Voltage Collapse and the Nigerian National Grid

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Abstract — A modern electric power system network (PSN) is typically a large and complex engineering system whose healthy existence is crucial to industrial and socio-economic development of Nations. Voltage instability and collapse contribute to large extent to system collapse or blackouts and it is one of the major concerns for today's electric power system operations. The Nigerian National grid (NNG) experiences on an average of thirty-five (35) system collapse every year over the past ten (10) years. This paper presents an overview and classification of system collapse on the NNG.

Keywords — **Voltage collapse, Voltage instability, and Nigerian National Grid (NNG)**

I. Introduction

THE function of a power system network (PSN) is to generate and transmit power to load centres at specified voltage and frequency levels and statutory limits exist for the variation about base levels. The nominal frequency shall be 50Hz ± 0.5%. Under system stress the frequency on the power system could experience variations within the limits of 50Hz ± 2.5% (i.e. 48.75 – 51.25 Hz and the nominal voltage shall be 330, 132, 33, 11 –kV ± 0.5% while Under system stress or following system faults, voltages can be expected to deviate outside the limits by a further ± 5% (excluding transient and sub-transient disturbances) [1]. As the system load changes, the resulting change in real and reactive power demands causes variation in the system voltage and frequency levels. The power system is equipped with controllers that reduce these variations to acceptable levels well within the statutory limits. In the operation and control of a power system network (PSN), voltage stability is a major concern to the power system engineer as the PSN nowadays operates very close to its stability limits [2]. This is due to increasing load demand, industrialization, environmental and economic factor which hampers the construction of new transmission lines and generating stations. This has caused most PSNs to be weak, heavily loaded and prone to voltage instability ([2] [3] [4].)

Voltage stability can be defined as the ability of a power system to maintain steady and acceptable voltage at all buses in the system at normal operating conditions, after being subjected to a disturbance ([5] [6].) It is desired that the power system remains in the equilibrium state under normal conditions, and reacts to restore the status of the system to acceptable conditions after a disturbance, i.e. the voltage after a disturbance is restored to a value close to the pre-disturbance situation.

A PSN is said to enter a state of voltage instability when a disturbance causes a gradual and uncontrollable decline in voltage. The causes of voltage instability are contigencies (line or generator outage due to faults), increasing load, external factors, or improper operation of voltage control devices and load variations. More importantly, where there is a mismatch between supply and demand of reactive power, that is inability of the system to meet the reactive power requirement.

Voltage collapse can therefore be defined as instability of a heavily loaded PSN that leads to declining voltage and eventually blackout. This has severe consequence on the system security and negates the essential service of delivering uninterrupted reliable power to the customers. Figure 1 shows the progress of a voltage collapse phenomenon. The system voltage decreases slowly as the demand increases untill a critical point is reached. At this point, any slight increase in demand will give rise to a large decrease in voltage, until the demand could no longer be satisfied which eventully leads to voltage collapse.

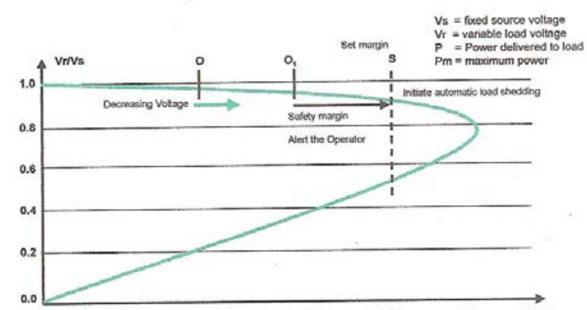

Figure 1: Progress of a voltage collapse case.

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The paper is organised as fellows. Section II presents power system stability while section III discusses the Nigerian national grid (NNG). Section IV deals with classification of system collapse on the NNG and section V presents the conclusion.

II. Power System Stability

Power system stability has been recognized as an important problem for secure system operation since the 1920s. Many major blackouts caused by power system instability have illustrated the importance of this phenomenon [7]. The world has witnessed several voltage collapse incidences in the last decades, prominent incidents that attracted much attention happened at Belgium (Aug 1982), Sweden (Dec. 1983), Tokyo (July1987), Tennessee (Aug. 1987), Hydro Quebec (March 1989) and the recent major blackout incidence that happened in 2003 in North America and some parts of Europe [8] The NNG witness several collapses as recorded in PHCN records. A comprehensive list comprising the time frame is summarized in ([5], [6], [8] and [9].)

According to the IEEE/CIGRE joint task force, *"Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact."* [10]. Figure 2 Shows the classification of power system stability according to IEEE/CIGRE joint task force.

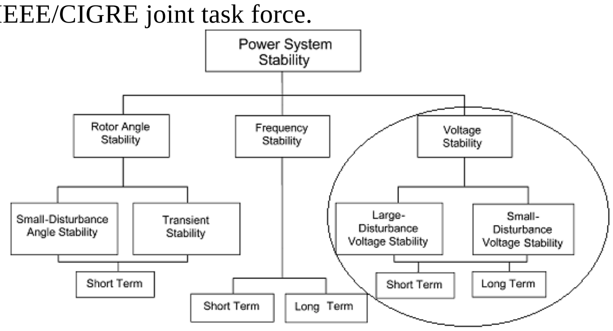

Figure 2. Classification of power system stability [10].

Based on the size of the disturbance, voltage stability can be further classified into the following two subcategories:

i. Large-disturbance voltage stability refers to the system's ability to maintain steady voltages following large disturbances such as system faults, loss of generation, or circuit contingencies.
ii. Small-disturbance voltage stability refers to the system's ability to maintain steady voltages when subjected to small perturbations such as incremental changes in system load.
iii. Voltage stability may be either a short-term or a long-term phenomenon.
iv. Short-term voltage stability involves dynamics of fast acting load components such as induction motors, electronically controlled loads, and HVDC converters. The study period of interest is in the order of several seconds.
v. Long-term voltage stability involves slower acting equipment such as tapchanging transformers, thermostatically controlled loads, and generator current limiters. The study period of interest may extend to several or many minutes, and long-term simulations are required for analysis of system dynamic performance ([11], [12].)

III. The Nigerian National Grid

The present installed capacity of the Nigerian National Grid (NNG) is about 6000MW, of which about 67 percent is thermal and the balance is hydro-based. By 2005, the transmission network consisted of 5000km of 330-kV lines, and 6000km of 132-kV lines. The 330-kV lines fed 23 substations employing transformer with voltage rating of 330/132-kV with a combined capacity of 6,000 MVA or 4,800 MVA at a utilization factor of 80%. On the other hand, the 132-kV lines fed 91 substations employing transformer with voltage rating of 132/33-kV with a combined capacity of 7,800 MVA or 5,850 MVA at a utilization factor of 75%. The system frequency is 50 Hz. The transmission network is overloaded with a wheeling capacity less than 4,000 MW. The NNG is characterized by poor voltage profile in most parts of the network, especially in the North, inadequate dispatch and control infrastructure, radial and fragile grid network, frequent system collapse, exceedingly high transmission losses [1]. The NNG is highly stressed and weak, this makes it prone to voltage instability and eventually voltage collapse [13]. The NNG diagram is as shown in figure 3.

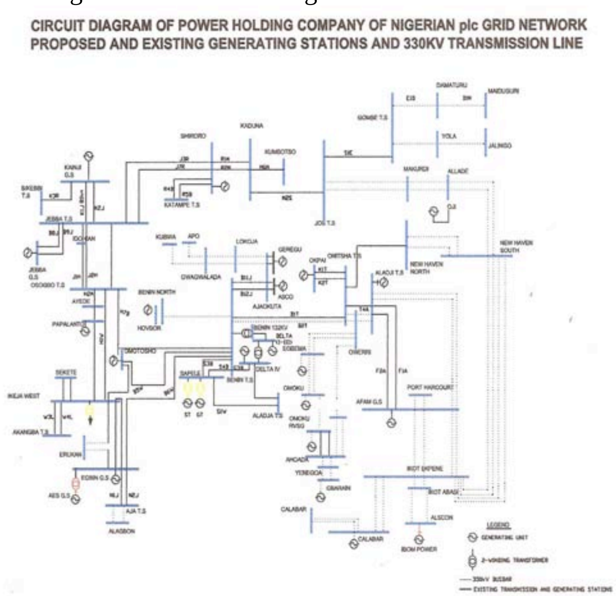

Figure 3: Nigerian National Grid 330kV Transmission Line.

The unreliability of the Nigerian PSN has impacted on the nation's socio-economic development and industrialization hence, the recent launch of the roadmap of the power sector reform by the Federal government [14].

Voltage collapse in PSN is an undesired phenomenon that occurs due to voltage instability and is generally associated with weak or stressed system (heavily loaded lines), long lines, radial networks, faults and /or reactive power shortages. Its occurrence is not frequent in developed countries despite their large and complex networks but its frequency is high in

Nigeria. Voltage collapses are highly catastrophic anytime they occur.

On the Nigerian national grid, the system collapse phenomenon is frequently experienced and often leads to either partial or total system collapse (black out), which greatly impairs the nation's socio-economic development and industrialization. This high rate is due to the fact that the NNG is weak, highly stressed, long and radial in nature hence lacking flexibility ([15], [16], [17].)

Statistics shows that system collapse on the NNG is very high. Table1 shows the statistical data of both partial (p/c) and total (t/c) collapse on the Nigerian National grid from January 2000 to December 2009 [17].

Table 1: System Collapses for the period of 2000-2009 on the NNG [18].

Year	09	08	07	06	05	04	03	02	01	00
P/Collapse	20	16	8	10	15	30	39	32	5	6
T/Collapse	19	26	18	20	21	22	14	9	14	5
Total	39	42	27	30	36	52	53	41	19	11

This problem of system collapse is on the increase resulting in insecurity and unreliability of the entire PSN. This shows that we have an average of 35 collapses in a year. The inconvenience and economic cost it inflicts on both domestic and industrial customers is high and unbearable. The resultant power outages cost the nation an estimated $1 billion per year (2.5% of GDP) [19]. Lack of adequate electric power has caused the closure of many industries that rely heavily on adequate power supply. Small businesses and heavy machine manufacturers are severely affected by the abysmal performance of the Power Holding Company of Nigeria (PHCN). Generally, the citizens are also affected socially, psychologically and physically due to inadequate and unstable power supply. On the overall PHCN has contributed in no small way to the stagnation of Nigeria economy. Poor services have forced most industrial customers and individuals to install their own power generators, at high costs to themselves and the Nigerian economy.

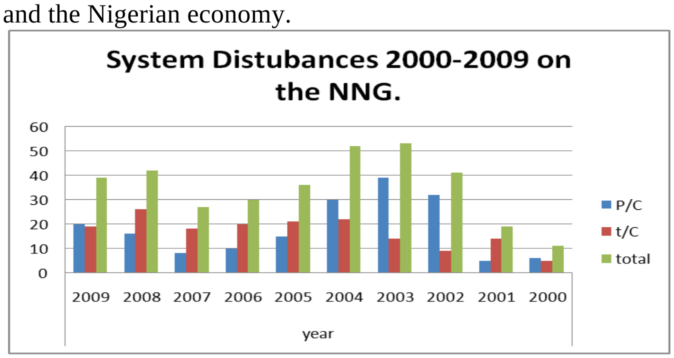

Figure 11: Bar chart showing the PHCN system disturbances form 2000 to 2009

When various components of power utility supply system experience complete seasure of energy flow, the system can be said to have total collapsed resulting in total blackout while partial collapse is when the network is islanded into two and one island is in blackout while on the other energy is flowing [14].

IV. CLASSIFICATION OF SYSTEM COLLAPSE ON THE NNG

The essence of classifying the system collapse on the NNG is to be able to know the system disturbances that are responsible for the high system collapse on the NNG and then proffer focused solutions to reduce the system collapse on the NNG. The summary of major system disturbances for three years i.e. 2008, 2009 and 2010 that gave rise to system collapse are classified as shown below:

Table 2: Classification System Collapses for the period of 2008-2010 on the NNG

Nature of Disturbances	2008	2009	2010
Faults	36	33	118
Gas (low pressure or lack)	2	5	0
Overload	1	2	3
Frequency	2	0	2
No reason	1	0	0

From table 2 above it can be deduced that fault induced collapse are predominant which reveal the nature of the NNG-as weak, stressed system (heavily loaded lines), long lines and radial networks. NNG is highly venerable to voltage instability.

It could be seen that the high rate of system collapse is largely due to technical challenges of the network. The state of the power system equipment and the entire network operation shows that there are also political challenges.

Technical Challenges are:

I. Old and obsolete power system equipment.
II. Inadequate compensation equipment on the system.
III. Faulty and weak protection system
IV. Weak network leading to indiscrimin ate tripping of the lines.
V. Generation shortage due to increasing cusunmers demand.
VI. Wheeling power is weak.
VII. Poor maintenance culture.

Political challenges are:

I. Neglect from Government over long period.
II. The National leaders pay lip service to the development of the power sector. It has been seen as an avenue to loot.
III. The sector has been fully politicized.
IV. Corruption like cankerworms has eaten deep into the sector hampering it growth and development.

If the power sector will develop and consumers will reliable power supply then the technical and the political problems must be adequately handled. The government and the operator of the PHCN must be strong willed in handling the challenges. Investing more finance into the sector so that up-grading could be carried out to solve all the technical challenges and to install state of the art facilities.

The government must be willing to fight corruption and contract inflation to a standstill because it is a drain pipe that must be block otherwise steady power supply is not insight.

V. Conclusion

The classification of system collapse on the NNG is to help know the system disturbances that are responsible for the high system collapse on the NNG. The technical and political challenges must of necessity be tackled squarely by both government and the management of PHCN.

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