DEFORMATION MONITORING AND ANALYSIS OF OSHIE FLOWSTATION SOLAR TURBINE FOUNDATION USING GEOMATIC TECHNIQUE WITHOUT SSI EFFECT

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Abstract: The foundation of gas turbine engines are subject to their severe thermal environment, including thermal gradients, high temperature, vibrations and high speed spinning of the blades. Turbine generator foundations sits on concrete and soil supporting mediums and needs to be monitored. Using surveying technique such as spirit levelling technique the foundation of the oshie flow station gas turbine was investigated for one week with observations taking in the morning and evening times to check the vertical deformation without consideration to the soil structure effects.Free vibration analysis is also performed in order to find the natural frequencies and the corresponding mode shapes in additional to force vibration analysis.

The response was assessed at the Foundation during the operational conditions using Abaqus (v 6.13) program and results of the analysis Showed that the natural frequency of the turbine foundation should be far different from machine operating frequency to avoid resonance, also the response of the system without taking the SSI effect.

Keywords: Deformation, Displacement Turbine, Geomatic, Spirit Leveling

1.0 INTRODUCTION

The monitoring of the deformation of engineering structures is of high priority and importance in ensuring their safety and effective use. The need for such monitoring can be used for the knowledge of the mechanical behaviour of the structure (Ono, M. N., Eteje, S. O., Aghedo, H. O., and Oduyebo, F. O., 2018). Engineering structures such as dams, bridges, viducts, high rise buildings, turbine engine foundations just to mention a few are susceptible to deformations due to environmental factors such as ground water level change, tidal phenomena, tectonic phenomena (Erol et al, 2006) and technical factors such as vibrations.

There are many different types of engineering machines that produce periodic forces as the rotary machine, the impact and the reciprocating machine. The suitability selection of the foundation is depending upon the type of the machine itself, the geometric size and capacity of the machine. The effect of soil on the structure's response becomes of great interest especially for the power plan station (Ali, L. A., Jasim, M.A., and Saba, I. J., 2017).

Usually, the analysis of the turbine generator foundation is considered as very important problem due to the interactions between the machine foundation and the supporting soil medium (Ibrahim, M.A.,2011).

For such machine foundations, the important parameters in designing and analysis are the natural frequency and the amplitudes at the natural operation, and also the safety and stability performance of the machines is depending largely depending on the manufacture, design, and the supporting medium (Tripathy S. and Desai, A. K., 2015). In common design problems of the loading, assuming the buildings to .be as fixed at their basis, but in reality, the soil medium that supporting such buildings allow the movement for some extent due to the ability of the soil to deform; this may lead to change the stiffness for the whole structural system. The interdependent behavior of the structure and soil should be taken into account when design and analysis of the structures especially for heavier structures like turbine power plant station (Ali et al, 2017).

Many researches followed the numerical representation of the behavior and response of the physical problems of machine foundation under the effect of dynamic and static loads. Karthigeyan, V., Prakhya, G. K. V., and Vekaria, K. (2001) Presented a finite element model for steam turbine foundation with tabletop type by a combination of beam and plate elements. Prakash, S., and Puri, V. K. (2006) Discussed the analysis method of determining the response of the machine foundation subjected to vibration loads. Ming F., Tao W. and Hui, L. (2012) investigate the effect of soil-structure interaction (SSI) on the response of the turbine foundation system using the three

dimensional viscous-spring boundary elements with taking the full interaction among the machine, foundation and soil medium. Jayarajan, P., & Kouzer, K. M. (2014) Presented detailed
Procedures to model the turbo-generator foundation by finite element method and performed the dynamic analysis to check
the resonance conditions and ensure that the amplitude is within the accepted limitsTripathy et al, (2015) presented dynamic response analysis of finite element model for turbo generator foundation taking into considering the Winkler spring soil model, solid finite elements and dynamic loading conditions using SAP:2000 17.1 software.

Rahnema, H., Mohasseb, S., and JavidSharifi, B. (2016) were inspected a new approach to suggest the possible solutions of the soil-structure interaction effect.

Ali, et al 2017, investigated the dynamic response of local site condition in Iraq considering and ignoring the influence of soil-structure interaction on the response of gas turbine-generator foundation in additional to the foundation free vibration analysis for Al-Mansuriya station. Abaqus v.6.13 finite element software was used for 3D simulations including the whole project (the foundation and local soil site). Ono, M.N., Agbo, J. A., Ijioma, D. I and Chubado, M., (2014) presented the establishment of baseline data for monitoring of deformation using Global Positioning System to monitor bridge deformation.

1.2 Aim of the Study

The aim of this study is to investigate the dynamic structural response on the foundation vibration of Oshie solar gas turbine ignoring the effect of soil-structure interaction using geomatic technique known as precise spirit levelling method.

1.2.1 Objectives

To achieve the above aim, the following objectives were considered:

i. To investigate the the free vibration analysis in order to get the natural frequency of the foundation.
ii. To investigate the displacement of the solar turbine foundation using geomatic terrestrial precise spirit levelling method of observation
iii. The use of statistical analysis for displacement investigation.

1.3 Study Area

Oshie flow station is powered by a solar gas turbined plant. It is located in Ahoada west local government area of Rivers State in the Niger Delta region of Nigeria. This plant is powered by the gas supply system flowing from the Oshie field operated by NAOC.

1.4.1 Geographical Location

The study area is located between longitudes 6°30’14.91”E and 6°30’ 20.53”E and latitudes 5°06’01.34”N and 5°06’06.15”N. It is (see Figures 1.0 and 1.1).

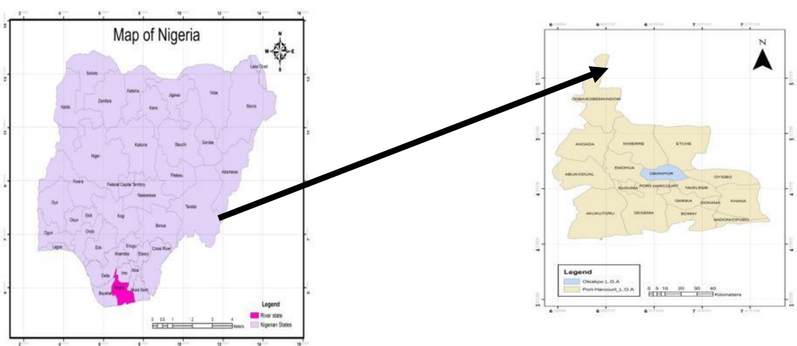

Fig 1.1: google imagery of the flow station

2.0 REVIEW OF DEFORMATION MEASUREMENT IN GEOMATICS

Deformation measurements may consist of different methods; these include structural and geotechnical methods, foundation simulation modelling, terrestrial survey techniques and positioning with space-based systems. The selection of appropriate methods or combination of methods for deformation studies will depend upon the cost, the accuracy required and the scale involved (Wan A., Kamaluddin., Zulkarmin M.A., 2003). Conventional survey techniques involve the measurement of angles, directions, spatial distances and height differences using instrumentations and measurement methods adapted from traditional geodetic practice e.g. digital theodolites, precise levels, etc deformation surveys by space-based technique includes Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR) and the Global

Positioning System (GPS). Of these, GPS offers a great advantage in terms of productivity and is the most cost-effective (Wan et al, 2003).

In this study to investigate the possible deformation on the turbine foundation, the geodetic observation using precise spirit levelling terrestrial method was used at different epochs of time. The measurement epochs of the vertical displacement are adjusted independently and the estimation of the deformation is done by calculating the vertical difference between epochs. The first epoch is considered as the initial measurement.The scheduling of measurements, the required accuracy and the identification of the location of control points should take into account the existing geotechnical (or others) designs, that define or anticipate the size, the velocity and the recursiveness of displacement as well as any other associated data. This paper highlights the performance of geomatic technique which is the conventional geodetic survey method using precise spirit levelling for the Oshie flow station solar turbine foundation.

2.1 DEFORMATION MONITORING NETWORK:

To monitor ground displacements, it is imposed to represent the area under investigation by a number of points that are durably monumented. These points are the stations of a geodetic control network. Usually, two categories of stations must be included in the network: the reference stations (reference network), which are located in geologically stable areas and the control or monitoring stations (relative network), which are located within the limits of the deformed part of the ground or the construction itself. In this way, the determination of the movement of the structure under investigation is measured relative to the reference ones. Depending on their area covered, deformation network may categorize as being of a local, regional, national or global extent. Commonly, the establishment of deformation network involves: network design, the field work campaign, and network analysis. The design answers the question of where the network points should be measured in order to achieve the required network quality.Network geometry is an important aspect that has to be considered in order to achieve accurate conventional survey results (Wan et al, 2003).

3.0 METHOD OF INVESTIGATION

The method of investigation used for this study is the geomatics precise spirit levelling technique and finite element model ignoring soil structure interaction.

3.1 Geodetic Precise Spirit Level method:

Which deals with the determination of the relative heights or elevation of points or objects with the measurement of the verticality of the object? With the use of the precise spirit levelling instrument and the level staff the displacement in terms of the elevation on the foundation is determined.

In this method the datum station was selected to serve as a reference to the measurements to be taken. Ten points were selected on the foundations of the turbines and levelling observations were taking on them. The spirit level furnishes a horizontal line of sight, and levelling staff is used to determine the vertical displacement of the points below the horizontal line (Kanetkar, T. P., and Kulkarni, S. V., 2017). A morning and evening observation and measurement was made on the same points for seven days and the measurements were subjected to statistical analysis to determine the mean estimate of each point.

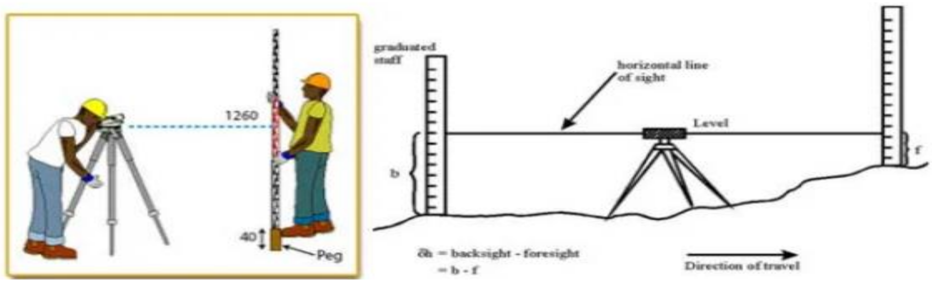

Figure 2.0 showing spirit levelling setup. Source: Kanetkar, T. P., and Kulkarni, S. V., 2017.

3.2 Finite Element Model method:

In the case of ignoring the effect of soil structure interaction, RC turbine-generator foundation was modeled using same model adopted by Ali, et al 2017, using Abaqus v.6.13 finite element software It is a software application used for both the modelling and analysis of mechanical components and assemblies (pre-processing) and visualizing the finite element analysis result; using the quadratic elements and replacing the soil mass in the system by linear distributed springs in vertical and horizontal directions as shown in Fig.3. The springs were attached to the foundation at each node where the soil should be considered. The springs coefficients were calculated based on (Whitman and Richard 1967).

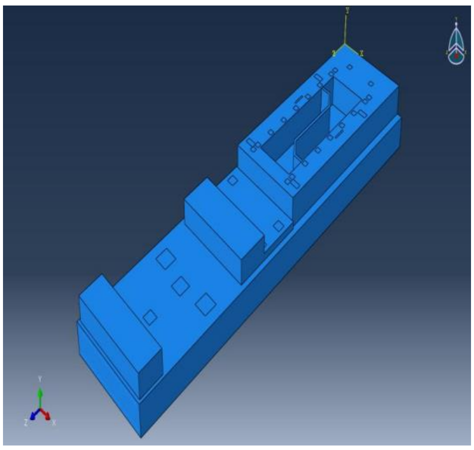

Figure 2.0: Pictural Isometric view of the turbine foundation Source: Ali, et al 2017 and Abaqus v.6.13 software.

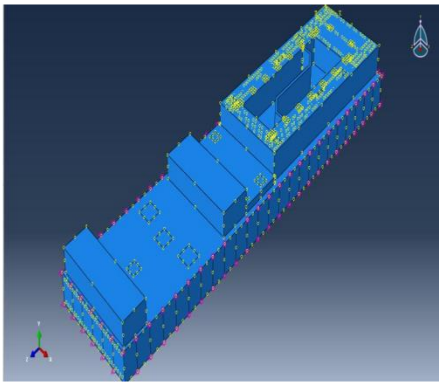

Figure 3: Finite Element model without Soil Structure interaction. Source: Ali, et al 2017 and Abaqus v.6.13 software.

4.0 DATA ANALYSIS, RESULTS AND DISCUSSIONS

The data analysis and results of this study is divided into two stages: finite element model and vertical displacement estimate using statistical analysis. The stages mentioned above area discussed in the following sections:

4.1 Finite Element model without Soil Structure interaction:

In this method a simulation model of the turbine displacement is created and subjected toa time series analysis at various frequencies without considering the effect of soil structure interaction.A free vibration analysis was performed in the absence of the external forces and any other motions. This is performed in order to get the natural frequencies of the system and describing the principle behavior of the system.

The figures below summarize the structure frequency corresponding to each mode shape. The first mode shapes showed the foundation with vertical bending along Y-axis at frequency 26.065 Hz, while the second and third mode shape showed the torsion around the Z-direction at frequency equal to 32.625 Hz and 36.228 Hz respectively. The fourth mode shape showed the vertical movement of the foundation along Y- direction while the last two mode-shapes have a bending and torsional behavior as shown in Fig (4) and Table 1.

Table 1: FEM Free vibration analysis results

Mode No.	Frequency (cycle/sec)	Frequency (rad/sec)	Period T(sec)	Symmetrical/ Unsymmetrical.	Description
1	26.065	163.77	0.0384	Symt. z-axis	Vertical bending
2	32.625	204.99	0.0306	Symt. z-axis	Bending +torsion
3	36.228	227.63	0.0276	unsym.	Bending + torsion
4	36.551	299.66	0.0274	symt. z-axis	Vertical bending 2 waves
5	42.054	264.23	0.0237	unsym.	Bending +torsion
6	44.985	282.65	0.0222	symt. z-axis	Bending +torsion

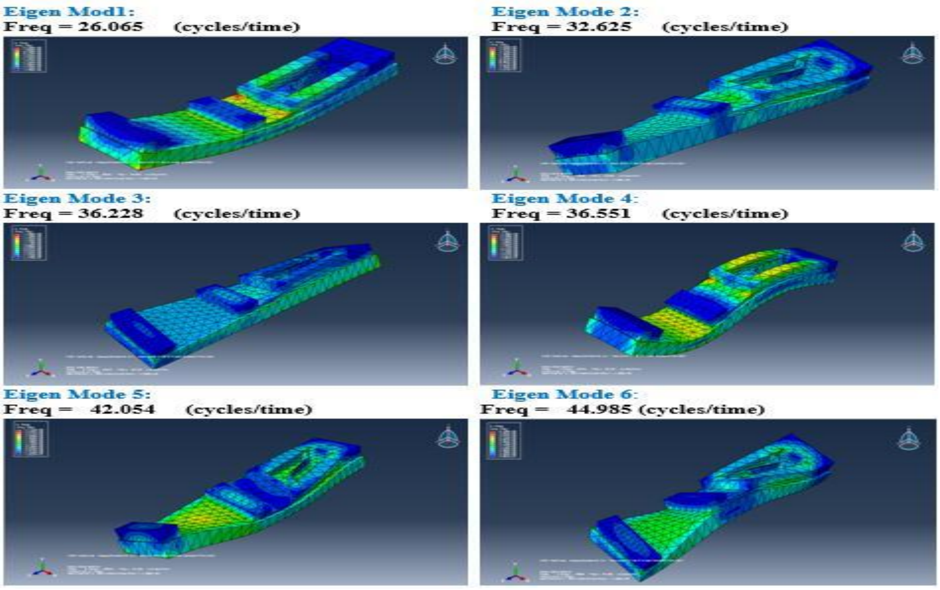

Figure 4: Mode shapes of the turbine-generator foundation. Source: Ali, et al 2017 and Abaqus v.6.13 software.

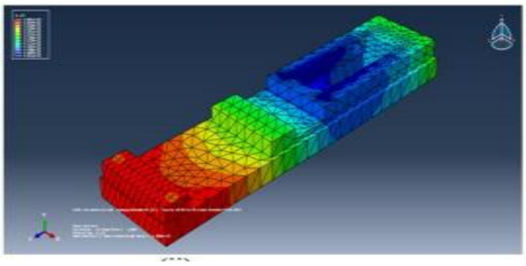

Figure 5: Vertical displacements of foundation and soil without soil structure interaction consideration Source: Ali, et al 2017 and Abaqus v.6.13 software.

4.2 vertical displacement estimate using statistical analysis:

The conventional vertical deformation statistical analysis method was applied to all the data sets obtained from each of the turbine foundation using the spirit levelling derived height differences. And the results that obtained from evaluating these data sets are shown in the graphics (see Figure 6, and Figure 7)

OBSERVED POINTS	DAY1(28/06/09)	DAY2(29/06/09)	DAY3(30/06/09)	DAY4(01/07/09)	DAY5(02/07/09)	DAY6(03/07/09)	DAY7(04/07/09)
A1	27.3330	27.3354	27.3339	27.3323	27.3333	27.3331	27.3300
A2	27.3373	27.3364	27.3309	27.3369	27.3381	27.3375	27.3369
A3	27.3355	27.3357	27.3307	27.3349	27.3359	27.3345	27.3352
A4	27.3328	27.3323	27.3274	27.3319	27.3322	27.3309	27.3313
A5	27.3367	27.3362	27.3312	27.3367	27.3368	27.3361	27.3357
A6	27.3353	27.3370	27.3366	27.3369	27.3369	27.3365	27.3362
A7	27.3311	27.3300	27.3299	27.3304	27.3307	27.3284	27.3299
A8	27.3335	27.3345	27.3323	27.3329	27.3322	27.3322	27.3356
A9	27.3342	27.3326	27.3324	27.3327	27.3334	27.3319	27.3316
A10	27.3346	27.3346	27.3341	27.3346	27.3342	27.3342	27.3345

Figure 6: Spirit level mean data elevations for turbine generator foundation after 7 days observation. Source: Eke S.N,2020

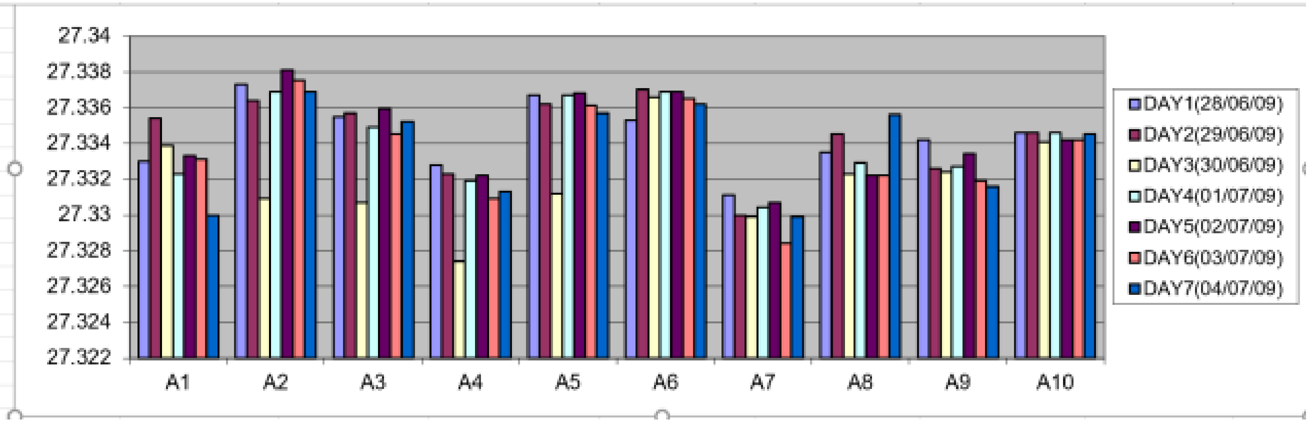

Figure 7: Model shapes of the turbine-generator foundation vertical displacement variability for seven days. Source: Eke S.N, 2020

In the graphics, height changes according to consecutive measurement campaigns are seen.

5.0 CONCLUSIONS

In this study the investigation of the dynamic structural response on the foundation vibration of Oshie solar gas turbine ignoring the effect of soil-structure interaction using geomatic technique known as precise spirit levelling method have been carried out with different operating frequencies. Furthermore, the FEM free vibration analysis was performed to determine the fundamental natural frequency and the model shapes of the foundation. As such the following conclusion is drawn:

Software can be used to perform and model deformation of foundation of solar turbine-generator foundation in order to get the natural frequencies of the system and describing the principle behavior of the displacement of the system.

The use of geodetic spirit leveling method of displacement to investigate solar turbine-generator foundation can be possible. According to investigation of the result of the second evaluation, it was seen that changes in heights of some points on the foundation over different epoch. However, while the soil interaction is not considered, it is understood that these changes, seemed to be deformations on the object points on the foundation according to statistical results of the displacements occurring on the points of investigation.

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