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Utilization of Under Frequency Load Shedding (UFLS) and Under Voltage Load Shedding (UVLS) Schemes in Improving Voltage Level at Injection Substations

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***Abstract*—**Optimizing load shedding (LS) in developing country has become a major control challenge facing the power distribution companies today resulting from poor generation to losses of power via the transmission lines and theft of energy at the distribution levels. This paper deals with LS issue posed on the utility providers, most load shedding scheme proposed so far used either voltage or frequency parameters known as under frequency voltage load shedding (UFLS) by this it means in a situation where frequency is 50 ± 0.25 Hz the utility provider will no longer ahead to the stipulated laws governing the frequency and for the under voltage load shedding (UVLS) scheme the percentage voltage drop which is + or - 6% in line with International Electrotechenical Commission (IEC 60038) will be violated, in this paper both (UFLS) and (UVLS) indices were used in achieving a more comprehensive, effective, and reliable load shedding strategy from the result analysis of the network which comprise of three feeders and sixty-three substation using ETAP 12.6 in running the load flow analysis, it was very clear that all buses in service as at the time of this analysis violated the percentage voltage drop but with the exception of a particular substation which also doubles at point load which was within the percentage voltage drop both at peak period and off peak period of the day with the combination of both method UFLS and UVLS the substation which were outside the acceptable voltage and frequency range were now operate within the stipulated rule also the substations on the distribution network (Feeder) were automated to drop or pick load on its own without any human interference the system.

***Keywords*—** frequency, load shedding, under voltage, power distribution, substation

I. Introduction

As the use of electric power energy increase there is need to increase the generating capacity, improve the transmission network and the distribution system, if any country must develop technologically investment in its power sector should be given priority [1]. Power generation in Nigeria as at 5th August, 2014 the generating capacity in the country was below 6175.5MW [2] Which clearly shows that for a population of over 155,215,573 people as at July, 2011 population size estimate [3], which clearly shows that an individual is entitled to less than 30 watt of electricity power supply [1]; [13], this was one of the reason that led to the deregulation of the Nigeria Power Sector which initially started by the unbundling of the Power Holding Company of Nigeria (PHCN) into three major sections, with six generating stations (GenCOs), one transmission company (TransCo), and eleven Distribution companies (Discos) [4]. The Act that was passed into law that led to the unbundling of PHCN also brought about the Nigeria Electricity Regulatory Commission (NERC) with its responsibility.

To regulate the power sector

i. To oversee the various power industry and their frequency

ii. They shall enforce and institute the regulatory activity in the power sector.

iii. They shall be responsible for the issuance of licenses to the unbounded PHCN such as generating, transmission and distribution and other relating power trading companies.

iv. They are to also look into special cases of licenses through the Legislative Act.

v. They are to look into policy as it affects environmental management, resources, public issues, renewable energy reports, publication, statistical data relating to power issues and enforcing regulations and standards in power sector [5]; [6].

With the Act passed by the federal government of Nigeria which has brought about new key players into the power sector and given them the autonomy to generate and distribute power in an autonomous pattern, the poor generation of power at the various generating station(s) has led to unreliable power supply, frequent power outages, frequent system collapse in the Nigerian Grid system resulting in virtually perpetual load shedding in the power distribution network, with load shedding as a major challenge in the distribution network.

Load Shedding (LS) in electrical power system could be defined as an emergency or deliberate measure taken to retain power system stability thereby preventing system collapse [7]; [8].

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II. METHOD AND THEORETICAL ANALYSIS

A. *Optimizing Load Shedding*

Various methods and techniques have been used in carrying out load shedding activity in power system in order to put an end to the numerous problems associated with LS. Such method often deployed is the Under Frequency Load Shedding (UFLS) or the Under Voltage Load Shedding (UVLS). In this paper, both the Under Frequency Load Shedding and the Under Voltage Load Shedding were deployed. The advantage associated with this research is its ability to detect the need for distribution network to carry out and optimize its load shedding activity without external interference making the system fully automated by putting an end to frequent overload conduction and preventing frequent shutdown of power system facility in the distribution system [9]; [13]. The commonly used load shedding technique is known as the frequency load shedding, which is as a result of an imbalance in the active power of the power system and further manifest in change of frequency of the power system network. [10]; [11]. During load shedding activity, loads are grouped or classified as: (a) Urgent load (b) Semi-urgent load (c) Unnecessary load [12]; [13].

The Nigeria power system is a very complex system as a result of its size, using manual load shedding operation in such a complex interconnected system can result in system unreliability, poor power quality, delay in load shedding operations, and conceptions to special feeders and possible hazards which may hinder or stall the smooth operation of power system distribution activity. Deploying an Automated load shedding in power distribution system will help improve the power quality of power systems, improve the reliability of the system, reduce the man power needed in carrying out load shedding activities, Automatic load shedding will also eliminate the delay operations associated with manual load shedding, Automatic load shedding will also prevent the issue of special feeders there by given equity to all power consumer at the distribution end and finally prevent possible hazard associated with manual load shedding.

B. *Ughelli -15 (U-15) Injection Substation Network Structure*

Ughelli- 15, 15MVA, 33/11kV injection substation, has a communication name (U-15) which has a common boundary with Transcorp Power Generating Station, at KM 20 Ughelli – Patani Express Road, Ughelli, Delta State, Nigeria. Ughelli-15, 15MVA, 33/11kV injection substation gets its power supply from a 33kV transmission line via Transcorp Generating Power Limited, Transcorp generating power plant generates at 16kV and its been fed into a 30 MVA, 132/33kV transformer, which stepped up the 16kV to 132/33kV the output which in turn feeds the Ughelli-15, 15 MVA, 33/11kV Injection Substation. The Injection Substation and generating station have common boundary and are both interconnected with conductor size of 150mm² cross sectional area, and from Ughelli-15, 15MVA, 33/11kV injection substation to its various distribution substations are connected also with conduc tor size of 150mm² conductors.

Figure1: Photo View of U-15, 15MVA, 33/11kV Injection Substation.

Figure 2: Photo View of U-15, 15MVA, 33/11kV Injection Substation.

Figure 3: Reading being taken from one of the substation feeder pillar.

III. DATA PRESENTATION

The data used in this analysis were collected at the various substations in the network under investigation, photo view on data collection point is shown on figure3. The table below shows the data collected from the three feeders with data of eleven substations representing the entire network shown on the table below.

Table 1: OLD ROAD Transformer Feeder (Sub-Station)

S/N	OLD ROAD FEEDER	PEAK- PERIOD			OFF PEAK –PERIOD			STATUS
	SUBSTATION RATING (11kVA/0.415kVA)	REAL POWER	POWER FACTOR (φ)	APPARENT POWER (kVA)	REAL POWER	POWER FACTOR (φ)	APPARENT POWER (kVA)	
1	AIRTEL (50kVA)	8.3009	0.85	9.765764706	2.687	0.85	3.161176471	Ok
2	MTN 1 (50kVA)	1.059	0.89	1.191250142	0.82	0.88	0.951156775	Ok
3	OLD ROAD (300kVA)	180.85	0.893666667	214.6634798	112.53	0.952333333	117.1331381	Ok
4	OGBERODE (500kVA)	189.8	0.926666667	205.2765193	112.9	0.926666667	124.0259662	Ok
5	LONDON (500kVA)	246.42	0.943333333	262.5791896	163.18	0.962333333	169.5352424	Ok

Table 2: ECN FEEDER (Sub-Station) Readings (Summary)

S/N	ECN FEEDER	PEAK- PERIOD			OFF PEAK –PERIOD			STATUS
	SUBSTATION(S)	REAL POWER	POWER FACTOR (φ)	APPARENT POWER (kVA)	REAL POWER	POWER FACTOR (φ)	APPARENT POWER (kVA)	
1	BALAGBA (300kVA)	145.4	0.920666667	157.9959172	85.43	0.924333333	92.18102369	Ok
2	SENIOR STAFF QUARTERS (300kVA)	240.54	0.963666667	249.9551006	153.12	0.959666667	159.0703162	Ok
3	AIRTEL 1 (50kVA)	8.601	0.953333333	9.081333236	2.085	0.96	2.174210865	Ok
4	JUNIOR STAFF QUARTERS (300kVA)	179.54	0.942	190.9237751	50	0.906333333	55.41667071	Ok
5	EKPAREMRE 1 (300kVA)	129.04	0.959	134.3130223	68.13	0.933666667	72.90949881	Ok

Table 3: BETA GLASS PLC FEEDER (Sub-Station) reading

S/N	BETA GLASS PLC FEEDER	PEAK- PERIOD			OFF PEAK –PERIOD			STATUS
	SUBSTATION(S)	REAL POWER	POWER FACTOR (φ)	APPARENT POWER (kVA)	REAL POWER	POWER FACTOR (φ)	APPARENT POWER (kVA)	
1	BETA GLASS PLC (500KVA)	200.5	0.953333333	211.1192578	77.39	0.923	83.58202125	Ok

IV. SIMULATION AND ANALYSIS

Electrical transient analyser program (etap) 12.6 environment software program was utilized for the analysis of u-15 network load flow study. figure 4 shows the screen for run or simulation mode on etap 12.6 software. some of the data used for analysis are the various bus id, normal kva, voltage, voltage in per unit, percentage voltage drop also the various status of the substation that were under consideration, for the simulation and analysis of the data obtained from the field shows the status of the various substation used in this research and the result from this analysis is represented on the summary of this paper.

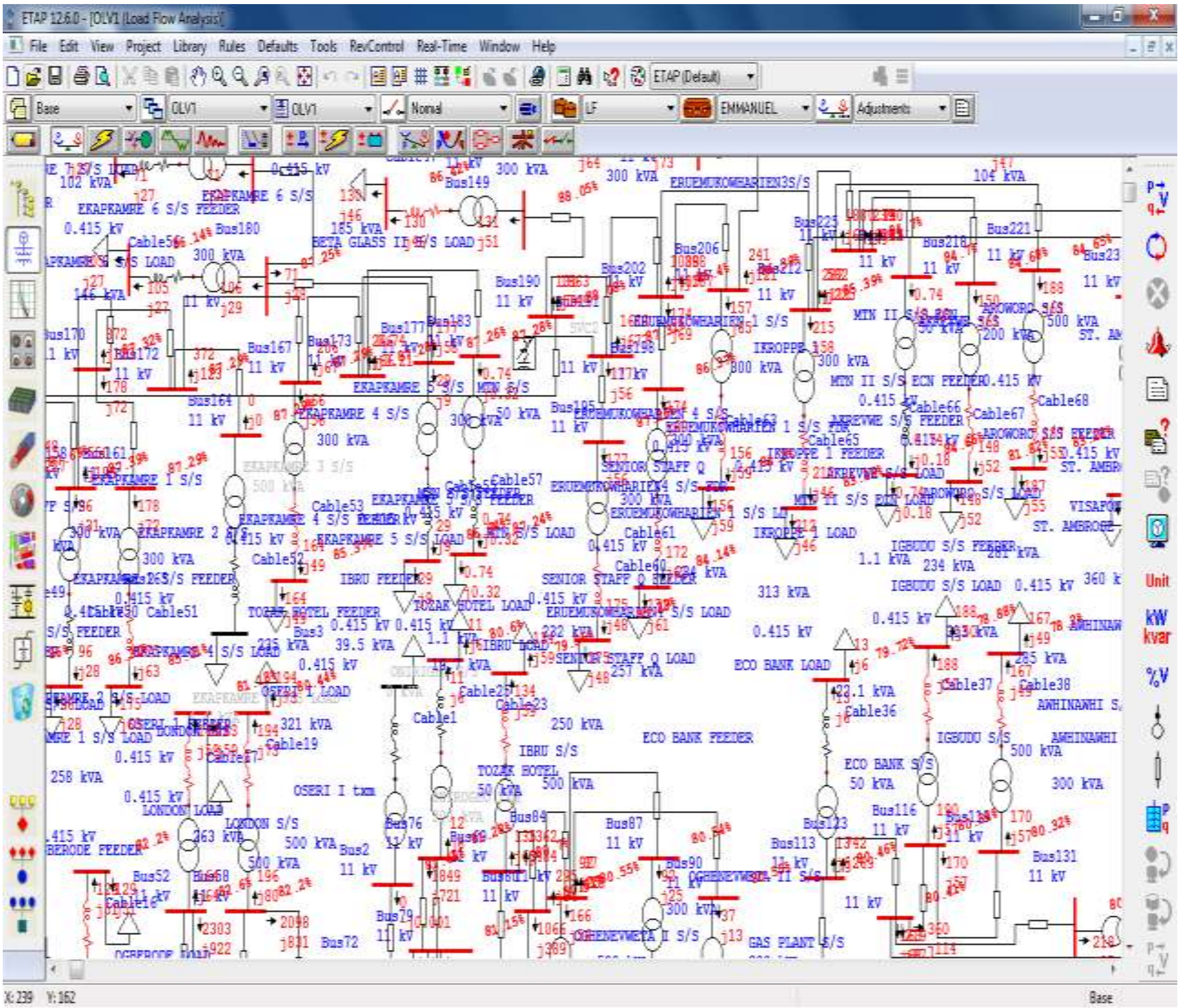

Figure 4: Simulation (RUN) Mode of U-15 Network in ETAP 12.6

Table 4: Load flow Report for the Network showing Nominal kV, voltage, voltage in per unit, Percentage Voltage Drop for each bus during peak period (Peak Period Result Summary).

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S/N	BUS ID	Nominal kV	Voltage	Voltage Pu	%Voltage Drop	Remark
1	AIRTEL 1 FEEDER	0.415	87.45	0.8745	12.55	Voltage Drop Outside Acceptable limit
2	AIRTEL O-R FEEDER	0.415	84.01	0.8401	15.99	Voltage Drop Outside Acceptable limit
3	BALAGBA S/S FEEDER	0.415	86.72	0.8672	13.28	Voltage Drop Outside Acceptable limit
4	BetaG-load FEEDER	0.415	96.26	0.9626	3.74	Voltage Drop Within Acceptable limit
5	EKAPKAMRE 1 S/S FEEDER	0.415	86.19	0.8619	13.81	Voltage Drop Outside Acceptable limit
6	JUNIOR STAFF QTERS S/S FEEDER	0.415	85.87	0.8587	14.13	Voltage Drop Outside Acceptable limit
7	LONDON S/S BUS	0.415	81.1	0.811	18.9	Voltage Drop Outside Acceptable limit
8	MTN I S/S FEEDER	0.415	84	0.84	16	Voltage Drop Outside Acceptable limit
9	OGBERODE S/S FEEDER	0.415	82.09	0.8209	17.91	Voltage Drop Outside Acceptable limit
10	OLD ROAD S/S FEEDER	0.415	81.71	0.8171	18.29	Voltage Drop Outside Acceptable limit
11	SENIOR STAFF QTERS FEEDER	0.415	85.13	0.8513	14.87	Voltage Drop Outside Acceptable limit

Table5: Load flow Report for the Network showing Nominal kV, voltage, voltage in per unit, Percentage Voltage Drop for each bus during peak period (Off-Peak Period Result Summary).

S/N	BUS ID	Nominal kV	Voltage	Voltage Pu	%Voltage Drop	Remark
1	AIRTEL 1 FEEDER	0.415	92.98	0.9298	7.02	Voltage Drop Outside Acceptable limit
2	AIRTEL O-R FEEDER	0.415	90.68	0.9068	9.32	Voltage Drop Outside Acceptable limit
3	BALAGBA S/S FEEDER	0.415	92.4	0.924	7.6	Voltage Drop Outside Acceptable limit
4	BetaG-load FEEDER	0.415	98.21	0.9821	1.79	Voltage Drop Within Acceptable limit
5	EKAPKAMRE 1 S/S FEEDER	0.415	91.85	0.9185	8.15	Voltage Drop Outside Acceptable limit
6	JUNIOR STAFF QTERS S/S FEEDER	0.415	92.37	0.9237	7.63	Voltage Drop Outside Acceptable limit
7	LONDON S/S BUS	0.415	88.72	0.8872	11.28	Voltage Drop Outside Acceptable limit
8	MTN I S/S FEEDER	0.415	90.56	0.9056	9.44	Voltage Drop Outside Acceptable limit
9	OGBERODE S/S FEEDER	0.415	89.34	0.8934	10.66	Voltage Drop Outside Acceptable limit
10	OLD ROAD S/S FEEDER	0.415	89.44	0.8944	10.56	Voltage Drop Outside Acceptable limit
11	SENIOR STAFF QTERS FEEDER	0.415	91.37	0.9137	8.63	Voltage Drop Outside Acceptable limit

Table6: Load flow Report for the Network showing Nominal kV, voltage, voltage in per unit, Percentage Voltage Drop for each bus during peak period (Peak Period Result Summary with UFLS and UVLS Installed).

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S/N	BUS ID	Nominal kV	Voltage	Voltage Pu	%Voltage Drop	Remark
1	AIRTEL 1 FEEDER	0.415	97.86	0.9786	2.14	Voltage Drop Within Acceptable limit
2	AIRTEL O-R FEEDER	0.415	97.32	0.9732	2.68	Voltage Drop Within Acceptable limit
3	BALAGBA S/S FEEDER	0.415	97.06	0.9706	2.94	Voltage Drop Within Acceptable limit
4	BetaG-load FEEDER	0.415	99.94	0.9994	0.06	Voltage Drop Within Acceptable limit
5	EKAPKAMRE 1 S/S FEEDER	0.415	96.44	0.9644	3.56	Voltage Drop Within Acceptable limit
6	JUNIOR STAFF QTERS S/S FEEDER	0.415	96.1	0.961	3.9	Voltage Drop Within Acceptable limit
7	LONDON S/S BUS	0.415	96.07	0.9607	3.93	Voltage Drop Within Acceptable limit
8	MTN I S/S FEEDER	0.415	97.65	0.9765	2.35	Voltage Drop Within Acceptable limit
9	OGBERODE S/S FEEDER	0.415	96.27	0.9627	3.75	Voltage Drop Within Acceptable limit
10	OLD ROAD S/S FEEDER	0.415	95.19	0.9519	4.81	Voltage Drop Within Acceptable limit
11	SENIOR STAFF QTERS FEEDER	0.415	97.08	0.9708	2.92	Voltage Drop Within Acceptable limit

Table7: Load flow Report for the Network showing Nominal kV, voltage, voltage in per unit, Percentage Voltage Drop for each bus during peak period (Off-Peak Period Result Summary with UFLS and UVLS Installed).

S/N	BUS ID	Nominal kV	Voltage	Voltage Pu	%Voltage Drop	Remark
1	AIRTEL 1 FEEDER	0.415	99.12	0. 9912	0.88	Voltage Drop Within Acceptable limit
2	AIRTEL O-R FEEDER	0.415	98.79	0.9879	1.21	Voltage Drop Within Acceptable limit
3	BALAGBA S/S FEEDER	0.415	98.48	0.9848	1.52	Voltage Drop Within Acceptable limit
4	BetaG-load FEEDER	0.415	100.23	0.10023	0.23	Voltage Drop Within Acceptable limit
5	EKAPKAMRE 1 S/S FEEDER	0.415	97.92	0.9792	2.08	Voltage Drop Within Acceptable limit
6	JUNIOR STAFF QTERS S/S FEEDER	0.415	98.26	0.9846	1.54	Voltage Drop Within Acceptable limit
7	LONDON S/S BUS	0.415	98.86	0.9886	2.14	Voltage Drop Within Acceptable limit
8	MTN I S/S FEEDER	0.415	98.85	0.9885	1.15	Voltage Drop Within Acceptable limit
9	OGBERODE S/S FEEDER	0.415	97.99	0.9799	2.01	Voltage Drop Within Acceptable limit
10	OLD ROAD S/S FEEDER	0.415	97.75	0.9775	2.25	Voltage Drop Within Acceptable limit
11	SENIOR STAFF QTERS FEEDER	0.415	98.21	0.9821	1.79	Voltage Drop Within Acceptable limit

V. SIMULATION RESULT SUMMARY

From the analysis carried out from the network under investigation using ETAP 12.6 in running the load flow study, bellow shows the outcome of the above data collected from the network used in the modeling of the network in an ETAP 12.6 environment.

1. The load flow analysis carried out on U-15 network comprises of 63 buses, with voltage ranging between 74.58 to 96.26 at peak period and 81.14 to 98.21 at off peak period.
2. From the load flow analysis carried out it shows that during peak period all 63 buses did run till they got to the accepted voltage level in Nigeria that is + or - 6%.
3. It was observed that During off peak period Beta Glass load feeder bus was within the acceptable range of + or - 6% and all other 62 buses violated the acceptable voltage range.
4. From the analysis it was observed that during peak period the highest percentage voltage drop was at Omotor sub-station bus 21.99% and the lowest percentage was at Beta Glass load feeder bus 3.74%.
5. U-15 analysis further shows that the load during peak period is 7.323MW and 3.8Mvar. and that for off peak period was 4.441MW and 1.949Mvar. respectively.
6. The analysis shows that the total loss during peak period is 0.89MW, 1.578Mvar. and 0.328MW, 0.566Mvar. at off peak period.

VI. CONCLUSION

From the simulation result data above it is clear that the power quality at the distribution level violated the stipulated or acceptable voltage range, thereby putting house hold equipment and properties of the country's citizenry in jeopardy hence there is need for the relevant authority to act fast and do less of talking before the situation finally slips out of control in other to restore power quality and security in the country.

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