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Abstract

This paper presents the results of vibration acceleration measurements of building structures as a result of equipment operation in NPP powerhouse hall.

Acceleration measurements were carried out at foundation column support or at different points of turbine foundation plate by means of three-dimensional accelerometer and RefTek 130 recorder.

As a result of these measurements the spectrograms used for steady-state response visualization of building structures were obtained, harmonics were identified and maps of harmonic source location as well as vibration level range were compiled.

Assessment of measurements conducted has shown the followings: spectral distribution of responses changes with time in a minor way, which means steady-state effect caused by vibration sources. Many of harmonics were recorded at each response; these were identified by means of suggested automatic search algorithm. The overall picture of identified harmonics shows clearly harmonic frequencies from 25 to 225 Hz at turbine vibration frequency of 25 Hz.

Keywords (separated by '-'): Vvibration assessment - Nuclear power plant - Harmonics identification - Spectrogram - Acceleration deviation maps

Chapter 34
Vibration Level Assessment of Nuclear Power Plant Powerhouse Hall

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Keywords Vvibration assessment • Nuclear power plant • Harmonics identification • Spectrogram • Acceleration deviation maps

34.1 Introduction

This paper presents the results of vibration acceleration measurements of building structures as a result of equipment operation in NPP powerhouse hall of Balakovo Nuclear Power Plant (Russia).

The following tasks were completed in this study:

1. Oscillation's acceleration of bearing columns made of steel was measured at the bottom level of machinery plant.
2. Oscillation's acceleration was measured at different points of turbo-generator foundation plate.
3. Spectrograms were obtained to visualize the response of the structure.
4. Harmonic oscillations were identified and the harmonic diagram was obtained.
5. The maps of oscillation range and the sources of harmonic were obtained.

34.2 The Equipment of Powerhouse Hall

Powerhouse hall is constructed like a steel rack consisting of three parts: powerhouse hall, deaerator shop and pipeline service shop. The dimensions of the powerhouse hall are the following: 127×45 m; the bottom of the roof truss is marked at the level of +35, 50 m. A turbine-generator set and additional equipment are located in powerhouse hall. The deaerator shop is placed along the powerhouse hall and has the following dimensions: 127×12 m; the bottom of the roof truss is marked at the level of +42,00 m.

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34.3 Measurement Points of Oscillation Acceleration

Measurements of oscillation acceleration were carried out by means of tri-axis accelerometer produced by the company RefTek 131B-01/3 [1]. Signal recording was done by 6-channel seismic recorder RefTek 130-01. The sampling frequency was 500 Hz. In the Fig. 34.1 are shown the points of measurement carried out at the bottom of the columns of powerhouse hall.

For each point observed the measurements of oscillation acceleration were carried out as orthogonal triaxial oriented (three measuring point) or as uniaxial measurements (one measuring point). At the same time oscillation acceleration were measured at two points on the foundation plate of turbine. Acceleration sensors were rigid located to the columns by means of a screw-clamp and through embedded parts to the foundation plate.

34.4 Measurement Analysis Methods

A block diagram in the Fig. 34.2 presents the procedure applied for analysis of measurements results. Signals, recorded by sensors, were cleared of a drift. Afterwards a selection was carried out of the data files obtained for each sensor for further processing.

Vibrations, recorded by each sensor, is a total vibrations induced by different oscillation sources, which behavior can be permanent, alternating or impulse. As a result some alternating or impulsive points of structure oscillations may occur. The following methods were used to take into consideration exposures mentioned above:

1. To obtain spectral-response characteristics Fourier transformation were applied [2].
2. To visualize stationary of an oscillation development a spectral recording was carried out.
3. To identify harmonics of signals the harmonic identification method was used [3].
4. To visualize images formed by different criteria the maps of distribution for calculated criteria in plan of powerhouse hall were used.

The current vibration level was estimated by means of criteria distribution map. By criterion should be understood to mean some test feature – in this paper it is oscillation amplitude or location of sources of harmonic oscillations.

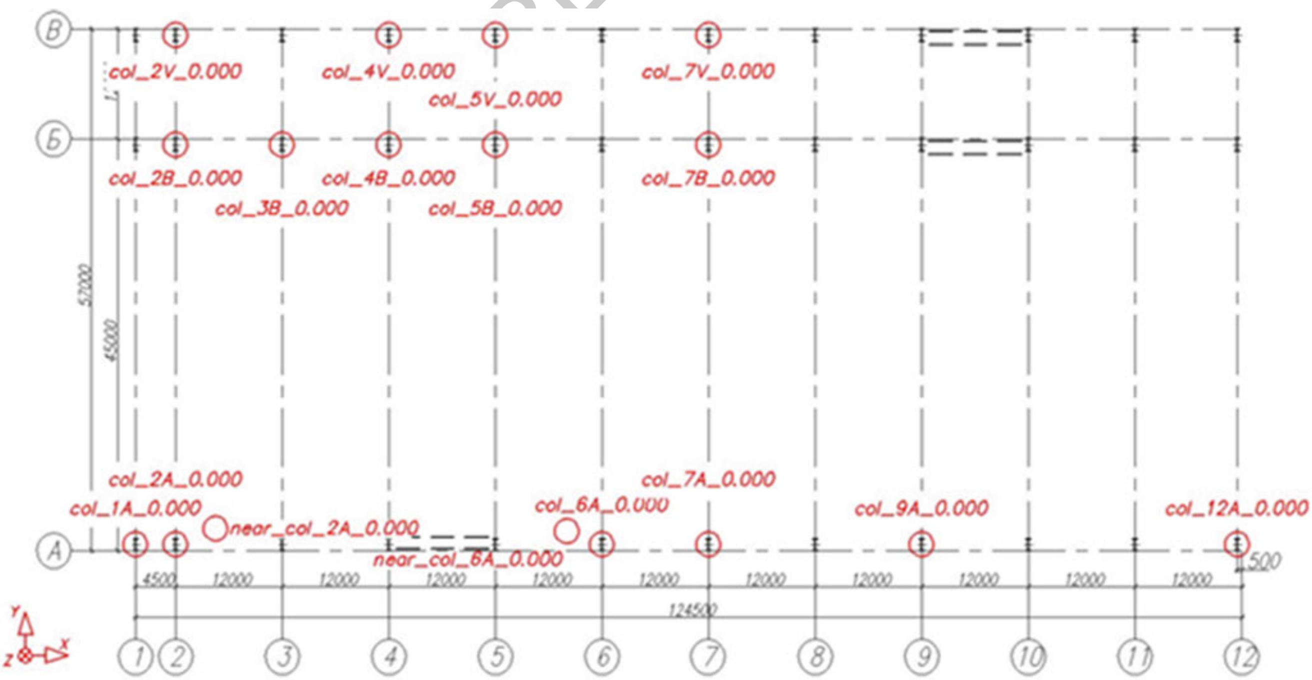


Fig. 34.1 Plan of measurement point location

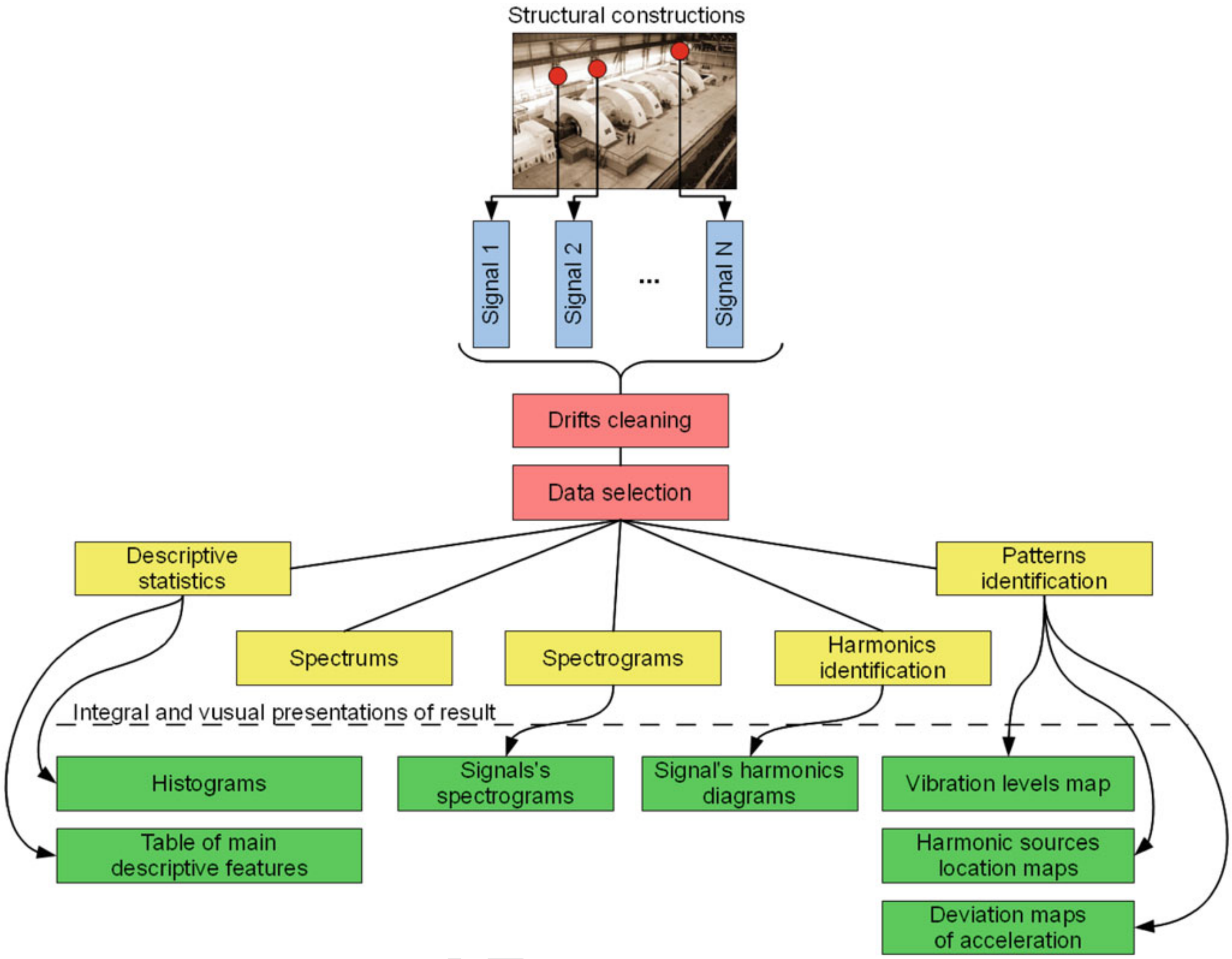


Fig. 34.2 Diagram of measurement data analysis

34.5 Calculation of Spectral Frequency-Time Characteristics

It is necessary to obtain sufficient volume of data in order to identify the most harmonics. In case spectral distribution changes in a minor way over period of time, it is sufficient to obtain a small amount of data to analyze harmonic. Otherwise this amount of data should be enlarged according to changes in spectral distribution over a period of time.

Convenient tool to visualize changes of spectral distribution over a period of time is spectrogram. Spectrogram is a time-varying spectral representation that shows how the spectral density of a signal varies with time. Spectrograms presented in this paper were obtained my means of STFT method [2].

In the Fig. 34.3 it is shown an example of a typical spectrogram, which was drown for a period of 163.4 c (ten data series constructed due to 8,192 points at the report rate of 500 Hz) for the column : col-2V-0.000-Ch1 (Fig. 34.1). All amplitudes of spectrogram were normalized through division into maximum value in order to obtain maximum amplitude, which equals to 1.

Data are noisy, but pulse-spike amplitudes could be seen at the frequencies of 25 Hz, 50 Hz and which are close to 50 Hz. Spectral division changes in a minor way.

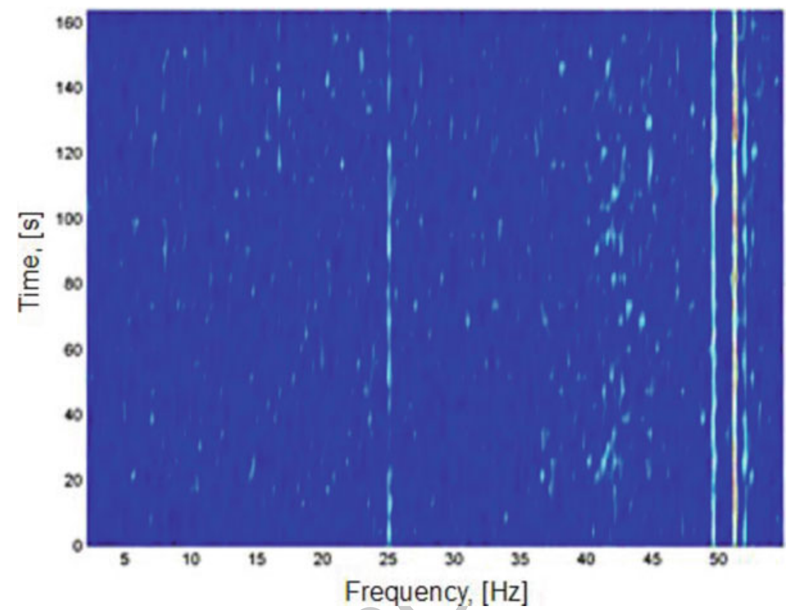


Fig. 34.3 Typical spectrogram of structure response

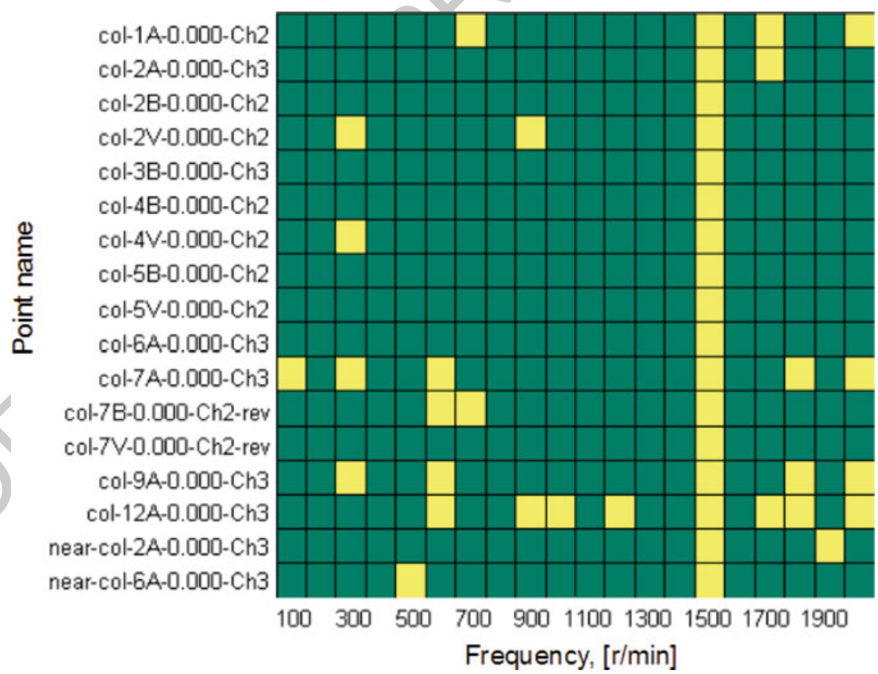
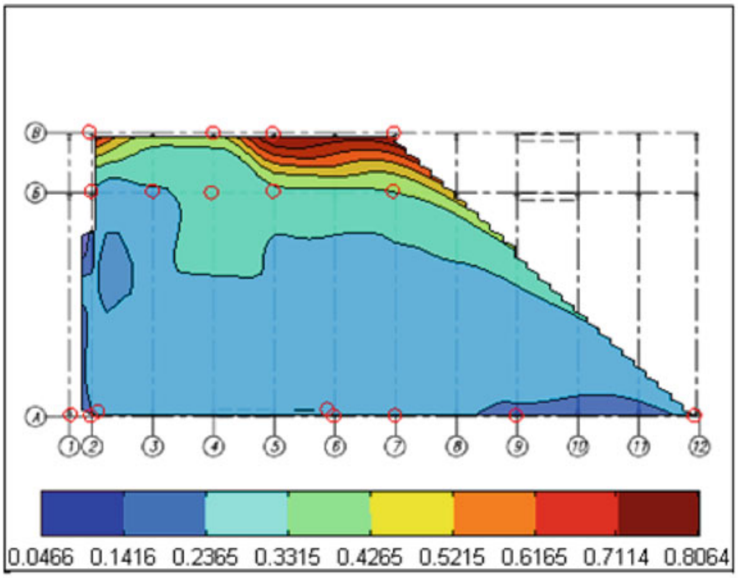


Fig. 34.4 Frequencies of harmonic vibration sources identified along the axis X

34.6 Harmonic Identification Results

A method of procedure for harmonic identification was developed by the authors and applied for all responses of this structure. Five accesses each consisting out of 4,096 data were carried out for each point to identify harmonics. To make data submission more convenient the harmonics identified as to each response were aggregated with an accuracy of 100 r/min (1.67 Hz). The cumulative diagram of the harmonics identified for all observed points is presented in the Fig. 34.4, where an occurrence of a harmonic for the frequency specified is drown in white. In the Fig. 34.4 we can see for the majority of signals well-defined harmonics at the frequency of 25 Hz, which are a multiple of 25–50, 75, 100, 125, 150, 175, 200, and 225 Hz. It is probably due to the following fact: the turbine, which rotation frequency is 25 Hz, is based on a plate and supplies vibrations to all structures nearby the turbine plate.

The composition of harmonic vibration sources of powerhouse hall is well known. However by means of the method introduced were identified the vibration sources with the rotation frequencies given in Fig. 34.4.



Point name	Accel [m/s^2]
col-1A-0.000-Ch2	0.0539
col-2A-0.000-Ch3	0.0699
col-2B-0.000-Ch2	0.1637
col-2V-0.000-Ch2	0.7608
col-3B-0.000-Ch3	0.1463
col-4B-0.000-Ch2	0.2167
col-4V-0.000-Ch2	0.3627
col-5B-0.000-Ch2	0.2360
col-5V-0.000-Ch2	0.7602
col-6A-0.000-Ch3	0.0934
col-7A-0.000-Ch3	0.0918
col-7B-0.000-Ch2-rev	0.2571
col-7V-0.000-Ch2-rev	0.8064
col-9A-0.000-Ch3	0.0466
col-12A-0.000-Ch3	0.0922
near-col-2A-0.000-Ch3	0.0763
near-col-6A-0.000-Ch3	0.0666

Fig. 34.5 Deviation map of column acceleration identified along the axis X

As it is seen in the Fig. 34.4 the most common sources with the rotation frequencies of 600 r/min is appearing four times, whereas the frequency of 1,500 r/min (25 Hz, turbine and possibly other sources) is appearing in all cases except of two signals and the frequency of 1,800 r/min (930 Hz) – is presented three times. An example of the harmonic sources location map with corresponding rotation frequencies is shown below in the Fig. 34.7.

34.7 Acceleration Deviation Maps

As far as the response division was close to normal, the most appropriate measure of deviation can be triplicate rate of standard deviation value σ. This deviation value guarantees that the data obtained will be within the range $[\overline{x} - 3\sigma; \overline{x} + 3\sigma]$ ($\overline{x}$ -standard deviation) with a probability of 99.7%.

Acceleration deviation maps were made separately for each direction of measurements, one of these is shown in the Fig. 34.5, were the acceleration deviation is presented leftwards and the corresponding vector of information is given in the table rightwards. The analysis has shown that the largest acceleration deviations correspond to points of column oscillations induced in lateral direction. The largest deviation along the X-axis is 0.8064 m/s^2 (col-7V-0.000-Ch2-rev), along the Y-axis – 1.4033 m/s^2 (col-5V-0.000-Ch3), along the Z-axis – 0.2038 m/s^2 (col-5V-0.000-Ch1).

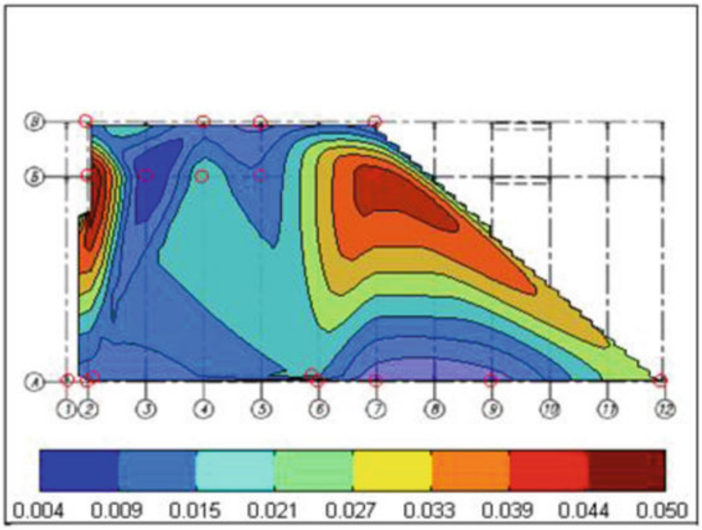
34.8 Acceleration Amplitude Maps

The maps of acceleration amplitude were made for frequencies, where the largest amplitudes of acceleration were identified: 25, 50 Hz. An example of acceleration amplitude map at the frequency of 25 Hz is shown in Fig. 34.6.

The largest acceleration amplitude along the X-axis is 0.0503 m/s^2 (col-2B-0.000-Ch2), along the Y-axis – 0.0173 m/s^2 (col-7A-0.000-Ch2), along the Z-axis – 0.0299 m/s^2 (near-col-2A-0.000-Ch2).

For vertical oscillations at the frequency of 25 Hz it is established that the amplitude for column points of turbine service plate near-col-6A-0.000-Ch2 near-col-2A-0.000-Ch2 is well above then for the columns of transverse frame of powerhouse hall. This probably related to the fact that these points are located on the columns, which are more closely connected to load-bearing elements of turbine.

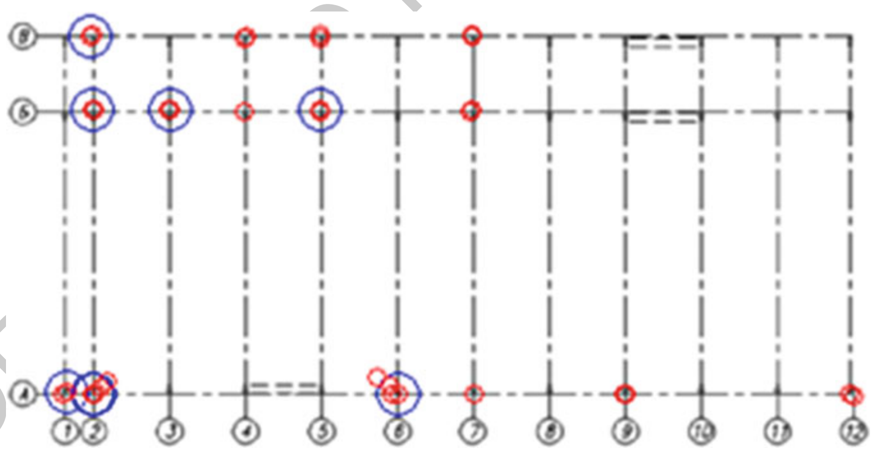
For the frequency of 50 Hz the largest acceleration amplitude along the X-axis is 0.0094 m/s^2 (col-7V-0.000-Ch2-rev), along the Y-axis – 0.0094 m/s^2 (col-6A-0.000-Ch2), along the Z-axis – 0.0081 m/s^2 (near-col-6A-0.000-Ch2).



Point name	Accel [m/s^2]
col-1A-0.000-Ch2	0.0036
col-2A-0.000-Ch3	0.0114
col-2B-0.000-Ch2	0.0503
col-2V-0.000-Ch2	0.0087
col-3B-0.000-Ch3	0.0051
col-4B-0.000-Ch2	0.0223
col-4V-0.000-Ch2	0.0113
col-5B-0.000-Ch2	0.0151
col-5V-0.000-Ch2	0.0065
col-6A-0.000-Ch3	0.0113
col-7A-0.000-Ch3	0.0059
col-7B-0.000-Ch2-rev	0.0417
col-7V-0.000-Ch2-rev	0.0050
col-9A-0.000-Ch3	0.0067
col-12A-0.000-Ch3	0.0270
near-col-2A-0.000-Ch3	0.0125
near-col-6A-0.000-Ch3	0.0201

Fig. 34.6 The amplitude map of column acceleration measured along the X axis

Fig. 34.7 Harmonic sources location map at the frequency 10 Hz



34.9 Harmonic Sources Location Maps

Harmonic sources location maps were made for the mostly well-defined frequencies: 10 Hz (600 r/min); 25 Hz(1,500 r/min); 30 Hz (1,800 r/min). In Fig. 34.7 the measurement points are shown in bold, whereas locations of harmonic oscillations are circled. Sources were identified according to the measurement data obtained unidirectional.

The affecting frequency of 10 Hz (1,500 r/min) were identified in each measurement points, which probably means that turbine affects all the structures. For the frequencies of 15 Hz (600 r/min) and 30 Hz (1,800 r/min) the sources were identified only for some measurement points, this implies that the harmonic sources with the frequencies given are located locally.

34.10 Conclusions

Joint accelerations of columns and turbine plate were measured in this paper. For most of structure points oscillations are induced by different sources of exposure and dominant harmonics were fixed only for some directions of measurement points.

Maximum of accelerations (triplicate standard deviation) were identified for col-5V-0.000-Ch3 and col-7V-0.000-Ch3-rev (acceleration along the Y-axis) at the rate of 1.4 and 1.14 m/s^2.

Spectral distribution of responses changes slightly over period of time; this implies that the impact of vibration sources is of stationary nature.

Multiple harmonics were fixed in each response and identified by means of suggested method of harmonics automated search. When analyzing the overall picture of harmonic identification, harmonic frequencies of 5, 10, 25, 30, 33 Hz are well defined.

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References

1. http://reftek.com/products/index.htm
2. Oppenheim AV, Schafer RW, Buck JR (1999) Discrete-time signal processing. Prentice Hall, Upper Saddle River, 870 p
3. Andersen P, Brincker R, Ventura C, Cantieni R (2008) Modal estimation of civil structures subject to ambient and harmonic excitation. In: Proceedings of the 26th international modal analysis conference (IMAC), Orlando, 8 p

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