Accepted for review: 13-10-2020
Accepted for publication: 09-12-2020

Development of Hybrid Generator as Alternative Renewable Energy

*Nu'Man Fahmi, Mohd Saiful Bahari**
Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
**saifulbahari@uitm.edu.my*

ABSTRACT

The hybrid generator is one of the renewable energy projects that is expected to solve the problem related to the accessibility of the electricity and its cost. It can be classified as one of the green technologies as the main resource of the system in producing the electricity comes from the magnetic induction from the solenoid. Differently from a diesel generator, it produces electricity by consuming the diesel fuel and releases CO_2 gas to the environment. Other types of a generator such as solar and wind turbines whose efficiencies are dependent by the season and weather. Hybrid generator systems generate electricity by converting the force from the magnetic induction into mechanical energy and then once again convert it into electrical energy through the generator. Developing the prototype of the hybrid generator involves the simulation of combination magnet solenoid to show how the system reacts when magnetic flux from solenoid exist. This prototype build is using translation motion and then converted into rotational motion to generate power. In the fabrication process, the design of the prototype will be guided in developing the system. Besides, the existing generators concept is being referred to while replacing their energy source by magnet and solenoid. The solenoid will act as an energy supply that generates mechanical energy and transfer it using the crankshaft to the generator to convert it into electrical energy. An improvement can be made to the current prototype of a hybrid generator to increase its capability and efficiency to generate more electricity. The significance of this study is to introduce a new alternate energy that is better and can solve the problem with the current generator to generate electricity.

Keywords: *Hybrid generator, renewable energy, green technologies.*

Introduction

Numerous investigations have been done in the past few years on renewable energy. In general, this study will define how to generate the electric power from the green energy or renewable energy using the magnetic mechanism as the element sources from the low voltage input and will generate a high output voltage. The concept is similar to the generator using the oil and diesel to run the engine. But for the concept an electric generator its device that converts mechanical energy obtained from an external source into electrical energy as the output. Most of the renewable energy method is hard and difficult to implement because of the limitation and very complex installation procedure. Thus, the hybrid generator will solve all the issue from the current renewable energy limitation by providing clean and sustainable energy sources. However, this renewable also has its limitation and disadvantages. Their performance is based on the natural resources which are not constant and steady [1]. Sometimes the energy produced is not effective due to many losses for maintenance and service. For example, the traditional power grid is more reliable compared to a solar and hydropower plant. It is because the traditional system is producing lots of energy compared to renewable energy. This hybrid generator can outcome the limitation of the existing renewable energy technology due to set up cost and space requirement aspect [2,3]. The purpose of the hybrid generator system is to help these people who live isolated from the mainland and also the people who live in a place that has no energy supply such as indigenous people. With the development of the hybrid generator system as an alternate energy supply, it can replace diesel generators that consume diesel and cost a lot of money to transport diesel from the mainland. The most important thing about the hybrid generator is that it is renewable energy. It produces zero carbon dioxide and causes no harm to the environment. The principle of the generator is converting mechanical energy to electrical energy through a rotating shaft with the aids of a little amount of electricity from the sources such as a battery. When the electric is generated, it will recharge the battery so that the generator will keep running for a long time without the need to replace the battery once again. With a hybrid generator system, the world has another alternate source to generate enough power for the people who live in an isolated

community and also reduce the demand for diesel generators and at the same time, reduce pollution that is caused by the burning fuel of the generator.

A Generator as an Alternate Energy

Malaysia is committed to using renewable energy as its main power supply. Our government has set up a target of 20% penetration of renewable energy sources by 2025. Although today we only achieve approximately 2% of the penetration compared to 23% to the total generation mix. The percentage is still too far from what our government targeted because most of our power is generated by natural gas and coal [4]. A generator is a device that transforms a type of energy into electricity. Even though energy can't be produced or made, it can be transformed. There are several forms of energy, such as thermal, kinetic, chemical or potential power, that a generator may convert. The most popular is mechanical. It is also called dynamo when a generator transforms mechanical energy to electricity [5]. Generators are popular and well-known devices in today's industry. They are used, for example, to harness electricity from wind turbines in power plants, or just to power a house in the case of a power failure. Electromagnetic induction is a key factor in a generator's operation. This phenomenon was discovered by Michael Faraday and it states that a current is produced in a conductor when it is moved through a magnetic field. Once the shaft and coil start spinning around the shaft, there is some current and electromotive force produced [6].

Solenoid

Solenoids are coils of wire that create a magnetic field when there is current applied to it. A solenoid is best suited for any application that needs immediate action as the magnetic field is created instantly. Moreover, they are inexpensive due to their simplicity, and they can fit a lot of power into a very small form factor. However, a solenoid is most efficient for a short distance because the force generated is proportional to the position of their moving element. Valve interlock and electromechanical relay are the examples of solenoid application [7]. As a matter of fact, at some point, almost every industry was operated by a solenoid. In the manufacturing process line, pick and place robots use solenoid to open and close clamps to handle items. Storage silos have a pneumatic or hydraulic cylinder to drive its gates. In the medical sector, solenoids have also been used to displace critical fluid such as blood or medicine injected into patients' bodies in the emergency room [8].

Lenz's Law

Lenz's Law is an electromagnetic induction current produced by the reaction between the magnet and solenoid. The initial changes magnetic field opposes with induced current and direction of the flow current base on Fleming's right-hand rule. According to Faraday's Law, when the flux changes occur, the induced current will create a magnetic field. Lenz's can be simplified into two conditions which magnet moving inwards the coil and magnet moving away from the coil. Figure 1 shown the magnet is moved toward the coil the flux that creates in the coil produced induced current. The induced current that produced will repel the magnet because of the same polarity [9].

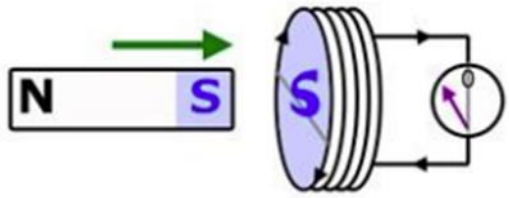

Figure 1: Same polarity condition (Repelled).

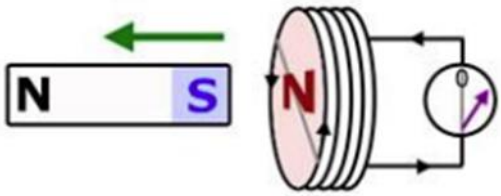

Figure 2: Different polarity (Attraction).

Figure 2 shows the magnet is moved away from the coil, the magnetic flux of the coil will decrease and the polarity will have changed that caused the reaction between coil and magnet changed from repelled to attract.

Design of Hybrid Generator System

The hybrid generator system shown in Figure 3 converts the mechanical energy from the solenoid into the electrical energy through the motor-generator. It converts the mechanical energy from the translation motion of the shaft as a result of the force produced by a solenoid and transfers the energy through a rotating shaft connecting to the motor-generator. Magnet and solenoid are the main sources of the system. A solenoid is a coil of wire used as an electromagnet. It is a device that converts electrical energy into mechanical energy. Solenoid creates a magnetic field from electric

current and uses the magnetic field to create linear motion. Lenz Law stated that the direction of an induced emf. will be such that if it were to cause a current to flow in a conductor in an external circuit, then that current would generate a field that would oppose the change that created it. By using the concept of the Lenz law which makes the magnet can move forward and backwards by changing the flux of the solenoid. The structure system fundamental segment will include the solenoid framework, crankshaft, drive framework, generator, UPS reinforcement battery and controller of current contribution for the cycle of the sustainable power source. A solenoid is a coil of wire used as an electromagnet.

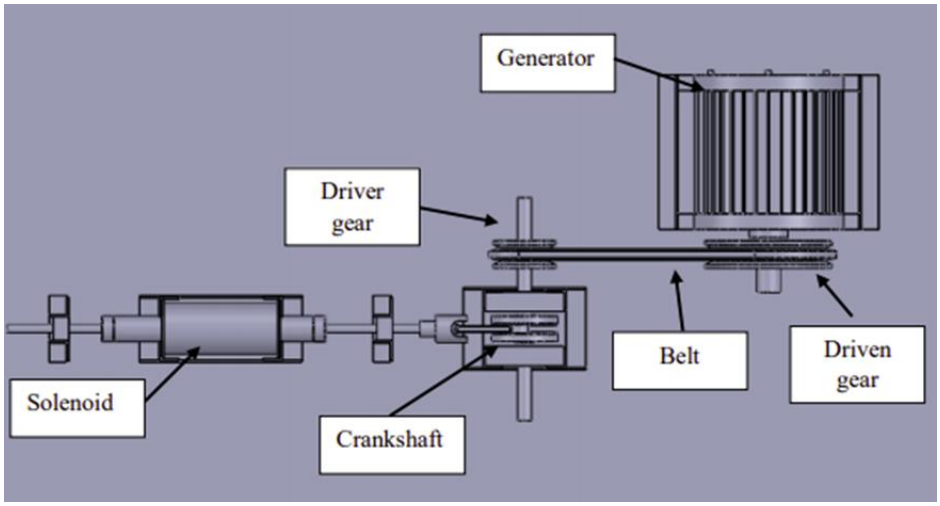

Figure 3: Hybrid generator system design.

The input power source will be constrained by the control box that controls the amount of current into the solenoid. The translation motion of the solenoid will be transferred to the generator by a crankshaft. UPS battery backup will store the electric generated by the generator.

Electromagnets are non-permanent magnets which when there is current flow through the coil, it will produce a magnetic field. It will continue to create magnetic fields long as there is current flow through the coil [10]. It was also known as an electrically induced magnet show in Figure 4. A magnetic material such as an iron will act as a core that will be surrounded by a wire of coil through which the electrical current is transmitted to magnetize the core [11].

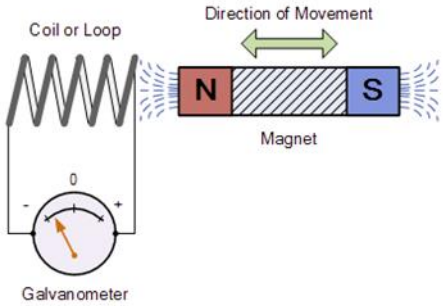

Figure 4: Electromagnetic induction by moving magnet [4].

Compare to the permanent magnet, an electromagnet can manipulate the magnetic field by controlling the value of electric current. However, it needs to be continuously supplied with an electric current to maintain the field operative. The strength of the magnetic field is also determined by the number of turns of the coil. A higher number of turns will increase the strength of the magnetic field [12].

The magnetic field is produced in any wire that has a current flow to it. However, compared to the straight wire, a coiled wire produces a magnetic field stronger. In coiled wire, each turn of the wire has its magnetic field. If we add more turns to the coil, the strength of the magnetic field will also increase [13]. Theoretically, force is directly proportional to the number of turns of the solenoid (N) and inversely proportional to the length of the gap between solenoid and piece of metal (g). Supposedly, when N increased and g was decreased, the value of force applied to the shaft will be increase [14]. This will cause the shaft to move forward and backwards faster. Since the shaft is connected to the gear by the crankshaft, when the velocity of the shaft increase, the angular velocity at the driven gear should also

increase. Figure 5 show the half-section view of solenoid build based on Lenz's Law to push magnet move left and right after some amount of AC introduce to the solenoid coil.

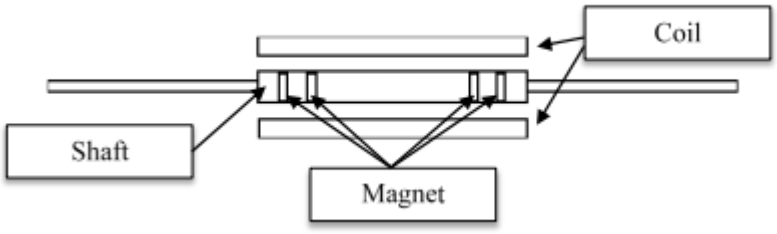

Figure 5: Half section view of Solenoid build based on Lenz's Law.

The performance of the hybrid generator was being simulated to determine its output with the current of 0.3 Ampere as the input. Initially, the force produced by the solenoid with numbers of turns (N) and the length of the gap between the magnet and metal (g) as the variables was calculated using equation 1. The values of the number of turns were 100, 200, 300 and 400 and the length of a gap which was 0.8mm, 0.9mm and 1mm. The value to be constant where current (I), magnetic constant (μ0), and the cross-sectional area of the solenoid (A). When current been supplied to the solenoid, the solenoid will produce a magnetic field that exerts a force on the shaft. This combination of magnetic and electric forces on a shaft is called Lorentz force.

Simulation

The simulation was done using Solidwork software. The performance of the hybrid generator has been simulated to determine its output with the current of 0.3 Ampere as the input. Initially, the force produced by the solenoid with numbers of turns (N) and the length of the gap between the magnet and metal (g) as the variables was calculated. The values of the number of turns were 100, 200, 300 and 400 and the length of a gap which was 0.8 mm, 0.9 mm and 1 mm. The value to be constant where current (I), magnetic constant (μ0), and the cross-sectional area of the solenoid (A). When current is supplied to the solenoid, the solenoid will produce a magnetic field that exerts a force on the shaft. This combination of magnetic and electric forces on a shaft is called Lorentz force. The force was then calculated by plugging the parameters which were dimensions and other properties of the magnet into the equation of:

$$F = \frac{(N \times I)^2 \mu_0 A}{2g^2} \tag{1}$$

With the values of the force produced by the solenoid were obtained, the simulations were then run in Solidwork by applying force to the shaft. The values of the force applied to the shaft were based on the data from Excel. The time for the simulation was set for 30 seconds to make sure that the system can achieve its stable state.

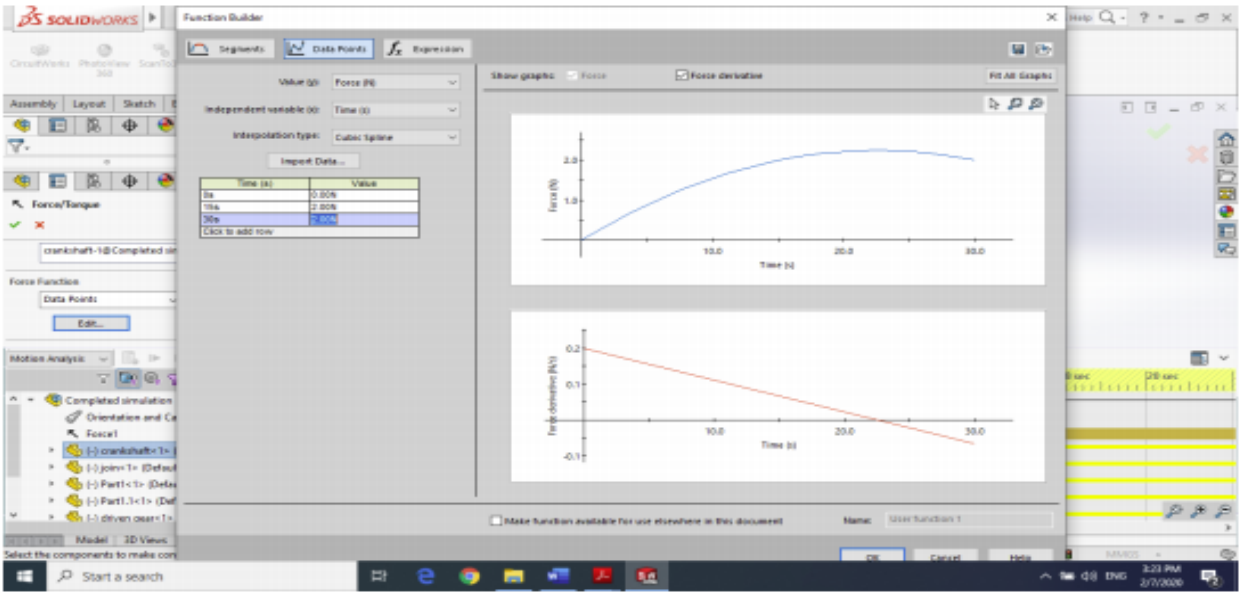

Figure 6: Force applied to the shaft.

The simulations were let to run until finished. There were a total of 12 simulations been done with different values of the number of turns of a solenoid (N) and length of the gap between solenoid and piece of metal (g) as the inputs.

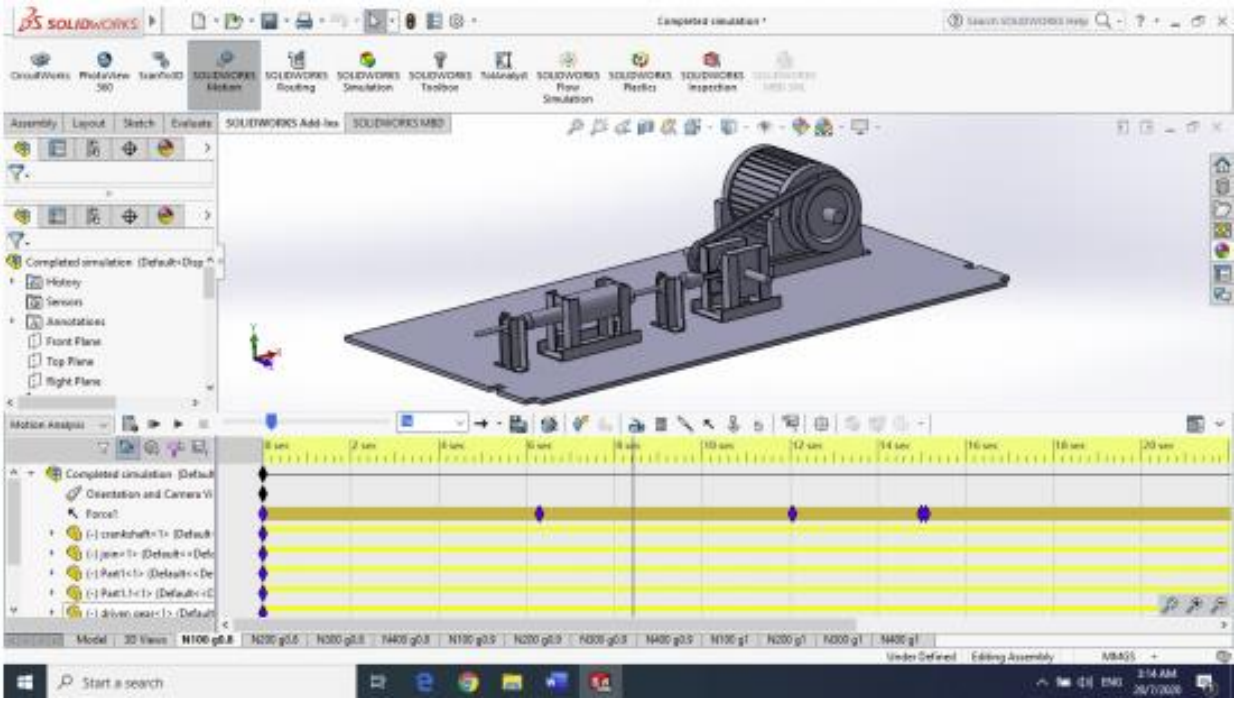

Figure 7: Simulation in Solidwork.

Next, the values of angular velocity at the driven gear were obtained from the graph. The steps were repeated by changing the value of force applied to the shaft according to the number of turns of a solenoid and the length of the gap between solenoid and piece of metal.

The result was based on the values of forces generated from the solenoid in excel and also based on the graph of angular velocity vs time obtained from the Solidwork. From the graph obtained, the minimum value of angular velocity and the maximum angular velocity when the system achieved its steady-state were recorded in the excel. The value needs to be converted to revolution per minute (rpm) as the value given from the simulations were in degree per second. The average angular velocity values were then determined. With the data obtained, a graph of average angular

velocity against the length of the gap between solenoid and piece of metal was plotted to determine the best setup of the solenoid for the hybrid generator system

Results and Discussion

A magnetic field is produced in any wire that has a current flow to it. However, compared to the straight wire, a coiled wire produces a magnetic field stronger. In coiled wire, each turn of the wire has its magnetic field. If we add more turns to the coil, the strength of the magnetic field will also increase. Theoretically, force is directly proportional to the number of turns of the solenoid (N) and inversely proportional to the length of the gap between solenoid and piece of metal (g). Supposedly, when N increased and g was decreased, the value of force applied to the shaft will be increase. This will cause the shaft to move forward and backwards faster. Since the shaft is connected to the gear by the crankshaft, when the velocity of the shaft increase, the angular velocity at the driven gear should also increase.

Table 1: Force and average angular velocity when g = 0.0008 m

Current (A)	No of turn of solenoid	Length of the gap (m)	Force (N)	Angular velocity (RPM)	Average angular velocity (RPM)
0.3	100	0.0008	1.877	130 - 173	151.5
0.3	200	0.0008	7.506	182 - 212	197
0.3	300	0.0008	16.888	252 - 336	294
0.3	400	0.0008	30.023	335 - 556	445.5

Table 1 shows the result of average angular velocity achieved with the number of turns of the solenoid as variable and the length of the gap between solenoid and piece of metal was constant at 0.0008 m. Based on the table, the highest average velocity achieved was 445.5 rpm with several turns of the solenoid of 400 when the force of 30.023 Newton applied to the shaft. At the number of turns of 100, the average angular velocity was the lowest which was 151.5 rpm.

Table 2: Force and average angular velocity when g = 0.0009 m

Current (A)	No of turn of solenoid	Length of the gap (m)	Force (N)	Angular velocity (RPM)	Average angular velocity (RPM)
0.3	100	0.0009	1.483	114 - 131	122.5
0.3	200	0.0009	5.931	174 - 203	188.5
0.3	300	0.0009	13.344	237 -278	257.5
0.3	400	0.0009	23.722	258 - 344	301

Result in Table 2 shown the simulation when the length of the gap between the solenoid and a piece of metal increased to 0.0009 m. The highest average velocity achieved was 301 rpm while the lowest was 122.5 rpm. The highest force applied to the shaft was 23.722 Newton and the lowest was 1.483 Newton.

Table 3: Force and average angular velocity when g = 0.001 m

Current (A)	No of turn of solenoid	Length of the gap (m)	Force (N)	Angular velocity (RPM)	Average angular velocity (RPM)
0.3	100	0.001	1.201	114 - 133	123.5
0.3	200	0.001	4.804	144 - 202	173
0.3	300	0.001	10.808	211 - 281	246
0.3	400	0.001	19.215	225 - 337	281

Simulation result in Table 3 was running with the length of the gap between solenoid was increased to 0.001 m. The highest average velocity achieved was 281 rpm when the force of 19.215 Newton applied to the shaft while the lowest average angular velocity was 123.5 rpm with the force of 1.201 Newton applied. Based on the project, the best build for the solenoid is with the number of turns of the solenoid, N=400 and the length of the gap between solenoid and piece of metal, g=0.0008 m. The hybrid generator system should achieve 445.5 rpm of angular velocity at the driven gear. This build is the best when comparing to other build tested in the simulation for the generator to generate more electricity.

Conclusion

For the generator to generate more power and achieve the expected target of 1kW generated by the system, improvement of the solenoid can be made. A solenoid is the heart of the system. It receives current from the battery and creates a force to move the shaft forward and backwards. From the result, the new build of a solenoid which is with the number of turns, N=400 and the length of the gap between solenoid and piece of metal, g=0.0008 m, the hybrid generator is capable of achieving 445.5 rpm at the driven gear. The value is much higher than the value of angular velocity achieved by the current prototype which was only 288 rpm. Overall, the objective of the project which is to develop a prototype of a hybrid generator is successful. Throughout the simulation, the best build for the solenoid was identified to be included in the design of a hybrid generator system. Improvement has been made on the current prototype to increase its capability. The second objective is to introduce a new alternative method of generating energy. With the current result from the simulation, the hybrid generator system is now capable to be introduced as the new alternate method of generating energy. The system will be much efficient and able to generate more power.

Acknowledgement

The research team wishes to thank the Universiti Teknologi MARA under the grant numbers 600-RMC/LESTARI SDG-T 5/3 (135/2019) for the financial support and the Research Management Institute (RMI) of UiTM for the management assistant.

References

[1] A. Elliot, “Solving Energy Challenges in Remote Communities,” Third W., 2018, pp. 1–7, 2018.
[2] U. Shahzad, “The need for renewable energy sources,” ITEE J. ISSN Int. J. Inf. Technol. Electr. Eng., pp. 16–18, 2015, [Online]. Available: http://blog.wwf.ca/blog/2015/12/10/the-need-for-renewable-energy-in-thearctic/.
[3] R. G. Newell, D. Raimi, and G. Aldana, “Global Energy Outlook 2019: The Next Generation of Energy,” Resour. Futur., p. 46, 2019.
[4] J. Mohtasham, “Review Article-Renewable Energies,” Energy Procedia, vol. 74, pp. 1289–1297, 2015.
[5] Aris Vourvoulias, “5 Advantages and 5 Disadvantages of Solar Energy,” Greenmatch, 2019. https://www.greenmatch.co.uk/blog/2014/08/5- advantages-and-5-disadvantages-of-solar-energy.
[6] P. Mishra, “Main Components, Working, Advantages and Disadvantages,” Sol. Power Plant, 2017, [Online]. Available: https://www.mechanicalbooster.com/2017/12/solar-powerplant.html#comments.
[7] E. Kabir, P. Kumar, S. Kumar, A. A. Adelodun, and K. H. Kim, “Solar energy: Potential and future prospects,” Renew. Sustain. Energy Rev., vol. 82, no. October, pp. 894–900, 2018.

[8] H. Wagner, "Introduction to wind energy systems," vol. 00011, pp. 1–16, 2017.
[9] C. A. Rieg, C. J. Smith, C. J. Crabtree, A. R. M. Forsting, and A. Bechmann, "Wind turbines : current status , obstacles , trends and technologies Wind turbines : current status , obstacles , trends and technologies," 2016.
[10] A. Kahan, "EIA projects nearly 50% increase in world energy usage by 2050, led by growth in Asia," *Int. Energy Outlook*, pp. 2019–2021, 2019.
[11] W. S. W. Abdullah, M. Osman, M. Z. A. A. Kadir, and R. Verayiah, "The potential and status of renewable energy development in Malaysia," Energies, vol. 12, p. 2437, 2019.
[12] H. Ritchie and M. Roser, "Renewable Energy," Our World Data, pp. 1–24, 2017.
[13] E. R. Omar Azhar, Omar Othman, Nadzri Asma, Ibrahim Abdul, Anas Mohd, Energy in Malaysia: Towards a Brighter Future, vol. 12. Selangor: The IBR Asia Group Sdn. Bhd, 2017.
[14] M. Issa, H. Ibrahim, I. Adrian, and R. Lepage, "A Review and Comparison on Recent Optimization Methodologies for Diesel Engines and Diesel Power Generators," Power Energy Eng., vol. 07, no. June 2019, p. 26, 2019.