2017 年度 試験研究助成 一覧

＜インドネシア＞2017 年度　試験研究助成テーマ一覧

2017/09/14

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2		Desulfurization of Liquid Feul Using Rice Straw Supported Nanoparticle (Fe3O4/NCs and Cu/NCs) Prepared from Waste Materialsl 廃棄物から調製した稲わら担持ナノ粒子（Fe3O4 ナノコンポジットおよび銅ナノコンポジット）を用いた液体燃料の脱硫化	Dr. Ir. Antonius Herry Cahyana
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2		Development of A New Gas Sensor for Detection of Toxic Gas of Environment 環境中の有毒ガス検出のための新しいガスセンサの開発	Prof. Dr.-lng. Mitra Djamal Drs. Maman Budiman, M.Eng, Ph.
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FINAL REPORT

OSAKA GAS FOUNDATION
OF INTERNATIONAL CULTURAL EXCHANGE
Year 2017/2018

BIOHYDROGEN PRODUCTION BY TACKLING METHANOGENESIS
IN A MICROBIAL ELECTROLYSIS CELL (MEC) THROUGH
BIOLOGICAL COMPETITION

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I. INTRODUCTION

1.1. Background

In the age of intense industrial activities and population growth, the world is facing an environmental problem in the increased amount of pollutant released to the nature. Pollutants can be found in soil, aquatic systems, as well as the air. The effects of pollutants vary according to its type. In general, they are harmful to the ecosystem and its components. For example, fossil fuels contribute to the release of Greenhouse Gases (GHGs) to the atmosphere. GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and water vapor. These gases are tightly linked to the global warming phenomena. Global warming itself has generated momentum in the shift into clean energy not only within the academic community but the political sector as well, as proven by the Paris Agreement and similar international accords concerning environmental protection. As a result, sustainable energy sources are offered, especially for fuel such as: methanol, compressed natural gas, and ethanol. However, these options are problematic in their adoption due to the need of major infrastructural changes and lack of private benefits (Kumar, Britter, & Gupta, 2009).

Recently, hydrogen emerges as an alternative energy in lieu of fossil fuels. Burning hydrogen gas (H_2) emits close to zero carbon dioxide and pollutants to the atmosphere (Kadier, Kalil, et al., 2016). Hydrogen combustion in an internal-combustion engine emit, for the most part, water vapor alongside a fraction of nitrogen oxides, while in fuel cells/electrochemical engines the process is much cleaner as zero nitrogen oxide is released (Hoffmann & Dorgan, 2012). Moreover, hydrogen fuel is considered high in calorific value in the range of 120-142 MJ/kg in comparison with petrol fuel at 44-46 MJ/kg or diesel fuel at 45 MJ/kg ("Heat values of various fuels - World Nuclear Association," n.d.). From the political and economic point of view, hydrogen fuel has no direct opposition (Kumar et al., 2009). Hydrogen fuel can be made from almost all types of feedstock, including gasoline, coal, natural gas, nuclear, gas, biomass, wind, and solar power, which allows the current giant in the energy sector, the oil industry, to shift to this new platform. All these factors support the idea that hydrogen is predicted to be the fuel of the future.

To date, hydrogen fuel is mainly derived from fossil fuels via steam reforming, pyrolysis, and gasification (Acar & Dincer, 2014). Aside from fossil-based resources, hydrogen fuels are also derived from electrolysis of alkaline solutions at high temperatures.

However, the processes above require a lot of energy and are not always environmentally friendly (Saraphirom & Reungsang, 2010). Ultimately, they are not suitable nor sustainable hydrogen production processes if one seeks to replace fossil fuel with a clean, renewable one.

Several hydrogen production processes from renewable resources have been assessed thoroughly (Kadier, Kalil, et al., 2016; Saraphirom & Reungsang, 2010); coined as green methods (GM). These processes include water electrolysis, biophotolysis, photo-fermentation, and dark fermentation, each bearing their own advantages and disadvantages (Lalaurette, Thammannagowda, Mohagheghi, Maness, & Logan, 2009; Azwar, Hussain, & Abdul-Wahab, 2014; Dincer & Zamfirescu, 2012). Water electrolysis and photofermentation require high energy input in order to produce hydrogen (Dincer & Zamfirescu, 2012). On the other hand, biophotolysis as well as dark fermentation require less energy input yet both methodologies are lacking in hydrogen production efficiency (Manish & Banerjee, 2008; Ust'ak, Havrland, Muñoz, Fernández, & Lachman, 2007). Among the biological pathways, dark fermentation has the highest substrate conversion rate (Meherkotay & Das, 2008). Most of these processes result in biohydrogen, referring to hydrogen gas produced through various biological routes or thermo-chemical biomass treatment (Lu et al., 2011).

1.2. BES in MEC Configuration as a Potential Hydrogen-Generating Platform

Bioelectrochemical Systems (BES) are a decade-old technology that allows production of value-added compounds from wastewater through electrical current input (Hong Liu, Grot, & Logan, 2005). These systems include microbial fuel cells (MFC) and microbial electrolysis cells (MEC). BESs themselves have been developed for a wide range of applications, including wastewater treatment, fuel gas production (H_2 & CH_4), nutrient removal and recovery, chemical synthesis, desalination, and bioremediation (Hong Liu et al., 2005; Sleutels, Ter Heijne, Buisman, & Hamelers, 2012).

Core tenet of BES operation relies on the presence of a group of microorganism called exoelectrogens/anode-respiring bacteria (ARB) that are capable of utilizing an external insoluble electrode as electron acceptor. These microorganisms metabolize organic matter anaerobically and transfer the extra electrons generated in the process to the electrode. The flow of electrons is used to reduce protons into hydrogen at the system's cathode, producing biohydrogen (Hong Liu et al., 2005; Montpart, Rago, Baeza, & Guisasola, 2015; Sleutels et al., 2012).

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While processes occurring in MFC are thermodynamically favored, hydrogen production in MEC is not and requires electrical input. When compared to already existing technologies such as dark fermentation and photosynthesis, MEC is better at producing biohydrogen because of several reasons: Firstly, they require much lower energy input compared to water electrolysis. Secondly, they have higher hydrogen yield than most alternatives (Lin et al., 2007). Thirdly, the MEC only requires organic waste as feed. When compared to conventional hydrogen production from fossil fuel in a refinery process (Lin et al., 2007), MEC is much more sustainable both in terms of environmental consequences (does not emit pollutants) and using renewable resources as input (Lin et al., 2007).

1.3. Drawbacks in Utilizing MEC - Methanogenesis

MEC utilizes the biochemical pathway of exoelectrogenic bacteria to produce H_2. Exoelectrogenic or Anode Respiring Bacteria (ARB) are capable of transferring electrons gained from their metabolism out of the cell and use solid materials as electron acceptor, in this case the anodes. The electrons will flow through the electrode and directed to the cathode to react with protons, yielding hydrogen. The protons are generated in anodic oxidation process and are transported from the anode to the cathode through the electrolyte (Rago, Ruiz, Baeza, Guisasola, & Cortés, 2015).

MEC operates under anaerobic condition. The system utilizes organic matter as substrates. As a result, a range of microbial community can flourish inside the MEC, including methanogens. Methanogens are obligate anaerobic microorganisms that are able to generate methane from both carbon substrate such as acetate or molecular H_2 (H. Hu, Fan, & Liu, 2008). Naturally, the presence of methanogens in the MEC reduce H_2 yield as a result of carbon substrate competition with exoelectrogens and/or hydrogen product consumption. The produced CH_4 may stem from the solution, the electrodes, or the wall of the reactor. The proliferation of methanogens is one of the most reported cause of failures and biggest challenge of MEC utilisation (H. Hu et al., 2008; Lu et al., 2011; Lu, Xing, & Ren, 2012; Rago et al., 2015). The activity of methanogens in a biohydrogen producing MECs severely suppresses the yield and purity of the product.

Methanogens may be divided into two types: acetoclastic and hydrogenotrophic. Acetoclastic methanogens, for example, methanobacteriales (MBT) and methanomicrobiales (MMB) convert acetate into methane (Karthikeyan, Cheng, Selvam, Bose, & Wong, 2017; Lu et al., 2012). The presence of acetoclastic methanogens that consume the same carbon substrate prove to be a competitor to exoelectrogens, in turn decreases electron transfer efficiency from the electron donor to the electrode (Lu et al., 2011). On the other hand, hydrogenotrophic methanogens make use of hydrogen produced in the cathode alongside carbon dioxide as substrates for methane generation (Karthikeyan et al., 2017; Lu et al., 2011). Methanocarcinaceae (MSC) and Methanosaetaceae (MST) are examples of hydrogenotrophic methanogens (Lu et al., 2012).

The methanogen proliferation problem is especially true in a membraneless, single-chambered MEC. In this configuration, H_2 can freely diffuse from the cathode to the solution. However, membranes used in double or triple-chambered MEC systems are known to be very expensive. Rozendal, Hamelers, Rabaey, Keller, & Buisman, (2008) suggested that ion exchange membrane can be accounted for nearly half of the capital cost of a laboratory-scale MEC.

Knowledge and understanding of the methanogenesis process and the metabolic system of the methanogens is crucial, given that the presence of methanogens is detrimental to hydrogen production process especially in single-chambered MECs. Researchers are aware of the problem, thus techniques/methodologies to prevent loss from methanogenic activity are actively developed in order to gain high hydrogen yield and purity from future implementation of this platform.

1.4. Current Efforts to Suppress Methanogenesis

Over the past years, several approaches have been used to optimize H_2 production through methanogenesis inhibition, such as: temperature manipulation, antibiotics, UV irradiation, cathode exposure to air, pH treatment, applied voltage conditioning, and addition of halogenated hydrocarbons (Catal, Lesnik, & Liu, 2015; Hou et al., 2014; H. Hu et al., 2008; Lu et al., 2011; Zhang, Bai, Fan, & Hou, 2016). However, these methodologies can still be improved in their applications.

The effect of parameter manipulations such as temperature and pH cannot be isolated towards methanogens, which prove to be disadvantageous to the growth of exoelectrogens (Chae et al., 2010; Kim, 2003; Lu et al., 2011). On the other hand, the addition of chemical substances such as antibiotics and halogenated hydrocarbon manage to selectively inhibit methanogens (Catal et al., 2015; Zhang et al., 2016). However, the use of antibiotics and chemicals possess environmental risk and increased difficulty in sludge and spent medium removal. Currently, little to no research is aimed towards biological means of methanogen population control in MECs.

The novelty that comes from utilizing microbes-based solution for solving environmental problems comes from the fact that they are very diverse in number, each possessing their own unique genetic makeup and enzyme pathway. These microbes can be found on nearly any habitat, successfully adapting to whatever the environment has in store for them. Some microbes are known to synthesize useful products for humans including biofuel and drugs, while others break down pollutants (Anne Trafton, n.d.).

In one account back in 2010, when the Deepwater Horizon oil spill happened and released approximately 4.9 million barrels of crude oil to the Gulf of Mexico (*Summary Report for SubSea and SubSurface Oil and Dispersant Detection: Sampling and Monitoring*, n.d.), scientists discovered that the indigenous microbial community is capable of degrading the spillage. It has been noted that various compounds in the crude oil were degraded by different kind of microbes as well (P. Hu et al., 2017).

Alluding to the case above, by design one should select potential competing microbes from those that strive in wastewater to be used inside the BES providing a suitable environment for these bacteria to grow and adapt. As microbes are also exceptionally remarkable at adaption, it is hypothesized that microbial community found in wastewater, for example denitrifiers, will be able to compete with the methanogens for substrate and act as a biological control to prevent methanogen population from rising too high. This could successfully lead to methanogen population suppression and increase biohydrogen production in the MEC.

1.5. Research Description

This research proposes the introduction of biological control method through bioelectrode enrichment with isolated colony of denitrifying bacteria to the MEC system as natural competitor to methanogens, ultimately aiming for inhibition of methanogenic, hydrogenotrophic microbial growth. Denitrification is the conversion pathway of fixed nitrogen compounds (NO_3^- & NO_2^-) into gaseous nitrogen compounds such as NO, N_2O, and N_2. Based on this ability, denitrifying bacteria is the commonly used biological technique to clean aqueous nitrate and nitrites out of the water (Clifford & Liu, 1993). The process preferably occurs in anaerobic environment, such as those found in MEC system (Zumft, 1997). Bioelectrochemical Systems (BES) have been previously demonstrated for nutrient removal and recovery, one of the applications is nitrogen removal utilizing the denitrification pathway (Kelly & He, 2014; Hao Liu, Yan, & Shen, 2014a). Zhu, Wang, Yan, He, & Zhang, (2017a) developed a three-chambered BES reactor for simultaneous biohydrogen production and nitrate removal. However, single-chambered BES configuration to accommodate for both hydrogenesis and denitrification are yet to be developed to the extent of the Author's knowledge.

Theoretically, the methanogens and the denitrifying bacteria will compete with each other for hydrogen. This research intends to analyze the relationship between denitrifiers and methanogens and its effect on biohydrogen yield, and to demonstrate a novel method of reducing hydrogenotrophic methanogens population in an MEC reactor through direct biological competition. By achieving both outcomes, it could lay down the necessary path for future researches with aim to increase biohydrogen production in an MEC.

1.6. Objectives

This research aims to:

1. Introduce and evaluate biological means of methanogen control in an MEC system through bioelectrodes enrichment with denitrifying bacterial isolate.

2. Demonstrate single-chambered MEC as platform technology for water treatment (denitrification) and hydrogen generation.

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1.7. Research Alignment and Contribution to OGFICE

The research is aligned with OGFICE's funding company, Osaka Gas, in its aims. Aside from biohydrogen as clean energy, also aiming at the utilization of BES as a platform for wastewater treatment in this case at denitrification. For reasons stated above, a shift into a cleaner form of energy is also a step into environmental preservation through minimization of burdens added to the environment from human activities. Moreover, denitrification serves directly as an effort to tackle the issue of water pollution, especially in Indonesia where the resources and effort surrounding wastewater treatment in lacking.

The Osaka Gas Group has formulated an 'Environmental Philosophy' in 1992 and has begun integrating environmental conservation activities in accordance with its policy. The research fits in nicely into CSR Charter II of the company, which calls for environmental protection and contribution towards realizing a sustainable society.

II. METHODS

2.1. Research Stages

This research titled "Improvement of Biohydrogen Production in Microbial Electrolysis Cell (MEC) System by Tackling Methanogenesis through Biological Competition at the Biocathode" aims to ascertain the effect of denitrifier presence in a MEC towards the growth of methanogen. Denitrifier culture will first be grown in anaerobic medium will be inoculated into the MEC reactor. The inoculated reactor will be then run in parallel with a control in order to confirm the hypothesis of the research.

Only of resulting variable of the experiment that is considered important and correlates with the hypothesis will be analyzed, which is the headspace gas located in the space between rubber septum and the working fluid of the reactor. The composition of the headspace gas present in an inoculated reactor will be compared to the that of control reactor, in order to know the effect of denitrifier and its metabolic products in the reactor.

Other variables which will be regarded as supporting additional information are reactor voltage, color of the working volume, and the visual appearance of the electrode. Change in recorded voltage and therefore current is used to determine the time the medium needs to be replaced. Color change of the liquid will confirm the growth of microorganism inside the reactor. Growth of white, thin-like substance on the anode is assumed to be the biofilm of the exoelectrogenous bacteria. Evolution of bubbles on the cathode will be used to confirm evolution of gas, in this case H_2 which is known to have relatively low solubility in water (0 – 1,5 mg/L at T = 25°C, P_{H_2} = 1 atm) that makes it insoluble in water (Kadier et al., 2015). The stages of the research as a whole is picturized in Figure 1.
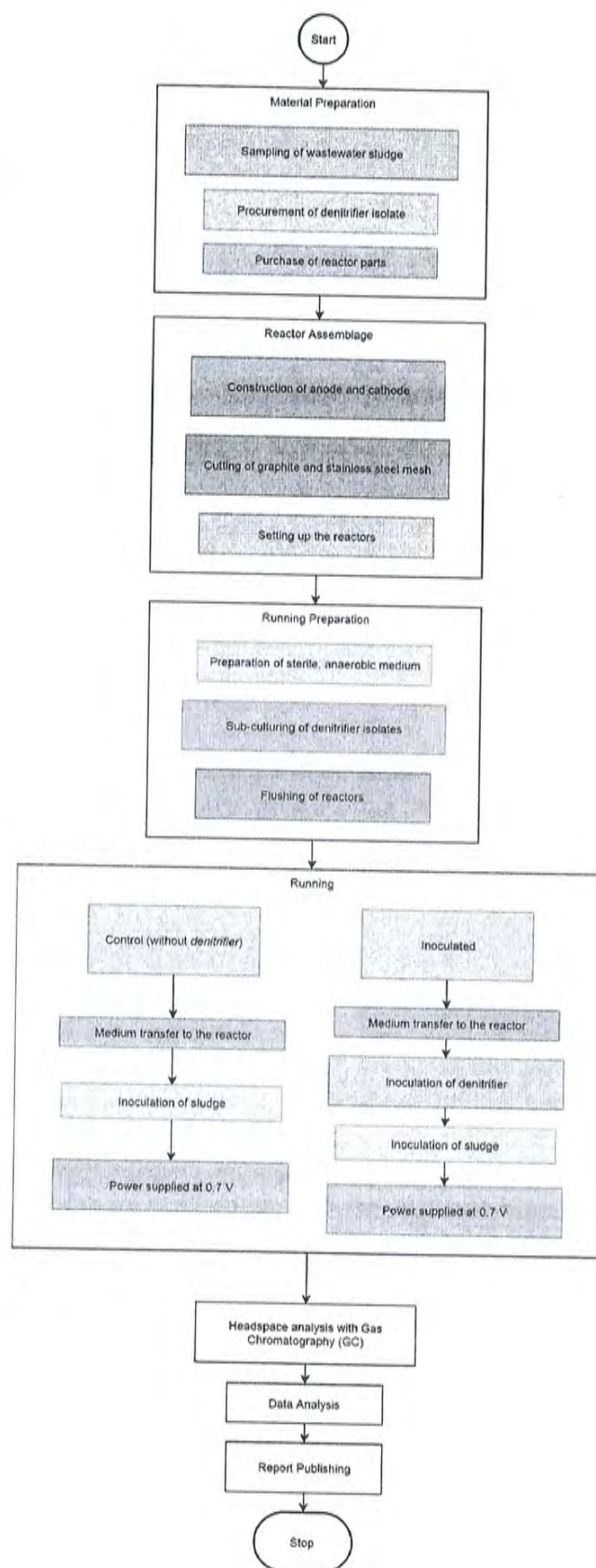
Figure 1. Research Flowchart

2.2. Research Variables

2.2.1. Independent Variable

Independent variable is a variable which has its value changed in such a way that its effect to the experiment can be determined. In this research, the independent variables are the source of wastewater sludge and the type of denitrifier. Different wastewater source will have different diversity of bacterial consortium that will affect the performance of the reactor in producing H_2.

Isolates of denitrifier chosen selected had been confirmed to be classified as heterotrophic denitrifier, which is a class of denitrifier which is capable of converting organic substrates into energy, without consuming available inorganic sources such as H_2. This research use 2 denitrifier isolates to determine the ability of different genus of denitrifying bacteria to inhibit methanogen. The isolates used are *Bacillus cereus* and *Pseudomonas stutzeri*, both obtained from InaCC LIPI (an Indonesian governmental body that maintain culture collection).

2.2.2. Controlled Variable

Controlled variable is defined as the variable that has its value kept constant until the end of the experiment. In this research, the controlled variables are MEC configuration and the operational voltage of the reactor. Reactor configuration is the same for all, which is in a closed-circuit configuration connected to a programmable power supply in which the output of the power supply is made parallel in order to accommodate more than one reactor at once. Electrical current is neede din MEC operation as conversion of carbon-based substrates to H_2 on the cathode is not a spontaneous reaction (Liu, Grot, & Logan, 2005) and the addition of such current aims to trigger reduction in the cathode to produce H_2. The voltage used in the experiment is set at 0.7 Volt DC in order to create the current density needed without causing water electrolysis which may produce H_2 (Logan et al., 2011).

2.2.3. Dependent Variable

Dependent variable is defined as the variable whose value is dependent on the independent and controlled variable. In this research, the dependent variable is the composition of headspace gas.

2.3. Materials

All the instrument and equipment required in the research are listed in Table 1, while the required materials and chemicals are listed in Table 2.

Table 1. List of Equipment Required

No	Tools	Function
1	Alligator Clip	To connect the circuit together.
2	Autoclave	To sterilize equipment and material to be used in the experiment.
3	Gas Chromatography	To analyze headspace gas with Argon carrier and TCD instrument.
4	Glass Vial	Functions as the reactor and storage of anaerobic medium.
5	Hand Drill	To bore holes in electrodes.
6	Isomolded Graphite Plate (0.125" thickness)	Functions as the anode.
7	Multimeter	To measure voltage, resistance, and current.
8	Petri Dish	As a container in which microorganism will be cultured.
9	Power Supply	Functions as energy source for the reactor.
10	Resistor	To measure voltage of the reactor.
11	Rubber Septum	To seal the glass vial and prevent gas exchange between the glass and the outside environment.
12	Silicon Tube	Functions as the N_2 gas line and vacuum pump line.
13	Sonicator	To remove debris from the recently-finished electrode.
14	Stainless Steel Mesh	Functions as the cathode.
15	Stainless Steel Wire	To connect electricity to the cathode.
16	Syringe	To transfer various kind of materials into and out of the reactor.
17	Teflon Tube	Functions as the N_2 gas line and vacuum pump line.
18	Thermal Conductivity Detector	To detect gas composition in the reactor
19	Titanium Wire	To connect electricity to the anode.
20	Vacuum Pump	To purge gas out of the glass vial.

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Table 2. List of Materials Required

No	Materials	Function
1	Abrasive Paper	To increase the surface area of the electrode.
2	Alcohol 70%	To sterilize materials before entering laminar hood.
3	Anaerobic Medium	As the main working fluid in the reactor and allows growth of anaerobic bacteria.
4	Isolate of *B. cereus*	As the tested denitrifier isolate.
5	Isolate of *P. stutzeri*	As the tested denitrifier isolate.
6	KNO_3	As a component of TSA medium used.
7	Methylene Blue	Functions as an anaerobic indicator.
8	N_2 Gas	Used in the flushing process to remove oxygen and create an anaerobic condition.
9	Phosphate-Buffered Saline (PBS) 0.01 M	As the medium for sludge and denitrifier inoculation into the reactor.
10	Trace Element Solution	As a component of anaerobic medium.
11	Tryptose Soy Agar (TSA)	As a medium to grow denitrifier isolates.
12	Wastewater Sludge	As a source of methanogen and exoelectrogen.

III. RESULTS

In this research, the experiment is done twice by utilizing sludge obtained from two different reservoirs, which are located in Pluit, North Jakarta (Waduk Pluit) and Pulo Gadung, East Jakarta (Waduk Ria-Rio). Headspace analysis is done every end of a cycle, i.e. the period of MEC operation until the liquid medium is replaced with a new one. Gas chromatography is the only analytical equipment utilized in this experiment as it is deemed enough to answer the hypothesis of the experiment, in which the only dependent variable is the headspace gas composition of the reactor.

Medium replacement is done accordingly to the value of the reactor current, which is defined by literature as when the current of the reactor is recorded at a value of <0.01 mA (Call & Logan, 2011). As the resistor used has a value of 10Ω, the value of reactor voltage with which set a standard for medium replacement is 0.1 mV. The curve for the change in reactor voltage over time can be observed in Figure 1, where the curve represents the recorded voltage of reactor A in the first cycle of operation utilizing sludge obtained from Ria-Rio Reservoir.
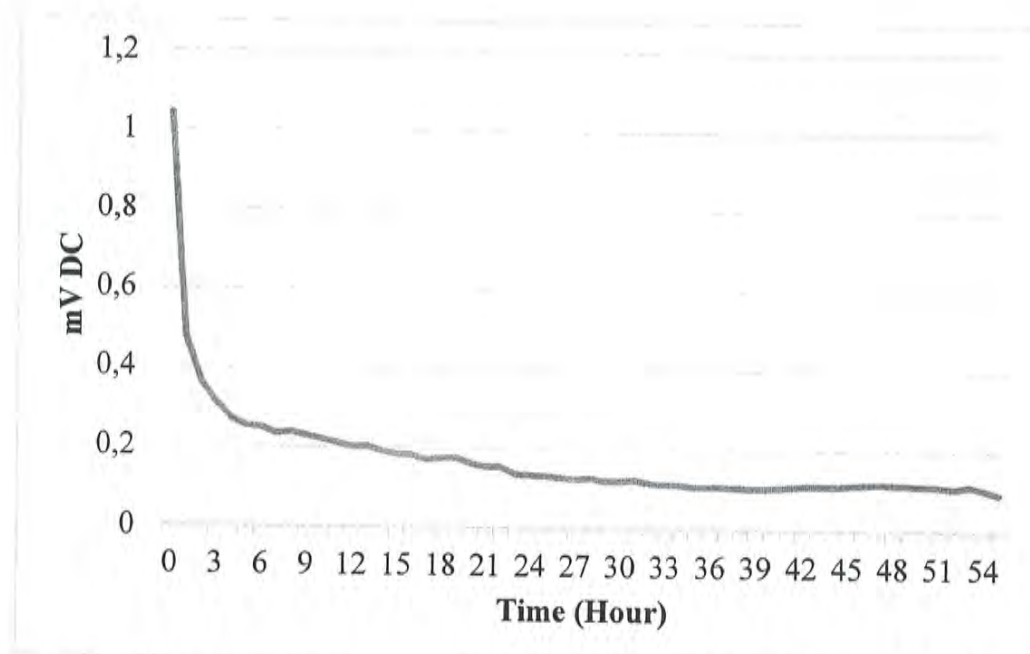
Figure 1. Result of voltage measurement on reactor inoculated with *P. stutzeri* in the first cycle

From Figure 1, it can be inferred that after approximately 50 hours, the recorded voltage value goes down below 0.1 mV. The definition of one cycle for this experiment is based on this graph, where after ±50 hours the medium of the reactor is replaced.

4.1 Hydrogen Production Utilizing Sludge Obtained from Pluit Reservoir

In the first batch of the experiment, the sludge used was obtained from the Pluit Reservoir. The sludge was sampled manually by hand in which a plastic bowl was used to sample the water from a depth of as deep as the hand's reach. The sludge obtained was dilute due to the fact that the sampling site is close to the water surface, whereas the expected sludge sampled from a deeper site would yield a more viscous and muddy-textured sludge. The sample would then be contained in a falcon tube, then put in a mobile cooling box to store the wastewater in a cold environment (4°C). This is done in order to preserve the wastewater and prolong its storage time (Castro, Queirolo, Quevedo, & Muxí, 2002). The obtained chromatograms are as follows in Figure 2.
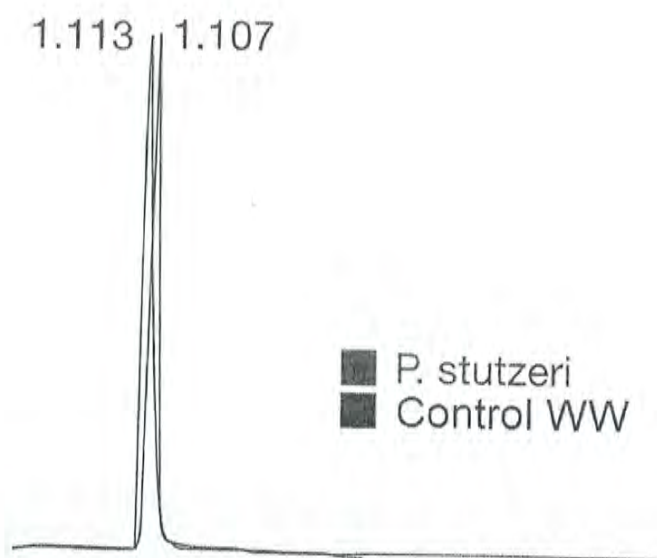
Figure 2. Chromatogram results of reactors inoculated with *P. stutzeri* and control reactor after 1 cycle of reactor operation

Chromatogram peak for H_2 signature was not observed in the range of 0.5–0.6 retention time. The only peak that were observed referred to ambient headspace gas in the range of 1.0–1.1 retention time, where this ambient gas are gases aside from CO, CO_2, CH_4, and H_2. It is posits that no H_2 was produced utilizing the sludge obtained from Pluit Reservoir. Considering that all the elements of the reactor such as electrodes, medium, voltage, etc. have been optimized accordingly to the literature, it concludes that the lacking element would be the **absence of exoelectrogenic bacteria**. This type of bacteria is integral in MEC operation due to its ability to donor electrons to the anode through biofilm attachment. The electrons are byproducts of its metabolism of organic substrates present in wastewater sludge. As the voltage that used in the experiment is low enough (0.7 V) to prevent H_2 evolution from other means (such as water electrolysis) except from assistance of exoelectrogenic bacteria, it inferred that the sludge sample lacked this particular bacteria community.

4.2 Hydrogen Production Utilizing Sludge Obtained from Ria-Rio Reservoir

In the second batch of the experiment, sludge obtained from Ria-Rio Reservoir is used. In this case, the sludge was sampled with the assistance of local workers that were capable of sampling the deeper part of the reservoir. Compared to previously obtained sludge from Pluit Reservoir, the Ria-Rio sludge was noticeably more viscous and consists of liquid and solid fraction. The sludge was collected in a falcon tube, and then stored in a mobile cooling box to keep the sludge in a cold temperature at about 4°C before storing it at the lab refrigerator. This second batch consists of 4 cycles of MEC operation, and chromatogram results will be analyzed per cycle.

4.2.1 Results of First Cycle
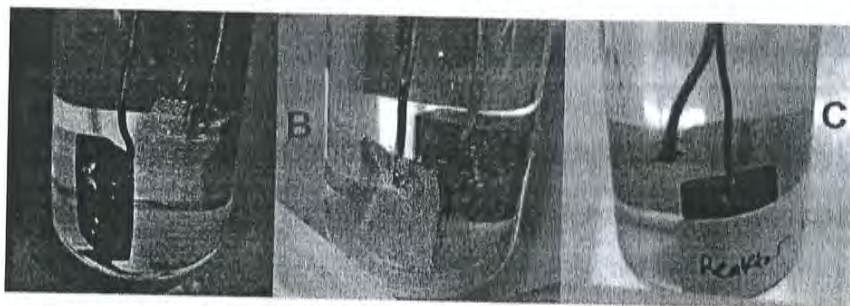
Figure 3. Evolution of gas bubbles in the cathode after ±20 hrs of reactor operation
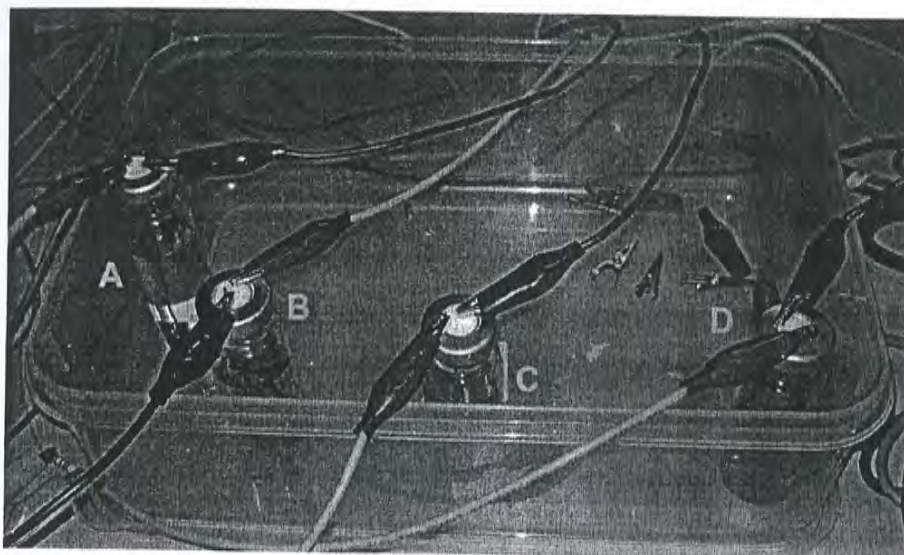
Figure 4. Discoloration of medium at Reactor A, B, and C as observed
after ±20 hrs of reactor operation

Visual observation of the reactors after ±20 hrs of operation, showed that discoloration only happens at reactor A, B, and C, whereas reactor D (control) retained its light blue coloration caused by the presence of indicator methylene blue. Reactor A showed the highest degree of discoloration where the medium was almost colorless, while reactor B and C still retained their light blue coloration. Between reactor C and D, reactor C is more colorless than reactor B. The visual observation posits that there is **growth of microorganisms in the reactors that leads to the discoloration in the medium,** while the control reactor which only contain the sterile medium did not show any sign of microbial growth. This observation proved that 1) the configuration of the reactor is satisfactory to keep the reactor isolated from outside environment and 2) the sterilization of both medium and reactor is successful to prevent unwanted growth. Furthermore, **evolution of gas bubbles were observed attached at the cathode of reactor** A, B, and C, which is the H_2 gas that evolved in the reactor but did not dissolve into the medium due to its low solubility in water (Kadier *et al.*, 2015). The overall result of visual observation is summarized in Table 1.

Table 1. Reactor Observation after ±20 hrs of operation

Reactor	Medium Color	Gas Bubbles
A (*P. stutzeri*)	Almost colorless	Observed
B (*B. cereus*)	Discolored blue	Observed
C (*Wastewater*)	Discolored blue	Observed
D (Control)	Light blue (no change)	Not observed
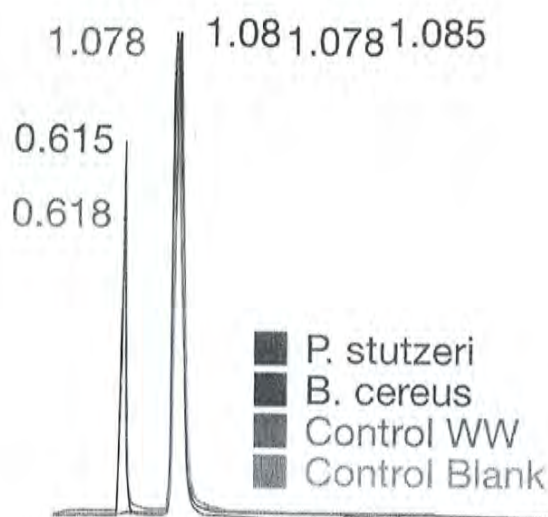
Figure 5. Chromatogram of the 4 reactors in first cycle of reactor operation (after ±70 hrs)

Chromatogram results yielded peak for H_2 only at reactor A and C, while for reactor B and D, the H_2 peak was not observed. H_2 composition at the headspace of reactor A is 29.06%, while at reactor C the H_2 composition is 24.63%. Evolution of H_2 in the reactor proved that in the sludge obtained from Ria-Rio Reservoir, **there were active exoelectrogenic community whose electrons (which were byproducts of their metabolism) assisted in the operation of MEC reactor, in this case reducing the H^+ ions present in the medium to become H_2.**

Comparing to the results of the first batch of experiment where the sludge was obtained from a shallow depth, it can be posited that the sludge that can be used in the operation of MEC has to be located in the deeper parts of reservoir, where the oxygen concentration is low and exoelectrogenic communities proliferate.

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This is due to the fact that exoelectrogenic bacteria occupies the niche of anaerobic respiration utilizing Fe ions/elemental sulphur (S) as terminal electron acceptor in the sludge (Wilson & Kim, 2016). The overall result of gas chromatography analysis can be observed in Figure 6.
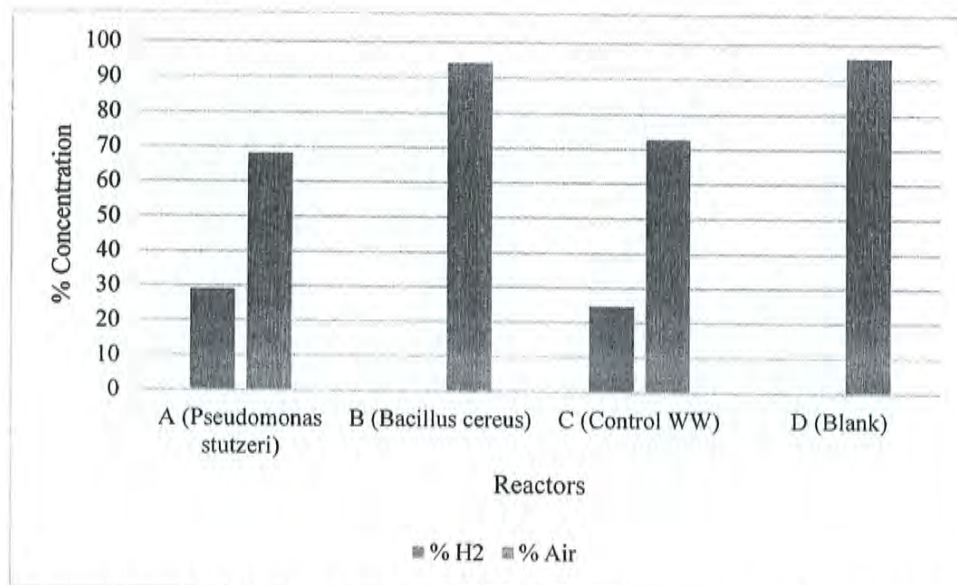
Figure 6. Result of GC analysis in first cycle of reactor operation (after ±70 hrs)

The expected difference in H_2 production to prove the hypothesis was yet to be seen in this cycle, in two different scenarios. Firstly, the difference in production rate is not seen due to the long duration of reactor operation, whereas a shorter headspace sampling duration would prove the difference in production rate. Secondly, it could mean that the methanogens were yet to be active and consume the produced H_2 in the first cycle.

From this first cycle, several conclusions can be derived. Firstly, the reactor configuration and experimental design were verified to be capable of producing H_2 through MEC mechanism, as only headspace samples of reactors inoculated with sludge sample showed H_2 peaks in the chromatogram, whereas sample of the control reactor D did not show peak for H_2. This proved that indeed at the used voltage of 0.7 V, H_2 can only be produced by the reactor if the MEC mechanism works and not by other means (such as water electrolysis), accordingly to the literature cited.

4.2.2 Results of Second Cycle

Figure 7. Discoloration of medium at Reactor A, B, and C as observed in second cycle after ±20 hrs of reactor operation

Visual observation of the reactors at second cycle (± 20 hrs) showed that all reactors but reactor D had their medium discolored completely to colorless. Compared to the first cycle, this cycle's **discoloration happened faster. This may be caused due to the faster microbial growth in the reactor as they had acclimated to the environment inside the reactor**. The overall result of visual observation is summarized in Table 2.

Table 2. Reactor Observation at second cycle (±20 hrs of operation)

Reactor	Medium Color
A (*P. stutzeri*)	Colorless
B (*B. cereus*)	Colorless
C (*Wastewater*)	Colorless
D (Control)	Light blue (no change)

Chromatography analysis of the second cycle that concluded after ±40 hrs of reactor operation showed H_2 peak only on chromatograms of reactor A and C, while reactor B and D did not show the peak. H_2 composition at the headspace of reactor A is 10.85%, while at reactor C the H_2 composition is 5.60%. From this result where the headspace was sampled on a shorter reactor operation, the hypothesis can be concluded that **the presence of denitrifier in the reactor do gives a positive effect on reactor, namely the higher rate of H_2 production**. For the same configuration of reactor, the similar medium composition, and the similar reactor operation, **reactor A which has been inoculated with the denitrifier *P. stutzeri* resulted in 100% higher H_2 production rate compared to uninoculated reactor C**. The overall result of gas chromatography analysis can be observed in Figure 8.
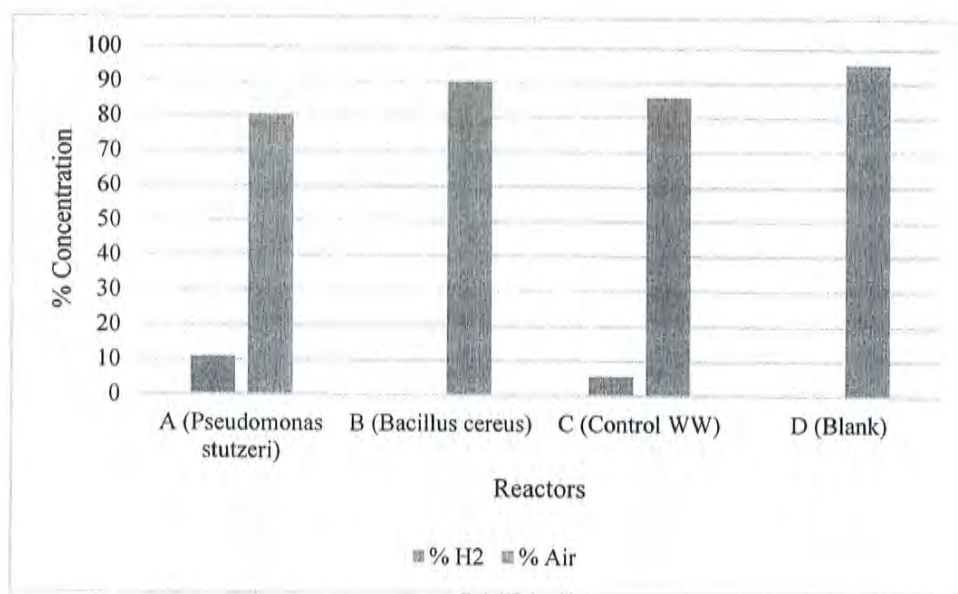
Figure 8. Result of GC analysis on second cycle (after ±40 hrs)

As the chromatography analysis in this cycle was done in a faster interval, it could be seen that on a similar period of reactor operation, **reactor inoculated with denitrifier was capable of producing higher quantity of H_2** as expressed in a higher H_2 composition in the headspace. This difference in production rate will be even more relevant if the reactor is to be scaled-up for H_2 production to achieve a high yield.

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4.2.3 Results of Third Cycle

Visual observation of the reactors at third cycle (±20 hrs) showed that all reactors but reactor D again had their medium discolored completely to colorless. **This result is consistent with the previous cycle.** The overall result of visual observation is summarized in Table 3.

Table 3. Reactor Observation at third cycle (±20 hrs of operation)

Reactor	Medium Color
A (*P. stutzeri*)	Colorless
B (*B. cereus*)	Colorless
C (*Wastewater*)	Colorless
D (Control)	Light blue (no change)

However, in this cycle the peak for H_2 were only seen on chromatogram of reactor A with a composition of 2.95%, whereas for reactor B and C the peak was not observed. The overall result of gas chromatography analysis can be observed in Figure 9.
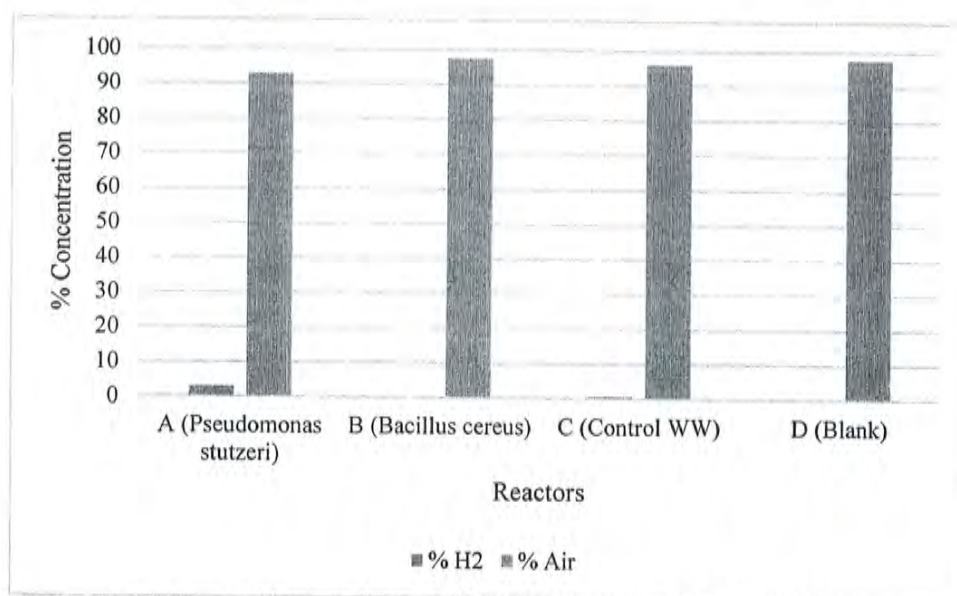
Figure 9. Result of GC analysis on third cycle (±50 hrs)

The percentage of H_2 detected in the headspace was significantly lower than previous cycles, where even after longer reactor operation, the quantity of H_2 produced is still very small. The H_2 production rate thus was slowed down or even halted entirely. It is posits that this could be **caused either due to the denitrifier or the exoelectrogen bacteria entering *lag phase* due to the depleted nutrients**.

4.2.4 Results of Fourth Cycle
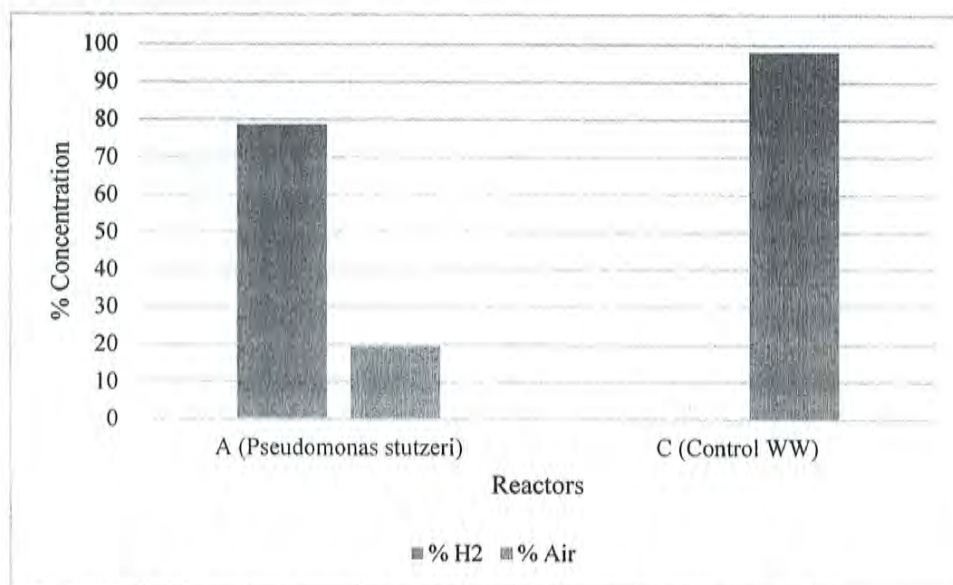
Figure 10. Result of GC analysis on fourth cycle (±70 hrs)

In the fourth cycle, even though reactor C did not show any peak for H_2, reactor A showed one as chromatography analysis of reactor A headspace gas resulted in 78.60% H_2 concentration, far higher than any of the previous cycle.

From this result, the integrity of the equipment used in the experiment can also be validated. The rubber septum, although pierced multiple times with syringe needles during inoculation, medium replacement, and GC analysis, still retained its function to prevent gas exchange between the reactor and the ambient air. This is proven because the reactor is still capable of retaining and accumulating H_2 molecules, which are the smallest out of all gas molecules, inside it and prevent H_2 from bleeding out. This proved that the rubber septum used was suitable for this experiment and thus chromatogram results from sample of headspace gas is valid.

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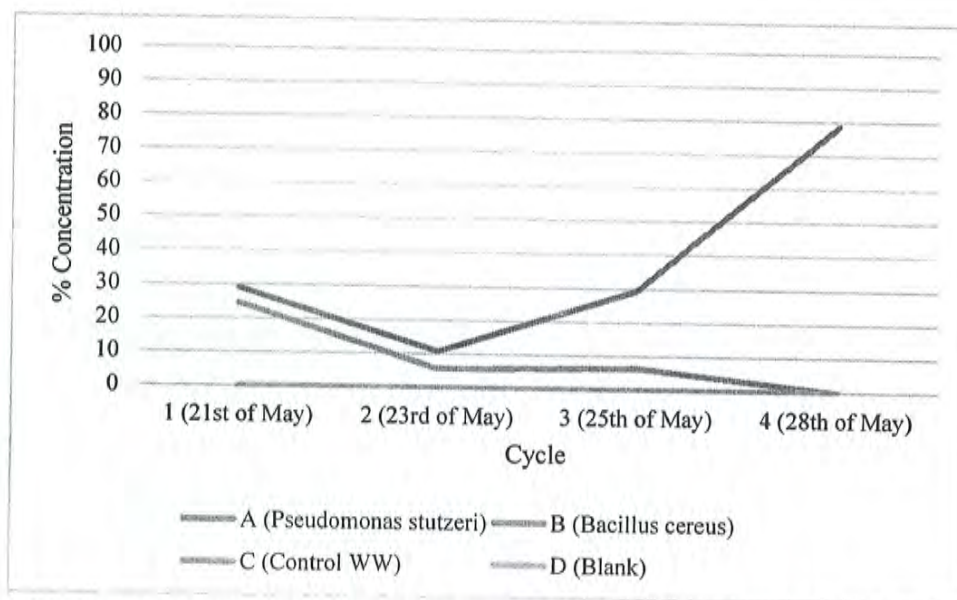
Figure 11. Overall production of H_2 over the course of 4 cycles by the reactors

From this experiment, it can be inferred that only reactor A which had been inoculated with the denitrifier *P. stutzeri* were capable of retaining it H_2 production on subsequent cycle of MEC operation and even demonstrated higher rate of production, compared to reactor C which had its rate of production slowed and even stagnated. It conclude that the hypothesis had been proven from this 4 cycle of reactor operation.

4.3 *Bacillus cereus*

In this experiment, the *Bacillus cereus* strain ordered from InaCC LIPI (catalog number: B1198) was found to be consistently difficult to culture in the laboratory. According to the website from which this strain was ordered, this particular strain of *Bacillus* was isolated from larva gut originated from a protected forest in the Mekongga region, Tinukari, Southeast Celebes. *Bacillus cereus* was known to cause infection to both humans and animals, releasing various toxins that cause diseases in the host, such as diarrhea (Stenfors Arnesen, Fagerlund, & Granum, 2008).

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Bacillus cereus cultured in 3 different types of medium, which are: Nutrient Agar (NA), Trypticase Soya Agar with addition of 10 mM KNO_3, and anaerobic liquid medium formulated according to Tugtas (2007). NA was chosen as one of the medium candidates due to LIPI recommending the culturing of *Bacillus* with NA. TSA with addition of 10 mM KNO_3 was chosen according to literature due to its common use as a growth medium for various types of denitrifiers (Heylen, 2007; Tiedje, 1988).

Bacillus is grown in an NA agar plate made accordingly to the streak plate procedure, where NA is formulated according to the volume of medium needed. After autoclaving the medium, the still-hot medium is then poured in to the plate, and kept in a UV-equipped laminar hood. After the agar cools and hardens, plate of *Bacillus* isolate is then inserted into the laminar hood. An inoculating needle is flamed in a spiritus lamp, then used to pick a single colony in the isolate plate. The needle will then be streaked in the agar plate accordingly to the streak plate procedure (several times until the colony is diluted). Inoculated medium plate will then be covered in a cling wrap, and then incubated upside-down inside the incubator. The result of the inoculation can be seen on Figure 12, taken after incubation period of ±15 hrs.
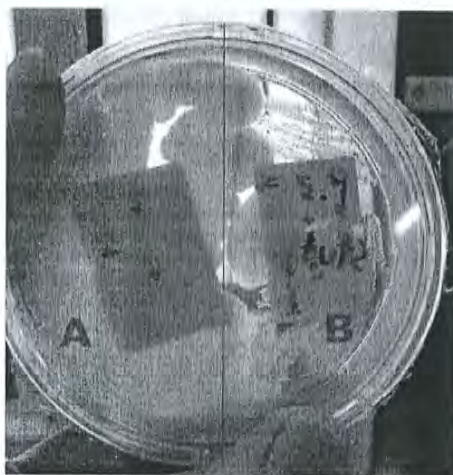
Figure 12. (A) Result of *Bacillus cereus* inoculation in NA medium after ±15 hrs of incubation; (B) Result of *Pseudomonas stutzeri* inoculation in NA medium after ±15 hrs of incubation

From Figure 12, it can be inferred than in a relatively short incubation period, *B. cereus* was found to be in a state of blanket growth. This was most likely contamination by mold which was being incubated in the same oven, considering NA is not a selective growth medium for *Bacillus* growth ("Bacillus - Media by Microorganism," n.d.).

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For comparison, cultivation of *B. cereus* is commonly done in medium supplanted with Polymixin B, which is a selective substance that inhibits gram-negative growth (Netten & Kramer, 1995). *B. cereus*, gram-positive bacteria will be exempt from the inhibition of Polymixin B.

Similar phenomena were also found when cultivating *B. cereus* in a TSA medium with addition of 10 mM KNO$_3$, where blanket growth was once again found and made it hard to ascertain single *B. cereus* colony. The light growth was also found on different sides of the plate, unlike usual streak plates result where the single colonies would be concentrated on one side of the plate due to having the lightest dilution. It conclude that these issues arose due to the difficulty of obtaining the appropriate selective medium in the research timeline, where the required selective medium needs to be imported from abroad. Figure 13 illustrated the attempt of cultivating *B. cereus* with TSA + 10 mM KNO$_3$ medium.
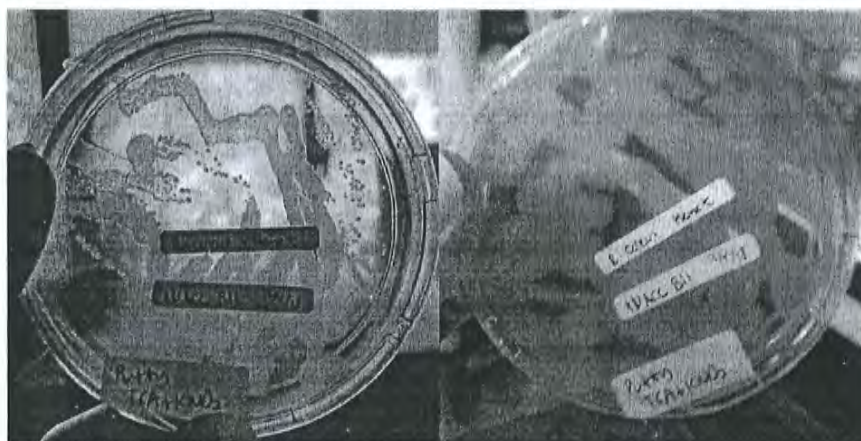
Figure 13. (Left) Result of *Bacillus cereus* inoculation in TSA medium after ±15 hrs of incubation; (Right) Observation of the inoculate after ±125 hrs of incubation at 18th of April

One of the reason that it figured out as to why this particular *Bacilus* strain was hard to culture was due to the lack of proper incubator. As the optimal temperature for *B. cereus* growth ranges between 30-40 °C (El-Arabi & Griffiths, 2013), it is posit that the shortcoming of the equipment led to contamination of the *Bacillus* petri dishes with other kinds of microorganism aside from *B. cereus*.

The last type of medium used to culture *B. cereus* is anaerobic liquid medium, chosen to assist in inoculating the denitrifier into the reactor, formulated according to Tugtas (2007). In addition, also attempted culture using a differently-formulated medium according to Bellini, Gutiérrez, Tarlera, & Scavino (2013) with trace mineral formulation following Touzel & Albagnac (1983). A single colony from the stock plates will be taken with an inoculating needle, then immersed in 0.01 M PBS. A 1 ml volume of PBS that had been immersed in the *Bacillus* strain will be taken with a syringe, then inserted into the sterile stock medium to be incubated. All procedures were done in laminar hood. Inoculated medium vials will then had their rubber septum covered with cling wrap and incubated in the oven upside down. These procedures were done to minimize contamination risk that might happen due to leaks in the rubber septum after being pierced with needles. Figure 14 illustrated the attempt at growing *B. cereus* in liquid medium.

Figure 144. Observation after ±20 hrs of incubation. No significant color change was seen in all vials.

After ±20 hrs of incubation, no significant color change was found in all vials, although vials inoculated with *P. stutzeri* isolate expressed a higher degree of turbidity compared to the uninoculated control vial. It posit that this might be caused due to the incubation period not being long enough. All vials were then returned back to the oven to be incubated.

On the other hand, the lack of growth or change in color in the control vial proved the integrity of the vials to prevent contamination of microorganism. From this result, it found that this incubation setup was valid for the experiment.
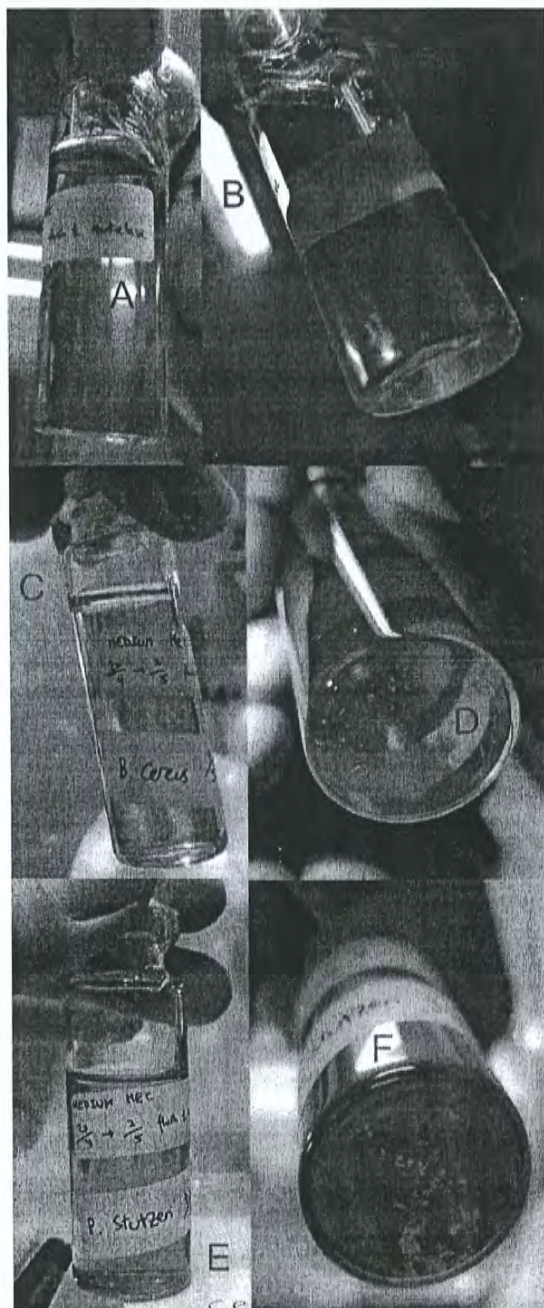
Figure 155. Observation of medium after ±45 hrs of incubation, (A) & (B) Control vial ; (C) & (D) *B. cereus* vial ; (E) & (F) *P. Stutzeri* vial.

After about ±45 hrs of incubation, significant visual change was found on inoculated medium where white, film-like growth was found inside the vial. Quantitatively, the growth was found more proliferated in *P. stutzeri* vial compared to the *B. cereus* vial.
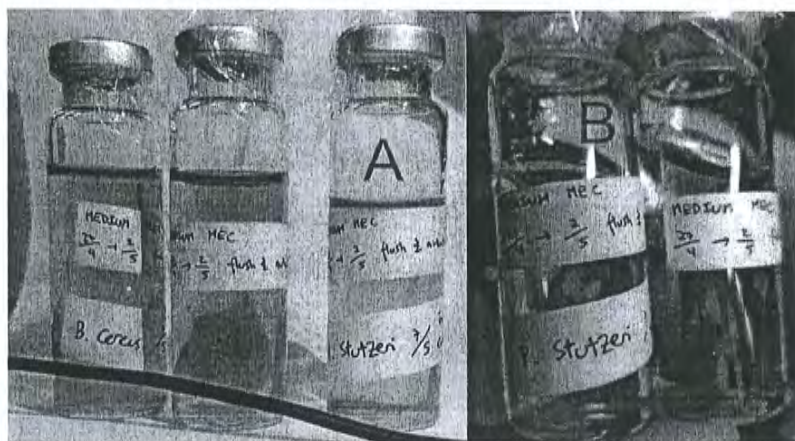
Figure 166. Observation of medium after ±50 hrs of incubation ; (A) Color comparison of the three vials ; (B) Color comparison between *P. stutzeri* and control vial

Qualitatively, the change in medium color was found to be more exhibited in *P. stutzeri* vial compared to *B. cereus* vial. Medium inoculated with *P. stutzeri* was discolored and changing to colorless, while medium of *B. cereus* still maintained a similar light blue color like the control reactor. From this result, it found that for the similar duration of incubation and medium formulation, the medium is more suited for *P. stutzeri* growth as seen in a faster growth rate.

Figure 177. Color observation of the vials after ±90 hrs of incubation

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After ±90 hrs of incubation, the most significant change in medium color was found at *P. stutzeri* vial in which the medium turned completely colorless. Although there is a slight degree of discoloration in *B. cereus* vial compared to the control vial. It came to two different scenarios for the failure of culturing *B. cereus* in this experiment.

The first scenario is related to the formulation of the liquid medium employed in this experiment. White (1972) stated that *B. cereus* needs at least 2 types of essential amino acid for growth, where in an unenriched medium *B. cereus* will fail to grow. According to Rosenfeld *et al.* (2005), *B. cereus* strain needs both high concentration of amino acid and pyruvate to be able to grow fermentatively in an anaerobic condition, which is the type of growth expected in an anaerobic environment inside the reactor. Growth rate of *B. cereus* was found to be drastically reduced in a poor amino acid-containing medium compared to a rich one, where a high concentration of amino acid was found to stimulate bacterial growth. This is the first scenario as to why *B. cereus* failed to grow in this medium.

The second scenario is related to the presence of Fe^{3+} ions in this medium formulation. Kalantari (2008) found that Fe^{3+} ions are toxic and inhibitive to *B. cereus* growth. The result of findings made by Kalantari (2008) can be seen on Figure 18.
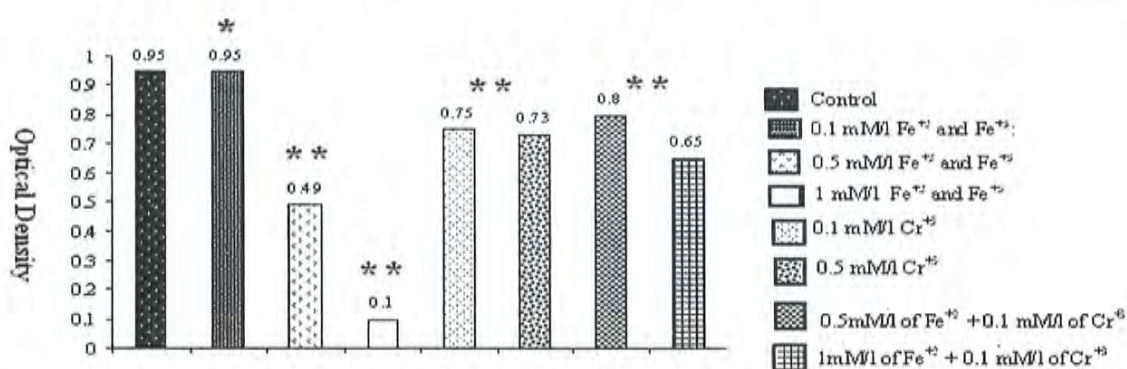
Figure18. Inhibition of *B. cereus* by several types of Fe ions after 3.5 hrs of incubation in 37 °C temperature (Source Kalantari, 2008)

As shown in Figure 20, a 0.5 mM/L concentration of Fe^{3+} ions were sufficient to reduce the growth rate of *B. cereus* to half the rate of control growth. As the formulation of this liquid medium contained 0.37 mM/L of Fe^{3+} ions, there must also be a degree of inhibition towards *B. cereus* growth.

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RESEARCH FINAL REPORT
OSAKA GAS FOUNDATION
OF INTERNATIONAL CULTURAL EXCHANGE
Year 2017/12018

Desulfurization of Liquid Fuel Using Rice Straw Supported Nanoparticle (Fe₃O₄/NCs and Cu/NCs) Prepared from Waste Materials

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THE CENTER FORSCIENCE AND TECHNOLOGY RESEARCH
(csTR)
UNTVERSITY OF INDONESIA

DEPOK, NOVEMBER 2018

Lembar Pengesahan

SUMMARY RESEARCH PROPOSAL

1	Research Project Title	:	Desulfurization of Liquid Fuel Using Rice straw Supported Nanoparticle (Fe_3O_4/NCs and Cu/NCs) prepared from waste materials
2	Principle Investigator		
	a. Name	:	Dr.Ir. Antonius Herry Cahyana
	b. Rank/Status	:	Lecturer
	c. Main Field of Specialization	:	Synthesis Organic Chemistry
	d. Department	:	Chemistry
	e. Faculty	:	Mathematics and Natural Sciences, University of Indonesia
3	Summary of Research Project	:	In general, nanoparticles (NPs) are described as particles having diameter sizes less than or equal to 0.1 μm (100 nm) and with specific properties that depend mainly on their size . Synthesis of NPs in polymer media have been promising due to their ease of processing such as by using agricultural waste rice straw. In Indonesia, straw is an abundant cellulosic by-product from the production of crops such as rice, corn and soybean. The natural fiber comes from stalks, leaves, and seeds is sources of polymer cellulose. Small sized magnetite iron oxide nanoparticles (Fe_3O_4-NPs) and Cu-NPs with were successfully synthesized using iron rust reacted with waste home activity such as frying oil. This nano-NPs showed high activity in applied of gasoline pertaman for desulfurization adsorbent. In this work, we prepare material for nanocomposites s) : rice straw/Fe_3O_4-NCs and rice straw/ Cu-NPs were

			prepared at room temperature in aqueous media using waste frying oil (jelantah) with iron rust, and continuing adding with treated cellulose from rice straw as supporting agent, and using urea as reducing agent and stabilize with TEOS as capping agent. To our knowledge, this is the first research on the synthesis and characterization of rice straw/Fe_3O_4-NCs. Batch experiments were conducted to assess the adsorptive potential of synthesized nanocomposit rice straw/Fe_3O_4-NCs and rice straw/ Cu-NPs.Four sets of open batch as a function of time were conducted for the selective adsorption of thiophene and 1-benzothiophene as representatives of organo- sulfur compounds. Next, continuing apply to domestic fuel gasoline such as pertamax, pertalite and diesel (solar). The percentage removal was calculated for the sulfur compounds to determine the efficacy of synthesized nano-adsorbents.
4	Field of Disciplines	:	Organic synthesis and green catalyst nanopartcles
5	Research Location	:	Department of Chemistry, University of Indonesia, Depok
6	Time of Research Project	:	September 2017 – August 2018

CONTENTS

ABSTRACT

Environmental regulations on sulfur contents have prompted research on high-level desulfurization for near-zero sulfur. To meet lower sulfur requirements, refiners need to operate their conventional hydrodesulfurization (HDS) unit at more severe conditions than usual, such as higher temperature, higher pressure and longer residence time and some aromatic sulfur-containing compounds such as alkylated dibenzothiophenes are resistant to HDS treatment. Therefore, new design approaches, such as adsorption desulfurization was proposed for efficient production of ultra low sulfur fuels. In general, nanoparticles (NPs) are described as particles having diameter sizes less than or equal to 0.1 μm (100 nm) and with specific properties that depend mainly on their size. Synthesis of NPs in polymer media have been promising due to their ease of processing such as by using agricultural waste rice straw.

In Indonesia, straw is an abundant cellulosic by-product from the production of crops such as rice, corn and soybean. The natural fiber comes from stalks, leaves, and seeds is sources of polymer cellulose. Small sized magnetite iron oxide nanoparticles (Fe_3O_4-NPs) and Cu-NPs with were successfully synthesized using iron rust reacted with waste home activity such as frying oil. This nano-NPs showed high activity in applied of gasoline pertamax for desulfurization adsorbent. A magnetic cellulose supported Fe_3O_4 nanoparticles composite was designed as a highly efficient and eco-friendly adsorbent for organic sulphur contained in liquid fuels. In this work, we have prepared material for nanocomposites : rice straw/Fe_3O_4-NPs and Cu-NPs with rice straw, were prepared at room temperature in aqueous media using waste frying oil (jelantah) with iron rust, and continuing adding with treated cellulose from rice straw as supporting agent, and using urea as reducing agent and stabilize with TEOS as capping agent. To our knowledge, this is the first research on the synthesis and characterization of rice straw/Fe_3O_4-NCs. Batch experiments were conducted to assess the adsorptive potential of synthesized nanocomposit rice straw/Fe_3O_4-NCs and rice straw/ Cu-NPs.

Research Report

Osaka Gas Foundation of International Cultural Exchange

(OGFICE)

Principal Investigator:

Anita Alni, PhD

Academic Unit

Research Division	:	Organic Chemistry
Faculty/School	:	FMIPA

INSTITUT TEKNOLOGI BANDUNG

October 2018

I. IDENTITY PAGE

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2. Topic   : Carbondioxide fixation
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			Hrs/week	Months
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2.	Fathia Rizky	Chemistry, 20516053	10	12

5. Approved budget   : US $ 4300

Head of Academic Unit   Bandung, October 20th, 2018
                                                Principal Investigator

Prof. Dr. Edy Tri Baskoro   Dr. Anita Alni
NIP. 196405221989031002   NIP. 198301052012122003

I. EXECUTIVE SUMMARY

1. **TITLE OF RESEARCH** : Carbondioxide fixation on catalytic membranes Coated with silver nanoparticles

2. **HEAD OF RESEARCH TEAM** : Dr. Anita Alni

3. **TEAM MEMBERS** : Dr. Muhammad Ali Zulfikar

4. **OFFICIAL ADDRESS** :Division of Organic Chemistry, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Jalan Ganesa 10 Bandung

5. **EXTENDED ABSTRACT** :

The rise of atmospheric CO2 levels is causing serious impact on the environment. Increase of the sea level due to the melt of polar ice has caused floods in many parts of the world. On the contrary, consumption of hydrocarbon fuel as well as many other carbon compounds are rising as the world progress towards industrialization. If reduced, CO_2 can be a valuable source of hydrocarbon, hence offer a close-loop waste to consumption circle that might undertake the climate change issue in the long run. In addition to reducing greenhouse gas emissions, CO_2 conversion processes will reduce our dependency on fossil fuels for chemical synthesis.

In this research, a fixation of CO2 gas has been carried out to transform it into usable fine chamicals. The transformation was added by polymeric material impregnated with silver metal as catalyst. The first step was synthesis of polymeric material and its characterization via FTIR spectroscopy and surface imaging by scanning electron microscope (SEM). During the synthesis, the reaction mixtures were purged with CO2 gas to form selectivities against other gases. Two polymeric material namely polymethyl metacrylate (PMMA) and silver coated polymethyl metacrylate (PMMA-Ag) have been prepared.

The second part of the project was to utilize the polymeric material as support and catalyst in chemical transformation. Reaction was carried out at Parr gas reactor system under 3 barr of CO2 pressure at 50°C. The reactions were monitored and analysed by NMR spectroscopy to identify the formation of product. Reactions were carried out towards phenyl acetylene to form aromatic carboxylate. NMR spectra showed that for reaction with PMMA-Ag yielded the fixation product while without the Ag catalyst, the product was not observed. Part of this work has been published in national journal, while draft for international journal is being prepared. Reaction were performed using CO2 gas from commercial sources while applications towards flue gases have not been accomplished, particularly due to the difficulty of getting the gas from industry.

6. **LIST OF RESEARCH OUTPUT**

-Accepted National Journal (attached)

-Draft of paper to be submitted to International Journal (in preparation)

Research Report

Osaka Gas Foundation of International Cultural Exchange

(OGFICE)

| *Research Title* |
| DEVELOPMENT OF A NEW GAS SENSOR FOR DETECTION OF TOXIC GAS OF ENVIRONMENT |

Principal Investigator:

Prof. Dr. –Ing. Mitra Djamal

Academic Unit

| Research Division | : | FTETI |
| Faculty/School | : | FMIPA |

INSTITUT TEKNOLOGI BANDUNG

October2018

I. IDENTITY PAGE

1. Title : Development of A New Gas Sensor for Detection of Toxic Gas of Environment
2. Topic : Global environmental problems
3. Research Period : November 2017 – November 2018
4.1. Principal Investigator :
   a. Full Name : Prof. Dr. –Ing. Mitra Djamal
   b. Academic Rank : Professor
   c. NIP : 19600522 198503 1 002
   d. Current Position : Lecturer
   e. Academic Unit : FMIPA
   f. Office Address/Phone/Fax/E-mail : 022-2500834/2506452
   g. Home Address/Phone/Fax/E-mail : mitra@fi.itb.ac.id

4.2 Members of the Team:

No	Name and Academic Rank	Field of Expertise	Institution	Allocation of Time	
				Hrs/week	Months
1	Prof. Dr. –Ing. Mitra Djamal	Instrumentation Physics	ITB	10	12
2	Dr. Maman Budiman	Instrumentation Physics	ITB	10	12

4.3 Research Assistants/Students (mention names when available):

No	Name	Departement and NIM	Allocation of Time	
			Hrs/week	Months
1.	Melany Febrina	Physic / 30215001	10	12

5. Approved budget : Rp. 50.000.000,- (US $ 3,292)

Head of Academic Unit

Bandung, 13 October 2018
Principal Investigator

Prof. Dr. Eng. Khairurrijal
NIP. 19690502 6 199103 1 002

Prof. Dr.-Ing. Mitra Djamal
NIP. 19600522 198503 1 002

I. EXECUTIVE SUMMARY

1. **TITLE OF RESEARCH** :DEVELOPMENT OF A NEW GAS SENSOR FOR DETECTION OF TOXIC GAS OF ENVIRONMENT
2. **HEAD OF RESEARCH TEAM** :Prof. Dr. –Ing. Mitra Djamal
3. **TEAM MEMBERS** :Dr. Maman Budiman
4. **OFFICIAL ADDRESS** :Physics Building,Jl. Ganesha No 10, Bandung

   40132, West Java, Indonesia

5. **EXTENDED ABSTRACT** : It has successfully built a gas sensor using thermopile based on thermal conductivity measurement. The gas sensor aims to detect toxic gas concentrations in the environment. In the initial test, this sensor has been successfully applied as a CO_2 gas detector. The built-in sensors possess low production costs, low power consumption and are easily manufactured. From the conducted experiments, the sensor can work well and the results can be validated with the established theory, as evidenced by the RMS error of 0.78. The measurement results are also in a good agreement with the model predictions Mason and Saxena for the thermal conductivity of gas mixtures.

6. **LIST OF RESEARCH OUTPUT** :

   a. 1 patent has been "**registered**" on Indonesian Patent" (Patent Number : **P00201709270)**

   b. 1 paper "**Published**" on "**Measurement Journal**".

   Title of paper :**DEVELOPMENT OF A SIMPLE CO$_2$ SENSOR BASED ON THE THERMAL CONDUCTIVITY DETECTION BY A THERMOPILE**

   Journal : "Measurement Journal" indexed by Scopus (**Q2**)

   Publisher : Elsevier BV

   H index : 54

   Impact factor : 2.359

Research Report

Osaka Gas Foundation of International Cultural Exchange

(OGFICE)

Research Title
Synthetic Natural Gas Production from CO
Using Dynamic Fixed Bed Reactor

Principal Investigator:

Dr. Yogi Wibisono Budhi

Academic Unit

Research Division	:	Perancangan dan Pengembangan Proses Teknik Kimia
Faculty/School	:	Industrial Technology

INSTITUT TEKNOLOGI BANDUNG

October 2018

1. IDENTITY PAGE

1. Title
: Synthetic Natural Gas Production from CO Using Dynamic Fixed Bed Reactor

2. Topic
: Technologies concerned with natural gas

3. Research Period
: November 2017 – November 2018

4.1. Principal Investigator
:
   a. Full Name
: Dr. Yogi Wibisono Budhi
   b. Academic Rank
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   c. NIP
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   d. Current Position
: Faculty Member
   e. Academic Unit
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No	Name and Academic Rank	Field of Expertise	Institution	Allocation of Time	
				Hrs/week	Months
1	Dr. Jenny Rizkiana	Modelling	Teknik Kimia ITB	10	10

4.3 Research Assistants/Students (mention names when available):

No	Name	Departement and NIM	Alocation of Time	
			Hrs/week	Months
1.	Utari Nuravifah, ST.	Chemical Engineering, 23017044	15	10
2.	Neng Tresna U.C., MSi	Chemical Engineering, 33017005	15	10

5. Approved budget
: US $ 4500

Head of Academic Unit

Prof. Deddy Kurniadi, Dr.Eng.
NIP. 196709301988101001

Bandung, 19 October 2018
Principal Investigator

Dr. Yogi Wibisono Budhi
NIP. 197102101999031001

I. IDENTITY PAGE

1. Title : Synthetic Natural Gas Production from CO Using Dynamic Fixed Bed Reactor
2. Topic : Technologies concerned with natural gas
3. Research Period : November 2017 – November 2018
4.1. Principal Investigator :
    a. Full Name : Dr. Yogi Wibisono Budhi
    b. Academic Rank : Associate Professor
    c. NIP : 197102101999031001
    d. Current Position : Faculty Member
    e. Academic Unit : KK Perancangan dan Pengembangan Proses Teknik Kimia
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4.2   Members of the Team:

No	Name and Academic Rank	Field of Expertise	Institution	Allocation of Time	
				Hrs/week	Months
1	Dr. Jenny Rizkiana	Modelling	Teknik Kimia ITB	10	10

4.3   Research Assistants/Students (mention names when available):

No	Name	Departement and NIM	Alocation of Time	
			Hrs/week	Months
1.	Utari Nuravifah, ST.	Chemical Engineering, 23017044	15	10
2.	Neng Tresna U.C., MSi	Chemical Engineering, 33017005	15	10

5. Approved budget : US $ 4500

Head of Academic Unit   Bandung, 19 October 2018
                                        Principal Investigator

Prof. Deddy Kurniadi, Dr.Eng.   Dr. Yogi Wibisono Budhi
NIP. 196309301988101001   NIP. 197102101999031001

I. EXECUTIVE SUMMARY

1. **TITLE OF RESEARCH** :
   Synthetic Natural Gas Production from CO Using Dynamic Fixed Bed Reactor

2. **HEAD OF RESEARCH TEAM** :
   Dr. Yogi Wibisono Budhi

3. **TEAM MEMBERS** :
   Dr. Jenny Rizkiana

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5. **EXTENDED ABSTRACT** :
This report addresses the production of Synthetic Natural Gas (SNG) for providing energy both for chemical feedstock and heat from CO_2 by catalytic reaction in a dynamic fixed bed reactor. The production of methane (CH_4) as SNG can be conducted through hydrogenation of CO, usually catalyzed by Ni as active site of material. Subsequently, methane can be converted into energy through utilization as fuel in combustion engines with fewer emissions. Methanation reaction is simultaneously also accompanied by steam formation (WGSR). The objective of this research was to investigate the production of Synthetic Natural Gas (CH_4) through hydrogenation of CO in the dynamic operation of fixed bed reactor. The focus of the research was to design the reactor and to develop the transient operation procedure to effectively produce the SNG with high conversion.

The research was carried out through reactor modeling and simulation using package software of FlexPDE version 7. The methanation simulation model was developed for 1D with transient term involving mass and energy balances. The kinetic data and reaction rate were taken from literature. This modeling was conducted to determine the effect of feed ratio and feed flowrate to selectivity, conversion, and productivity in the steady state (base case) and forced unsteady state operation. The reactor was assumed to be plug flow model with dimension to be determined at operating pressure of 6.2 bar and a temperature of 560 K. The mass of catalyst in the reactor was designed. The feed gas mixture consists of H_2, CO, and CO_2 at certain ratio. The average of superficial velocity in steady condition was 1.5 m/s. The dynamic reactor operation was studied to determine the proper switching time.

Future implementation in Indonesia is profoundly promising due to the need of primary feedstocks and energy. This research has been conducted at Chemical Engineering ITB. The research member consists of competent people in their field: Dr. Yogi Wibisono Budhi (Process Intensification), Dr. Jenny Rizkiana (modeling), Neng Tresna Umi Culsum, SSi.MSi. (PhD student), and Utari Nuravifah, ST. (Master student). The collaboration between ITB, TU Delft, PT Pupuk Sriwidaja has been targeted in this research.

6. **LIST OF RESEARCH OUTPUT**
   - **International Journal Publication**
   a. Budhi, Yogi W., Nuravifah, U., Sophiana, Intan C., Rizkiana, J., Modeling and Simulation of a Reverse-Flow Reactor for Methane Production from Synthetic Gas, IOP Publishing (under process)
   b. Budhi, Yogi W., Wisnuaji, Bagus A., Judistira, Gusrinisa, G., and Ferry, V., Effect of Dynamic Concentration of Methane Oxidation in a Reverse Flow Reactor, IOP Publishing (under process)
   c. U.Nuravifah, S.E.Putri, Y.W.Budhi, Simulation of Effective Ni-based Catalyst Design Using Microkinetic Models of COX Methanation on Dynamic Fixed-Bed Reactor, IOP Publishing (under process)
   - **International Conference/Proceeding**
   a. Budhi, Yogi W., Nuravifah, U., Sophiana, Intan C., Rizkiana, J., Modeling and Simulation of a Reverse-Flow Reactor for Methane Production from Synthetic Gas, International Conference on Energy Science, Bandung, September 2018.
   b. Budhi, Yogi W., Wisnuaji, Bagus A., Judistira, Gusrinisa, G., and Ferry, V., Effect of Dynamic Concentration of Methane Oxidation in a Reverse Flow Reactor, International Conference on Energy Science, Bandung, September 2018.
   c. U.Nuravifah, S.E.Putri, Y.W.Budhi, Simulation of Effective Ni-based Catalyst Design Using Microkinetic Models of CO_X Methanation on Dynamic Fixed-Bed Reactor, 3rd MRS-id Meeting 2018, Denpasar Bali, 2018.

II. TECHNICAL REPORT

Introduction

As a result of the continuous reduction of crude oil and gas resources, and the increasing concern for greenhouse effects due to human CO_2 emissions, recent focus has been put on the development of renewable and environmentally friendly energy from wind and sunlight. As these energy sources are intermittent the produced electricity needs to be balanced for power grid stability purposes. Electricity storage via power-to-gas (PtG) technology is a promising solution to tackle this issue. The PtG process links the power and natural gas grids by the conversion of electrical energy into a chemical energy carrier, substitute natural gas (SNG).

SNG is produced via two steps: H_2 production through water electrolysis and H_2 conversion with an external CO_2 source into CH_4 via the methanation reaction. The resulting SNG can be injected into the existing gas grid or gas storages and can easily be utilized in the already well-established infrastructure and conversion systems. The methanation reactor used in a PtG facility needs to be highly load flexible in order to follow the H_2 profile from the electrolyzer as closely as possible, thus keeping the H_2 storage tank as small as possible, while satisfying SNG quality requirements.

Methane (CH_4), which can be obtained as a major component in natural gas, currently is

Final Report

The Characteristic of Spectral Reflectance of LAPAN-IPB (LAPAN-A3) Satellite and Landsat 8 over Agricultural Area in Probolinggo, East Java

1. Arif Kurnia Wijayanto

Center for Environmental Research, Bogor Agricultural University

2. Sri Malahayati Yusuf

Center for Environmental Research, Bogor Agricultural University

3. Wiwid Arif Pambudi

Center for Environmental Research, Bogor Agricultural University

Submitted to:

Center for Environmental Research

Bogor Agricultural University

for

The Osaka Gas Foundation of International Cultural Exchange (OGFICE)

October 2018
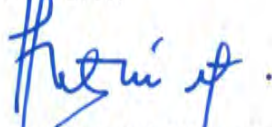
General Information

Title   :   The Characteristic of Spectral Reflectance of LAPAN-IPB (LAPAN-A3)
                                      Satellite and Landsat 8 over Agricultural Area in Probolinggo

Researchers:

1   Name   :   Arif Kurnia Wijayanto, M.Sc

    Institution   :   Center for Environmental Research, Bogor Agricultural
                                      University

    Address of institution   :   Gedung PPLH Lantai 2-4, Jl. Lingkar Akademik, Kampus IPB
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2   Name   :   Dr Sri Malahayati Yusuf, M.Si

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                                      +62-251-8622134 E-mail: pplh@apps.ipb.ac.id

Bogor, ... October 2018

Center for Environmental Research,   Principal Investigator,
Bogor Agricultural University,
Director,

Dr. Ir. Hefni Effendi, M.Phil   Arif Kurnia Wijayanto, M.Sc

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Executive Summary

Since 2012, Bogor Agricultural University (IPB) and the National Agency of Aeronautics and Space (LAPAN) have approved a partnership to develop satellites which was later named LAPAN-IPB Satellite or LAPAN-A3. This is a micro-experimental satellite which was launched on June 2016 mainly developed to support Indonesia's food security and environmental monitoring program. Landsat is United States' (NASA/USGS) operational satellite mainly developed for earth observation. Landsat-8 is the latest operating satellite in the series of Landsat satellite. Both LAPAN-A3 and Landsat have quite equal specification. However, it is important to investigate the difference of characteristic compared to Landsat 8 as which has been commonly used by Indonesian researcher in the field of agriculture for years. Probolinggo is a regency in East Java, Indonesia – with large area of agriculture. Based on the facts, Probolinggo would be a very suitable place to this study.

The study area was Probolinggo regency at East Java province. Satellite data of LAPAN A3/IPB used in the analysis of its spectral characteristic over agricultural area in Probolinggo acquired on September 18, 2018. The LANDSAT 8 image data used is data (Path 118, row 065) with acquisition date on September 12, 2018. Instruments used in field observation such as handheld GPS, spectrophotometer, and drone. Field data measurement was done by collecting spectral reflectance of some agricultural crops located at study area. There were 4 agricultural crops observed in the field observation: (1) paddy, (2) corn, (3) sugar cane, and (4) onion.

Spectral reflectance from the four crops are quietly the same. Except for paddy which has the lowest reflectance on peak of green band compared to other crops. On Blue, Green and Red band, spectral profile of LAPAN-A3/IPB are always lower than Landsat 8. On the other hand, on NIR band, LAPAN-A3/IPB is always higher. From corn and onion, NIR band of Landsat 8 OLI has highest correlation to NIR band of LAPAN-A3/IPB based on its coefficient of determination (R^2). However, on the other hand this band found having low correlation from paddy and sugar cane. NDVI value range from both satellites data are quietly similar. NDVI from Landsat 8 OLI ranged from -1 to 0.622844, while NDVI from LAPAN-

A3/IPB ranged from -1 to 0.461655. NDVI from Landsat is able to differentiate water more clearly than LAPAN-A3/IPB, indicated by low NDVI value.

It is concluded that LAPAN-A3/IPB has quite similar spectral characteristic compared to LANDSAT-8 OLI. Although there is some difference of spectral characteristic from some crops. It is recommended to consider the age or growth stage of each crop. This is to avoid spectral mis-interpretation due to difference in growth stage. More sample also required to be observed. The more samples, the better quality of model will be.

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The Osaka Gas Foundation of International Cultural Exchange (OGFICE)

Research Grant FY 2017/2018

Final Report

Landuse Change Analysis for Hydrology Response and Planning Management of Cibeet Sub-Watershed, West Java, Indonesia

1. Setyo Pambudi Nugroho

2. Luluk Dwi Wulan Handayani

3. Riski Meidiza

4. Gilang Munggaran

Enviromental Research Center (PPLH)

General Information

Title	:	Landuse Change Analysis for Hydrology Response and Planning Management of Cibeet Sub-Watershed, West Java, Indonesia

Researchers:

1	Name	: *Setyo Pambudi Nugroho, SP., M.Si*
	Institution	: *Enviromental Research Center (PPLH) IPB*
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2	Name	: *Luluk Dwi Wulan Handayani, SP., M.Si*
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3	Name	: *Riski Meidiza, SP*
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4	Name	: *Gilang Mungaran, SP., M.Si*
	Institution	: *Enviromental Research Center (PPLH)*
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Center for Environmental Research,
Bogor Agricultural University,
Director,

Dr. Ir. Hefni Effendi, M.Phil

Bogor, 12 October 2018
Principal Investigator,

Setyo Pambudi Nugroho, SP. M.Si

i

Executive Summary

The watershed has an important role in the hydrological cycle as a catchment area and channeling water. Hence, it is necessary to plan a good watershed management, so that the watershed is maintained its sustainability and the availability of water around the watershed area is fulfilled. Ecosystems damaged in watersheds causes function of hydrological become worse, the environmental services provided will be reduced. This watershed damage is caused by unplanned landuse changes.

One of them is the Cibeet Sub-watershed which is part of the Citarum watershed which is included in the priority watershed category 1. Cibeet sub-watershed is chosen as the research location because this watershed is part of the Citarum Downstream watershed that supports energy security and food security in West Java. The Citarum watershed is currently designated as a watershed with critical conditions. The cause of watershed ecosystems damage is landuse change. Landuse changes affect the watershed main function as a regulator of the hydrological cycle. Hence, it is necessary to plan KTA-based land management (Soil and Water Conservation). Various efforts have been made by BPDASHL Citarum-Ciliwung Watershed in improving the Citarum watershed biophysics such as the RHL program (Forest and Land Rehabilitation) and the application of SRA (Water Infiltration Wells). Watershed land management planning can be done with the SWAT (Soil Water Assessment Assessment) model.

The SWAT model application in this study can be used to predict the influence of landuse changes in 2011, 2014 and 2017 on the hydrological characteristics of the Cibeet Sub-watershed. In addition, it also evaluates land allotment in the West Java Spatial Plan for 2025, so that it can provide watershed management recommendations based on several land use scenarios from the Cibeet Sub-watershed in maintaining water availability. This research is useful as a material consideration for stakeholders related to regional planning, so that it can formulate the best and sustainable regional planning around the Cibeet Sub-watershed.

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Final Report

Identification of Mangrove Forest Using Object Based Image Analysis in Bontang, East Kalimantan

1. Vina Nurul Husna

Center for Environmental Research

2. Pungki Ari Wibowo

Center for Environmental Research
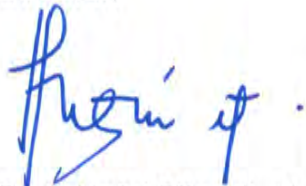
General Information

Title

: Identification of Mangrove Forest Using Object
Based Image Analysis in Bontang, East Kalimantan

Researchers:

1 Name : *Vina Nurul Husna, S.Si*

   Institution : *Center for Environmental Research*

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Bogor, 11 October 2018

Center for Environmental Research, Principal Investigator,
Bogor Agricultural University,
Director,

Dr. Ir. Hefni Effendi, M.Phil   Vina Nurul Husna, S.Si

Executive Summary

Mangrove forests have several functions, namely preventing the intrusion of sea water, erosion, abrasion, and was instrumental in the formation of the island and stabilize the presence of coastal habitat. Bontang has an extensive mangrove ecosystem because Bontang is located in coastal areas. However, the inventory of mangrove ecosystem and its condition is still not very detailed because of mangrove located in remote area. Remote sensing providing opportunities for identifying, monitoring, mapping and calculation of the extent of land cover and deforestation. One of the technologies and methods in the identification of remote sensing image information that is object-based image analysis (OBIA). The research objective was to determine the extent of mangrove forests in Bontang in 2018 using Landsat remote sensing data. This research provides advice on land use planning in the management of coastal mangrove forests.

The results of this study indicate that there is an increase in mangrove area in Bontang City from 2017 to 2018 at 18.68% due to the many conservation activities for mangrove conservation. These conservation activities should not only consider the quantity but also species diversity so that many benefits can be obtained from each type of mangrove.

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The Osaka Gas Foundation of International Cultural Exchange (OGFICE)

Research Grant FY 2017/2018

Final Report

Comparison of Spatial, Temporal and Spectral Resolution between Landsat 8 Imagery and LISAT Imagery (Case study: Jatiluhur Reservoir, West Java, Indonesia)

1. Prita Ayu Permatasari

Environmental Research Center, Bogor Agricultural University

2. Sri Muslimah

Center for International Forestry Research

3. Bagus A. Utomo

Environmental Research Center, Bogor Agricultural University

Submitted to:

Center for Environmental Research

Bogor Agricultural University

for

The Osaka Gas Foundation of International Cultural Exchange (OGFICE)

October 2018

General Information
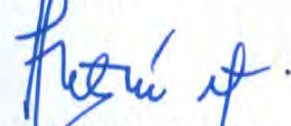
Title   : Comparison of Spatial, Temporal, and Spectral Resolution between Landsat 8 Imagery (Case study: Jatiluhur Reservoir, West Java, Indonesia)

Researchers:

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Bogor, 12 October 2018

Center for Environmental Research,   Principal Investigator,
Bogor Agricultural University,
Director,

Dr. Ir. Hefni Effendi, M.Phil   Prita Ayu Permatasari, BSc.

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Final Report

Drought Monitoring using LISAT (LAPAN-IPB Satellite) and Landsat 8 Satellite Imagery in Pakisjaya District, West Java

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Center for Environmental Research, IPB

2. Irza Arnita Nur

Center for Environmental Research, IPB

3. Nur Riana Rochimawati

Center for Environmental Research, IPB

Center for Environmental Research

Bogor Agricultural University

for

The Osaka Gas Foundation of International Cultural Exchange (OGFICE)

October 2018

General Information

Title
: Drought Monitoring using LISAT (LAPAN-IPB Satellite) and Landsat 8 Satellite Imagery in Pakisjaya District, West Java

Researchers:

1 Name
: Luisa Febrina Amalo, B.Sc

Institution
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2 Name
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3 Name
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Bogor, 12 October 2018

Center for Environmental Research,
Bogor Agricultural University,
Director,

Principal Investigator,

Dr. Ir. Hefni Effendi, M.Phil

Luisa Febrina Amalo, B.Sc

Executive Summary

Drought is a natural hazard indicated by the decreasing of rainfall and water storage in the region and impacting agricultural sector. Recently, satellites data are widely used for calculating the drought indices. Satellite data is an easy, quick, and inexpensive tools in monitoring drought in the regional scale. Since 2010, Bogor Agricultural University (IPB) and the National Institute of Aeronautics and Space of Indonesia (LAPAN) had launched satellite, called "LISAT" LAPAN-IPB Satellite. Not so many papers are addressing LISAT data application for environmental monitoring, particularly for drought monitoring. Therefore, it is important to evaluate whether or not LISAT data can be used for drought and climate monitoring compared to Landsat 8 OLI/TIRS satellite imagery. The objectives of the research are (1) to compare NDVI values from two different satellites –LISAT and Landsat (2) to analyzed the relationship between climate variability using spatial rainfall data with NDVI values over Pakisjaya District in specific time of study, (3) to validate NDVI derived from LISAT data with field observation. The study area will focus in Pakisjaya District, Karawang, West Java, one of Java agricultural production center. The biggest potentials in Pakisjaya district are agriculture, plantations and fish ponds. Therefore, the identification of drought in Cirebon is expected to be used as an early warning of drought and mitigation measures to reduce the impact of drought on agricultural sustainability. The results showed drought occurrence in 2017 was caused by the shifting of wet season. Wet season that should occurred in January, but from rainfall estimation using CMORPHs, wet season was delayed to April. It is associated with NDVI data derived from LISAT and Landsat 8 results. Highest NDVI was found in April, and the lowest NDVI was found in January. Nevertheless, NDVI value derived from LISAT were low than literature, but generally from the pattern, it can differentiate well different land used observed. Therefore, normalization on LISAT imagery is needed for further study to increase the accuracy. Overall, this study can be used as drought mitigation, particularly for the agricultural farmers, so that they can arrange the suitable planting time.

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RINGKASAN LAPORAN AKHIR
GERAN PENYELIDIKAN OSAKA GAS
END OF OSAKA GAS
GRANT REPORT SUMMARY

A.	**Tajuk Projek** *Project Title*	:	ENHANCING DURABILITY OF NATURAL SOFTWOOD USING POLYMER MATRIX
	Ketua Penyelidik *Project Leader*	:	JOSEPHINE LAI CHANG HUI
	Fakulti/Institut *Faculty/Institute*	:	FAKULTI KEJURUTERAAN
	Ahli Kumpulan Penyelidik *Research Team Members*	:	ASSOC. PROF. DR. RUBIYAH BAINI DR. REZAUR RAHMAN NUR SYUHADA AHMAD ZAUZI NUR AMALINA SHAIRAH ABDUL SAMAT
B.	**Tarikh Geran Diluluskan** *Grant Approval Date*	:	5 DISEMBER 2017
	Tempoh Projek *Project Duration*	:	1 TAHUN
	Peruntukan Yg. Diluluskan *Budget Approved*	:	USD 1800/RM 7500
	Perbelanjaan Terkini *Expenditure To-Date*	:	RM 4911

C. Pencapaian Keseluruhan
Overall Achievement
Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki..
Describe the achievements in relation to the original objectives, hypothesis and research problems.
In this study, there is very minimum work that has been reported on elastomeric polymer nanocomposites (EPNCs) using agricultural wastes, especially in combining two different types of agricultural wastes with elastomeric polymer to form nanocomposites. The aim of this study was to synthesize polyvinyl alcohol/palm kernel shell/coconut kernel shell elastomeric polymer nanocomposites (PVA/PKS/CKS EPNCs) via solution casting method, and to investigate the effect of different ratios of PVA matrix on the physic-mechanical, morphological and moisture absorption properties of PVA/PKS/CKS EPNCs.

D. Pencapaian Utama
Key Findings

PVA/PKS/CKS EPNCs were prepared via solution casting method and the properties of EPNCs were characterized through Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), tensile testing and moisture absorption test. Test results showed that increasing the PVA content increased the tensile strength properties of EPNCs as well as provided smooth with no porous surface morphology. However, beyond certain percentage of PVA content, the moisture absorption increased too. Therefore, 55wt% of PVA/PKS/CKS EPNCs was chosen as the best EPNCs as it had the best overall properties from the aspect of physico-mechanical, morphological and moisture absorption.

E, Hasil Penyelidikan
Deliverables

Sila tandakan item yang berkaitan pada senarai berikut:
Please tick the relevant items below:

	Item	Bilangan/*Number*
	Kertas teknikal/bersiri dalaman *Internal technical/serial papers*	
	Tesis/disertasi pelajar sarjana *Student's Masters thesis/dissertation*	
	Tesis pelajar PhD *Student's PhD thesis*	
	Kertas persidangan tempatan *Local conference papers*	
	Kertas persidangan antarabangsa *International conference papers*	
	Makalah dalam jurnal tempatan *Local journal papers*	1
	Makalah dalam jurnal antarabangsa *International journal papers*	
	Monograf atau buku *Book/monograph*	

Lain-lain/*others* (sila nyatakan/*please specify*)

N/A

Sila senaraikan maklumat (pengarang, tahun, tajuk, jurnal/penerbit, jilid, halaman) bagi penerbitan/tesis yang dihasilkan (jika ada).
Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)

Lai, J. C. H., and **Yusof, N. L.** (2018). Physico-Mechanical, Morphological Properties of Polyvinyl Alcohol/Palm Kernel Shell/Coconut Kernel Shell Elastomeric Polymer Nanocomposites. Journal of Applied Science and Process Engineering, vol. 5 (2): 296-303.

F. Pengecaman Output
Output Identification

Sila tandakan penerangan yang berkaitan pada senarai berikut:
Please tick the relevant description as given below:

	Suatu sumbangan besar kepada bidang ilmu yang berkaitan *A major contribution to knowledge (new knowledge) in the respective discipline*
/	Suatu sumbangan kecil tetapi bermakna kepada bidang ilmu yang berkaitan *A minor but important contribution to knowledge in the respective discipline*
	Suatu sumbangan besar kepada teknologi/ciptaan/algoritma dalam bidang yang berkaitan *A major contribution to technology/invention/algorithm or a tangible product*
	Suatu sumbangan kecil tetapi bermakna kepada teknologi/ciptaan/algoritma berkaitan *A minor but important contribution to relevant technology/invention/algorithm*
	Terdapat potensi yang baik untuk kajian lanjutan ke arah pemasaran *There is a good potential for further R & D and commercialization*
	Suatu sumbangan besar kepada kerangka polisi pengurusan/garis panduan *A major contribution to management policy framework/guidelines (in relevant areas)*
	Suatu sumbangan kecil tetapi bermakna kepada kerangka polisi pengurusan/garis panduan *A minor contribution to management policy framework/guidelines (in relevant areas)*
	Sesuai untuk dijadikan bahan pengajaran/*case study* atau bahan latihan *The finding is suitable for use as a complementary teaching/training material (a case study)*
	Suatu output yang baik dan berpotensi untuk memenangi hadiah penyelidikan *A quality output that has a potential for winning a research award*
	Suatu bahan yang baik/sesuai untuk hebahan atau pameran *A good/suitable material for showcasing/publicizing/exhibition*

Lain-lain/*Others* (Sila nyatakan/*Please specify*)
N/A

G. Sinopsis Hasil Penyelidikan bagi Tujuan Promosi
Synopsis for Promotional Purposes
(Beri huraian ringkas yang tidak melebihi 400 perkataan dan dalam bahasa yang mudah, bagi maksud hebahan hasil penyelidikan ini melalui media massa dan 'Unimas Research Update')
(Please provide a synopsis not exceeding 400 words, in a not-too-technical language, for the purpose of promoting this research findings through the mass media and Unimas Research Update).

PVA/PKS/CKS EPNCs were prepared by solution casting method and was successfully investigated in terms of physical, mechanical, morphological and moisture absorption properties. Incorporation of PVA matrix at 55wt% showed the best adhesion and compatibility with PKS and CKS filler among all the nanocomposites. Based on the FTIR results, 55wt% PVA matrix showed the least OH bonding compared to other ratios which proved that 55wt% PVA/PKS/CKS EPNCs could form strong bonding between matrix and fillers. In addition, 55wt% PVA/PKS/CKS EPNCs showed the smoothest surface morphology with well compatibility of matrix and fillers compared to other ratios nanocomposites. Tensile strength of PVA/PKS/CKS EPNCs were significantly enhanced with the introduction of 55wt% PVA matrix into PKS and CKS fillers, with clear proven from moisture absorption test. The addition of {KS and CKS into PVA polymer matrix improved the properties of pure PVA polymer matrix and this can be applied in structural applications.

Catatan Penting/Important Notes

Penyelidik diminta mengemukakan kepada Pusat Penyelidikan:
- Borang ini dalam kedua-dua bentuk bercetak dan elektronik

Researchers are required to submit to the Research Centre:
- *This form in both hard- and soft-copies*

9 JANUARI 2019

………………………………….. …………………………………

Tandatangan (Penyelidik Utama) **Tarikh**

Signature (Principal Researcher) Date

A.	**Tajuk Projek** *Project Title*	**: Low Power and Low Energy Design of Asynchronous Communication Circuit with Novel Design of Completion Detectors**
	Ketua Penyelidik *Project Leader*	**: Norhuzaimin Julai**
	Fakulti/Institut *Faculty/Institute*	**: Engineering**
	Ahli Kumpulan Penyelidik *Research Team Members*	**: Shamsiah Suhaili**
B.	**Tarikh Geran Diluluskan** *Grant Approval Date*	**: 1st January 2018**
	Tempoh Projek *Project Duration*	**:1 year**
	Peruntukan Yg. Diluluskan *Budget Approved*	**:RM 4500**
	Perbelanjaan Terkini *Expenditure To-Date*	**:RM1,000**

C. Pencapaian Keseluruhan
Overall Achievement
Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki..
Describe the achievements in relation to the original objectives, hypothesis and research problems.

In digital design, there are two types of design, synchronous design and asynchronous design. In synchronous design, global clock is one of the main system that consume a lot of power. The power in synchronous design is consumed by clock even if there is no data processing take place. The asynchronous design that depends on data is clockless and as far as the power is concerned, asynchronous design does not consume much power compared with synchronous design and this really make asynchronus design the preffered choice for low power consumption.

Besides having low power consumption, there are many advantages of aynchronous design compared with synchronous design. First the absence of clock skew. Clock skew refer to the arrival time difference of the clock signal to reach different parts of the system. The clock skew is one of the design challenge in synchronous design. The presence of process variations may cause adverse effect on the clock frequencies.Second the" Better than worst case performance". The worst case scenarion need to be taken into account in synchronous design to ensure the circuit won't fail under the worst case scenario. For asynchronous design, the average case performance is the most likely case due to the data-dependant data flow and functional unit that exhibit data-dependant delay. Third the Automatic adaption to physical properties. Delay is depended on many factors such as process variation, environment factors (temperature) and voltage supply. In synchronous design, these factors need to be considered and to ensure the design is reliable, the worst of the above conditions need to be calculated accordingly. However, in asynchronous design, since it is depended on the data as a clock, the above factors are automatically adjusted and hence the designer need not to worry the functionality of the circuit even under the worst case scenario. And finally, reduced electromagnetic interference. Synchronous circuit needs to be very precise with the clock system and this result in very narrow spectral band in the clock frequency. Any interference for example due to electromagnetic interference with the system clock in synchronous design may result in the circuit to function slower or even it will completely fails. This is not the case for asynchronous design as the activities of the circuit is very much independent from one to another. Therefore, a more distributed noise spectrum which results from independent activities in asynchronous design makes the circuit to be more reliable compared with synchronous design. The testing devices can be done by using FPGA which is one of the most popular medium to implement digital logic. . This research proposed new dual rail completion detector (CD), 3-6 CD, 2-7 CD and 1-4 CD for on-chip communication that are used widely in an asynchronous communication system. The design of CD is based on the principle of sum adder. After designing the circuit by using Altera Quartus II CAD tools, synthesis and implementation process is executed to check the syntax error of the design. When the design is successful, the simulation process will take place. In this project

D. Pencapaian Utama
Key Findings

This research proposed new dual rail completion detector (CD), 3-6 code detector, 2-7 code detector and 1-4 code detector for on-chip communication that are used widely in an asynchronous communication system
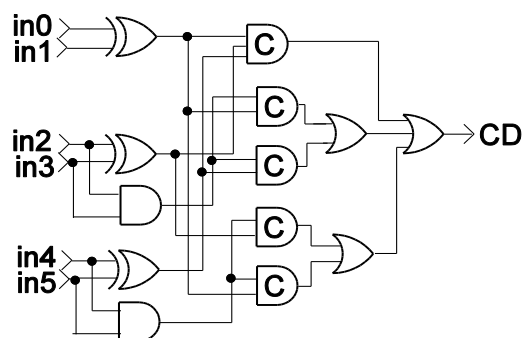
Proposed 3-6 code detector   Proposed 2-7 code detector
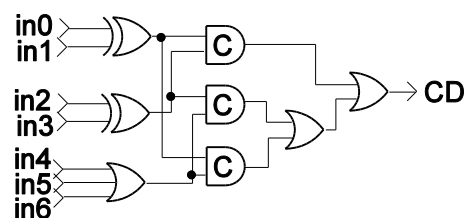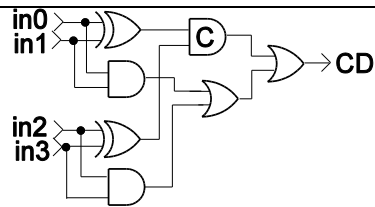
Proposed 1-4 code detector

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    Deliverables

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X	Kertas persidangan tempatan *Local conference papers*	(1)
	Kertas persidangan antarabangsa *International conference papers*	
	Makalah dalam jurnal tempatan *Local journal papers*	
	Makalah dalam jurnal antarabangsa *International journal papers*	
	Monograf atau buku *Book/monograph*	

Lain-lain/*others* (sila nyatakan/*please specify*)

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Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)
Has been accepted in EnCon2018. Expected to be published in 2019

F. Pengecaman Output
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G. Sinopsis Hasil Penyelidikan bagi Tujuan Promosi
Synopsis for Promotional Purposes
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Catatan Penting/Important Notes

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- Borang ini dalam kedua-dua bentuk bercetak dan elektronik

Researchers are required to submit to the Research Centre:
- *This form in both hard- and soft-copies*

Norhuzaimin Julai   22/1/2019

…………………………………..   ……………………………
   Tandatangan (Penyelidik Utama)   **Tarikh**
   Signature (Principal Researcher)   Date

A.	**Tajuk Projek** *Project Title*	:	Energy-efficient Resource Management for Massive MIMO-enabled Small Cell Networks
	Ketua Penyelidik *Project Leader*	:	Dr Ade Syaheda Wani Marzuki
	Fakulti/Institut *Faculty/Institute*	:	Faculty of Engineering
	Ahli Kumpulan Penyelidik *Research Team Members*	:	Dr Dayang Azra Awang Mat Dr Dayang Norkhairunnisa Abg Zaidel Dr Kismet Hong Ping Dr Shafrida Sahrani Dr Rohana Sapawi
B.	**Tarikh Geran Diluluskan** *Grant Approval Date*	:	5 December 2017
	Tempoh Projek *Project Duration*	:	January 2018- December 2018
	Peruntukan Yg. Diluluskan *Budget Approved*	:	USD 1,920.00 (RM8,000.00)
	Perbelanjaan Terkini *Expenditure To-Date*	:	RM 4,515.50

C. Pencapaian Keseluruhan
Overall Achievement
Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki..
Describe the achievements in relation to the original objectives, hypothesis and research problems.

In this research, the objectives are to optimize the performance of massive-MIMO-enabled small cell networks with wireless backhaul links, and to design an energy-efficient resource allocation

scheme for such networks. As small cells are likely to be installed in random locations, it is difficult to avoid inter-cell interference, considering that these cells rely on wireless backhaul connectivity to forward their traffic demands. In a conventional Heterogeneous Network (HetNet) with a dense deployment of small cells, existing approaches for allocating resources for backhaul connectivity seem inefficient in terms of energy and resource management. Moreover, various cell sizes in HetNets result in unequal loads and thus lead to an imbalance in radio resource utilization. Finding the optimal frequency assignment solution that would consume the least amount of spectrum and support dynamic backhaul transmission links will be challenging sue to this issue. Thus, we proposed a time-based cluster-based resource allocation concept for A time-based cluster-based frequency allocation concept for multi-hop wireless SCN backhaul transmission links in a Massive MIMO environment.

The proposed work utilizing Massive MIMO technology to support network densification, in this case small cell networks. Large antenna arrays in massive MIMO can focus the radiated energy precisely towards the intended receivers, thereby efficiently reducing intra-and intercell interference, which are common issues in small cell deployment. In this work, multi-hop backhaul connectivity for Massive MIMO-enable small cell networks was utilized, by applying a cluster-based resource allocation scheme. In this scheme, small cells that do not cause interference are grouped, and allocated with the same sub-channel for their backhaul transmission links. The cluster set needs to be updated at a regular interval to reflect the change in the topology. The motivation behind this is to allocate the resources to these multi-hop backhaul links in such a way to maximize the network spectral efficiency by allowing frequency reuse in the same radiated region of the Massive MIMO.

The proposed solution has proved that the performance of the network has been improved in terms of energy and power consumption, throughput, spectral efficiency and fairness index.

D. Pencapaian Utama
Key Findings

In an ultra-dense small cell deployment, the key challenge is to provide an extensive backhaul connectivity, as the number of dedicated fibres available is limited. Furthermore, the densification of these small cells will eventually lead to higher energy consumption, compared to the existing macrocell base stations alone. Therefore, we formulate the problem of traffic backhauling in a multi-hop wireless SCN, so that their massive traffic can be backhauled to the core network, while minimizing power consumption.

The energy consumption problem for backhaul links meant for Massive MIMO-enabled small cell networks is formulated, with the goal of minimizing total power consumption. This includes the power derived from the small cells within the same radiated region of a Massive MIMO antenna and their wireless backhaul transmissions. The performance of the proposed work is evaluated and compared against the existing traffic backhauling approach considered in [1], [2], [3]. In the existing approach, the number of connecting links/hops is given the maximum weight for measuring the goodness of the backhauling route. The number of small cells is varied and the results are monitored. Each set of simulation scenarios (with different topology and traffic

demand) was sampled 1000 times to get the sample mean of overall network and backhaul power consumption, network delay and energy efficiency. The results are discussed as follows:
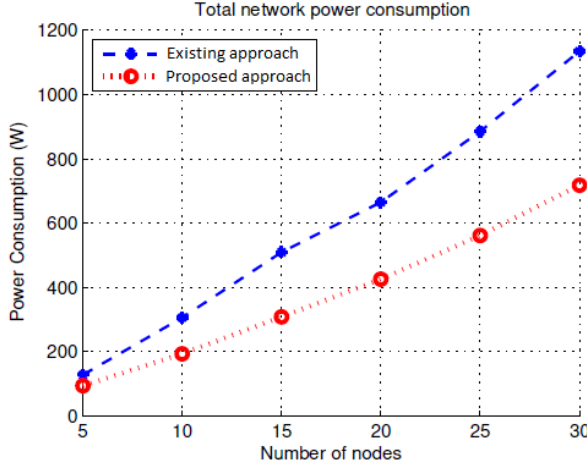
Figure 1:
Total network power consumption comparison
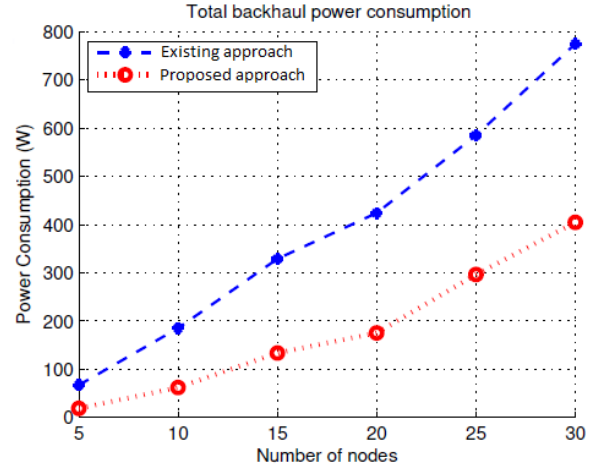
Figure 2:
Total network power consumption comparison
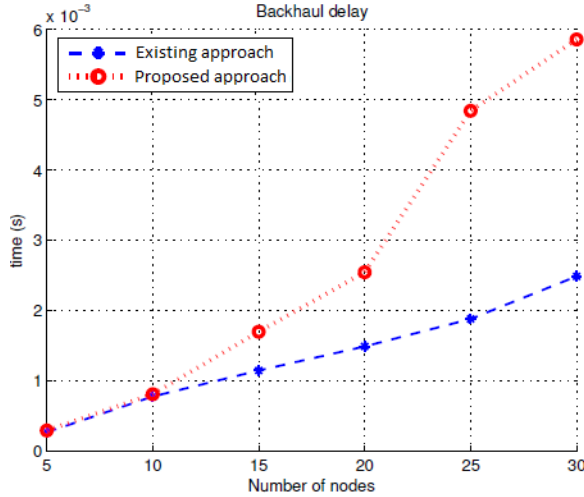
Figure 3:
Network backhaul delay comparison
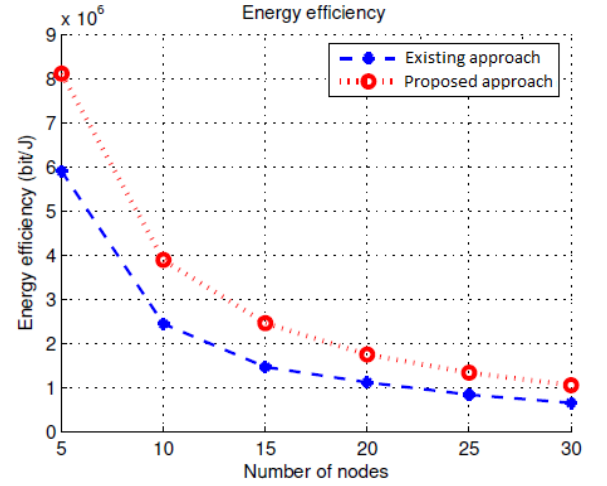
Figure 4:
Energy efficiency comparison

As shown in Figure 1, the total network power consumption of the proposed work and the existing traffic backhauling approach for different numbers of small cells in a Massive MIMO-enabled wireless SCN, are evaluated. The total network power consumption in the existing approach is higher than the proposed solution, and as the number of nodes increases, the gap between the two approaches becomes significantly larger. In our proposed work, the traffic is forced to flow via specific links so that these links can be fully utilized and the spectrum efficiency can be maximized. The backhaul power consumption (see Figure 2) for both approaches shows similar trends to the total network power consumption graph, shown in Figure 1. However, lower backhaul power consumption is achieved in both approaches, compared to the total network power consumption, as only the power consumed by the backhaul links is computed.

Figures 1 and 2 revealed that the proposed approach can significantly reduce both total network

and backhaul power consumptions. However, there is a trade-off between these power components and backhaul delays (Figure 3). When the number of small cells within the same radiated region is less than 10, the total backhaul delay for both approaches is approximately similar; however, the gap of network delay increases with the increasing number of small cells. The lowest range of delays is achieved for existing approach, ranging from approximately 0.295 ms to 2.49 ms, for the number of small cells ranging from 5 to 30. Conversely, our proposed approach achieved delays, with a range from 0.295 ms to 5.86 ms. Thus, the proposed approach balances the performance trade- off between the number of resource allocated due to number of hops taken and the energy consumption. The increase in delay in our work however, is not significant as according to ITU's (G.114) specifications, the end-to-end delay has to be more than 150 ms before the degradation of QoS can be perceived.

In Figure 4, the energy efficiency of both approaches is depicted for various small cell densities in wireless SCN and this efficiency is maximized by implementing the proposed approach. This outcome resulted from the fact that lower power consumption in a multi-hop traffic backhauling is achieved in the proposed scheme via the use of an effective resource allocation scheme, leading to a higher energy efficiency.

[1] G. Zhang, T. Q. S. Quek, M. Kountouris, A. Huang, and H. Shan, "Fundamentals of heterogeneous backhaul design : Analysis and optimization," IEEE Transactions on Communications, vol. 64, no. 2, pp. 876–889, Feb 2016.

[2] D. Karia and V. Godbole, "New approach for routing in Mobile Adhoc Networks based on Ant Colony Optimisation with Global Positioning System," Networks, IET, vol. 2, no. 3, pp. 171–180, Sept 2013.

[3] U. Siddique, H. Tabassum, E. Hossain, and D. I. Kim, "Wireless backhauling of 5G small cells: challenges and solution approaches," IEEE Wireless Communications, vol. 22, no. 5, pp. 22–31, October 2015.

E, Hasil Penyelidikan
Deliverables

Sila tandakan item yang berkaitan pada senarai berikut:
Please tick the relevant items below:

	Item	Bilangan/*Number*
	Kertas teknikal/bersiri dalaman *Internal technical/serial papers*	
/	Tesis/disertasi pelajar sarjana *Student's Masters thesis/dissertation*	In progress
	Tesis pelajar PhD *Student's PhD thesis*	
/	Kertas persidangan tempatan *Local conference papers*	In progress of submission
	Kertas persidangan antarabangsa *International conference papers*	

	Makalah dalam jurnal tempatan *Local journal papers*	
	Makalah dalam jurnal antarabangsa *International journal papers*	
	Monograf atau buku *Book/monograph*	

Lain-lain/*others* (sila nyatakan/*please specify*)

Sila senaraikan maklumat (pengarang, tahun, tajuk, jurnal/penerbit, jilid, halaman) bagi penerbitan/tesis yang dihasilkan (jika ada).
Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)

F. Pengecaman Output
Output Identification

Sila tandakan penerangan yang berkaitan pada senarai berikut:
Please tick the relevant description as given below:

	Suatu sumbangan besar kepada bidang ilmu yang berkaitan *A major contribution to knowledge (new knowledge) in the respective discipline*
	Suatu sumbangan kecil tetapi bermakna kepada bidang ilmu yang berkaitan *A minor but important contribution to knowledge in the respective discipline*
	Suatu sumbangan besar kepada teknologi/ciptaan/algoritma dalam bidang yang berkaitan *A major contribution to technology/invention/algorithm or a tangible product*
/	Suatu sumbangan kecil tetapi bermakna kepada teknologi/ciptaan/algoritma berkaitan *A minor but important contribution to relevant technology/invention/algorithm*
	Terdapat potensi yang baik untuk kajian lanjutan ke arah pemasaran *There is a good potential for further R & D and commercialization*
	Suatu sumbangan besar kepada kerangka polisi pengurusan/garis panduan *A major contribution to management policy framework/guidelines (in relevant areas)*
	Suatu sumbangan kecil tetapi bermakna kepada kerangka polisi pengurusan/garis panduan *A minor contribution to management policy framework/guidelines (in relevant areas)*
/	Sesuai untuk dijadikan bahan pengajaran/*case study* atau bahan latihan *The finding is suitable for use as a complementary teaching/training material (a case study)*
	Suatu output yang baik dan berpotensi untuk memenangi hadiah penyelidikan *A quality output that has a potential for winning a research award*
	Suatu bahan yang baik/sesuai untuk hebahan atau pameran *A good/suitable material for showcasing/publicizing/exhibition*

Lain-lain/*Others* (Sila nyatakan/*Please specify*)

G. Sinopsis Hasil Penyelidikan bagi Tujuan Promosi
Synopsis for Promotional Purposes
(Beri huraian ringkas yang tidak melebihi 400 perkataan dan dalam bahasa yang mudah, bagi maksud hebahan hasil penyelidikan ini melalui media massa dan 'Unimas Research Update')
(Please provide a synopsis not exceeding 400 words, in a not-too-technical language, for the purpose of promoting this research findings through the mass media and Unimas Research Update).

The advancement of wireless mobile and communication technologies has increased the needs for higher data rates, wider capacity and coverage in the future 5G deployment. This crucial needs can be satisfied by a significant network densification through the deployment of small cells. To further support a highly dense small cell networks, massive MIMO technology is integrated into an existing heterogeneous network in this work. In such systems, a massive number of antennas is deployed at each macrocell site to form a network for small cell traffic backhauling purposes. In general, any centralized resource management approach for massive MIMO-operated small cell networks is infeasible due to large number of small cells and their random deployments. This causing a concern in which the uncoordinated resource management may cause a severe cross-tier interference, hence exacerbating the network performance. Moreover, the varying traffic conditions from these small cells may cause load imbalance in the network, thus a fixed amount of resource allocated to these cells will not be practical.

The main motivation for this research is to address the need for adaptive resource allocation scheme in massive MIMO systems in a small cell-assisted network to cater for an increased network coverage, capacity and spectrum efficiency. The integration of massive MIMO and small cells could be the next promising candidate for 5G systems. In this work, the simulation work for optimizing the resource allocation for backhaul wireless small cell networks will be involved. Research finding will include an adaptive and green resource allocation scheme that can mitigate both co-and cross-tier interference, hence increasing the network QoS.

In this research, an energy-efficient resource management scheme for multi-hop traffic backhauling solution for 5G Massive MIMO-enabled Small Cell Networks was proposed. The resources are allocated based on the optimization function which models the total network power consumption by deriving the power consumed by the small cells and their wireless backhaul links. Then, the low power traffic backhauling paths with optimum resource allocation for a multi-hop wireless SCN are selected. Considering the time complexity of the optimization model, a heuristic solution to reduce the backhaul power consumption in the 5G SCNs was also considered. The simulation results for the proposed approach reveal a significant reduction in the backhaul power consumption and much higher energy efficiency.

Catatan Penting/Important Notes

Penyelidik diminta mengemukakan kepada Pusat Penyelidikan:
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Researchers are required to submit to the Research Centre:
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Tandatangan (Penyelidik Utama) **Tarikh**

Signature (Principal Researcher) Date

RINGKASAN LAPORAN AKHIR
GERAN PENYELIDIKAN OSAKA GAS
END OF OSAKA GAS
GRANT REPORT SUMMARY

A.	**Tajuk Projek** *Project Title*	**:**	**A STUDY ON POCKET UNUSED SPACE AT UNIMAS WEST CAMPUS FOR POTENTIAL INFILL DEVELOPMENT TOWARDS A LIVELIER, CONDUCIVE SUSTAINABLE CAMPUS ENVIRONMENT**
	Ketua Penyelidik *Project Leader*	**:**	Dona Rose bt Amer Koesmeri
	Fakulti/Institut *Faculty/Institute*	**:**	Faculty of Engineering (Currently, Faculty of Built Environment)
	Ahli Kumpulan Penyelidik *Research Team Members*	**:**	AP Dr Siti Halipah Ibrahim Prof Ar Nurakmal Abdullah Goh AP Dr Azhaili Baharun Dr Bambang Karsono Zayn Al-Abideen Gregory Yon Syafni bt Samat
B.	**Tarikh Geran Diluluskan** *Grant Approval Date*	**:**	5/12/2017
	Tempoh Projek *Project Duration*	**:**	1 year (12 months)
	Peruntukan Yg. Diluluskan *Budget Approved*	**:**	RM 7000 (USD 1,680.00)
	Perbelanjaan Terkini *Expenditure To-Date*	**:**	RM 4,488.00

C. **Pencapaian Keseluruhan**
Overall Achievement
Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki.
Describe the achievements in relation to the original objectives, hypothesis and research problems.

The objective of the study was to identify and record potential infill spaces in UNIMAS West Campus, especially on the existing structures and unused spaces. From the study, it was found that UNIMAS campus has void spaces that have a lot of potential to develop.

The study identified potential usage to these spaces that could promote vibrant and conducive campus environment. The spaces shall be able to connect existing structures; thus it shall add value to the existing buildings.

D. Pencapaian Utama
Key Findings
Based on the identification of the pocket under used spaces in the campus, researchers have come up with a draft Infill Development Mapping for the UNIMAS West Campus. The mapping is based on the suggestion that a campus planning shall look into a balanced development which will encompass environmental, social and economic aspects in order to create a unifying campus system.

E, Hasil Penyelidikan
Deliverables

Sila tandakan item yang berkaitan pada senarai berikut:
Please tick the relevant items below:

	Item	Bilangan/*Number*
	Kertas teknikal/bersiri dalaman *Internal technical/serial papers*	
	Tesis/disertasi pelajar sarjana *Student's Masters thesis/dissertation*	
	Tesis pelajar PhD *Student's PhD thesis*	
	Kertas persidangan tempatan *Local conference papers*	
X	Kertas persidangan antarabangsa *International conference papers*	*Pending Publication
	Makalah dalam jurnal tempatan *Local journal papers*	
	Makalah dalam jurnal antarabangsa *International journal papers*	
	Monograf atau buku *Book/monograph*	

Lain-lain/*others* (sila nyatakan/*please specify*)

Sila senaraikan maklumat (pengarang, tahun, tajuk, jurnal/penerbit, jilid, halaman) bagi penerbitan/tesis yang dihasilkan (jika ada).
Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)

* Pending Publication of Journal Paper

F. Pengecaman Output
Output Identification

Sila tandakan penerangan yang berkaitan pada senarai berikut:
Please tick the relevant description as given below:

	Suatu sumbangan besar kepada bidang ilmu yang berkaitan *A major contribution to knowledge (new knowledge) in the respective discipline*
	Suatu sumbangan kecil tetapi bermakna kepada bidang ilmu yang berkaitan *A minor but important contribution to knowledge in the respective discipline*
	Suatu sumbangan besar kepada teknologi/ciptaan/algoritma dalam bidang yang berkaitan *A major contribution to technology/invention/algorithm or a tangible product*
	Suatu sumbangan kecil tetapi bermakna kepada teknologi/ciptaan/algoritma berkaitan *A minor but important contribution to relevant technology/invention/algorithm*
X	Terdapat potensi yang baik untuk kajian lanjutan ke arah pemasaran *There is a good potential for further R & D and commercialization*
	Suatu sumbangan besar kepada kerangka polisi pengurusan/garis panduan *A major contribution to management policy framework/guidelines (in relevant areas)*
X	Suatu sumbangan kecil tetapi bermakna kepada kerangka polisi pengurusan/garis panduan *A minor contribution to management policy framework/guidelines (in relevant areas)*
X	Sesuai untuk dijadikan bahan pengajaran/*case study* atau bahan latihan *The finding is suitable for use as a complementary teaching/training material (a case study)*
	Suatu output yang baik dan berpotensi untuk memenangi hadiah penyelidikan *A quality output that has a potential for winning a research award*
	Suatu bahan yang baik/sesuai untuk hebahan atau pameran *A good/suitable material for showcasing/publicizing/exhibition*

Lain-lain/*Others* (Sila nyatakan/*Please specify*)

G. Sinopsis Hasil Penyelidikan bagi Tujuan Promosi
Synopsis for Promotional Purposes

(Beri huraian ringkas yang tidak melebihi 400 perkataan dan dalam bahasa yang mudah, bagi maksud hebahan hasil penyelidikan ini melalui media massa dan 'Unimas Research Update')
(Please provide a synopsis not exceeding 400 words, in a not-too-technical language, for the purpose of promoting these research findings through the mass media and Unimas Research Update).

A campus shall be a comprehensive development that values the university community where teaching, learning activities, research, administrative operations and leisure are conducted in an approach that enhances and protects the environment. A conducive environment resulted from a well-planned campus, will support the campus community structure altogether.

Infill development in UNIMAS shall be the process of developing vacant or pocket under-used spaces within existing developed campus areas. Ideally, infill development encourages development within the defined footprint. A successful infill development planning should focus on the job of crafting well-functioning campus environment. Infill sites are normally located within existing development which reduce the need for major earthwork of which indirectly reducing emission for earthwork activities. Thus it has a significant economic benefit in avoiding new infrastructure development.

The objective of the study was to identify and record potential infill spaces in UNIMAS West Campus, especially on the existing structures and under used spaces. From the study, it was found that UNIMAS campus has void spaces that have a lot of potential to develop.

The study identified potential usage to these spaces that could promote vibrant and conducive campus environment. The spaces shall be able to connect existing structures; thus it shall add value to the existing buildings. Based on the identification of the pocket under used spaces in the campus, researchers have come up with a draft Infill Development Mapping for the UNIMAS West Campus. The mapping is based on the suggestion that a campus planning shall look into a balanced development which will encompass environmental, social and economic aspects in order to create a unifying campus system. Attention to the planning of infill development is essential to ensure that the future new development fits the existing context, to be structured and integrated accordingly with the existing campus environment.

Catatan Penting/Important Notes

Penyelidik diminta mengemukakan kepada Pusat Penyelidikan:
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31/01/2019

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Tandatangan (Penyelidik Utama) **Tarikh**
Signature (Principal Researcher) Date

A.	**Tajuk Projek** *Project Title*	:	**CONSERVING INDIGENEOUS CULTURE THROUGH FIRE PREVENTION : DEVELOPING A LONGHOUSE PASSIVE FIRE BARRIER**
	Ketua Penyelidik *Project Leader*	:	Zayn Al-Abideen Gregory
	Fakulti/Institut *Faculty/Institute*	:	Faculty of Engineering (Currently, Faculty of Built Environment)
	Ahli Kumpulan Penyelidik *Research Team Members*	:	Dr Bambang Karsono Yon Syafni bt Samat Dona Rose Koesmeri Prof Ar Nurakmal Abdullah Goh
B.	**Tarikh Geran Diluluskan** *Grant Approval Date*	:	23/1/2018
	Tempoh Projek *Project Duration*	:	1 year (12 months)
	Peruntukan Yg. Diluluskan *Budget Approved*	:	RM7000
	Perbelanjaan Terkini *Expenditure To-Date*	:	Nil

C. **Pencapaian Keseluruhan**
Overall Achievement
Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki..
Describe the achievements in relation to the original objectives, hypothesis and research problems.

The research team visited three longhouses in the Seri Aman area: two built of wood in the 1980s-1990s and one built of masony and reinforced concrete in recent years.

Photodocumentation of architectural details and the site itself were taken.

Measurements were carried out, resulting in a plan drawing to scale of the two wooden longhouses.

Impromptu interviews were conducted with local residents.

D. **Pencapaian Utama**
   Key Findings

Partition walls between units are in place, together with fire safety equipment such as portable fire extinguishers. Local government officials are responsive in testing and replacing fire extinguishers. Nonetheless the interconnected nature of the longhouse prevents further improvements to fire safety, if building continues to be from wood.

Residents of the modern masonry longhouse appeared to thoroughly enjoy their building, and the transition to modern materials does not appear to negatively affect their communal culture or lifestyle. The idea that a particular typology must remain frozen in time to be authentic must be challenged and rethought. Rather than perpetuating *wooden* longhouse construction in the face of fire risk, perhaps architects can work with other stakeholders to develop new materials and forms to conserve the vibrant, living communal culture that is the animating soul of the wooden longhouse.

E, **Hasil Penyelidikan**
   Deliverables

Sila tandakan item yang berkaitan pada senarai berikut:
Please tick the relevant items below:

	Item	Bilangan/*Number*
	Kertas teknikal/bersiri dalaman *Internal technical/serial papers*	
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	Tesis pelajar PhD *Student's PhD thesis*	
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	Kertas persidangan antarabangsa *International conference papers*	
	Makalah dalam jurnal tempatan *Local journal papers*	
	Makalah dalam jurnal antarabangsa	

| | *International journal papers* | |
| | Monograf atau buku
 Book/monograph | |

Lain-lain/*others* (sila nyatakan/*please specify*)

The research team still hopes to publish findings in 2019.

Sila senaraikan maklumat (pengarang, tahun, tajuk, jurnal/penerbit, jilid, halaman) bagi penerbitan/tesis yang dihasilkan (jika ada).
Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)

F. Pengecaman Output
Output Identification

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Please tick the relevant description as given below:

	Suatu sumbangan besar kepada bidang ilmu yang berkaitan *A major contribution to knowledge (new knowledge) in the respective discipline*
X	Suatu sumbangan kecil tetapi bermakna kepada bidang ilmu yang berkaitan *A minor but important contribution to knowledge in the respective discipline*
	Suatu sumbangan besar kepada teknologi/ciptaan/algoritma dalam bidang yang berkaitan *A major contribution to technology/invention/algorithm or a tangible product*
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	Terdapat potensi yang baik untuk kajian lanjutan ke arah pemasaran *There is a good potential for further R & D and commercialization*
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	Suatu sumbangan kecil tetapi bermakna kepada kerangka polisi pengurusan/garis panduan *A minor contribution to management policy framework/guidelines (in relevant areas)*
X	Sesuai untuk dijadikan bahan pengajaran/*case study* atau bahan latihan *The finding is suitable for use as a complementary teaching/training material (a case study)*
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	Suatu bahan yang baik/sesuai untuk hebahan atau pameran *A good/suitable material for showcasing/publicizing/exhibition*

Lain-lain/*Others* (Sila nyatakan/*Please specify*)

G. Sinopsis Hasil Penyelidikan bagi Tujuan Promosi
Synopsis for Promotional Purposes
(Beri huraian ringkas yang tidak melebihi 400 perkataan dan dalam bahasa yang mudah, bagi maksud hebahan hasil penyelidikan ini melalui media massa dan 'Unimas Research Update')
(Please provide a synopsis not exceeding 400 words, in a not-too-technical language, for the purpose of promoting this research findings through the mass media and Unimas Research Update).

Archtectural researchers from the Faculty of Built Environment visited several longhouse in the Seri Aman area to investigate the ruinous fires that are a frequent and recurring problem among traditional wooden longhouses. After examining the ways longhouses are built and speaking with the people who live there, researchers suggest that the true spirit of the longhouse is not that it should be made of wood, but that it should be designed in a way that allows the traditional communal culture and social lifestyle of the people to flourish. Once it is recognized that the goal is preservation of way of life and not merely a type of building, architects and the communities can begin to imagine new ways to build longhouses that serve the culture and lifestyle of the people while keeping them safe.

Catatan Penting/Important Notes

Penyelidik diminta mengemukakan kepada Pusat Penyelidikan:
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Tandatangan (Penyelidik Utama)
Signature (Principal Researcher)

…………21/1/2019………
Tarikh
Date

4

A.	**Tajuk Projek** *Project Title*	:	A mathematical approach of predictive control formulation for three level neutral point clamp based indirect matrix converter
	Ketua Penyelidik *Project Leader*	:	Hazrul Bin Mohamed Basri
	Fakulti/Institut *Faculty/Institute*	:	Fakulti Kejuruteraan
	Ahli Kumpulan Penyelidik *Research Team Members*	:	Kasumawati Lias Assoc. Prof. Dr Wan Azlan Wan Zainal Abidin Prof. Ir. Dr. Al-Khalid Othman
B.	**Tarikh Geran Diluluskan** *Grant Approval Date*	:	1 Jan 2018
	Tempoh Projek *Project Duration*	:	Satu tahun
	Peruntukan Yg. Diluluskan *Budget Approved*	:	RM4,000 (USD960)
	Perbelanjaan Terkini *Expenditure To-Date*	:	RM3,543.50

C. Pencapaian Keseluruhan
Overall Achievement
Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki..
Describe the achievements in relation to the original objectives, hypothesis and research problems.

The unbalanced system is an actual commercial and industrial issue. Researchers normally discount this aspect and assume the nonlinearities to be negligible to simplify analysis. However,

this matter should be treated with high precaution to avoid the instability of the power system. In actual implementation, when energy is supplied to a three-phase load, the risk of having an unbalanced load must be considered. If this case occurs, the power-conversion system must provide a path for the zero-sequence current to avoid system instability [1]. Hence, conventional three-leg and three-phase power converters are unsuitable for such applications. An alternative to this problem is to use a four-leg voltage-source inverter at the load side, where the fourth leg serves a path for the zero-sequence current. These systems are required in some applications, such as active power filters, un-interruptible power supplies, active front-end rectifier, distributed power systems, and rural electrification schemes, where arbitrary load profiles are present. These profiles utilize the four-leg topology, which requires accurate current control. Other examples of the application are grid-connected distributed generation systems, which operate in an islanded mode and require four-wire topology to supply local load during temporary loss of the grid supply [2].

Currently, few topologies offer a stable operating system for an unbalanced source or load, as described in [1], [3]–[8]. One passive approach to provide zero-sequence current control employs the split dc-link connection [7]. The neutral point of the load is connected to the neutral of the split dc-link capacitor to regulate the imbalance at the load side. Two evident drawbacks of this solution are the under-utilized dc-link voltage of the connection and the need for an over-sized capacitor to hold the dc-link voltage ripple at an acceptable level if a significant degree of imbalance is present. The dc-link voltage ripple occurs because both dc-links have nearly constant potential [2]. Another topology that can provide the neutral connection to an unbalanced load employs a conventional VSI with Δ/Y or zigzag transformer as a zero-sequence trap. The connection of the delta winding to the inverter and the Y windings to the load can cause the zero-sequence current to be trapped in the delta windings, thus creating balance to the load to some extent [9]. However, the challenge of implementing this solution is the bulky space needed for the transformers. The control scheme based on the PI controller can be implemented to control the four-leg topology [10]. However, the cascaded structure of this control and the tuning of PI controllers are very complicated and time consuming. To regulate the unbalanced loads, six Proportional-Integral (PI) controllers should be designed. Controlling the nonlinear load, which is another crucial point, is more difficult because positive-, negative-, and zero-sequence current components should be extracted at every sampling time by the digital controller. Pulse width modulation (PWM) is a well-known modulation scheme that has been applied in almost all topologies because of its simplicity. The attempt to implement this strategy was described in [11]–[13]. The most interesting finding is that the variable switching frequency from this strategy yields critical harmonic profiles, and the switching signal generation for highly unbalanced load conditions can be inaccurate. Other complex control schemes have been developed, such as robust control [14], adaptive control, and repetitive controller [15]–[17], all of which are mostly applied in uninterrupted power supply (UPS) systems. Most of these modulation schemes are complicated and difficult to apply because they can hardly control the high degree of imbalance [18].

Additional studies have been conducted on 3-D space vector modulation (3D–SVM), which provides good performance in terms of dc-link utilization, output distortion profile, and low switching frequency. However, the computational requirement for this control scheme is extremely high because of the complex steps necessary to calculate the duty cycle [8], [19], [20]. These features are certainly not suitable for actual laboratory and industrial applications. A space-vector modulation (3D–SVM) switching scheme for a four-leg VSI exhibits higher dc-link utilization, less harmonic content, and less switching loss than that of sinusoidal PWM [1]. The only drawback of the 3D–SVM is that it requires complex steps to calculate the duty ratios for each leg and can become a computational burden [2]. Model predictive control is an interesting

alternative to the control scheme mentioned above. The proposed predictive current offers fast dynamic response, which can be applied to various types of topologies. Moreover, its flexibility is the most powerful aspect that has motivated researchers and engineers to study this control scheme. With a simple modification of the embedded cost function, the nonlinearities and system constraints can be included and treated with ease.

D. Pencapaian Utama
Key Findings

1- Mathematical modeling for unbalance system
2- Robust and intuitive load current control using model predictive approach

E, Hasil Penyelidikan
Deliverables

Sila tandakan item yang berkaitan pada senarai berikut:
Please tick the relevant items below:

	Item	Bilangan/*Number*
	Kertas teknikal/bersiri dalaman *Internal technical/serial papers*	-
	Tesis/disertasi pelajar sarjana *Student's Masters thesis/dissertation*	-
	Tesis pelajar PhD *Student's PhD thesis*	-
	Kertas persidangan tempatan *Local conference papers*	1
	Kertas persidangan antarabangsa *International conference papers*	-
	Makalah dalam jurnal tempatan *Local journal papers*	-
	Makalah dalam jurnal antarabangsa *International journal papers*	-
	Monograf atau buku *Book/monograph*	-

Lain-lain/*others* (sila nyatakan/*please specify*)

Sila senaraikan maklumat (pengarang, tahun, tajuk, jurnal/penerbit, jilid, halaman) bagi penerbitan/tesis yang dihasilkan (jika ada).
Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)

F. **Pengecaman Output**
Output Identification

Sila tandakan penerangan yang berkaitan pada senarai berikut:
Please tick the relevant description as given below:

	Suatu sumbangan besar kepada bidang ilmu yang berkaitan *A major contribution to knowledge (new knowledge) in the respective discipline*
X	Suatu sumbangan kecil tetapi bermakna kepada bidang ilmu yang berkaitan *A minor but important contribution to knowledge in the respective discipline*
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	Terdapat potensi yang baik untuk kajian lanjutan ke arah pemasaran *There is a good potential for further R & D and commercialization*
	Suatu sumbangan besar kepada kerangka polisi pengurusan/garis panduan *A major contribution to management policy framework/guidelines (in relevant areas)*
	Suatu sumbangan kecil tetapi bermakna kepada kerangka polisi pengurusan/garis panduan *A minor contribution to management policy framework/guidelines (in relevant areas)*
	Sesuai untuk dijadikan bahan pengajaran/*case study* atau bahan latihan *The finding is suitable for use as a complementary teaching/training material (a case study)*
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Lain-lain/*Others* (Sila nyatakan/*Please specify*)

G. **Sinopsis Hasil Penyelidikan bagi Tujuan Promosi**
Synopsis for Promotional Purposes
(Beri huraian ringkas yang tidak melebihi 400 perkataan dan dalam bahasa yang mudah, bagi maksud hebahan hasil penyelidikan ini melalui media massa dan 'Unimas Research Update')
(Please provide a synopsis not exceeding 400 words, in a not-too-technical language, for the purpose of promoting this research findings through the mass media and Unimas Research Update).
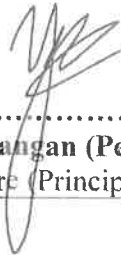
In this research project, the predictive current control was implemented to a four-leg voltage-source inverter to control balanced and unbalanced load conditions. The proposed topology can provide the path for zero-sequence current when unbalanced three-phase loads are connected. Eight distinct combinations of balanced, lightly unbalanced, moderately unbalanced, and heavily unbalanced conditions were subjected to experimental validation. The results indicate that among all eight cases, the proposed scheme can offer outstanding reference tracking ability with a very low harmonics profile. The robustness test demonstrates that the system is sensitive to resistive loads rather than inductive ones. In addition, with the model predictive control, the switching frequency of the fourth leg was optimally reduced to lessen the switching stress of the inverter. The experimental results demonstrate that predictive control is very effective because it intuitively considers the discrete nature of the converter-switching states.

Catatan Penting/Important Notes

Penyelidik diminta mengemukakan kepada Pusat Penyelidikan:
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09/01/2019

....

Tandatangan (Penyelidik Utama)   **Tarikh**
Signature (Principal Researcher)   Date

Model Predictive Current Control Fed by Four-leg Voltage Source Inverter Under Balanced and Unbalanced Load Conditions

**1Hazrul Mohamed Basri , Kasumawati Lias, Wan Azlan Wan Zainal Abidin, Al-Khalid Othman

Abstract

This study investigates the finite control set–model predictive current control (PCC) of a four-leg voltage-source inverter. This topology can supply energy to unbalanced three-phase loads by providing the path for a zero-sequence load. The proposed control strategy takes advantage of the discrete nature of the power converter system to predict the future behavior of the output current. PCC is based on an optimal approach that selects the most accurate switching signals among 16 valid switching states by computing the minimum cost function and applying the optimal switching state to the next sampling time. The performance of the proposed control was experimentally validated using LabVIEW FPGA™. Results show that the proposed control can provide independent balanced and unbalanced load current tracking with low harmonic distortion content.

Keywords: Model predictive control, Current control, Four-leg inverter, Unbalance load

I. INTRODUCTION

The unbalanced system is an actual commercial and industrial issue. Researchers normally discount this aspect and assume the nonlinearities to be negligible to simplify analysis. However, this matter should be treated with high precaution to avoid the instability of the power system. In actual implementation, when energy is supplied to a three-phase load, the risk of having an unbalanced load must be considered. If this case occurs, the power-conversion system must provide a path for the zero-sequence current to avoid system instability [1]. Hence, conventional three-leg and three-phase power converters are unsuitable for such applications. An alternative to this problem is to use a four-leg voltage-source inverter at the load side, where the fourth leg serves a path for the zero-sequence current. These systems are required in some applications, such as active power filters, un-interruptible power supplies, active front-end rectifier, distributed power systems, and rural electrification schemes, where arbitrary load profiles are present. These profiles utilize the four-leg topology, which requires accurate current control. Other examples of the application are grid-connected distributed generation systems, which operate in an islanded mode and require four-wire topology to supply local load during temporary loss of the grid supply [2].

Currently, few topologies offer a stable operating system for an unbalanced source or load, as described in [1], [3]–[8]. One passive approach to provide zero-sequence current control employs the split dc-link connection [7]. The neutral point of the load is connected to the neutral of the split dc-link capacitor to regulate the imbalance at the load side. Two evident drawbacks of this solution are the under-utilized dc-link voltage of the connection and the need for an over-sized capacitor to hold the dc-link voltage ripple at an acceptable level if a significant degree of imbalance is present. The dc-link voltage ripple occurs because both dc-links have nearly constant potential [2]. Another topology that can provide the neutral connection to an unbalanced load employs a conventional VSI with Δ/Y or zigzag transformer as a zero-sequence trap. The connection of the delta winding to the inverter and the Y windings to the load can cause the zero-sequence current to be trapped in the delta windings, thus creating balance to the load to some extent [9]. However, the challenge of implementing this solution is the bulky space needed for the transformers. The control scheme based on the PI controller can be implemented to control the four-leg topology [10]. However, the cascaded structure of this control and the tuning of PI controllers are very complicated and time consuming. To regulate the unbalanced loads, six Proportional-Integral (PI) controllers should be designed. Controlling the nonlinear load, which is another crucial point, is more difficult because positive-, negative-, and zero-sequence current components should be extracted at every sampling time by the digital controller. Pulse width modulation (PWM) is a well-known modulation scheme that has been applied in almost all topologies because of its simplicity. The attempt to implement this strategy was described in [11]–[13]. The most interesting finding is

that the variable switching frequency from this strategy yields critical harmonic profiles, and the switching signal generation for highly unbalanced load conditions can be inaccurate. Other complex control schemes have been developed, such as robust control [14], adaptive control, and repetitive controller [15]–[17], all of which are mostly applied in uninterrupted power supply (UPS) systems. Most of these modulation schemes are complicated and difficult to apply because they can hardly control the high degree of imbalance [18].

Additional studies have been conducted on 3-D space vector modulation (3D–SVM), which provides good performance in terms of dc-link utilization, output distortion profile, and low switching frequency. However, the computational requirement for this control scheme is extremely high because of the complex steps necessary to calculate the duty cycle [8], [19], [20]. These features are certainly not suitable for actual laboratory and industrial applications. A space-vector modulation (3D–SVM) switching scheme for a four-leg VSI exhibits higher dc-link utilization, less harmonic content, and less switching loss than that of sinusoidal PWM [1]. The only drawback of the 3D–SVM is that it requires complex steps to calculate the duty ratios for each leg and can become a computational burden [2]. Model predictive control is an interesting alternative to the control scheme mentioned above. The proposed predictive current offers fast dynamic response, which can be applied to various types of topologies. Moreover, its flexibility is the most powerful aspect that has motivated researchers and engineers to study this control scheme. With a simple modification of the embedded cost function, the nonlinearities and system constraints can be included and treated with ease.

This paper is organized as follows. Section II presents the mathematical equations used to determine the output voltage. Section III addresses the discretized mathematical model of the three-phase R,L load using the forward Euler approximation. The same section elaborates the predictive current control algorithm with the associated cost function. Section IV presents and elaborates on the experimental results. Lastly, Section V recapitulates the research findings in the conclusion. In this paper, the authors focused on the robustness evaluation of the proposed control scheme.

2. PROPOSED TOPOLOGY

The four-wire voltage source inverter is a revolutionized version of the conventional three-phase three-wire inverter to connect with nonlinear and/or unbalanced three-phase loads. This topology presents a similar connection format as the voltage-source inverter with an additional leg to create a path for the zero-sequence current in case of unbalanced or nonlinear load. The four-leg voltage source inverter consists of eight IGBTs with a reverse blocking diode, as depicted in Figure 1.
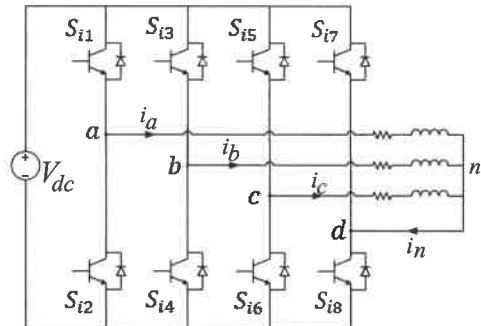
Figure 1: Four-leg Voltage-source Inverter (4L-VSI)

Every leg of this topology operates as a stand-alone, single-phase, and half-bridge inverter producing output from the dc-link voltage. Each leg can be connected to the load either by the positive or negative rail of the dc-link, depending on the gating signal given to the switch. Only two valid switching states can be generated at each leg because of the gating signal constraints. Both S_{i7} and S_{i8} follow the same rules for the other six switches. In other words, S_{i7} and S_{i8} commute in a complimentary mode to avoid the short circuits of the dc-link and the disruption of the load current because of the inductive nature of the load. Considering all four legs, a total of 16 valid switching states can be counted. The fourth leg increases the number of gating signals and indirectly escalates the complexity of the control compared with that of the conventional VSI. However, the main advantage of this configuration is the independent generation of voltages on each phase of the inverter, which can also be controlled using a proper control scheme [21]. The neutral point of the star-connected load is directly connected to the fourth leg of the inverter to allow the current flow of neutral current i_n. This path is provided by the fourth leg. Considering the zero-sequence path, the zero-sequence current i_n can be formulated as Equation (1).

$$i_n = -(i_a + i_b + i_c) \tag{1}$$

To define the mathematical model of the converter, the relationship between the switching signals and the load voltages must be established. Similar to any type of inverter, the rudimentary principle of the four-leg inverter is that the semiconductor switches are used to connect each terminal of the load to the positive P or negative N dc-link terminal. The calculation of the output voltage is very straightforward compared to that of the conventional two-level voltage-source inverter. The output voltage whose phase is shorted by either S_{i7} or S_{i8} is considered null because no load exists between the output phase and node d. Equation (2) expresses the relationship between the dc-link voltage with the load voltage. For the four-leg topology,

the load voltage of the inverter can be expressed as the different voltage potentials between the upper-level inverter switch and S_{i7}. Table 1 summarizes the allowable inverter-switching states.

$$v_o = \begin{bmatrix} S_{i1} - S_{i7} \\ S_{i3} - S_{i7} \\ S_{i5} - S_{i7} \end{bmatrix} v_{dc} \tag{2}$$

Table 1: Allowable inverter-switching states

	S_{i1}	S_{i3}	S_{i5}	S_{i7}	v_{ad}	v_{bd}	v_{cd}
1	1	1	1	1	0	0	0
2	1	1	1	0	v_{dc}	v_{dc}	v_{dc}
3	1	1	0	1	0	0	$-v_{dc}$
4	1	1	0	0	v_{dc}	v_{dc}	0
5	1	0	1	1	0	$-v_{dc}$	0
6	1	0	1	0	v_{dc}	0	v_{dc}
7	1	0	0	1	0	$-v_{dc}$	$-v_{dc}$
8	1	0	0	0	v_{dc}	0	0
9	0	1	1	1	$-v_{dc}$	0	0
10	0	1	1	0	0	v_{dc}	v_{dc}
11	0	1	0	1	$-v_{dc}$	0	$-v_{dc}$
12	0	1	0	0	0	v_{dc}	0
13	0	0	1	1	$-v_{dc}$	$-v_{dc}$	0
14	0	0	1	0	0	0	v_{dc}
15	0	0	0	1	$-v_{dc}$	$-v_{dc}$	$-v_{dc}$
16	0	0	0	0	0	0	0

3. PREDICTIVE CURRENT CONTROL

As mentioned in [24]–[26], FCS–MPC considers a finite number of valid switching states for the converter to solve an optimization problem at every sampling time T_s. Each valid switching state is considered to predict the behavior of the system by using a discrete model. The number of predictions is given by the number of valid switching states of the converter. Each prediction is compared with its respective reference using a predefined cost function. The switching state that minimizes this cost function is finally selected and applied in the converter during the next sampling time. This step is carried out without requiring any modulation stage [22]. The goal of this control scheme is to determine the optimum switching state of the converter, which generates the least amount of tracking error with respect to the load reference and optimizes the switching frequency of S_{i7}. The optimal switching state will be applied in the next commutation. The derivative of the load current in the continuous-time model in Eq. (3) can be approximated based on the forward Euler approximation with sampling period T_s [23].

$$\frac{di_o(t)}{dt} \approx \frac{i_o^{k+1} - i_o^k}{T_s} \tag{3}$$

$i_o = [i_a \quad i_b \quad i_c]^T$ represents the three-phase load currents, and superscript k and $k+1$ denote the instantaneous and one-step prediction value respectively.

A simple application of Kirchoff's law allows the dynamic of the output current to be expressed. The differential equation given in Eq. (4) provides the mathematical relationship between the output voltage and the current.

$$\frac{di_o}{dt} = \frac{1}{L}v_o - \frac{R}{L}i_o \tag{4}$$

Here, $v_o = [v_{ad} \quad v_{bd} \quad v_{cd}]^T$ designates the three-phase load voltages.

The discretization process is performed by merging Eqs. (3) and (4). Finally, the predicted load current can be expressed as Eq. (5).

$$i_o^{k+1} = \left(1 - \frac{T_s R}{L}\right) i_o^k + \frac{T_s}{L} v_o^k \tag{5}$$

Cost function is the essential element to ensure the overall performance of the predictive control. The concept of predictive control lies in the optimization of the cost function. It represents the control requirement of the algorithm. Here, the two control requirements are (a) outstanding load reference tracking and (b) reduction of the switching frequency of S_{i7}.

For the first control requirement, sub-cost function g_1 is defined in Eq. (6) to evaluate the load current error between the predicted values on each phase with the reference values. This sub-cost function can independently perform the load current tracking for each respective output phase.

$$g_1 = \sum_{o \in \{a,b,c\}} \left| i_o^{ref} - i_o^{k+1} \right| \tag{6}$$

The switching frequency reduction of S_{i7} is handled by another sub-cost function denoted by g_2. A weighting factor is associated to this sub-cost function to adjust the degree of importance of the switching reduction as indicated in Eq. (7).

$$g_2 = \left| S_{i7}^{prev} - S_{i7}^{k+1} \right| \qquad\qquad (7)$$

The value of λ_{sw} is directly correlated with the switching frequency. For this topology, the fourth leg will bear the high-frequency stress to control the zero-sequence current. The direct consequence of this phenomenon is the over-heating of both S_{i7} and S_{i8}. Over-heating may result in the short lifespan of the switches. To avoid this problem, proper switching control must be implemented. This step can be carried out by reducing the switching frequency of the fourth leg. The logic behind this objective is to force the predicted switching signal to remain at the same signal as the previous state. Based on Eq. 7, increasing λ_{sw} will cause the cost function to prioritize the switching stress reduction over the reference load tracking. Thus, this parameter needs to be carefully selected to avoid compromising the tracking capability of the load current. Both control requirements can be achieved using the cost function elaborated in Eq. (8).

$$g = g_1 + \lambda_{sw} \cdot g_2 \qquad\qquad (8)$$

Predictive controller satisfies all the aforementioned constraints by using the following five steps and programmed in FPGA as depicted in Figure 2.

   i) Measure the load current
   ii) Predict the behavior of the load current for each valid switching states
   iii) Evaluate the cost function g for each prediction
   iv) Select the switching state that minimizes the cost function
   v) Apply the new switching states to the converter during the next sampling time.
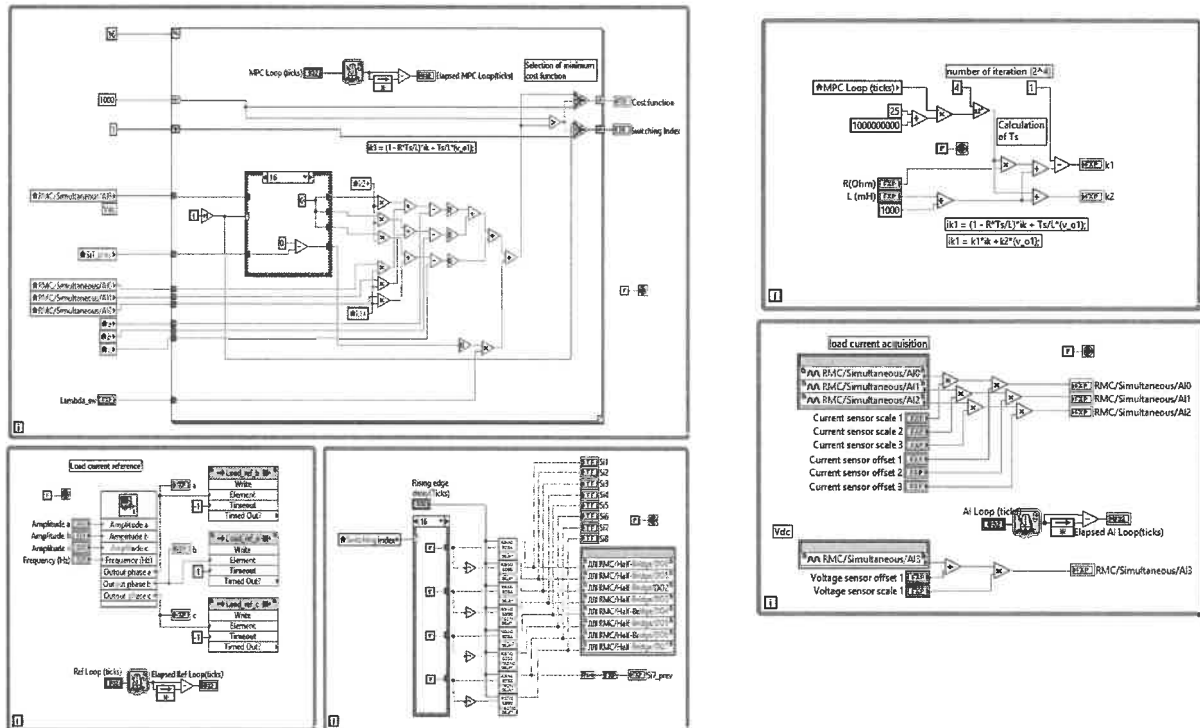
Figure 2: LabView Programming for Model Predictive Control

4. RESULTS AND DISCUSSION

To validate the stability and robustness of the proposed predictive current control scheme, a laboratory prototype of a two-level three-phase four-wire voltage-source inverter is built. The balanced and unbalanced load current references are studied with a host PC equipped with NI LabVIEW FPGA 2014 module. Figure 3 depicts the laboratory setup used for this project. A National Instruments Single-Board RIO General Purpose Inverter Controller (GPIC) NI9606 with on-board mezzanine card NI 9683 is utilized to acquire analog data and generate the digital output to the gate driver. Eight unidirectional RB-IGBTs with ultra-fast recovery diode IRGP30B120KD from International Rectifier are the switching devices used for this project. Three current sensors LEM25NP and one voltage transducer LV25N are pre-scaled to acquire appropriate analog signals before sending them to the simultaneous analog input of the GPIC board. The ON/OFF firing signals are made available from eight gate drivers based on HCPL3120 powered by a 5 V isolated supply.
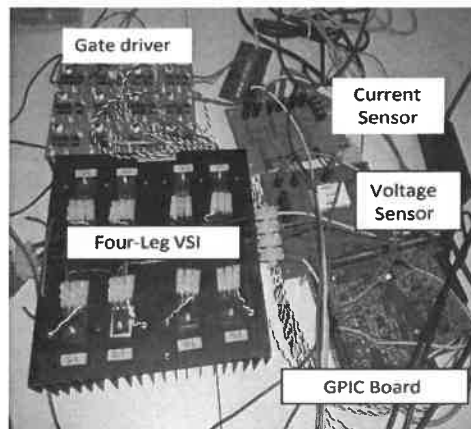
Figure 3: 4L-VSI experimental prototype

For this test, the four-level degree of unbalance is investigated, as shown in Table 2. During this test, the balanced and unbalanced three-phase references are sinusoidal with 50 Hz temporal frequency. The optimal load current condition for the 110 V dc-link voltage connected to 24 Ω resistive load and 46 mH inductive load is 2A. This condition is considered a benchmark in the following analysis.

Table 2: Robustness test table

| Case	Reference signal I_{max}(A)	R per phase	L per phase	Degree of unbalance (%)
1	2,2,2	24,24,24	46,46,46	0
2	2,2,2	24,28,24	62,46,62	(Balanced)
3	1,1.5,2	24,24,24	46,46,46	19.25
4	1,1.5,2	24,28,24	62,46,62	(Lightly unbalanced)
5	1,0,2	24,24,24	46,46,46	57.73
6	1,0,2	24,28,24	62,46,62	(Moderately unbalanced)
7	0,0,2	24,24,24	46,46,46	100
8	0,0,2	24,28,24	62,46,62	(Highly unbalanced)

Case 1 represents an ideal case where the reference signals are balanced and the loads are distributed equally for all phases. The sinusoidal reference current for all phases is set to 2A magnitude with a temporal frequency equal to 50 Hz. Figure 4 showcases the three-phase load current and neutral current from Case I. As expected, for a perfectly balanced reference, the neutral current converge toward zero at a steady state with only high-order harmonics because of the switching commutations. The total harmonic distortion content is less than 5% at each phase, as shown in Fig. 5. The fast dynamic response is obtained with practically no overshoot for all three output currents. Hence, the proposed control scheme can provide good reference tracking ability in Case I.
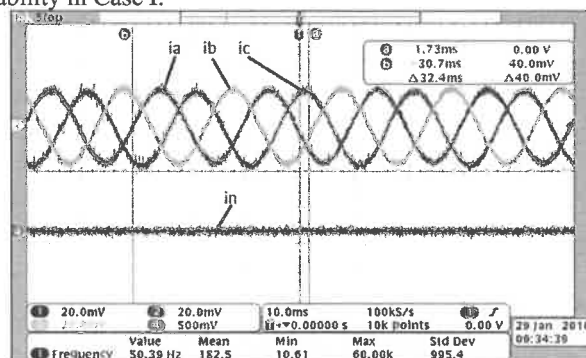
Figure 4: Signal waveform for Case 1

The same reference signal is given in Case 2, but it is applied to an unbalanced load distribution. This control strategy can generate very good load current with a sinusoidal format waveform despite the unbalanced load distribution. The effect of the unbalanced loading can be observed from the increased THD value at phase b. The high value of resistive load at phase b significantly affects the total distortion. The test indicates that the THD% is higher than 5%. Another robustness test will be

elaborated in the next section to confirm that an uneven resistive load distribution contributes more to high distortion than an inductive load. Case 2 yields similar load current waveform as case 1.
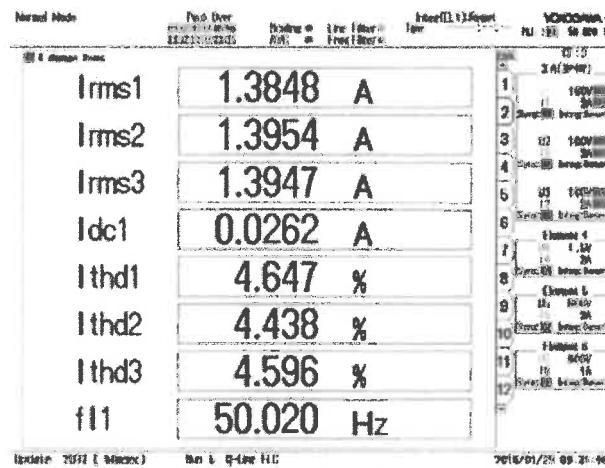
Figure 5: THD values for Case 1

Case 3 represents the unbalanced reference connected to the balanced load. Figure 6 demonstrates that the proposed predictive current control can control each current independently. Neutral current i_n circulates in the neutral connection because of the unbalanced load distribution to ensure that the load current follows the reference. The neutral current, which is the sum of the three-phase currents, flows through the neutral connection and develops a sinusoidal waveform because the unbalanced references are given the same reference frequency. This result verifies that the predictive strategy can control each current independently. The load current reference at phase a is set at only 50% of the optimal value, whereas phases b and c are respectively given 75% and 100% of the optimal values. This un-proportional reference not only produces the zero-sequence current but also creates an uneven harmonic distribution, as presented in Table 3. Higher THD% values can be observed when the load reference deviates from the optimal values.
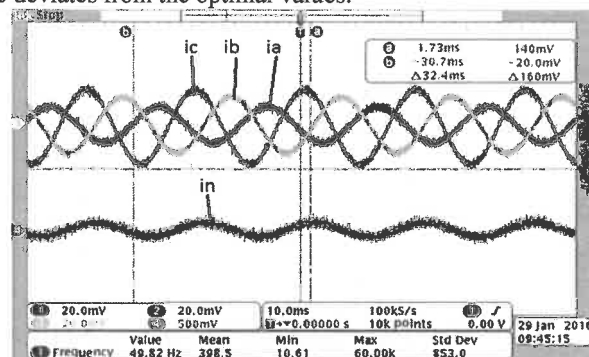

Figure 6: Signal waveform for Case 3

Case 4 appraises the effect of lightly unbalanced load reference connected to the unbalanced three-phase RL loads. The independent load current reference tracking remains present. The generated load current follows the reference values, but with slightly higher distortion compared to that in Case 3 because of the uneven load distribution. The load current and neutral current waveform imitates the one in case three because both cases are given same reference load current.

Figure 7 demonstrates Case 5 where critical conditions emulate a disconnection of a phase by setting the current reference as 0A. The THD% of phase b should be discounted because of the non-sinusoidal shape of the load current. Another conclusive remark that can be drawn is that a higher amount of distorted supply current can be observed if the difference between the amplitude is larger. Phase c is given the optimal reference current values. Thus, the recorded THD% value for this phase is below 5%. In Case 6, the same load current tracking trend as those in Cases 2 and 4 can be observed. However, phases a and c both exhibit slightly higher total distortions, which increase by approximately 10%, because of the different loading conditions. Case 7 represents the study of a highly unbalanced case where phase c is fixed to the optimum value, whereas phases a and b are set to 0A, as shown in Fig. 8. The reference signals given for this case emulate highly unbalanced conditions. The measured load current follows the reference with a very low THD value at phase c because of the independent load current-generation ability of the predictive current control. Based on the same logic as in Cases 5 and 6, the value of $THD\%$ at phases b and c should be discounted. The event of a highly unbalanced reference with uneven three-phase load distribution is examined in Case 8. A similar tendency is observed as that in Cases 2, 4, and 6 for the reference load tracking.
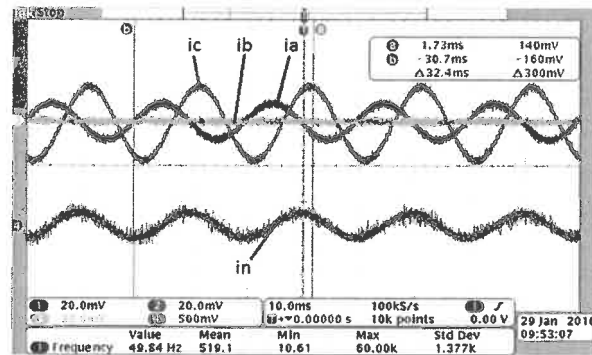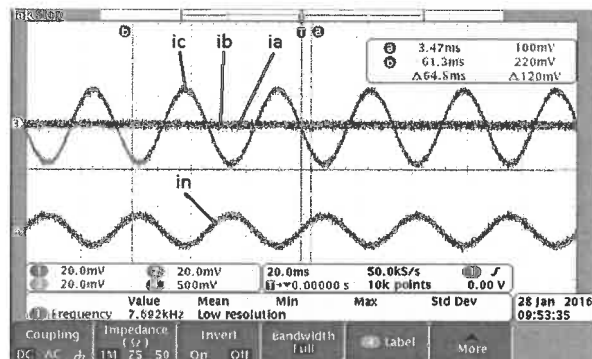
Figure 7: Signal waveform for Case 5

Figure 8: Signal waveform for Case 7

Table 3: Quantitative comparison

Degree of imbalance (%)	THD_i% profile			
	Minimum %		Maximum %	
	Proposed	[24]	Proposed	[24]
0 to 25	3.282	5.5962	6.917	7.4422
25 to 50	Not given	Not given	Not given	Not given
50 to 75	3.646	5.4763	7.245	6.8745
100	3.558	Not given	N/A	Not given

Tables 4 and 5 list the quantitative and qualitative comparative studies between the proposed control strategy and topology with the one reported in literature.

4. CONCLUSION

In this paper, the predictive current control was implemented to a four-leg voltage-source inverter to control balanced and unbalanced load conditions. The proposed topology can provide the path for zero-sequence current when unbalanced three-phase loads are connected. Eight distinct combinations of balanced, lightly unbalanced, moderately unbalanced, and heavily unbalanced conditions were subjected to experimental validation. The results indicate that among all eight cases, the proposed scheme can offer outstanding reference tracking ability with a very low harmonics profile. The robustness test demonstrates that the system is sensitive to resistive loads rather than inductive ones. In addition, with the model predictive control, the switching frequency of the fourth leg was optimally reduced to lessen the switching stress of the inverter. The experimental results demonstrate that predictive control is very effective because it intuitively considers the discrete nature of the converter-switching states.

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RINGKASAN LAPORAN AKHIR
GERAN PENYELIDIKAN OSAKA GAS
END OF OSAKA GAS
GRANT REPORT SUMMARY

A.	**Tajuk Projek** *Project Title*	**:**	Drying Processing of *Lemantak* (Sago Powder) using An Automated Machine for Cottage Industries in Sarawak
	Ketua Penyelidik *Project Leader*	**:**	Dr Shahrol Mohamaddan
	Fakulti/Institut *Faculty/Institute*	**:**	Fakulti Kejuruteraan
	Ahli Kumpulan Penyelidik *Research Team Members*	**:**	i. Muhamad Fadzli Ashari ii. Abang Mohamad Aizuddin iii. Dr Abang Mohd Nizam Abang Kamaruddin
B.	**Tarikh Geran Diluluskan** *Grant Approval Date*	**:**	1 January 2018
	Tempoh Projek *Project Duration*	**:**	1 year
	Peruntukan Yg. Diluluskan *Budget Approved*	**:**	USD 2,400 (RM 10,000)
	Perbelanjaan Terkini *Expenditure To-Date*	**:**	RM 9,866

C. Pencapaian Keseluruhan
Overall Achievement
Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki.
Describe the achievements in relation to the original objectives, hypothesis and research problems.

In this project, the conceptual design and analysis of a new sago drying machine was completed. Finite element analysis (FEA) simulation software was applied together with mathematical modelling in order to prove the conceptual design. Based on the mathematical modelling and simulation analysis results, the new design of sago drying machine is considered acceptable and safe to be fabricated. Unfortunately, more time is needed in order to fabricate and test the

machine. Therefore, the focus of this study is more on the simulation analysis.

One final year project thesis was produced from this grant. Besides, one conference paper and one journal paper were also published as the output. The output from this grant can be considered as a minor contribution to the knowledge related to sago drying. This research has a potential to be expanded since the sago drying is one of the major research topics in Sarawak.

D. Pencapaian Utama
Key Findings

- A new design of sago drying machine
- Mathematical modelling of the design structure
- Simulation analysis of the design structure using finite element method (FEA)
- Proposed material for sago design machine

E, Hasil Penyelidikan
Deliverables

Sila tandakan item yang berkaitan pada senarai berikut:
Please tick the relevant items below:

	Item	Bilangan/*Number*
	Kertas teknikal/bersiri dalaman *Internal technical/serial papers*	
	Tesis/disertasi pelajar sarjana *Student's Masters thesis/dissertation*	
	Tesis pelajar PhD *Student's PhD thesis*	
✓	Kertas persidangan tempatan *Local conference papers*	InTEX 2018
	Kertas persidangan antarabangsa *International conference papers*	
✓	Makalah dalam jurnal tempatan *Local journal papers*	Journal of Sustainability Science and Management (2019), 14(4), pp. 86-93, ISSN 2672-7226
	Makalah dalam jurnal antarabangsa *International journal papers*	
	Monograf atau buku *Book/monograph*	

Lain-lain/*others* (sila nyatakan/*please specify*)

1. One final year student (Lew Hao Xian)

Sila senaraikan maklumat (pengarang, tahun, tajuk, jurnal/penerbit, jilid, halaman) bagi penerbitan/tesis yang dihasilkan (jika ada).
Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)

Lew Hao Xian, *Conceptual Design and Analysis of Sago Drying Machine*, Final Year Project Dissertation, Universiti Malaysia Sarawk (UNIMAS), 2018

F.   Pengecaman Output
Output Identification

Sila tandakan penerangan yang berkaitan pada senarai berikut:
Please tick the relevant description as given below:

	Suatu sumbangan besar kepada bidang ilmu yang berkaitan *A major contribution to knowledge (new knowledge) in the respective discipline*
✓	Suatu sumbangan kecil tetapi bermakna kepada bidang ilmu yang berkaitan *A minor but important contribution to knowledge in the respective discipline*
	Suatu sumbangan besar kepada teknologi/ciptaan/algoritma dalam bidang yang berkaitan *A major contribution to technology/invention/algorithm or a tangible product*
	Suatu sumbangan kecil tetapi bermakna kepada teknologi/ciptaan/algoritma berkaitan *A minor but important contribution to relevant technology/invention/algorithm*
	Terdapat potensi yang baik untuk kajian lanjutan ke arah pemasaran *There is a good potential for further R & D and commercialization*
	Suatu sumbangan besar kepada kerangka polisi pengurusan/garis panduan *A major contribution to management policy framework/guidelines (in relevant areas)*
	Suatu sumbangan kecil tetapi bermakna kepada kerangka polisi pengurusan/garis panduan *A minor contribution to management policy framework/guidelines (in relevant areas)*
	Sesuai untuk dijadikan bahan pengajaran/*case study* atau bahan latihan *The finding is suitable for use as a complementary teaching/training material (a case study)*
	Suatu output yang baik dan berpotensi untuk memenangi hadiah penyelidikan *A quality output that has a potential for winning a research award*
	Suatu bahan yang baik/sesuai untuk hebahan atau pameran *A good/suitable material for showcasing/publicizing/exhibition*

Lain-lain/*Others* (Sila nyatakan/*Please specify*)

G.   Sinopsis Hasil Penyelidikan bagi Tujuan Promosi
Synopsis for Promotional Purposes
(Beri huraian ringkas yang tidak melebihi 400 perkataan dan dalam bahasa yang mudah, bagi maksud hebahan hasil penyelidikan ini melalui media massa dan 'Unimas Research Update')
(Please provide a synopsis not exceeding 400 words, in a not-too-technical language, for the purpose of promoting this research findings through the mass media and Unimas Research Update).

The increasing demand for sago flour indicates the need to enhance its production. The objective of this research is to propose a new design of a sago drying machine and conduct a finite element analysis (FEA) simulation on its structure. The sago drying machine was developed based on a tray-mixer concept. Mathematical modelling and simulation analysis were conducted on three critical parts; the tray, support plate and mixer. The maximum stress for the tray bending was

6.51 MPa with manual calculation and 7.37 MPa with simulation analysis. The tray-bending deflection was 0.52 mm with manual calculation and 0.53 mm with simulation analysis. For support plate bending, the maximum stress was 17.33 MPa with manual calculation and 12.87 MPa with simulation analysis. The deflection for support plate bending was 1.06 mm with manual calculation and 1.04 mm with simulation analysis. Lastly, the maximum stress acting on the mixer was 1.09 MPa and maximum deflection was 0.0035 mm. The error between mathematical calculation and FEA simulation was based on different assumptions on the model and limitation of dimensions covered, for example, the 2D and 3D views. Data from this research could be used to improve the structural design of a new sago drying machine.

Catatan Penting/Important Notes

Penyelidik diminta mengemukakan kepada Pusat Penyelidikan:
- Borang ini dalam kedua-dua bentuk bercetak dan elektronik

Researchers are required to submit to the Research Centre:
- *This form in both hard- and soft-copies*

17/9/2019

………………………………….. ……………………………
Tandatangan (Penyelidik Utama) **Tarikh**
Signature (Principal Researcher) Date

A.	**Tajuk Projek** *Project Title*	:	Development of High Strength and Ductile Fiber Reinforced Concrete (FRC) mixed with treated Palm Oil Fuel Ash (POFA)
	Ketua Penyelidik *Project Leader*	:	Dr Raudhah Binti Ahmadi
	Fakulti/Institut *Faculty/Institute*	:	Department of Civil Engineering, Faculty of Engineering, University Malaysia Sarawak, 94300 Kota Samarahan, Sarawak.
	Ahli Kumpulan Penyelidik *Research Team Members*	:	Professor Dr Mohammad Abdul Mannan Dr Idawati Binti Ismail
B.	**Tarikh Geran Diluluskan** *Grant Approval Date*	:	5 Disember 2017
	Tempoh Projek *Project Duration*	:	Januari 2018- June 2019
	Peruntukan Yg. Diluluskan *Budget Approved*	:	RM 6000
	Perbelanjaan Terkini *Expenditure To-Date*	:	RM 5500

C. Pencapaian Keseluruhan
Overall Achievement
Huraikan pencapaian berbanding objektif, hipotesis serta permasalahan asal yang diselidiki..
Describe the achievements in relation to the original objectives, hypothesis and research problems.

This study investigates the mechanical behavior of Fibre- Reinforced Mortar (FRM) mixed with Treated Palm Oil Fuel Ash (POFA). This research is divided into 4 stages which are;

determination of optimum mix design, determination of optimum amount of POFA, determination of optimum amount of fibres and analysis of displacement ductility ratio. In the compressive strength result it can be seen that sample with 40% POFA inclusion mixed with 10kg/m^3 poly propylene fibres gives higher strength compare to 100% OPC mixed with 10kg/m^3 poly propylene fibers. Other than that, sample with 40% POFA inclusion mixed with 15kg/m^3 and 10kg/m^3 poly propylene fibres give the highest ductility ratio which are 7.8 and 13.3 for 28 and 56 days respectively. Scanning Electron Microscopy (SEM) was conducted to observe the surface morphology of the fibre reinforced mortar. Based on the results and observations from various POFA inclusions with 10, 15, and 20 kg/m^3 of poly propylene fibers, impressive results was obtained on the mechanical strength for 40% POFA with additions of 10 kg/m^3 and 15kg/m^3 of poly propylene fibres. It can be concluded that the addition of POFA can enhance the strength properties of the mortar in term of compressive strength while, fibers can enhance the tensile properties of the mortar which is beneficial in reducing the usage of Ordinary Portland Cement (OPC) and Steel Bar Reinforcement.

D. **Pencapaian Utama**
   Key Findings

1. Result in stage 1 shows that the highest compressive result test was by sample with SP = 2% and 0.20 w/c ratio which is 69.1 MPa at 28days. This sample mix design was used for the entire research.

2. Result in stage 2 shows that mortar sample with 10% POFA inclusion gives the highest compressive strength which is 96.3 MPa. However, after considering few factor which had been agreed upon such as lowering the usage of cement in cocnrete, 40% POFA inclusion was used for the next stage.

3. Results in stage 3 shows that the compressive strength of Fibre Reinforced Mortar that contains 40 % microfine POFA as partial cement replacement mixed with 10 kg/m^3 of polypropylene fibre gives the highest reading of compressive strength at 56 days of curing which is 79.5 MPa. While, fibre Reinforced mortar for 100% OPC with 20 kg/m^3 of polypropylene fibre give the highest reading of compressive strength at 56 days of curing which is 82.4 MPa. Hence, the optimum Fibre Reinforced Mortar in term of compressive strength will be 40% microfine POFA with 10 kg/m^3 fibres.

4. Fibre Reinforced Mortar (FRM) sample with 40% POFA and inclusion of fibres (10 – 15 kg/m^3) shows a relatively good ductility ratio value. This is due to the good fibres bond with mortar due to contribution of POFA properties such as low particle size compared to Ordinary Portland Cement (OPC).

5. Scanning Electron Microscopy (SEM) results shows the morphology of the sample at the age of 7 and 28 days. The differences can be seen from the bond of mortar and fibres whereby the sample at age 28 days shows a good fibre-mortar bonding results

E, **Hasil Penyelidikan**
Deliverables

Sila tandakan item yang berkaitan pada senarai berikut:
Please tick the relevant items below:

	Item	Bilangan/*Number*
	Kertas teknikal/bersiri dalaman *Internal technical/serial papers*	
√	Tesis/disertasi pelajar sarjana *Student's Masters thesis/dissertation*	1
	Tesis pelajar PhD *Student's PhD thesis*	
√	Kertas persidangan tempatan *Local conference papers*	1
	Kertas persidangan antarabangsa *International conference papers*	
	Makalah dalam jurnal tempatan *Local journal papers*	
√	Makalah dalam jurnal antarabangsa *International journal papers*	1
	Monograf atau buku *Book/monograph*	

Lain-lain/*others* (sila nyatakan/*please specify*)

Sila senaraikan maklumat (pengarang, tahun, tajuk, jurnal/penerbit, jilid, halaman) bagi penerbitan/tesis yang dihasilkan (jika ada).
Please specify the publications (authors, year, title, journal/publisher, volume, page nos.) (if any)

Saiful, M. S. (2019) Mechanical Behaviour of Fibre Reinforced Mortar (FRM) Mixed With Palm Oil Fuel Ash (POFA). **Master Thesis**, Universiti Malaysia Sarawak (In progress for submission and for viva session)

Ahmadi, R., Lucas, D.E., Machillies, E., Saiful, M.S., Mannan, M.D. and Ismail, I. (2018) Effect of fibre (Polypropylene) Volume in Mortar Mixed with POFA (2018). **INTEX-2018. Oral Presentation**

Ahmadi, R., Lucas, D.E., Machillies, E., Saiful, M.S., Mannan, M.D. and Ismail, I. (2018) Effect of fibre (Polypropylene) Volume in Mortar Mixed with POFA (2018) *Journal of Sustainability Science and Management* (JSSM). (Waiting for approval)

Publication to International Journal is in progress.

F. Pengecaman Output
Output Identification

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√	Suatu sumbangan kecil tetapi bermakna kepada bidang ilmu yang berkaitan *A minor but important contribution to knowledge in the respective discipline*
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	Terdapat potensi yang baik untuk kajian lanjutan ke arah pemasaran *There is a good potential for further R & D and commercialization*
	Suatu sumbangan besar kepada kerangka polisi pengurusan/garis panduan *A major contribution to management policy framework/guidelines (in relevant areas)*
	Suatu sumbangan kecil tetapi bermakna kepada kerangka polisi pengurusan/garis panduan *A minor contribution to management policy framework/guidelines (in relevant areas)*
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	Suatu bahan yang baik/sesuai untuk hebahan atau pameran *A good/suitable material for showcasing/publicizing/exhibition*

Lain-lain/*Others* (Sila nyatakan/*Please specify*)

G. Sinopsis Hasil Penyelidikan bagi Tujuan Promosi
Synopsis for Promotional Purposes
(Beri huraian ringkas yang tidak melebihi 400 perkataan dan dalam bahasa yang mudah, bagi maksud hebahan hasil penyelidikan ini melalui media massa dan 'Unimas Research Update')
(Please provide a synopsis not exceeding 400 words, in a not-too-technical language, for the purpose of promoting this research findings through the mass media and Unimas Research Update).

The durability of the materials is a key factor in selection of building materials in civil construction. The society is now concerned with the cost of building materials, duration of construction work, infrastructure refurbishment and rehabilitation. These factors are important to be considered in order to achieve longer life spans of certain structures.

Based on the results and observations from various POFA inclusions with 10, 15, and 20 kg/m^3 of poly propylene fibers, impressive results was obtained on the mechanical strength for 40% POFA with additions of 10 kg/m^3 of poly propylene fibres which is 79.5MPa compressive

strength value. It can be concluded that the addition of POFA can enhance the strength properties of the mortar in term of compressive strength while, fibers can enhance the tensile properties of the mortar which is beneficial in reducing the usage of Ordinary Portland Cement (OPC) and Steel Bar Reinforcement.

It is expected that this high strength fiber reinforced concrete (HSFRC) can help to improve the durability of houses in coastal area in Sarawak which are exposed to corrosion. Besides, HSFRC could sustain high amount of loadings and impact which can be beneficial for buildings located in high seismic areas.

Catatan Penting/Important Notes

Penyelidik diminta mengemukakan kepada Pusat Penyelidikan:
• Borang ini dalam kedua-dua bentuk bercetak dan elektronik
Researchers are required to submit to the Research Centre:
• *This form in both hard- and soft-copies*

13 September 2019
Tandatangan (Penyelidik Utama)   **Tarikh**
Signature (Principal Researcher)   Date