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Interactive comment on "Establishing a robust testing approach for displacement measurement on a rotating horizontal axis wind turbine" *by* Nadia Najafi and Allan Vesth

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Interactive comment on "Establishing a robust testing approach for displacement measurement on a rotating horizontal axis wind turbine" by Nadia Najafi and Allan Vesth Anonymous Referee #3 Received and published: 4 January 2018

General Comments This work aims at developing a new 3D photogrammetric calibration technique which can be used for infield vibration tests on utility-scale horizontal axis wind turbines. For this purpose some dynamic experiments and measurements are conducted on a small scale wind turbine model in the lab. Regarding the content, the methods described in the article can be very useful for the lab tests but unfortu-

nately they are not applicable to the infield tests efficiently as claimed. Therefore, the paper needs significant major revisions in order to show that the proposed system can also be used in the field. Below you can see my recommendations

RESPONSE: Thank you for reconsidering the paper and constructive comments. In the following I tried to be precise in answering and satisfying the points.

* All the commentsare applied to the marked document that has been attached to the supplement.

** Allthe page numbers, reported in the answers, are based on the marked document that has been attached to the supplement.

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COMMENT 1: The term photometry is mis-used in the text. I think this word should be corrected as photogrammetry. Photometry: The science of measurement of visible light in terms of its perceived brightness to human vision. Photogrammetry: Determination of the 3D coordinates of the points on an object by using 2D images taken from different locations and orientations.

RESPONSE: The comment is absolutely true. I replaced photometry with photogrammetry in the whole document.

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COMMENT 2: Photogrammetry can be easily used in small scale lab measurements performed in the controllable environments but infield tests have their own specific problems. For example, the authors mention about the accuracy of the device they used (Leica Nova MS50). The proposed accuracy is 0.035 mm in x and y directions and 1mm in z direction. However, this accuracy can never be reached in the field. It is not related to the accuracy of the device. In the field, the target will never be at standstill, it will be vibrating continuously. Even at low wind speeds the vibration amplitude can be +/- 10- 20 cm. Besides, due to the mean wind speed, this vibration

will not be a zero average vibration. How can you claim that you will reach 1 mm accuracy if the target itself is vibrating +/- 10-20 cm.

RESPONSE: I totally agree that the experiment in the field is much more challenging thaen the experiment in the lab and one of the challenges will be definitely the vibrations during the calibration. Therefore the turbine vibrations should be considered during the calibration process and also uncertainty analysis. It could be suggested that the calibration is to be done in a calm weather condition with low wind to minimize the inaccuracies due to the wind induced vibrations. However the Leica Nova MS50 coordinate measurement is based on wave form digitizing technology (WFD) that is able to send out the short pulses with a frequency of up to 2 MHz toward the target [1] and it enables the Leica Nova MS50 to capture even very fast vibrations while the most dominant natural frequencies of the large wind turbines barley exceed 10 Hz. To notify the challenges that need to be considered in the field measurement, more explanation has been added to page 15 that provides information in paragraphs 3 and 4.

[1] Maar, H., Zogg, H. M. (2014): WFD – Wave Form Digitizer Technology Leica Geosystems AG Heerbrugg, Switzerland

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COMMENT 3: Leica Nova MS50 or similar total stations can only take measurement at one point at a time and then they move to the next data point. Therefore, it takes quite a lot of time to take measurements on 35 reference points. Could you please make an estimation related to time required to take measurements at 35 or maybe 100+ reference points? How can you guarantee that the wind speed so the vibration will not change within this period? Regarding the personal experience about Leica Nova MS50 coordinate measurement in the field, it takes less than 2 hours for the device to pick the coordinates of 100+ reference points.

RESPONSE: The changes of vibration and wind speed should be considered during the calibration, as you noted. This issue could be addressed with synchronizing the im-

age acquisition system and Leica Leica surveillance device during camera calibration. This point is also mentioned in the added information about experiment in the field in page 14.

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COMMENT 4: During the calibration at the site, how are you going to rotate the blades manually by a specific angle step by step? How are you going to move the device from one point to another and how are you going to guarantee that the physical conditions, blade pitch angle or yaw angle or wind speed (so the amplitude of the vibration) will be constant. These conditions can easily be fulfilled in a lab environment but not at the field. Under these circumstances bundle adjustment method is the only possibility because you take measurements at all the points simultaneously. The method you proposed may provide a higher accuracy in lab environment where calibration is performed in an isolated room where there is no wind but not in the field where there is always some sort of wind and noisy vibration.

RESPONSE: They are fair points and should be considered during full scale experiment. During the camera calibration in the field, we should break the turbine and then release the break shortly until it reaches the expected position. The pitch and yaw angles could also be locked within the calibration and the vibration amplitude and wind speed change can be addressed using the Leica surveillance device and camera synchronization.

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COMMENT 5: The extrinsic calibration values are valid only for a certain yaw and pitch angle. During the rotation these values do change continuously, and then you will have to recalibrate the system by using the new values. Are you planning to stop the turbine and to take some new calibration measurements with Leica system? You should explain in more detail how this method will be applied to the in-field tests?

RESPONSE: The calibration method that is proposed in this paper is a 3D calibration due to the 3D distribution of the points on the rotor, nacelle and turbine tower. Therefore if the turbine yaws or the blades pitch within a reasonable range, the calibration is still valid for the measurement and there is no need for recalibration. However I absolutely agree that a comprehensive study should be done on the range where camera calibration is valid in the filed measurement.

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COMMENT 6: Illumination is always the most important problem. That is why the markers you propose can only be used for close range of photogrammetry. For long range measurements, using reflective markers is the only choiceto reach the sufficient contrast levels. In the text page 14 line 20 you wrote that matt markers should be used. This suggestion makes the situation even worse, for long range measurements the markers should be as bright as possible to increase the contrast, otherwise the markers cannot be seen from long distances.

RESPONSE: Illumination and reflection are one of the main challenges in photogrammetry, as you mentioned. Using reflective markers is associated with some problems such as not enough contrast with the background during the day time, providing sufficient illumination for the markers on large structures, significant changes of reflection angles and reflection quality during turbine operation and also miscalculation of the rotational plan that cause systematic errors during the measurement. Non-reflective, black and white markers have been already used for displacement measurements on large structures such as bridges [1,2,3] that proves that optical long range measurements are possible using non-reflective markers and with choosing the proper size and shape for the markers. In addition they do not need extra light sources than the sun (day light) and with having matt markers even the day light reflection on the markers is avoided to a great extent that decreases a lot the systematic error due to the light reflection. [1] Lee, J. J., and Shinozuka, M. (2006): Real-Time Displacement Measurement of a Flexible Bridge Using Digital Image Processing Techniques, pp.105-114,

Experimental Mechanics (46). [2] Feng, D., Feng, M. Q., Ozer, E., and Fukuda, Y. (2015): A Vision-Based Sensor for Noncontact Structural Displacement Measurement, pp.16557-16575, Sensors (15). [3] Yang, J., Peng, C., Xiao, J., Zeng, J., and Yuan, Y. (2012): Application of videometric technique to deformation measurement for large-scale composite wind turbine blade, pp.292-300, Applied Energy (98).

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COMMENT 7: Page 2 line 5 ‘’the transducers load the structure with their weight that changes the dynamic properties of the structure and need expensive correction”. This statement is correct only if you perform some tests on very small models. I agree that an accelerometer of 100 grams can be considered as an added mass for a small scale model but weight of a real wind turbine or a real bridge is not affected by the weight of an accelerometer of 100 grams. Could you please remove this sentence?

RESPONSE: The sentence is removed.

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COMMENT 8: P2 line 23 ‘’is” should be ‘’are”.

RESPONSE: Fair point, it is corrected.

********** COMMENT 9: P8 line 5 please change ‘’angel to ‘’angle”.

RESPONSE: Fair point, it is corrected.

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COMMENT 10:

Page 11 line 13: You wrote that rotational speed of 30 rpm can cause an elongation on metal rod blades. Could you please check these values again? I am not sure but I do not think that such a low speed can cause a noticeable elongation on metal rods?

RESPONSE: That is true, this part is removed from the text.

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COMMENT 11: Page 16: It is not clear how to read and interpret Table 1. Could you please explain in more detail what the distance between the light rays is? A sketch would be very helpful.

RESPONSE: More explanation regarding Table 1 is added to page 11, just before Table 1.

Please also note the supplement to this comment:
https://www.wind-energ-sci-discuss.net/wes-2017-49/wes-2017-49-AC3-supplement.pdf

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