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DEVELOPMENT OF AN EFFICIENT LOAD MANAGEMENT SYSTEM FOR IMPROVED HEALTH CARE DELIVERY IN NIGERIA

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ABSTRACT

Epileptic supply of electrical power poses serious problem in the realization of improved health care delivery system in most third world countries. To address this problem most of the medical centers in these countries have resorted to the use of emergency power supplies, which are now used as almost normal power supply in Nigeria. Due to enormous cost arising from this overuse, incessant and often delayed manual switching between presumed emergency and normal power supplies, medical centers in these countries have not been able to respond to emergency needs of patients in critical conditions. In this work, therefore, a simplified load management scheme is developed for application in medical centers. It classified hospital loads based on functionality and locations to provide alternate load prioritization schemes. Using this system, automatic adding and shedding of loads as well as changing over of power source were achieved. A Matlab-based a Human Machine Interface (HMI) with associated program was provided for the simulation of the work. Federal Medical Center Owerri, Nigeria was used as test case, with reduced change over time and optimal system loading based on available capacityt.

Keywords: ***Automatic load scheduling, Energy efficiency, Load prioritization, Human machine interface, System monitoring***

1. INTRODUCTION

The issue of irregular power supply in Nigeria has caused a lot of challenges in our hospitals. Ninety percent of equipment used in the clinical and medical diagnosis of patients in the medical centers is powered by electricity. These include the ECHO machine, CTC Scan, X-ray machines, radiotherapy machine and many others. Besides, a blood bank must run on constant electricity. From the ophthalmology to the obstetrics and gynecology departments, nothing works except with electricity [1].

Incessant power outages and at times near or total system collapse have paralyzed these departments, and also made the equipments to breakdown frequently. In this situation, hospitals are unable to maintain cold chain (i.e. vaccines that need to be kept under cold temperatures from site of manufacture to the point of administration to patients, in order to preserve its efficacy), carry out laboratory investigation, maintain regular operations and attend to emergencies in theatre [2-8].

Most times, pregnant women go to dark labor rooms. Some patients in critical care units are asked to go home by their consultants because of lack of electricity to carry out diagnosis, operation, surgeries and investigations that will save their lives. In many occasions, patients undergoing operations have lost their lives because of unplanned power outage and inability to change to emergency supply due to manual operation. Irregular power supply has also affected the quality of training the student doctors get from the hospital which is supposed to be the hallmark of tertiary institution for medical professionals [9].

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Furthermore, in an attempt to increase accuracy, reduce radiation exposure and to achieve compatibility with advance imaging equipment (i.e. computerized tomography), there is need to introduce medical robotics for improved health care delivery in Nigeria. This is an interdisciplinary field that focuses on developing electromechanical devices for clinical applications. This enables new medical techniques to be adopted by providing specialized support during critical surgical procedures [10].

Currently in most hospitals in developing country, surgery is performed by manually inserting needle under single-view fluoroscopic radiological guidance. This procedure is challenging; it requires extensive experience due to lack of three-dimensional information of the inter-operative X-ray imager. To overcome this problem, several researchers investigated the use of robotic systems to assist in needle placement for defining target anatomy [11]. In addition, through computer assisted surgery, a surgeon obtains a 3 – Dimensional visualization allowing greater visibility and corrective alignment [12].

Furthermore joint replacement surgery with the aid of a navigation system helps improve the procedure and yields better results. The system empowers surgeons to accurately fit new implant components specifically to the anatomy of the body, potentially giving: faster recovery, improvement to quality of life, decreased possibility of a revision surgery, more exact implant placement, and optimal joint positioning which restores mobility. One of the most challenging issues in research and development of medical technology is to create a multidisciplinary group of clinicians and engineers that can effectively communicate and collaborate in order to bring benefits to people's lives. A surgical robot can provide manipulations and views of anatomical structures and surgical sites that are not accessible to human fingers or within the line of sight of a surgeon. In fact robotic systems can enable surgeons to explore procedures that would not be otherwise possible [13].

The paper is arranged in the following manner. Section 2 presents justification for the introduction of an automated load management system for a health care centre, overview of load management as well as its strategies. Section 3 contains modeling, design consideration and the development of implementation algorithm. Section 4 exhibits simulated results and accompanying discussions. Finally, the conclusions are given in section 5.

Load management is a process of balancing the supply of electricity on the network with the electric load. This can be achieved by direct intervention of the consumer by the adjustment of connected loads and internal generation. [14-18].

Sometimes, the load on a system can approach the maximum generating capacity or the rate at which the load is increasing can surpass the rate at which generating output can be increased. When this happens, the distribution network users must either find additional supplies of energy or find ways to curtail its load. In Nigeria, the picture for electricity as of now is not a very rosy story. We have an installed capacity of about 6,000 MW from Table 1.1.However because of lack of prior maintenance; it is generally about 50 percent availability [19-20]. In view of these and other problems related to breaking of pipelines in the Niger Delta, about 30 percent of power is lost yearly.

The development of various sectors of the economy such as Industry, Agriculture, Health, Education, Tourism etc depends heavily on reliable, adequate and economically priced power supply and Nigeria lags significantly behind in access, quality and availability of public electricity supply. The present generating capacity of 3355 MW from table 1.1 is not enough to drive the economy. It is also gross inadequate for a population of about 150 million.

This threatens the actualization of the socio-economic goals of alleviating poverty and of jobs and wealth creation. South Africa has 40,000 MW with a population of 50 million and Brazil has 100,000 MW with a population of 192 million [21]. Vision 2020 strategic objective for the power sector is to efficiently deliver sustainable, adequate, qualitative, reliable and affordable power in a deregulated market. In order to achieve the vision 2020, Nigeria will need electricity generation capacity of about 35,000MW by 2020. There is need to increase power generation by rehabilitating existing PHCN power plants and completion of some on-going Independent Power Plant (IPPs) projects. The completion of National Independent Power Plant Projects, Large Hydro Plants, IPPs and renewable power as well as granting of incentives to new entrants to power generation would increase power generation to 35000 mega watts by 2020.

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The distribution system is faced with a number of infrastructure and operational challenges. The sparse (scattered) geographical distribution of generation points makes electrical energy to be distributed on very long distances (from 300-500KM).This results in line voltage and power loss as high as 25% in Nigeria (compared with 3% in the US and 0.5% in Japan) [22].The frequency of power outages in the distribution sector do not meet industry standard. Manufacturing industries need steady power supply. Their change over time or interruption should not be more than 10 seconds as applicable in developed countries.

Nigerian's Federal Government is doing its best to transform the power sector. However, despite all the money spent in the power sector, vision 2020 cannot be actualized without an efficient load management scheme whereby loads are streamlined according to priority.

The problem with distribution in Nigeria is as follows: network is weak; there is a lot of power theft via illegal connections. There is also the problem with people not paying their electricity bills [23] and also lack of system planning. This causes interruption of electricity. Because of this epileptic power supply in Nigeria, essential load consumption centers like medical institutions must plan internally how to correctly provide for its demand by embarking on private electricity generation [24].

Furthermore, there are some places where electricity is needed constantly without any form of interruption. Any power interruption can pose serious challenges in life-saving facilities (hospitals) as well as in the service industries like banks, data centers, manufacturing industries and other essential service providers. In a hospital for instance, the need for an uninterruptible power supply cannot be over emphasized. The theater where various operations are carried out, the labor wards, casualty wards and the X-ray departments there is need for constant power supply to avoid loss of lives. Blood bank must run on constant electricity as well as the laboratories to carry out diagnosis and laboratory investigations. Electric power is, therefore, constantly needed to provide the essential medical services, save lives and run the appliances and laboratory equipment. Interruptions in power supply in this sector pose a serious menace and mar the effectiveness of such services hence the need for uninterruptible power supply for continuity of operation in these emergency facilities. The main objectives of this study are to develop an algorithm for determining system loading condition, for this will show when the system is under loaded, normal or overloaded and to develop a Matlab based programming for the implementation of the developed algorithm.

2. SYSTEM DESIGN

The power balance equation is given by:

$$P_D = \sum_{i=1}^{N} (P_i) \quad (1)$$

Where P_D is the aggregate power demand from all the connected loads and P_i is the power supplied by all connected generators. The constraint equation is

$$P_D - \sum_{i=1}^{N} (P_i) = 0 \quad (2)$$

The essence of load management is to ensure that equation (2) is satisfied within the operational constraints as much as possible, and to reduce wastage. The designed considered how to improve the present distribution system of Federal Medical Center Owerri Nigeria as shown in the single line diagram of Figure 1 which is manually operated and do not meet emergency needs as desirable for a topmost life-saving center in the city. With each of the two functional generators rated at 500kVA and power factor of 0.8, the active power available (P_i) is 400kW.

Readings taking from the various load points at this facility gave the aggregate load demand as 326.8kW. Therefore from the power balance equation (2), the system at FMC Owerri presently is not operating efficiently. This is due to the fact that there is an unaccounted generated power of 73.2kW whenever both of the two functional generators are operating. The proposed load management system aimed at solving this inefficiency contained a digital master controller (DMC) for automatic operation and protective microprocessor based relays as shown in Figure 2.

The new designed had the loads connected in clearly distinguishable feeder breakers so as to enhance the classification of the loads and development of appropriate load adding and load shedding modules based on priority and customer request. The details are provided hereafter.

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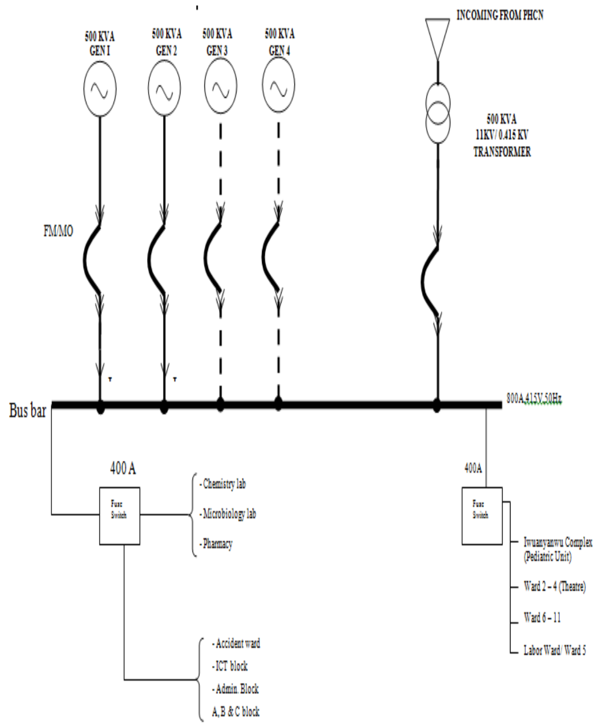

Figure 1: Present Power Distribution Network for FMC Owerri

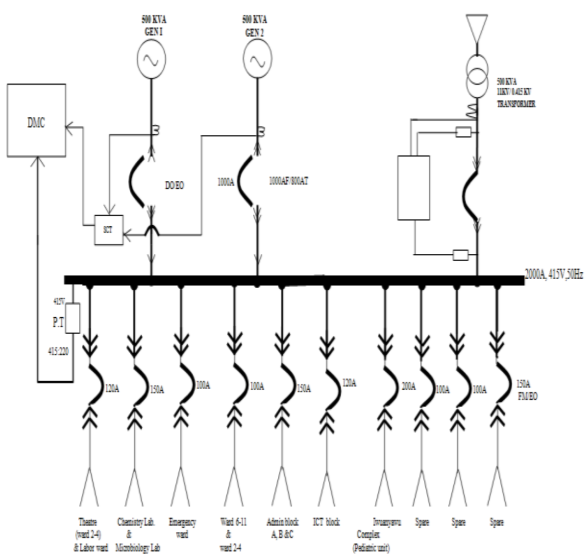

Figure 2: Proposed Power Distribution Network for FMC Owerri

2.1 Design Consideration

- Development of a Matlab program that will read in network and system data.
- The program will perform Load Analysis. The Load Analysis will be determined by the type of loads FMC has and by their load consumption.
- The program will also determine the capacity of the bus bar.
- The program will rank the system loads into levels 1-8 for Load Add (LA) and levels 0-7 for Load Shed (LS) given certain operational conditions.
- The program should be able to determine when to add or shed load with conditions. The Load Shed is determined by Priority list (the less important ones are disconnected first).
- Display the result as a bar chart for Load Shedding and Load Adding operations.
- The conditions should also indicate when the system is overloaded
- Indicate shedded loads or added loads dynamically
- Also Algorithm and Flow Chart would be clearly indicated.

2.2. Load Add and Load Schedule

	LOAD ADD (LA)	LOAD SHED (LS)
Level	1	0
Level	2	1
Level	3	2
Level	4	3
Level	5	4
Level	6	5
Level	7	6
Level	8	7

Load level 1 is the level of highest priority and also the level of zero load shed indicating no load shedding. Load level two is the level of second priority and load shed of 1 indicating the level of final load shed. Continuing in that order, load level 8 is the load level of least priority and also the level of 7 load shed indicating the first to be shed.

3. SYSTEM IMPLEMENTATION

3.1 Scheme Implementation Algorithm

The implementation process involved development of a model algorithm that began with a health care specification of requirement and progress through information gathering [25] to review of an existing system, (FMC, Owerri), planning, modeling and code development [26].

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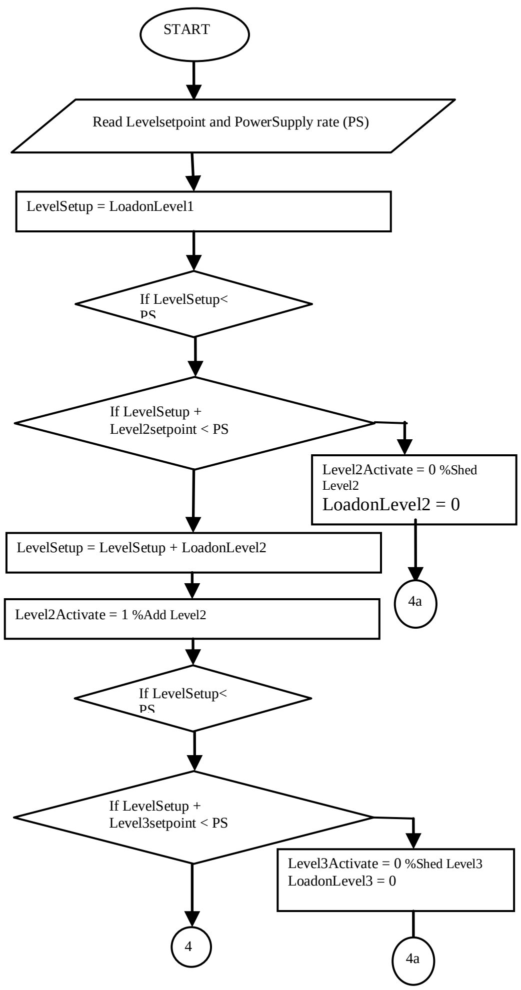
Then an associated MATLAB based program was developed and simulated to determine the automated load management scheme. A summarized operational algorithm is shown in Figure 3.

When normal supply is not available, Gen 1 comes on. Activate level set point, level set up and power supply. The level setup is equal to load on level 1 because level 1 is the level of no load shedding (highest priority).



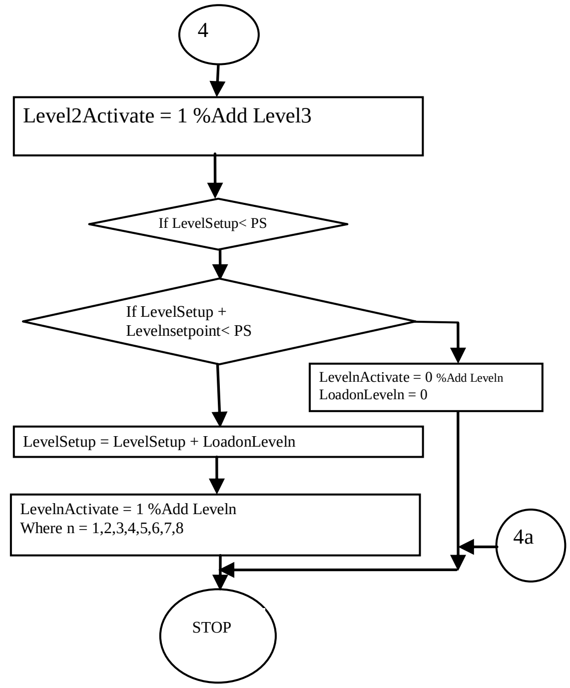


Figure 3: Implementation Flowchart

If level set up is less than power supply and level set up plus load in level 2 are still less than power supply, you add level 2 but if not, you shed level 2. If level set up which is now level set up plus load on level 2 plus load on level 3 are less than power, you add level 3 but if not, you shed level 3. This will continue till all the load levels will be added if there is available power supply, if not, all the load levels will be shedded because of insufficient power supply except Load on level 1 which is zero load shed.

3.2. Proposed Function-Based Load Level Classification [27]

Level 1 -	Accident and Emergency Ward Theatre Labour Ward X-ray department Chemistry Lab Microbiology Lab
Level 2 -	Pediatric Unit
Level 3 -	Ward 1, 2 and 4
Level 4 -	Ward 6, 7 and 8
Level 5 -	Ward 9, 10 and 11
Level 6 -	ICT
Level 7 -	Pharmacy and Admin Block A, B & C
Level 8 -	Borehole

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3.3. Proposed Appliance-Based Load Level Classification [28]

Level 1 – All the bulbs in all the blocks

All the Life – Saving equipment

Level 2 - All the fans in the entire block

Level 3 - All the computers and UPS

Level 4 - All the air conditions in all the blocks

Level 5 - Water pump

4. RESULTS AND DISCUSSIONS

Load consumptions were automatically taken after each minute while graphs were plotted after 5 minutes as illustrated in Figure 5.

4.1 Load Variation When Normal Supply Is Available

Initially all the appliances are assumed to be on between the time interval, there was reduction in power consumption because all the loads in level 1 are not all utilised. Because of this reduction, level 2 was activated.

4.1.1 Transition from normal power supply to gen 1

From 2.01pm to 2.02pm there was constant power consumption. At 2.02pm normal power supply was not available, then GEN 1 came on at 2.03 till 2.06, all the variations are power consumption

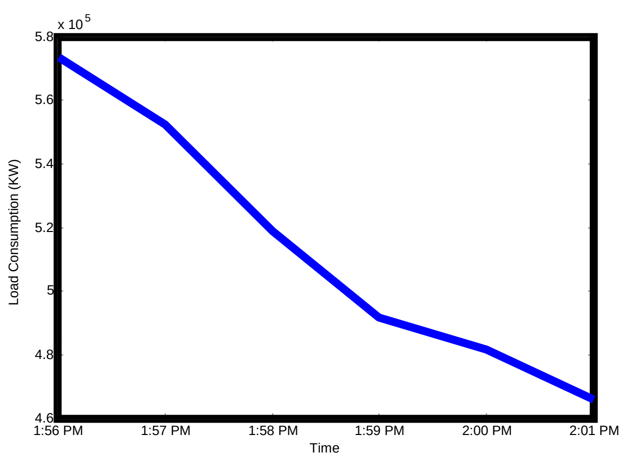

Figure 4: Load consumption with time (Snapshot steady declining consumption)

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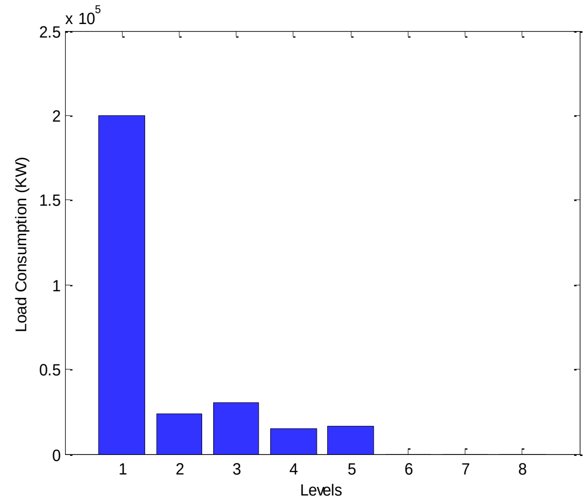

Figure 5: Load Consumption with load levels

4.1.2 Histogram illustrating the level states

It depicts the levels when GEN 1 is on. Levels 2, 3, 4 and 5 were added due to low load consumption in level 1.

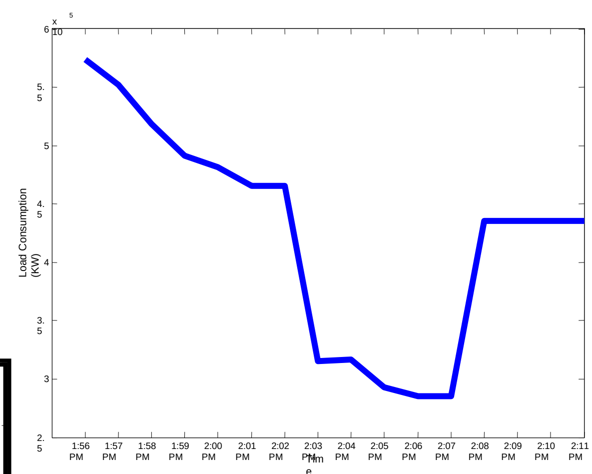

Figure 6: Load Consumption with Time (showing longer duration)

4.1.3. Specified Load Consumption

The sharp increase at 2.07pm depicts the coming online of GEN 2, while that between 2.08 and 2.11 shows specified no variation in load.

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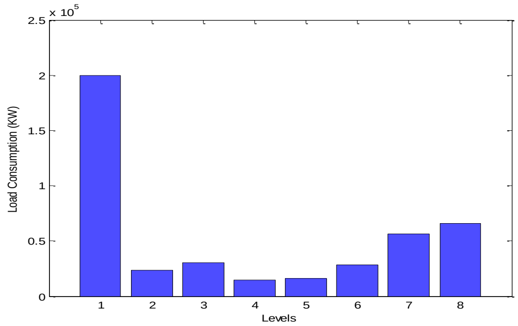

Figure 7: Load Consumption with Load Levels

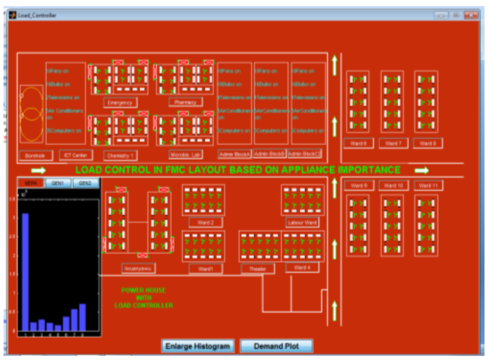

Figure 8: Human Machine Interface showing load control in FMC layout based on appliance importance.

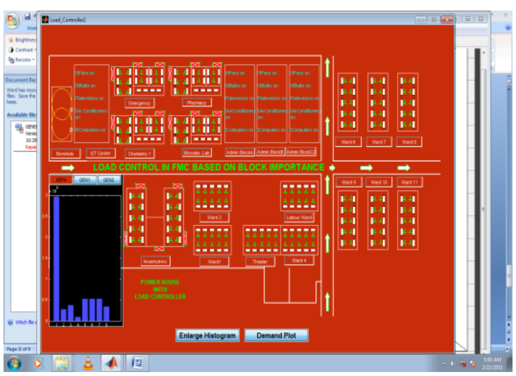

Figure 9: Human machine interface showing load control in Federal Medical Centre (FMC) based on block importance

5. CONCLUSION:

This work developed a load classification scheme for a Health Care Center. Load prioritization based on functions and appliances has also been achieved. Load analysis was also carried out. A one-lined facility diagram was also developed which gave greater feasibility and accommodating future expansion when compared with existing network at FMC Owerri.

An algorithm for determining system loading condition was developed. This shows when the system is under loaded, normal or overloaded. Also, an automated load adding and load shedding algorithm based on system loading condition and customer priority has been achieved. This will automatically shed load when the system is overloaded and add load when the system is under loaded. A Matlab Program for the implementation of the algorithm was developed. This includes a Human Machine Interface (HMI) for simulation of the developed program under varying conditions. Appropriate recommendations for improvement of load management schemes in emergency facilities and essential service providers were made.

The scheme developed in this work may be applied as a generalized load management scheme for medical facilities, data centers, research institutions and other places requiring minimal power interruption with slight modifications. Load control is actually done based on the type of work a firm does. In a Health Care Center where saving of life is of utmost priority, it may be necessary to recommend their load control based on functions. This is because if it is based on appliances, there may be wastages at some times when they are not utilized. Sometimes, it may be suitable to utilize hybridization of both functions and appliances depending on the availability of power.

Essential load consumption centers, service providers and emergency facilities may adopt this scheme for improvement of load management. This will prevent the system from overload thereby maximize benefits. Finally, it will guarantee uninterruptible power supply to areas of utmost priority by shedding off the areas of less importance.

There may be need to develop a load management system based on hybridized load classification. This is necessitated by the fact that there is no facility whereby its operational pattern will accept a 100% function nor appliance classification. Optimal load management may therefore utilize a mixed classification based on time and need. This therefore may pose fresh research problems which require future work.

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