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Automatic Control Model for Load Shedding in Atani 33KV Injection Substation - Nigeria Network

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Abstract

Energy demand is high and the so is the satisfaction derived from steady power supply. Power availability and steady supply promotes business undertaking in most localities. This in turn promotes economic growth and human wellbeing. There are serious challenges facing the power sector in Nigeria which covers generation, transmission and distribution. This has led to unsteady power supply and incessant power outage. Lack of power infrastructures, ageing facilities, poor maintenance, negligence and overloading the transformers are factors that can affect power supply as they affect inability to manage the power generated properly. Managing the little generated power for the teaming users becomes difficult. The allocated power to different load centers is inadequate resulting to emergency load shedding. This paper focuses on how to reduce this emergency load shedding in distribution lines. Automatic control method was adopted to reduce emergency load shedding in distribution lines, with emphasis on allocate load (megawatts) to maintain, monitor and raise alarm if consumption exceeds the allocated load. This method also presents control or isolation mechanism for substations that exceeds load allocation. The Atani 33KV Injection Substation in Anambra State was used as a case study where distribution line outages data was collated and automatic control model using MATLAB was used to analyze the distribution Line Network outage data and results were simulated. Hypertext Pre-processor (PHP) software was used to write a program that monitored and controlled load allocation.. The result showed that automatic control model reduces emergency load shedding by 8%. This model can be extended to the entire grid to reduce emergency load shedding.

Keywords: Emergency Load Shedding, Power Outage Reduction, Automatic Control Model and Improved Power Supply

1.0 Introduction

Electricity generation, transmission and distribution have suffered a number of challenges in Nigeria. Nigeria got her first electricity utility company in 1929 but power generation began in 1896. There have been changes in nomenclature due to change in government and government policy as a result of failure to meet with the mandate of the electricity organizations over the years. In 1929, it was Nigerian Electricity Supply Company, in 2000 the National Electric Power Authority (NEPA) was saddled with the generation, transmission and distribution of electric power in Nigeria. By the year 2005, Power Holding Company of Nigeria (PHCN) was formed as a transitional corporation that comprises of the 18 successor companies (6 generation companies, 11 distribution companies and 1 transmission company) created from NEPA. In 2010, the Nigerian Bulk Electricity Trading Plc (NBET) was established as a credible off-taker of electric power generation companies. By November 2013, the privatization of all generation and 10 distribution companies was completed with the Federal Government retaining the ownership of the transmission company. The privatization of the 11th distribution company was completed in November 2014. None of these efforts by the government and the policy makers of the government had given lasting solutions and road map for sustainable power supply owning to corruption, maladministration, embezzlement of funds, poor maintenance of facilities, ageing facilities and lack of equitable technology to manage the power sector. This is not acceptable for an emerging economy like Nigeria where constant and reliable power supply is very much needed which this work tries to address.

1.1 Power Outage

Power outage can occur as a result of maintenance or failure in electricity facility. There are planned outages, load shedding, forced outages and Emergency Load shedding, etc. The former is outage which occurs when there is maintenance work that can be as a result of ascertaining the insulation resistance of the transformer, recasting of cable or conductors, replacing out dated panel or any other component. Load Shedding is an outage that occurs as a result of drop in generation which will prompt the system operator to shed load in order to maintain the load that will not cause problem to the system or lead to force outage or system failure. Forced Outage occurs as a result of fault on the line which takes place when vegetation touches the line that causes earth fault, or when two lines meet that cause overcurrent fault. Also when the generated power is not used, this can cause a 330KV line to have a very high frequency and can result in system collapse. Emergency Load shedding occurs when the consumed power exceeds the allocated power.

1.2 Techniques of Reducing Emergency Load Shedding in Distribution Network

Many techniques, tools and methods have been employed to reduce outage in transmission lines which includes clearing the right of way, clearing vegetation, using modern protection systems, using fuzzy logic and artificial neural network as a tool to reduce outage, increasing the generating capacity to meet the growing demand, forecasting using mathematical formula to calculate the anticipated load for an area, etc. These methods notwithstanding, the current rate of outages, especially load shedding is alarming. Automatic control technique will be introduced in this work to reduce emergency load shedding in distribution networks.

2.0 Review of Previous Works

Akudo, (2009) opined that clearing vegetation or trees under the transmission line or distribution line will help to reduce outage. The work further suggested that regular check on vegetation across the network should be a routine. From the recommendation, transmission lines that are free from vegetation or trees experience less outages while distribution lines that had unchecked vegetation recorded high outages attributed to vegetation. However, most distribution and transmission line outages are due to equipment limitation or over load and load shedding due to low vegetation.

Eze, 2012, explained the need for clearing the right of way in transmission and distribution lines. Regular cutting down of trees across the distribution line will reduce Earth fault experienced on the distribution line. The Enugu Electricity Distribution Company (EEDC) district that observes routine clearing of the right of way, recorded less outages due to Earth fault, while the district that neglected it experienced frequent outages due to Earth fault. Also, 80 % of the outages that is experienced in distribution are due to transformer overload and load shedding attributed to the primary distribution voltage in 33KV lines, particularly emergency load shedding. The use of fuzzy logic to reduce outage in distribution line was explored and modeled. The result showed that when the line was opened, outage was experienced, while in another case, when fuzzy logic was used outage is experienced. In another model that incorporated another system and fuzzy logic was used when there is outage, the fuzzy logic will cause the system to undergo stress and returned back to normal without tripping. Ene, 2014 integrated a live line in a model ascertain whether such recommendation is obtainable in the real life, while Arua, 2015 proposed fuzzy sliding model to maintain the system from tripping during fault. The work is similar to that of Ene, 2014, with the difference in the sliding mode. Such model had not been integrated into the Nigeria power system to see how is fared which was a problem.

Madueme, 2015, proposes the use of artificial Neural Networks to reduce outage duration. The work described the development of a fast, efficient, artificial neural network (ANN) based on fault diagnostic system (FDS) for the location of fault on the power system network. The principal functions of the diagnostic system were: detection of fault occurrence, identification of faulted sections and classification of faults into types. These were achieved through a cascaded, multilayer ANN structure using the back propagation (BP) learning algorithm. The work further showed that the FDS accurately identified high impedance faults, which are relatively difficult to identify for high impedance faults with other methods. A problem with the model was that the actual location of the fault was not shown.

Magily and Eteiba 2014, described the use of Adaptive Network fuzzy inference system (ANFIS) to reduce outage duration. The break way of this work was that the ANFIS locates the exact point of the fault. However, most outages in distribution line due to load shedding and emergency load shedding were not presented. A new line outage simulation method for reactive power flows that minimizes the errors resulting from the use of linear system models was presented. The proposed method formulates a line outage as a local non-linear constraint optimization problem.

3.0 Methodology

The chosen area of study is the Atani 33kV Injection Sub-station and the method adopted was real time technique and the data collation on power outage from Distribution Company of Nigeria outage records. MATLAB software, Hypertext Preprocessor (PHP) software, Personal computer were the tools used in this work. Data collection of distribution line outage was retrieve from 2014 to 2017 in application of automatic control to distribution line network and simulation of outage result were carried out.

3.1 Control Systems

The control system is an interface between the system and the ammeters which switch the substation OFF when the consumed megawatts exceed the allocation. The system responds to the message of OFF, but that is if the system is within the allocated megawatts where the system allows the ON situation. The control systems response to the sensor values through the actuators which prompts action based on the command it received.

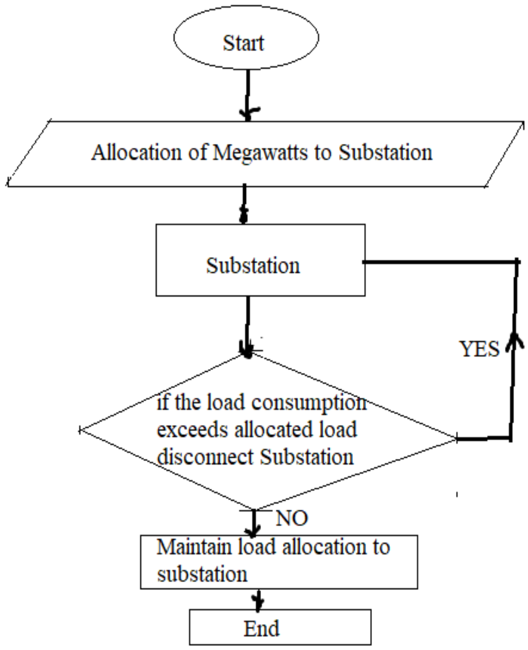


Figure 1: Flow chart of the model for automatic network control technique

The flow chart reveals at a glance how to achieve the aim of this work which is to reduce emergency load shedding in distribution lines.

a. MATLAB Application

The design was done as a script which can allocate load, control and isolate the system when a particular substation exceeds their load allocation.

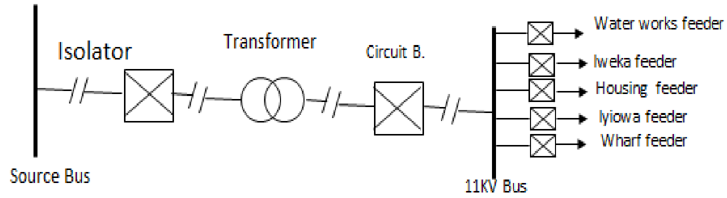


Figure 2: Single line of a distribution network architecture

System Description

Source bus: The source bus is a 33kV bus where all the 33kV line feeders are connected. The source bus is TCN 33kV line bus and is located at General Cotton Mill (GCM). This is where the 33kV feeder that feeds Atani injection substation is connected.

Isolator: It is used to isolate or separate high voltage apparatus such as circuit breakers and transformers.

Circuit breaker: Is a device that interrupts the abnormal or fault current.

Transformer: Transformer is a static electrical machine which transfers electrical power from one circuit to another at constant frequency, but the voltage can be altered, that is the voltage can either be decreased or increased according to the voltage requirement.

Load: Load is a device or appliances that consumes electrical energy in the form of current and transform it into other forms like heat and light etc.

Mathematical relationship of real-time techniques

Mathematical equations employed in the MATLAB script are given as follows:

$Power\ (P) = VI\ Cos\theta$ (1)

Where,

P = power

V = voltage

I = current

$Cos\theta$ = Phase angle

Using power loss equation

$P = I^2R$ (2)

Where, P = Power, 1^2 = *current* and R = resistance

Let $R = £$ (3)

Where £ is the comparator that compares when the consumed load exceeds the allocated load. Therefore, equation 2 becomes

$P = I^2R$

$P = I^2£$ (4)

So, £ determines whether there will be power or not and let $£_0$ indicate when the consumed load exceeds the allocated loads, which makes £ to isolate the substation automatically, giving:

$P = I^2£_0$ (5)

If $£_0 = 0$

$P = 0$

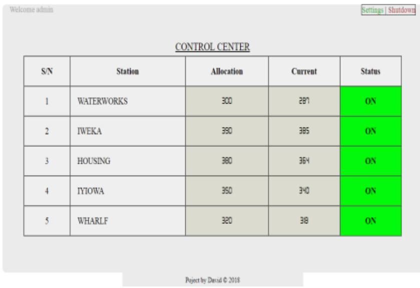
Let $£_1$ indicate when the consumed load is equal or below the allocated Load, which makes $£_1$ to allow current flow to the substation automatically, giving:

$P = I^2£_0$

If $£_1 = 1$ Then, $P = 1^2 \times 1$ and subsequently, $P = 1^2\ £_1$ which is the desired result.

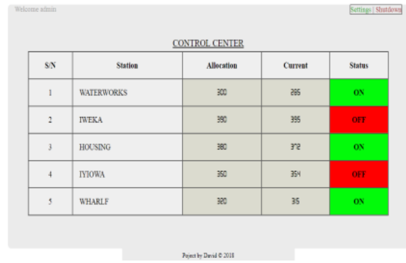
b. PHP CONTROL MODEL

The control model has been done in PHP interface. The unit of load allocation and current are in ampere.



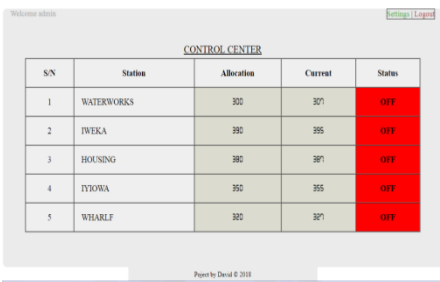
S/N	Station	Allocation	Current	Status
1	WATERWORKS	300	287	ON
2	IWEKA	390	385	ON
3	HOUSING	380	364	ON
4	IYIOWA	350	340	ON
5	WHARLF	320	318	ON

Figure 3: PHP control model



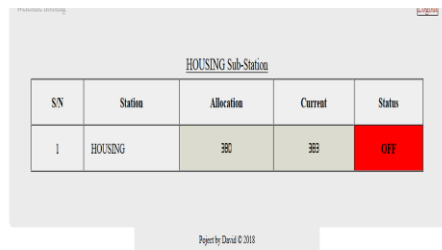
S/N	Station	Allocation	Current	Status
1	WATERWORKS	300	295	ON
2	IWEKA	390	395	OFF
3	HOUSING	380	372	ON
4	IYIOWA	350	354	OFF
5	WHARLF	320	315	ON

Figure 4: PHP control model



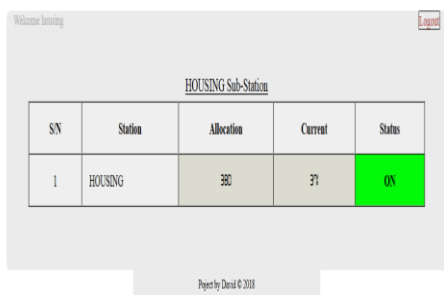
S/N	Station	Allocation	Current	Status
1	WATERWORKS	300	307	OFF
2	IWEKA	390	395	OFF
3	HOUSING	380	387	OFF
4	IYIOWA	350	355	OFF
5	WHARLF	320	327	OFF

Figure 5: PHP control model



S/N	Station	Allocation	Current	Status
1	HOUSING	380	383	OFF

Figure 6: PHP control model



S/N	Station	Allocation	Current	Status
1	HOUSING	380	371	ON

Figure 7: PHP control model

The figures above shows the control model of PHP, the name of the Substation, load allocation, load consumption and the PHP controllers which isolate the substation that exceeded their load consumption automatically and sends signal to turn then off, hence indicating OFF. However, if the substation maintains their load allocation, the PHP controller allows them to be ON.

3.2 Data Collection on Distribution Line Outage

The outage occurrences on 33kV and 11kV obtained from Atani injection substation distribution line were used. Outages are grouped, which include, load shedding, emergency load shedding, planned outage and forced outage. The tables that follows shows the outcome of load shedding, emergency load shedding, Forced outage and planned outage for 2017, 2018, 2019 and 2020 but only 2017 and 2018 tables will be shown because of space.

Table 1: Outage Occurrence for Forced Outage in 2017 (Disco outage record book)

Month	Total number of Outage occurrence For 33kv	Total number of Outage For 11kv	Total number of Outage duration For 33kv in hrs	Total number of Out duration for 11kv in hrs
Jan	5	**7**	40.11	50.14
Feb	6	8	35.12	60.14
March	7	9	24.11	72.55
April	8	10	30.11	88.66
May	7	11	20.11	80.66
June	3	5	40.12	55.60
July	1	2	10.33	20.22
Aug	4	5	10.40	45.70
Sept	3	4	14.44	60.57
Oct	4	6	15.40	70.77
Nov	4	7	16.77	90.70
Dec	2	4	8.14	33.31

Table 2: Outage Occurrence due to Forced Outage in 2018 (Disco outage record book)

Month	Total number of outage occurrence for 33KV	Total number of outage occurrence for 11KV	Total number of outage duration for 33kV In hours	Total number of outage duration for 11KV in hour
Jan	4	10	10.14	90.12
Feb	2	11	10.44	100.14
March	4	10	10.45	80.44
April	3	12	10.41	120.44
May	4	13	10.45	150.44
June	5	11	19.14	140.22
July	6	12	17.17	145.23
Aug	4	18	25.00	160.45
Sep	4	11	30.12	45
Oct	4	14	14.12	42
Nov	1	11	19.14	30
Dec	94	12	15.14	25

Table 3: Outage Occurrence due to Planned Outage In 2019 (Disco outage record book)

Month	Total number of outage occurrence for 33KV	Total number of Outage occurrence For 11KV	Total number of outage duration for 33kv In hours	Total number of outage duration for 11KV in hour
Jan	-	-	-	-
Feb	-	-	-	-
March	-	-	-	-
April	-	-	-	-
May	-	-	-	-

June	-	1	-	5.3
July	-	-	-	-
Aug	-	-	-	-
Sept	-	-	-	-
Oct	-	1	-	6.1
Nov	-	-	-	-
Dec	-	-	-	-

Table 4: Shows The Outage Occurrence due to Force Outage In 2020 (Disco outage record book)

Month	Total number of outage occurrence for 33KV	Total number of outage occurrence for 11KV	Total number of outage duration for 33kV In hours	Total number of outage duration for 11KV in hour
Jan	2	17	16	90.44
Feb	4	15	14	100.55
March	5	17	20	120.66
April	3	18	30	140.61
May	6	20	30.11	90.12
June	4	21	40.11	99.44
July	3	21	17.11	41.45
Aug	4	19	14.12	100.92
Sep	3	14	19.14	99.44
Oct	3	39	16.15	199
Nov	3	41	14.6	200.20
Dec	94	25	15.17	99.11

Table 5: Outage Occurrence due to Emergency Load Shedding In 2020 (Disco outage record book)

Month	Total number of outage occurrence for 33KV	Total number of outage occurrence for 11KV	Total number of outage duration for 33kV In hours	Total number of outage duration for 11KV in hour
Jan	2	60	5.11	145
Feb	4	71	16.11	190
March	4	61	17.11	330.12
April	4	71	25.11	160.50
May	3	51	20.12	490.14
June	4	71	25.14	190.4
July	34	21	39.14	350.14
Aug	3	80	14.14	300.14
Sept	3	81	12.9	290.12
Oct	3	91	15.99	390.14
Nov	34	104	14.14	400.14
Dec	2	90	9.11	200.15

From the above data, the 11kV line experienced more outages than 33kV line. Other findings showed that more outage and duration of hours occurred over the years attributed to emergency load shedding. From the tables, the total outages and duration in a month could be observed where some days, no outage was experienced in both the 33kV and 11kV lines, while some days, outage might occur in a particular 33kV line while the 11kV line that is not attached to the 33kV line will not experience any outages. Some days, outages may not occur in the 33kV line while the 11kV experienced outages, while also, both 33kV and 11kV lines experienced outages simultaneously.

3.3 Application of Automatic Control Model to Distribution Network

The automatic control script model was written in MATLAB to see the results and encrypted in PHP that monitored the megawatts per hour in order to reduce emergency load shedding or ensure that the consumed megawatts did not exceed the allocated megawatts. The system was designed with interface between the ammeter which switches the OFF and ON button to give access when each substation exceeds the load allocation and automatically switches off the defaulting substation.

4.0 Results and Discussions

In order to reduce the emergency load shedding experienced in Nigeria distribution line. Data obtained in the tables shows the number of times and duration that outages occurred as a result of emergency load shedding. The developed automatic control model applied to the Atani 33kV substation showed the following results.

Table 6: Atani 33kV substation used as a test result for Planned Outage,Housing feeder, 2017.

Month	Total number of outage occurrence	Total number of outage duration in hours
Jan	1	5.5
Feb	-	-
March	-	-
April	1	2
May	-	-
June	-	-

Table 7: Atani 33kV Injection substation used as a test result for Load Shedding for Housing Feeder, 2017.

Month	Total number of outage Occurrence	Total number of outage duration in hours
Jan	14	54.14
Feb	12	45.20
March	20	55.11
April	16	15.12
May	25	150.10
June	19	125.16

Table 8: Atani 33kV substation used as a test result for Emergency load shedding for Housing Feeder, 2017.

Month	Total number of outage Occurrence	Total number of outageduration in hours
Jan	9	70.65
Feb	8	90.11
March	6	140.59
April	10	169
May	-	-
June	-	-

Table 9: Atani 33kv substation used as a test result for Forced Outage, For Housing Feeder, 2017

Month	Total number of outage Occurrence	Total number of outage duration in hours
Jan	4	10.17
Feb	8	30.10
March	1	3.10
April	7	40.00
May	9	67.14
June	4	24.18

Table 10: The Atani 33kV Injection Substation result used as a test system for outage for Iweka Feeder for Forced outage, 2017

Month	Total number of outage occurrence	Total number of outage duration in hours
Jan	10	96.26
Feb	12	79.78
March	13	120.89
April	16	125.59
May	4	25.00
June	3	12.11

Table 11: The Atani 33kV Injection Substation result used as a test system for load shedding for Iweka for load shedding, 2017

Month	Total number of outage Occurrence	Total number of outage duration in hours
Jan	3	45.25
Feb	4	50.75
March	3	45
April	4	20
May	12	160.42
June	14	129.52

Table 12: The Atani 33kV Injection substation result used as a test system for Emergency Load Shedding for Iweka Feeder, 2017

Month	Total number of outage Occurrence	Total number of outage duration in hours
Jan	6	87.67
Feb	7	98.59
March	8	120.51
April	9	168.22
May	-	-
June	-	-

Table 13: The Atani 33kV Injection substation result used as a test system for Planned Outage for Iweka, 2017

Month	Total number of outage occurrence	Total number of outage duration in hours
Jan	-	-
Feb	-	-
March	1	3.15
April	-	-
May	2	8.12
June	-	-

Table 14: The Atani 33kV Injection substation result used as a test system for Emergency Load Shedding For Water works, 2017.

Month	Total number of outage occurrence	Total number of outage duration in hours
Jan	6	87.67
Feb	7	98.59
March	8	120.51
April	9	168.22
May	-	-
June	-	-

Table 15: The Atani 33kV Injection substation result used as a test system for Forced Outage For Water works, 2017

Month	Total number of outage occurrence	Total number of outage duration in hours
Jan	15	280.45
Feb	20	278.44
March	21	300.45
April	22	345.6
May	25	299.14
June	15	169.26

Table 16: The Atani 33kV Injection substation used as a test system for Forced Outage for Water works feeders, 2017

Month	Total number of outage occurrence	Total number of outage duration in hours
Jan	10	196.75
Feb	12	178.65
March	14	160.64
April	15	198.54
May	16	196.14
June	25	209

Table 17: Shows the Atani 33kV result used as attest system for Water works for planned outage, 2017

Month	Total number of outage occurrence	Total number of outage duration in hours
Jan	-	-
Feb	-	-
March	1	5
April	-	-
May	-	-
June	-	-

Table 18: Shows the Atani 33kV Injection Substation result used as attest system for Planned Outage for Iyiowa Feeder, 2017

Month	Total number of outage occurrence	Total number of outage duration in hours
Jan	-	-
Feb	-	-
March	1	6
April	-	-
May	-	-
June	-	-

Table 19: The Atani 33kV Injection Substation result as attest system for Emergency Load Shedding for Iyiowa Feeder, 2017

Month	Total number of outage occurrence	Total number of outage duration in hours
Jan	6	60.55
Feb	7	80.67
March	8	90.59
April	9	112.78
May	-	-
June	-	-

Table 20: The Atani 33kV Injection Substation result used as a test system for Iyiowa for loadshedding, 2017

Month	Total number of outage Occurrence	Total number of outage duration in hours
Jan	4	30.14
Feb	5	40.14
March	4	45.12
April	5	36.11
May	8	140.42
June	9	120.55

Table 21: The Atani 33kV Injection Substation result used as a test system for Forced Outage For Iyiowa feeder, 2017

Month	Total number of outage occurrence	Total number of outage duration in hours
Jan	15	120.16
Feb	20	114.89
March	21	180.77
April	22	175.66
May	25	120.14
June	15	9.11

Table 22: The Atani 33kV Injection Substation result used as a test system for Forced Outage for Wharf, 2017

Month	Total number of outage occurrence	Total number of outage duration in hours
Jan	15	160.99
Feb	20	135.77
March	21	220.67
April	22	199.64
May	25	178.99
June	15	112.12

Table 23: The Atani 33kV Injection substation result used as attest system for Emergency Load Shedding for Wharf Feeder, 2017

Month	Total number of outage Occurrence	Total number of outage duration in hours
Jan	6	87.67
Feb	7	98.59
March	8	120.51
April	9	168.22
May	-	-
June	-	-

Table 24: The Atani 33kV result used as a test system for Load Shedding for Wharf Feeder, 2017

Month	Total number of outage Occurrence	Total number of outage duration in hours
Jan	4	60.54
Feb	5	45.66
March	4	70.65
April	5	67.89
May	8	149.57
June	9	180.11

Table 25: The Atani 33kV Injection Substation result used as a test system for Planned Outage for Wharf feeder, 2017

Month	Total number of outage occurrence	Total number of outage duration in hours
Jan	-	-
Feb	-	-
March	1	4
April	-	-
May	-	-
June	-	-

So, from Tables 6-25, the automatic control model was not introduced from January 2017 to April 2017. It can be seen that the total number of outage occurrence and total duration in hours for emergency load shedding was reduced, which the main objective of this work to reduce emergency load was shedding thereby reducing outages in the transmission line. Generally, the automatic control model was introduced from May 2017 and June 2017 as can be seen. From Table 23, emergency load shedding was reduced compared to emergency load shedding between January and April.

4.1 Simulation of Outage Results

The simulation of outage results are shown below:

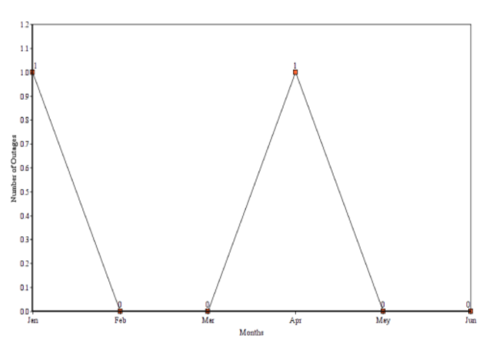


Fig 8: Atani 33kV Injection Substation result used as a system for planned outage for Housing feeder

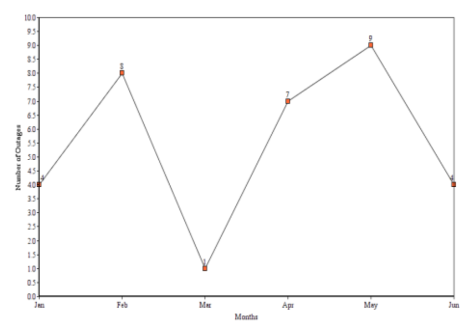


Fig. 9: Atani 33kV Injection Substation result as a test system for forced outage for Housing feeder

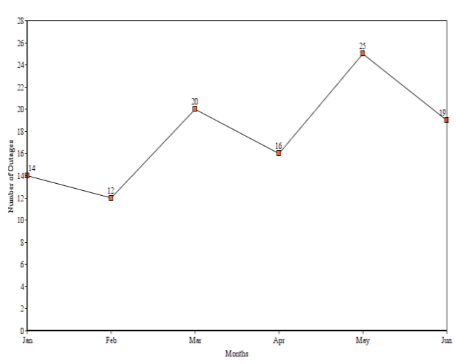


Fig 10: Atani 33KV Injection Substation result used as a test system for load shedding for Housing feeder.

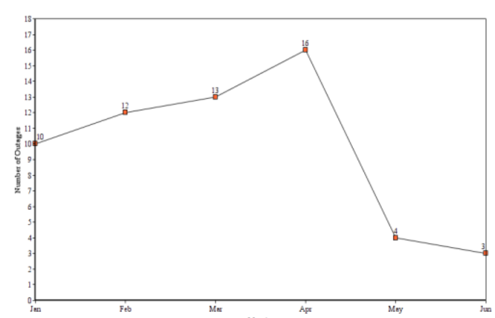


Fig.11: Atani 33kV Injection Substation result used as a test system for shedding for Housing feeder.

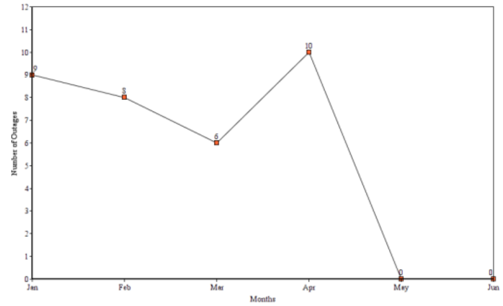


Fig. 12: Atani 33KV Injection Substation result used as a test emergency load shedding for Housing Feeder

The horizontal axis represents months, the vertical axis represents outage occurrences. The numerical values in the horizontal axis represent the six months. The number of outage occurrence are plotted on the vertical axis, as can be seen from the graphs where there are more outage occurrences ranging from January, February March and April, for planned outage, forced outage, load shedding and emergency load shedding. However, when real time technique was introduced in May and June, the outage occurrence was eliminated for Housing feeder, Iweka feeder, Water works feeder, Iyiowa feeder and Wharf feeder in terms of emergency load shedding.

Conclusion

This work has presented an application of automatic control model to reduce emergency load shedding in transmission lines. The technique allocates load or megawatts to maintain, allocate sheet for hourly reading, and monitor load and isolate the substation that exceeded their load allocation in transmission line. The system is capable of allocating load through the system administrator. The allocation is programmed and the system isolates the substation that exceeds their load allocation automatically and keeps the substation that maintains their load allocation ON.

In order to reduce transmission line outage in Nigeria transmission network, the following are recommended: Automatic control technique should be adopted to allocate megawatts to the substation and be monitored to maintain the allocated megawatts in order to eliminate emergency load shedding. Proper study should be carried out to identify over loaded transformers and this exercise should be in a routine manner. Intelligence system should be adopted to locate faults thereby reducing the duration of outage during faults. Very long and fragile lines should be re-enforced to improve the voltage stability and efficiency in the network and new substations should be built to reduce fault associated with long line. Vigilant groups with modern security intelligence and facility should be introduced to ward off vandals and right of way should be a routing check. The automatic control model has its disadvantage as it does not reduce forced outage, hence it recommended for further study to reduce forced outage in the distribution line.

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