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Analysis of Nigerian Electric Power System Frequency using FDR Measurements

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Abstract

This paper presents the result of prolong measurements and statistical data analysis of Nigerian power system frequency, obtained from Frequency Disturbance Recorder (FDR),the FDR installation experience, and also provides a comparative study between previous findings by other researchers and the present, in order to establish the current control status of the system. To assess the validity of the measurement, some part of the data were validated with data collected from Transmission Company of Nigeria (TCN).The result of 2016 indicates that the control action is worst as compared with the 2006, 2007, and 2011 results.

Keywords: *FDR, frequency, control action.*

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Background to the Study

Frequency is a very important parameter in Electric power system; it is a measure of balance between the active power generated and the active power consumed (Chudamani, 2009). At this balance, the frequency of the system is constant(Kothari, 2006),i.e. 50Hz in the case of Nigeria. Any mismatch between the generation and consumption (load plus losses) the frequency deviates from the nominal. Although there are other interferences that lead to the frequency deviation such as lightning, etc., but at steady state, frequency is common all over the interconnected system (Luigi Vanfretti. Joe H. Chow, 2010). The Nigerian power system is characterized by insufficient generation, insufficient transmission lines, and incompatible governor controls (Sadiq, 2013), in such a situation, the system is exposed to risk of stress and the last resort is to introduce load shedding. Load shedding in Nigeria is done manually which is characterized by human error (Vanfretti luigi, 2007). Disturbances such as: loss of load, loss of generation and transmission line trip causes frequency deviation.

One principal reason for Power system monitoring and control is to ensure that the frequency of the system did not deviate from the normal range (i.e. $49.75 \leq f \leq 50.25$) (NERC, 2014). Any frequency outside this range subjects the system into risk of stress and if the frequency persist below 48.75 Hz, then the system will certainly collapse leading to serious black out, while impending damages in the case of frequency exceeding 51.25Hz, thus causing substantial economic loss and jeopardizing national security. It is therefore, essential to monitor and control the frequency in order to save the system from collapsing and prevent electrical/electronic equipment from damage.

In this paper, result of prolonged measurements of Nigerian power system frequency is discussed and a comparative analysis between different selected years and the present has been done in order to measure the current health status of the system.

The remainder of this paper is organized as follows: section II described the implementation of Frequency Monitoring Network (FNET) structure and data capturing, Data validation is presented in section III, section IV provides the result of the analysis and comparative study between different years while section V draw conclusions of the work.

The FNET Implementation and Data Capturing

The FNET Implementation

The application of FDRs all over the interconnected power system for a wide area internet based centralized monitoring is known as FNET (Dong jin, 2013).Basically, the FNET comprises of two main components: the FDRs which serve as the sensor devices and the information management system (IMS). The FDRs perform local Global Positioning System (GPS) synchronized measurements of voltage phase angle, phase voltage magnitude and phase frequency. Thus these measurements are time stamped and reported at 0.1 seconds interval and then transmitted to the central server for further usage. The Mishandles the data collection, storage, communication, database operations, and web services (Dong jin, 2013).For the purpose of this research, a local frequency monitoring network (LFNET) was set up. The LFNET comprises two main components; the FDR and a personal computer (PC) which serves as the information management unit. A small server program which normally comes with the FDR was installed in the in the PC to enable connectivity for monitoring, data collection and storage. The measurement / LFNET set up is shown in figure 1, the network was installed such that the GPS antenna is directly facing the sky in order to facilitate good reception. The FDR is directly connected to 230V socket. An external storage (Database) is incorporated to serve as a support to the PC as a huge amount of data is captured.

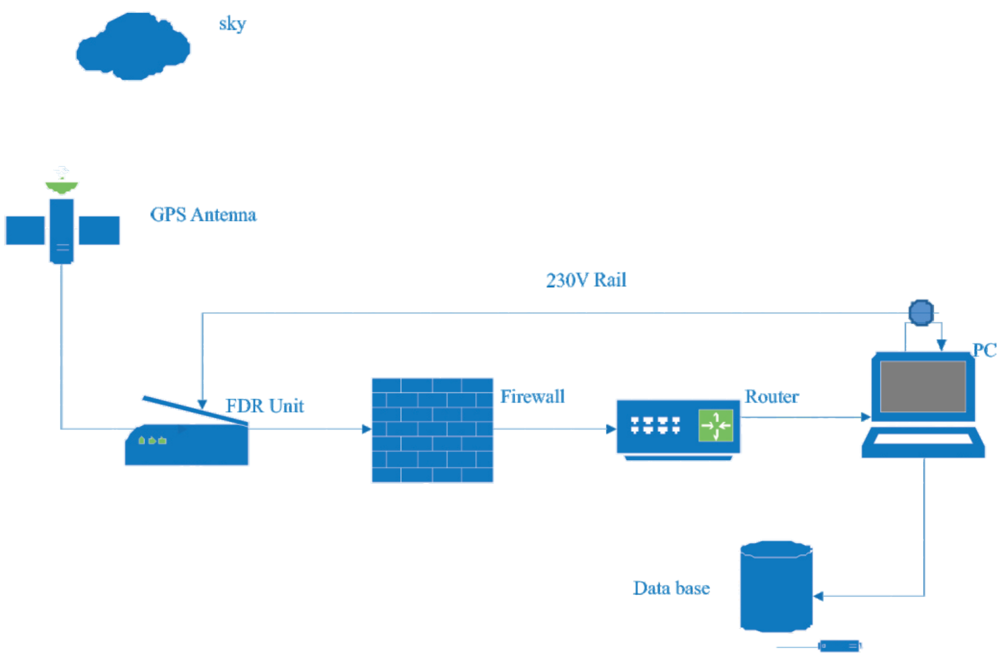


Figure1: The Measurement / LFNET Set Up

Data Capturing

Following a successful implementation of LFNET, two month data were captured from the network during different days between January, February, and March, 2016. However, during the measurements a lot of outages and loss of GPS Signal were experienced. Figure 2 shows the screen shot of the data retrieving at a laboratory in the Department of Electrical and Computer Engineering Ahmadu Bello University, Zaria. The screen comprises nine columns, the first column is showing the serial number of the data captured, the second column indicate the date at which the measurement was carried out and the third column shows the time (instant) of data captured. Column C, provides the sample rate, D and E columns presents the initial and the final frequencies captured at that very instant respectively. Column F is the voltage magnitude captured, G, shows the voltage angle while H column is a remark indicating successful captured or unsuccessful due to GPS signal lost.

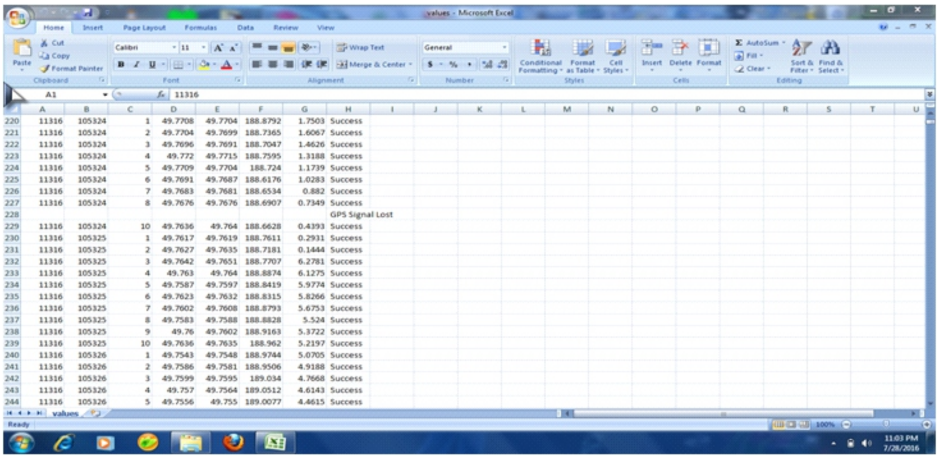


Figure 2: Screen Showing Data Reception From LFNET

Data Validation

A two hour data was collected from TCN 132kV/33kV station in Zaria; corresponding to Monday 14th march, 2016 at 8pm to 10pm. the data were plotted together with the equivalent data of LFNET at one minute interval as shown in the figure 3. It can be seen from the plot that, a close agreement has been established between the two data, indicating and justifying the fact that frequency is a common measure all over the interconnected network. The disparity between the data is due to human error and error associated with the TCN frequency Meter as it is manually recorded.

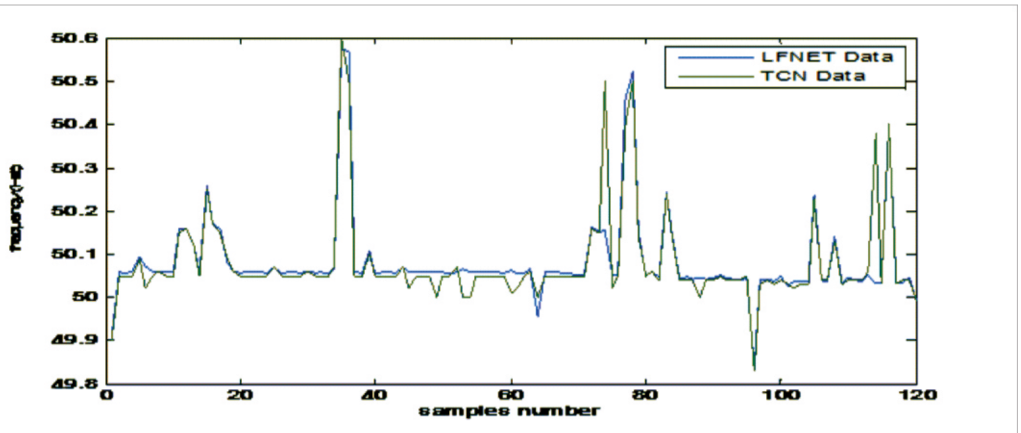


Figure 3: Data validation plot

Analysis and Comparative Study of the Measurements

Data plots Analysis

Some measures of dispersion as well as measure of central tendency were computed using SPSS Statistics software 2014 version. Also, in order to observe the stochasticity and probabilistic behavior of the frequency and to ease understanding of the system, a complete one day sample was extracted and probability distribution of the data were plotted using MATLAB R2013a version. Figure 4 shows a sample plot of the data. From the plot, it can be seen that the frequency is randomly changing moving out of the band that has been stipulated by Nigerian Electricity Regulatory Commission (NERC). This plot is an indication that sometimes the system operates under serious stress with below frequency threshold level, which simply means that the total Mega Watt (MW) load of the system is more than the total capacity MW generated at those instances. The upper part of the graph shows over –frequency, meaning that the total generated MW is greater than the total MW load; in such a circumstance the loads that are rated to operate at 50 Hz suffer very much. Mostly frequency deviation happens due to less careful load-frequency control measures taken by the National Control Centre (NCC) i.e. lack of proper coordination between the NCC and various load centers. in an attempt to avoid system collapse, consequently causing damage to the loads and the optimal utilization of the system is compromised.

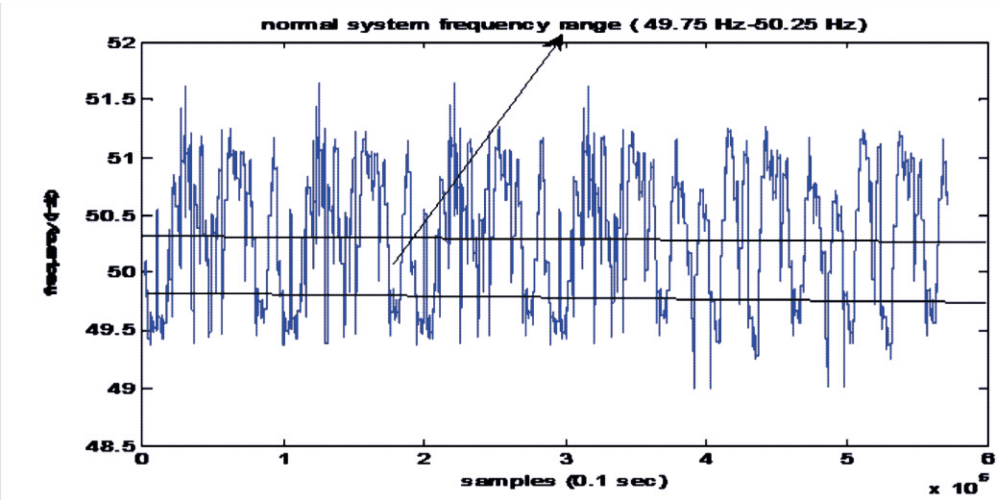


Figure 4: The frequency dynamics plot

The whole measurements were merged together in a way that the probabilistic behavior of the frequency can be assessed, which yield to a quasi- normal curve of figure 5. A healthy system is expected to produce a normal distribution curve with a narrow band between 49.75Hz and50.25Hz ($Hzf5.0=\Delta$)and a maximum probability distribution value at 50Hz. It is obvious from the graph that these benchmarks are clearly compromised.

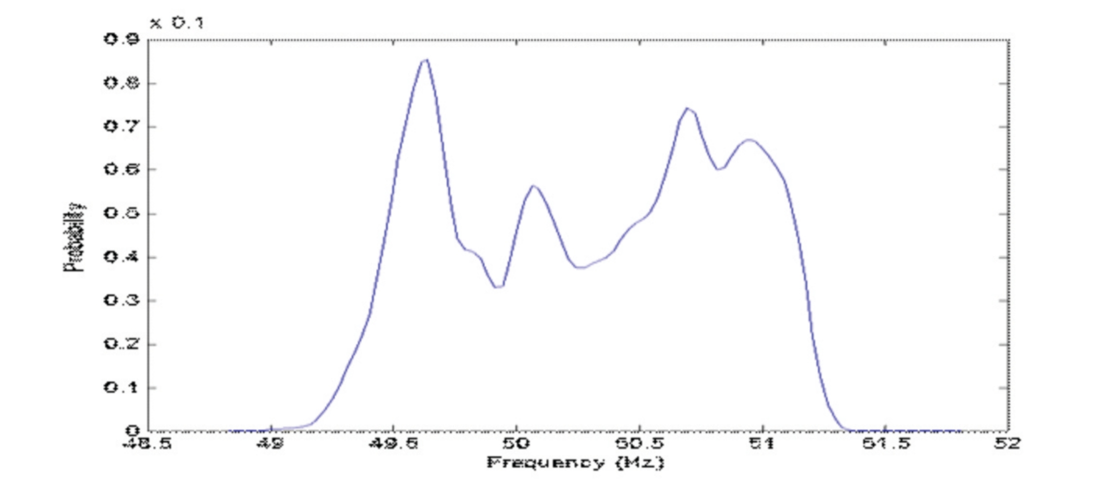
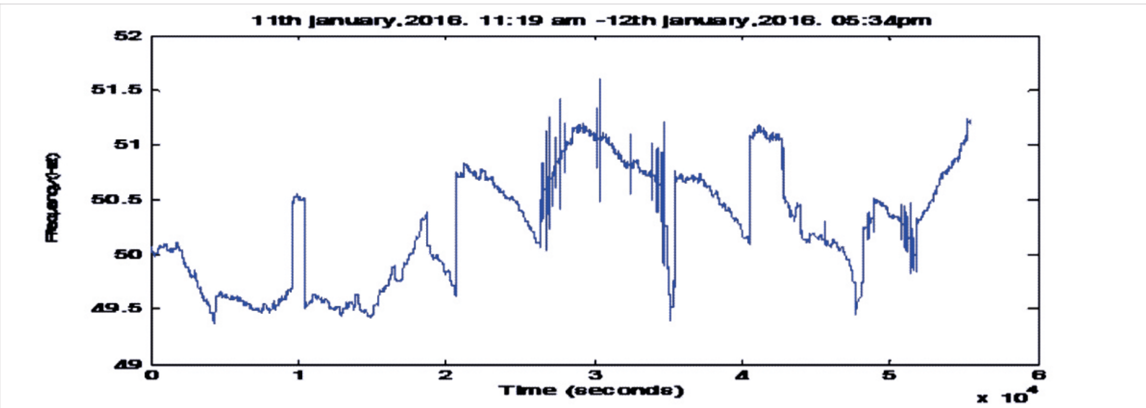
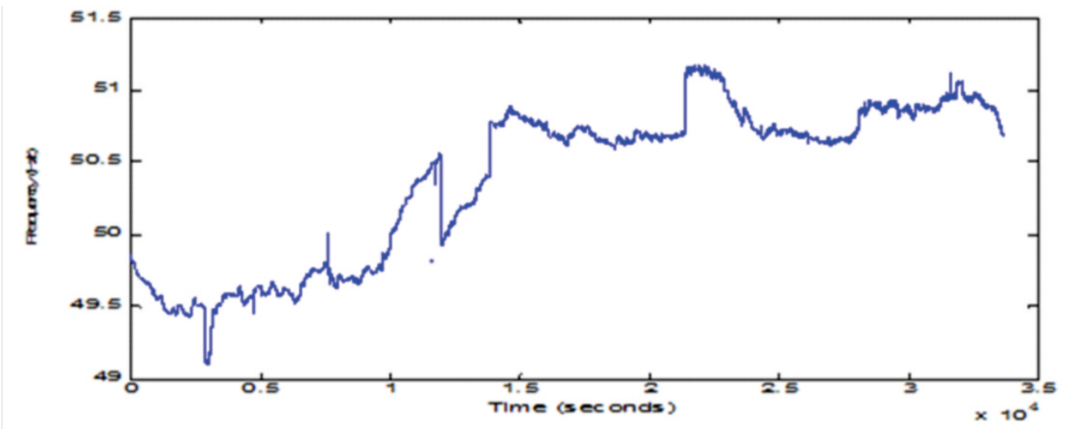


Figure 5: Probability Distribution of the Data

Studies of events of different days reveal that the system frequency doesn't have a definite pattern. This can be seen from the figure 6 a.) And b.)Events of 11th and 12th January, 2016. The frequency is dynamically responding to the rising and falling trend of the load and generation, although it is random but in an increasing pattern.



a.) Frequency record of 11th January, 2016.



Frequency record of 12th January, 2016

Figure 6: Frequency Measurements record of Different Days

Statistical data Analysis and Comparison

The statistical indices of the prolonged measurement taken in 2016 have been computed, table 1 shows the summary of the result and comparison between some selected years and the present for the research to establish whether there is improvement in the control action or not.

Table 1: Comparison Between some Selected year's Measurements and the Present

Statistical Indices	Frequency,2006 (Hz)	Frequency,2007 (Hz)	Frequency, 2011 (Hz)	Frequency, 2016 (Hz)
Min.	49.14	48.91	49.3	48.9948
Max.	51.26	51.28	50.59	51.6482
Mean	50.36	50.28	50.02	50.3429
Median	50.38	50.31	49.96	50.4337
Mode	49.78	49.56	49.81	49.6624
Standard D.	0.269	0.3954	0.1797	0.5402
Range	2.118	2.374	1.288	2.6534

All the previous year's data were captured at Bauchi and was presented by (Kumo, 2012). To this extent, it can be observed that the result of 2016 measurements is worst in terms of control action as compared with that of 2006, 2007, and 2011 with regulation band$Hzf6534.2=\Delta$, $Hzf118.2=\Delta$, $Hzf374.2=\Delta$ and $Hzf2887.1=\Delta$ respectively. The modal frequency which is determine to be the main frequency at which the system mostly operates is outside normal hence the system mostly operates at stress. The mean and the standard deviation are all outside the desired values, while the NCC have tried much in avoiding system collapse (minimum frequency recoded being 48.9948Hz) but considering the maximum value (51.6482Hz) is a hazardous frequency in electronics systems operation.

Conclusion and Recommendations

The analysis of Nigerian power system frequency has been presented in this paper. It has been established that the system mostly operates at serious pressures of stochastic under- and over-frequencies which are both undesirable. When comparing with previous year's assessment, it has been realized that the system frequency control is worse at present. In line with the current system situation, it is recommended that a better control infrastructure, such as frequency relay, used in load shedding should be put in place, for proper control and optimal system utilization. Secondly, the power utility companies should endeavor to establish FNET system as it will provide accurate measurements, thus giving room for further research on the system dynamics and enhance proper monitoring and control. Finally, to overcome the problem of GPS signal lost encountered during the measurement a further research to developed prediction model is hereby recommended, this will also serve as a means of system security to a situation that need urgent attention.

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