Photovoltaic (PV) Hybrid System using Homer

Fairuz Bin Wahab
Faculty of Electrical Engineering
Universiti Teknologi MARA
40450 Shah Alam,
Selangor

ABSTRACT – Nowadays, renewable energy come as one of energy source that really important for our life. Photovoltaic Hybrid System is one of the renewable energy that's very popular now. This system is really useful in rural area because of geographic condition. This project presents the design of a PV hybrid system using HOMER software. This case study will know whether the system is acceptable to supply the load and also can determine performance of each component that been combined. For this case study the loads are Sekolah Kebangsaan Kaingaran Ranau and the teacher's quarters are been choose.

Keyword: Photovoltaic (PV) Hybrid System, HOMER Software

1.0 INTRODUCTION

In the last few years, the interest in renewable energy for power generation has been increasing because of environmental issues and the depletion of fossil fuels. The huge technological improvements for photovoltaic cells (PV) along with their decreasing cost seem to justify their use as a possible solution [1]. Photovoltaic systems are solar energy supply systems, which either supply power directly to electrical equipment or feed energy into the public electricity grid [2].

Sometimes PV modules are not economical or practical to provide all energy. It is because when loads are relatively constant during summer or if winter peak sun is very low, it may take a large number of modules to meet requirements. In such cases, it may be more economical to provide some of the system energy needs by another means, such as a diesel generator. A system that uses PV for part of its energy production and other means for the balance of the production is called a hybrid system [3]. A conceptual advantage of hybrid systems, compared to systems with a single renewable source, is their high reliability without any need to oversize the system components, to meet for example extended time periods with small renewable energy production [4].

Supplying electricity to remote or rural areas is often more economical with decentralized generation than with grid extensions, especially when there is a relatively low consumption density. Examples are both technical applications like cell phone networks or village power supplies. Particularly if the average solar irradiation vanes strongly throughout the year, hybrid systems e.g. consisting of a PV generator, a diesel generator set as backup and a battery storage are often used to reliably and cost effectively provide electricity in autonomous systems [5].

For this case study, HOMER software has been chosen to design the PV hybrid system that consist of PV array, generator set, battery, and inverter . The HOMER software can evaluate a range of equipment options over varying constraints to optimize small power systems. This type of analysis could aid in the planning of large-scale rural electrification projects [6,10]. This software will analyze the system including cost summary, electrical production, PV, generator, battery and converter. It will know the performance and criteria each part of the result. The load that has been selected is Sek. Keb. Kaingaran which is one of the school in rural area in Sabah.

2.0 SCOPE OF WORK

Several scope of works involved in this project as follows:

- Study the concept of PV hybrid system, basic operation and the characteristic.
- Learn to use HOMER software in order to develop the design of the project.
- Run the simulation and observed the results.
- Detected any problems and overcome it.
- Analyzed the result and make discussion.

3.0 METHODOLOGY

3.1 HOMER software

Homer is one the software that can design and evaluate for off-grid and grid-connected power systems for remote area, stand alone and distributed generation applications. HOMER's have ability to evaluate the economic and technical feasibility in order to account for variation in technology costs and energy resource availability. This software consists of 2 parts that can be considered which is equipment used and resources. The important resources will consist of solar resources, diesel fuel and temperature.

3.2 Equipment considered

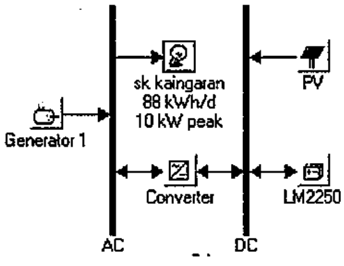
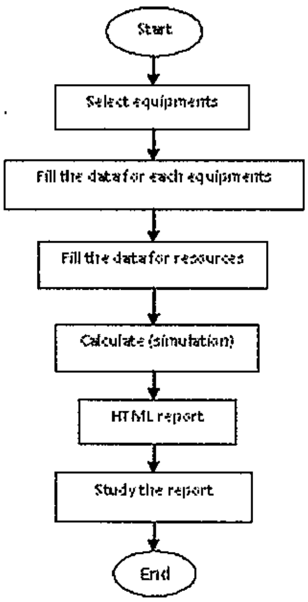


Figure 1

Figure 1 show the equipment that has been used considered in order to simulate using Homer. It includes:

- Photovoltaic arrays
- Converter
- Diesel Generator set
- Battery banks
- Loads

3.3 Flow chart for the simulation



This project will start by collecting all the data needed in order to start a simulation. The data are get from Power Technologist Sdn Bhd. The data include a cost of equipment use, the load assumtion of Sek. Keb. Kaingaran, details of equipment use and also the resources. Then all the data needs is fill in Homer software. Simulation will be start after complete editing the data corresponding in each part of equipment and resources. Lastly, study the HTML report that has been got from the simulation.

3.4 Data

For PV array, the estimation cost for 1kW is RM4303 with sizes 30kW use. That's mean the RM4303 is the cost for 1kW source and 30kW is PV arrays capacity power. The lifetime is 25 years and its derating factor is 80%. Derating factor is like an efficiency or ability of the PV array to absorb sunlight. The slope for the module to stand is 15° and the ground reluctance is 20%. This PV array will consider effect of temperature.

For battery, the estimation cost for one battery is RM2469. This design used 2 strings which is 24 batteries per string. This system uses 2 string connections because to support the loads for 2 days anatomy with voltage 48V output. The minimum lifetime is 5 years. Figure 2 show details of battery that should be consider for this design. Data for lifetime curve and capacity curve are getting from Fiamm Sdn Bhd. For this 30kW design, battery LM2250 was been choose. The nominal capacity for this type of battery is 2250Ah and the nominal voltage is 2V. The round trip efficiency and minimum state of charge are 87% and 15% respectively.

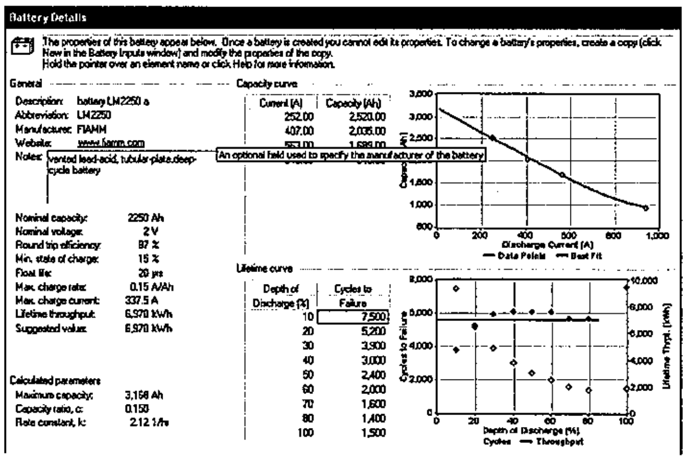


Figure 2

For generator, the estimation cost for 1kW is RM2379. The size of the generator has to be considered is 32kW. That's mean it is a higher level of production that generator need to operate. The operating hours for this generator is 15000 hours and the min load ratio is 30%. It's mean that the generator can run with minimum 30% of the loads size.

For converter, the estimation cost for 1kW is RM2379. The size of converter is 28.8kW which is maximum power that can through the converter. The efficiency of this converter is 94% and the lifetime use is 15 years.

The load profile is based on an actual load for Sek. Keb. Kaingaran and teacher's quarter. Figure 3 illustrates this load profile. A small base load of 1.196kW occurs at 1am until 4am and slowly increases until noon. This is the peak time load which is 10.43kW. Small peaks of average 4kW occur in the evening from teacher's quarter. The average (kWh/d) and average (kW) is 88.2kWh/d and 3.68kW respectively. The total daily load averages 88.2 watt-hours per day.

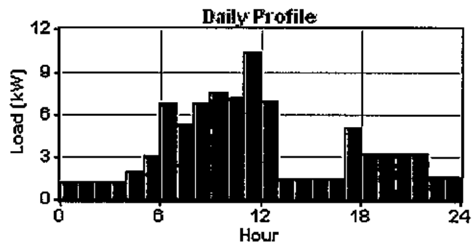


Figure 3

The solar resource profile over a one-year period is shown as in figure 4. For state of Sabah, the location of latitude and longitude are 5° 40' N latitude and 117° 59' E longitude. The time zone for the state is GMT +08:00. Solar radiation data for this region was obtained from the NASA Surface Meteorology and Solar Energy website [7]. The annual average solar radiation for this area is 4.4kWh/m^2/d. In different country like Egypt the solar resource is higher because of different radiation of sunlight.

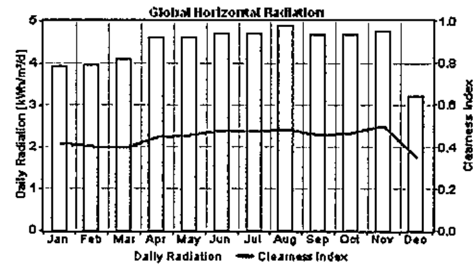


Figure 4

Figure 5 shows the temperature in Sabah which is used for temperature resource. Temperature is one of the important parts that must be considered when designing PV hybrid system using Homer. It will affect the efficiency of solar PV arrays. Different country or places usually will have different temperature. The annual average for the temperature in Sabah is 26.2°C.

Month	Temperature (°C)
January	25.7
February	25.3
March	26.4
April	26.7
May	27.1
June	26.4
July	26.6
August	26.3
September	26.1
October	26.4
November	25.8
December	26.0
Annual average:	26.2

Figure 5

The study included a sensitivity analysis on the price of diesel fuel. This price can vary considerably based on region, transportation costs, and current market price. Price information from both the World Bank and the International Energy Agency (IEA) show that average diesel prices ranged from $0.40/L to $0.70/L in 2000 [8, 9]. The diesel fuel for Malaysia now is RM1.70/L but to consider the cost of delivery the cost of fuel is up to RM5/L.

4.0 RESULT AND DISCUSSION

The result produces is obtained from HTML report that has been simulated. The result obtained can be divided in several parts which is system architecture, cost summary, electrical production, PV array output, generator output, battery output and converter output.

4.1 System Architecture

Table 1: System architecture

PV Array	30kW
Generator	32kW
Battery	48 battery cell
Inverter	28.8kW
Rectifier	28.8kW

From the table 1, it can be concluded that PV array will produce 30kW, generator will produce 32kW, battery will produce 48V, and converters will accept 28.8kW through them. All this value will use for the installation of PV hybrid system.

4.2 Cost Summary

Table 2: Cost summary

Total net present cost	RM 489,500
Levelized cost of energy	RM 1.189/kWh
Operating cost	RM 7,608/yr

Table 3: Net present costs

Component	Capital (RM)	Fuel (RM)	Total (RM)
PV	129,090	0	129,090
Generator	76,128	97,255	173,383
Battery	118,512	0	118,512
Converter	68,515	0	68,515
System	392,245	97,255	489,500

Table 4: Annualized costs

Component	Capital (RM/yr)	Fuel (RM/yr)	Total (RM/yr)
PV	10,098	0	10,098
Generator	5,955	7,608	13,563
Battery	9,271	0	9,271
Converter	5,360	0	5,360
System	30,684	7,608	38,292

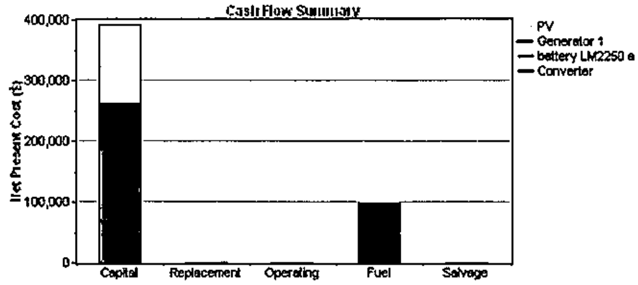


Figure 6: Cash flow summary

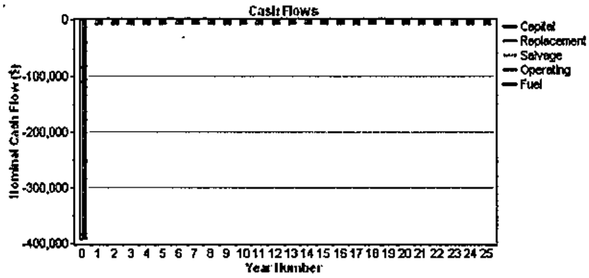


Figure 7: Cash flows

Table 2 shows the system cost summary. The cost summary is cost that been obtained by simulation to know how much cost used for PV hybrid project. The total net present cost is RM489, 500, and the operating cost is RM7, 608/year. The operating cost is the cost summary for fuel that will use to run generator.

Table 3 and table 4 show the system net present cost and the annualized cost. The net total capital of this system includes the cost of the fuel that is used to run the generator. The annual cost is cost per year which is from cost net present cost. The net fuel cost is RM97, 255 and that means the cost per year is RM7, 608 which is the operating cost. The net cost for each component are PV arrays- RM129,090, generator- RM76, 128, battery- RM118, 512, converter-RM68, 515. All of these components are important in order to calculate for net cost. It's because all of the component are needed for the installation of the system.

Figure 6, shows the cash flow summary for the equipment use for the installation. From the figure, it shows that PV array, battery and fuel is one of the larger cost produce than the other. Figure 7 show the cash flow which is included all total capital that should be considered in order to build the system.

4.3 Electrical

Table 5: Electrical production

Component	Production (kWh/yr)	Fraction
PV array	34,896	90%
Generator	4,090	10%

Table 6: Load consumption

Load	Consumption (kWh/yr)	Fraction
AC primary load	32,194	100%
Total	32,194	100%

Table 7: Electrical output result

Quantity	Value	Units
Excess electricity	2,274	kWh/yr
Unmet Load	0.000185	kWh/yr
Capacity shortage	0.00	kWh/yr
Renewable fraction	0.895	-

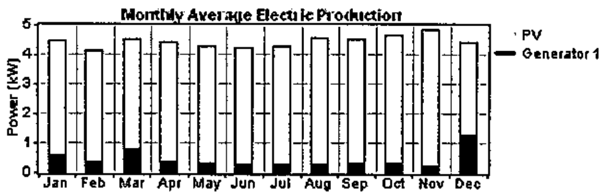


Figure 8: Monthly average electric production

The tables above show the result of electrical production. The results that produced on electrical production consist of PV array and the generator output where is very important for the system. From the result, PV arrays produce 34, 896kWh/yr which is 90% from the system mean while generator produces 4, 090kWh/yr which is 10% from the system. The AC primary load for this system is 32, 194kWh/yr.

Refer to the system design assumption; PV arrays will produce 90% and generator 10% produce power for the system. That mean this system is acceptable because it has the same value of percentage and also the load produce is less than source of PV array. Figure 8 shows the monthly average electric production. It shows that the PV arrays run more than the generator and every month at least 4kW of electrical production produced. In December the figure shows that the generator runs more than previous month because of weather.

4.4 PV Array

Table 8: PV output result 1

Quantity	Value	Unit
Rated capacity	30.0	kW
Mean output	95.6	kWh/d
Capacity factor	13.3	%
Total production	34,896	kWh/yr

Table 9: PV output result 2

Quantity	Value	Unit
Minimum output	0.00	kW
Maximum output	21.8	kW
PV penetration	108	%
Hours of operation	4,323	hr/yr
Levelized cost	0.289	RM/kWh

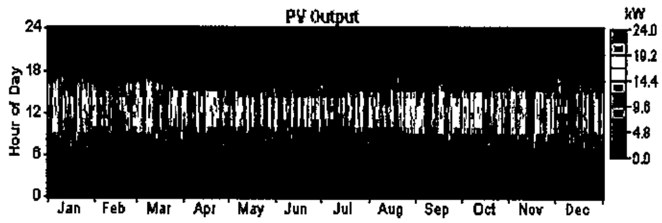


Figure 9: PV output

From table 8 and table 9, the rated capacity of the PV produce is 30kW. The maximum and mean output produce are 21.8kW and 3.98kW for the whole year. The capacity factor for the PV array running is 13.3% and it hours of operation is 4, 323 hr/yr. Capacity factor is ability the PV to produce a power. The maximum output for the PV array is 21.8kW. So that means the value is the higher power produce for the whole year. Figure 9 show the PV output for a year. It shows the PV running from 7am until 7pm with their power produces. For the black scale, the PV does not operate. So, battery and generator will support the system when PV can't operate well. PV will increase the number of power until noon. It is because the radiation is better from 11am to 2 pm.

4.5 Generator

Table 10: Generator output result 1

Quantity	Value	Unit
Hours of operation	195	hr/yr
Number of starts	18	starts/yr
Operational life	76.9	Yr
Capacity factor	1.46	%
Fixed generation cost	12.8	RM/hr
Marginal generation cost	1.25	RM/kWhyr

Table 11: Generator output result 2

Quantity	Value	Unit
Electrical production	4,090	kWh/yr
Mean electrical	21.0	kW
Minimum electrical	9.60	kW
Maximum electrical	32.0	kW

Table 12: Generator output result 3

Quantity	Value	Unit
Fuel consumption	1,522	L/yr
Specific fuel consumption	0.372	L/kWh
Fuel energy	14,972	kWh/yr
Mean electrical efficiency	27.3	%

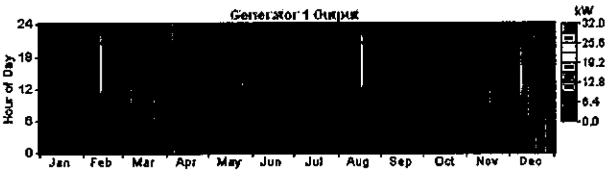


Figure 10: Generator output

From table 10 above, the hours of operation for generator are 195hr/yr. This operational life will be 76.9 year. So that mean the generator run less than 500hr/yr and it will extend almost 80 years lifetime. The electrical production is 4, 090 kWh/yr. Figure 5.5 show the generator output. The colors in the figure 10 show that time were generator will run. Besides that, it shows that the generator will start 18 times in a year. From table 11shows the maximum, mean and minimum electrical outputs are 32.0kW, 21.0kW and 9.6kW respectively. From table 12 shows the fuel consumption to run the generator is about 1, 522 L/yr which is 0.372 L/kWh. That means the generator needs 1522 liters of fuel in a year to operate. The fuel energy input is 14, 972kWh/yr with mean electrical efficiency 27.3%. The electrical efficiency is percentage ability for the generator run less or more.

4.6 Battery

Table 13: Battery configuration

Quantity	Value
String size	24
String in parallel	2
Bus voltage (V)	48

Table 14: Battery output result 1

Quantity	Value	Unit
Nominal capacity	216	kWh
Usable nominal	184	kWh
Autonomy	50.0	Hr
Lifetime throughput	334,556	kWh
Battery wear cost	0.000	RM/kWh
Average energy cost	0.174	RM/kWh

Table 15: Battery output result 2

Quantity	Value	Unit
Energy in	18,534	kWh/yr
Energy out	16,204	kWh/yr
Storage depletion	60.5	kWh/yr
Losses	2,269	kWh/yr
Annual throughput	17,333	kWh/yr
Expected life	19.3	yr

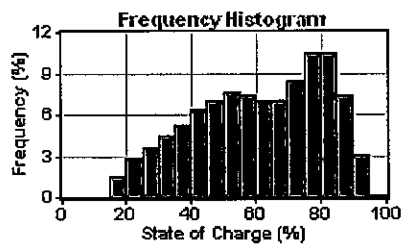


Figure 11: Frequency histogram

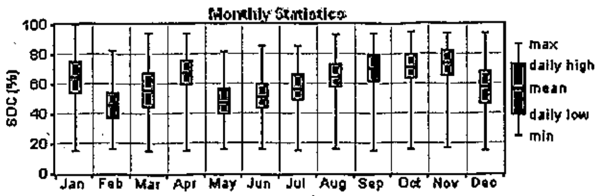


Figure 12: Monthly statistics

Figure 13: Battery bank state of charge

Table 13 shows that, battery will connect in 2 string which is 2V per battery and total value is 48V. Table 14 and table 15 are result for battery. It shows that the expected life for this battery is 19.3 years. The energy that will come in is about 18, 534 kWh/yr and energy out is 16, 204kWh/yr. For the nominal capacity that battery can store 216kWh and it useable nominal capacity is 184kWh. The useable capacity is not nominal capacity is because the battery have 15% of capacity left for recharge. That mean to charge a battery it must have some energy left in the battery.

Figure 12 show the monthly statistic for state of charge (SOC) of the battery in percentage. SOC is rate for charging battery from depth of discharge (DOD) until it fully charge. DOD is rate for the battery to supply or support the loads. Figure 13 show the hourly operated of battery in a year. The red color in figure 13 mean that the battery supplies the load 100% of the nominal capacity. When the batteries supply 100%, it means that the PV array not operated in that time and the load consumption is higher than the other month.

4.7 Converter

Table 16: Result inverter output

Quantity	Inverter	Units
Capacity	28.8	kW
Mean output	3.6	kW
Minimum output	0.0	kW
Maximum output	10.4	kW
Capacity factor	12.4	%
Hours of operation	8,566	hrs/yr
Energy out	31,344	kWh/yr
Energy in	33,346	kWh/yr
Losses	2,002	kWh/yr

Table 17: Result Rectifier output

Quantity	Rectifier	Units
Capacity	28.8	kW
Mean output	0.3	kW
Minimum output	0.0	kW
Maximum output	28.8	kW
Capacity factor	1.2	%
Hours of operation	188	hrs/yr
Energy out	2,922	kWh/yr
Energy in	3,108	kWh/yr
Losses	186	kWh/yr

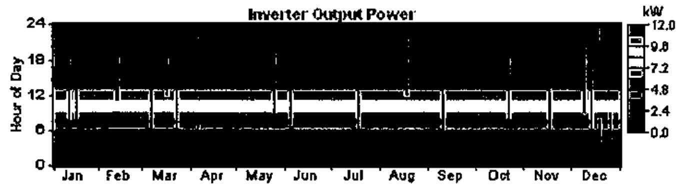


Figure 14: Inverter output power

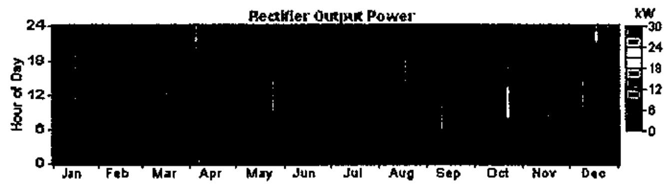


Figure 15: Rectifier output power

From table 16 and 17, the capacity for inverter and rectifier is 28.8kW. The mean output for those converters are 3.6kW for inverter and 0.3kW for rectifier. The maximum output for inverter is 10.4kW and for rectifier is 28.8kW were shown in figure 13 and figure 14. Hours of operation is for inverter is 8, 566hrs/yr and for rectifier is 188 hrs/yr. Energy in for inverter is 33, 346kWh/yr and it energy out is 31, 344kWh/yr. So the losses for this converter is 2, 002.

Energy in for the rectifier is 3, 108kWh/yr and it energy out is 2, 922kWh/yr. So the loss for this rectifier is 186kWh/yr. The energy that workout through inverter is larger than the rectifier. It is because the inverter is operated to change the DC voltage from PV array whereby it happen usually, but different with the rectifier. It has also been shown at the both figure 13 and 14 whereby the inverter is slightly fully operated in a year than the rectifier. The rectifier operates when the generator is fully loading the system and sends the AC voltage to rectifier to change it to DC to store into battery. The generator will run when PV and battery can't support the loading. Refer to figure 13, the red color means that PV and batteries can't operate. The decreasing colors mean that the batteries.

4.0 CONCLUSION

After doing this design on hybrid PV system using Homer, the conclusions from the research can be drawn as the followings:

- Simulated Homer result shown that the system design is acceptable to power up for whole Sek. Keb. Kaingaran.
- The consumption of PV array produce more power based on hour operation compared battery and generator.
- Result from the running software shown as a system design. Whereby PV array 90% and generator 10%.
- Instead of technical information and justification, Homer can be used for commercial especially in budgetary cost.

5.0 FUTURE DEVELOPMENT

Future development for this system is by upgrade the performance of PV array, the battery and the generator. The upgrade for PV array will be on improvement for the solar will absorb sun radiation and the state of charge SOC of the battery can be improved so that the system will be more reliable and more efficient to support a maximum load. For the generator, the fuel will change to fuel cell by using hydrogen. Hydrogen can be produced by electrolysis of water from renewable energy and stored in special tanks. By using this way, it produces electricity from the hydrogen without any greenhouse emission. Then the design of HOMER will be add one more source which is hydrogen cell.

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Appendix

SK Kaingaran Load Study
XBA 2107

Time	Power Allowance for all Classrooms	Power Allowance for all Teachers' Quarters	Power allowance for compound lighting	Power allowance for library	Power allowance for Pra School	Power allowance for Operation Room	Power allowance for Office/ Teachers Room	Power allowance for Science Lab	Power allowance for Room A1/A2/A3/A4	Combined Hourly Load
0.100am		0.98	0.216							1.196
0.200am		0.98	0.216							1.196
0.300am		0.98	0.216							1.196
0.400am		0.98	0.216							1.196
0.500am		1.736	0.216							1.952
0.600am		3.136								3.136
0.700am	2.752	0.892		0.216		0.716	0.988	0.344	0.944	6.852
0.800am	1.85	0.28		0.216	0.816	0.5	0.7	0.2	0.8	5.362
0.900am	1.85	0.98		0	0.816	0.7	1.1	0.2	1.2	6.846
10.00am	2.9	0.98		0.4	0.816	0.5	0.7	0.4	0.8	7.496
11.00am	2.6	0.98		0.45		0.7	1.1	0.2	1.2	7.23
12.00pm	1.6	5.18		0.45		0.7	1.1	0.2	1.2	10.43
13.00pm	1.6	1.54		0.55		0.7	1.1	0.2	1.2	6.89
14.00pm		1.54								1.54
15.00pm		1.54								1.54
16.00pm		1.54								1.54
17.00pm		1.54								1.54
18.00pm		5.084								5.084
19.00pm		2.984	0.216							3.2
20.00pm		2.984	0.216							3.2
21.00pm		2.984	0.216							3.2
22.00pm		2.984	0.216							3.2
23.00pm		1.38	0.216							1.596
24.00pm		1.38	0.216							1.596
	15.152	**45.564**	**2.376**	**2.282**	**2.448**	**4.516**	**6.788**	**1.744**	**7.344**	
total										**88.214**