Development of an Arduino microcontroller-based Automatic Load Shedding Module for Teaching and Research

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Abstract—**In this paper, an Automatic Load Shedding module is developed for teaching and research. The module uses an Arduino microcontroller combined with a switching circuit to implement a load shedding plan in four settlements of a laboratory-scale urban settlement. The switching plan, in line with the power Distribution Company (DISCO) approval, is done to ensure optimal usage of the available 7.5MW as against the 10MW power demand. The developed module is useful as a teaching aid for illustrating power system automation among undergraduates.**

Index Terms—Arduino; Automatic Load Shedding; DISCO; microcontroller; teaching and research.

INTRODUCTION

In Nigeria and many parts of Africa, government is faced with the challenge of meeting the needs of the populace in the midst of available meager financial resources. As a result of this financial challenge, many of the laboratories in the high schools and tertiary institutions are not well equipped. Where the equipment exist, they are either in poor conditions, obsolete or very few in number and thus inadequate to meet the required needs. Students in these institutions learn scientific theories without necessary and adequate facilities to turn the theories learnt in the classrooms to practical realities. This situation has led to a great reduction in the standard of education and the quality of graduates produced by such institutions.

Load-shedding is a deliberate shutting down part of a power distribution system when the load demand is more than the generated power capacity. This is done in order to prevent system instability arising from overloading or even an entire system collapse [1, 2]. It is a way of redistributing power to various customers when demand for power is greater than what the power system can supply without system collapse. According to Amu and Somolu [3], the distribution system has posed a lot of problems for power managers in the area of providing economic and reliable power supply in Nigeria as a result of poor planning and the random nature of growth of cities. The development of the distribution system is always lagging behind the growth of the cities. In many parts of Africa, load-shedding is manually carried out with the aid of a circuit breaker which isolates certain area of electrical network from the power source while the un-isolated areas enjoy power. Problems associated with manual load-shedding include: high risk of electrocution, operators can easily forget to switch over power when necessary, it requires the physically presence of operators and many personnel who have to run shift duties in order to perform switching operations at specified time. The employment of many personnel leads to increase in the overhead cost of running the company. Apart from the listed points, human error is usually associated with manual operations and all these result in low efficiency in the system.

In the advanced countries like the United States of America, United Kingdom and the likes, even when load-shedding is to be carried out, it is not manually done. This is because the power system designs in these countries include communication-enabled Intelligent Electronic Devices (IED) that sense the need for load-shedding. These in turn communicate the sensed signals to power systems controllers that is, the Programmable Logic Controller (PLC) that initiates the switching operation. The PLC communicates with the electromechanical relays which in turn opens/closes the circuit breaker and switching is carried out [4, 5].

In Nigeria for example, there are lots of challenges with the power system such that electricity is not readily available to the generality of the people. One of the reasons being poor investment in the power system leading to poor quality of supply. After the commissioning of Egbin thermal station in 1986, there was no investment in generating plants until 2003

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[6]. In view of this investment gap, there exist electric power infrastructure deficit which has resulted in a wide supply – demand gap. Studies have shown that the distribution system has poor reliability values [7, 8] Poor load shedding practices accounts for a large portion of this low reliability values [9]. The manual method of load shedding being undertaken by the power Distribution Companies (DISCO) results in inefficiency of power system management. This could be due to:

- Dearth of information about automatic load shedding techniques and modern power management procedures, even among some staff of the power generation/distribution companies
- Lack of adequate laboratory equipment to impart the required skills in high schools and tertiary institutions
- Use of obsolete equipment by electric utilities
- Power system infrastructure are not made smart; and
- Vandalism of power system infrastructure

In order to address some of these challenges, there is the need to create awareness and provide necessary tools to educate stakeholders about the modern methods of power system management. This new method is a complete shift from the manual methods being practiced to automation of power systems, in line with international best practices. This paper therefore seeks to create awareness about the automatic method of load shedding as well as develop a laboratory scale load shedding module to assist teaching and research of power system engineering relating to automatic load shedding among undergraduates.

II. METHODOLOGY

A laboratory scale load shedding module is being developed. The construction of the module involves: constructing an architectural model of an urban settlement, developing anArduino microcontroller-based power distribution circuit and programming of the automatic load shedding scheme.

A Architectural model of the urban settlement

A laboratory-scale architectural model depicting an urban settlement was constructed. The buildings in this module were grouped into four settlements. The settlements are the residential area, commercial area, industrial area and the University Teaching Hospital. It also includes the office of the power Distribution Company (DISCO). The block diagram of the module including their connection to the source of power (DISCO) is shown in Figure 1 while the pictorial view of the model is as shown in Figure 2.

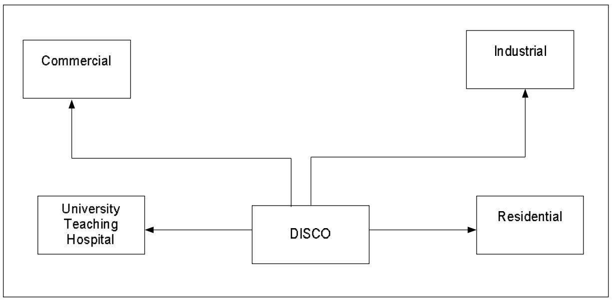

Figure 1. Connection of power from the DISCO to the 4 urban settlements

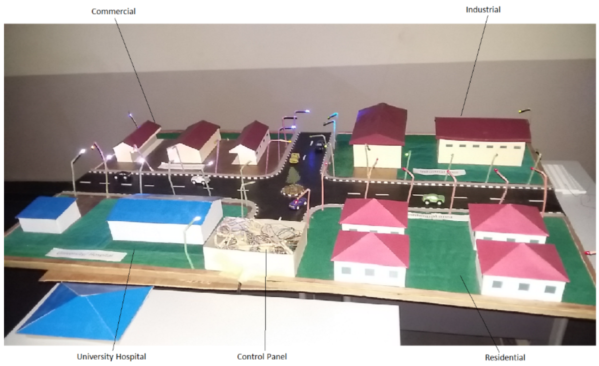

Figure 2. Architectural model of the urban settlement showing the DISCO and the four settlements

B. Construction of the Arduino Microcontroller-Based Power Distribution Circuit.

The DISCO as shown in Figure 3 houses an Arduino Uno microcontroller and associate circuit through which power is supplied to four of the laboratory-scale settlements. Arduino is an open-source hardware accompanied with open-source software {10, 11]. Light Emitting Diodes (LEDs) are used to represent the electric loads in the settlements. The circuit diagram is shown in figure 4, consisting of the Arduino Uno micro-controller and the switching circuit. The Arduino microcontroller is used as a substitute for the Programmable Logic Controller (PLC) normally used for industrial control schemes. The Arduino connects to a switching transistor through a 220 ohm biasing resistor. The transistor is used to switch the LEDs on or off depending on the signal received from the digital output pins of the micro-controller. The circuit is designed to ensure that all LEDs for a particular settlement goes on/off at the same time depending on the control signal received from the microcontroller.

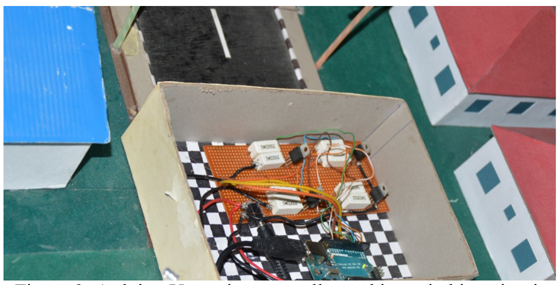

Figure 3. Arduino Uno microcontroller and its switching circuit

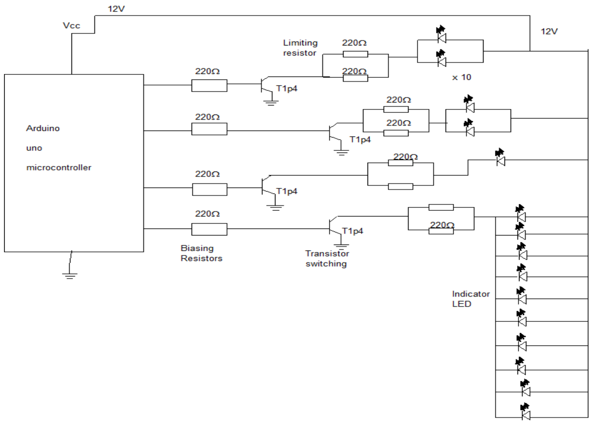

Figure 4. Circuit diagram of the Arduino Uno connected to the switching circuit and LEDs

C, Programming of the Automatic Load shedding Scheme

A program is written using the Arduino sketch to implement the load shedding plan approved by the DISCO. The program is written on a PC or laptop and uploaded to the microcontroller via a USB cable.

For the purpose of this study, each student was given a scenario in which he/she was employed as a power system engineer in an electricity distribution company with insufficient power, a maximum of 7.5MW out of the 10MW power required for the city. As a result, there was the need for load shedding. The city to be managed was grouped into four divisions namely: residential, industrial, commercial and University Teaching Hospital (UTH). The student was required to: prepare in a tabular form a load shedding plan meant to manage the available 7.5MW within a period of twenty four (24) hours. He is to write a program that implements the load shedding plan using the Arduino micro-controller. He is expected to run the load shedding programme using the lab-scale load shedding module to test (simulate) the intended load shedding plan to validate its suitability for the city.

Maximum power usage was assumed for each of the settlements

a. University Hospital – 2.5MW
b. Industrial – 3MW
c. Commercial – 2.5MW
d. Residential – 2MW

Load shedding plan was prepared based on the maximum power assumed for each settlement. This was to ensure that the total available power of 7.5MW was not exceeded despite the 10MW power demand of the 4 settlements. The load shedding plan in Table 1 shows the period of power availability in each of the settlements within a 24 hour period; while Table 2 shows the assumed power allocation, bearing in mind the maximum available power of 7.5MW.

TABLE 1. Power Distribution for Different Time Zones

Time zones	Res.	Ind.	Comm.	UTH
6:00am – 9:00am	1	0	1	1
9:00am – 12:00pm	1	1	0	1
12:00pm – 3:00pm	1	0	1	1
3:00pm – 6:00pm	1	1	0	1
6:00pm – 9:00pm	1	1	0	1
9:00pm – 12:00am	1	1	0	1
12:00am – 3:00am	1	1	0	1
3:00am – 6:00am	1	1	0	1

Note: 1 = ON, 0 = OFF

TABLE 2. Power Consumed In Each Time Zone

Time zones	Res. (MW)	Ind. (MW)	Comm. (MW)	UTH (MW)	Total (MW)
6:00am – 9:00am	2	0	2.5	2.5	7
9:00am – 12:00pm	2	3	0	2.5	7.5
12:00pm – 3:00pm	2	0	2.5	2.5	7
3:00pm – 6:00pm	2	3	0	2.5	7.5
6:00pm – 9:00pm	2	3	0	2.5	7.5
9:00pm – 12:00am	2	3	0	2.5	7.5
12:00am – 3:00am	2	3	0	2.5	7.5
3:00am – 6:00am	1	1	0	1	7.5

Note: Total power supplied at any given 3-hour period does not exceed the 7.5MW available

A programme was written using the Arduino Sketch language to implement the load shedding schedule of Tables 1 and 2. The flowchart is shown in Figure 5, while Appendix A shows the Arduino sketch. The programme was uploaded to the Arduino Uno microcontroller housed in the DISCO of the laboratory scale urban settlement module from the PC using a USB cable connection. After this the PC was disconnected, but the Arduino continues to perform switching operations in the different settlements in line with the plans in Tables 1 and 2 as shown in Figure 6.

III. RESULTS

The result of the simulation exercise shows that for a period of 3 hours (6:00am – 9:00am), the residential, commercial and industrial areas have their power supply on with a maximum power consumption of 7MW while the industrial area is off. After this period elapses, automatic switching occurs and so for another 3 hours (9:00am – 12:00pm), the residential, industrial and University Teaching Hospital have their power on while the commercial area is off with a total of 7.5MW of power used. It should be noted that this programme was made to run for 24 seconds representing 24 hours and covering the eight time zones. This is was due to the fact that 1 second was used to represent 1 hour and so 24 hours scheme operated for 24 seconds.

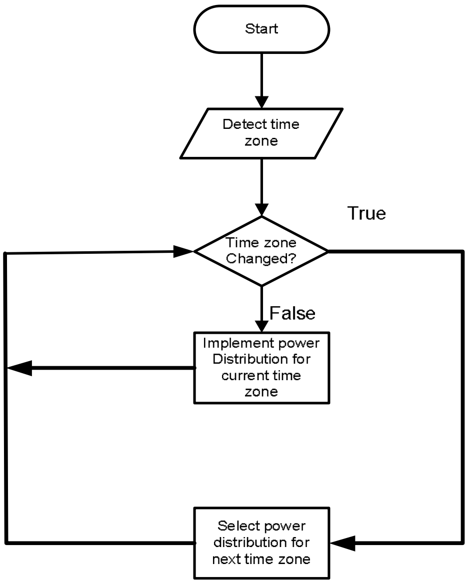

Figure 5. Flow Chart of the Automatic Load Shedding (ALS) plan

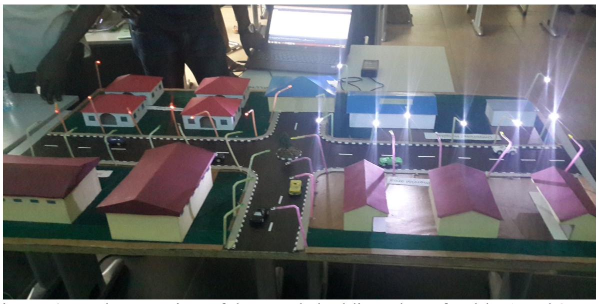

Figure 6. Implementation of the Load shedding plan of Tables1 and 2 on a laboratory-scale urban settlement

IV. CONCLUSION

In this paper, a laboratory-scale Automatic Load Shedding module was developed and used for teaching university undergraduates the concept of power system automation. This is for the purpose of awareness creation and development of teaching aids using low cost and locally available materials. A programmed microcontroller was used to automatically perform switching operations in 4 settlements of the lab-scale architectural model of urban settlement and to optimize the available power, in line with the DISCO load shedding plan. This was done without human intervention as against the practice in many parts of Africa. Since the scheme was automated, human error was completely eliminated. Future work would include the incorporation of remote and real-time power monitoring and control capabilities. This would make it suitable for teaching and research of modern power concepts such as the micro grid, and the smart grid.

REFERENCES

[1]www.searchdatacenter.techtarget.com/definition/load-shedding, retrieved on July, 24, 2017.

[2] I. Rashidul,K. K. Masud,I. Abu, and Forhad,"Co-Ordinate Load control and Load Shedding Balance by using Microcontroller," International Journal of Scientific & Engineering Research, vol. 3, no 4. 2012.

[3] L.A. Amu, and A. F. Somolu, "The Development of The Nigerian Electric Power System(1973 – 1990)". Lagos: University of Lagos Press and Bookshop Limited, 2015.

[4] G. L. Clark and S.W. Bowen,"Power system operation and control in Electrical Power Generation, Transmission and Distribution," 3rd ed.,Boca Raton: CRC Taylor and Francis Group, 2012, pp. 27-6-27.8

[5] C. Ozansoy,and K. Frearson, "IEC 61850-based islanding detection and load shedding in substation automation systems," *Turkish Journal of Electrical Engineering & Computer Sciences*, vol. 24, no 6, pp. 4858-4873, 2016.

[6] P. C. Asiodu, "Foreword to "The Development of the Nigerian Electrical Power System (1973-1990) by Amu and Somolu". Lagos: University of Lagos Press and Bookshop Ltd., 2015.

[7] J. J. Popoola, A. A. Ponle, and T. O. Ale, "Reliability Worth Assessment of Electric Power Utility in Nigeria: Residential Customer Survey", *AUJ.T*, pp. 217-224 2010.

[8] A. O. Melodi and P.T. Ogunboyo, "Power Distribution Problems on 11 kV Networks in Akure, Nigeria," in *Proc. 2013 IEEE Nigercon 2013 Conf.,* pp. 293-301.

[9] A.O. Melodi and K. O. Temikotan "A Model Supply Unavailability Perspective of Existing Nigerian Township Electricity Distribution.", *Journal of Engineering Reseach in Africa*.

[10] Arduino Home, https://www.arduino.cc/, retrieved on July 23, 2017.

[11]http://www.appropedia.org/Open-source_microcontrollers, retrieved on July 23, 2017.

APPENDIX A
THE ARDUINO CODE FOR ALS

```
void setup() {
/*
THIS PROGRAMME IMPLEMENTS AN AUTOMATIC LOAD SHEDDING PLAN FOR 4 SETTLEMENTS ON A LABORATORY SCCALE URBAN SETTLEMENT.IT PROVIDES A TEACHING AID FOR STUDENTS OF POWER SYSTEMS ENGINEERING WITH INTEREST IN POWER SYSTEMS AUTOMATION.
 OLUGBENGA K. OGIDAN AND KEHINDE TEMIKOTAN.
JULY 23, 2017*/

 // HERE PINS ARE ASSIGNED TOTHE VARIOUS SETTLEMENTS:
pinMode(4,OUTPUT);//Commercial
pinMode(2,OUTPUT);//Residential
pinMode(7,OUTPUT);//UniversityHospital
pinMode(8,OUTPUT);//Industrial
// pinMode(4,INPUT);
}
/*THIS SECTION IMPLEMENTS THE POWER DISTRIBUTION OF TABLES 1 AND 2 BASED ON THE DIFFERENT TIME ZONES*/

//TME ZONE 1: 6:00AM TO 9:00AM
void loop() {
digitalWrite(4,HIGH);
digitalWrite(2,HIGH);
digitalWrite(7,HIGH);
digitalWrite(8,LOW);
delay(3000);

//TME ZONE 2: 9AM TO 12:00PM
digitalWrite(4,LOW);
digitalWrite(2,HIGH);
digitalWrite(7,HIGH);
digitalWrite(8,HIGH);
delay(3000);
```

```
//TME ZONE 3: 12:00PM TO 3:00PM
digitalWrite(4,HIGH);
digitalWrite(2,HIGH);
digitalWrite(7,HIGH);
digitalWrite(8,LOW);
delay(3000);

//TME ZONE 4: 3:00PM TO 6:00PM
digitalWrite(4,LOW);
digitalWrite(2,HIGH);
digitalWrite(7,HIGH);
digitalWrite(8,HIGH);
delay(3000);

//TME ZONE 5: 6:00PM TO 9:00PM
digitalWrite(4,LOW);
digitalWrite(2,HIGH);
digitalWrite(7,HIGH);
digitalWrite(8,HIGH);
delay(3000);

//TME ZONE 6: 9:00PM TO 12:00 AM
digitalWrite(4,LOW);
digitalWrite(2,HIGH);
digitalWrite(7,HIGH);
digitalWrite(8,HIGH);
delay(3000);

//TME ZONE 7: 12:00 AMTO 3:00AM
digitalWrite(4,LOW);
digitalWrite(2,HIGH);
digitalWrite(7,HIGH);
digitalWrite(8,HIGH);
delay(3000);

//TME ZONE 18: 3:00AM TO 6:00AM
digitalWrite(4,LOW);
digitalWrite(2,HIGH);
digitalWrite(7,HIGH);
digitalWrite(8,HIGH);
delay(3000);
}
```