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Fully Automatic Solar Powered Oil-Water Separation System for Grease Trap Controlled by Arduino: A Conceptual Design

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Abstract*: Pipeline clogging in food premises frequently emerges, particularly in small range restaurants. Fat, oil and grease (FOG) disposed from food premises becoming root cause for this issue and pollute drainage system. The aimed of this project was to remove the FOG from wastewater and with automatic oil disposal system using renewable energy. Power input system was improved by designing and developing the solar tracker system for automatic oil disposal grease trap controlled by Arduino and light radiation sensor. The solar tracker was designed based on engineering design methodologies including the survey, house of quality (HOQ), morphological chart and pugh method to ensure the engineering criteria achieved with the concern of customers satisfaction. Light radiation sensor was used to improve the efficiency of solar tracker by detecting the location of sun and Arduino will give a command to the motor based on a signal received from a light radiation sensor. Dual axis solar panel with light radiation sensor gave significant reduction in terms of time consumption used to absorb energy from the sun with average amount of voltage of approximately 1.82 volt compared to fixed solar panel which has average amount of voltage of approximately 1.35 volt. The newly designed dual axis solar tracker also has advantage on flexibility where it can be put at different angle and places.

Keywords* : Oil-water Separation, Light Radiation Sensor, Grease Trap, Energy Harvesting.

I. INTRODUCTION

Blockage in drainage system of food processing facilities (FPF) such as fast food restaurants, food courts, and caterings become a concern for long term which caused by the fat, oil and grease (FOG) deposits in sewer. Urbanization of an area causing growth of FPFs and increasing the amount of FOG consumption in that area. In India, the urban recharge component of groundwater was more than ten times greater than the natural recharge [1]. This situation emphasized the importance of on-site sanitation. Alkaline detergents used in FPFs (PH>10) acted as oxidizer and react with FOG to create the formation of saturated fat in sewer pipes through the chemical reaction called as saponification [2]. Common cooking oils ranged from 0-548 mg/g contains in sewer FOG [3]. The sewer FOG discharged from untreated wastewater becomes cooling down, harden, and stick inside the pipelines. This development of FOG, starting to reduce the diameter of pipes and reduce the flowrate of water. At a point, it is completely blocking the flow of water and causing over flow. In Denmark, total insurance payment amounted to about 800 million EUR was distributed as a results of urban flooding events [4]. Flooding's are increasing the risk of water-borne and vector-borne diseases, which effect the healthy environment of human's. Water-borne disease are causing by mixture of dirty water in drinking water leads to the serious illness such as Guinea worm disease, typhoid and cholera. Flooding are indirectly increasing the risk of vector-bornediseases. Flooding is causing standing water which help to expand the vectors breeding (mosquitos), improving potential of spreading of the diseases such as dengue, malaria and yellow fever. Grease trap is a mechanical device used to prevent the discharge of FOG in a drainage system. Grease traps also known as grease abatement system, grease interceptors, grease separator's or grease recovery units used to separate FOG and food waste from wastewater which discharge to the drainage system through gravitational separation. Grease traps are having multiple sections to separate grease and solid particles such as rice and meat from wastewater. Greases which having less density then water will rise up and trap to surface of water and solid particles will trap in bottoms of water and wastewater will discharge to the sewer. Hydromechanical grease traps normally using principles of wastewaters heat and gravity to split up the FOG from it. The splitted grease need to be collected or cleaned manually and often to avoid mixtures of high thickness of greases with water again. On the other side, Gravity Grease Separator used multi-compartments to reduce the speed of flow rate and separate the FOG and water based on gravitational principles [5]. The combinations of mechanical and electrical parts in grease trap will be a very efficient grease trap. Solar power un-pollutant renewable energy source is obtainable in every part of the world. A solar power system uses photovoltaic (PV) to collect the sun's energy.

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The Malaysian Government has boarded on continuous effort in the development of renewable energy through various support and promotion programs as designed in Malaysia Economic Planning Unit. PV cells utilize solar based energy to create a chemical reaction that produces power. Every cell contains a semiconductor; normally, silicon in one of a few structures (single-crystalline, multi-crystalline, or thin- layer), with polluting influences (either boron or phosphorus) diffused all through and is encased with a silk screen. Cells are merged together through a circuit and frame right into a module. Semiconductors allow the electrons freed from impurities by the sun's rays to move rapidly and into the circuit, generating electricity [6]. A PV module must have an inverter to alternate the DC current into alternating current that allows you to be serviceable by way of electrical gadgets and well suited with the electric grid. Less efficient of solar systems initiated by fixed mounted and do not follow the variation of the solar position. Usually, a sun tracker can be categorized in two types; passive trackers and active trackers. However, the most efficient and prominent sun trackers was found based on the form of polar-axis [7] and azimuth-elevation types [8]. Throughout these, they can be either single axis tracking or double axis tracking. The most frequently used configurations in double axis tracking are polar-axis and azimuth-elevation, which can improve amount of captured solar energy by 30 to 50% compared to fixed tilt device. Until this moment, there is no other designs such as mechanical passive grease trap that dispose oil automatically and using solar power energy. The expected significance of this study is to assess the improvement fixed based solar panel to sun tracker solar panel by using light radiation sensor. Other significance impact would be studying whether the Arduino can improve the consumption of energy and system effectiveness.

II. METHODOLOGY

The first stage of this research project was customer survey using simple random sampling method [9]. It begins with the distribution of questionnaire to 50 small restaurant owners to gather the issues that are related to the cleanliness and food waste disposal in their food premises sewage system. The information collected during this stage will reveal the most important data about project design and customer's needs. Followed by the second stage which was to rank engineering characteristics that depicts the customer needs in tackling their issues. The third stage was using morphological chart to produce the idea and thoughts as indicated based on the customer's concern. The fourth stage was the Pugh method, selection of a design by building up a method to pick the best design from the considered design compared to the datum. Next, material selection and conceptual design was used to choose materials considering the cost, behaviors to the environment and application in conceptual design. The design of the project must be flexible and valuable for the customer as per Pugh method. The sixth stage was testing, where the prototype will be compared between fixed axis and dual-axis solar panel.

III. RESULTS AND DISCUSSIONS

A. Survey Analysis

The survey involved twenty questions where selected respondents of this questionnaire are from restaurants in Kluang, Johor Bharu, Kuala Lumpur, Kuantan and Seremban. Data collection of this survey analysis proved the relevance and necessity of designing the prototype for this project. The analysis was used to design a dual axis solar tracker for a grease trap based on 50 respondent's expectations.

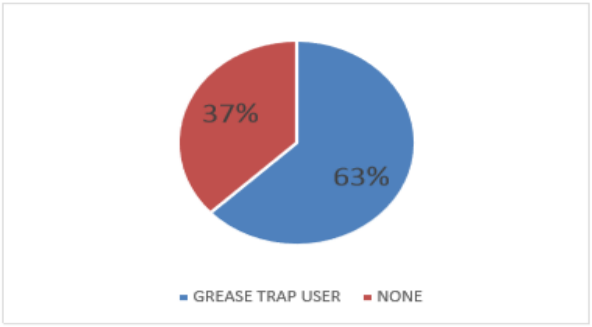

Fig. 1. Grease trap user.

Pie chart in the figure 1 shows that out of 50 restaurants, only 63% of restaurants have grease trap and 37% of restaurants are did not have grease trap. It can be said that there were still a number of owners who were not aware on the important of the existence and function of grease trap. A few owners said that the currently available grease trap is not affordable and they still needs to maintain it after the purchased.

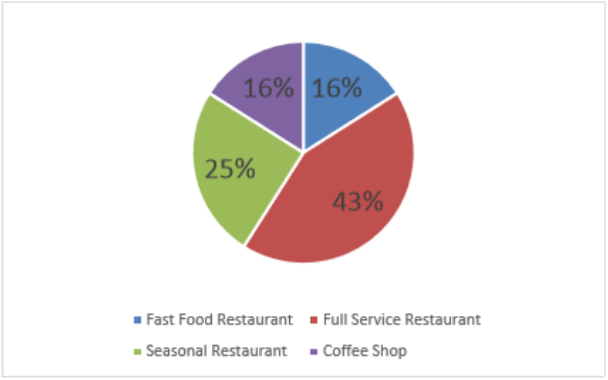

Fig. 2. Type of respondents.

Figure 2 shows the type of facility that surveyed. A large portion was covered by the full-service restaurant with 43%, following by a seasonal restaurant with 25% and 16% of fast food restaurant and 16% of coffee shop respectively. This will help designer to consider the fluid flowrate during the disposal since full service restaurants ran the dishwashing at most compared to others. The pie chart in figure 3 shows the frequency of clogged drain and piping in premises. Out of 50 restaurants, 24% of restaurants never encountered such a problem previously, 38% of restaurants were occasionally having this problem, 26% were frequently facing this problem and 16% infrequently facing this problem.

Based on observations, full-time restaurants and seasonal restaurants which do not have grease trap was usually encounter clogging problem and very least amount of coffee shops encountered clogging problem previously since the number of oily foods in coffee shops is very small in comparison to other restaurants. Only 19% of restaurants out of 39 restaurants maintained their grease trap by waste hauler and the rest 81% preferred to maintain their grease trap by using own workforce because hiring the third party to clean grease trap would increase the maintenance cost and some of them mentioned they do not afford to hire the third party to maintain their grease trap.

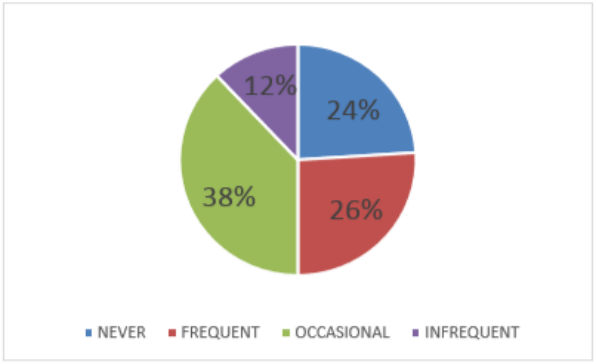

Fig. 3. Frequency of clogged drain and piping.

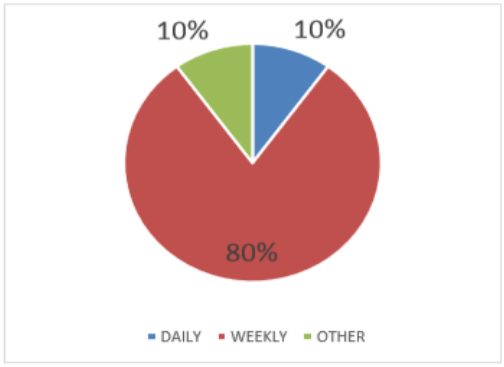

Fig. 4. Frequency of grease trap inspection.

Figure 4 shows the frequency of inspecting grease trap. 80% of users inspected grease trap weekly and 10% of users inspected grease trap daily. It was assumed that restaurant owners concern about the uptime of grease trap and helped them to maintain hygiene of food premises. Another 10% only inspected grease trap if there was abnormality.

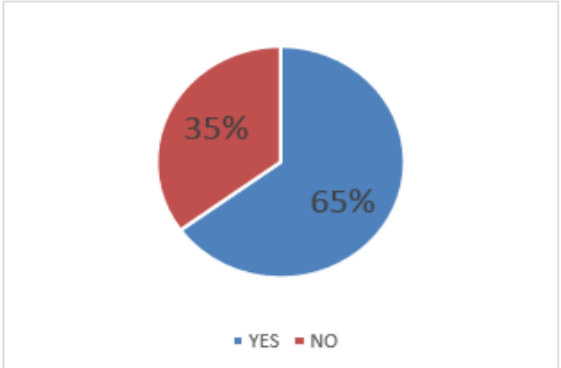

Fig. 5. Awareness on the effect of FOG.

Based on figure 5, only 65% of grease trap users are aware of impact of fat, oil and grease (FOG) to the environment of premises and balance 35% are not aware of impact of FOG even though they are using grease trap in premises. This indicated that most of the owners believed grease trap helped them to avoid drainage clogging and reducing bad odors caused by drainage system.

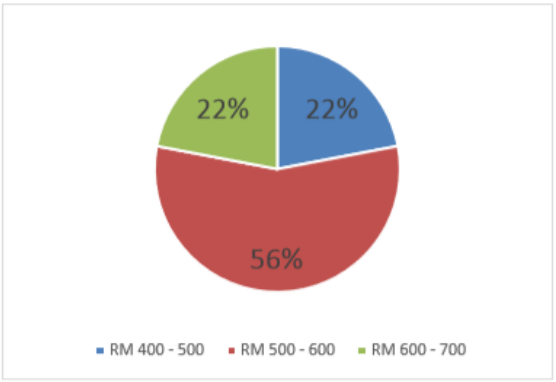

Fig. 6. Affordable price for grease trap.

Figure 6 shows the willingness of restaurant's owner to spend for a grease trap. Majority of them choose the range of RM500-600 which is 56%. 22% of the respondents choose the range of RM400-500 and the remaining 22% choose the range of RM600-700 respectively.

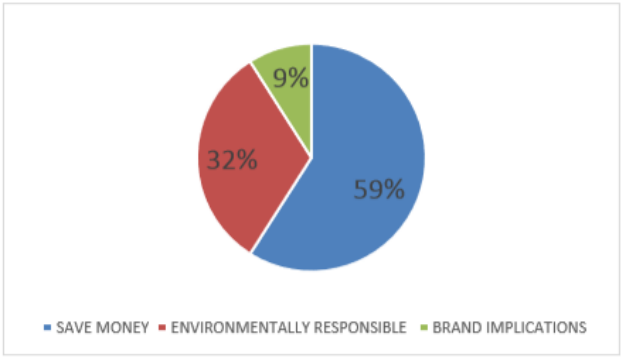

Fig. 7. Factors of using solar energy.

In figure 7, 59% of the respondents thought the solar energy may help them to reduce the amount of electricity bills, while 32% of respondents thought solar energy are environmentally friendly. This shows they have knowledge of about renewable energy and its advantage and 9% of respondents are considering solar energy because of implications of brands.

B. House of Quality

Figure 8 shows the House of Quality (HoQ) which helps to identify the engineering characteristics that are the most important to fulfilling the customer requirements. A total of seven customer requirements on the design specification of solar tracker have been identified and their feedback on each criterion has been translated into quantifiable engineering characteristics. In the design of solar tracker, the size, raw material, cost and portability of tracker are rated as the most important criteria.

This is due to the reason that the raw material used and its size relates directly to the weight of solar tracker, whereas the portability of solar brings effect to the ergonomics factor. On the other hand, costing of the solar tracker will effect on increasing price of automatic oil disposal grease trap system with a solar tracker. The raw material used in solar tracker has a significant effect on,

or in the other word, strong correlation to the weight. Hence their relationship are rated '9'. The size has nothing to do with the backup power for Arduino-UNO and servo motor. The interaction between the shape of tracker and design of tracker is graded with strong positive interaction because of the changes in the shape of tracker effect design of tracker. On the other hand, the interaction between the backup power and ergonomics is strong negative due to the reason that using a rechargeable battery as a backup power for Arduino and servo motor would increase the weight of solar tracker caused reduce in ergonomics of the product.

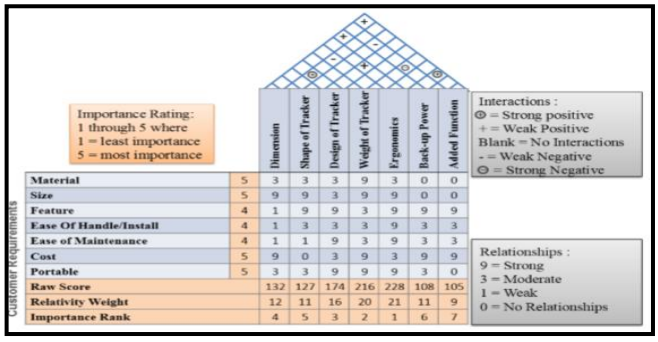

Fig. 8. House of quality.

C. Morphological Chart & Pugh Method

Table 1 shows the morphological chart of solar tracker organizing the possible solutions for each parameter. This morphological chart allows the idea generation on the following conceptual design. Conceptual design is the result of synthesizing the more possible combinations of a possible solution for each parameter. Five possible combinations of sub problem solution identified are generated from the morphological chart. Out of them, three were selected to be compared with datum.

Table- 1: Morphological chart

	Option 1	Option 2	Option 3	Option 4	Option 5
Weight	5kg	6kg	3kg	7kg	4kg
Material	Mild steel	Stainless steel	Polymer	Aluminum	Stainless Steel
Maintenance	2 weeks once	Daily	Monthly	Weekly	2 weeks once
Design	Dual Axis Solar Tracker	Single Axis Solar Tracker	Fixed Solar	Dual Axis Solar Tracker	Single Axis Solar Tracker
Location	Portable	On ground	On roof	On ground	On Roof
Power Source	Battery 12Volts	Battery 12Volts	NIL	Battery 12Volts	Battery 12Volts
Number of servo motor	2	1	NIL	2	1
Programming	Arduino UNO	PLC	NIL	Raspberry	Arduino UNO

In table 2, the grease trap design alternative 1 is superior to the reference/datum. Alternative 1 is chosen to be the design for further development since it ranks the highest in advantages over the datum. By using Pugh concept selection method, the four possible combinations of sub problem solutions can be compared qualitatively in every single alternative to a datum alternative. The specifications and characteristics of tracker 1 design are sketched with consideration to all the customer needs. The sketch of tracker 1 design is shown in figure 9.

Table- 2: Pugh decision matrix

CRITERIA	Tracker 1	Tracker 2		Tracker 4
Cost	+	-	D	-
Design	+	-		+
Size	+	-	A	-
Ease Of Handle	+	+		+
Material	-	+	T	-
Ease of Maintenance	+	S		S
Portability	+	-	U	-
Weight	S	+		-
Added Function	+	-	M	-
∑+	7	4		3
∑S	1	1		1
∑-	1	5		6

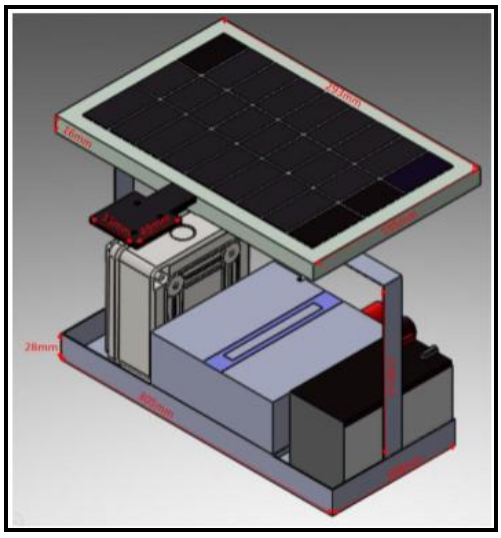

Fig. 9. Solar tracker system.

Figure 9 shows part of the system which consists of solar panel, inverter, 12 volts battery, servo motor, junction box and speed controller. The solar panel on the top with short circuit current of 0.31A which able absorb the sun's ray as a source of energy for generating direct current. The solar panel is connected with two MG995 servo motor used to move solar panel as sun move to increasing amount of solar energy generating by solar panel. The direct current will be converted to alternating current by an inverter which at the middle between the battery and speed controller. At the same time, the battery will be recharged by alternating current that converted from an inverter.

D. Circuit Diagram of Solar Tracker

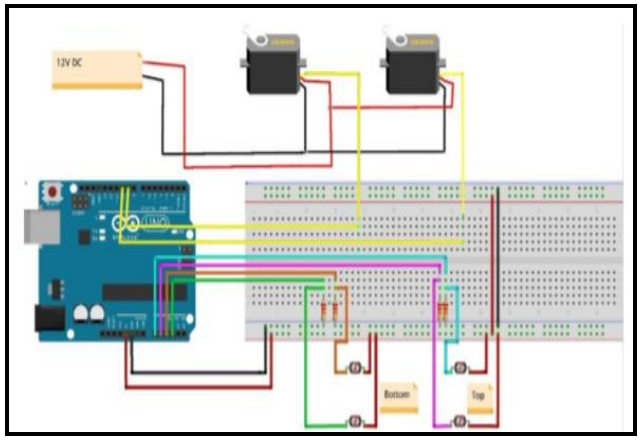

Fig. 10. Circuit diagram of dual axis solar tracker.

Figure 10 shows a circuit diagram of dual axis solar tracker created by using Fritzing software. As shown in the figure, Arduino UNO was used as a microcontroller for this project because hardware and software and it is an open source electronics prototyping platform that is flexible and rewritable. Besides that, servo motors used a moving mechanism in this project for the various reasons. Most importantly, servo motor consumes less energy to the same mechanism then stepper motor. It reduced the power wastage of battery. Servo motor also has better characteristics then stepper motor in term of loop capabilities, dependency of load and has excellent response to the controller. In this project, Arduino UNO and servo motor used external power source (dry cell battery 12v) to operate because if solar tracker's power generation in zero also Arduino and motor able to work and its increasing power generation of solar tracker. In this project, four photoresistor sensor as known as light-dependent sensors (LDR) used to detect the position of the sun and send feedback to microcontroller automatically (Wen et al., 2018). Four 20kΩ resistors are used to control the sensitivity of light-dependent sensors (LDR) to the sunlight. The minimum angle to rotate is set to 20° and maximum angle to 160° to avoid the solar panel from hitting the body of solar tracker.

E. Voltage Generation Analysis

The voltage generated by fixed solar at a stationary position is maximum at 13:00 pm which is 1.48V and drop with respect to the time as in table 3. In the dual-axis tracking system, two of the axis of solar tracker is moving along with the suns in horizontal axis direction and vertical axis direction. The maximum voltage generated by dual axis solar tracker is 2.31V. The value in table 3 shows that the maximum power is generated in between 12:00-13:00 pm when the intensity of sunrays is highest (Ng et al., 2019). A comparative analysis was performed using two systems, i.e., dual-axis solar tracker and fixed solar. The results shows that the use of the dual-axis solar tracker able to produced 1.82 volt/hour on average compared with a fixed solar panel only able to produce 1.35 volt/hour. This shows dual axis solar tracker would increase the ability of solar panel used to generate higher power for automatic oil disposal grease trap.

Table- 3: Voltage generation by solar tracker

Time	Reference Time [Minute]	Voltage Generation (Fixed)	Voltage Generation (Dual Axis)
1000	60	1.22	1.41
1100	60	1.36	1.62
1200	60	1.42	2.31
1300	60	1.48	2.28
1400	60	1.37	1.91
1500	60	1.31	1.64
1600	60	1.29	1.56
Average	60	1.35	1.82

IV. CONCLUSIONS

It has been argued in this paper that dual axis solar tracker for solar panel can generate greater power compared to fixed solar panel. Both systems generate maximum power between 12:00 and 13:00 pm. However dual axis solar power capable of generating 0.47 volt/hour more than fixed solar panel. It was possibly due to the presence of photoresistor sensor in dual axis solar tracker which detected the spot with highest light intensity. The sensitive property towards light ensured maximum voltage generation for every measurement compared to fixed solar panel.

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