# PROCEEDING

ICONETSI

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i

# 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 20$^{th}$ 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**

i

**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.

**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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**(ICONETSI 2020)**

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# TABLE OF CONTENTS

i

## CYBER SECURITY AND ARTIFICIAL INTELLIGENCE



## SOFTWARE ENGINEERING

## AUTOMATION, MECHATRONICS AND ROBOTICS



## LOGISTICS AND SUPPLY CHAIN

## SUSTAINABLE ENERGY AND ENVIRONMENT

RESEARCH-ARTICLE

# Experimental Testbed for Solar PV-Battery Hybrid System

**Authors:** Dena Hendriana, Erikson Ferry Sinaga, Arko Djajadi Authors Info & Claims

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## ABSTRACT

Indonesia has a high potential of solar energy due to its location on the equator and in this paper, experimental testbed for PV-Battery hybrid system is developed and discussed. The hybrid system is designed to supply electricity during the night time with on-grid inverters. Practical and inexpensive solar PV-Battery hybrid system was developed and tested in Tangerang area with flexible AC electric production during the daytime as well as the night time. Practical issues for hybrid system were

level of charged, solar panel electric production is sensitive to its position and clearness from the shading, measurement of cable and component temperature is needed to justify enough cable size to deliver designed electric power, enough capacity of the component and quality of connections, care need to be taken when Lithium-ion batteries are used due to possible explosion for too high charging current.

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## *Index Terms*

Experimental Testbed for Solar PV-Battery Hybrid System

↓ Hardware

↓ Power and energy

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# Experimental Testbed for Solar PV-Battery Hybrid System

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## Abstract

Indonesia has a high potential of solar energy due to its location on the equator and in this paper, experimental testbed for PV-Battery hybrid system is developed and discussed. The hybrid system is designed to supply electricity during the night time with on-grid inverters. Practical and inexpensive solar PV-Battery hybrid system was developed and tested in Tangerang area with flexible AC electric production during the daytime as well as the night time. Practical issues for hybrid system were discovered such as limited range of inverter output voltage, sensitivity of solar panel electric production to its position and shading, accurate DC current sensor, cable and component over-heating, lower inverter conversion efficiency than what specification states, safety on charging Lithium-Ion battery. Conclusions from this study are that wet battery seems to store more electric energy and more robust than the free maintenance battery, battery voltage is not a good indicator for battery level of charged, solar panel electric production is sensitive to its position and clearness from the shading, measurement of cable and component temperature is needed to justify enough cable size to deliver designed electric power, enough capacity of the component and quality of connections, care need to be taken when Lithium-ion batteries are used due to possible explosion for too high charging current.

## Keywords

Photovoltaic, PV, solar panel, battery, hybrid system.

## CCS CONCEPTS

•Hardware~Power and energy~Energy distribution~Smart grid

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## 1. Introduction

Most household is powered by electricity from city electric energy supplier. However, the price of the electricity keeps going higher therefore electricity use needs to be more efficient. To reduce electricity bill, other sources of energy should be considered that can be converted to electricity such as sun radiation, wind, running water, biomass, etc. see [1,2,3,4,5].

The source of energy that is availably abundant in Indonesia is sunlight. Sunlight is available almost everywhere and anytime of the year with different sun radiation intensity due to local weather, such as clouds, fogs, temperature and rains [6,7]. The weather is changing every day and every month and average sun radiation energy can be analyzed in every location to calculate available electric energy harvested from the sun radiation.

Sunlight is only available during the daytime and most household electric demand is high during the night time when the occupants come back home from their daily activity. Energy storage device is needed to store electricity generated from the sunlight during the daytime to make it available during the night time. Battery is mostly used for this purpose. However, the price for battery with enough capacity for household Solar PV system is still expensive. Application of battery for PV system has been discussed in [1,2,8] and optimization of battery capacity for Solar PV system needs to be done in order to minimize the investment cost.

## 2. Literature Review

### 2.1. PVGIS in Indonesia

Photovoltaic Geographical Information System (PVGIS) is a free online solar energy calculator for almost the whole world from America, Europe, Africa and Asia by the European Commission's science and knowledge service [9]. It can calculate annual, monthly and daily output of average power and energy and potential electric generation by solar PV panel with different tilt and orientations. PVGIS utilizes map representing yearly average of daily global solar irradiation on a horizontal and inclined surface. The weather map data is derived by data enhancement of HelioClim-1 database [10] which contains 20-years average, period of 1985-2004. PVGIS contains several calculations

- Computation of clear-sky global irradiation on a horizontal surface.
- Sky obstruction by local terrain features (hills or mountains) calculated from the digital elevation model.

- Interpolation of the clear-sky index and computation of global irradiation on a horizontal surface.

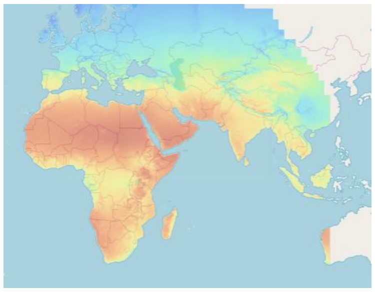

**Figure 1: Map of global irradiation in Africa and Asia containing 20-years data average [9].**

Fig.1 shows the global irradiation map in Africa and Asia. It shows that solar irradiation in Indonesia is not as high as in Africa due to lower solar irradiation level, however, it is still high enough to be harvested for electricity.

## 2.2. Poly-Crystalline Solar Panel

The most common solar panel sold in the market is Poly-Crystalline silicon based solar panel with its efficiency converting sunlight energy to electrical energy of around 17%. Recently, its price is getting lower due to advancement of technology in manufacturing process for this type of solar panel and abundantly cheap raw material. Market share of Poly-Crystalline solar panel in the year of 2010 is around 53% [11]. This type of solar panel is used for this development. Other type of solar panel is Mono-Crystalline which is slightly more efficient than Poly-Crystalline but slightly more expensive, see Fig. 2.

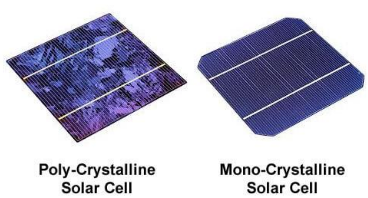


**Figure 2:** Comparison of Poly-Crystalline and Mono-Crystalline.

## 2.3. Battery

There are several types of battery that can be used for solar PV hybrid system, such as lead-acid, nickle-cadmium and sodium-sulfur batteries. However, automotive 12-Volt lead-acid battery is quite common to be used due to its availability and affordability. In the hybrid system, the battery voltage should be set as high as possible to reduce electric current for the same electric power. However, the battery voltage should be suitable with electric charger controller being used in the hybrid system. Typical charger controller works with multiple options of voltage: 12V, 24V, 36V, 48V, or higher.

Battery is not only used to store electric energy, it can also be used to stabilize the electric grid system. Battery storage power plant with large power capacity can be used for short-term peak power supply and ancillary services to provide frequency respond to minimize power outages.

Other type of battery, Lithium-ion batteries type 18650 was tested in this study. Its specification is 3400 mAH, 3.7 Volt and its continuous discharge current of 20 A. However, the batteries exploded due to too high charging current during the first day. We stopped using this type of battery due to safety.

## 2.4. On-Grid Inverter

One of important component in the Solar PV-Battery hybrid system is on-grid inverter. This device can convert DC to AC electric current. The term on-grid means that AC electric output of the inverter can be injected to an electric power grid. To inject electric power safely and efficiently into the grid, on-grid inverters must accurately match the voltage and phase of the grid sine wave AC waveform. A high-quality on-grid inverter has a fixed unity power factor and its phase angle is within 1 degree of the AC power grid.

On-grid inverter is designed to produce zero power when the utility grid goes down. This is a NEC requirement [12] to ensure that in the event of blackout, the on-grid inverter will shut off to prevent electric power transfer to the wireline harming workers fixing the grid wires.

Typical specification of the on-grid inverter can be seen in Fig. 3. This inverter has a conversion efficiency from DC to AC of around 86%.

Technical parameter — GTI-D-series

| Model | GTI-D1000B | GTI-D600B | GTI-D300B |
|---|---|---|---|
| Output Power | 1000W | 600W | 300W |
| Solar Panel | Vmp:35-39V,Voc:42-45V | | |
| MPPT Voltage Range | 30-40V | | |
| AC Voltage Range | 190-260V | | |
| Voltage Frequency | 50HZ±1% | | |
| Power factor | >97.5% | | |
| MPPT Efficiency | >99% | | |
| Total Harmonic | <5% | | |
| Phase Shift | <2% | | |
| Conversion Efficiency | >85% | >86% | >87% |
| Maximum Efficiency | >89% | >89% | >90% |
| Operating | -20°C-45°C | | |
| Waterproof Rate | Interior Design | | |
| Cooling Mode | Intelligent design of the electric fan control system | | |
| Standby Power Loss | 2-3W | | |
| Product Size | 257*195*88.5mm | 210*195*88.5mm | 180*195*88.5mm |

**Figure 3: On-grid inverter specification.**

Notice that this inverter works in the range of grid voltage of 190-260 Volt. In some area, it is often that PLN voltage drops below 190 Volt and when this happens, the inverter cannot produce AC electricity until the grid voltage higher than 190 Volt.

## 2.5 Electric Charger Controller

The main purpose of electric charge controller is to protect the battery from over-charging and over-discharging which can reduce battery performance or lifespan. The controller can stop charging process when the voltage of battery exceeds a set high voltage level. Maximum power point tracker (MPPT) is a technology that can adjust charging rates depending on battery level to charge closer to the battery maximum capacity [13].

Charger controller may have battery temperature monitoring to prevent over-heating of the battery.

## 2.6 Heat on Cable and Component

A solar cable is used to interconnect solar panels and electric components in the solar PV hybrid system. Solar cable is designed to be ultra violet resistant, weather resistant and can be used in wide range of temperature.

Over-heating on a cable can take place when high electric current occurs on the cable, such as due to short-circuit, or simply because the cable is too small to deliver the required electric power. Over-heating cable can cause damage to the cable, shorten its lifespan and can cause fire and injury.

Good solar PV system should not have cable over-heating problem in its system and enough cable size is used in the system.

# 3. Methods

## 3.1. Experimental Testbed System

**Table 1: Battery configurations for each group.**

| Group Number | Group -1 | Group - 2 | Group - 3 | Group - 4 |
|---|---|---|---|---|
| Battery number | 3 | 3 | 3 | 3 |
| Type of battery | Free Maintenance | Wet | Wet | Free Maintenance |
| Battery Capacity | 100 Ah | 60 Ah | 100 Ah | 100 Ah |
| Total Voltage | 36 V | 36 V | 36 V | 36 V |
| Total KWh Capacity | 3.6 KWh | 2.16 KWh | 3.6 KWh | 3.6 KWh |

Testbed of Solar PV hybrid system is developed with solar panel and battery as main component in the system. This system is designed to store electric energy in the battery to be used in the night time after 18:00 where household electric demand start to go higher. Electric supply from the hybrid system will stop whenever the battery runs out of energy. Concept of hybrid system can be seen in Fig. 4. Total solar panel capacity is 4000 Watt Peak (Wp) and splitted into 4 groups with each of 1000 Wp. Each group is equipped with different group of 3 units of 12-Volt batteries in series with total of 36V connected to electric charger controller. Each group of battery is connected to on-grid inverter with a switch connector controlled by an Arduino Mega System. Each group is also equipped with power meter to measure electric energy and power deliver to the power grid. Different types of battery is used to measure their performance, see Table 1.

Capacity calculation for this system as follows. Each group uses 1000 Wp solar panel. Based on PVGIS result on the site from previous work [14], annual electrical energy using 1kWp solar panel is 1260 kWh, or average 3.45 kWh per day. Ideally, total battery capacity should be able to store 3.45 kWh generated during daytime to be used in the night time.

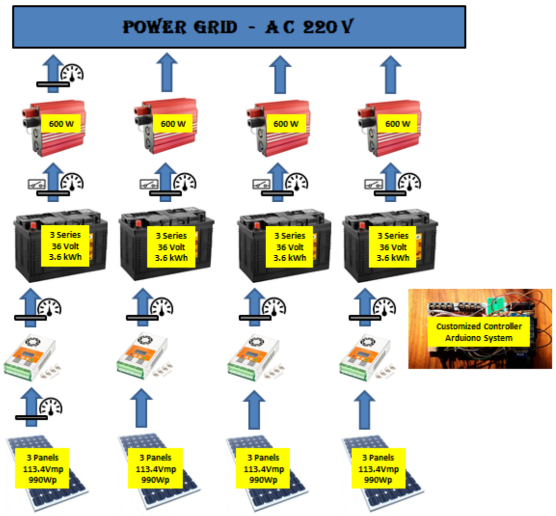


**Figure 4: Four (4) groups of Solar PV-Battery hybrid system each consists of 1000 Wp solar panel, electric charger controller, 3 units of 12V battery and 600W on-grid inverter.**

With the energy of 3.45 kWh per day, 600 Watt On-Grid inverter can run for 3.45 kWh / 0.6 kW = 5.75 hours. When the inverter is ON at 18:00, it should run until 23:45.

Ideally, four of the hybrid systems can save total electric energy of 3.45 kWh x 4 = 13.8 kWh and with the PLN price of 1 kWh to be Rp. 1,500 the total saving is 13.8 x 1,500 = Rp. 20,700 per day or Rp. 621,000 per month.

## 3.2. Setting Parameter

An Arduino Mega is used in the hybrid system as an electronic controller to control and turn ON/OFF the on-grid inverters and electric fan. The inverter activation depends on current time, battery voltage, and rule for electric delivering process.

Electric fan is used to cool the electric panel box and it turned ON based on inverter activation and current time. Source of heats inside the panel box are inverters and electric chargers. The electric chargers are usually on peak of demand during the middle of the day when sun is on the peak.

## 3.3. Prototype

Prototype of four (4) groups of solar PV-Battery hybrid systems was constructed in an electric panel box with the size of 1.2m x 0.8m x 0.25m for electric components and wirings as shown in Fig. 5.

In the electric panel box, 4 units of electric charger controller and 4 units of on-grid inverters are installed. In the middle, 4 units of MCB for DC electric lines along with 4 units of Surge Protection Device (SPD) are installed to protect from electric surge of possible lighting. 2 units of MCB for AC electric lines are also added. 8 units of DC power meters are installed on the door panel. To measure electric energy from and to the batteries.

The batteries are stored in a rack outside of the panel box and connected by large wirings.

**Figure 5: Electric panel box containing electric components of four groups of solar PV-Battery hybrid systems.**

When the hybrid systems are running and the box door is closed, the air inside the box is hot. So, the air inside the box is hot during the daytime when the charger controllers are running and during the night time when the inverters are running. To cool the box, small fan is installed on the door to pull fresh air entering the box and the rules for the fan:

Fan is ON if

- Current time between 12:00 to 18:00
- Or when any of inverter is ON

When the prototype was tested, the inverters were not running for around 6 hours as estimated based on amount of kWh and they were running only for around 1 hour. It seems that the battery capacity is significantly less than what stated in its specifications. Because of this situation, condition of inverter ON is set to only let them run with maximum of two units simultaneously.

Night time: Inverter ON if

- Current time between 18:00 to 06:00
- Battery voltage > 31 Volt
- Maximum of 2 units running simultaneously

The last condition is applied to extend the electric power supply from the hybrid system.

On the other hand, since the battery capacity is low, there will be excess electricity from solar panel that cannot be stored in the battery during the daytime. To utilize this excess electricity, inverters can be ON during the daytime when the battery is considered full. Inverter rule during daytime:

Daytime: Inverter ON if

- Battery voltage > 42 Volt

Daytime: Inverter OFF if

- Battery voltage < 37.5 Volt

# 4. Results and Analysis

## 4.1. System Performance Measurement

There are several practical problems in running the prototype:

- One of the inverters failed only after 2 weeks testing. Mosfet components inside the inverter were failed and burned.
- One of solar cable failed after only 4 weeks testing. One of the connectors was failed and burned.
- Cables to the battery were hot even though the cable size requirement is satisfied. This might due to low quality of cables.
- Power meter from the solar panel to the electric charger controller is not working well.
- Lithium-ion batteries type 18650 exploded due to too high charging current.
- All current sensors were not working properly. So, electric power and energy cannot be calculated. Only voltage sensors are working although sometimes giving incorrect value.

Fig. 6 shows the history of battery voltage of each group for one-day data.

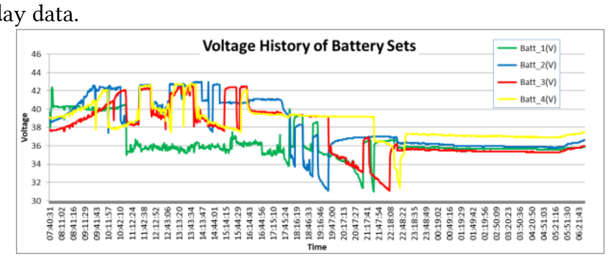


**Figure 6: One-day data for the history of each group battery voltage.**

The graphs shows that battery 2, 3 and 4 were charging started from around 6:00 in the morning indicated by the rise of voltages. Voltage sensor for battery 1 seemed to be failed at the beginning. When the battery voltage reached 42V, starting with battery 2, then 4, and 3, the corresponding inverters were ON indicated by the drop of voltage due to power drawing by the inverters. When the battery voltage reached 42V at the first time around 10:00 in the morning, the corresponding inverter was ON only for few minutes. This indicates that the battery was not really full. Around 11:00, battery voltage 2, 3, and 4 are dropping for longer time, indicating longer inverter runs. Short inverters run happened again at around 13:15. Battery voltage 3 and 4 are dropping from14:00 to 15:15 indicating longer inverter runs for number 3 and 4.

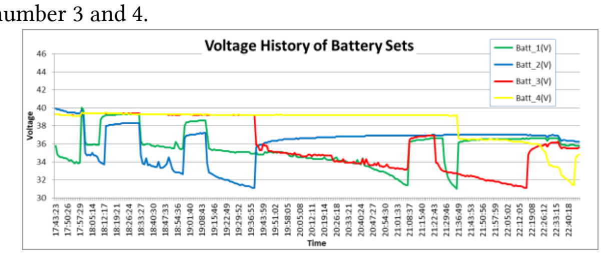


**Figure 7: History of each group battery voltage after 18:00.**

Fig. 7 shows the same history data but zooming at the period after 18:00 to 23:00 when all hybrid systems produce their energy out to supply the electricity. The graph shows that at 18:00, battery 1 and 2 are working for around 10 minutes and stopping for around 20 minutes, from 18:10 to 18:33. Both are working again and stopping again around 18:58. Again, both are working at around 19:11. Battery 2 runs out of energy at around 19:38 indicated by its voltage drops to lower limit of 31V. At the same time, battery 3 starts to work together with battery 1 and both are stopping at 21:08. Then both are running again at 21:24 and battery 1 runs out of energy at 21:36. At the same time, battery 4 starts to work together with battery 3. Battery 3 runs out of energy at around 22:16 and battery 4 runs out of energy around 22:44. From this history, it shows that Battery 1 runs the longest and battery 3 runs the second longest.

To complete the data, Fig. 8 shows graph of inverter flag ON/OFF. Note that even though the inverter flag is ON, sometimes the actual inverter is OFF, indicated by battery voltage to remain high. This could be due to PLN voltage to be less than 190 Volt which prevents the inverter to be running.

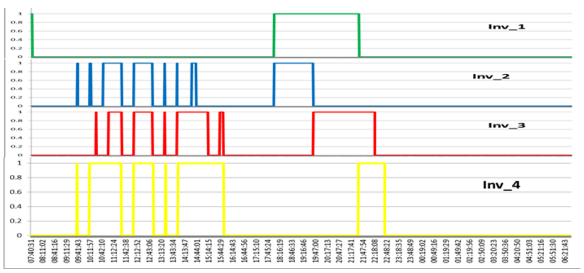


**Figure 8: History of each group inverter flags (1=ON, 0=Off)**

Based on this one-day data, we can conclude:

- battery 1 is completely not working during the daytime and gives the longest power during the night time.
- battery 4 is the most active power generation during the daytime and short during the night time.
- Battery 3 (wet type) seems to store more electric energy than battery 4 (free maintenance type) indicated by battery 3 running longer during the night time.
- Battery voltage is not a good indicator for battery level of charged. Battery charging current should do better.
- Voltage sensor for battery 1 is not reliable.

## 4.2. Energy Analysis of kWh Measurements

The solar PV-Battery hybrid system is equiped with 4 DC power meters and 1 AC power meter as shown in Fig. 9.

Manual data taking from these power meters has been done for several days and the data is shown in a table Fig. 10. Note that the energy measurements will cover both daytime and night time inverter activities.

The table in Fig. 10 shows that for 9 days of testing, battery 1, 2, 3, and 4 produced 16, 15, 26 and 26 kWh and all the DC energy combined is 83 kWh. Notice that hybrid system group of 3 and 4 produces 60% more than group 1 and 2. This could be due to solar panel position for group 3 and 4 to be higher and more open to the sunshine than group 1 and 2.

**Figure 9: AC and DC power meters.**

| No | Day | Date | Hour | KWh AC | KWh Batt_1 | KWh Batt_2 | KWh Batt_3 | KWh Batt_4 |
|---|---|---|---|---|---|---|---|---|
| 1 | Sunday | 03-11-19 | 7:31 | 148.2 | 77 | 58 | 53 | 59 |
| 2 | Monday | 04-11-19 | 6:26 | 154.7 | 79 | 59 | 55 | 62 |
| 3 | Tuesday | 05-11-19 | 7:14 | 160.9 | 81 | 60 | 57 | 64 |
| 4 | Wednesday | 06-11-19 | 7:55 | 168.5 | 84 | 62 | 60 | 67 |
| 5 | Thursday | 07-11-19 | 6:43 | 172.7 | 86 | 63 | 62 | 68 |
| 6 | Monday | 11-11-19 | 7:13 | 204.9 | 91 | 72 | 76 | 82 |
| 7 | Tuesday | 12-11-19 | 6:35 | 212.4 | 93 | 73 | 79 | 85 |
| *9 day enegy generation (7-1):* | | | | **64.2** | **16** | **15** | **26** | **26** |
| | | | | | | | *Total DC energy generation:* | **83** |

**Figure 10: AC and DC power meter manual collection data for several days and total AC and DC energy calculations.**

Notice also that energy measurement from AC power meter is less than from total DC power meters, with ratio of 64.2/83 = 77%. This is due to conversion efficiency for DC to AC electric current change in the inverters which is 86% based on their specification. The possibility is that the actual inverter conversion efficiency is lower than what is stated, or inverter standby electric consumption which is around 2-3 watt that increase DC electric consumption without producing AC current, or DC power meter is not very accurate.

## 4.3. Thermal Measurements

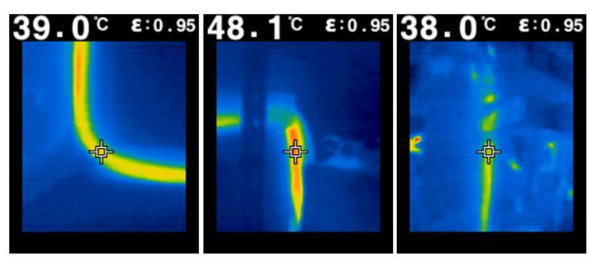


**Figure 11: Thermal image of cables connecting to the batteries.**

When electric current in the cable is too high, over-heating can happen. This effect is investigated in the prototype at time of 19:00 when we expect large current to the inverter and to the output of the hybrid system. Heat measurements on the cables are done using thermal imaging camera FLIR TG165. The results for cables connected to the battery are shown in Fig. 11. It shows that cable temperature can be as high as 48C which is quite hot.

This indicates that the cable needs to be improved with larger cable.

Fig. 12 shows the thermal image results of the cable connecting to the DC power meter on the box door. It shows that the DC power meter temperature can go up to 56C which indicates that the current flowing to the component larger than its capacity.

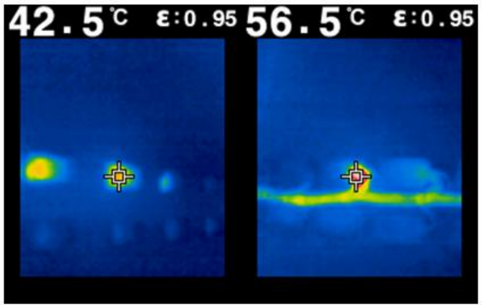


**Figure 12: Thermal image of cables connecting to the DC power meters on the box door.**

Fig.13 shows thermal image for batteries. The surface temperature of batteries are less than 33C, which is low temperature. However, battery cable connectors are quite hot.

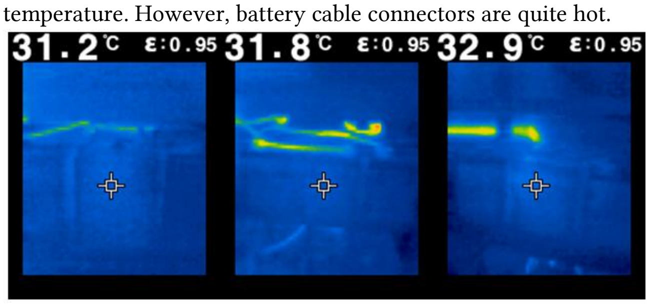


**Figure 13: Thermal image of batteries.**

## 5. Conclusions

When the hybrid system actively produces AC electricity during the daytime, electric energy left in the battery is low and the battery cannot produce AC electricity optimally during the night time. Optimization needs to be done to maximize AC electric production during the night time.

Wet battery seems to store more electric energy and more robust than the free maintenance battery. It might due to some leakage of the free maintenance battery and the cell becomes dry.

Battery voltage is not a good indicator for battery level of charged. Battery charging current should do better.

Solar panel electric production is sensitive to its position and clearness from the shading.

Inverter conversion efficiency can be lower than what the specification states which might due to inverter standby electric consumption.

Measurement of cable and component temperature is needed to justify enough cable size to deliver designed electric power, enough capacity of the component and quality of connections.

Care need to be taken when Lithium-ion batteries are used due to possible explosion for too high charging current.

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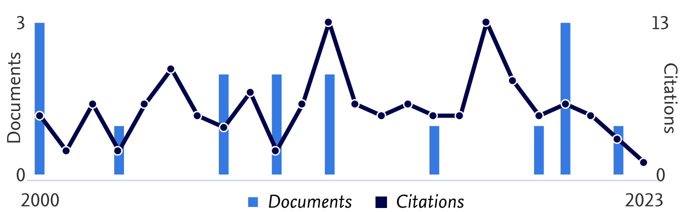


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