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EXTENDED ABSTRACTS

Damage Detection in Bolted Connections of Power Transmission Towers Using Machine Learning-Based Methods (Bagging Trees)

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1. Introduction

There have been many studies regarding the health monitoring and detection of transmission towers, among which we can refer to the article by Yen et al. in 2009, who investigated damage detection in transmission towers with a limited number of sensors those modal parameters were obtained from the measured environmental vibration data. In their research, mode shape and frequency were used to identify the system. Also, stiffness reduction was also suggested to damage detection. Structural health monitoring by using features such as natural frequencies and mode shapes has attracted the attention of a number of researchers. Damage detection in power transmission towers using these features and using soft computing methods was also considered by Skarbek et al. in 2014. They have investigated frequency damage indicators by simple processing and using neural network for power transmission tower. In 2019, Zhao et al obtained the natural frequency of the 110 kV power transmission tower using the sub-random space method and found that the detected natural frequency is dependent on the wind speed. However, the current article tries to damage detection in the connections due to the lack of access to real data and experimental data and based on numerical modeling of a limited number of possible damages that occurred in the legs of the splice connection of power transmission tower.

Fig. 1. Thefting the bolts of the connected members in the leg of the power transmission towers

One of the most frequent causes of damage on lattice towers is theft. (Fig. 1). The important point is that due to the difficulty of accessing the upper levels of the lattice towers and also the heavier members used in the lower part of the towers (The members of the lower part have larger lengths due to geometry and have a higher cross-sectional area due to structural reasons), the rate of thefting is much higher in the lower members. Therefore, it is necessary to use a method that can determine any damage in members or damage in connections before it leads to irrecoverable damage. In this regard, this article tries to determine the

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location and severity of damage in the connections of this type of structures by providing a method based on changes in the modal parameters of the structure, such as changing the frequency characteristics and mode shapes.

2. Methodology

During this research, based on the specifications of a real case, a power transmission tower was modeled in SAP2000 software, and then it was subjected to environmental stimulation, and for the final purpose of this research, which is to identify the damage in splice connections, the connections of this structure was modeled in a 9-meter range in IDEASTATICA software. The stiffness analysis was done on the connections, and then used the results to specify set of damages in connection at model in SAP2000 software. The response acceleration time history at level of tower's Leg level were used for structure's feature extraction. Then using features such as natural frequencies and mode shapes (first 5 modes) were used to create datasets to complete the damage identification process. An available Ensemble Method in Classification Learner App Matlab was used to process different dataset and identify damage at connectins. The process of identifying different damages was done in two stages: (1) detection of damage in various connections of each leg within 9 meters of the entire tower (legs) and (2) detection of different damages in connection bolts whose damage was detected in the previous stage.

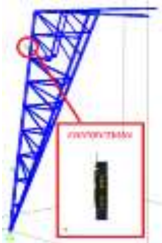
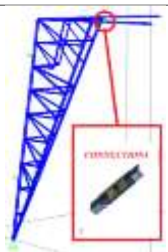
Connection 1	
Connection 2&3	
Connection 4	
Connection 5	

Fig. 2. Showing the different connection locations of a legs of the laticce towers

The whole process that was carried out in this article is shown in Fig. 3.

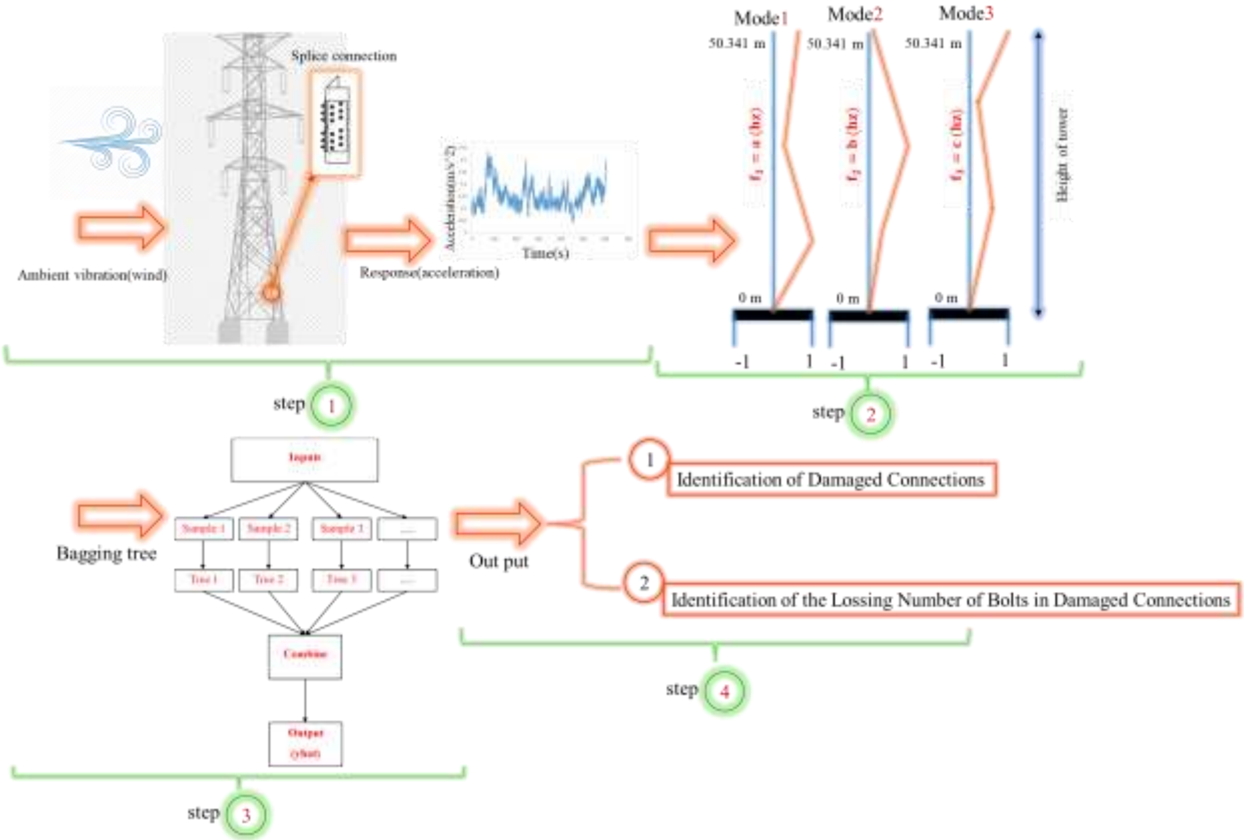


Fig. 3. Flowchart of damage detection on this article

4. Conclusions

As mentioned above, after the implementation of all planned damage scenarios according to the results obtained from IDEASTATICA and SAP2000 software, to advance the goals of structural health monitoring, we tried to collect data for damage identification operations. During this operation, the acceleration data of each of the damage scenarios implemented in 4 points of the examined range in all 4 legs. Then we tried to extract the sensitive features to damage. For this purpose, we used parameters such as natural frequency and mode shapes. The collected dataset was used as an input during the classification process and labeled according to each damage scenario. The following results were obtained:

- ✓ The influence of various damages in the mode shapes is more than the natural frequencies.
- ✓ The severity of the changes in the mode shapes that are affected by the reduction in the number of different bolts in the same type of damages (for example, damage scenarios of group A that only reduce the number of different bolts in one connection) , is more intense and tangible than the case where different types of damage are the same with the reduction of the number of bolts (for example, damage scenarios of A_2 and B_2 types that have the same number of bolts reduced (reduce 2 bolts) but the number connections that have reduced bolt are different (A: damage in one connection out of five connections in one leg, B: damage in one connection out of five connections in one leg)).
- ✓ In all four legs, damage detection using information from 4 sensors is more accurate.
- ✓ Damage detection with one sensor located on the leg under investigation provides better results than other situations where there is only one sensor. It is necessary to explain that we divided the available data into training and testing data (with a ratio of 70 to 30).
- ✓ In the general comparison between different damage scenarios in this research, the scenarios that had similar types of reduce the bolt showed more sensitivity to damage than the damage scenarios that included different types of different reduce the bolt. However, it is necessary to explain that with the increase in the number of damaged bolts, the sensitivity to damage increases in all scenarios.

5. References

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