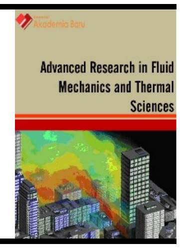
Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



Development of Temperature Preference Learning System to Optimize the Energy Consumption in the Building

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ARTICLE INFO

Article history:
Received 3 January 2018
Received in revised form 13 April 2018
Accepted 5 July 2018
Available online 12 August 2018

Keywords:
Automatic control system, indoor environment management, energy saving, temperature

ABSTRACT

It is undeniable that as technology advances, robots will slowly start taking over the more labour intensive jobs hence pushing the human workforce from labour intensive work into a more intellectual intensive work. This shift in workforce also means the usage of office spaces where a multitude of cooling appliances are used to maintain the overall temperature of the office however, it is simply energy inefficient as well as expensive to leave all the appliances on all the time as the amount of people vary and so too does the need for said appliances to be on throughout the day. This work addresses the problems mentioned above by implementing an environmental preference learning algorithm coupled with a system which can be deployed to control and received feedback of any electrical appliances from a distance via Bluetooth. For this purpose, we used the appliance preference patterns exhibit by people corresponding to the room temperature as well as number of people in the room the time as the learning data and subsequently use it to determine what appliance should be on or off at any given time and condition so that the preferred room temperature as well as optimum room comfort level can be achieved.

1. Introduction

Energy conservation is an emerging issue or topic for humanity as the backlash from our past and current over reliance on fossil fuel. This reliance is starting to show its ugly side in the form of global warming to rising sea levels. There are many type of renewable sources research such as solar thermal, wind, water, heat (peltier systems) [1-3] and lightning [4] aimed to solve said issue. However, replacing our current dependencies on fossil fuel would not only take a while but also be difficult due to the currently low energy output from renewable sources comparatively. In addition to that due to currently high energy consumption rate, it would require a larger space dedicated for

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energy generation just to match the current energy output that is being generated today not to mention the cost for said infrastructure. According to Mohd Firdaus *et al*., [20] discuss about economic potential and benefit of photovoltaic (PV) potential in terms of financial ability, time of investment and risk involved in South East Asia [5].

With that said, the best thing that can be done now would be to instead reduce the power consumption pre-capital so that we can start the process of changing our dependency from non-renewable to renewable energies and the place that should start would be by conserving energy used for air-conditioning may it be for residential, commercial or industrial units. This is because it was found in a previous study that approximately 60% of all energy generated globally is used for residential, commercial and industrial purposes and half of it is used specifically for space heating and cooling only whereas a good 30% of it is ineffective and unnecessary [6-8]. Hence it would be safe to assume that a reduction in energy consumption within this division itself would be able to reduce the overall energy consumption by a significant amount.

Energy on the other hand is constantly being wasted with the way air-conditioning is being used in a room or building where it is often left on at full blast (24 degrees Celsius or lower) all day [6] regardless of the amount of the quantity of people in the room as often times the when there is a large quantity of people in the room that it is valid to turn the air conditioning on at full blast to compensate for the additional heat exuberated by the people however when there's only one or two individuals in the room, having the air conditioning on at full blast is not only costing the company money due to its unnecessary power consumption but also becomes downright uncomfortably cold for the people in the room as there's no longer a significant amount of heat exuberated from "bodies" for the air conditioning to offset. On cost alone, an air-conditioner at full blast (18℃ or lower) is estimated to cost RM1.20 an hour just to maintain the temperature of the room the size of 36 sqm and from a study made by Hua Xianzhe, it can be assume that the fine tune control of the temperature output from the air-conditioning unit can greatly reduce energy consumption [9].

Now, with that said it is also worth noting that humanity has become accustom to a certain level of convenience such as having a nice cooling environment to live and work in as of such merely removing said cooling element would not be a viable option as it would directly affect the quality of work as well as quality of life of the employee themselves [10, 11]. There are numerous ideas to solve this issue among which are the heatsink design research for solving optimum thermal problem [13-16]. Another idea would be to connect all existing heating and cooling elements within the room using the internet of things [12]. Mapping out the possible heat transfer interaction between itself and its surroundings so that an automated system can automatically can optimally determine the appliances. Subsequently the system would need to be able to turn on or off automatically so that optimum temperature for thermal comfort can be achieve [17, 18] at any given time of the day or whenever it should be on in the first place i.e. presence of people in the room hence indirectly reducing the amount of energy consumption.

In this paper, we present an algorithm coupled with a system that can connect multiple heating and cooling devices together to a system mainframe using Arduino Uno coupled with HC-05 and HC-06 Bluetooth transmitters and receivers. The algorithm which is programmed to the mainframe will then register each individual device automatically run a temperature regulation function via turning on and off from the list of heating/cooling devices that has been registered. In the process of regulation, it will also continuous learn from the various input of the user may it be turning the fan, air conditioning unit or the heater in comparison with the current room temperature as well as the number of people that are present in the room to determine whenever to increase the preferred temperature of decrease the preferred temperature for future references.

2. Methodology

The project as mentioned previously consist of 3 parts which is the hardware which accommodates the function, the learning function and the algorithm itself. The algorithm is the function which determines the optimum configuration of what appliances that needs to be turned on at any given time to achieve the desired temperature or whenever to turn all the appliances off because there is nobody in the room for a long time as seen in Figure 1.

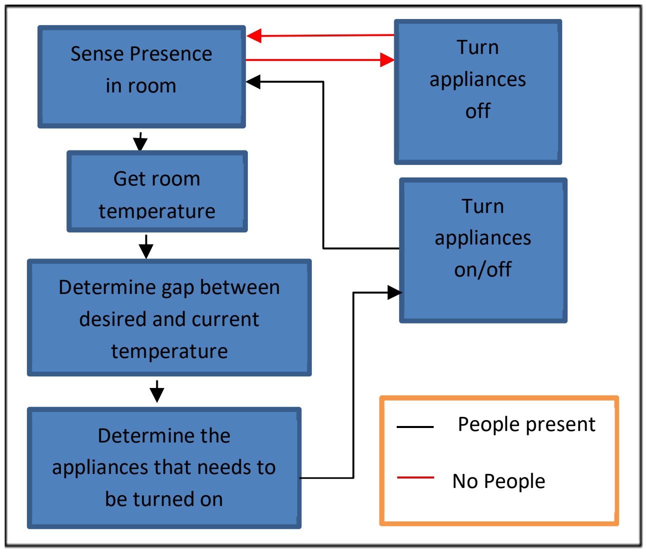

Fig. 1. Expected algorithm operation

The 2nd part deals with the learning function whose goal is to determine what is the desired temperature or fine tune said temperature as well as determine what neutral elements should be turned on or off with consideration to the current room temperature as well as the quantity of people in the room. To do this, we run an interrupt sub routine that is prodded when data is being received from the heating, cooling or neutral devices. The routine will take into consideration its current mode of operation and determine whenever if the abrupt turning on or off of heating/cooling appliances is indicative of the user wanting it to heat up or cool down faster or if the user would prefer the overall temperature to be hotter or cooler compared to the preferred temperature. In this event, the temperature that was keyed into the remote was recorded and average up using the following formula

$$T_{d(new)} = \frac{T_{d(old)} + T_{manual\ input}}{2} \quad (1)$$

Neutral devices such as fans whom does not affect the temperature of the house will on the other hand will have its operational frequencies recorded to the condition chart of the program so that during said conditions are true then the specific neutral devices will turn on or off i.e if the user frequently turns the fan off when the temperature is at preferred temperature then in the following iterations when preferred temperature is achieve the fan will automatically turn off.

The last part deals with the hardware implementation. To implement said system, an Arduino UNO was used as the microcontroller. Said microcontroller would then be connected to HC-05 and multiple HC-06 Bluetooth module to facilitate the transfer of data from the main controller hosting the algorithm to the slave controller which turns the appliances on or off or to relay information back to the main controller such as indoor and outdoor temperature or presence of people without the need of a vast array of wires sprawling throughout the room as seem in figure 2. Arduino's ability to read voltage levels allows for a method to control the AC frequency value via computations [19], furthermore, with minor additions of either cameras or motion sensor the Arduino is more than capable of counting the number of people in the room [20-21].

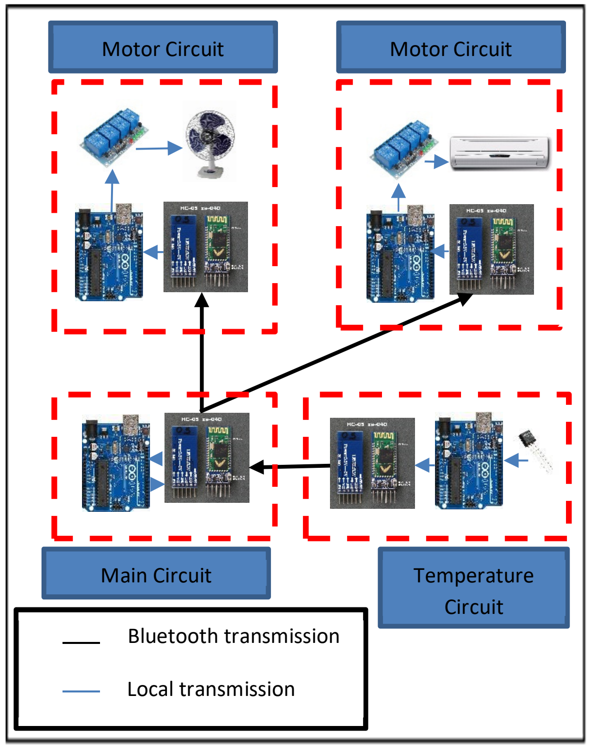

Fig. 2. Figure showing hardware communication

3. Results and Discussion

Dispersion of nanoparticles in a base fluid not only contributes to enhancement of thermal conductivity, but also because of greater heat transfer area, superior convective heat transfer coefficient can be achieved, which will also lead to enhancement of heat transfer. The structure of polymer emulsion microgels system containing a certain amount of water during film-forming process was revealed by SEM in Figure 1.

Simulation of the system's algorithm was done in a closed room where there were temperature sensors connected inside and outside the room. The results seen in Table 1 and 2 shows the capability of the system to operate with a varied amount of connected devices in the efforts to maintain temperature in the room to the preferred temperature at all times and hence reducing overall energy consumption in the room.

Table 1
The possible decisions made by the AI based on all possible situations

	Air Cond	Vent	Neutral
$T_1 > T_2 > T_d$	**Turn On** Case A	**Turn Off**	**Turn On** Case D
$T_1 > T_d > T_2$	**Turn Off**	**Turn On** Case B	**Turn On** Case D
$T_d > T_1 > T_2$	**Turn Off** Case C	**Turn Off**	**Turn Off**
$T_d > T_2 > T_1$	**Turn Off**	**Turn On** Case B	**Turn Off**
$T_2 > T_d > T_1$	**Turn Off** Case C	**Turn Off**	**Turn Off**
$T_2 > T_1 > T_d$	**Turn On** Case A	**Turn Off**	**Turn On** Case D

where,
T1 = Temperature inside the room
T2 = Temperature outside the room
Td = Desired temperature
Case A = Temperature of unit (n) is dropped. If unit (n) temp is maxed, decrease temp of the next air conditioner unit (n+1)
Case B = If unit (n) is already on, turn on unit (n+1)
Case C = Temperature of unit (n) is increased. If unit (n) temp is maxed, then unit (n) is turned off and temp of unit (n+1) is increased
Case D = When all know unit is already on and maxed out or if there is no air conditioner unit

Table 2
Table showing all possible outcome from the learning input corresponding to the mode

Condition	Manual Action	$T_{d(old)}$	$T_{d(new)}$	Explanation
$T_1 > T_2 > T_d$	Case 1	24°C	24	No change
	Case 2		27	Temp up
	Case 3		27	Temp up
$T_1 > T_d > T_2$	Case 1	24°C	24	No change
	Case 2		27	Temp up
	Case 3		27	Temp up
$T_d > T_1 > T_2$	Case 1	24°C	21	Temp drop
	Case 2		24	No change
	Case 3		24	No change
$T_d > T_2 > T_1$	Case 1	24°C	21	Temp drop
	Case 2		24	No change
	Case 3		24	No change
$T_2 > T_d > T_1$	Case 1	24°C	21	Temp drop
	Case 2		24	No change
	Case 3		24	No change
$T_2 > T_1 > T_d$	Case 1	24°C	24	No change
	Case 2		27	Temp up
	Case 3		27	Temp up

where,
Case 1 = Set air conditioner to a lower temperature setting than the current preset (18°C)
Case 2 = Set air conditioner to a higher temperature setting than the current preset (30°C)
Case 3 = Turn off air conditioner
$T_{d(old)}$ = Original default preferred temperature
$T_{d(new)}$ = Preferred temperature after undergoing learning alteration

Next, we ran a simple simulation with the assumptions that the presence of a person would increase the room temperature by 0.5 $°C$, and every 1 $°C$ increment in the air conditioner will reduce the power consumption by 5% [9] and the preferred temperature was preset to 24℃. The system will run in accordance to the developed decision matrix that is seen in Table 1 where the temperature is increased or decreased by units of 0.5 $°C$ in correspondent to the increase in temperature exuded by a person. The experiment is done to see the possible power consumption with said system compared to without said system using UTeM Air Conditioning policy which turns the appliances at full blast (19℃) from 9 to 5 as a reference without taking into account external effects to the temperature within the room. The number of people in the room was deduce base on the average usage of the common room in the faculty of electrical engineering for the University Teknikal Malaysia Melaka throughout the day and can be seen in Fig. **3**. The temperature of the room without the air conditioner was obtained from the temperature records of Malacca throughout August 2017 which averaged the temperature at 6am – 12pm to be 25℃ and temperature at 6pm – 12am to be 30℃. The simulated results temperature of the room with and without the system can be seen in figure 3 whereas the resulting difference in power consumption can be seen in Figure 4.

From the graph in Figure 3, by using the system the temperature of the room through the day can be maintained at 24℃ via reduction and increment of temperature setting corresponding to the number of people in the room as long as the amount of heat exuberated by the people does not exceed the cooling capabilities of the air conditioner at which point the temperature of the room would increase regardless.

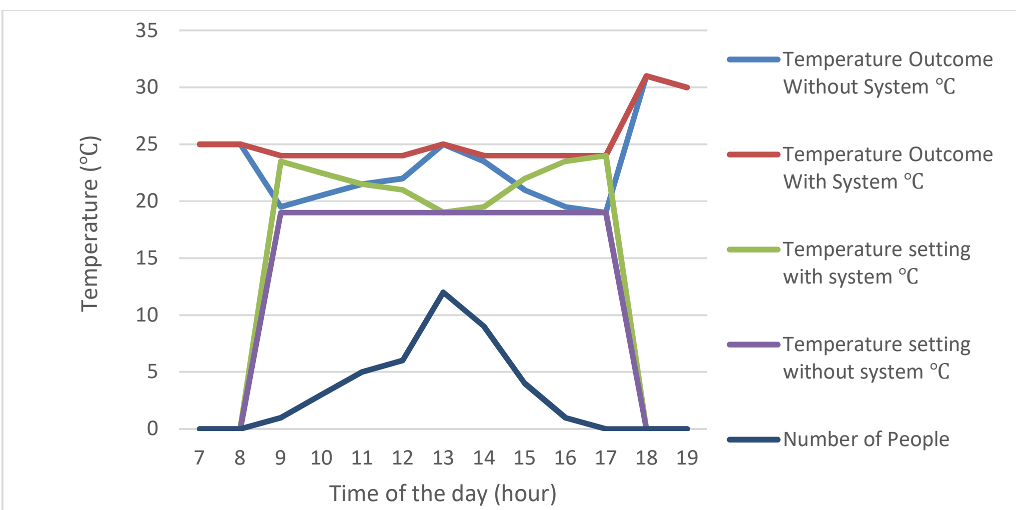

Fig. 3. Figure showing the comparative outcome of temperature setting and room temperature base on the number of people in the room between with and without system implementation

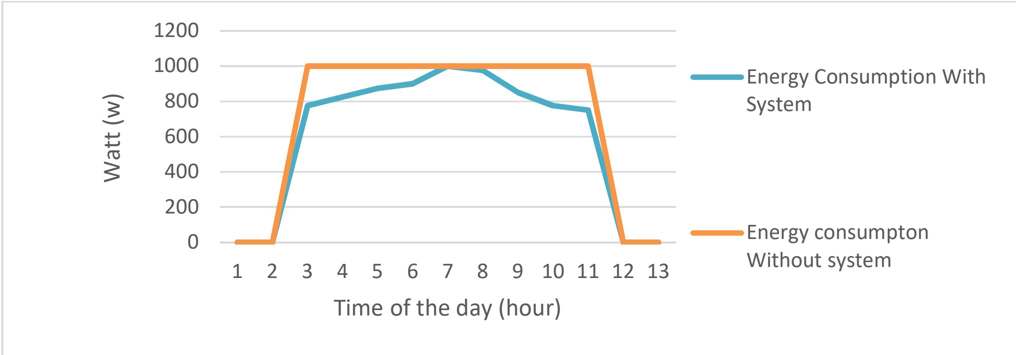

Fig. 4. Figure showing the simulated power consumption in the room between the application with and without the system

Power consumption can be calculated by getting the difference between temperature setting and multiplying it by 5% in correspondent to the reduction of energy consumption per °C . It is evidently from Figure 4 the system will always conserve energy in comparison to a room without the system as long as the heat exuberated by the number of people does not exceed the cooling capabilities of the air conditioning unit.

Lastly, we tested the learning capabilities of the system by monitoring the value of preferred temperature (T_d) using the same simulation method when there is a manual increasing or decreasing the temperature setting or turning off the air conditioning system all together assuming there are people in the room and the temperature inside the room (T_1) already takes into consideration the heat exuberated by the people.

4. Conclusion

From this project, it is now shown that a method to connect a varied amount of device to a central system easily as well as controlling all of said devices with a singular goal of maintaining the overall room temperature in an effort to reduce the energy consumption of the room can and has been accomplish.

Furthermore, the designed algorithm when utilizing the system mention is more than capable in significantly reducing the energy consumption when comparing the power consumption for UTeM's air conditioning policy which turns the central air Cond at maximum at 9am and turns it off at 5pm the total watt consumption of the day would be total up into an estimate of 9000 watts whereas when implementing the designed system, because the air Cond output was changed based on the amount of people present we are able to reduce the consumption to an estimate of 7725 watts which is a 14.1% reduction in energy consumption.

Lastly, with integration of a learning program, the algorithm becomes more than capable of personalizing its temperature control in accordance to the preference of the user by monitoring his manual input to the cooling devices and cross referencing them with the current operational mode of the algorithm at the moment.

For future works, extension of the learning algorithm to encompass the neutral devices such as fan or vents should be looked into. Besides that, actual implementation of this work should be done in order to validate the simulation results which has been obtained above for the designed system.

Acknowledgments

Authors are grateful to Ministry of Higher Education Malaysia and Universiti Teknikal Malaysia Melaka (UTeM) for the financial support through RAGS Research Grant funding RAGS/1/2015/TK0/FTK/03/B00118 project.

References

[1] Shalsam, N. M. H., M. H. Harun, M. S. Yahaya, K. A. M. Annuar, M. F. M. A. Halim, M. H. C. Hasan, and M. F. Yaakub. "A study on the potential of Peltier in generating electricity using heat loss at engine system." *Proceedings of Mechanical Engineering Research Day* 2016 (2016): 96-97.

[2] Harun, M. H., K. A. M. Annuar, M. F. M. A. Halim, M. H. C. Hasan, M. S. M. Aras, and M. F. Yaakub. "Peltier and seebeck efficacy of hot and cold air system for portable O-REF (oven & refrigerator) application." *Proceedings of Mechanical Engineering Research Day* 2016 (2016): 81-82.

[3] Johari, Siti Halma, Mohd Faiz Che Pa, Khalil Azha Mohd Annuar, Suziana Ahmad, and Madiha Zahari. "Performance analysis of portable power generator by using TEG module." *Proceedings of Mechanical Engineering Research Day 2016*2016 (2016): 79-80.

[4] Mohd Farriz Md Basar, Khalil Azha Mohd Annuar, Madiha Zahari, Muhamad Faizal Yaakub, Mohd Firdaus Mohd Ab Halim, "A New Source of Renewable Energy from Lightning Return Stroke: A Small Scale System" (2011) PJP/2010/FKE(10A)S641.

[5] Mohd Firdaus bin Mohd Ab Halim, Mohamad Haniff Harun, Khalil Azha Mohd Annuar, Arman Hadi bin Azahar and Nik Azran bin Ab Hadi, "Photovoltaic economic potential for investment portfolio in south east asia" (2016) ARPN Journal Of Engineering And Applied Sciences, Vol. 11, No. 19, pp. 11260-11265.

[6] Jain, Manu, N. Kaushik, and Kayalvizhi Jayavel. "Building automation and energy control using IoT-Smart campus." In *Computing and Communications Technologies (ICCCT), 2017 2nd International Conference on*, pp. 353-359. IEEE, 2017.

[7] Wongpatikaseree, Konlakorn, Takashi Okada, and Yasuo Tan. "Analysis of the thermal comfort and power consumption in apartment domain." In *Consumer Electronics (GCCE), 2015 IEEE 4th Global Conference on*, pp. 423-426. IEEE, 2015.

[8] Ab Halim, Mohd Firdaus Mohd, Umar Al-Amani Azlan, M. Haniff Harun, Khalil Azha M. Annuar, S. Halma Johari, A. Rahim Abdulla, and M. Faisal Hushim. "Lighting Retrofit Scheme Economic Evaluation." *Indonesian Journal of Electrical Engineering and Computer Science* 5, no. 3 (2017): 496-501.

[9] Xianzhe, Hua. "Room temperature and humidity monitoring and energy-saving system." In *Computer Science & Education (ICCSE), 2011 6th International Conference on*, pp. 537-540. IEEE, 2011.

[10] Amoo, A. L., H. A. Guda, H. A. Sambo, and T. L. G. Soh. "Design and implementation of a room temperature control system: Microcontroller-based." In *Research and Development (SCOReD), 2014 IEEE Student Conference on*, pp. 1-6. IEEE, 2014.

[11] Shafiei, N., M. H. Harun, K. A. M. Annuar, M. F. A. Halim, M. S. M. Aras, and A. H. Azahar. "Development of Portable Air Conditioning System Using Peltier and Seebeck Effect." *Journal of Telecommunication, Electronic and Computer Engineering (JTEC)* 8, no. 7 (2016): 97-100.

[12] Babovic, Zoran B., Jelica Protic, and Veljko Milutinovic. "Web performance evaluation for internet of things applications." *IEEE Access* 4 (2016): 6974-6992.

[13] Annuar, Khalil Azha Mohd, and Fatimah Sham Ismail. "Optimal pin fin arrangement of heat sink design and thermal analysis for central processing unit." In *Intelligent and Advanced Systems (ICIAS), 2014 5th International Conference on*, pp. 1-5. IEEE, 2014.

[14] Ismail, Fatimah Sham, Madiha Zahari, Mohamad Haniff Harun, Mohd Annuar, Khalil Azha, Mohd Ab Halim, Mohamad Firdaus, and Siti Halma Johari. "Thermal analysis of staggered pin fin heat sink for central processing unit." *Australian Journal of Basic and Applied Sciences* 9, no. 19 (2015): 68-73.

[15] Rosli, R., KA Mohd Annuar, and F. S. Ismail. "Optimal pin fin heat sink arrangement for solving thermal distribution problem." *J. Adv. Res. Fluid Mech. Therm. Sci* 11 (2015): 1-18.

[16] Annuar, Khalil Azha Mohd, Fatimah Sham Ismail, Mohamad Haniff Harun, and M. F. M. A. Halim. "Inline pin fin heat sink model and thermal performance analysis for central processing unit." *Proceedings of Mechanical Engineering Research Day* 2015 (2015): 35-36.

[17] Buhari, Seyed Mohamed, Nor Jaidi Tuah, Kim Onn Chong, Sei Guan Lim, and Abd Ghani Naim. "Fuzzy based room temperature control by integrating sensors and cameras with a grid." In *Computational Intelligence for Communication Systems and Networks (CIComms), 2013 IEEE Symposium on*, pp. 61-65. IEEE, 2013.

[18] Kopmann, Nina, Rita Streblow, and Dirk Müller. "Test of new control strategies for room temperature control systems fully controllable surroundings for a heating system with radiators." In *Smart Cities and Green ICT Systems (SMARTGREENS), 2015 International Conference on*, pp. 1-6. IEEE, 2015.

[19] Ab Halim, Mohd Firdaus bin Mohd, Mohamad Haniff Harun, Khalil Azha Mohd Annuar, Suziana Ahmad, and Mohd Hanif Bin Che Hasan. "Measurement of low frequency signal of power grid using Arduino." In *Energy Conversion (CENCON), 2015 IEEE Conference on*, pp. 96-101. IEEE, 2015.

[20] Ab Halim, Mohd Firdaus bin Mohd, Mohamad Haniff Harun, Khalil Azha Mohd Annuar, and Suziana Ahmad. "MONITORING GRID FREQUENCY." (2006).

[21] Saadon, Intan Mastura, Herlanda Windiarti, Md Nazri Othman, Emy Zairah Ahmad, and Khalil Azha Mohd Annuar. "River Debris Management System using Off-Grid Photovoltaic Module." In *MATEC Web of Conferences*, vol. 97, p. 01070. EDP Sciences, 2017.