SOLAR PHOTOVOLTAIC POWER PLANT OPTIMIZATION UNDER NET ENERGY METERING (NEM) SCHEME

LEE CHEE LEONG

MASTER OF ELECTRICAL ENGINEERING

A project report submitted in partial fulfilment of the requirements for the award of Master of Engineering (Electrical)

Lee Kong Chian Faculty of Engineering And Sciences

Universiti Tunku Abdul Rahman

December 2016

DECLARATION

I hereby declare that the project report is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTAR or other institutions.

Signature: __________________

Name: __________________

ID: __________________

Date: __________________

APPROVAL FOR SUBMISSION

I certify that this project report entitled "**SOLAR PHOTOVOLTAIC POWER PLANT OPTIMIZATION UNDER NET ENERGY METERING (NEM) SCHEME**" was prepared by LEE CHEE LEONG has met the requirement standard for submission in partial fulfillment of the requirements for the degree of Master of Electrical Engineering in LKC Faculty Engineering and Sciences at Universiti Tunku Abdul Rahman.

Approved by:

Signature : __________________

Supervisor: __________________

Date: __________________

ACKNOWLEDGEMENT

I would like to express my thanks to my mentor, Dr. Lim Boon Han for assisting me all the way from the very beginning. This NEM simulation idea actually came from Dr. Lim Boon Han. At the very beginning, VBA was not applied until Dr. Lim shows me how powerful of this VBA tools is. Also, I would like to thank Dr. Chua Kein Huat (lecturer and also BESS researcher in UTAR), he gave me a lot of guidelines regarding the electricity bill calculation of TNB. Dr. Chua is an expert in BESS too. I would like to thank Mr. David (head of estate department of UTAR) and Mr. Sie Kun (Electrical engineering year 4 student) on assisting me to get the load profile of the KB building of UTAR from the control room. It is tough to gather all the info but with the assistance from all the above personnel, the simulation program had enough data to generate a reliable result at the end. The simulation program will be kept by Dr. Lim Boon Han for further improvement and research purpose after this submission. Last but not least, I gain a lot of extra knowledge on how to work out the project in a more coordinated way. Last, I would like to thank my classmate, Mr. Kuan and Mr. Ho in thesis discussion.

ABSTRACT

SOLAR PHOTOVOLTAIC POWER PLANT OPTIMIZATION UNDER NET ENERGY METERING (NEM) SCHEME

LEE CHEE LEONG

Net Energy Metering include energy generation, and energy storage. Renewable energy is mostly inconsistent. Renewable energy management optimization is important. This research created a program simulation on how the variable combination such as the size of BESS (Battery energy storage system), the size of solar panel, the percentage of peak shaving, DOD and so on to achieve the highest saving, highest ROI and highest IRR. This report discusses peak shaving with using the simulation program. Microsoft Excel VBA was used during this research. The load profile of the energy of University Tunku Abdul Rahman's KB

building was used as a case study in this research. There are 16 charts showing different condition with different variable's value and researcher found that highest ROI doesn't give the highest saving. A lot of variables required in order to calculate the efficiency of NEM. This research simulation program is able to give the user a very clear picture of the design of the NEM. It shows the size of the solar pv system, the capacity of BESS (Battery Energy Storage System), saving per month, ROI, IRR, investor capital, loan and a lot of financial parameters a banker may need to judge if the investment worth. As result from the simulation, 60% depth of DOD (depth of discharge) of BESS will achieve the highest saving gain.

CONTENTS

1.

LIST OF TABLES

LIST OF FIGURE

Figures **Pages**

ABBREVIATION

E	Energy
P	Power
L	lifespan of cycle
K	Constant
Q	Constant
DOD	Deep of discharge in percentage
PV	Present Value
FV	Future value
Yr index	Year index.

Definitions

1. “Solar capacity” means the capacity of the solar panel in terms of power rating with the unit of kW. Eg. 20 kW.
2. “BESS” stand for battery energy storage system.
3. “BESS capacity” means the capacity of the BESS in terms of energy with the unit of kWh. E.g. 100 kWh.
4. “DOD” means the depth of discharge of the BESS system in terms of percentage. 10% means the BESS discharge 10% energy from the total energy it contains.
5. “Upper p” means the energy level where will be shaved from the maximum energy consumption per 5 minutes interval.
6. “Lower p” means the energy level where the system will still draw the power from the utilities company although the load level is low. This is to charge up the BESS.
7. “TNB Tariff” means the different tariff defined by TNB. Eg. A is for residential while B is for commercial.
8. “TNB buying rate” means the rate offer by TNB to buy the surplus energy from the consumer.
9. "Monthly saving" means the costs saving measured in monetary term denominated in RM
10. “Break Even point” means the number of months the investment needed in order to achieve break even.
11. “Grand total 20 years” means the total gain after 20 years of the investment. This amount of gain was calculated based on present value.
12. “Earn/ Capital Ratio” means the total gain (income – expenses – capital) divided by the capital. All monetary value calculated to present value.

13. “Solar Performance index” is a constant directly reflect the efficiency of the solar panel. Different latitude and longitude on earth will need different solar performance index.
14. “Peak point of kWh per 5 mins” means largest energy consumption in that particular five minutes.
15. “Peak/Off Peak” is the criteria that applied to certain electricity tariff of TNB. Some tariff doesn’t apply peak/off peak. “PEAK PERIOD” means the period between 0800 hours and 2200 hours (TNB_Berhad, 2006). “OFF-PEAK PERIOD” means the period between 2200 hours and 0800 hours.
16. “Kilowatts of maximum demand” for any month shall be deemed to be twice the largest number of kilowatt-hours supplied during any consecutive thirty minutes in that month. (TNB_Berhad, 2006)

CHAPTER

1. INTRODUCTION

A traditional grid is where the utilities company build a power network and transfer the energy from the power plant to consumer. This old business model are centric to utilities rather than consumers (Sajjad, et al., 10-13 June 2015). However, when renewable energy becomes relatively important to the earth especially to counter the climate change nowadays, engineers are required to create a method to apply the renewable energy within the current grid, this is part of the idea of smart grid. The advent of new technology and steep fall in the cost of photovoltaic (PV) systems has rendered feed-in-tariff (FIT) scheme obsolete (Dutta, et al., 2016). Net energy metering (NEM) is gradually superseding the former as it promotes the growth of mini solar generations at every house (Dutta, et al., 2016). Net metering is a policy proposed to promote the generation of power from small renewable systems. Under net metering, a system owner receives retail credit for all the electricity they generate when they produce more electricity than they consume during any given billing period (Hossain & Iqbal, 2014).

1.1 Objective

The objective of this project is to study solar power plant optimization methods under the new net energy metering scheme that is proposed by Sustainable Energy Development Authority (SEDA) of Malaysia. This scheme encourages self-consumption of energy for the owner (either residential, commercial or community). The surplus energy can be sold to TNB at a rate.

This project will consider the optimum plant configuration and design to maximize the advantage under this scheme. Various scenarios will be considered in this case study. Storage may be incorporated depends on conditions as well as price. Levelized cost of electricity (LCOE) and owner's profit are two performance indicator. This study will be carried out mainly using Microsoft Excel, or programming languages, such as VBA. Some basic experiments or measurement will be carried out in order to gather useful information for the optimization process. In this project, UTAR Sungai long campus Block KB will be used as a case study.

1.2 Problem Statement

NEM scheme is what SEDA will commence to after the last FIT in the past few years. However, how to manage the usage so that the end user can gain the maximum advantage is always a question at this moment. Factory user use a lot of energy during the weekday, probably more than what they can generate. However there will have extra energy generated during the weekend when the factory is not in operation. So there is two way for the unconsumed energy, store it in battery or sell it to the utility by input the power to the grid. Of course, store it in the battery will be a good way to help to reduce the maximum demand but the battery cost a price. Also, sell it back to the utility will save the battery price but the factory will need to pay for the maximum demand when they need.

Energy storage in battery required professional and precise calculations. Battery efficiency varies with different DOD, operating temperature, charge in rate, discharge rate and so on.

CHAPTER

2. LITERATURE REVIEW

Net metering is a key enabling factor for smart (mini) grids. Energy demand for the individual apartments and common areas is calculated using the daily energy consumption behavior of occupants for typical days of each month of the year. (Sajjad, et al., 10-13 June 2015)

In the user-centric model, the consumers will be transformed into a prosumer with generation and control capabilities, able to change the flow of both energy and money. This transformation requires attraction of distributed private investment. It is also crucial to overcome some fears of the distributors and to create better equilibrium between the distributors and the users. (Sajjad, et al., 10-13 June 2015).

2.1 BESS

BESS is an abbreviation of battery energy storage system. The battery energy storage system (BESS) can be used to reduce this peak demand and thus reduce the plant's electricity bill by discharging a stored energy during load peaks (Oudalov, et al., 2007) (see Figure 5)

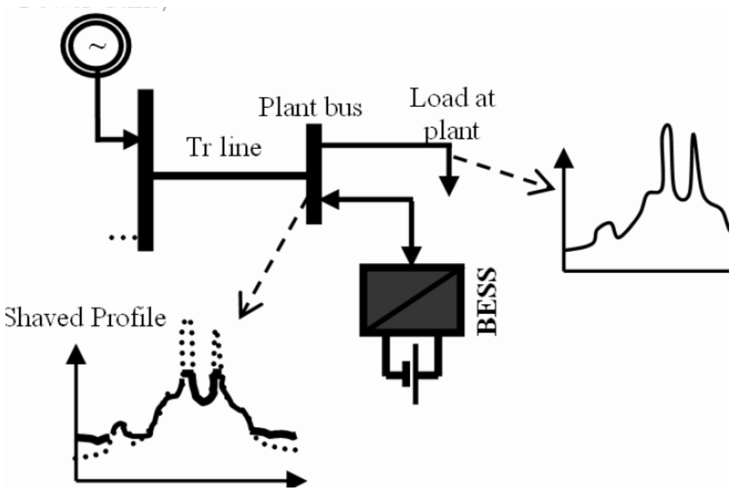

Figure 1 Load peak shaving by battery energy storage system
(Oudalov, et al., 2007)

2.2 Battery type

Deep-cycle, lead-acid batteries have been employed in renewable energy and reliably used in off-grid applications globally for decades. In the consideration of cost, typical deep cycle lead acid batteries cost about half as much as lithium-ion (Zipp, 21 August 2015). Ignoring other ageing effects, the total energy throughput is fixed so that one cycle of 100% DOD is roughly equivalent to 2 cycles at 50% DOD and 10 cycles at 10% DOD and 100 cycles at 1% DOD (see Figure 2 Deep cycle lead acid lifecycle versus Depth of Discharge) (Woodbank Communications Ltd, 2005).

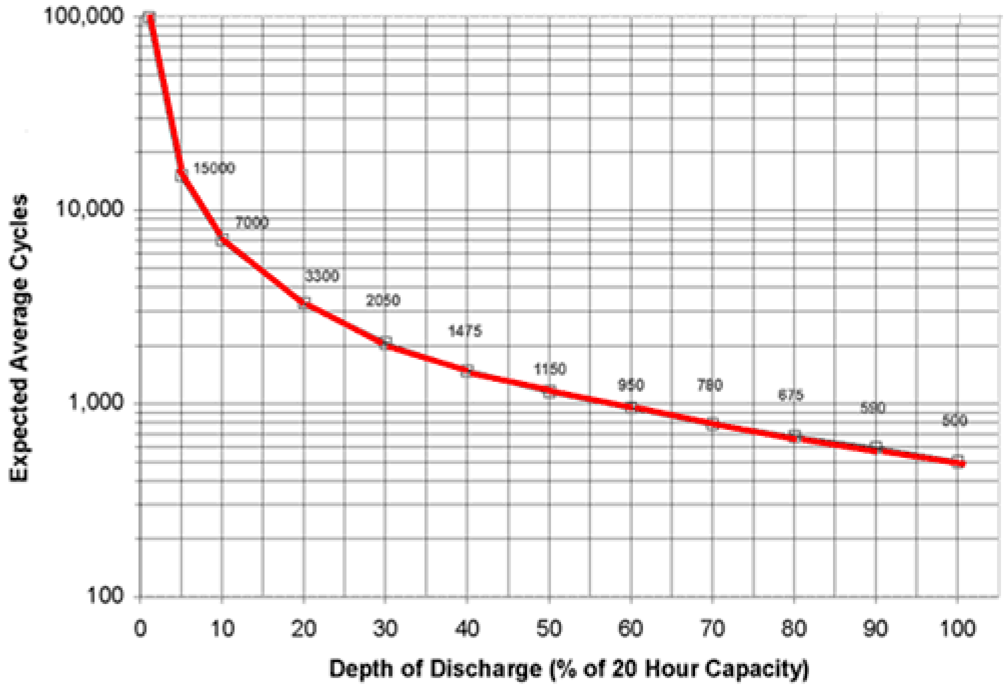

Figure 2 Deep cycle lead acid lifecycle versus Depth of Discharge (Woodbank Communications Ltd, 2005)

2.3 Peak shaving

Peak shaving means shave the load profile from mountain shape to flat during. Peak power usage will create maximum demand and usually utilities company charge consumer a maximum demand charge other than the kWh energy charge. Utilities Company defines a peak and off peak hour according to the usage of the consumer. Usually, peak/off peak (refer to definition part) rate applied to the large customer in industrial and commercial. The method of calculation of electricity by utilities might vary by different territory. However, the way of electricity fees calculations are about the same all around the world. In this report, the electricity tariff by utilities company Tenaga Nasional

Berhad of Malaysia will be taken as a case study. The electricity bill consists of kWh and also maximum demand (refer to definition). Usually, the latest corresponds to the highest power demand during a specific time range and often reaches a level of 50% of the plant’s electricity bill (Oudalov, et al., 2007).

CHAPTER

3. MATERIAL AND METHODOLOGY

This project mainly on creates a comprehensive simulation program to determine the changes of the electricity and also the impact to the user after the applied of NEM. Table 1 are the key parameters which has been considering in the simulation program.

Table 1 Important Factor

Factor	Units
Solar size	kW
BESS Capacity	kWh
DOD Depth of discharge	%
Battery storage by cost	kWh / RM
Monthly saving	RM
Building load maximum demand	kW
Break Even Month	Month
Grand total after 20 years	RM
Maximum demand charges	RM / kW
Energy charges per unit	RM / kWh
Lifespan of battery	yr
Earn / Capital ratio	-
BESS Inverter	RM
BESS air conditioner	RM
BESS Renovation cost	RM

3.1 Schedule of Research Progress

The total duration of the research of this project was seven weeks including the submission of the report. Five weeks was spent to generate the simulation program and debug. The arrangement was made to meet up with Dr. Lim Boon Han every Wednesday in order to discuss the progress of the research. Application of VBA was suggested by Dr. Lim in order to get comprehensive data. There is approximately 240, 000 calculations made for every Run by clicking on the generate button (See Table 4).

Table 2 shows the work progress of this research.

Table 2 Work schedule of research.

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
Task	Excel formula						
	Tariff analyze						
		VBA					
			Debug				
				Report writing			
						Report submission	

3.2 Excel Programing with VBA

The energy load profile of building KB of University Tunku Abdul Rahman was used as research material. Load profile was split to 5 minutes per interval as shown in chart (see Table 3)

Table 3 Energy load calculated every 5 minutes

Time	Solar	Power of load	Load
12:00 AM	0.00 kwh	120.0 kw	10.00 kwh
12:05 AM	0.00 kwh	120.0 kw	10.00 kwh
12:10 AM	0.00 kwh	120.0 kw	10.00 kwh
12:15 AM	0.00 kwh	120.0 kw	10.00 kwh
12:20 AM	0.00 kwh	120.0 kw	10.00 kwh
12:25 AM	0.00 kwh	120.0 kw	10.00 kwh
12:30 AM	0.00 kwh	120.0 kw	10.00 kwh
12:35 AM	0.00 kwh	120.0 kw	10.00 kwh

A five minutes energy consumption was determined with the following equation.

$$E = \frac{P}{60} \times 5$$

The unit of energy is kWh. The unit of power is kWh. The power 120.0 kW shown in Figure 2 above in line with 12:00 AM indicated that the average power it consumed from 12:00 AM till 12:05 AM.

There was quite a number of formulas created to calculate the energy when it integrates with solar and BESS. Five sheet were created which is Main, Cost_Gain, Financial, Electricity and Energy.

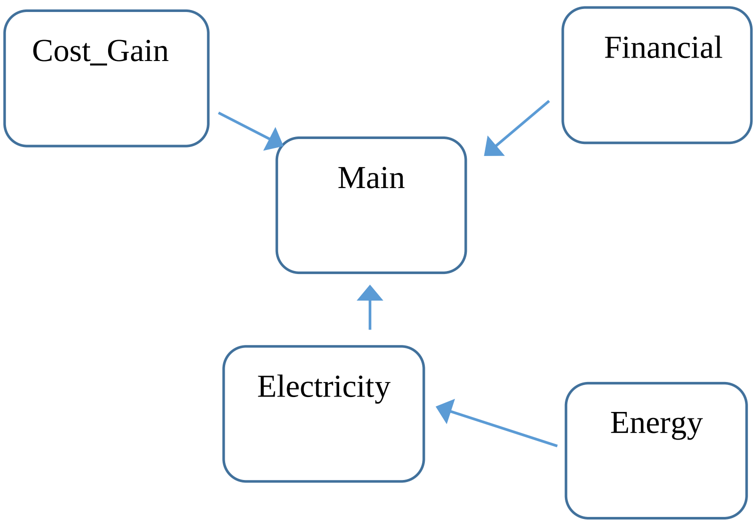

Figure 3 Block diagram, relations between the five excel sheet calculation

3.3 Main Sheet

Also called program interface. Main sheet contains the most basic thing as researcher need to put in for the simulation. E.g. solar capacity, BESS size, DOD, upper p, and so on. Table 4 is the Main sheet. Program user just needs to enter the solar size, DOD, and upper p, and then click on the “Generate” button. The program will then generate the results. Of course, related parameters have to be filled in the other sheet before this step. The cell filled with green color are those cell needed to be filled by researcher. The rest of the value will be determined by formula and VBA by the program such as lower p and BESS capacity and so on. BESS will be determined from Electricity sheet base on calculation.

Table 4 Main Sheet-Program interface

	A	B
Please fill in the blank with desired value		
Solar Capacity	310 kw	500 kw
BESS Capacity	1,016 kwh	1500 kwh
DOD	50%	50%
Upper p	73.00%	
Lower p	7.03%	
TNB Tariff	C1	C1
Please fill in the Data for analysis		
Working days	21.8 days	21.8 days
Weekend	8.7 days	8.7 days
Average day of month	30.5 days	30.5 days
TNB Buy Rate RM / Kwh	31.00	0.32
Monthly Saving	2,226.67	
Break Even Point	240	
Grand total 20 years	(9,578)	
Earn / Capital Ratio	-3.121	
	Generate	

3.4 Cost_Gain Sheet

This sheet contains the cost and the saving gain with the investment of NEM system. It includes solar costing, BESS, expenses and so on. Expenses including manpower for maintenance purpose, air-conditioning for BESS, labour for regular checking work. Table 5 shows the Cost Gain Sheet.

Table 5 Cost _ Gain Sheet

	A	B	C	D	E	F
1	**Descriptions**				A	B
2	**First Capital of Project**					
3	Solar panel Capacity			kw	310	500
4	BESS Capacity			kwh	1016	1500
5						
6		**Factor**			**Cost Build**	**Cost Build**
7	Solar panel	6,768	RM/kw	RM	2,097,942	3,383,778
8	BESS (Battery)	350.00	RM/kwh	RM	355,605	525,000
9	BESS (Inverter)	30.00	RM/kwh	RM	30,480	45,000
10	BESS (Aircond)	10.00	RM/kwh	RM	10,160	15,000
11	BESS (Others)	20.00	RM/kwh	RM	20,320	30,000
12	BESS renovation cost	50.00	RM/kwh	RM	50,801	75,000
13		460.00	Total Cost	RM	2,565,309	4,073,778
14						
15	**Maintenance Cost**					
16	**BESS cost by 20 year**	**Lifespan**			**Total**	**Total**
17	panel life time (Excluded)	20.0	year	RM	-	-
18	BESS Battery	1.4	year	RM	261,042	7,707,821
19	BESS Inverter	5.0	year	RM	6,096	9,000
20	BESS Aircond	8.0	year	RM	1,270	1,875
21	BESS Others	5.0	year	RM	4,064	6,000
22			Total yearly cost	RM	272,472	7,724,696
23			**Monthly Cost**	RM	**22,706**	**643,725**
24						
25	**BESS cost by month**	**Factor**			**Fees**	**Fees**
26	Engineer	2	RM/kwh	RM	2,032	3,000
27	Technician	2	RM/kwh	RM	2,032	3,000
28	Aircond Electricity	1	RM/kwh	RM	1,016	1,500
29	BESS Room Rental	10	RM/m^3	RM	1,016	1,500
30			Total monthly cost	RM	6,096	6,000
31						
32	**Space**	**Factor**			**Area**	**Area**
33	Solar panel Area	1	M^2/kw	m^2	310.00	500.00
34	BESS area	10	M^3/kwh	m^3	101.60	150.00
35	**Electricity Saved Per Month**					
36		Total Cost per month			28,802.09	649,724.68
37		Saving from electricity per month			31,028.76	30,995.50
38			Total Amount		2,226.67	(618,729.18)

Cost build equation

$$Solar\ cost\ (E7) = solar\ size(E3) \times solar\ factor(B7)$$

$$Battery\ cost\ (E8) = Battery\ size(E4) \times Battery\ factor(B8)$$

Battery is the core item in BESS. Battery lifespan always a major element to determine the profit and loss. Battery lifespan varies by the operating temperature, charging current, discharging current, depth of discharge as well. Figure 13 shows a standard lifespan of a lead acid battery at a given temperature and discharge rate (Woodbank Communications Ltd, 2005).

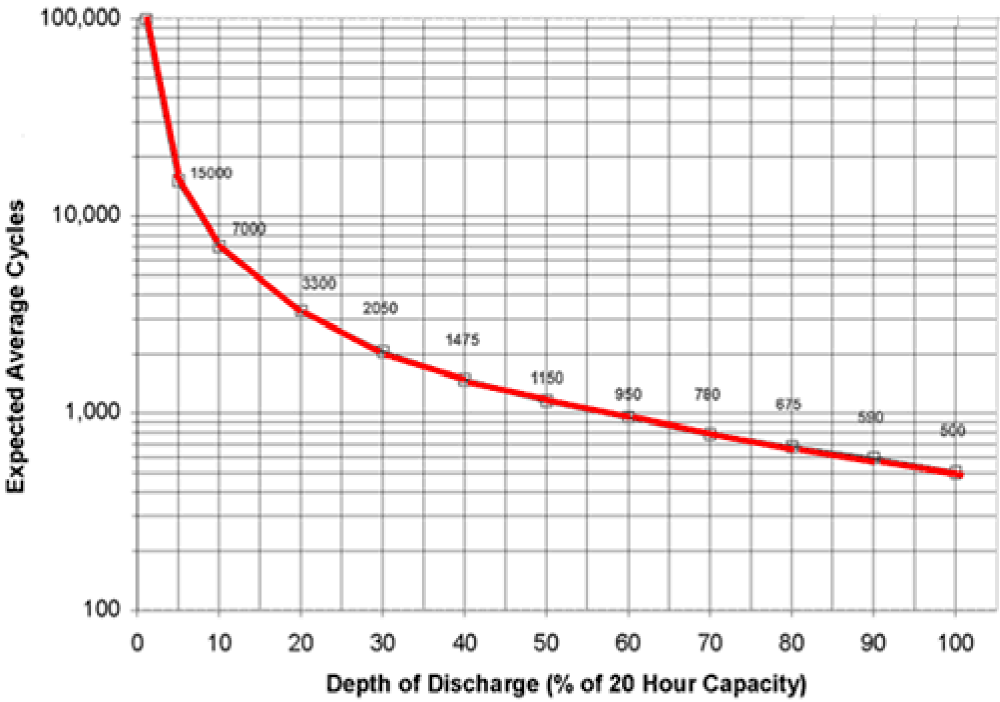

Figure 4 Battery lifespan (Woodbank Communications Ltd, 2005)

The below calculation was made to build a formula for the simulation calculation.

DOD 20% refer to 3300 cycle

DOD 80 % refer to 675 cycle

L = lifespan of cycle

K = Constant

Q = Constant

DOD = deep of discharge in percentage

$$L = K - Q\sqrt{DOD}$$

The above formula will be applied for the DOD from 10% to 40% in order to get the lifespan of the battery. Below is the solution.

$3300 = K - Q\sqrt{20}$ ------1

$675 = K - Q\sqrt{80}$ ------2

$$Q \approx 587$$

$$K \approx 5925$$

Equation for Battery lifespan $L = 5925 - 587\sqrt{DOD}$

Table 6 Lifespan of a battery with different DOD

DOD %	L	
20	3300	cycle
25	2990	cycle
30	2710	cycle
35	2452	cycle
40	2212	cycle
45	1987	cycle
50	1774	cycle
55	1572	cycle
60	1378	cycle
65	1192	cycle
70	1014	cycle
75	841	cycle
80	675	cycle

3.5 Financial Sheet

Here conclude the financial proposed method. Period of installment, down payment, the loan from bank and etc. Table 7 shows the outlook of the sheet.

Table 7 Financial Sheet Budget

	A	B	C	D
1			**A**	**B**
2	**Expenses**			
3	First Capital	RM	2,565,309	4,073,778
4	Maintenance Fees	/yr	272,472	7,724,696
5				
6	Down payment percentage		10%	10%
7	Down payment	RM	256,531	407,378
8	Bank loan	RM	2,308,778	3,666,400
9	Loan interest rate		5%	5%
10	length of loan	yr	7	3
11	Installment /month	RM	37,105	117,121
12	Total Income after 20years	RM	402,963	
13	Total Capital	RM	(3,068,594)	
14	Total expenses after 20yrs	RM	(6,912,502)	
15	Grand total	RM (000)	(9,578.13)	
16	Earn / Capital Ratio	RM	-3.121	
17	Break even point		240	320126

Also, the present value of the income and expenses for any given month was calculated in financial sheet. As showed in Table 7 and Table 8.

Table 8 PV calculation in financial sheet

Inflations rate			3%					
Abosulte	Month	yr index	Income FV	Income PV	Capital FV	Capital PV	Expenses PV	Accumulated
	0	0.00	-	-	RM 256,530.89	RM 256,530.89		(256,530.89)
320126	1	0.08	RM 2,226.67	RM 2,221.19	RM 37,105.36	RM 37,014.07	RM 28,802.09	(320,125.87)
383635	2	0.17	RM 2,226.67	RM 2,215.73	RM 37,105.36	RM 36,923.01	RM 28,802.09	(383,635.25)
447059	3	0.25	RM 2,226.67	RM 2,210.27	RM 37,105.36	RM 36,832.17	RM 28,802.09	(447,059.24)
510398	4	0.33	RM 2,226.67	RM 2,204.84	RM 37,105.36	RM 36,741.56	RM 28,802.09	(510,398.06)
573652	5	0.42	RM 2,226.67	RM 2,199.41	RM 37,105.36	RM 36,651.17	RM 28,802.09	(573,651.90)
636821	6	0.50	RM 2,226.67	RM 2,194.00	RM 37,105.36	RM 36,561.00	RM 28,802.09	(636,820.99)
699906	7	0.58	RM 2,226.67	RM 2,188.60	RM 37,105.36	RM 36,471.05	RM 28,802.09	(699,905.53)
762906	8	0.67	RM 2,226.67	RM 2,183.22	RM 37,105.36	RM 36,381.33	RM 28,802.09	(762,905.73)
825822	9	0.75	RM 2,226.67	RM 2,177.85	RM 37,105.36	RM 36,291.82	RM 28,802.09	(825,821.79)
888654	10	0.83	RM 2,226.67	RM 2,172.49	RM 37,105.36	RM 36,202.53	RM 28,802.09	(888,653.93)
951402	11	0.92	RM 2,226.67	RM 2,167.15	RM 37,105.36	RM 36,113.47	RM 28,802.09	(951,402.35)
1014067	12	1.00	RM 2,226.67	RM 2,161.81	RM 37,105.36	RM 36,024.62	RM 28,802.09	(1,014,067.25)
1076649	13	1.08	RM 2,226.67	RM 2,156.50	RM 37,105.36	RM 35,935.99	RM 28,802.09	(1,076,648.84)
1139147	14	1.17	RM 2,226.67	RM 2,151.19	RM 37,105.36	RM 35,847.59	RM 28,802.09	(1,139,147.33)
1201563	15	1.25	RM 2,226.67	RM 2,145.90	RM 37,105.36	RM 35,759.39	RM 28,802.09	(1,201,562.91)
1263896	16	1.33	RM 2,226.67	RM 2,140.62	RM 37,105.36	RM 35,671.42	RM 28,802.09	(1,263,895.80)
1326146	17	1.42	RM 2,226.67	RM 2,135.35	RM 37,105.36	RM 35,583.66	RM 28,802.09	(1,326,146.20)
1388314	18	1.50	RM 2,226.67	RM 2,130.10	RM 37,105.36	RM 35,496.12	RM 28,802.09	(1,388,314.31)
1450400	19	1.58	RM 2,226.67	RM 2,124.86	RM 37,105.36	RM 35,408.79	RM 28,802.09	(1,450,400.33)
1512404	20	1.67	RM 2,226.67	RM 2,119.63	RM 37,105.36	RM 35,321.68	RM 28,802.09	(1,512,404.47)
1574327	21	1.75	RM 2,226.67	RM 2,114.42	RM 37,105.36	RM 35,234.78	RM 28,802.09	(1,574,326.92)
1636168	22	1.83	RM 2,226.67	RM 2,109.21	RM 37,105.36	RM 35,148.09	RM 28,802.09	(1,636,167.89)
1697928	23	1.92	RM 2,226.67	RM 2,104.02	RM 37,105.36	RM 35,061.62	RM 28,802.09	(1,697,927.58)
1759606	24	2.00	RM 2,226.67	RM 2,098.85	RM 37,105.36	RM 34,975.36	RM 28,802.09	(1,759,606.19)
1821204	25	2.08	RM 2,226.67	RM 2,093.68	RM 37,105.36	RM 34,889.32	RM 28,802.09	(1,821,203.91)

Income FV refers to the income generated from the difference of the electricity. When the electricity after NEM being applied is less than the previous electricity fees, it is categorized as an income. Income PV is the equivalent present value refer to future value, so the capital PV work in the same way. Expenses PV will never change due to the expenses in the future will increase according to the inflation rate. Below are the formulas

$$year\ index = \frac{number\ of\ month}{12}$$

$$Income\ PV = Income\ FV\ \times \frac{1}{(1 + inflation)^{(year\ index)}}$$

$$Capital\ PV = Capital\ FV\ \times \frac{1}{(1 + inflation)^{(year\ index)}}$$

Table 9 Income, expenses and capital

Inflations rate			3%					
Abosulte	Month	yr index	Income FV	Income PV	Capital FV	Capital PV	Expenses PV	Accumulated
9109875	223	18.58	RM 2,226.67	RM 1,285.57	-	-	RM 28,802.09	(9,109,874.71)
9137394	224	18.67	RM 2,226.67	RM 1,282.41	-	-	RM 28,802.09	(9,137,394.39)
9164917	225	18.75	RM 2,226.67	RM 1,279.26	-	-	RM 28,802.09	(9,164,917.22)
9192443	226	18.83	RM 2,226.67	RM 1,276.11	-	-	RM 28,802.09	(9,192,443.20)
9219972	227	18.92	RM 2,226.67	RM 1,272.97	-	-	RM 28,802.09	(9,219,972.33)
9247505	228	19.00	RM 2,226.67	RM 1,269.84	-	-	RM 28,802.09	(9,247,504.58)
9275040	229	19.08	RM 2,226.67	RM 1,266.71	-	-	RM 28,802.09	(9,275,039.96)
9302578	230	19.17	RM 2,226.67	RM 1,263.60	-	-	RM 28,802.09	(9,302,578.45)
9330120	231	19.25	RM 2,226.67	RM 1,260.49	-	-	RM 28,802.09	(9,330,120.06)
9357665	232	19.33	RM 2,226.67	RM 1,257.39	-	-	RM 28,802.09	(9,357,664.76)
9385213	233	19.42	RM 2,226.67	RM 1,254.29	-	-	RM 28,802.09	(9,385,212.56)
9412763	234	19.50	RM 2,226.67	RM 1,251.21	-	-	RM 28,802.09	(9,412,763.44)
9440317	235	19.58	RM 2,226.67	RM 1,248.13	-	-	RM 28,802.09	(9,440,317.40)
9467874	236	19.67	RM 2,226.67	RM 1,245.06	-	-	RM 28,802.09	(9,467,874.44)
9495435	237	19.75	RM 2,226.67	RM 1,242.00	-	-	RM 28,802.09	(9,495,434.53)
9522998	238	19.83	RM 2,226.67	RM 1,238.94	-	-	RM 28,802.09	(9,522,997.68)
9550564	239	19.92	RM 2,226.67	RM 1,235.89	-	-	RM 28,802.09	(9,550,563.88)
9578133	240	20.00	RM 2,226.67	RM 1,232.85	-	-	RM 28,802.09	(9,578,133.12)
				RM 402,963.23		**RM 3,068,594.33**	**RM 6,912,502.03**	**(9,578,133.12)**
				total income		**total capital**	**total expenses**	**Grand total**

3.6 Electricity Sheet

Electricity sheet comprises the way to calculate the electricity fees. Below is the major formula in Table 10,

$$BESS\ size = \frac{Discharge\ of\ kWh\ BESS}{DOD}$$

Table 10 Electricity bill part 1

		Original	A
Solar Capacity	kw	-	100
Solar Performance Index	%	-	70%
BESS Size	kwh	-	76.34 kwh
Depth of Discharge (DOD)	%	-	66.00%
Peak point of kwh per 5 mins	kwh	-	142.25 kwh
Upper p %	%	-	89%
Upper p	kwh	-	126.60 kwh
Lower p 1st iteration	kwh		15.65 kwh
Lower p %	%	-	7.0%
Lower p	kwh	-	10.00 kwh
Conditions			Surplus
Discharge of kwh BESS	kwh	NA	50.38 kwh
Charge of kwh BESS	kwh	NA	512.55 kwh
Surplus per day	kwh	NA	462.17 kwh
Surplus per month	kwh	NA	13,330.78 kwh
TNB tariff		C1	C1
Peak/off-peak		NO	NO
Maximum demand		YES	YES
total kwh from TNB	kwh	537,155.00	518,634.81 kwh
Maximum demand	kw	1,657.00	1,519.23
Monthly			
Energy Needed	kwh		518,634.81 kwh
Energy from solar	kwh		19,603.39 kwh
Energy used during peak hour	kwh		17,173.42 kwh
Energy used during off peak hour	kwh		1,450.00 kwh
Surplus rate from TNB	Sen/kwh	NA	31.00

Table 11 shows the comparison of regular electricity bill and the electricity bill after implementation of NEM system. The original column in Table 11 shows regular electricity bill while A column shows the electricity fees structure with NEM implementation.

Table 11 Electricity bill part 2

B	C	D	E
		Original	A
		Rate	Rate
Below 200		36.50	36.50
Below 300		36.50	36.50
Below 600		36.50	36.50
Below 900		36.50	36.50
Above 900		36.50	36.50
Peak	sen/kwh	NA	NA
Off Peak	sen/kwh	NA	NA
Maximum demand	RM/kw	30.30	30.30
Minimum Charge	RM	600.00	600.00
First 200	kwh	200	200
Next 100	kwh	100	100
Next 300	kwh	300	300
Next 300	kwh	300	300
Above 900	kwh	536,255	499,196
kwh cost		196,061.58	182,534.96
MD cost		50,207.10	37,239.91
ICPT 0.0225/kwh		(12,085.99)	(11,252.16)
Surplus from NEM Program			-
Total		234,182.69	208,522.72
Discount TNB C1U		(23,418.27)	(20,852.27)
Sub Total		210,764.42	187,670.45
GST 6%		12,645.87	11,260.23
KWBTSS		3,546.27	3,301.61
Grand Total		226,956.55	202,232.28

3.7 Energy Sheet

Column P in Table 12 generates the maximum demand of the load profile. The bottom of column N shows discharged kWh and charged kWh which indicated that the conditions of the BESS after during one full day. Discharged kWh smaller than charged kWh indicated that there is surplus energy. Surplus energy will be sold back to the utilities company.

Table 12 and Table 13 are the energy sheets which represent the energy conditions at midnight and noon respectively. It breaks down the energy load profile to 5 minutes interval. The calculation of load has mentioned (See Page 9). BESS 1st, 2nd, 3rd and 4th iteration was used to determine the lower p with upper p value given. Column P in Table 12 generates the maximum demand of the load profile. The bottom of column N shows discharged kWh and charged kWh which indicated that the conditions of the BESS after during one full day. Discharged kWh smaller than charged kWh indicated that there is surplus energy. Surplus energy will be sold back to the utilities company.

Table 12 Energy calculation with four iterations to obtain lower p value

D	E	F	G	H	I	J	K	L	M	N	O	P
Bess	Need to be filled in by user			Upper p		103.843 kwh	103.843 kwh	103.843 kwh	103.843 kwh			
	Time	Solar	Power of load	Load	Clean_load	BESS 1st Iteration	BESS 2nd Iteration	BESS 3rd Iteration	BESS 4th Iteration	BESS Energy Accumulate	TNB	Max Demand
Weekday	11:20 PM	0.00 kwh	120.0 kw	10.00 kwh	10.00 kwh	1.00 kwh	0.00 kwh	0.00 kwh	0.00 kwh	243 kwh	10.00 kwh	120 kwh
Weekday	11:25 PM	0.00 kwh	120.0 kw	10.00 kwh	10.00 kwh	1.00 kwh	0.00 kwh	0.00 kwh	0.00 kwh	243 kwh	10.00 kwh	120 kwh
Weekday	11:30 PM	0.00 kwh	120.0 kw	10.00 kwh	10.00 kwh	1.00 kwh	0.00 kwh	0.00 kwh	0.00 kwh	243 kwh	10.00 kwh	120 kwh
Weekday	11:35 PM	0.00 kwh	120.0 kw	10.00 kwh	10.00 kwh	1.00 kwh	0.00 kwh	0.00 kwh	0.00 kwh	243 kwh	10.00 kwh	120 kwh
Weekday	11:40 PM	0.00 kwh	120.0 kw	10.00 kwh	10.00 kwh	1.00 kwh	0.00 kwh	0.00 kwh	0.00 kwh	243 kwh	10.00 kwh	120 kwh
Weekday	11:45 PM	0.00 kwh	120.0 kw	10.00 kwh	10.00 kwh	1.00 kwh	0.00 kwh	0.00 kwh	0.00 kwh	243 kwh	10.00 kwh	120 kwh
Weekday	11:50 PM	0.00 kwh	120.0 kw	10.00 kwh	10.00 kwh	1.00 kwh	0.00 kwh	0.00 kwh	0.00 kwh	243 kwh	10.00 kwh	120 kwh
Weekday	11:55 PM	0.00 kwh	120.0 kw	10.00 kwh	10.00 kwh	1.00 kwh	0.00 kwh	0.00 kwh	0.00 kwh	243 kwh	10.00 kwh	120 kwh
	Total solar	**1,992 kwh**	**Total**	**18,623 kwh**							**16,631kwh**	**1,246 kwh**
			Peak	**17,173 kwh**								
			Off peak	**1,450 kwh**								
			Average	**64.66**	**Discharged**	**-508.0 kwh**	**-508.0 kwh**	**-508.0 kwh**	**-508.0 kwh**	**243 kwh**		
	Peak Power	**142.25 kwh**			**Charged kwh**	**870.3 kwh**	**773.2 kwh**	**773.2 kwh**	**773.2 kwh**	**874 kwh**		
	DOD	**50.00%**			**Nett Energy**	**362.3 kwh**	**265.2 kwh**	**265.2 kwh**	**265.2 kwh**			
	Conditions	**Surplus**			**n**	**99**	**98**	**98**	**98**			
					Lower p week	11.000 kwh	10.000 kwh	10.000 kwh	10.000 kwh			

The first row of Table 13 shows from time 9:15 pm to 9:20 pm, solar panel generated 10.63 kWh. Load consumed 71.67 kWh. The energy from utility company was 71.67 kWh. BESS was charging with solar energy. However, when the load was above the upper p value (which is 102.42 kWh in this table) the BESS will allocate part of the solar energy to load side so to reduce the energy draw from utility company (As shown in the row with blue circle). With this method, the maximum demand will be controlled at upper p value 102.42 kWh.

Table 13 The management of BESS when the load consume is above upper p and or below upper p

	Need to be filled in by user			Upper p		102.420 kwh	102.420 kwh	102.420 kwh	102.420 kwh			
	Time	Solar	Power of load	Load	Clean_load	BESS 1st Iteration	BESS 2nd Iteration	BESS 3rd Iteration	BESS 4th Iteration	BESS Energy Accumulate	TNB	Max Demand
Weekday	9:15 AM	10.63 kwh	860.0 kw	71.67 kwh	61.04 kwh	10.63 kwh	10.63 kwh	10.63 kwh	10.63 kwh	1,342 kwh	71.67 kwh	770 kwh
Weekday	9:20 AM	10.73 kwh	900.0 kw	75.00 kwh	64.27 kwh	10.73 kwh	10.73 kwh	10.73 kwh	10.73 kwh	1,353 kwh	75.00 kwh	805 kwh
Weekday	9:25 AM	10.83 kwh	940.0 kw	78.33 kwh	67.50 kwh	10.83 kwh	10.83 kwh	10.83 kwh	10.83 kwh	1,364 kwh	78.33 kwh	842 kwh
Weekday	9:30 AM	10.83 kwh	980.0 kw	81.67 kwh	70.83 kwh	10.83 kwh	10.83 kwh	10.83 kwh	10.83 kwh	1,375 kwh	81.67 kwh	880 kwh
Weekday	9:35 AM	10.93 kwh	1,020.0 kw	85.00 kwh	74.07 kwh	10.93 kwh	10.93 kwh	10.93 kwh	10.93 kwh	1,385 kwh	85.00 kwh	920 kwh
Weekday	9:40 AM	11.01 kwh	1,060.0 kw	88.33 kwh	77.32 kwh	11.01 kwh	11.01 kwh	11.01 kwh	11.01 kwh	1,396 kwh	88.33 kwh	960 kwh
Weekday	9:45 AM	11.09 kwh	1,100.0 kw	91.67 kwh	80.58 kwh	11.09 kwh	11.09 kwh	11.09 kwh	11.09 kwh	1,408 kwh	91.67 kwh	1,000 kwh
Weekday	9:50 AM	11.09 kwh	1,140.0 kw	95.00 kwh	83.91 kwh	11.09 kwh	11.09 kwh	11.09 kwh	11.09 kwh	1,419 kwh	95.00 kwh	1,040 kwh
Weekday	9:55 AM	11.16 kwh	1,180.0 kw	98.33 kwh	87.18 kwh	11.16 kwh	11.16 kwh	11.16 kwh	11.16 kwh	1,430 kwh	98.33 kwh	1,080 kwh
Weekday	10:00 AM	11.22 kwh	1,220.0 kw	101.67 kwh	90.44 kwh	11.22 kwh	11.22 kwh	11.22 kwh	11.22 kwh	1,441 kwh	101.67 kwh	1,120 kwh
Weekday	10:05 AM	11.22 kwh	1,250.0 kw	104.17 kwh	92.94 kwh	9.48 kwh	9.48 kwh	9.48 kwh	9.48 kwh	1,451 kwh	102.42 kwh	1,155 kwh
Weekday	10:10 AM	11.28 kwh	1,280.0 kw	106.67 kwh	95.38 kwh	7.04 kwh	7.04 kwh	7.04 kwh	7.04 kwh	1,458 kwh	102.42 kwh	1,183 kwh
Weekday	10:15 AM	11.34 kwh	1,310.0 kw	109.17 kwh	97.83 kwh	4.59 kwh	4.59 kwh	4.59 kwh	4.59 kwh	1,462 kwh	102.42 kwh	1,205 kwh
Weekday	10:20 AM	11.34 kwh	1,340.0 kw	111.67 kwh	100.33 kwh	2.09 kwh	2.09 kwh	2.09 kwh	2.09 kwh	1,464 kwh	102.42 kwh	1,219 kwh
Weekday	10:25 AM	11.39 kwh	1,370.0 kw	114.17 kwh	102.78 kwh	-0.36 kwh	-0.36 kwh	-0.36 kwh	-0.36 kwh	1,464 kwh	102.42 kwh	1,228 kwh
Weekday	10:30 AM	11.43 kwh	1,400.0 kw	116.67 kwh	105.24 kwh	-2.82 kwh	-2.82 kwh	-2.82 kwh	-2.82 kwh	1,461 kwh	102.42 kwh	1,229 kwh

Figure 5 shows an energy graph in a complete day with solar size 200 kW, BESS 1476 kWh, DOD 66%, upper p 72%, and lower p 11.16%. Energy graph was marked with three arrow which indicated three different region for user to understand how BESS work to reduce the maximum demand charges.

Zone A was the lowest energy consumptions period during the day. However, the energy draw from TNB was more than the load because this is the time for the BESS to charge up for what it had discharged in the previous day.

During Zone B, the energy supplied from TNB was exactly same with the load. Solar system (Blue line) was providing energy to the system and the solar energy will be used to charge up BESS as shown (Blue line and yellow line was overlapping).

During zone C, load was above the upper p value and BESS was triggered to be energy provider. So, in this period, load gets energy from solar system, BESS, and also TNB. However, system need to maintain the energy supplied from TNB at the desired upper p value, this is where the maximum demand reduced.

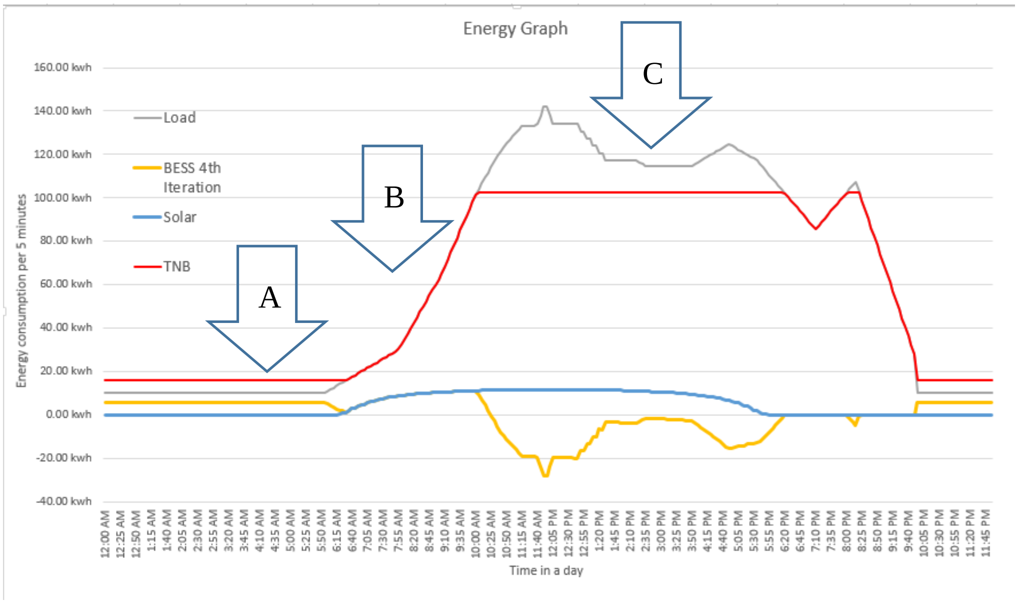

Figure 5 Load profile with integrating with BESS and Solar, 200 kW, BESS 1476 kWh, DOD 66%, upper p 72%

CHAPTER 4

4. Results and Discussion

NEM simulation takes the parameters from main sheet to generate data. During the simulation, four different conditions were simulated which is 20%, 40%, 60%, and 80% of DOD. Each DOD conditions will have four groups of data in order to plot graph. This four groups of data are saving per month, number of months to achieve breakeven, total gain after 20 years, and earn / capital ratio after 20 years.

In order to let researcher to understand the results in a better way, 4 sets of simulations was made. However, only one set of the result being discussed here which is saving per month at 20% DOD, number of months to breakeven at 20%

DOD, grand total saving after 20 years at 20% DOD, and earn / capital ratio at 20% DOD.

4.1 Saving per month at 20% DOD

Figure15 shows 200 kW solar panel is having the most saving per month, the definition of saving here refers to total gain per month minus total expenses per month installment per month.

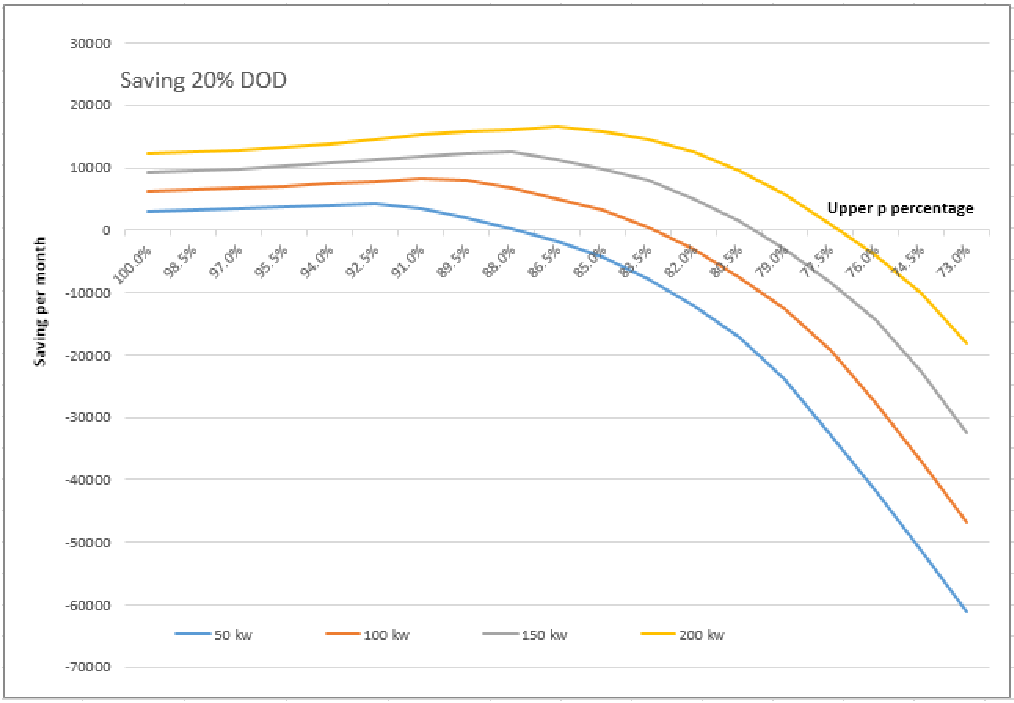

Figure 6 Saving per month with 20% DOD

X-Axis is upper p value which varies from 100% to 73% gradually while Y-Axis is the saving per month. 50 kW is having the less saving per month. The saving gain from the solar panel is obvious as the larger of solar panel create larger energy to decrease the consumption of energy from utilities company. The largest saving of 50 kW fall on 92.5% upper p approximately while largest saving of 200 kW fall on 86.5% upper p approximately. The saving of yellow line (200 kW) reduces after 86.5% cause by the increase of the BESS capacity. When there is a large area to cut out by BESS in order to reduce maximum demand. The BESS increase dramatically. The saving from maximum demand does not overcome the cost of the BESS. This is the reason why the saving per month does not just increase linearly with the reduced of upper p.

Whenever there is a lower upper p, it indicates that more maximum demand will be chopped off. However, the lower of upper p will generate a higher lower p. Chopping off maximum demand need energy. There are only two ways, solar and the discharge of BESS.

Table 14 shows that most of the system give a negative saving after it has an upper p which lower than 76%.

Table 14 Saving per month value at 20% DOD

		Solar size →		50	
Saving ↘		50 kw	100 kw	150 kw	200 kw
up ↓	100.0%	3084	6174	9264	12354
1.50%	98.5%	3330	6420	9510	12600
	97.0%	3451	6679	9769	12859
DOD	95.5%	3728	7114	10262	13352
20%	94.0%	3880	7414	10779	13869
	92.5%	4187	7870	11324	14609
	91.0%	3454	8176	11847	15234
	89.5%	2022	8036	12165	15757
	88.0%	266	6681	12470	16155
	86.5%	-1767	5016	11298	16461
	85.0%	-4332	3101	9753	15879
	83.5%	-7803	443	7886	14473
	82.0%	-12110	-3149	5105	12553
	80.5%	-17125	-7556	1337	9513
	79.0%	-23868	-12662	-3177	5626
	77.5%	-32678	-19058	-8338	1028
	76.0%	-41883	-27615	-14416	-4182
	74.5%	-51375	-36982	-22767	-10065
	73.0%	-61229	-46727	-32386	-18210

4.2 Breakeven month at 20% DOD

Table 15 shows the number of months needed for the NEM investment in order to achieve breakeven. As the longest duration set in the simulation program was 20 years, so it represent the breakeven will never achieve when the value determined was 240. It might fall at 250 or even longer but an investment which needs more than 20 years to achieve breakeven will not be the good option usually. Upper p values vary from 100 % gradually with the decrease of 1.5% per step.

Table 15 Breakeven month at 20% DOD

		Solar size →			
Breakeven Month ↘		50 kw	100 kw	150 kw	200 kw
up ↓	100.0%	167	165	164	162
0.015	98.5%	152	158	158	158
	97.0%	149	150	153	154
DOD	95.5%	140	140	145	147
20%	94.0%	140	135	136	141
	92.5%	136	129	130	132
	91.0%	207	127	124	127
	89.5%	240	137	123	123
	88.0%	240	198	122	121
	86.5%	240	240	150	120
	85.0%	240	240	199	131
	83.5%	240	240	240	158
	82.0%	240	240	240	206
	80.5%	240	240	240	240
	79.0%	240	240	240	240
	77.5%	240	240	240	240
	76.0%	240	240	240	240
	74.5%	240	240	240	240
	73.0%	240	240	240	240

Figure 7 shows the breakeven graph with 20% DOD. X-Axis is upper p value decrease gradually from 100% to 83.5%. At upper p value 95.5%, 100 kW and 50 kW solar having the lowest breakeven point while 200 kW having the longest breakeven month. This happens due to maximum demand saving is not high enough to cover the solar cost. Various size of solar gave different breakeven point. Although the order of breakeven did not follow exactly the size of solar, however the shape of the graph shows that the higher solar size will achieve shorter breakeven period.

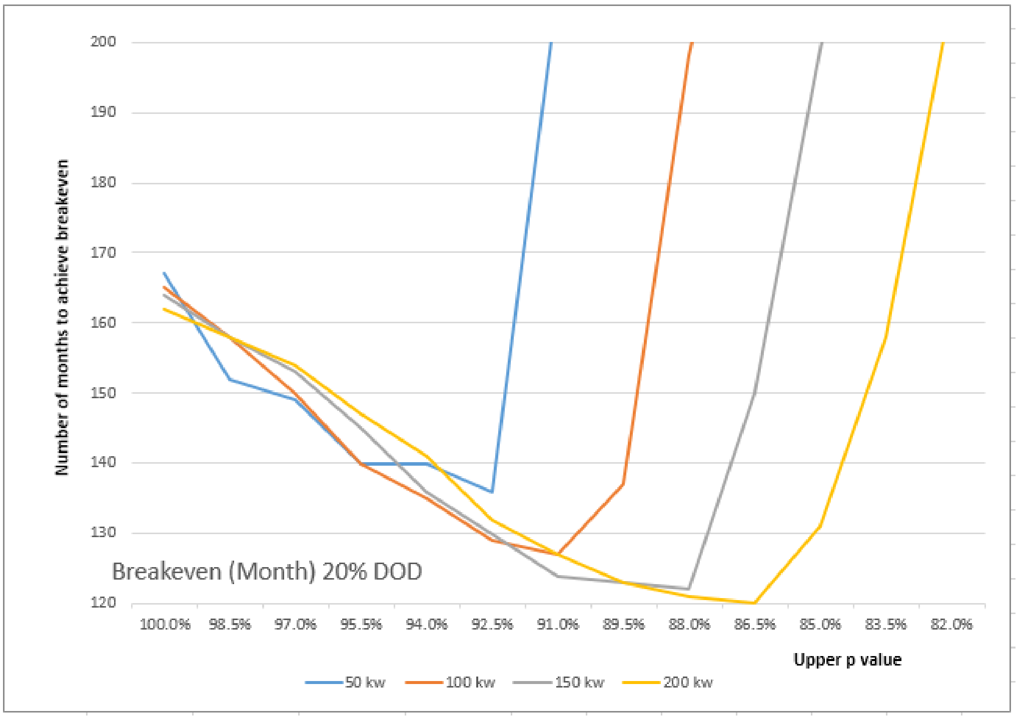

Figure 7 Breakeven month 20%DOD

4.3 Grand total after 20years at 20%DOD

Table 16 shows the grand total earning after 20 years in the unit (RM'000). With compare to saving per month, the 50 kW solar NEM will cross X-Axis (zero grand total earning) at around 91% upper p. This indicated that the saving at 91% upper p which is RM 3454 per month is just the threshold of the NEM to achieve no lost.

The maximum saving per month for 50 kW solar fall on 92.5% (See Page 27) and also the grand total saving fall on 92.5% upper p.

Table 16 Grand total earning after 20 years at 20% DOD

		Solar size →		50	
Grand total 20 yrs ↘		50 kw	100 kw	150 kw	200 kw
up ↓	100.0%	136	280	430	587
0.015	98.5%	181	324	475	632
	97.0%	195	371	522	679
DOD	95.5%	234	447	611	768
20%	94.0%	243	490	704	862
	92.5%	275	557	793	996
	91.0%	66	590	876	1103
	89.5%	-307	519	912	1186
	88.0%	-756	164	944	1240
	86.5%	-1269	-263	632	1273
	85.0%	-1906	-749	233	1098
	83.5%	-2755	-1408	-242	731
	82.0%	-3799	-2285	-930	244
	80.5%	-5008	-3352	-1848	-504
	79.0%	-6620	-4582	-2940	-1450
	77.5%	-8715	-6114	-4183	-2561
	76.0%	-10901	-8149	-5640	-3816
	74.5%	-13155	-10374	-7627	-5227
	73.0%	-15493	-12686	-9911	-7167

Figure 8 shows the graph of the grand total after 20 years with 20% DOD. With no doubt, with the higher solar size, it will create higher saving. However to determine an investment proposal, a very accurate data and parameter are required. Determine a way to let user obtain highest ROI (return of investment) in any type of load profile will be our main objective on this project.

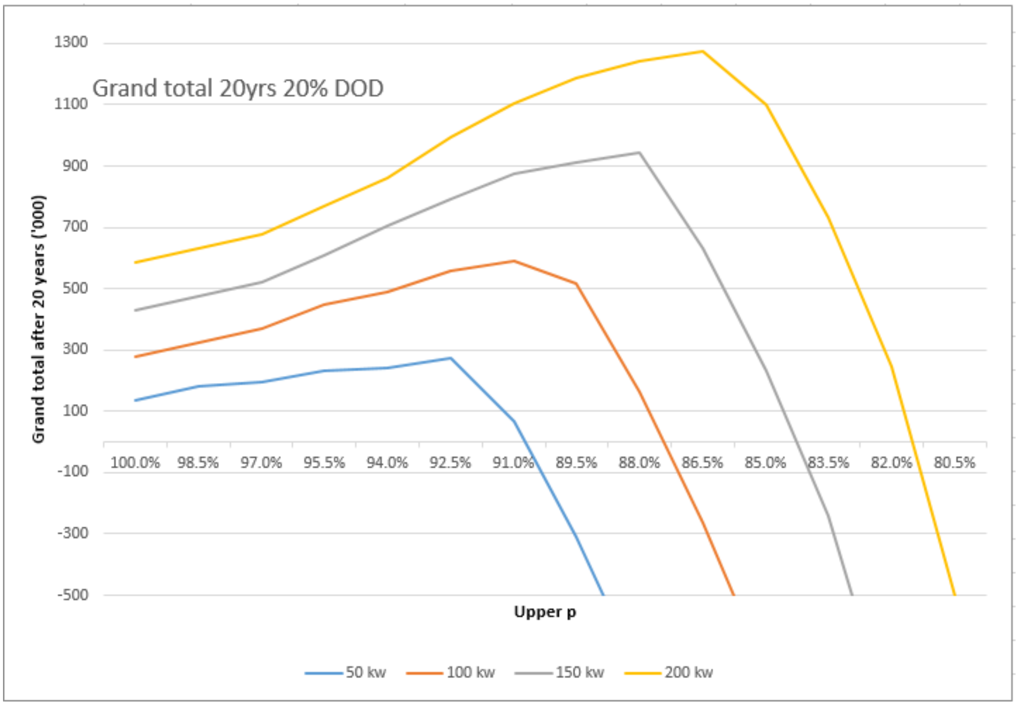

Figure 8 Grand total after 20years with 20% DOD

4.4 Earn / Capital at 20% DOD

Table 17 shows the earn/capital ratio. As mentioned above, earn refers to the grand total after 20 years. This group of data shows NEM investor about what size of the solar and BESS should be used for this load profile in this conditions to achieve maximum return with minimum capital.

100 kW solar will have maximum earn/capital ratio at upper p level 91% which is 0.664. This means that investor will gain RM 0.664 with every RM 1 of investment.

Table 17 Earn/Capital ratio with 20% DOD

		Solar size →		50	
Earn / Capital ↘		50 kw	100 kw	150 kw	200 kw
up ↓	100.0%	0.322	0.334	0.345	0.356
0.015	98.5%	0.428	0.387	0.381	0.383
	97.0%	0.455	0.443	0.419	0.412
DOD	95.5%	0.531	0.532	0.490	0.466
20%	94.0%	0.528	0.575	0.565	0.523
	92.5%	0.571	0.643	0.631	0.604
	91.0%	0.117	0.664	0.691	0.666
	89.5%	-0.456	0.554	0.707	0.712
	88.0%	-0.940	0.157	0.719	0.736
	86.5%	-1.337	-0.225	0.447	0.746
	85.0%	-1.698	-0.572	0.152	0.618
	83.5%	-2.052	-0.946	-0.145	0.387
	82.0%	-2.364	-1.332	-0.502	0.121
	80.5%	-2.624	-1.689	-0.884	-0.226
	79.0%	-2.878	-2.000	-1.243	-0.587
	77.5%	-3.111	-2.294	-1.564	-0.932
	76.0%	-3.282	-2.586	-1.861	-1.247
	74.5%	-3.410	-2.818	-2.175	-1.535
	73.0%	-3.511	-2.999	-2.447	-1.851

Figure 9 shows earn/capital ratio. At 97%, the highest ratio is 50 kW solar, follow by 100 kW, 150 kW, and 200 kW. However, small solar size can't have a low upper p value. 50 kW's ratio will drop rapidly right after 92.5%.

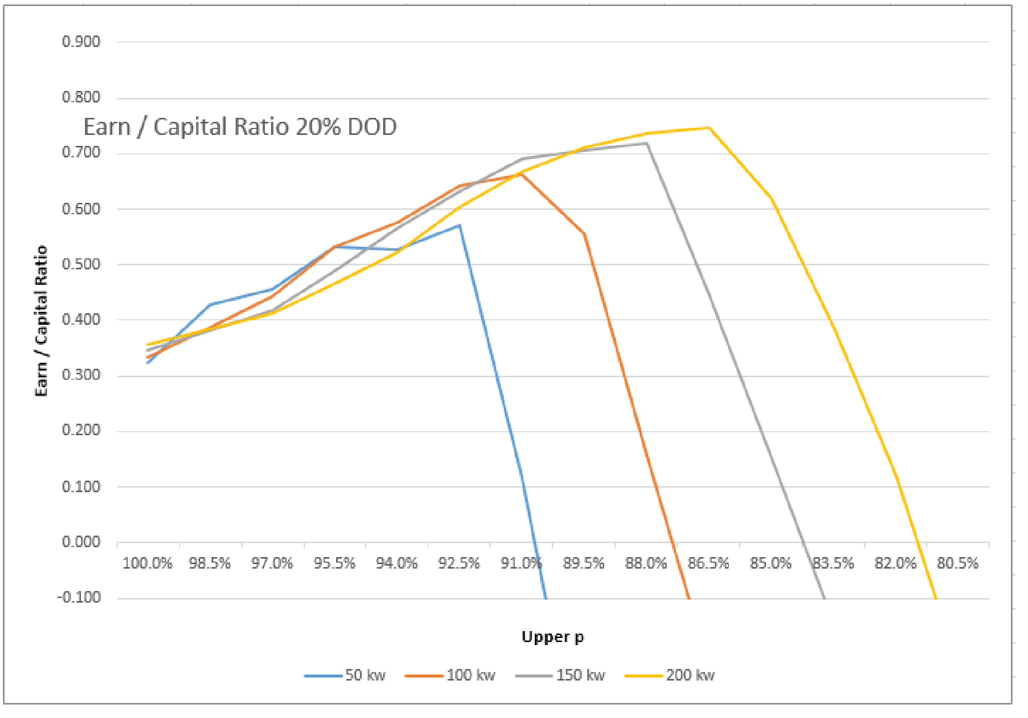

Figure 9 Earn/Capital Ratio at 20% DOD

4.5 100 kW solar, saving per month with various DOD

Table 18 shows one solar size, with various upper p versus various DOD from 20% to 80%.

Table 18 100 kW solar, saving per month with various DOD

		DOD →			
100 kw Saving ↘		20%	40%	60%	80%
up ↓	100.0%	6173.648	6173.648	6173.648	6173.648
	98.5%	6420.363	6420.363	6420.363	6420.363
	97.0%	6678.736	6678.736	6678.736	6678.736
	95.5%	7114.472	7138.818	7144.421	7139.929
	94.0%	7414.351	7530.215	7556.882	7535.500
	92.5%	7869.726	8105.762	8160.086	8116.529
	91.0%	8176.136	8595.207	8691.657	8614.323
	89.5%	8035.739	8826.396	9008.368	8862.463
	88.0%	6680.552	8355.436	8740.914	8431.837
	86.5%	5016.155	7705.752	8324.769	7828.439
	85.0%	3101.422	6911.374	7788.242	7085.166
	83.5%	443.080	5687.188	6894.130	5926.399
	82.0%	-3149.265	3923.147	5550.878	4245.758
	80.5%	-7556.066	1688.350	3815.972	2110.037
	79.0%	-12661.985	-950.538	1744.876	-416.317
	77.5%	-19057.586	-4334.864	-946.398	-3663.283
	76.0%	-27615.297	-8968.893	-4677.383	-8118.331
	74.5%	-36981.625	-14070.303	-8797.213	-13025.196
	73.0%	-46727.130	-19390.878	-13099.381	-18143.926

Figure 10 shows that the saving per month does not change linearly with the increase of DOD. 60% of DOD gave the highest saving value compare to the rest while 80% was just slightly higher that 40%. When DOD rate high, it actually shorten the lifespan of the battery, this is the reason why the saving did not proportional to the rate of DOD.

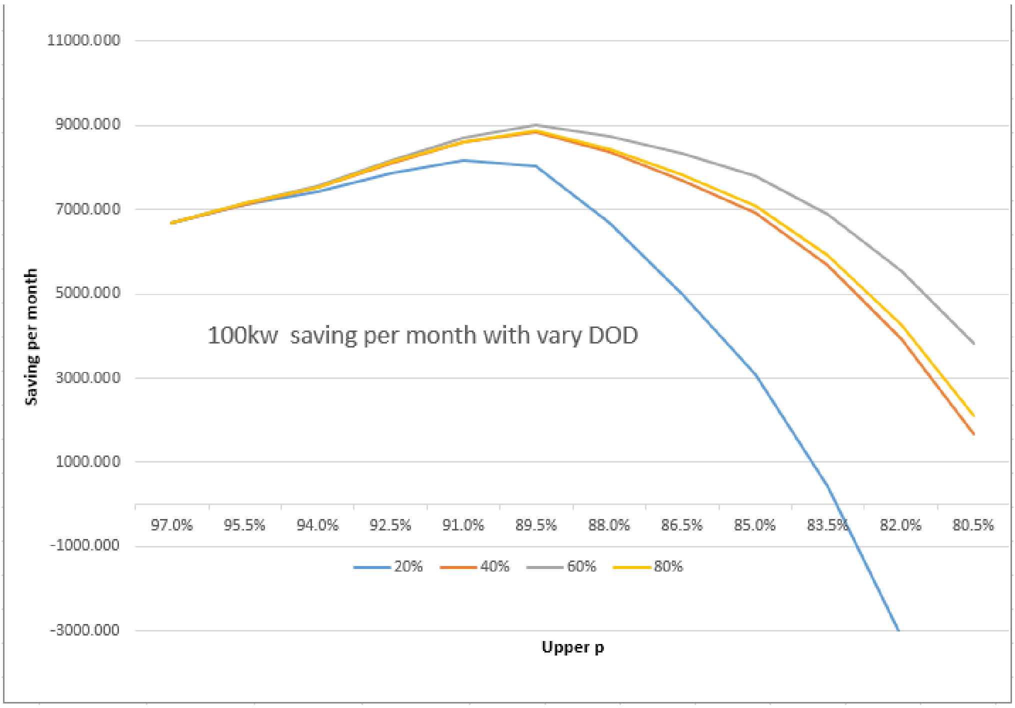

Figure 10 100 kW solar, saving per month with various DOD

4.6 100 kW solar, breakeven month with various DOD

Table 19 shows 100 kW solar, breakeven with various DOD. Refer to 89.5%. It will not be surprised with 60% DOD 100 kW solar was actually having the shortest breakeven month instead of 80%. With the same reason, 80% DOD reduce the battery efficiency and increase the expenses indirectly.

Table 19 100 kW solar, breakeven with various DOD

		DOD →			
100 kw Breakeven ↘		20%	40%	60%	80%
up ↓	100.0%	165.000	165.000	165.000	165.000
	98.5%	158.000	158.000	158.000	158.000
	97.0%	150.000	150.000	150.000	150.000
	95.5%	140.000	139.000	139.000	139.000
	94.0%	135.000	131.000	130.000	131.000
	92.5%	129.000	122.000	120.000	120.000
	91.0%	127.000	116.000	113.000	113.000
	89.5%	137.000	116.000	110.000	111.000
	88.0%	198.000	132.000	120.000	122.000
	86.5%	240.000	157.000	134.000	139.000
	85.0%	240.000	196.000	154.000	164.000
	83.5%	240.000	240.000	192.000	219.000
	82.0%	240.000	240.000	240.000	240.000
	80.5%	240.000	240.000	240.000	240.000

Figure 11 shows the graph of breakeven month with various DOD, 100 kW. The shortest breakeven observe was 110 month which is quite acceptable at this market for solar renewable energy.

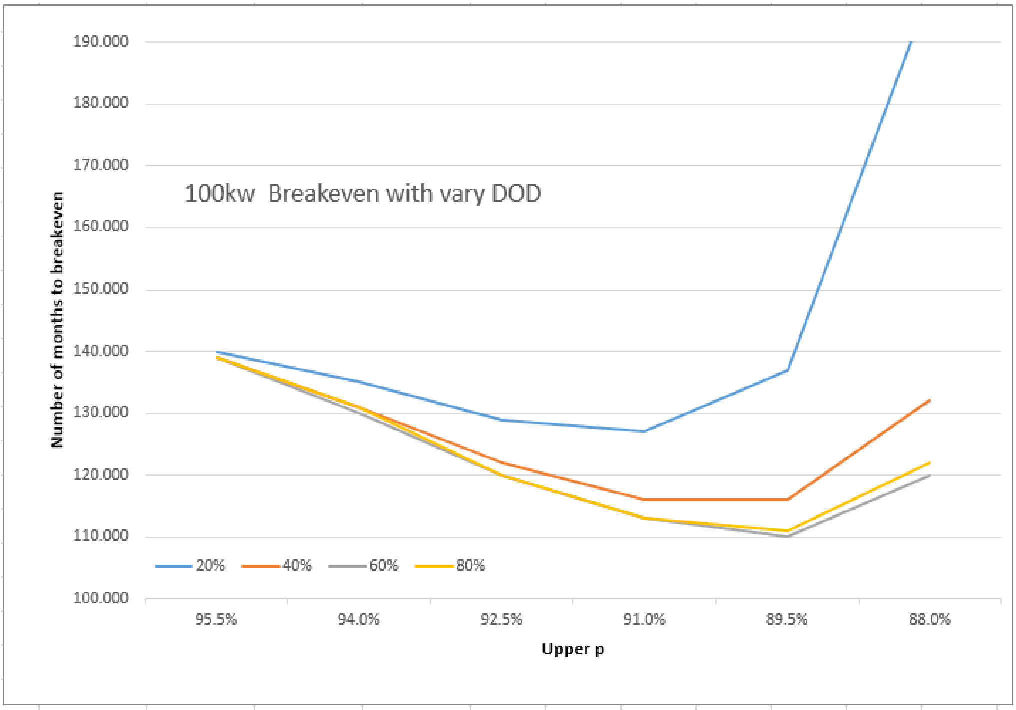

Figure 11 100 kW solar, breakeven with various DOD

4.7 100 kW solar, grand total with various DOD

Table 20 shows grand total saving after 20 years with various DOD. From row 91.0% upper p, it shows that 60% DOD have highest earning compared to the rest.

Table 20 100 kW solar, grand total with various DOD

		DOD →			
100 kw Grand total ↘		20%	40%	60%	80%
up ↓	100.0%	279.815	279.815	279.815	279.815
	98.5%	324.463	324.463	324.463	324.463
	97.0%	371.221	371.221	371.221	371.221
	95.5%	447.056	452.972	454.490	453.929
	94.0%	489.967	518.125	525.347	522.676
	92.5%	557.463	614.825	629.539	624.097
	91.0%	590.198	692.043	718.166	708.505
	89.5%	518.673	710.823	760.109	741.882
	88.0%	163.684	570.723	675.128	636.516
	86.5%	-263.458	390.182	557.840	495.835
	85.0%	-749.014	176.900	414.395	326.562
	83.5%	-1408.088	-133.638	193.257	72.361
	82.0%	-2285.107	-566.332	-125.469	-288.513
	80.5%	-3352.174	-1105.548	-529.292	-742.408
	79.0%	-4582.377	-1736.200	-1006.160	-1276.150
	77.5%	-6113.520	-2535.527	-1617.778	-1957.189
	76.0%	-8149.181	-3617.633	-2455.299	-2885.165
	74.5%	-10373.527	-4805.497	-3377.307	-3905.495
	73.0%	-12686.353	-6042.953	-4338.932	-4969.130

Figure 12 shows the graph of grand total with various DOD. With 100 kW solar chosen, 60% DOD have the highest gain.

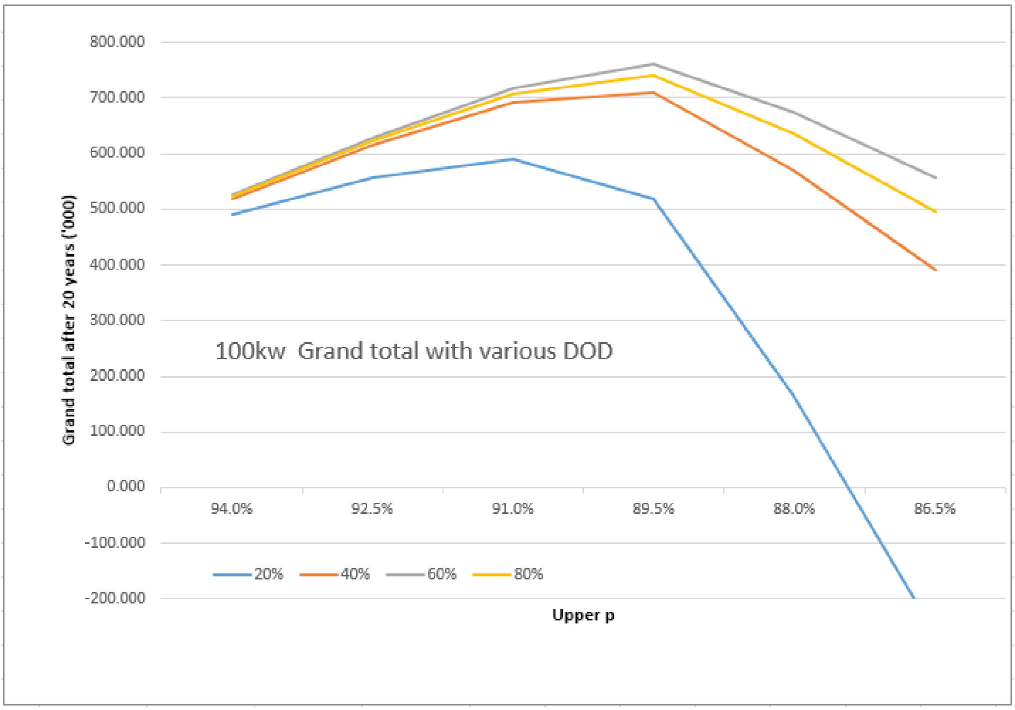

Figure 12 100 kW solar, grand total with various DOD

4.8 100 kW solar, earn/capital with various DOD

Table 21 shows 100 kW solar, earn/capital ratio. As expected, the greatest return of investment fall on 60% DOD of 100 kW solar at upper p 89.5%.

Table 21 100 kW, earn/capital with various DOD

		DOD →			
100 kw Earn/Capital ↘		20%	40%	60%	80%
up ↓	100.0%	0.334	0.334	0.334	0.334
	98.5%	0.387	0.387	0.387	0.387
	97.0%	0.443	0.443	0.443	0.443
	95.5%	0.532	0.540	0.542	0.542
	94.0%	0.575	0.613	0.624	0.621
	92.5%	0.643	0.722	0.743	0.739
	91.0%	0.664	0.801	0.840	0.833
	89.5%	0.554	0.802	0.874	0.861
	88.0%	0.157	0.606	0.745	0.716
	86.5%	-0.225	0.388	0.588	0.538
	85.0%	-0.572	0.165	0.416	0.342
	83.5%	-0.946	-0.115	0.183	0.072
	82.0%	-1.332	-0.444	-0.111	-0.273
	80.5%	-1.689	-0.783	-0.434	-0.660
	79.0%	-2.000	-1.110	-0.761	-1.063
	77.5%	-2.294	-1.448	-1.118	-1.512
	76.0%	-2.586	-1.814	-1.526	-2.038
	74.5%	-2.818	-2.127	-1.892	-2.522
	73.0%	-2.999	-2.385	-2.204	-2.948

Figure 13 shows the graph 100 kW solar, earn/capital ratio various DOD.

With no doubt, for 100 kW solar, having a BESS which give a 60% DOD will be the best way to carry out this NEM program in this building.

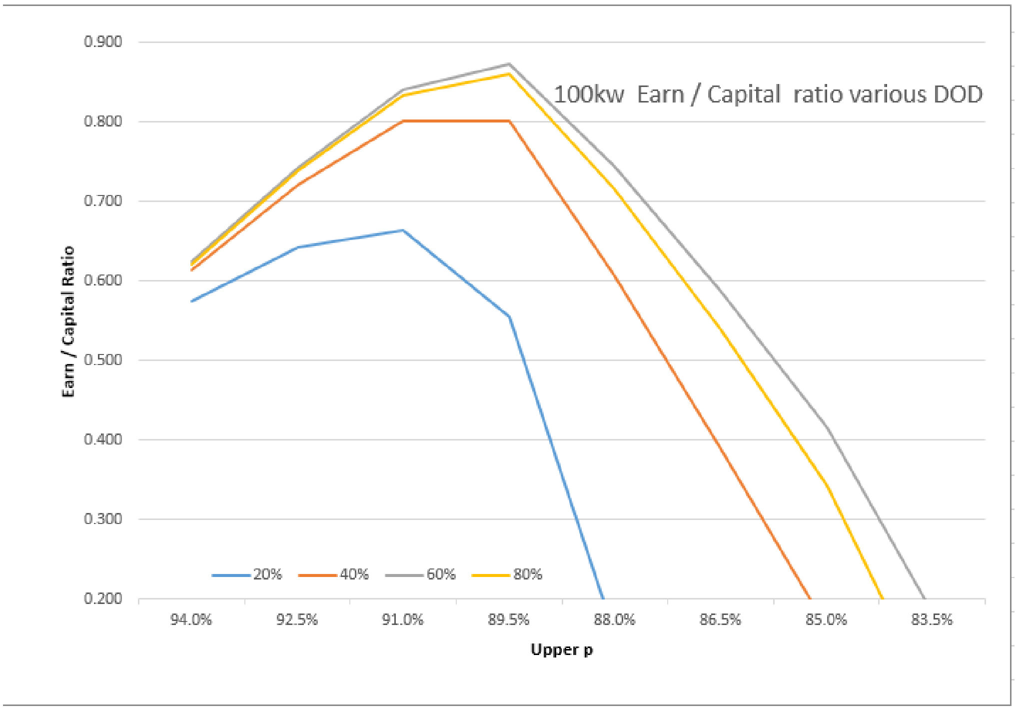

Figure 13 100 kW solar, earn/capital ratio various DOD

CHAPTER

5. Conclusion

To achieve a very accurate simulation result, complete information and profile is important. Price of BESS, solar, renovation cost and etc. Although several of DOD has been input to the simulation program to determine the highest gain. However, the step of the DOD is too far until the line from the graph does not shows too comprehensive.

Further, the temperature of the working environment of BESS was not taking in count. This issue effect the battery performance. Simulation program does not cover the temperature due to time constraint. From section 4.5 to 4.8, the various of DOD is 20% per step. So this is not fine enough to determine an accurate value. This simulation program in excel, per generation data took about 3 to 4 minutes. So it is important to have a great high speed computer to do the data generation. The major variable need to be set to determine the greatest return are solar size, and the percentage of DOD.

Finally, the best NEM system propose for this building in order to achieve largest economic gain shows in Table 22.

Table 22 NEM system's parameters which could generate largest gain

B	C	D
Solar Capacity	50 kw	500 kw
BESS Capacity	74 kwh	1500 kwh
DOD	70%	70%
Upper p	91.00%	
Lower p	7.03%	
TNB Tariff	C1	C1
Please fill in the Data for analysis		
Working days	21.8 days	21.8 days
Weekend	8.7 days	8.7 days
Average day of month	30.5 days	30.5 days
TNB Buy Rate RM / Kwh	31.00	0.32
Monthly Saving	4,792.22	
Break Even Point	110	
Grand total 20 years	406	
Earn / Capital Ratio	0.880	
Total Investment	385,665	
	Generate	

REFERENCES

Dutta, S., Ghosh, D. & Mohanta, D. K., 2016. *Optimum solar panel rating for net energy metering environment.* s.l., International conference on electrical, electronics and optimization techniques (ICEEOT).

Hossain, M. s. & Iqbal, M. T., 2014. *Grid Connected Energy Storage System to Profit from Net-Metering and Variable Rate Electricity.* Toronto, Canada, 2014 Canadian Conference on Electrical and Computer Engineering.

Oudalov, A., Cherkaoui, R. & Beguin, A., 2007. *Sizing and Optimal Operation of Battery Energy Storage System for Peak Shaving Application.* Lausanne, IEEE 2007 PowerTech conference swizerland.

Sajjad, I. A. et al., 10-13 June 2015. *Net Metering Benefits for Residential Buildings: A case study in italy.* Rome, IEEE.

TNB_Berhad, 2006. *Tariff Book.* Kuala Lumpur: s.n.

Woodbank Communications Ltd, S. C. R. C. C. 7. (. K., 2005. *Woodbank Communications Ltd.* [Online] Available at: http://www.mpoweruk.com/life.htm [Accessed 05 11 2016].

Zipp, K., 21 August 2015. *Solar Power World.* [Online] Available at: http://www.solarpowerworldonline.com/2015/08/what-is-the-best-type-of-battery-for-solar-storage/
[Accessed 20 11 2016].

Appendix A

VBA program

```
Sub Macro1()
' Macro1 Macro
Dim i As Integer (Define I as integer)
Dim j As Integer (Define J as integer)
Dim k As Integer (Define K as integer)
For k = 0 To 3
Range("C6").Select
        ActiveCell.FormulaR1C1 = Cells(35 + 96 * k, 2)
     'Phase one
   For j = 4 To 9
      For i = 31 To 50
              Range("C4").Select
        ActiveCell.FormulaR1C1 = Cells(30, j)

   Range("C7").Select
           ActiveCell.FormulaR1C1 = Cells(i, 3)
               Range("C17").Select
   Selection.Copy
                       Cells(i + 96 * k, j).Select
               Selection.PasteSpecial   Paste:=xlPasteValues,   Operation:=xlNone,
SkipBlanks _
         :=False, Transpose:=False
Range("C18").Select
```

```
   Selection.Copy
                  Cells(i + 24 + 96 * k, j).Select
          Selection.PasteSpecial    Paste:=xlPasteValues,    Operation:=xlNone,
SkipBlanks _
      :=False, Transpose:=False
 Range("C19").Select
   Selection.Copy
                  Cells(i + 48 + 96 * k, j).Select
          Selection.PasteSpecial    Paste:=xlPasteValues,    Operation:=xlNone,
SkipBlanks _
      :=False, Transpose:=False
Range("C20").Select
   Selection.Copy
                  Cells(i + 72 + 96 * k, j).Select
          Selection.PasteSpecial    Paste:=xlPasteValues,    Operation:=xlNone,
SkipBlanks _
      :=False, Transpose:=False
   Next i
   Next j
   Next k
     Range("G2").Select
End Sub
```