PROCEEDING

ICONETSI

International Conference on Engineering and Information Technology for Sustainable Industry **2020**

28 - 29 September 2020

SGU Alam Sutera Campus, Prominence Tower,
Jalan Jalur Sutera Barat no. 15, Tangerang, Indonesia

ICPS
Published by ACM

The Association for Computing Machinery
1601 Broadway, 10th Floor
New York, New York 10019, USA

ACM ISBN: ISBN 978-1-4503-8771-2

MESSAGE FROM RECTOR

Swiss German University (SGU) has been established for 20 years. As a university committed to striving for quality education, SGU organizes its annual event, the International Conference on Innovation, Entrepreneurship and Technology – ICONIET to give a platform for researchers, practitioners, government officials to present and discuss their works. The ICONIET 2020 consists of two sub-conferences, namely "International Conference on Engineering and Information Technology for Sustainable Industry 2020 (ICONETSI)" on Monday & Tuesday, 28-29 September 2020 and "International Conference on Global Innovation and Trend in Economy (INCOGITE 2020)" on Thursday, 5 November 2020.

The conference has the same theme as the 20th anniversary of SGU, "Transforming Digitally, Empowering Globally". Digital transformation is a must. It connects technology specialists across all sectors and fields in order to meet business needs and market requirements. It builds innovation and high-tech know-how to assist business initiatives or to upgrade technology for future growth. SGU has also participated in education for empowering communities globally. By lifting up individuals within communities, SGU encourages and supports sustainable community and economic development. Good quality of education and research will generate technology, innovation and entrepreneurship which will eventually improve quality of life and the prosperity of societies, nations and the world as a whole.

This year, the ICONIET is conducted in the midst of pandemic Covid-19 and hence, will be fully virtual using video conferencing. I'd like to take this opportunity to welcome all honorable guests, speakers, presenters and participants, who have come not only from Indonesia, but also from different countries such as Germany, Japan, Malaysia, the United Stated, Singapore, Egypt and Taiwan.

I'd like to personally thank the Committee of ICONIET 2020, including the committee of ICONETSI and INCOGITE 2020, who have put their utmost efforts into organizing this event. I wish to express my gratitude to the Ministry of Research, Technology and BRIN for their continuous support to our research. I would also like to thank SGU's University partners, the South Westphalia University of Applied Sciences and the University of Applied Sciences Jena in Germany, as well as the International Management Institute (IMI) in Switzerland.

We do hope that the conference will be beneficial and mind-opening for all participating parties. Let us use this event to exchange ideas and to extend our networking virtually, with the aim of empowering the wider global community.

Respectfully yours,

Dr. rer. nat. Filiana Santoso
Rector of Swiss German University

MESSAGE FROM CONFERENCE CHAIR

I would like to welcome you to the 2020 1st International Conference on Engineering and Information Technology for Sustainable Industry, Tangerang, Indonesia. ICONETSI 2020 provides a scientific platform for both local and international researchers, engineers and technologists who work in all aspects of Engineering and Information Technology for Sustainable Industry to exchange their latest research results. In addition to the contributed papers, internationally well-known experts are also invited to deliver keynote and plenary speeches at ICONETSI 2020. We are honored to have the distinguished keynote speakers: Prof. Bambang PS Brodjonegoro, Ph.D of the Minister of Research and Technology – BRIN, INDONESIA; and also Prof. Dr. Engg. Koichi Murata of Nihon University, Japan; Prof. Dr. Eng. Agus Purwanto of Universitas Sebelas Maret, Indonesia; Assoc. Prof. Dr. Waseem Haider of Central Michigan University, USA; Dr. Anto Satriyo Nugroho of Agency for Assessment and Application of Technology – BPPT, Indonesia; Assoc. Prof. Yudi Fernando PhD M.LogM of Universiti Malaysia Pahang, Malaysia; and Dr. Charles Lim, BSc., MSc. of Swiss German University, Indonesia as our invited speakers.

The conference is organized as a set of tracks in Sustainable Energy and Environment, Production and Operation Management, Logistics and Supply Chain, Ergonomic and Human Factors, Automation, Mechatronics and Robotics, Cyber Security and AI, and Software Engineering.

In this first event of ICONETSI 2020, we have received 125 paper submissions from Germany, Japan, Taiwan, Singapore, Egypt and Indonesia. To ensure the high quality of papers in ICONETSI 2020, each submission is reviewed by no less than three reviewers through a blind review process. In addition, we also carefully check the similarity rating to avoid plagiarism, and the writing format according to the conference proceedings template for each submission. After a careful review process, the program committee accepted 76 high quality full papers for presentation in ICONETSI 2020.

The successful organization of ICONETSI 2020 has required strong support from Indonesia Honeynet Project, Industrial Engineering Higher Education Organizing Cooperation Agency (BKSTI), Pusat Unggulan Iptek (PUI) Baterai Lithium Universitas Sebelas Maret, and Indonesian Association for Pattern Recognition (INAPR).

Most of all, I thank you, the participants, for enriching this conference by your presence. I am thankful to the conference organizing committee members, the track chairs, the session chairs, and the numerous volunteers, without whose generous contributions, this conference would not have set a record number of presentations and number of participants, higher than our expectation, especially considering some difficulties that happened during the Covid-19 pandemic. We truly believe the participants will find the discussion fruitful, and will enjoy the opportunity of setting up future collaborations.

Warm Regards,
Assoc. Prof. Dr. Tanika D Sofianti
ICONETSI 2020 General Chair

Keynote Speaker

Prof. Bambang Permadi Soemantri Brodjonegoro, Ph.D

Minister of Research and Technology - The National Research and Innovation Agency of the Republic of Indonesia

Short Biography:

Prof. Bambang Permadi Soemantri Brodjonegoro, Ph.D is the Minister of Research and Technology and Head of the National Research and Innovation Agency of the Republic of Indonesia. Previously, he was the Minister of National Development Planning of the Republic of Indonesia from 2016 to 2019 and also the Minister of Finance from 2014 until 2016. He has also worked in various roles in the Ministry of Finance. The opportunities to contribute as the Minister of Research and Technology, Minister of National Development Planning, and Minister of Finance have established Prof. Brodjonegoro's career in integrating Indonesia's research, technology, innovation, development planning, financing, and economic stabilization. Prof. Brodjonegoro earned his Ph.D in Urban and Regional Planning from the University of Illinois at Urbana–Champaign, United States in 1997. Afterward, he started his academic career as a lecturer in Universitas Indonesia and became Dean of the faculty of economics, Universitas Indonesia from 2005 to 2009. His research mostly focuses on Economics. He has also been actively involved in various local and international organizations and Indonesian companies, including being the director-general of the Islamic Research and Training Institute (IRTI), Islamic Development Bank Group, Jeddah, The Kingdom of Saudi Arabia in 2010. He was also awarded several honor and awards, including Bintang Maha Putra Utama from President of Indonesia and Bintang Bhayangkara Utama from the Indonesian National Police.

Invited Speaker 1

On the Role of Industrial Engineering in the COVID-19 Era

Prof. Dr. Eng. Koichi Murata
Nihon University, Japan.

Abstract:

The purpose of this study is to consider the role of industrial engineering in the era of COVID-19. This paper is divided into three parts. Firstly, the history of industrial engineering is reviewed to confirm the richness and compensation of life brought by the division of labor. The second part describes the exchange that should be paired with the division of labor, and what it is likely to be, and then explains that the integration of the division of labor and its exchange is a future issue for humanity. The third part, regarding the touch strategy that is the first step of exchange, reviews the concept of visual management, which is a precedent case, and tries to systematize the three touch strategies that were tried in the early stages of the spread of COVID-19 in Japan. The results obtained from this survey show that it is important for industrial engineering, which has been trying to understand management resources from various perspectives, to engage not only in the division of labor, but also in their exchange. Also, in an era where environmental destruction and digitalization are progressing at a speed that humanity does not notice, the findings can be considered as a problem in order to produce human resource workers whose value is higher than ever.

Short Biography:

Koichi Murata is the head of operations & production management laboratory and a professor at the Department of Industrial Engineering and Management, College of Industrial Technology, Nihon University. He previously worked in industry as an industrial engineer at the flagship factory of Murata Manufacturing Co., Ltd., which is a global leader mainly in the manufacturing of electronic components. His research interests include operations & production management, kaizen, lean management, visual management, technology transfer, knowledge management, sustainable supply chain and others. Dr. Murata has published articles in international academic journals such as International Journal of Production Research, Sustainability, Journal of the Operations Research Society of Japan, and others. He was interviewed for NHK and the Associated Press (AP) about the prospects for the manufacturing industry.

Invited Speaker 2

Honeynet Threat Sharing – One step closer to Cyber Situational Awareness

Dr. Charles Lim, BSc., MSc., CTIA, CHFI, EDRP, ECSA, ECSP, ECIH, CEH, CEI
Swiss German University; Indonesia Honeynet Project

Abstract:

As organizations are digitally transforming their business, they are encountering security risks to slow down their intent. A collection of honeypots, i.e. honeynet, are often deployed in their infrastructure to detect the early cyber security attacks into the infrastructure, allowing the organization to be more aware of the emerging threats. Organizations may forge to stay relevant, timely and accurate in assessing these threats when they are willing to share these threats to the community of interest, providing the first step to cyber situational awareness.

Short Biography:

Charles Lim is a Cyber Security Researcher and Lecturer at Swiss German University, an independent researcher who works closely with Badan Siber dan Sandi Negara (BSSN) and a professional IT security related consultant and trainer. He is one of the recipients of the 2019 ISIF Asia Network Operations Research Grants and 2020 Internet Operations Research Grants. He also holds a few security professional certifications in the area of incident response, threat intelligence and security analyst, from ECCOUNCIL. He has a Doctorate degree in Electrical Engineering from Universitas Indonesia, Master of Science in Electrical Engineering from University of Hawaii, USA and his research includes Malware Analysis, Digital Forensics, Cloud Security, and IT Security Architecture. He is actively involved with many cyber security communities, such as Indonesia Honeynet Project (IHP), ACAD CSIRT (Academy Computer Security Incident Response Team), Indonesia Digital Forensics Association (AFDI), and others.

Invited Speaker 3

Recent Trends in 3D Printing

Assoc. Prof. Dr. Waseem Haider
Central Michigan University, USA

Abstract:

Additive manufacturing or 3D printing of metals is emerging and rapidly growing manufacturing technique from prototyping to large production runs. This process involves the fusion of metal powder bed by selectively melting above the melting temperature and building layers on top of each other. The imminent advantages of producing complex geometries, unprecedented manufacturing flexibility, product customization and at the same time economically viable process makes it a potentially disruptive technology for different industrial applications. The huge interest of industries for adapting this technology also brought the attention of research community to work in this area with full potential. The changed melting and solidification dynamics during additive manufacturing, results into striking differences in the microstructural evolution in comparison to the one obtained through conventional casting process. The microstructure variation strongly impacts the other structural properties of the material, e.g. mechanical, electrochemical etc. and this provides different avenues for the research community. Our group is working to elucidate the electrochemical response and the nature of passive oxide film formed on the additively manufactured 316L stainless steel for varying applications (biomedical, petrochemical and food industries).

Short Biography:

Dr. Waseem Haider is a tenured associate professor at School of Engineering and Technology, Central Michigan University, USA. He earned his PhD in Mechanical Engineering from Florida International University in 2010. He got a post-doctoral fellowship in materials science and engineering at Pennsylvania State University. Afterwards, he joined orthopedic research labs as a research scientist at State University of New York. Soon after that, he joined University of Texas as tenure track assistant professor where he served for three years. Dr. Haider's research focuses on Materials Science and Biomedical Engineering with special emphasis on Biomedical Materials Surface Chemistry, Electrochemistry, Bulk Metallic Glasses, and Nanomaterials. His research is supported by National Science Foundation and Department of Defense.

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Invited Speaker 4

Engineering Design and Blockchain Technology for Sustainable Industry: A Circular Economy Perspective

Assoc. Prof. Yudi Fernando PhD M.LogM
Universiti Malaysia Pahang, Malaysia

Abstract:

The manufacturing industry is an essential sector, especially in developing countries, and significantly contributes to a nation's economy. These significant contributions are due to the availability of vendors with capabilities supporting low-cost production with quality materials. These significant contributions should not overlook other outputs from this industry as one of the largest emitters of greenhouse gasses, pollution, and waste that contribute to negative environmental impacts. These externalities are due to waste from the energy and material resources required to be processed into finished products. While the manufacturing industry has contributed enormously to wealth and job creation, thus improving quality of life, this is happening at the expense of delivering unsustainable amounts of solid waste and pollution. Due to many competing factors, the manufacturing industry is transforming from a linear economy model (make, use and discard) to a global circular economy in which the components of products are fed back to production after their service life. Yet, scanty evidence exists on how the manufacturing firms report on the success story of the remanufacturing process of leftover materials, return products and scrap. In the past, environmental concerns were mostly neglected in the manufacturing and supply chain processes. Circular economy, a term which used to be known as the remanufacturing of scrap, is an alternative method to counter this issue. The engineering redesign needs to be adopted with the proper integrity platform. Blockchain technology can be used to improve visibility, transparency and the accurate computation of the production and overall supply chain's carbon footprint. Blockchain technology has a high level of security and cannot be hacked. It can be used to support the integration of energy production, utilization, transmission, and storage so that every carbon footprint activity and carbon trading transaction can be tracked and no data can be manipulated. In regard to the importance of engineering design using circular economy concept and industrial revolution 4.0 enabler technology like blockchain, I will be presenting a remanufacturing model for sustainable industry that will assist the industry and academia to find alternative solutions to turn waste into value-added products.

Keywords: remanufacturing; design; circular economy; blockchain technology; industrial revolution 4.0; sustainability

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Short Biography :

Yudi Fernando is an Associate Professor and holds a PhD. He is the Editor-in-Chief Industrial Management: An International Journal and Managing Editor of Journal of Governance and Integrity at the Faculty of Industrial Management, Universiti Malaysia Pahang. He is a Research Committee Chair and founding member of the Malaysian Association of Business and Management Scholars (MABMS). He is also a member of the Society of Logisticians, Malaysia/Pertubuhan Pakar Logistik Malaysia (LogM). Prof. Yudi is involved actively as the assessor for ABEST21 (Alliance of Business Education and Scholarship for Tomorrow) program-based accreditation system. His research interest is in the areas of sustainable supply chain; circular economy 4.0 and blockchain technology and he has supervised 9 PhDs, 11 ongoing, and more than 70 Master theses. His works can be found in the top tier journals such as: Journal of Cleaner Production, *Resources, Conservation* & Recycling, Sustainable Production and Consumption; tourism management International Journal of Information Management; Food Control, Journal of Energy Policy and others.

Invited Speaker 5

Biometrics Technology for Better Public Services

Dr. Eng. Anto Satriyo Nugroho
Center for Information and Communication Technology,
Agency for Assessment and Application of Technology (PTIK BPPT)

Abstract:

Kartu Tanda Penduduk Elektronik (KTP-el) is a National electronic ID card which is issued by the Indonesian government. The goal of KTP-el is to develop an accurate national population database, and ensure a single identity number (SIN) for the citizens. The unique identity of each citizen is verified using biometrics data: ten fingerprint scans, two iris scans and a face scan. More than 190 million citizens have had their biometrics data taken. The scale of biometrics data is the second largest biometrics data in the world after those collected by Unique Identification Authority of India (UIDAI). The data opens various applications such as biometrics authentication for banking, forensic identifications, and electronic voting. In this presentation, we will discuss several topics including biometrics testing of KTP-el Reader, the usage of KTP-el and biometrics for public services, and the future of biometrics data.

Short Biography:

Anto Satriyo Nugroho works for the Center of Information & Communication Technology, Agency for the Assessment & Application of Technology (PTIK BPPT), Indonesia. He completed his B.Eng. (1995), M.Eng. (2000) and Dr.Eng. (2003) in Electrical and Computer Engineering from Nagoya Institute of Technology, Japan. From 2003 to 2007, he was working as visiting professor at School of Life System Science & Technology, Chukyo University, Japan. His research interest is on pattern recognition and computer vision with applied field of interest in Multimodal biometrics Identification and Computer Aided Diagnosis for Malaria Detection. He is the 1st president of Indonesian Association for Pattern Recognition (INAPR), and an Indonesian Governing Board member of International Association of Pattern Recognition (IAPR). Dr. Anto Satriyo Nugroho is a member of IEEE, Indonesian Association for Pattern Recognition (INAPR), Indonesian Association for Computational Linguistics (INACL) and Indonesian Society of Soft Computing.

Invited Speaker 6

Recent Progress of Lithium Ion Battery for Electric Vehicles

Prof. Dr. Eng. Agus Purwanto, ST. MT
Lithium Battery Research and Technology Centre,
Universitas Sebelas Maret, Surakarta, Indonesia

Abstract:

At the end of 2019, the Nobel prize in chemistry was awarded for the advancement of Li-ion batteries considering its discovery promotes the current technology and lifestyle. Li-ion batteries (LIBs) are considered as a vital and predominant power source for various wireless and portable electronics, and have even been applied to high performance Electric Vehicles, especially BEV and HEV. It is predicted by 2030, the largest Li-ion Batteries market will be electric vehicles, mainly cars. As it progressed, current problems found during the development of LIBs were addressed and needed to be overcome such as performance, cost, weight and size. However, cell chemistry and thermal management became the main focus. Cell chemistry considers not only the electrochemical performance, but also its availability to avoid material shortage in the future. It appears that $LiFePO_4$ and graphite system was selected due to its safety properties. However, future trends tend to use nickel rich cathode and silicon-graphite anode for high voltage (up to 5 V) and high energy density batteries. However, high energy density results in high thermal runaway risk, thus making thermal management and failure mechanisms equally as important as cell chemistry. Failure mechanisms of LIBs have been extensively studied. From the material level, challenges such as undesired side reaction, particle breakage and passivation and metal dissolution are often found. However, the current technology of morphology control, nano-layer coatings and structural modification can be used to solve these problems. At the cell level, extensive safety tests, i.e. a mechanical test, thermal test and electrical abuse test are necessary to assure the safety of LIB cells for EVs. With good battery cell design, safety issues can still emerge due to the use of liquid electrolyte which is often flammable and unstable at elevated voltage and temperature. This phenomenon has initiated the development of solid electrolytes for high safety all-solid-state batteries (ASSB). In conclusion, LIBs bring numerous advantages for civilization, however, during worldwide EV application, intrinsic and extrinsic challenges still remain under investigation. With excellent efforts, high safety electric vehicles will undoubtedly be achieved in the near future.

Short Biography:

Agus Purwanto is recognized as an Indonesian developer of Lithium Ion Batteries (LIBs) [i] and the leader of the Centre of Excellence for Electrical Energy Storage Technology

(CEFEEST) Universitas Sebelas Maret. His current work is developing LIBs active material and design. He is the author of over 100 scientific papers, co-inventor of 14 inventions and a Professor in Chemical Engineering.

Agus Purwanto was born in Sragen, Indonesia in 1975 and currently lives with his family in Solo. He obtained his bachelor and master degree in Chemical Engineering from Institut Teknologi 10th November 1998 and 2002 respectively, and his Doctoral degree from Hiroshima University. He is taking a faculty position in the Chemical Engineering Department of Universitas Sebelas Maret.

Agus Purwanto has collaborated with many organizations and industries such as Indonesian Endowment Fund for Education (LPDP), Indonesian Institute of Science (LIPI), the National Nuclear Energy Agency (BATAN), PT Pertamina and Toyota. Agus Purwanto has received multiple awards including: Outstanding Lecturers of Universitas Sebelas Maret (2011), Academic Leader in Technology by Ministry of Research and Technology and Higher Education (2017), and Science and Technology Award by ITSF (2020).

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SUSTAINABLE ENERGY AND ENVIRONMENT

RESEARCH-ARTICLE

Simple Vertical Axis Wind Turbine for Low Wind Speed

Authors: Dena Hendriana, Eka Budiarto, Arko Djajadi Authors Info & Claims

ICONETSI '21: Proceedings of the 2021 International Conference on Engineering and Information Technology for Sustainable Industry • September 2020 • Article No.: 65 • Pages 1–6 • https://doi.org/10.1145/3429789.3429874

Published: 25 November 2020 Publication History

ABSTRACT

Wind energy is one of the potential renewable energy in Indonesia, however low wind speed turbine needs to be designed to adjust for available wind characteristic in the area. Vertical axis wind turbine with Savonius type is suitable for low wind speed application and in this paper turbine design has been optimized aerodynamically using computational fluid dynamics and following raw material size constraint. One-level savonius wind turbine has been designed and compared to previous work of

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Tangerang, Indonesia

Abstract

Wind energy is one of the potential renewable energy in Indonesia, however low wind speed turbine needs to be designed to adjust for available wind characteristic in the area. Vertical axis wind turbine with Savonius type is suitable for low wind speed application and in this paper turbine design has been optimized aerodynamically using computational fluid dynamics and following raw material size constraint. One-level savonius wind turbine has been designed and compared to previous work of two-lavel wind turbine. Based on CFD simulations, one-level turbine has better performance than the other one. Both wind turbines have large torque at zero RPM which indicates that they are suitable for low wind speed application.

CCS CONCEPTS

•Hardware~Power and energy~Energy distribution~Power conversion

Keywords

CFD, OpenFOAM, VAWT, wind turbine, low speed wind, vertical axis wind turbine

ACM Reference format:

Dena Hendriana, Eka Budiarto and Arko Djajadi. 2020. Experimental Simple Vertical Axis Wind Turbine for Low Wind Speed. In Proceedings of International Conference on Engineering and Information Technology for Sustainable Industry (ICONETSI 2020), September 28-29, 2020, Tangerang, Indonesia. ACM, New York, NY, USA, 6 pages.

1. Introduction

Wind turbine to harvest wind energy has been developed all over the world as one of the potential renewable energy resources. The wind turbine converts the wind's kinetic energy into electrical energy. There are two type of wind turbines, Horizontal Axis Wind Turbine (HAWT) and Vertical Axis Wind Turbine (VAWT). Large three-bladed horizontal-axis wind turbines (HAWT) are the overwhelming majority of wind turbine in the world now. These turbines have its main horizontal axis and electrical generator on the top of a tower as seen in Fig.1. Most of them will have a gearbox to increase slow blade rotation into faster rotation to suit electrical generator. Turbines are used in wind farms for commercial production. The blades are usually painted white for aircraft visibility reason. The size and height of the wind turbines increase every year. Currently, offshore wind turbines are designed for up to 8 MW and have a blade length up to 80 meters. Usual wind turbines will have tubular steel towers with its height of 70 to 120 meters. Wind turbines are designed to produce electric power in a range of wind speeds and the example is a General Electric turbine which has peak electric generated power of 2.5 MW. Its cut-in speed is 3 m/s, cut-out at 25 m/s and rated wind speed of 12 m/s [1], see Fig.1. This wind turbine costs around US$ 4.5 million installed.

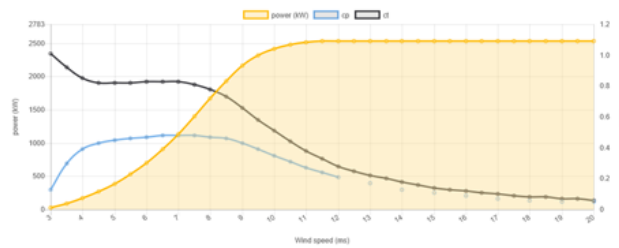

Figure 1: Horizontal axis wind turbine (HAWT) farm and Power curve of General Electric 2.5 MW wind turbine [1].

Vertical axis wind turbine company in Italy named Enessere [2] has a VAWT product with maximum power of 3.5 kW, cut-in wind speed around 4 m/s, rated wind speed 25 m/s, and maximum rotation speed 200 RPM. The product is designed to survive up to the wind speed of 39 m/s. Dimension of the turbine is total height of 8.85 m, tower height 6 m, rotor width 2.67 m, wing height 3.76 m as shown in Fig. 2 along with its power curve. Typical price of this wind turbine is around €60,000.

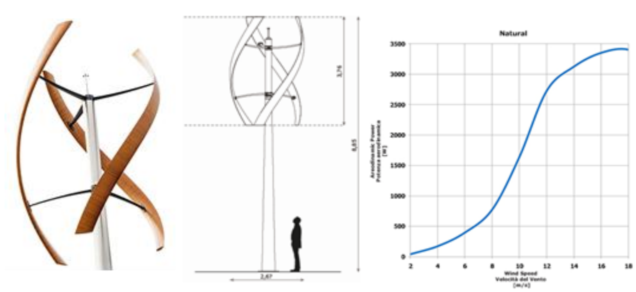

Figure 2: Vertical axis wind turbine (VAWT) product from Italian company Enessere with its power curve [2].

ICONETSI, September 28–29, 2020, Tangerang, Indonesia

ACM ISBN 978-1-4503-8771-2/20/09...$15.00
https://doi.org/10.1145/3429789.3429874

ESP3 Danida, Denmark embassy Indonesia, Ministry of ESDM Indonesia [3] have published a wind energy potential map in Indonesia as shown in Fig.3. The map shows that the most wind energy potential in Indonesia are Nusa Tenggara Timur, south Papua, south Sulawesi and south coastal region of Java. Wind energy in Indonesia is estimated to reach around 150 MW.

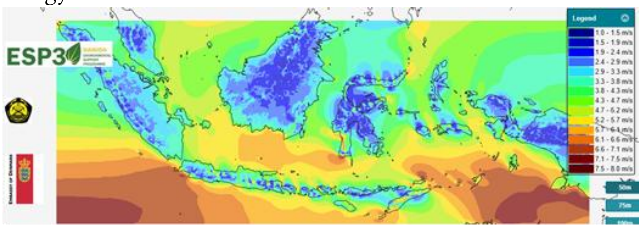

Figure 3: Wind energy potential map in Indonesia by ESP3 Danida, Denmark embassy and Ministry of ESDM [3].

Based on the map, it shows that maximum wind speed in Indonesia is only around 8 m/s. This is less than most rated wind speed for existing HAWT and VAWT products.

Badan Pengkajian dan Penerapan Teknologi (BPPT, Agency For The Assessment And Application Of Technology) has identified wind energy potential area in 10 java regions [4] as shown in Fig.4. In the report, the highest average wind speed is only 6.6 m/s which are in Ciemas Sukabumi and in Cikelet Garut and their potential wind power is 50 MW and 68 MW.

Figure 4: Wind energy potential in several areas in Java, Indonesia [4]

Most of existing wind turbine products are designed for wind speed of 12 m/s or more. In Indonesia, particularly in Java area, the highest average wind speed is only 6.6 m/s. Existing wind turbine products will not work well in Java area. New wind turbines designed for low wind speed, such as 4 m/s, is needed for Indonesia area. The turbine should have low cut-in wind speed such as 1 m/s to utilize low speed wind. Cut-out wind speed can be as low as 10 m/s so the foundation does not need to be very strong which lead to cheaper foundation.

Wind turbine design can be optimized using computer simulation. OpenFoam is a Computational Fluid Dynamics (CFD) software which is an open source software that can be used for this purpose [5]. This software has been applied to optimize wind turbine design by analyzing the air flow in a horizontal axist wind turbine, e.g. in [6]. The basic difference between wind turbine designs for high and low wind speed is in the area of the blades. Low speed wind turbine will require larger blade area to capture low air momentum to be converted to rotational motion of the turbine.

In this paper, a Vertical Axis Wind Turbine (VAWT) will be developed which is a continuation work from two level VAWT [7]. To further reduce the manufacturing price, two level VAWT will be converted into single level. OpenFOAM will be used to further optimize turbine blades with wind speed of 4 m/s.

2. Literature Review

There are two different type of vertical axis wind turbines, Darrieus and Savonius types. The Darrieus type of turbine consists of a number of curved aerofoil blades mounted on a rotating shaft. When the Darrieus turbine blades are rotating, the aerofoils are moving forward on the air in circular path creating lift force which gives a positive torque to the shaft in the direction it is travelling.

Savonius type of wind turbine works to convert the momentum of wind into torque on a rotating shaft. It consists of several scoop-shape of blades and when the scoop front side is facing the wind, it creates more drag than the back side facing scoop. This drag difference is creating positive torque for rotating the shaft.

2.1. Darrieus Type of VAWT

Development of Darrieus type of VAWT started after its invention by Georges Jean Marie Darrieus, a French aeronautical engineer, in 1926. Lately, computational fluid dynamic analysis and wind tunnel test has been done by Howell et. al. [8] in the development of Darrieus type of turbine. The paper showed that 3D CFD analysis agreed well with the wind tunnel test result while 2D analysis tended to over predict the Performance Coefficient Cp value at high TSR value. The wind tunnel results showed that maximum Cp value for two-bladed Darrieus wind turbine was at TSR value around 2.5 while for three-bladed one at TSR value of 2.0.

Twist angle of blade in the Darrieus type has been studied by Ismail et. al. [9]. This report explained different performance between 0 degree twist angle versus 30 degree twist angle wind turbine. The 0 degree wind turbine had higher maximum torque while 30 degree one had higher maximum power due to higher maximum RPM.

Typical Darrieus wind turbine have difficulties in protecting from extreme wind conditions and in making it self-starting. It is a challenge to design strong Darrieus turbine blades to survive high wind load due to its curvy shape. Also, the turbine produces small torque at 0 RPM because of small lift force generated at 0 RPM. This leads to higher cut-in wind speed.

2.2. Savonius Type of VAWT

Savonius type of wind turbine was invented by Sigurd Johannes Savonius in 1922. Recently, work on optimizing the shape of Savonius blade was done by Chan et. al. [10]. A genetic algorithm was incorporated into computational fluid dynamics simulations coupling with blade geometry definition and mesh generation in an iterative process to find optimal blade shape. Regular circular shape of blade, the maximum performance coefficient was around 20% at TSR value of 0.7. With genetic algorithm, the optimized blade shape turbine maximum performance was around 23% at TSR value of 0.9.
Twist angle of savonius blade has been studied by Lee et. al. [11] using computational fluid dynamic simulations and wind tunnel tests. From their works, it showed that changing blade twist angle would change its maximum performance coefficient and corresponding TSR value. For 0 degree twist angle blade, the maximum Cp is around 12.5% at TSR value around 0.65. For 45 degree twist angle blade, maximum Cp is around 14% at TSR of 0.6. For 90 degree twist angle blade, maximum Cp is around 10.5% at TSR of 0.5 and for 135 degree, maximum Cp is 11% at TSR 0.6. Based on this result, optimal blade twist angle is 45 degree.

2.3. Previous Work of VAWT design

This paper is based on previous work [7] to optimize Savonius type wind turbine as shown in Fig.5. The choise of Savonius type is because it has higher torque value at 0 RPM resulting lower cut-in wind speed and it will be more suitable for low wind speed area. The turbine has 2 levels, with identical blades, 2 pieces at each level. The total height of the turbine is 2.4 m and the total outer diameter is 2.4 m. The width of the turbine is chosen to maximize the utilization of plate material in the market, 1.2m. Gap size between two blades is around 0.5 m. Blade chord length is 2.12 meter.

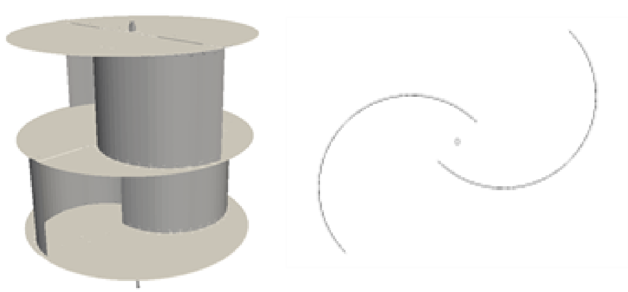

Figure 5: Two-level Savonius VAWT from previous work from different view angle and cut-section on the blade.

3. New One-Level VAWT Turbine Design

Further development of Savonius type of VAWT is done for low wind speed area with higher performance coefficient and maximal material utilization. Computational fluid dynamic analysis is used to optimize the blade aerodynamics.

Baseline design is based on maximal material utilization, which is a material plate of 1.2m x 2.4m. One level turbine design will save 1 circular material so the base design is as shown in Fig.6. The turbine has 4 identical blade with its height of 2.4m and chord length of 1.2m. Top and bottom identical plates has diameter of 2.4m, with structural strengthening. The arrangement of 4 blades is that each edge of the blade is 5 cm from the edge of base plate and each blade are 90 degree apart to each other.

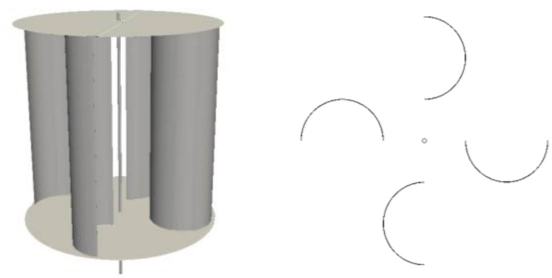

Figure 6: Baseline design for one-level Savonius wind turbine and cut-section of the blades.

3.1. Methodology - Computational Fluid Dynamics

Computer simulation analysis is performed using RANS turbulence method by the software OpenFOAM. OpenFOAM user guide [5] can be referred for more detail information. This open source software has been undergoing a lot of tests and validations by the CFD community in the world and good results have been reported everywhere.
In this analysis, incompressible solver with Reynolds Averaged Navier-Stokes (RANS) and with k-ω turbulence model is used. The module name in OpenFOAM is simpleFoam and the simulation is run to get steady-state solution. Setup of the simulation is sketched in the following Fig.7. Turbine surface velocity is set according to the desired rotational speed.

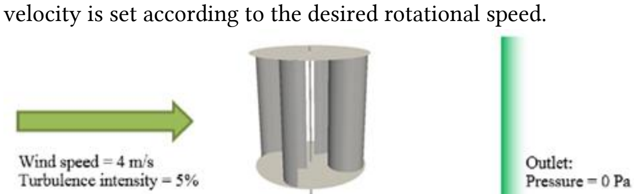

Figure 7: Simulation boundary conditions for turbine CFD analysis.

3.2. Methodology Baseline Results

Computer simulation is done on the baseline with fixed rotation of 50 RPM. Because the wind turbine is in similar shape every 90 degree rotation, computer simulation is done for 0 and 45 degree turbine orientations. The CFD results are shown in Fig.8. Wind turbine geometry is colored by air pressure, where blue is low pressure and red is high pressure.

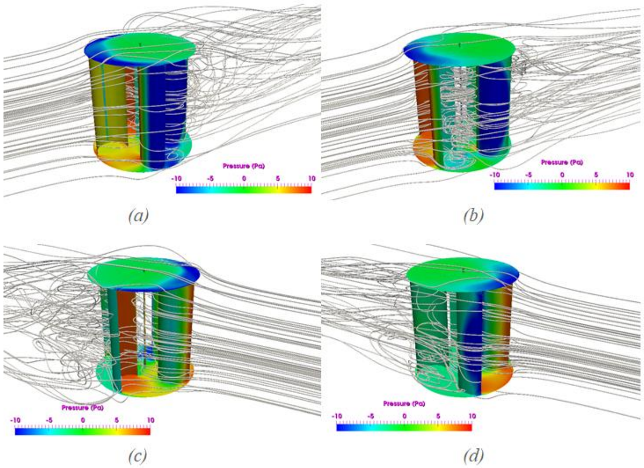

Figure 8: Wind turbine colored by air pressure with air streamlines (a) 0 degree orientation from right side view, (b) 45 degree orientation from right side view, (c) 0 degree orientation from left side view, (d) 45 degree orientation from left side view.

The results show that the convex surface of the blade has low pressure due to air flow acceleration on it while the concave surface of the blade has high pressure due to the air flow impingement on the surface. This condition is resulting a positive torque rotating the axis. Computer simulation calculates the total torque for 0 degree turbine orientation is close to twice of 45 degree orientation and its average torque will be used as a reference for other torque calculations.

3.3. Study of Different Number of Blade

Wind turbine with 5 blades has been investigated and the average power output for 50 RPM is around 12% less than 4 blade turbine. Simulation for 5 blade turbine is performed at 0 and 36 degree orientation and the result for 5 blade turbine is shown in Fig.9 along with normalized average power output comparison between 4-blade and 5-blade turbines.

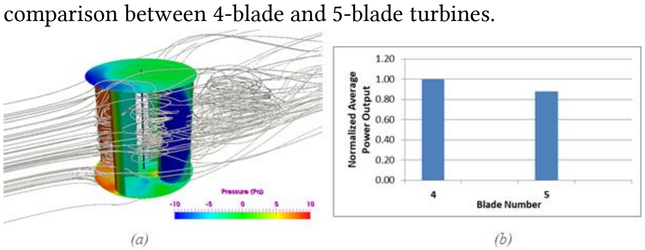

Figure 9: (a) 5-Bladed Turbine simulation result, (b) Normalized Average Power output comparison for 4-bladed and 5-bladed wind turbines.

The result shows that adding more blade to become 5-bladed wind turbine does not improve the performance of the turbine.This might due to having more blade create air flow blockage to other blades.

3.4. Study of Different Blade Radius

Next step is to optimize the radius of the blade with a constraint of chord length to be 1.2m. There are 3 radius are considered: 0.382m, 0.432m, 0.519m. Note that the baseline is using radius of 0.382m. The arrangement of blades with different radius is sketched as shown in Fig.10. The comparison is done with turbine orientation only 45 degree. The normalized power output of wind turbine with different blade radius is shown in Fig.10b. It shows that the larger the radius, the smaller the turbine power output.

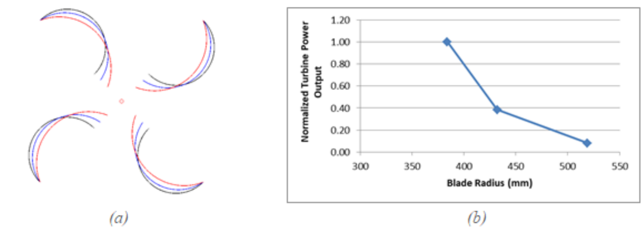

Figure 10: (a) Cross section of 3 turbine blades with different radius viewed from top, (b) Turbine power output for different blade radius.

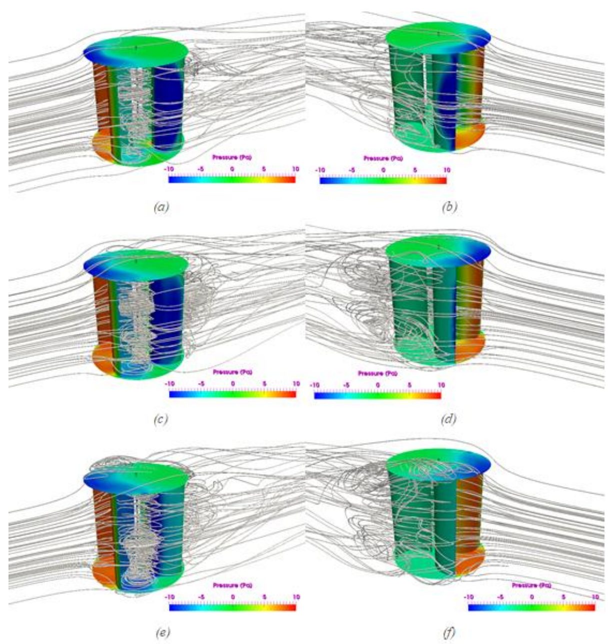

Fig Figure 11: Simulation results of wind turbine colored by air pressure with air streamlines, (a) case for blade radius 0.382m from right view and (b) from left view, (c) case for blade radius 0.432m from right view and (d) from left view, (e) case for blade radius 0.519m from right view and (f) from left view.

Simulation results for different blade radius are shown in Fig.11. Based on the images, the large changes when blade radius is larger is the convex face of the blade. When the radius is larger, convex face of the blade becomes having higher pressure which gives higher resistance to the rotation. The turbine will produce more power when the convex face of the blade has lower pressure and the concave face of the blade has higher pressure.

3.5. Study of Different Blade Orientation

Next optimization is on the blade orientations as shown in Fig.12a. In the test, rotational speed is 50 RPM. The outer edge of the blade is used to rotate blade orientation. The blade orientations considered are +10 degree (green curve in Fig.12a), 0 degree (black), -10 degree (red), -20 degree (blue), -22.5 degree (magenta), -30 degree (yellow). Note that blade orientation 0 degree is the baseline case. The orientation value of -22.5 degree is considered due to its special number, which is 90/4 degree. Simulation shows that from the baseline, increasing the blade orientation does not improve the power output. When the blade orientation is decreased, the power output is improving. Maximal power output which is twice of baseline power output, is obtained when blade orientation is -22.5 degree. Beyond -22.5 degree, the power output decreases.

Optimized wind turbine design from this study is using 4-blade, blade in half circle shape and blade orientation of -22.5 degree.

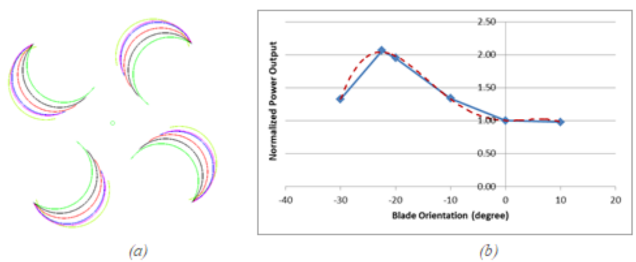

Figure 12: (a) Cross section of turbine blades with different orientations, (b) Normalized wind turbine power output for different blade orientation.

3.6. Optimized Design Performance

The Normalized average power output as a function of turbine RPM and normalized average torque output as a function of turbine RPM are shown in Fig.13.

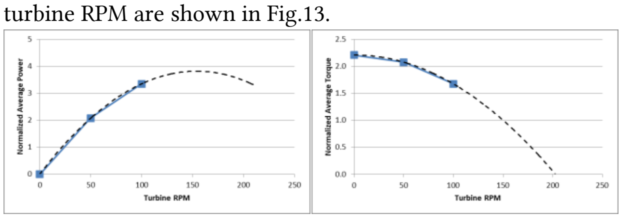

Figure 13: Normalized average turbine power output and normalized average torque as a function of turbine rotational speed.

Based on the Fig.13, the normalized average turbine power peak is at turbine rotational speed of 150 RPM. It seems to be in high value and it needs to be verified by experiment.

The simulation results for 50 rpm case with 0 and 45 degree orientation are shown in Fig.14. The images show that convex surface of the blade with blue color is significantly large at Fig.14a for 0 degree blade orientation while for 45 degree orientation convex surface with blue color moves to the other blade as shown in Fig.14d.

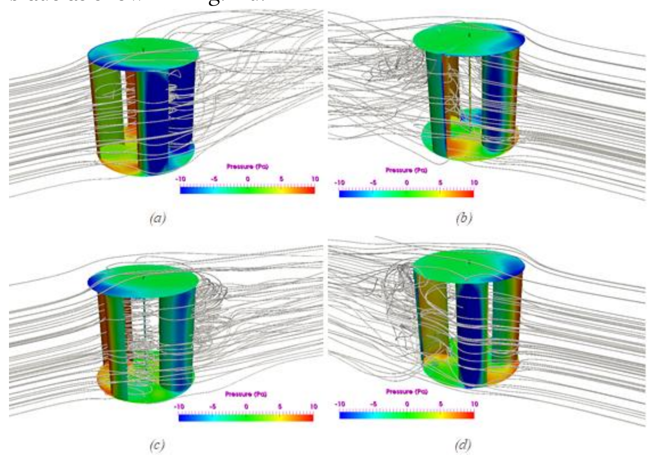

Figure 14: Wind turbine colored by air pressure for 50 RPM case, (a) 0-degree blade orientation, right side view, (b) 0 degree blade orientation, left side view, (c) 45 degree blade orientation, right side view, (d) 45 degree blade orientation, left side view.

3.7. Comparison to Previous Work

The optimized wind turbine design is compared with previous work and the comparion is shown in Fig.15. Both wind turbine have been optimized in term of its aerodynamics.

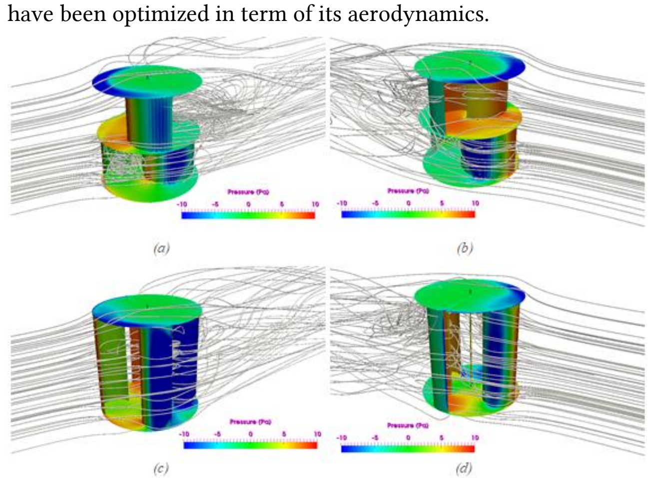

Figure 15: Wind turbine colored by air pressure, (a) Two-level wind turbine from previous work, right side view, (b) left side view, (c) One-level wind turbine, right side view, (d) left side view.

Their relative performance comparison is shown in Fig.16. Based on these graphs, One-level VAWT generate more power output and higher torques on wide range of turbine RPM. Based on CFD simulations, One-level VAWT is better than Two-level VAWT.

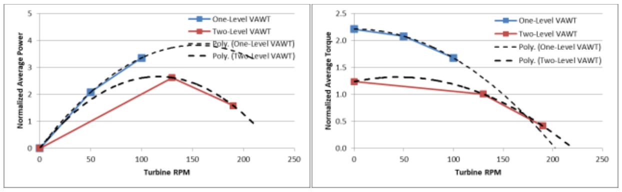

Figure 16: Wind turbine relative performance comparison between One-Level and Two-Level Turbines, (a) Normalized power output curve as a function of RPM, (b) Normalized torque output curve as a function of RPM.

4. Prototyping Process

Next step is to verify the performance of both wind turbines in the field. Prototype constructions for both turbines were done in a workshop at Pamulang, see Fig. 17. The plan is to put both wind turbines in Pelabuhan Ratu area which has a good wind energy potential. Our expectation is that both wind turbine will be performing well, and one-level turbine will perform slightly better than two-level turbine.

Figure 17: Prototype constructions for both (a) Two-Level and (b) One-Level wind turbines.

5. Conclusion

One-level wind turbine has been designed to optimize its aerodynamic performance with material size constraint to be available in the market. Based on consistent CFD simulation procedure, One-level VAWT performs better than Two-level VAWT from previous work.

Verification of the wind turbines performance should be done in the field to confirm simulation results.

Acknowledgement

This research is financed in part by the grant from the Ministry of Research and Higher Education (Kementerian Riset and Pendidikan Tinggi, Risetdikti), with the scheme Penelitian Terapan Unggulan Perguruan Tinggi.

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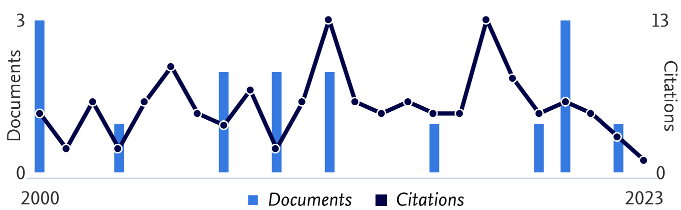

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