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Measurement system for wind turbines noises assessment based on LabVIEW ☆

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ABSTRACT

An automatic measurement platform based on powerful LabVIEW is designed and implemented for noise assessment of Wind Turbine Generator Systems (WTGS). The measurement method of IEC 61400-11 standard is set-up in order to ensure the consistency and accuracy of noises assessment. Firstly, the techniques of measuring wind speed, calculating apparent sound power at integer wind speed, identifying tonality and audibility at integer wind speed recommended in IEC 61400-11, are described briefly. And then, the measurement system is designed using LabVIEW development system with one PCMCIA card and one USB card inserted into a laptop. The whole system architecture with the hardware configures and software function modules, is introduced in detail. Finally, this system is applied to do noises assessing for GOLDWIND 77/1500 wind turbine and the results have been recognized by the authoritative agency of MEASNET. Benefiting from the module design of sub-virtual instrument in LabVIEW, this system has the characteristics of perfect functions, friendly using interface, high integration, low cost and great practicality. It has wide foreground for noises assessment of WTGS.

1. Introduction

Wind Turbines Generator Systems (WTGS) are favored in the switch-over to renewable energy. Because of the installation of WT in large numbers and the potential for installation near residences, WTGS noise is often discussed during sitting negotiations, and the noise radiation is still the major limitation in the tremendous development of wind energy [1,2]. There is a need for reliable noises assessment. If it was available, homeowners and local authorities could use the information to develop expectations regarding noise production before on field test observations, and then the improvements to the turbines might be made with relative ease and low cost [3].

In 1998, with the objective to perform measurements of equal quality which are sufficient for the mutual comparison, the International Electrotechnical Commission (IEC) established the first edition of IEC 61400-11: "Wind Turbine Generator Systems – Part 11: Acoustic Noise Measurement Techniques", and the newest edition (Ed. 2.1) was published in November 2006 [4]. Techniques such as wind speed (WS) measurement and apparent sound power, tonality and audibility calculation at integer WS are recommended in this document.

At present, the IEC 61400-11 has been used as criteria for assessment of WTGS noises. The related report ends with the presentation of the best practice guide line. NREL, A National Laboratory of US Department of Energy performed acoustic tested on the Whisper H40 wind turbine to characterize its noise emissions in accordance with procedures described in IEC 61400-11 with minor modifications on January and February, 2001 [5]. The test results were documented and disseminated in the form of NREL reports, technical papers, seminars, and colloquia, which

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supported the US wind industry in applying rational acoustic-design principles to the development and deployment of advanced wind turbines.

Engineers form Howe Gastmeier Chapnic Engineering (HGC Engineering) in Canada visited the Pubnico Point Wind Farm during the period from May 5 to 11, 2006 and measured the sound impact of the wind turbine generators according to IEC 61400-11 [6]. The measured results have given an appropriate assessment about the acoustic impact of wind turbine generators on residences, which indicated that the impact of the wind farm was continually audible to varying degrees.

Although the same standard is used, test practical experiences have shown that the measured results from different institutions through different measuring system are not sufficient and effective for the mutual comparison. There are big differences in the measured results using different measurement systems with different data acquisition and signal processing methods. Among all measurement institutions the Energy Research Centre of Netherlands (ECN) is credited by the International Measurement Network of Wind Energy Institutes (MEASNET) for noise measurements on WTGS according to IEC 61400-11. In order to ensure high quality measurements with uniform interpretation of standards and recommendations as well as interchangeability of results, ENC purchased Brüel&Kjær (B&K) products to complete noise measurements on WTGS, that brought a technology upgrade for acoustic measurement [7]. Before WTGS being put into use, its noises assessing should be conducted by the specialized agencies such as ENC. And the assessing results should meet the requirement of IEC 61400-11. If not, the second test or more times test would be carried out until the final test results meet the requirement. Therefore, it is a good choice that every WTGS manufacture has its own noises pre-assessing system before inviting the specialized certification agency to do assessment. In addition, most of companies or institutions that offer assessing services have adopted B&K PULSE data acquisition system to record WTGS noise and post-process the recorded data. But in the widespread application of B&K measurement system, some disadvantages or inconveniences have arisen. Firstly, being as general measurement system, the whole B&K PULSE system is costly with too many strong functions which are surplus to the WTGS noises assessment. If purchasing the test service provided by ENC, it will cost about $70,000. Secondly, the test procedure using the B&K system is very discommodious due to B&K products have no special measurement system designed for WTGS noise assessment. To develop the noises measuring system based on B&K products needs much manpower and long time. In the third place, the B&K measurement system is fragmented. The measurement system needs DAT-Recorder of Sony, 2-channel real time frequency, Diadem8.1 of Gfs Aachen, Excel 2000 of Microsoft, Dasy-Lab 7.0 of DATALOG, Compaq nx8220 of HP, all of which are separated and scattered so as to bring many inconveniences in operation.

Therefore, it is very necessary to design a low-cost, high-efficiency, easy-operation, universal and practical measurement system for WTGS noises. For the different type of wind turbine (WT) and wind farm sites, the configurations of the measurement set-ups change frequently, making it necessary to adapt not only the measurement system itself, but also very often the software. In this context, the possibility of flexible analysis software for the automation of measurement set-up would be of great practical value. Such a software platform would allow quick adaptation of measurement set-ups to new type WT and new conditions of wind farm.

In this paper, all these individual equipments have been integrated into one system as an organic whole based on LabVIEW virtual instrument software architecture, that brings a great convenience and facility for WTGS noises assessment. The paper is organized as follows: Section 2 is devoted to the elaboration of the key techniques about WTGS noises assessment such as WS measurements and apparent sound power, tonality and audibility calculation at integer WS. Section 3 describes the design of the whole system's hardware configures and software function modules with LabVIEW virtual instrument. In Section 4 the field experiment was carried out in Dabancheng No. 2 Wind Farm in China Xinjiang during July 2007, which lasted three weeks. To validate the performance of this measurement system, and critical measurement steps and analysis results are also given.

2. Principle of methodology

2.1. Wind speed measurement

The power curve is used to reversely calculate the WS. Since power curve is the result of long-term statistical properties about WS and power, and the correlation between measured sound pressure level and electrical power is very high up to the point of maximum power, the determination of the WS from power according to power curve is the preferred method and is mandatory for certification measurements [4]. Then the derived WS from reverse calculation should be corrected as:

$$V_H = V_D \left(\frac{p_{\mathrm{ref}} T_k}{p T_{\mathrm{ref}}} \right)^{\frac{1}{3}} \tag{1}$$

where T_k is the air temperature in K, $T_k = T_c + 273$; T_c the air temperature (°C); T_{ref} the reference temperature, $T_{\mathrm{ref}} = 288$ K; p the atmospheric pressure (kPa); p_{ref} the reference atmospheric pressure, 101.3 kPa; V_H the corrected WS at hub height (m/s); and V_D is the derived WS from power curve (m/s).

The corrected WS V_H is converted to the corresponding standard WS V_S at a reference height of 10 m and a reference roughness length of 0.05 m by assuming wind profiles in the following correction equation [4]:

$$V_S = V_H \left[\frac{\ln\left(\frac{Z_{\mathrm{ref}}}{Z_{0\mathrm{ref}}}\right) \ln\left(\frac{H}{Z_0}\right)}{\ln\left(\frac{H}{Z_{0\mathrm{ref}}}\right) \ln\left(\frac{Z}{Z_0}\right)} \right] \tag{2}$$

where $Z_{0\mathrm{ref}}$ is the reference roughness length of 0.05 m; Z_0 the roughness length; H the rotor centre height (hub height); Z_{ref} the reference height, 10 m; Z the height where V_z acquired; and V_H is the WS acquired at height H.