School of Electrical & Computer Engineering

EEET2334 – Renewable Electrical Energy Systems

GRID-CONNECTED RENEWABLE POWER SYSTEM FOR RESIDENTIAL USE

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Group: Thursday 12:30 – 2:30 (Odd)

Submission Date: 22/10/17

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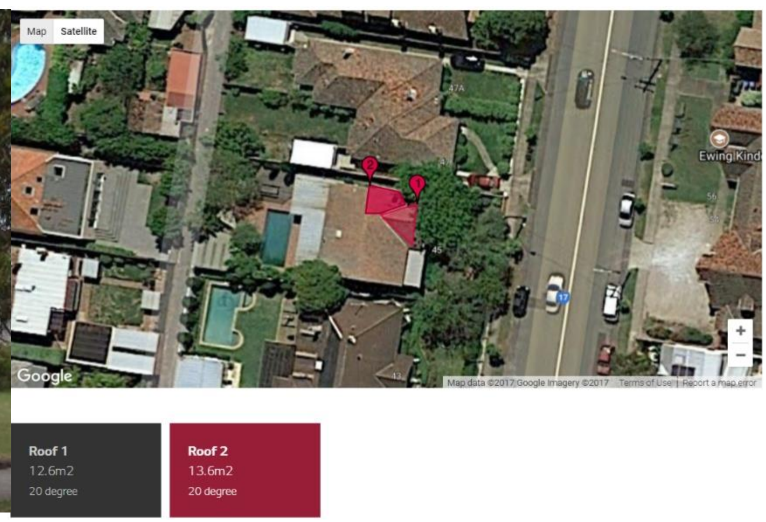
Introduction

The Assignments primary aim is to design a residential Micro-Grid with a PV power system. The pratical data allows to analyse the design of a power generating system for residential use in the residential area of Sunbury.

Aim

The major purpose of this experiment was to gain an experience and create the design of residential micro-Grid with practical system data by using the HOMER Pro software. The system should include a diesel generator, wind turbine, a PV system, a utility grid, a converter and a battery.

Design of House



Understand and compare your home electricity usage

A typical 2 person household in 3429 uses *

Summer	Autumn	Winter	Spring	Annual consumption
December-February	*March-May*	*June-August*	*September-November*	
10.4 kWh per day	**10.8 kWh** per day	**12.1 kWh** per day	**9.1 kWh** per day	**10.6 kWh** per day
933 kWh for Summer	**991 kWh** for Autumn	**1110 kWh** for Winter	**829 kWh** for Spring	**3863 kWh** per year

** these amounts are based on an average household in your localised zone. Individual usage will vary.*

The location of the residential house: 45 Burke Rd Sunbury, Victoria
House Size: 2 people
Figure 1: Diff weather average daily usage 2 people house in Sunbury [1]

According to the above figure 1, this showed that the average daily usage would increase in winter because the residents would use the heater to maintain the temperature. Therefore, this would spend more power per day. On the other hand, the residents would use fan in summer and autumn, so the the average daily usage would be more than the average daily usage in spring.

Backup Generator

Backup Generator choice: 6kVA Diesel Generator - 240V in Canopy Single Phase [4]
Price: $1,250
Fuel Tank Capacity : 15 Litres
Running Time : 10-12 Hours Depending On Load
Fuel Consumption : 1.1 litres/hour (Average)

Our design would use the 6kVA Diesel Generator, which cost 1.1 litres Fuel per hour. Therefore, this allow to provide the power from 10 to 12 hours. On the other hand, it has the mains failure detection system, so this can automatically switch to supply the power when the main power system happened problem.

Grid

The main electrical power stations located in Victoria are: Loy Yang A, Loy Yang B, and Yallourn [1]. They provide coal fired electricity with is then transmitted by companies like United energy which is distributed to Jemena and its retailers. The retailer we chose was AGL electricity [2] which charges $0.2483 for peak power usage with a grid sellback price of $0.06 per kWh.

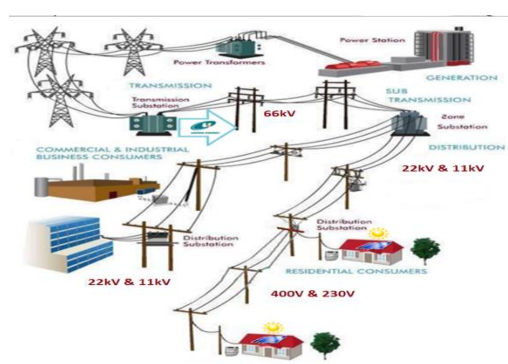
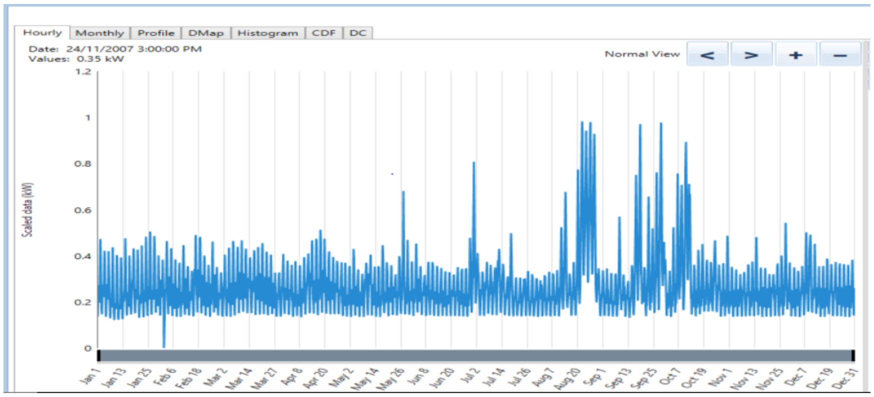
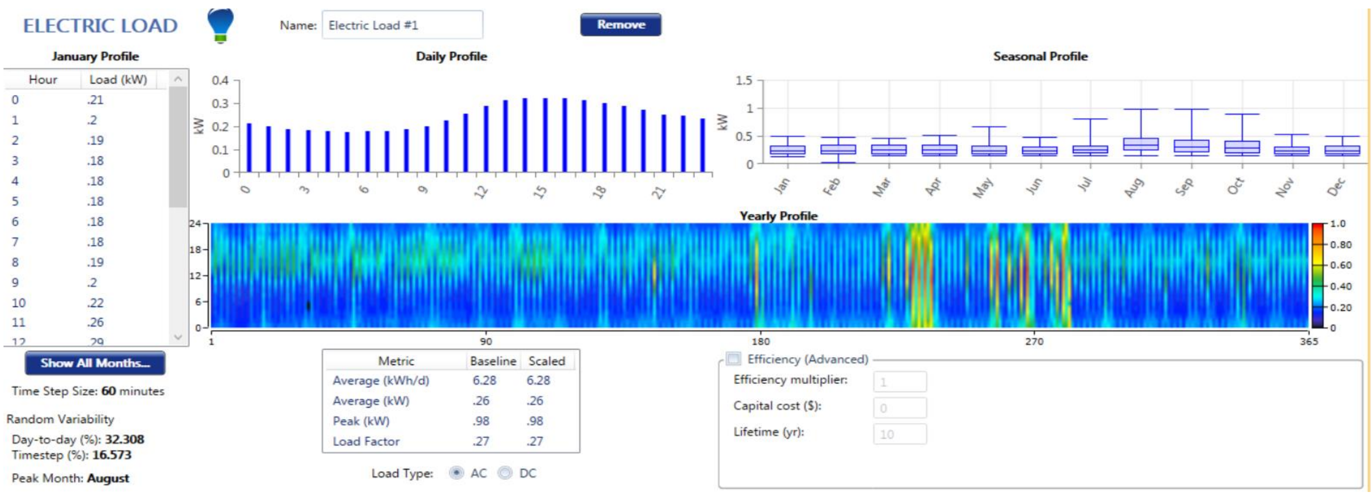


Figure 3: Electricity generation, transmission and distribution

Electrical Load



The average daily usage is 6.28 kWH/day for residential use. And it is seen that the peak power usage is in August which is coincidently in Winter season showing the peak power at 0.98kW.



Converter

SOLAR INVERTERS

ABB string inverters

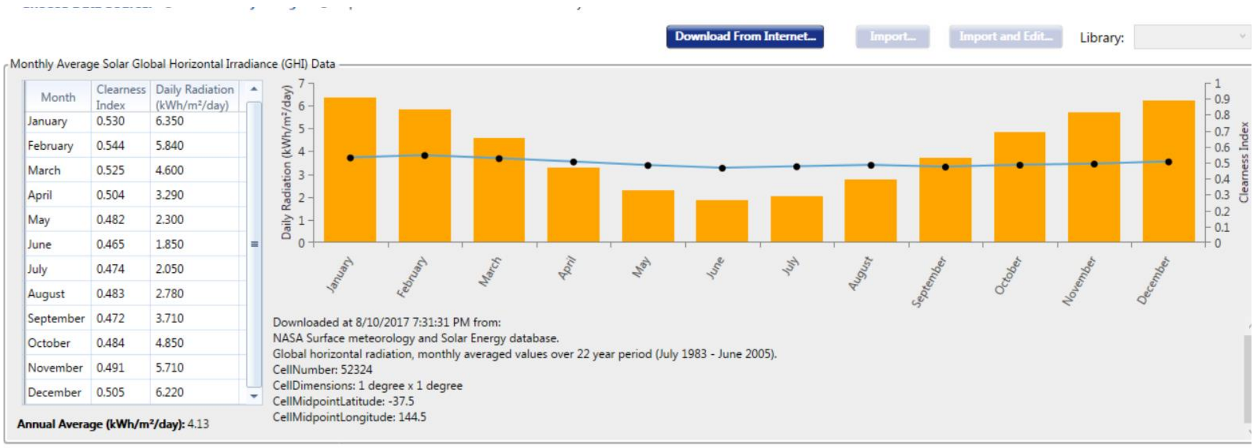
PVI-5000/6000-TL-OUTD

5 to 6 kW

Designed for residential and small commercial photovoltaic installations, this inverter fills a specific niche in the product line to cater for those installations producing between 5kW and 20kW.

The Maximum power of our design is about 6 kW. Therefore, our design will use a 6.2 kW inverter, which is costing $2,010.

PV



Month	Clearness Index	Daily Radiation (kWh/m²/day)
January	0.530	6.350
February	0.544	5.840
March	0.525	4.600
April	0.504	3.290
May	0.482	2.300
June	0.465	1.850
July	0.474	2.050
August	0.483	2.780
September	0.472	3.710
October	0.484	4.850
November	0.491	5.710
December	0.505	6.220

Annual Average (kWh/m²/day): 4.13

Month	Daily Temperature (°C)
January	20.530
February	20.600
March	18.290
April	15.000
May	11.700
June	9.240
July	8.150
August	8.850
September	10.980
October	13.660
November	16.500

Annual Average (°C): 14.37

https://www.wholesalesolar.com/solar-panels#lg

LG Mono X® PLUS

Average cost of each panel is $300. With 8 panels the total cost is $2400. Estimated total production 1790kWh/yr. Pac= 1790/(4.13)*365= 1.18kW -

$$T_{cell} = T_{amb} + \left(\frac{NOCT-20}{0.8}\right) \times S\,, \quad = 25 + \frac{45-20}{0.8} \times 1 = Tcell = 57.5°\text{C}\,, \Delta P =$$

$$0.0041(57.5 - 25) = 0.13325\%$$

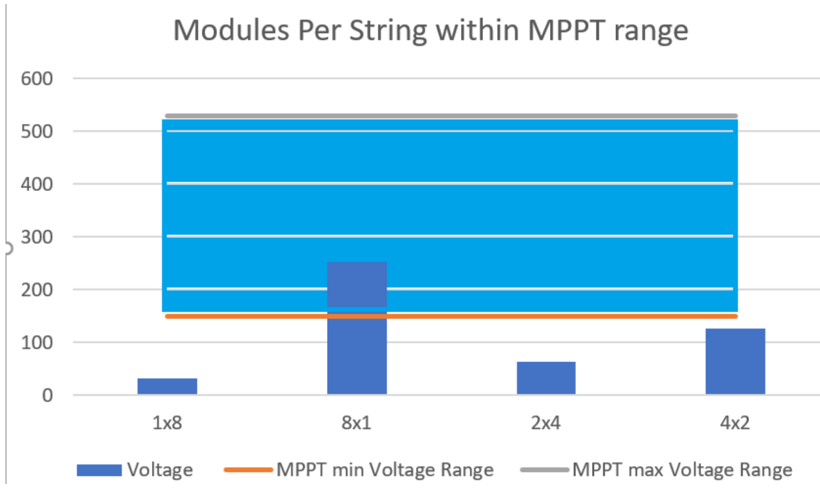
New Efficency from tempreture derating

100-13.325=86.675%

$$\therefore Conversion\ Efficiency = 0.86675 * 0.97 * 0.97 * 0.97 = 79\%$$

$$PDC = \frac{1790}{0.79} = 2265kW$$

$$PDC = 2100 * 0.79 = 1{,}659W$$



As each LG panel takes about $1.713m^2$and requiring 8 panels making 2400kW. The surface area needed is calculated:

$$1.713m^2 * 8 = 13.704m^2$$

$No.of\ Modules = \frac{2265W}{300W} = 7.55\ Panels.$ With 8 Modules the likely combinations would be 4x2, 2x4,8x1 and 1x8. With the MPP Voltage at 31.6V, the 8x1 combination works with our MPPT voltage range.

Assuming coldest mourning would be -15 degrees Voc would still be below 500V

$V_{OC,max} = V_{OC,string} \times [1 + 0.0038(T_{STC} - T_{amb})$ = 291V

Battery

Appropriate System Voltage: 1000W/12V= 83Amps (Avoiding current greater than 100A).

Crown CR220, 6V Flooded Battery

Crown Batteries:

- High quality deep-cycle batteries designed for deep cycling
- Designed for the slow charge and discharge of a solar or battery backup system

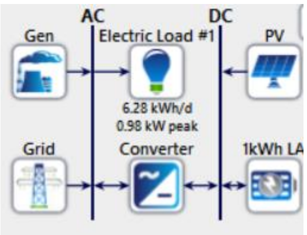
Model	Part No.	Voltage	Amp Hours	Type	Warranty	Size & Weight	Price
Crown CR220, 6V Flooded Battery	9960150	6VDC	220Ah	Flooded Lead Acid	3 Years	10.25 × 7.06 × 9.88 in 60 lbs	Qty 1 $135.00 Add to Cart

AH from battery= 6200W/12V*0.97 = 532 Ah $Assume\ Columb\ Efficiency\ of\ the\ battery: \frac{532}{0.9} = 591Ah$, We want the usuable battery storage to be 8 hours in case of any black outages however not be entirely off-grid.

$0.33 * 591 = 197\text{AH}\ \ \therefore Total\ Storage\ capacity \frac{197}{0.63*0.88} = 355Ah$

No. of batteries = 2parralel *2series = $540+160 (inc installation and shipping).

Simulation Modelling and Results



- Practicality of result:

Our design showed practicality; with the optimal result to stay on the grid due the the cheap electricity prices received from our plan. However, the operating cost is much higher and thus long term solar is the better deal. However, with the government rebate program, PV with an inverter is the optimal result.

- Simulation 1: Grid Only:

Architecture				Cost				System	PV		Converter		Grid	
PV (kW)	PV-MPPT (kW)	Gen (kW)	Converter (kW)	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Capital Cost ($)	Production (kWh)	Rectifier Mean Output (kW)	Inverter Mean Output (kW)	Energy Purchased (kWh)	Energy Sold (kWh)
				$0.248	$7,354	$568.83	$0.00	0					2,294	0

Operating cost is $569 but the main advantage of the grid is 0 initial capital invested.

- Simulation 2: Gridless with rebate program

Architecture				Cost				System	PV		Converter	
PV (kW)	PV-MPPT (kW)	Gen (kW)	Converter (kW)	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Capital Cost ($)	Production (kWh)	Rectifier Mean Output (kW)	Inverter Mean Output (kW)
2.00	1.00	1.10	5.00	$0.688	$20,410	$1,254	$4,201	39.4	1,577	2,228	0.0879	0.202

Gridless scheme increases the operating cost by 4 times the optimal result. However, can be useful in places with common outages and expensive electricity costs.

- Simulation 3: Generator Only & %50 increase in diesel

Gen (kW)	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)
1.10	$1.54	$45,544	$3,438	$1,100	0
1.10	$2.07	$61,353	$4,661	$1,100	0

Diesel price increase by 50% becomes proportional with its operation cost in this case $1500 more expensive. Initial capital will remain the same

- Simulation 4: Renewable plan

PV (kW)	PV-MPPT (kW)	Gen (kW)	Converter (kW)	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Capital Cost ($)	Production (kWh)	Rectifier Mean Output (kW)	Inverter Mean Output (kW)	Energy Purchased (kWh)	Energy Sold (kWh)
2.00	1.00	1.10	5.00	$0.226	$10,137	$299.22	$6,269	60.9	2,629	2,228	0	0.242	1,359	1,182
2.00	1.00	1.10	5.00	$0.216	$9,723	$308.98	$5,729	60.9	2,629	2,228	0	0.242	1,359	1,182
2.00	1.00		5.00	$0.207	$9,294	$319.09	$5,169	60.9	2,629	2,228	0	0.242	1,359	1,182
2.00	1.00		5.00	$0.198	$8,880	$328.85	$4,629	60.9	2,629	2,228	0	0.242	1,359	1,182

The cheapest capital shows operating cost at $328 cheaper than gridless by $240. Due to the battery and Generator being expensive investments we believe that it is unnescessary to be applicable.

- Simulation 5: Optimal result with rebate program

Architecture				Cost				System	PV		Converter		Grid	
PV (kW)	PV-MPPT (kW)	Gen (kW)	Converter (kW)	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Capital Cost ($)	Production (kWh)	Rectifier Mean Output (kW)	Inverter Mean Output (kW)	Energy Purchased (kWh)	Energy Sold (kWh)
2.00	1.00		5.00	$0.150	$6,753	$307.54	$2,777	60.9	1,577	2,228	0	0.242	1,359	1,182

The rebate program significantly improved the cost of the system by 40% thus reducing the operating cost by 10% and saving $1850 in initial capital.

Reference

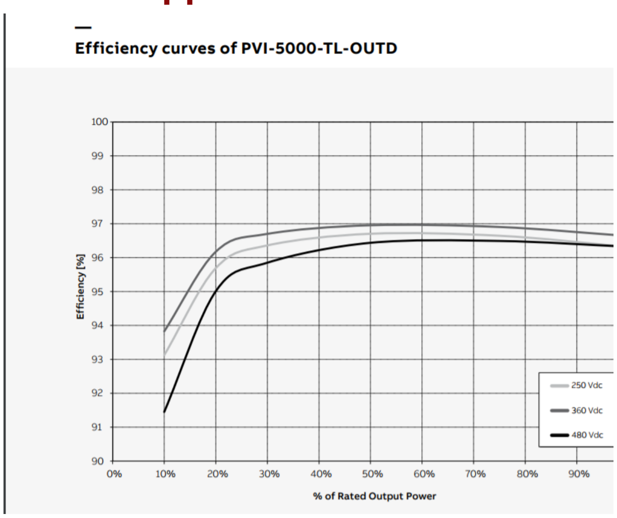
[1]"Understand and compare your home electricity usage | Energy Made Easy", Energymadeeasy.gov.au, 2017. [Online]. Available: https://www.energymadeeasy.gov.au/benchmark. [Accessed: 11- Oct- 2017].

[2]"ABB PVI 5.0 String Inverter", Theenergyhub.com.au, 2017. [Online]. Available: https://www.theenergyhub.com.au/abb-pvi-5-0-string-inverter.html. [Accessed: 11- Oct- 2017].

[3] "Construction EHV Transmission Line", Slideshare.net, 2017. [Online]. Available: https://www.slideshare.net/gsgindia/construction-ehv-transmission-line. [Accessed: 16- Oct- 2017].

[4]"6kVA Diesel Generator - Silenced Canopy - Perth and Brisbane", Ablesales.com.au, 2017. [Online]. Available: https://www.ablesales.com.au/diesel-generators-perth-melbourne-brisbane/diesel-generator-air-cooled/6kva-diesel-generator.html?gclid=EAIaIQobChMI6rOqv7fo1gIVl5K9Ch1RrAo2EAYYASABEgLwivD_BwE. [Accessed: 11- Oct- 2017].

Appendix



Appendix 1 Inverter

Type code	PVI-5000-TL-OUTD	PVI-6000-TL-OUTD
Input side		
Absolute maximum DC input voltage ($V_{max,abs}$)	600 V	
Start-up DC input voltage (V_{start})	200 V (adj. 120...350 V)	
Operating DC input voltage range (V_{dcmin}...V_{dcmax})	0.7 x V_{start}...580 V (min 90 V)	
Rated DC input voltage (V_{dcr})	360 V	
Rated DC input power (P_{dcr})	5150 W	6200 W
Number of independent MPPT	2	
Maximum DC input power for each MPPT ($P_{MPPTmax}$)	4000 W	
DC input voltage range with parallel configuration of MPPT at P_{acr}	150...530 V	180...530 V
DC power limitation with parallel configuration of MPPT	Linear derating from max to null [530 V≤V_{MPPT}≤580 V]	
DC power limitation for each MPPT with independent configuration of MPPT at P_{acr}, max unbalance example	4000 W [220 V≤V_{MPPT}≤530 V] the other channel: P_{dcr}-4000 W [90 V≤V_{MPPT}≤530 V]	4000 W [220 V≤V_{MPPT}≤530 V] the other channel: P_{dcr}-4000 W [120 V≤V_{MPPT}≤530 V]
Maximum DC input current (I_{dcmax}) / for each MPPT ($I_{MPPTmax}$)	36.0 A / 18.0 A	
Maximum input short circuit current for each MPPT	22.0 A	
Number of DC input pairs for each MPPT	2	
DC connection type	PV quick fit connector [3)]	
Input protection		
Reverse polarity protection	Yes, from limited current source	
Input over voltage protection for each MPPT - varistor	Yes	
Photovoltaic array isolation control	According to local standard	
DC switch rating for each MPPT (version with DC switch)	25 A / 600 V	
Output side		
AC grid connection type	Single-phase	
Rated AC power (P_{acr} @cosϕ=1)	5000 W [4)]	6000 W
Rated AC power (P_{acr} @cosϕ=±0.9)	5000 W [4)]	6000 W
Maximum AC output power (P_{acmax} @cosϕ=1)	5000 W [4)]	6000 W
Maximum apparent power (S_{max})	5560 VA	6670 VA
Rated AC grid voltage ($V_{ac,r}$)	230 V	
AC voltage range	180...264 V [1)]	
Maximum AC output current ($I_{ac,max}$)	25.0 A	30.0 A
Contributory fault current	32.0 A	40.0 A
Rated output frequency (f_r)	50 Hz / 60 Hz	
Output frequency range (f_{min}...f_{max})	47...53 Hz / 57...63 Hz [2)]	
Nominal power factor and adjustable range	> 0.995, adj. 0.8 inductive to 0.8 capacitive	
Total current harmonic distortion	< 3.5%	
AC connection type	Terminal block, cable gland M32	
Output protection		

Appendix 2 Solar Panel

Mechanical Properties

Cells	6 x 10
Cell Vendor	LG
Cell Type	Monocrystalline / P-type
Cell Dimensions	161.7 x 161.7 mm
# of Busbar	4
Dimensions (L x W x H)	1686 x 1016 x 40 mm
Front Load	6000 Pa
Rear Load	5400 Pa
Weight	18.0 kg
Connector Type	Genuine MC4, IP68 (Male: PV-KST4) (Female: PV-KBT4)
Junction Box	IP68 with 3 bypass diodes
Length of Cables	2 x 1000 mm
Front cover	High transmission tempered glass
Frame	Anodised aluminum with protective black coating

Certifications and Warranty

Certifications	ISO 9001
	IEC 61215, IEC 61730-1/-2
	IEC 61701(Salt Mist Corrosion Test)
	IEC 62716 (Ammonia Corrosion Test)
Module Fire Rating	Class C
Product Warranty	12 Years
Output Warranty of Pmax (Measurement Tolerance ± 3%)	Linear Warranty[1]

[1] 1) 1st year: 98%, 2) After 1st year: 0.55%p annual degradation, 3) 84.8% for 25 years

Temperature Characteristics

NOCT	45 ± 3 °C
Pmax	-0.41 %/°C
Voc	-0.30 %/°C
Isc	0.03 %/°C

Electrical Properties (STC[2])

Module Type	295 W	300 W
Maximum Power Pmax (W)	295	300
MPP Voltage Vmpp (V)	31.3	31.7
MPP Current Impp (A)	9.43	9.47
Open Circuit Voltage Voc (V)	38.6	38.9
Short Circuit Current Isc (A)	10.02	10.07
Module Efficiency (%)	17.2	17.5
Operating Temperature (°C)	-40 ~ +90	
Maximum System Voltage (V)	1000	
Maximum Series Fuse Rating (A)	20	
Power Tolerance (%)	0 ~ +3	

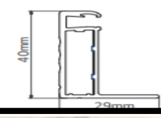
[2] STC (Standard Test Condition): Irradiance 1000 W/m², module temperature 25 °C, AM 1.5.
The nameplate power output is measured and determined by LG Electronics at its sole and absolute discretion.

Electrical Properties (NOCT[3])

Module Type	295 W	300 W
Maximum Power Pmax (W)	216	220
MPP Voltage Vmpp (V)	28.7	29.1
MPP Current Impp (A)	7.53	7.56
Open Circuit Voltage Voc (V)	35.7	36.0
Short Circuit Current Isc (A)	8.06	8.10

[3] NOCT (Nominal Operating Cell Temperature): Irradiance 800 W/m², ambient temperature 20°C, wind speed 1 m/s

Dimensions (mm)



Appendix 3 Electrcity Bill

...sions and rebates, AGL payment and the Centrepay scheme. To find more, visit agl.com.au/Concessions

...d an interpreter? Call 1300 307 245.
...是传译员吗? 请电上述号码。
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Energy efficiency. To track and help reduce your energy usage AGL offers a free online tool, My AGL IQ®. Visit agl.com.au/MyAGLIQ

Energy Plan:

Meter no.	Read type	Start reference*	End reference*	kWh
CZ137972	Actual	41,109	42,278	1,182.3...
CZ137972	Actual	11,854	12,511	669.019

*These reference reads are a guide only and may not reflect the total energy consumption for this billing period. Your next meter read is due between ... 14 Aug 2017. Please ensure easy access to your meter on these days.

How we've worked out your bill.

Previous balance and payments.

		Total
Previous balance	$277.65	
8 Mar 17 payment	$277.65cr	
10 Mar 17 dishonoured payment	$277.65	
27 Mar 17 payment	$277.65cr	
Balance brought forward		$0.00

New charges and credits.

	Units	Price	Amount		Total
Usage and supply charges					
Peak	1182.325kWh	$0.2483	$293.57		
Supply charge	90 days	$1.353	$121.77		
Other charges					
Paper Bill Fee			$1.75		
Dishonoured Payment Fee*			$3.50		
Total charges				+	$420.59
Credits					
Standard Feed-in Tariff*	669.019kWh	$0.05	$33.45cr		
30% Direct Debit Discount			$88.07cr		
2% Double Up Discount			$5.87cr		
Total credits				-	$127.39cr
Total new charges and credits				=	$293.20
Total GST				+	$32.14
Direct Debit amount (includes GST)				=	$325.34

*Item is not subject to GST. All other items are subject to GST.

Direct Debit amount	$325.34
Direct Debit date	6 Jun 2017
Reference number	4733 8918 9130 7032 10

Post Billpay

*3201 473389189130703210

Sign up to Direct Debit at agl.com.au/Payments or call 131 245.

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