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The Imperatives of Electrical Redundancy and Contingency Design for Critical Sections in a University Power Supply Network

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ABSTRACT
Power outages and electrical system failures have become inevitable occurrences in higher institutions of developing countries like Nigeria. Inadequate redundancy and contingency plans at the designing stage can worsen the situation of power supply, which often translates into several damages in materials and huge loss of man hours, these results in general low productivity of the institution. This paper seeks to discuss the importance of redundancy and contingency electricity power supply model in general and then, propose a particular redundancy and contingency design model for the Federal University of Technology Minna, Gidan Kwano Campus which is the focus of this paper. The proposed model shall consider the redundancy of transformer with its associate components like Circuit Breakers and Feeders within the University's substation and power utilization areas. Finally, the propose model shall consider redundancy and contingency network to service Identified Critical Sections. The network model shall be branched off from the distribution line coming from the Shiroro Hotel road injection station to the University's power substation.

Keywords: *Contingency, Critical Sections, Injection station, Redundancy, Substation, Transformer.*

1 INTRODUCTION

Electricity consumers such as individual, institutions, industries, companies and other organization will like to have continues uninterrupted power supply. However, unreliable power systems and the epileptic power supply from the power distribution company, still pose some major issues in the developing countries like Nigeria. One of the indices that are used in measuring the status of a nation is its economic advancement. Thus the position of a country is a function of such economic advancement, this may be difficult to achieve without adequate availability of energy supply needed to drive the economy. Emmanuel J.N, (2016), the dwindling of Nigeria's economy for some times now can be said to be largely due to non availability of adequate electricity energy.

The impact of inadequate power supply on the Nigeria economy as highlighted above goes down to every sector of the economy like university education which is under consideration by this paper. The management of electricity power supply to the university is an important factor in the growth of academic activities. Therefore, adequate plans and designs to effectively utilize the limited available power supply to the university campus should be of priority to the department of the university concerned with the provision, maintenance and management of electricity distribution on the campus.

1.1 ELECTRICAL REDUNDANCY AND CONTINGENCY

In general, redundancy of any system or component is the duplication of such component or material to function as the installed or activated component or material when the need arises. Electrical redundancy is therefore the duplication of electrical system or components of the system. In this case, it could be the transformers, Circuit Breakers, Feeders, Fuses or Cables. Redundancy can also be considered as the duplication in the form backup of critical components or functions of a system in order to achieve reliability of subsystem of a whole system. In any electrical system like the electrical controls systems that are normally built using a bunch of sub-systems has tendency for failures. It is important to provide safety in form of redundancy system in case of a single subsystem failure. Truninger (2017), according to Truninger, Redundant Systems do not increase safety if the failure of a system is not checked. Redundancy plan is to take care of prompt replacements if failure of a subsystem or component occurs.

Electrical engineering community (2013), describes Contingency as the non-functionality in the power systems like generator, transformer, transmission line and more or the change of the device state which may include the possibility in a transformer substation of an unplanned opened circuit breaker. Contingency plan is to check the change in the functioning of the device that will occur after the fault element is removed.

1.2 AIM AND OBJECTIVES

The aim of this paper is to establish a power distribution model that will ensure that the university makes maximum utilization of available power supply to the campus whenever there is power supply from the power supply company without recourse to the use of alternative power source like the generators. This aim will be achieved by the following objectives;

i. To Design electrical system redundancy models both at the substation and at the consumer transformer premises

ii. To design a proposed contingency model that will always ensure availability of power supply to the identified Critical Section of the University while maintenance or replacements are being carried out conveniently at the FUT Minna Gidan Kwano campus Substation with less pressure.

1.3 STATEMENTS OF THE PROBLEM

Generally, power supply in Nigeria has been a recurring problem. In the last few years Nigerians has witnessed acute shortage of power supply where some parts of the country stays for days with power supply for even less an hour.

Specifically, there was break down of electricity power supply system in Federal University of Technology Minna Gidan Kwano Campus between the month of June and July 2016. It was discovered that one of the 3MVA Transformers at the University's power substation blew off. This and other attendant faults has led to load-shedding till date, thus a reasonable percentage of the electricity power distribution problems the university is currently facing is internal, which is majorly from the university's power substation.

To fix the problem at the substation, some Critical Sections of the University as identified by this paper suffers while the repairs at the substation last. This paper seeks to solve this problem by proposing some models to ensure backups for breakdown systems or components and a model to ensure constant power supply to the identified Critical Sections when ever electricity power is available from the power supply authority.

1.4 REVIEW OF SOME RELATED ELECTRICAL REDUNDANCY AND CONTINGENCY DESIGNS

Many universities around the world and other organizations either private or governments, has different electrical redundancy and contingency design. For instance, the Brown University maintains it own campus electrical distribution system which serves the majority of the buildings and facilities on the main campus. Brown University (2013), Electricity is distributed on the campus at two operating voltages: 11.2 KV and 4.16 KV. This is three-phase-configured that was fed by the National Grid feeders to the University electrical distribution system at 11.2 kilovolts (KV). This was then distributed to the campus through the university's substations and underground electrical duct banks and circuits. Step down transformers then steps down the voltages to utilization voltage of 120/208 volts, three-phase 4 wire and/or 480/277 volts three phase four wire. This contingency was only focused on the voltages and failed to consider redundancy and contingency transformers and other electrical accessories.

The power demand of any country increases and also varies with the corresponding size of the economy and the population of that country. Therefore adequate plans must be put in place to handle any eventual fault situation and power overload situation, the allowable power consumption must also be put under constant checks. According to G.O. Anderson and K. Dikolobe (2002), the power utility company must carry out a thorough short circuit study of the system periodically so as to ensure an effective relaying and switching system. For instance in Bostwana, the authors mentioned that a computer software, POSCODAM (Power Systems Computing and Data Management), was designed to determine the contingency fault levels in the country's Electric Power Grid Network. This author said, can determine the contingency level directly while load flow is enable with the data recorded from the grid. One of the advantages of this design is that there will be no network reduction. However, the contingency design as was discussed by the authors, was unable to design for material and equipments contingency.

Jim Kennedy (2011), presented the survey by Forrester Research which states that nearly half of the declared disasters reported over a one-year period were due to power failures. Power failure response strategy was needed to ensure non escalation. One of the solutions suggested by the author was that an organization to determine critical requirements that needed emergency power, according to the author, electrical power requirements, or 'loads' are usually developed as part of a business impact analysis and risk assessment.

Electrical power failures occur at any time in transmission and distribution network, this can cause serious disruption to power flows, this can occurs for some very few seconds to days. Because of this uncertainty in power failures from the power supply sources, adequate measures an d alternative supply of electrical power must be provided to ensure reliability of or facilities and systems that cannot go without power e.g health care facilities, data processing, life safety systems, mission critical operations J.W. Gnan, (2010). This suggestion by the author is referring to redundancy and contingency plan which has relevance to this paper, however the author could specify the redundancy and contingencies needed for the critical areas as the author had listed.

According to D. Fauziah and Y Mulyadi, (2017), Electric power transmission system must operate reliably and continuously, but in fact there are many disturbances that affect the reliability and stability of the power system. The authors in their work used the Newton Raphson power flow method for contingency analysis to determine the weak elements of power system during release of component. Although their study was focused in South Bandung electric power system with voltage of 150 kV where they simulated and carried out the contingency analysis of IBT-II 500/150 KV at peak periods load in2013 to evaluate the system reliability when release of the Inter bus Transformer (IBT). We believe that the study could be applied to analyze contingency for other identified critical sections and components of power supply system elsewhere which their work did not consider.

Rajesh Tyagi and Jason W. Black, (2010) identifies short circuits and open circuits, downed lines and insulation failures as some of the reasons responsible for some faulty Transmission and distribution systems. The authors presented that in order to protect transmission, electrical power systems protection designs should be put in place in order to isolate faulty area from other active electrical network. To ensure this protection, the authors listed relays, circuit breakers, and tripping off equipment to be deployed in case of transmission lines while fuses and circuit breakers are to be deployed in case of distribution network. For the distribution contingencies, the authors proposed the proactive load shedding approach called Emergency Demand Response (EDR). However, the EDR is normally based on consumers' demand for some power consuming equipment in their premises or homes. This does not actually address the problems of identified critical sections in power distribution coverage areas.

2 METHODOLOGY

2.1 ELECTRICAL REDUNDANCY AND CONTINGENCY DESIGN FOR CRITICAL SECTIONS

The method employed to solve the problem raised by this paper, is to study and analyze the existing power supply by the supply authority from the Injection station at Shiroro road to the University power substation and the distribution network to the various consumers' transformers feeding units, departments and other power-consuming areas of the university. The analysis of the existing power supply and distribution network in figure 1 leads to the proposed electrical redundancy and contingency designs that will be discussed in the following subheadings of this very chapter. The paper then, identifies some critical sections of the university that should need power supply as constant as possible. The sections identified are; the University Senate building, the Information and Technology Services (I.T.S) building, the University Library, the Central Workshop and the Central Laboratory as proposed. The redundancy and contingency designs were proposed to take care of the entire distributions and the identified critical sections respectively.

2.2 EXISTING DESIGN POWER SUPPLY AND DISTRIBUTON NETWORK OF FUT MINNA GIDAN KWANO CAMPUS

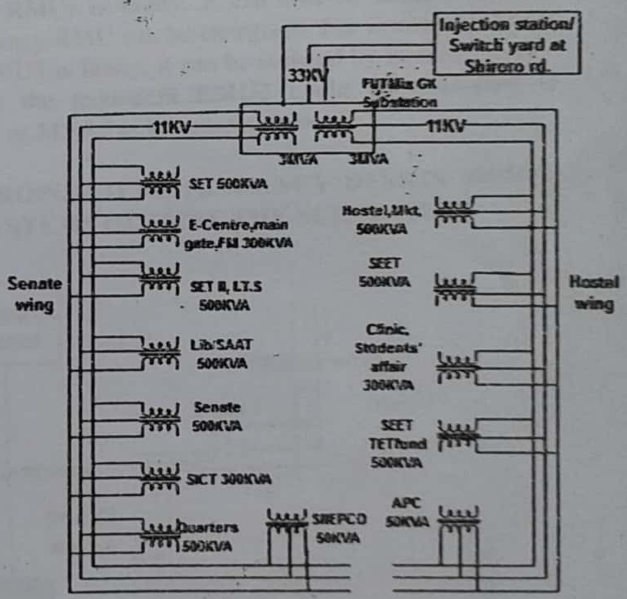

Figure 1: FUT Minna GK Campus power supply and distribution network

The power distribution network of Federal University of Technology, Minna Gidan Kwano Campus is shown in figure 1. The power supply network runs on 33KV line from the Transmission Company of Nigeria (TCN) from Shiroro Hotel road. It is a dedicated line entering the Gidan Kwano Campus and straight to the University Substation, at the substation, two 3MVA transformers 3MVA 1 and 3MVA 2 which are both step-down transformers, receives the incoming 33KV lines and step down to 11KV that were further extends out to various transformers that feeds Units, Departments and other power-consuming areas of the University campus as shown in figure 1. These consumers' transformers are also step-down transformers that steps down the incoming

11KV from the substation to 415 Volts which is the consumable voltage at the consumers' premises. The transformers are in various ratings like: 500KVA, 300KVA and 50KVA depending on the power consumption and load estimation of the particular area or premises to be served

2.3 PROPOSED REDUNDANCY DESIGN MODEL OF SYSTEMS WITHIN THE SUBSTATION

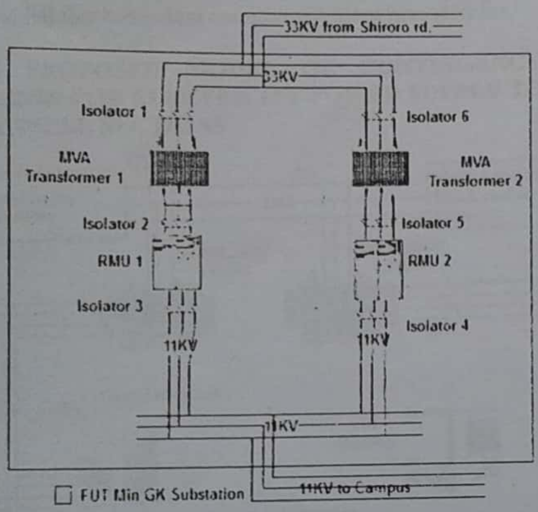

Figure 2: Redundancy model of systems within the Substation

Figure 2 shows the design model for redundancy of systems within the Substation. The general concept of this proposed model is for the redundancy design to follow the simple relationship below.

$$S_n = C_n$$

Where S_n = number of a particular system required and C_n = number of components needed as addendums for the required system S. But C may comprise of $x + y + z$ subcomponents.

Then, for redundancy of S, it is desired by this model that we have:

$$S_{n+1} = C_{n+1}$$

Where S_{n+1}= at least, an additional system required to provide for redundancy for the system. For the redundancy of C, we should have: C_{n+1}= at least, an additional component required to provide for redundancy for the component.

Now in our case as shown in figure 2, the main system is the transformer. If an MVA transformer or two MVA transformers are required by the design of the substation, then the redundancy design should provide for at least one additional MVA transformer. For instance of figure 2, MVA1 was required with RMU1 to step down the incoming 33KV. MVA2 and RMU2 should be designed as redundancy for MVA1 and RMU1 respectively. It is required that even for the two 3MVA transformers at the substation; at least one 3MVA was needed to provide for redundancy.

Where only one unit of MVA transformer which may be called MVA1 was designed for a substation and there was a breakdown, then the redundant MVA2 is immediately energized while the faulty MVA1 is isolated from the network by Isolator 1. This will allow repair work on MVA1 to commence conveniently. This is applicable also if the MVA2 was the faulty transformer. The RMU (Ring Main Unit) is an essential unit of the transformer arrangements inside any electricity power substation, if any of RMUs is faulty, it can still be isolated and the redundancy RMU can be energized. For instance in figure 2, if RMU1 is faulty, it can be isolated by Isolator 2 and 3 so that the redundant RMU2 could be connected to MVA1 or MVA2 as the case may be.

2.4 PROPOSED REDUNDANCY DESIGN MODEL OF SYSTEMS OUTSIDE THE SUBSTATION.

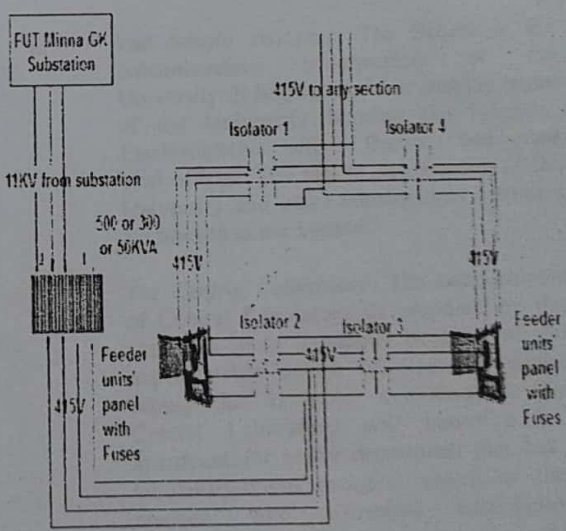

Figure 3: Redundancy model of systems outside the Substation to consumers' premises

Figure 3 is the proposed redundancy design model for a power distribution system outside the substation. The in this case is one of the power distribution transformers that supply power to a consumer's premises. They are step down transformers that steps down the 11KV lines coming from the University's substation to 415V at the consumers' premises. The transformer rating could be a 500KVA, or a 300KVA or a 50KVA as may be required, but they must all be 11KV/415V step down type. As proposed, a redundant transformer of the same rating should be installed beside with redundant feeder panel units which will normally comprise of unit fuses.

As explained in the case of figure 2, where the energized transformer in figure 3 is faulty, it could be isolated and the redundant transformer connected and energized, also a feeder panel unit that is faulty could be isolated by Isolator 1 and 2 or Isolator 3 and 4 as the case may be. This is also done for some other components like fuses provided that redundant components were provided for.

2.5 PROPOSED MODEL OF CONTINGENCY DESIGN FOR ELECTRICITY POWER SUPPLY TO CRITICAL SECTIONS

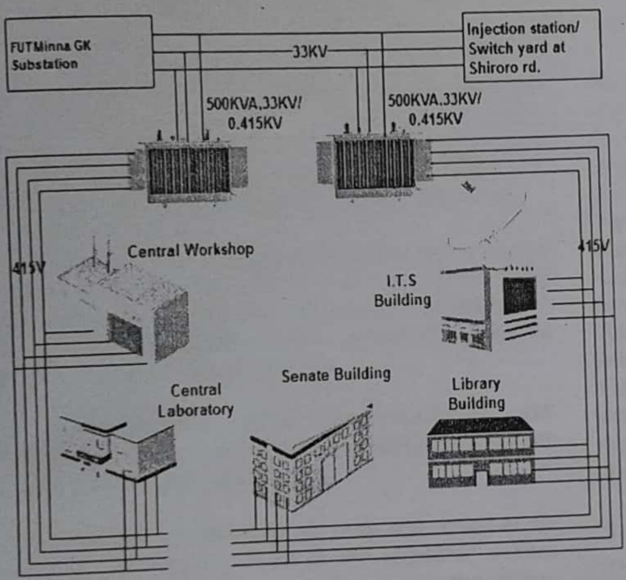

Figure 4: Contingency design for electricity power supply to Critical Sections

Figure 4 shows the proposed model of the contingency design for electricity power supply to the Critical Sections of the University as identified by the authors of this paper. These Sections as were listed earlier are considered very essential to the overall performance of the university.

To highlight the importance of the five Sections, the authors examine the role each of the Section plays to the general progress of the University.

i. *The Information Technology Services (I.T.S) Building*: The I.T.S is the Information and Communication Technology hub of the University and also serves as the University's gateway to the present world of Information Technology. The I.T.S is saddle with the mandate of conceptualizing, designing, implementing and managing all the ICT programs and projects of the university. Teaching, research, learning and all other academic and administrative activities learning are basically IT based now. The I.T.S is the custodian of the University's Data Centre that hosts the University e-porter, several sensitive Servers and Applications.

Internet services is key to all of the above, the internet must run twenty four hours round the clock. Electricity power supply is therefore required on 24 hours basis as well.

ii. *The Library Building:* The importance of Library in a University can never be emphasized. It hold the collection of books on almost all courses offered in the University, other relevant hard and soft paper materials necessary for research and references for both students and staff of the University. It offers staff and students the avenue for additional knowledge and to attend to assignments at any time of the day. Therefore, constant electricity power supply to the Library is very important.

iii. *The Senate Building:* The Senate is the Administrative headquarters of the University. It highest decision making organ of the University housing the Registry, Establishments office, Bursary and other vital offices. The day to day running of the University and other management activities are housed in the Senate.

iv. *The Central Laboratory:* The establishment of Central Laboratory as proposed by this paper is very strategic because of the unpredictable nature of electricity power supply that is under consideration. The Central Laboratory will house a Lab apartment for every department that has a laboratory-based practical aspect of their courses, like Chemical Engineering, Microbiology, Biochemistry, Biological sciences, Chemistry, Physics, Water Aquaculture and Fisheries, Animal Production and other similar departments.

Since specimens are always under observation in these departments mentioned above, it is therefore very important to have constant electricity power supply to the Central Laboratory as proposed. The University Health Services could also own a lab apartment here for obvious reasons.

v. *The Central Workshop:* The Central Workshop is another laboratory for mostly Engineering and Technical experiments such as; Metal fabrications, Building and civil Engineering constructions practice, moldings, pattern making, forgery, welding, electrical installation practices and other power consuming practice equipments are housed here. Therefore, constant electricity power supply is highly needed in the Central workshop.

By the proposed model as shown in figure 4, the contingency design is to branch off the 33KV lines coming from the Shiroro hotel road Injection station to the University's substation. This branching off is to connect the 500KVA transformers at the designated places as shown, the transformers are step down transformers that steps down the 33KV direct to 415V (0.415KV). These transformers are then connected to the identified Sections to serve as contingency power supply whenever there is fault that may cause the substation circuit to be opened.

Since it has been established that the greater percentage of the power supply problems during the period under consideration are within the University's substation, it then means that normally, there is power supply on the 33KV lines up to the substation.

2.6 ASSUMPTION AND ESTIMATION OF TRANSFORMERS AND POWER REQUIREMENT OF THE CRITICAL SECTIONS

Assumptions and estimation of our proposed choice of the transformers to supply power to the identified critical sections of the university was based on the power requirements of power -consuming equipments, systems or devices in those Sections.

For simplicity, we assumed the power requirement of an air condition unit. Thus we chose a 2 horse power (2Hp) air condition unit, be it a split unit or a window unit. As we know that a high capacity desktop or laptop with all professional configurations cannot draw more that 150 Watts or less. A 1hp will take 746 watts of power consumption: it will take an average of 10 computer systems to take in that amount of power. Although, power required for some heavy duty machines may be higher especially, in the Central workshop Section.

Now, considering our assumptions above, we assume an average of 100 hp. Where HP (horsepower), represents how much power a device is capable of putting out. Kilo-volt-amps abbreviated KVA, measure the apparent power of a circuit and it is found by multiplying the voltage times the current in a circuit. In order to convert from the HP capacity of a device to the number of KVA used, we need to know the capacity and the efficiency of the device. Divide the number of volt-amps used by 1,000 to convert from volt-amps to kilo-volt-amps (KVA).

With the above assumption of 100hp, we obtained that;

1 HP = 746watts.

In our case, 100HP =100 x 746=74600

Since we are proposing new transformers, the efficiency is 90% which is 0.9

Now we multiply our wattage by the efficiency thus:

$74{,}600 \times 0.9 = 67{,}140$

$67{,}140 \div 1000 = 67.14KVA$

By our assumption, if $67.14KVA$ is estimated for single Section say the I.T.S building, the power consumption can be extended to about $90KVA$. This means that five Sections could utilize $5 \times 90KVA = 450KVA$ transformer, but we have proposed a 500KVA transformer for about three Sections namely the I.T.S Building, The Senate Building and the Library. The transformer is very sufficient for the power need of these three Sections for now and even with additional power need in the near future. The second 500KVA was designed to serve the other two wings namely the Central Laboratory and the Central Workshop, as we mentioned earlier, we took into consideration the power need of some of the heavy duty equipments in the workshop or the laboratory with any future projections.

3 RESULTS AND DISCUSSION

The proposed redundancy and contingency design presented considered that averagely, the highest power-consuming utilities in a normal office are the Air-Conditionals. Thus with an assumed combined 100hp active at the same time, 67.14KVA was needed for all other utilities in that office building. With the 500KVA projected for three Sections and another 500KVA for two Sections, power requirement shall be met. The redundant systems and components available with the contingents network connections to the 33KV, constant power supply to the critical section is ensured. This reduces the cost of alternative power source like the Generators, break down system repairs are being affected while power supply on the 33KV is still being utilized by the identified critical sections.

4 CONCLUSION

From the proposed model, we have been able show that most of the power supply problems in the Federal University of technology Gidan Kwano campus are localized ones due to system failures from the University's electrical substation. We also proposed designed models for redundancy and contingency that will ensure maximum utilization of available power supply to the University. We recommend that the university authority should as a matter of urgency, look at the proposed model with a view to implementing it.

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