Potential of Structural Health Monitoring and Micro Energy Harvester System for VAWT

A.H. Ariffin, M.T.H. Sultan, F. Mustapha, A.U.M. Shah, S.N.A. Safri

Abstract: ***The application of wind energy is getting popular and progressively imposed in certain country as a renewable energy sources. The monitoring of structural integrity in wind turbine system becoming new focus due to time and cost incurred during the operational of wind turbine. The existing method required high cost in term of human resources and time consuming especially when the system facing sudden catastrophic failure. The catastrophic crash may occur when the process is failed to detect early microcrack in the turbine structure. Therefore, the implementation of structural health monitoring (SHM) system which is operated in real time monitoring and detecting microcrack is becoming crucial. The latest research and finding on the SHM in wind turbine system is discussed in the current review. Besides that, a new approach of micro energy harvester in SHM is reported as well. This approach may offer new idea and technology which need further enhancement for the real application.***

Index Term: SHM; Structural Integrity; Vertical Axis Wind Turbine; energy harvester; natural fibre

I. INTRODUCTION

As the reservoir is reducing these days, the alternative of wind energy applications has been the interest around the world [1]. Cumulative wind power from selected countries at 2004, 2010, 2011 and 2012 were compared in Figure 1 [2]–[5]. Pertaining the demand and suitable geographic reason, Asia is suggested to be a huge potential region for expanding this technology.

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Dr. Ahmad Hamdan Ariffin, Department of Aerospace Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia

Assoc. Prof. Ir. Ts. Dr. Mohamed Thariq Hameed Sultan, Department of Aerospace Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia

Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Products (INTROP), Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia

Aerospace Malaysia Innovation Centre (944751-A), Prime Minister's Department, MIGHT Partnership Hub, Jalan Impact, 63000 Cyberjaya, Selangor Darul Ehsan, Malaysia

Prof. Dr. Faizal bin Mustapha, Department of Aerospace Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia

Dr. Ain Umaira Md Shah, Department of Aerospace Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia

Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Products (INTROP), Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia

Dr. Syafiqah Nur AzrieSafri, Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Products (INTROP), Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia

In addition, it obviously shows that the wind energy knowledge has progressed extensively throughout the year [6].Wind turbines generally grouped into two which is Vertical Axis Wind Turbine (VAWT) and Horizontal Axis Wind Turbine (HAWT). It depends on the rotor shaft's axial direction. HAWT is commonly used for bigger size electrical power generation grid. However recently, researcher has started to change from HAWT to VAWT. Uniquely, several researchesconcluded that the VAWT offers better performance compared to the HAWT [3]. The VAWT can rotate at any wind direction. Furthermore, it can operate at low level height and easy access can be achieved by mounting the generator at ground level, which results in lowering the capital cost [7]–[9]. Monitoring and maintenance aspect in wind turbine should be given proper attention. Therefore, Structural Health Monitoring (SHM) system is proposed to comprehensively observe and screen the turbine system especially during the operation [10].

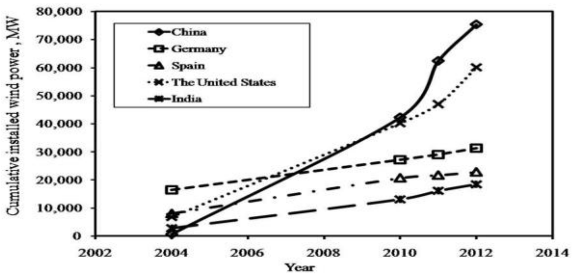

Fig. 1: Amount of installed wind power in several countries around the world [2]–[5]

The feedback of health information from the system can assist the engineers to refine the designs and manufacturingof wind turbine as well as the process of quality control, shipping and installation [6]. Several approaches in SHM are proposed in order to detect failures and damages in the wind turbine system and blade structure. The methods include acoustic emission, ultrasonics, thermal imaging, fibre optics, and the laser doppler vibrometer [6], [10]–[16]. Besides that, Macro Fiber Composite (MFC) and piezoelectric smart material offer better technology [17], [18]. It is not only to detect damage and deformation but perform as an electricity harvesting mechanism as well [19]–[23]. Consequently, piezoelectric material can play a role as wind vibration energy harvester or a micro harvester, while VAWT plays an important task as the main energy collector [22].

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II. VERTICAL AXIS WIND TURBINE

VAWT and HAWT are being thoroughly tested and improved [3]. The advantages of the VAWT as compared to the HAWT has been reported in previous finding [24]–[27]. Table 1 shows the comparison between the VAWT and the HAWT [7]–[9], [24]–[27].

Table 1: Differences between HAWT and VAWT [7]–[9], [24]–[27]

Item	Horizontal axis wind turbine (HAWT)	Vertical axis wind turbine (VAWT)
Tower sway	Large	Small
Wind velocity for start	Relatively high	Very low
Noise produced	Relatively high	Less
Self starting	Yes	No
Obstruction for birds	High	Less
Generator location	Not On ground	On ground
Yaw mechanism	Yes	No
Height from ground	Large	Small
Blade's operation space	Large	Small
Wind direction	Dependent	Independent
Ideal efficiency	50–60%	More than 70%
Overall formation	Complex	Simple

There are several VAWT types, which are as follows: the theCrossflex, Darrieus rotor–variable geometry oval trajectory, the Darrieus rotor – egg beater shaped, the twisted three bladed Darrieus rotor, the Darrieus–Masgrowe,Savonius rotor, Darrieus rotor, the Darrieus rotor–straight bladed, the two leaf semi rotary, the Zephyr turbine, the Combined Savoniusand Sistan wind mill [24]. Concerning the manufacturing process and fabrication costs, a reliable configuration of the Darrieus rotor-straight blade or giromill can be seen in Figure 2.

H-rotor is generally described as the two blades of the giromill [28]. Darrieus turbines is harmonised with the circumstances such as low average wind velocity, lightning risk and bird strike risk [25]. In terms of the performance of the VAWT, the central shaft produced a higher impact to the vibration [29]. Besides this, the efficiency of the VAWT can be increased with a greater length of the VAWT and the diameter of the turbine blades [29].

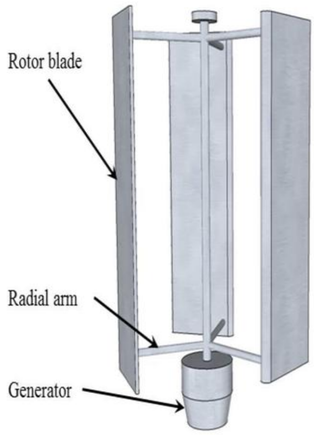

Fig. 2: Darrieus rotor –straight bladed [21], [25]

III. OVERVIEW OF STRUCTURAL HEALTH MONITORING (SHM) SYSTEM

Non-Destructive Evaluation (NDE) is a technique that can be done offline while SHM is a technique that can be performed in real time. Therefore, SHM has better advantages in determining and predicting damage compared to NDE [11],[30].

There are two type of SHM which is passive response and active response. In passive response category, the normal (default) data will be compared with the received periodical response. If signal changes was detected, engineers will automatically take appropriate action to inspect the structural health. The changes feedback response may take effect from any structures such as the motors, shafts, bearings and wind turbine blades [31], [32]. One of the passive response types is condition monitoring, while the active response will track the signal. Sudden changes in signal pattern will be notified back to the system.

The ultrasonic guided wave approach is one of the active response group. Rumsey [11] employed ultrasonic wave method on wind turbine blade to study the performance of the sensor. On the other hand, outlier analysis (OA), which was found to be a simple, practical and reliable approach, was employed by Mustapha et al. as a statistical method in damage detection [16]. In analysing the wind turbine blades, Marquez et al. reported the application of a time series based method, wave propagation and lamb frequency response functions[13].The time series analysis is suggested to be the most practical and convincingmethod for detecting damage. Comparing the wave propagation techniques, operational deflection shape and transmittance functions, it was recommended that for online turbine blades monitoring system, the best technique is the resonant comparison algorithm[33].

IV. MICRO-ENERGY HARVESTER

Piezoelectric material has started to be recognised as a micro-energy harvester. The potential was seen as a replacement to a lifelong or a conventional battery for low power devices [22], [34]. In the trial stage, piezoelectric material was implemented in the technology of an unmanned aerial vehicle (UAV), which in turns showing a positive outcome[35]. The mechanism

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involves the mechanical vibration, stress and strain and this can work as power sources. It can also originated from heaters and friction sources, thermal energy from furnaces, room light and sunlight. It can producemW or µW level power [36].

Biocomposites such as kenaf [37]–[40], and bamboo [41]–[44], has been rising in popularity among researchers. Some of the applications that has utilised biocomposites are the combat helmet [45], and UAV. Biocomposite was used as the blade material due to the high strength and stiffness to weight ratios [46], [47]. The effect of bonding technique of MFC in biocomposite turbine blade was studied as shown in Figure 6 [15], [48]. The study proposed that MFC bonded on the surface of turbine blade is the best performance in harvest micro energy.

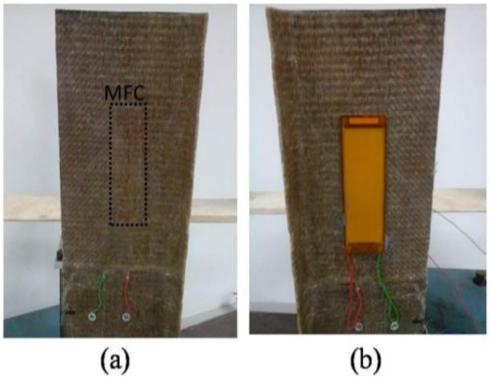

Fig. 6: Turbine blade made of woven kenaf composites (a) location for embedded MFC, (b) MFC bonded at the same location as the embedded MFC [15], [48]

Besides that, an autonomous sensing unit integrated with power harvesting technologies and SHM in a single, self-powered device has been studied[19]. It was found that a wireless impedance device sensor node can be powered by a multisource energy harvester [20]. The source power was came from vibration and solar energy. In a cloudy, bright, mild and high wind conditions, the experiment on a wind turbine was carried out.In an acceptable period of time, it adequately charged its input capacitor (0.1 F) to 3.6 V.

On the other perspective, MFC has its advanced features. Its flexibility makes it very effective to be bonded on vibrating and large structures and also its high electromechanical coupling coefficient [49]. Additionally, up to 65% electrical power can be generated by MFC from the input mechanical energy, results from the thin layer which is classified as a bimorph structure. Compared to the unimorph structure, the bimorph produces double output power [50]. A few research studies concerning MFC were conducted to investigate several parameters which could affect the MFC performance. It includes the output voltage across the resistor, the lateral beam deflection and the dissipated power [51][52] and MFC tiers effect [49].

V. CONCLUSIONS

Among the renewable energy, wind energy has a bright future to grow. The emerging of SHM technology in this sector will bring the wind energy a step forward in facing the fourth Industrial Revolution. Therefore, the application of SHM needs to be appropriately suited with the existing product. Besides that, the SHM system should offer additional value in the overall system. Therefore, the micro energy harvester is proposed as an enhancement for the system.

Extensive research of the SHM application should be conducted for the wind turbine system. Optimisation of the pattern recognition of the SHM system can be improved. A few issues and recent studies are highlighted in this chapter. Further analyses need to be conducted on the factors affecting the performance of micro energy harvesters. It includes the bonding Macro Fiber Composite (MFC) technique, i.e. whether it is bonded on the surface or embedded in the plate surface, the effect of resonance, the optimisation of the MFC location and the MFC on the biocomposite turbine blade. In addition, a study of circuit improvement for the micro energy harvester should be conducted to harvest the energy more efficiently.

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AUTHORS PROFILE

Dr. Ahmad Hamdan Ariffin,obtained his PhD in Aerospace Engineering from Universiti Putra Malaysia in 2015. He was awarded with Master of Engineering Science in Advanced Manufacturing from University of Malaya. His research focuses mainly on turbine blade aerodynamics, structural health monitoring system, biocomposites fabrication, structure vibration, cutting tool technology, and cooling system.

Assoc. Prof. Ir. Ts. Dr. Mohamed Thariq Hameed Sultan is an Associate Professor at Department of Aerospace Engineering, Faculty of Engineering, UPM Serdang, Selangor, Malaysia. He is also appointed as Head of Laboratory, Laboratory of Biocomposite Technology (BIOCOMPOSITE), Institute of Tropical Forestry and Forest Products (INTROP), UPM Serdang, Malaysia. He is also a Professional Engineer (PEng) registered under the Board of Engineers Malaysia (BEM), Charted Engineer (CEng) registered under the Institution of Mechanical Engineers UK, currently attached with Universiti Putra Malaysia. He obtained his Ph.D. from University of Sheffield, United Kingdom. His area of research interests includes Hybrid Composites, Advance Materials, Structural Health Monitoring and Impact Studies. He published a series of paper which contributed significantly to the development of his field. As he headed the work on development on composite structures, characterising bio-materials and aerospace materials which has led him to published more than 100 journal articles and 6 books with Elsevier.

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