate remote monitoring and control but provide an

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effective database management system where information on the consumption and pool energy contribution are viewed. However, scalability of the system is determined by the dynamic master controller.

II. Literature Review

When several systems are integrated and interfaced with a common bus, a completely monitored and controlled system could be achieved through remote operation due to its complexity. [8] Developed an IoT-based system for home energy management (monitoring and control) with android application interface. The use of a Bluetooth with low energy smart plug which comprises a relay, AC power socket, Hall Effect senor and a wireless communication module were integrated into an android based application system which facilitates the control and monitoring of the energy usages on the household appliances. The methodology used provided a broad use of IoT in domestic automation application that was able to control and maintain power usage in homes without human interference. This was also effective both in cost and energy consumption. The working of this system requires a lot of data usage in other to stay connected to the internet for the storage of data and for the effective maintenance of the system. The effective monitoring and control of energy usage in household was successfully implemented [11],[8]. Similarly, the use of blue-tooth and android-enabled device for real-time energy monitoring and control of power consumed in domestic appliances using Arduino was experimented [12]. The following materials were adopted: two compact fluorescent lamps, a fan, a tungsten bulb and a shunt motor were used as household appliances for a period of one hour. A current meter was used to determine the current consumed by these appliances; the output was processed by the Arduino uno microcontroller and displayed on a cellular device through a Bluetooth connection. The load curve calculated can be used to predict the future consumption of electrical power and energy for a certain period of time [13].

The use of smart network with IoT to monitor, control and manage a microgrid remotely gave access to a user-friendly human machine interface and supervisory control for all its critical assets. The performance of the microgrid at various loading conditions and available generators were monitored [14],[15]. The microgrid was controlled remotely using a personal computer along with communication systems for a process control server [16],[17].

The development of a single system that incorporates an android device; dynamic master controller with digital Human Machine Interface and data documentary system for the integrated Metropolitan energy management (monitoring and control) with Automatic Generator Starting scheme for experimentation model is the major focus in this work.

An economy without small and medium scale energy plan lacks sustainable developmental policy for its rural dwellers. Petty and micro-trading has to be encouraged by ensuring continuous and sustainable power supply. Every potential growing economy depends solely on energy supply to thrive. In cities, inconsistency in energy supply is not only attributed to shortage of energy in circulation but also attributed to unavailable monitoring and control scheme due to inadequate alternative energy integration scheme. Long duration of energy outage from the public power supply grid without an alternative supply is another factor affecting energy supply. Wastage of the already harvested energy from hybridized standalone system without energy integration scheme is another notable issue. Integrating the already hybridized miniature grid requires a formidable monitoring and control scheme. The distance of monitoring and control scheme from the control room is also a problem, in the event of excess energy in a particular location, no means of remotely and automatically switching of power to the most needed area and also putting ON the alternative energy source for continuous energy usage. Internet of thing enabled system for remote monitoring and control operation becomes inevitable for the Afikpo metropolis.

III. The Model Design Task

The primary task in this work is to develop an IoT-Enabled Dynamic Master Controller Model with Automatic Generator starting scheme for integrated Metropolitan Power Pool System monitoring and control Applications. This primary task will be achieved with the aid of the following sub-tasks:

i. To develop a Hybridized energy integration and injection model for Afikpo Metropolitan Power monitoring and control system;
ii. To develop an Automatic Generator starting scheme for Afikpo Metropolis;
iii. To develop an IoT-Enabled energy Model for Afikpo Metropolis;
iv. To formulate the energy management template for the integrated Metropolitan Power System;
v. To evaluate and analyze the design performance of the integrated Metropolitan Power System monitoring and control scheme.

IV. Methodology

A. Materials Resources

Software: Proteus 8.0, Arduino IDE, Sublime text, MongoDB and Android Gap.

Hardware: Arduino uno: AtMega 328; NRF Module:24L01; GSM Module: SIM900A; Relays: 220/12v; Liquid crystal display; Optocoupler: Pc 817; Resistors; Transistors; Switches; Bulb with Lamps: 12watt; Current Sensor: ASC 712; Battery: lithium 12volts and Voltage Regulator: LM7805

B. Methods

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i. The design of Afikpo Metropolitan Power System monitoring and control system Architecture

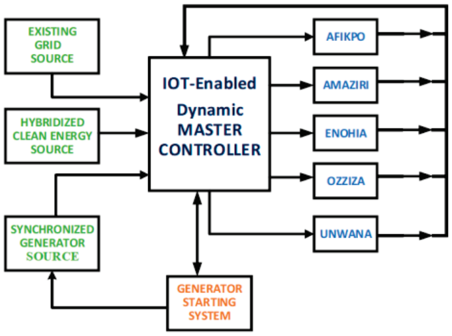

Fig 1: The IoT-Enabled Dynamic Master Controller Architecture [4]

ii. Circuit design for the software implementation of the energy integration and injection model

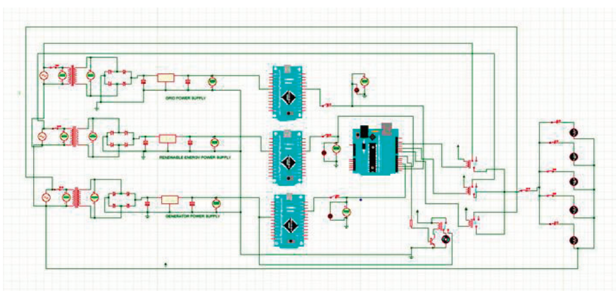

Fig 2: The Implementation Model for the DMC and ASS System

In Figure 2, the simulation model assumed four microcontroller configurations: the first slave controller controls energy coming from the already existing grid energy supply, the second slave controller takes care of the hybridized renewable energy supply and the third slave controller imitates the ON/OFF of the alternative generator supply, whereas the Dynamic Master controller coordinates the activity of the three slave controllers.

iii. IoT-Enabled-Dynamic Master Controller Model

Fig 3: The hardware Users interface Model

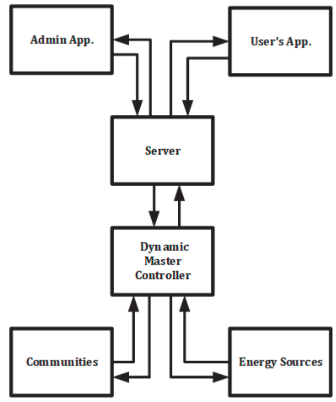

Fig 4: The hardware IoT-Enabled-Dynamic Master Controller Model

Figure 3 shows the hardware User-interface Model and Figure 4 shows the IoT-Enabled-Dynamic Master Controller Model for the integrated Metropolitan Power pool System monitoring and control scheme. This design is made-up of the following sections: The Admin / operator's signup and sign in Apps; Server (internet and database), Dynamic Master Controller which houses the human machine interface, the communities in the Metropolitan and the energy sources. The soft-touch remote user interface was developed with Cascaded Style Sheets (CSS), Hypertext Mark-up Language (HTML) and JavaScript. The HTML provides the overall outlook of the pool interface without any functionality given to the components of the pool interface. This allows for the arrangement of words and paragraphs on the interface. The Cascaded Style Sheets (CSS) provides several styles and colours used in designing the pool interface. It beautifies the interface making it eye-catching to the pool operator. The JavaScript gives functionality to the components of the interface. The components on the interface are buttons and switches. These buttons and switches are used to actuate the transfer of energy within the system. On the account of each energy transfer, JavaScript enables visible display of the device on the interface. The sign in and up interface for the operator are also designed, all the energy data were documented to the cloud through the server on-real time. The design uses monogoDB for the database development and Cordova for the android development.

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iv. Flow chat

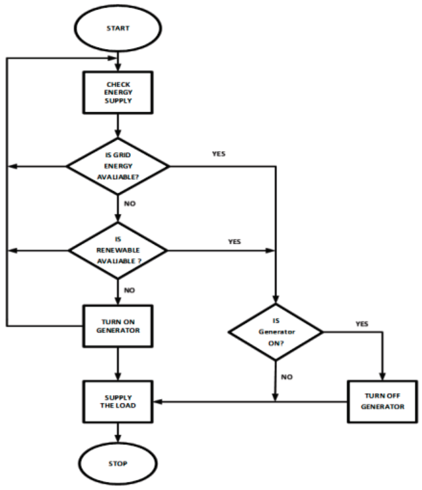

Fig 5: Flowchart of the IoT-Enabled Dynamic Master Controller Model

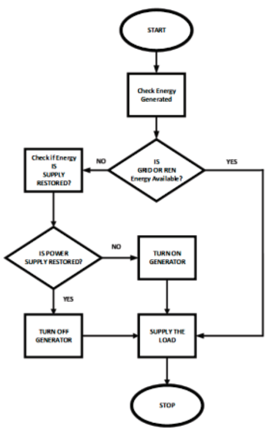

Fig 6: Flowchart of the Automatic Generator Starter Model

V. Results Discussion and Analysis

A. Hardware.

The three experimented sources of energy are as follows:

Grid, Renewable and Generator

Table I. Supply status at various experiment periods covering 24-hours

Energy Supply / Time Duration	Grid Supply (W)	RESs Supply (W)	Gens Supply (W)	Total Available Power (W)
6am-9am	300	150	90	540
9am-12pm	250	250	50	550
12pm-3am	200	355	0	545
3pm-6pm	350	100	155	545
6pm-9pm	400	50	60	510
9pm-12am	450	0	45	495
12am-3am	430	0	0	430
3am-6am	475	5	0	470

From the design in figure 2, 3 and 4, the three power supply sources were experimented for 24 hours and their respective power availability recorded in Table I.

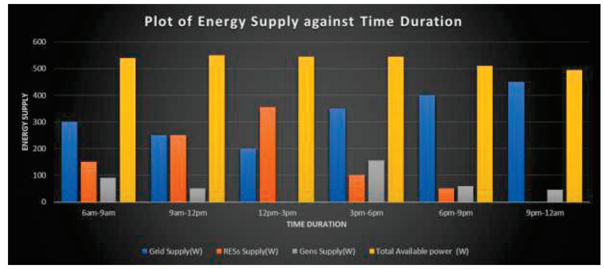

Fig 7: Diagram of the generated power available for Afikpo Metropolitan

Table II. The communities load Demand status over a 24- hours period

Communities/ Time Duration	Afikpo Load Line (W)	Amaziri Load Line (W)	Enohia Load Line (W)	Oziza Load Line (W)	Unwana Load Line (W)	Total Power Demand (W)
6am-9am	150	80	175	80	55	540
9am-12pm	200	100	120	100	30	550
12pm-3am	250	120	80	60	35	545
3pm-6pm	270	90	70	70	45	545
6pm-9pm	120	80	90	120	100	510
9pm-12am	100	75	80	90	150	495
12am-3am	80	70	70	110	100	430
3am-6am	85	75	80	120	110	470

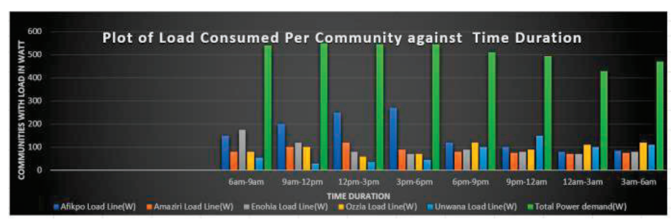

Fig 8: Diagram of the generated power available for Afikpo Metropolitan consumption

Table II shows the power supply status of the various sources of power supply. On the other hand, Table I shows the load demand status of the communities over a 24 hours period. It is evident that the monitoring and control scheme was able to maintain the level of generation required by the interconnected communities to sustain demand requirements. The implication of this result is that the developed monitoring and control scheme in this research is capable of sensing demand shortages or excesses and actuating necessary control actions to maintain power supply at the required demand level.

B. Mobile Application Interface Layout

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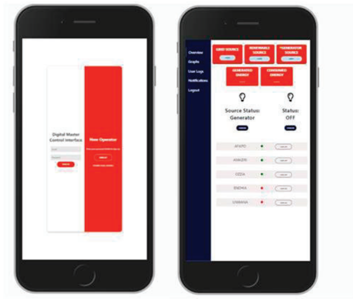

(a) (b)

Fig 9 (a) Android Sign-up/Sign-in Interface and (b) Android Remote Soft-touch human machine Interface

Figure 9(a) shows the developed Users and Admin Android sign-in/up page for the Metropolitan Power Pool System. Once the user signs up, the admin authenticates through the remote soft-touch human machine interface displayed in figure 11. Figure 9(b) shows the developed Remote soft-touch Human Machine interface for the integrated Metropolitan Power Pool System monitoring and control platform. Once a user signs up as in figure 9(a), the admin authenticates and the remote soft-touch human machine interface is displayed. This is where all the generated and the consumed power data in figure 5 and 6 are remotely viewed and regulated. The Sim 900A which is the GMS module and the Generator starting module communicates with the device through the IoT and at each sequence of the operations; data are documented on the cloud through the server. The database was developed with monogoDB to the document the system information such the trend and the history of the operation in each of the communities for both generated energy and consumption can be retrieved.

VI. Conclusion

The development of an Internet of Thing enabled model was achieved and the developed system was synchronized with the dynamic master controller for Metropolitan hybridized Power integrated system use. The developed system was used to guarantee constant power supply to the interconnected loads, multiple generators starting scheme were modeled within for the experimented area for onward energy integration into the miniaturized energy bus. The results obtained shows that the dynamic master controller regulated and monitored the hybridized integrated system with priority scan and the incorporated automated generator starting system functioned accordingly to maintain power supply level within demand at all times. Further research should be tailored towards addressing: Integrated Model for Selected Local Government Areas in order to encourage trans-local government energy integrated system; larger network coverage such as Zigbee network should be introduced and Local Government load assessment scheme should be introduced.

References

[1] N. A. Hidayatullah, A. C. Kurniawan, and A. Kalam, "Power Transmission and Distribution Monitoring using Internet of Things (IoT) for Smart Grid," in *IOP Conference Series: Materials Scienceand Engineering*, 2018, vol. 384, no. 1, pp. 1–8.

[2] I. M. Nayyef and A. A. Husein, "Design and Implementation of IOT Based Smart Power Monitoring and Management System Using WSNS," *Int. J. Embed. Syst. Appl.*, vol. 8, no. 4, pp. 1–16, 2018.

[3] A. Islam, K. Akter, N. J. Nipu, A. Das, M. Mahbubur Rahman, and M. Rahman, "IoT Based Power Efficient Agro Field Monitoring and Irrigation Control System : An Empirical Implementation in Precision Agriculture," in *2018 International Conference on Innovations in Science, Engineering and Technology (ICISET)*, 2019, no. October, pp. 372–377.

[4] K. E. Jack, D. O. Dike, J. C. Obichere, and M. Olubiwe, "The development of an Android Applications Model for the Smart Micro-Grid Power Pool System Monitoring and Control," *Int. J. Eng. Adv. Technol.*, vol. 9, no. 3, pp. 3474–3479, 2020.

[5] F. Duan, K. Li, B. Li, and S. Yang, "Research of Smart Power Utilization Service System Based on IoT," in *International Conference on Applied Science and Engineering Innovation (ASEI 2015) Research*, 2015, no. Asei, pp. 1427–1430.

[6] K. E. Jack, D. O. Dike, and M. Olubiwe, "Development of Human Machine Interface for the Control of the Integrated Hybridized Renewable Energy Resources in Community-based Power Pool System," *Int. J. Eng. Res. Technol.*, vol. 8, no. 10, pp. 586–596, 2019.

[7] L. M. L. Oliveira, J. Reis, J. J. P. C. Rodrigues, and A. F. De Sousa, "IOT based solution for home power energy monitoring and actuating," in *Proceeding - 2015 IEEE International Conference on Industrial Informatics, INDIN 2015*, 2015, pp. 988–992.

[8] S. J. Sahat, J. Tantya, Y. Bandung, L. B. Subekti, and D. Tanjung, "Internet of Things: Home Monitoring and Power Management Control Based on Android," in *ISESD 2018 - International Symposium on Electronics and Smart Devices: Smart Devices for Big Data Analytic and Machine Learning*, 2019, pp. 7–19.

[9] H. Shahinzadeh, J. Moradi, G. B. Gharehpetian, H. Nafisi, and M. Abedi, "Internet of Energy (IoE) in Smart Power Systems," in *2019 IEEE 5th Conference on Knowledge Based Engineering and Innovation, KBEI 2019*, 2019, pp. 627–636.

[10] Wang, Xinyan, and L. Jing, "Design of Intelligent Home Security Monitoring System based on Android," *2018 2nd IEEE Adv. Inf. Manag. Autom. Control Conf. 2018)*, vol. 233, no. 2, pp. 2621–2624, 2018.

[11] K. K. Jung and Y. J. Kim, "Design of smart monitoring system based on bluetooth low energy," in *International Conference on Electronics, Information and Communication, ICEIC 2018*, 2018, vol. 2018-Janua, pp. 1–3.

[12] T. J. Alexander, "An implementation of mobile control room environment in android platform for industrial applications," in *IEEE International Conference on Circuit, Power and Computing Technologies, ICCPCT 2015*, 2015, pp. 3–20.

[13] S. Banerjee and A. Roy, "Real-Time Monitoring and Control of Consumed Power for Household Appliances using Arduino Uno through Bluetooth and Android Application," in *2019 3rd International Conference on Trends in Electronics and Informatics (ICOEI)*, 2019, no. Icoei, pp. 529–533.

[14] K. Xia, S. Miao, X. Ding, L. Zhu, and P. Xu, "Design and application of the photovoltaic inverter equipment monitoring system on android platform," in *2013 International Conference on Electrical Machines and Systems, ICEMS 2013*, 2013, pp. 1494–1497.

[15] G. Rey, M. E. Arce, C. Ulloa, A. Cacabelos, and J. L. Miguez, "Automating, monitoring, and control of an ICE based micro-CCHP system using LabVIEW and Android," in *2015 IEEE Eindhoven PowerTech, PowerTech 2015*, 2015, pp. 3–8.

[16] K. R. Khan, A. Rahman, A. Nadeem, M. S. Siddiqui, and R. A. Khan, "Remote Monitoring and Control of Microgrid using Smart Sensor Network and Internet of Thing," in *1st International Conference on Computer Applications and Information Security, ICCAIS 2018*, 2018, pp. 1–4.

[17] M. A. H. M. Isa, M. F. A. Latip, N. Zaini, and Y. F. Alias, "Android-based application for real time energy monitoring of domestic electricity," in *Proceedings - 2015 IEEE Conference on System, Process and Control, ICSPC 2015*, 2016, no. December, pp. 134–139.

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