Department of Electrical and

Computer Engineering

ELEC 6421: Renewable Energy Systems

Instructor : Prof. Dr. Pragasen pillay

Design a Wind Energy System to power a House

Team Member name	ID number
Zain Ali Bhinder	[redacted]
Mohsin Hassan	[redacted]

Abstract

The project objective is to design an off-grid wind turbine system having an autonomy of 3-days using battery storage to provide a reliable and sustainable source of electric power. Homer Pro software is used to get the wind speed data for any Longitude and latitude using NASA average wind speed Models and annual load profile is updated in the software. Then converters, batteries and wind turbines are selected based on the wind profile, autonomy and peak load requirements. The wind turbine is selected such that it operates at max output even in the months of low wind speed based on the power vs wind speed curve. Then, cable specification and wiring diagrams required for the wind turbine are calculated and illustrated respectively.

Table of Contents

List of Tables

List of Illustrations

List of Appendices

Chapter 1: Specification and Layout of the House

1.1 Location of the House

The house which we selected for this project is located in [redacted] The specification of the location is given in the Table.1. This house contain 4 bed rooms, one living room, on drawing room and kitchen.

Country	[redacted]
Location	[redacted]
Latitude	[redacted]
Longitude	[redacted]
Time Zone	[redacted]

Table 1.1: Location Coordinates of the House

1.2 Dimensions of the House

The size of the house is given in the Table.2. We put the wind turbine in the backyard and the battery is on the ground floor near the backyard. The Frequency and voltage of the supply is 50Hz and 220V respectively.

Length of the house	***100ft***
Width of the house	*70ft*
Total area of the house	*7000ft*
Total number of rooms in the house	*9*

Table 1.2: Dimensions of House

Ground Floor ***First Floor***

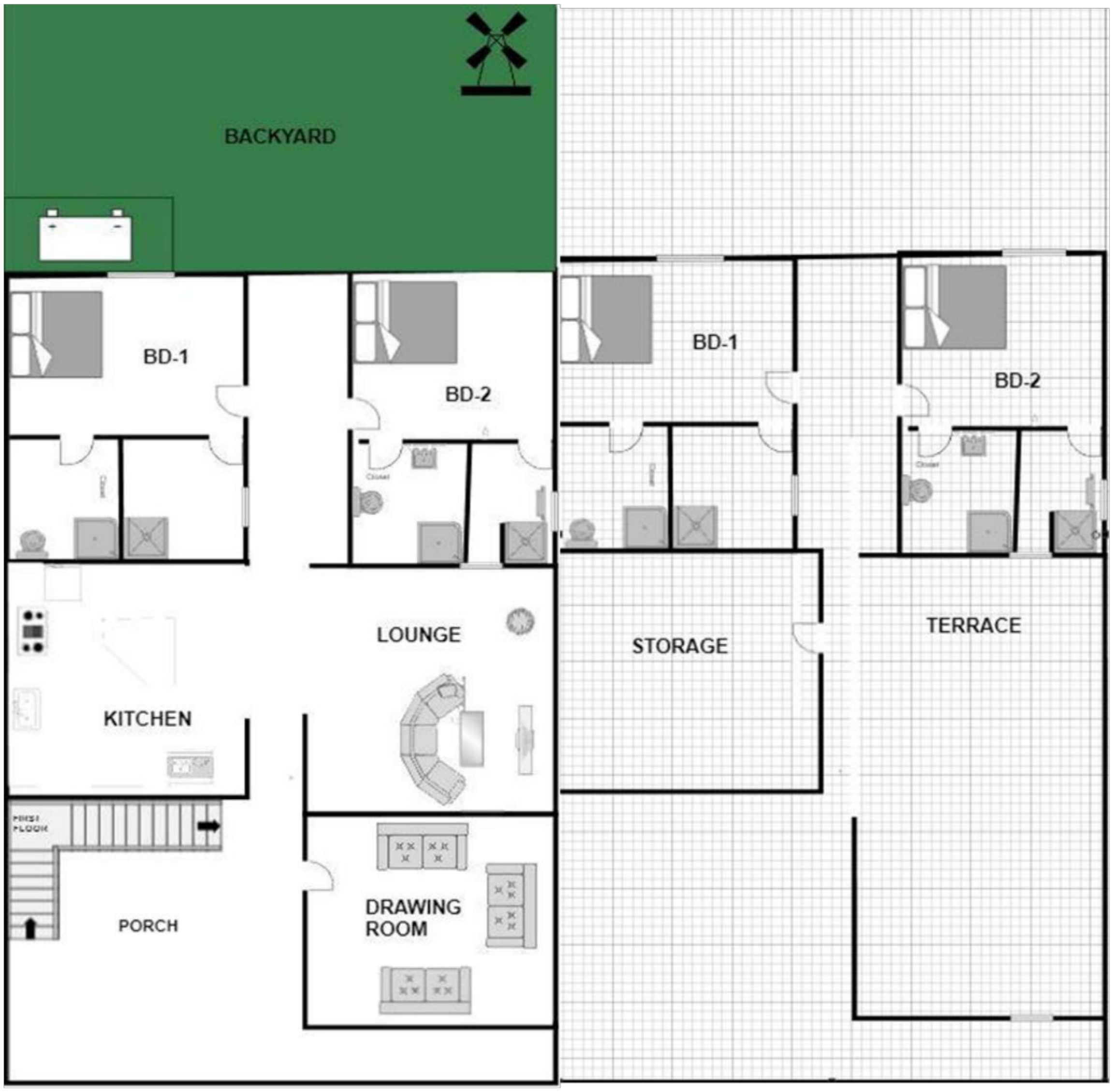


Figure 1.1: Layout of the House

1.3 Specifications of the Loads

There are two floors in the house, the ground floor and first floor. Each Bed room has 14w three LEDs and 1 Fan bathroom light and some miscellaneous loads like mobile charger and laptop charger etc. On the ground floor there are 2 bed rooms, 1- living room and 1 drawing room. Similarly, we have 2-bed rooms 1 terrace and 1 store room on the first floor of the house. In the living room we have 5 LED lights 4 fans and 1 TV. In the kitchen there are 2 LED lights microwave oven and fridge and some other appliances. Beside from all those loads we have 1 washing machine some other additional lights like porch light stairs lights etc. (details in the Table-3).

LOADS	power	current	Hr/day	Ah/day	Ah/week	Kwh/day
BED ROOM 1						
LED LIGHTS (14W)x3	42	0.19	6	1.15	8.0	0.252
Fan	80	0.36	10	3.64	25.5	0.8
Miscellaneous Load (Mobile charger ,Laptop charger)	150	0.68	4	2.73	19.1	0.6
Bathroom Lights	14	0.06	1	0.06	0.4	0.014
BED ROOM 2						
LED LIGHTS (14W)x3	42	0.19	6	1.15	8.0181818	0.252
Fan	80	0.36	9	3.27	22.909091	0.72
Miscellaneous Load (Mobile charger ,Laptop charger)	200	0.91	4	3.64	25.454545	0.8
Bathroom Lights	14	0.06	2	0.13	0.8909091	0.028
BED ROOM 3						
LED LIGHTS (14W)x3	42	0.19	5	0.95	6.68	0.21
Fan	80	0.36	12	4.36	30.55	0.96
Miscellaneous Load (Mobile charger ,Laptop charger)	100	0.45	2	0.91	6.36	0.2
Bathroom Lights	14	0.06	2	0.13	0.89	0.028
BED ROOM 4						
LED LIGHTS (14W)x3	42	0.19	7	1.34	9.35	0.294
Fan	80	0.36	10	3.64	25.45	0.8
Miscellaneous Load (Mobile charger ,Laptop charger)	100	0.45	1	0.45	3.18	0.1
Bathroom Lights	14	0.06	2	0.13	0.89	0.028
Living Room						
LED Lights (14W x5)	70	0.32	4	1.27	8.91	0.28
Fan x4	320	1.45	3	4.36	30.55	0.96
TV	100	0.45	2	0.91	6.36	0.2
Drawing Room						
LED Lights (14W x 6)	84	0.38	1	0.38	2.67	0.084
Fan(80Wx3)	240	1.09	2	2.18	15.27	0.48
Kitchen						
LED Lights (14Wx2)	28	0.13	5	0.64	4.5	0.14
Microwave oven	1000	4.55	5	22.73	159.1	5
Fridge 400W	400	1.82	14	25.45	178.2	5.6
Other appliances	200	0.91	1.5	1.36	9.5	0.3
Others Loads						
Washing Machine	500	2.27	1	2.27	15.91	0.5
Backyard Outdoor Light	14	0.06	2	0.13	0.89	0.028
Iron	1000	4.55	1	4.55	31.82	1
Porch Light (14W) x 2	28	0.13	11	1.40	9.80	0.308
Stairs Light (14W) x 2	28	0.13	11	1.40	9.80	0.308
Store light (14W)	14	0.06	1.5	0.10	0.67	0.021
Lobby Light (14W) x 3	42	0.19	7	1.34	9.35	0.294
Terrace light (14W) x 2	28	0.13	5	0.64	4.45	0.14
total	5190	23.59	160	98.77	691.4	21.729

Table 1.3:Specifications of the House Load

Chapter 2: Battery Specification and Sizing

2.1 Size and Specification of the Battery

In the phase 1 of this project, layout and location of the house was described along with the specifications of the load. Considering a Power factor of 0.9, the daily consumption in the house in terms of power is 5.190KW and energy is 24.143 kWh/day respectively. In real work practice, we have to consider efficiency and the losses suffered across different components which make up the wind energy system to power a house. For these reasons, efficiency of following components is assumed as such:

Component	Efficiency (η)
Battery Depth of Discharge (DOD)	80%
Wiring	98%
Battery Charge/Discharge Capability	90%
Inverter	92%

Table 2.1: Efficiency of different Components

Corrected Load is as follows:

$$\text{Corrected Load} = \frac{Load\ in\ Ah}{\eta_{wiring} \times \eta_{battery} \times \eta_{inverter}} = \frac{109.745}{0.98 \times 0.9 \times 0.92} \tag{2.1}$$

$$\text{Corrected Load} = 135.247\ \text{AH}$$

Battery specification is one of the most significant parts of the wind turbine design for a house. In our case, 48V system is chosen since it is easier scale to accommodate large wind turbine as compared to 12 or 24 V system.

For this project, it is assumed that there would be three no-wind days so battery bank must have an autonomy of three days to supply load continuously during that time period.

$$\text{Battery Capacity} = \frac{Corrected\ Load\ \times Autonomy\ \times Con\ factor}{DOD} \tag{2.2}$$

$$\text{Battery Capacity}\ = \frac{135.247\ \times 3 \times 4.58}{0.8} = 2324.5\ AH$$

Another alternate method to calculate the battery is given below:

$$\text{Battery Capacity} = \frac{Wh\ \times Autonomy}{V_{bat}\ \times\ \eta_{wiring} \times \eta_{battery} \times \eta_{inverter}\ \times DOD} \tag{2.3}$$

$$\text{Battery Capacity}\ = \frac{24143\ \times 3}{48 \times 0.8 \times 0.98 \times 0.9 \times 0.92} = 2324.5\ AH$$

Since the total battery capacity required is 2324.5AH-48V, so using homer software, **Discover AES 6.65kWh 48VDC** is selected. The reason for choosing this is that it is a lithium Iron Phosphate based battery with a round trip efficiency of 95% and lifetime is 38Mwhwithin 10 years. Max discharge current is 300Adc, which gives it a maximum discharge power of 14.4KW.

The number of batteries required for the load are given below:

$$\text{No. of Batteries} = \frac{Backup\ Battery\ Capacity}{Single\ Battery\ Capacity} = \frac{2324.5\ Ah}{130\ Ah} \tag{2.4}$$

$$\text{No. of Batteries} = 17.88\ \approx 18$$

So these 18 batteries would be connected in parallel so that combine capacity amounts to 2340 AH which can supply load during the 3-day no-wind period. The configuration layout of the batteries is given below:

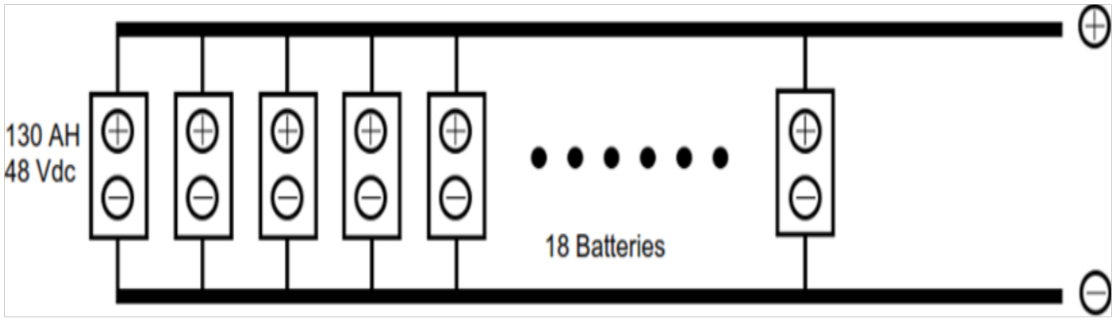


Figure 2.1: Configuration for Battery Pack

The datasheet of the battery is given in appendix.

Chapter 3: Converter Specification

3.1 Converter Specification

An inverter must convert the DC supply from the battery Bank to AC supply which is utilized by the loads in the house during the no wind days. Moreover, it will be required to charge the batteries when the loads will be fully dependent on the wind turbine. In our case, the house has a peak load of 5190 W at 220V 50Hz. According NEC, safety factor of 25-30% should be used for inverter so in our case, a safety factor of 25% is selected.

$$\text{Required Inverter Power} = \frac{KW \times Safety\ factor}{Inverter\ Efficiency} = \frac{5190 \times 1.25}{0.92} \qquad (3.1)$$

$$\text{Required Inverter Power} = 7051.63\ \text{W}$$

As per calculations, approximately 7052 W is required. Studer Xtender XTH 8000-48 is selected which can supply 7000VA of continuous power and 8000VA power for 30 min and an excessive short burst of 21kVA for 3 sec. This system can be used as an off-grid, on-grid or hybrid system depending on the requirements. It can charge the batteries at 120A and can supply a maximum of 50A current which is more than our calculated max current of 26.21A.

The datasheet of inverter is given in Appendix.

Chapter 4: Wind Turbine Specification

4.1 Wind Resource

The longitude and latitude of the selected destination is 24.946218, (24 deg 56 min) Longitude 67.005615 (67 deg 00 min) respectively. This longitude and latitude is fed into the homer software and monthly average wind speed at 50m above the surface of the earth over a 30 year period (Jan 1984-Dec 2013) is downloaded from the NASA Prediction of Worldwide Energy Resource (Power) database. The average wind speed with respect to different months is given below:

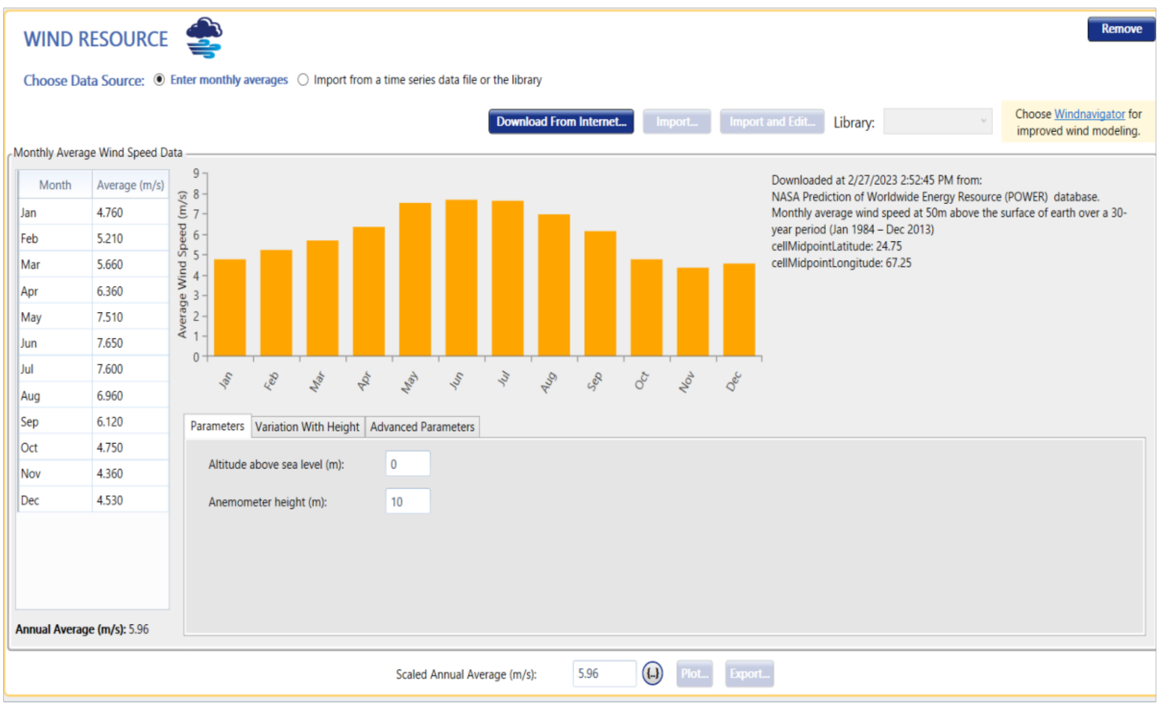


Figure 4.1: Monthly Average Wind Speed Data

4.2 Wind Turbine Selection

The annual average wind speed at the selected location is 5.96 m/s roughly equivalent to 6 m/s/ annually. The highest average wind speed ranging from 6.12-7.65 m/s is during the months of summer when there is peak load demand. Based on the average wind speed data, a wind turbine suitable can be selected. This can be achieved through by looking the Wind Turbine Power curve of different commercially available wind turbines and selecting the one most ideal in this situation by which maximum energy can be harvested. EOcycle EO10 whose Wind turbine Power Curve is given below:

Wind Speed (m/s)	Power Output (kW)
2.75	0.02
3	0.4
3.5	1.2
4	2.4
4.5	3.7
5	5.5
5.5	7.5
6	10.0
6.5	11.5
7	11.5
7.5	11.5
8	11.5
8.5	11.5
9	11.5

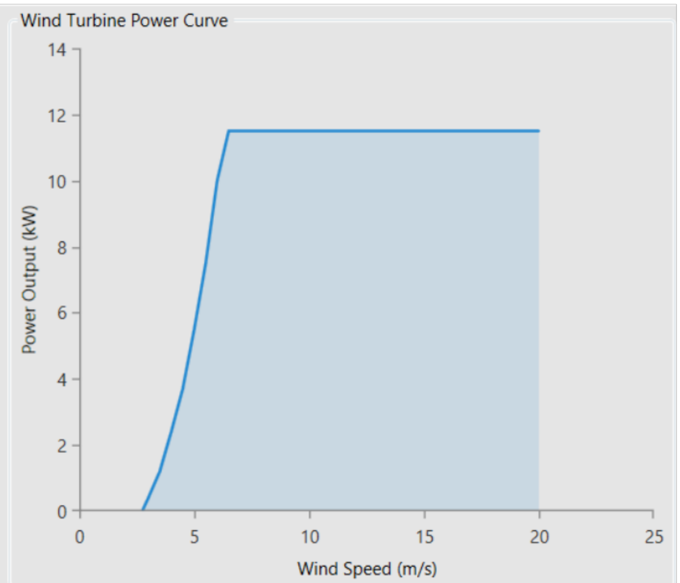


Figure 4.2: Wind Turbine Power Curve for Power (KW) Vs Wind Speed(m/s)

As can be seen from the Wind Turbine power curve, it provides rated output power of 10KW at a wind speed of 6m/s and even exceeds that in case of higher wind speed up to 11.5 KW. In our case, average wind speed annually is 6 m/s which is suitable to be employed.

Now, required rate of production by the wind turbine will be calculated as follows:

$$Rate\ of\ Production = \frac{Corrected\ Load\ in\ Ah/week}{4\ Day/week} = \frac{946.729}{96} = 9.862\ A \qquad (4.1)$$

For calculations of power, following parameters are taken:

Parameter	Value
Air Density (ρ)	1.225 kg/m^3
Coefficient of Performance (C_p)	0.44 at 6 m/s
Average Wind Speed (V)	5.96
D is diameter of Blade (D)	11.7 m
Efficiency (η)	0.8

Table 4.1: Parameters and their values used for calculating Power

$$Power = \frac{3}{4}\rho\eta C_p V^3 D^2 = \frac{3\ \times 1.225 \times\ 0.7\ \times\ 0.44\ \times 5.96^3 \times 11.7^2}{4} = 8201\ W \quad (4.2)$$

4.3 EOcycle EO10 Wind turbine Characteristics

The detailed diagram of the EO10 wind turbine is given below which illustrates all of the major systems used in the turbine. Specifications of each of these sub-systems will be discussed afterwards.

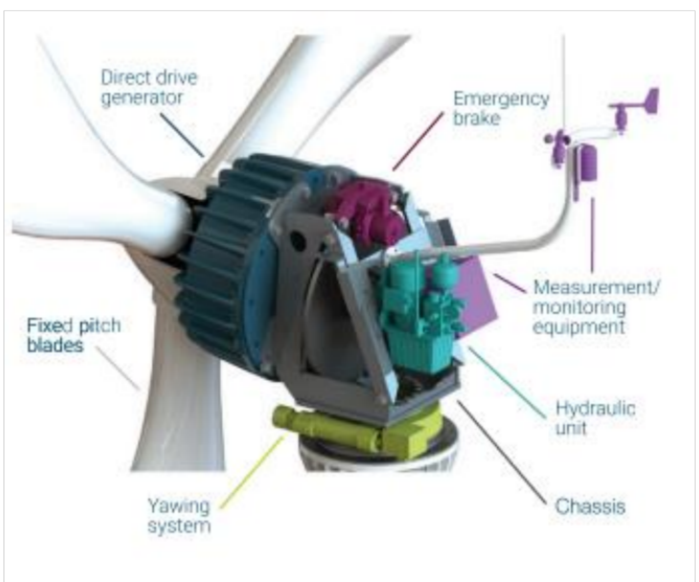


Figure 4.3: Detail Diagram of EO10 Wind Turbine along with all Sub-systems

4.3.1 Major Characteristics

The characteristics and their specifications are given below:

	Characteristics	Specifications
Main Data	Rate Power	10KW
	Rated Annual Average Wind Speed	6 m/s (21.6 km/h)
	Cut-in Wind Speed	2.75 m/s (10 km/h)
	Cut-out Wind Speed	20 m/s (72 km/h)
	Extreme Wind Speed	52.5 m/s (189 km/h), 3-sec Average
	Operating Temperature	-20 to 40°C
	Design Life	30 Years
	Certifications	IEC 61400-2, AWEA 9.1, UL1741,CE, CSA 22.2, G59/3

Table 4.2: Main characteristics of EO10 Wind turbine

4.3.2 Control and Electrical System:

The control and electrical system characteristics are given in the below table:

	Characteristics	Specifications
Control & Electrical System	Generator	EOcycle Transverse Flux Synchronous Permanent Magnet
	Generator Characteristics	10KW @90 rpm, 45.45A Continuous duty,1.15 SF, Passively air-cooled
	Power Converter and Controls	PLC-based utility interactive unit for power management, turbine control and monitoring
	Power Converter Specifications	10KW, 220V, 50HZ, 45.45A
	UI	LCD Touch Screen
	Lightning Protection	Blade-integrated Mesh, Lightning Rod on Nacelle and Electrical Surge Protectors

Table 4.3: Electrical and Control System Characteristics and their Specification

4.3.3 Rotor and Blades

The braking system characteristics are given in the below table:

	Characteristics	Specifications
Rotor & Blades	Rotor Diameter	11.7 m
	Rotor Swept Area	107.5 m^2
	Hub Type	Fixed Pitch
	Number of Blades	3
	Blade Length	5.6 m
	Blade Material	Epoxy/Glass Fiber Composite

Table 4.4: Rotor and Blade Characteristics including their specifications

4.3.4 Braking System

The characteristics of Braking System are given Below:

	Characteristics	Specifications
Braking System	Normal Shutdown	Generator Stall, Yaw Assisted
	Emergency Shutdown	Generator stall with resistors, Yaw and Disk-brake assisted
	Emergency Rotor Brake-Type	Fail-safe Hydraulic Disk Brake

Table 4.5: Characteristics of braking system

4.3.5 YAW system

The specifications of YAW system of EO10 turbine are given below:

	Characteristics	Specifications
Yaw System	Type	Active Electro mechanical
	Controls	PLC with wind directions/speed sensors, automatic Cable unwind

Table 4.6: Characteristics and Specifications of YAW System

4.3.6 Towers

The available heights of the YAW system are given below:

	Characteristics	Specifications
Towers	Type	Tubular hot-dip galvanized monopole with work platform, climbing step bolts and safety climbing cable
	Heights	16.8, 23.8, 30 or 36 m

Table4.7: specifications of Towers used in the Wind Turbine

4.4 Homer Implementation:

The load calculation was done in phase 1 and then battery and inverter specification was done in phase 2 and in the phase 3, suitable wind turbine is chosen. All of the data is used and implemented on the Homer Pro software.

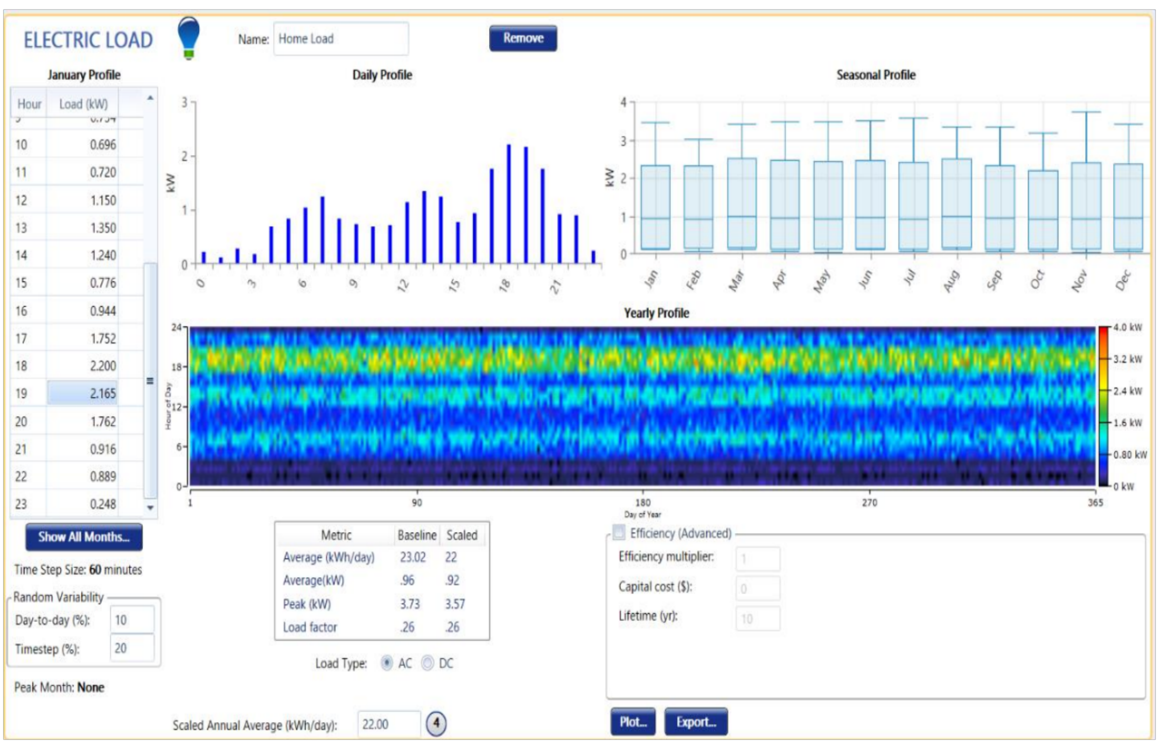


Figure 4.4: Electric Load Calculated in Phase 1

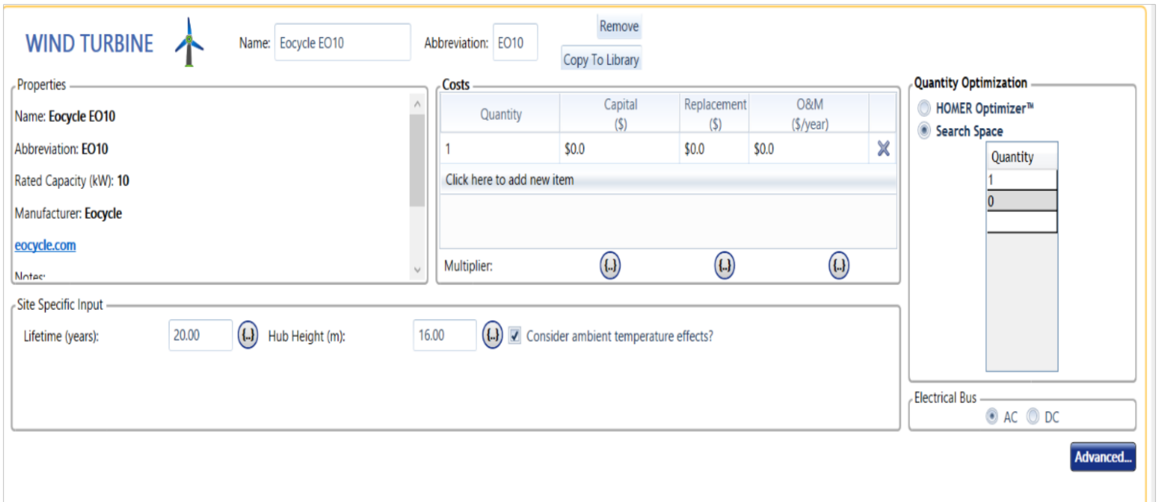


Figure 4.5: Selected Wind Turbine Based on the Power Curve Characteristics

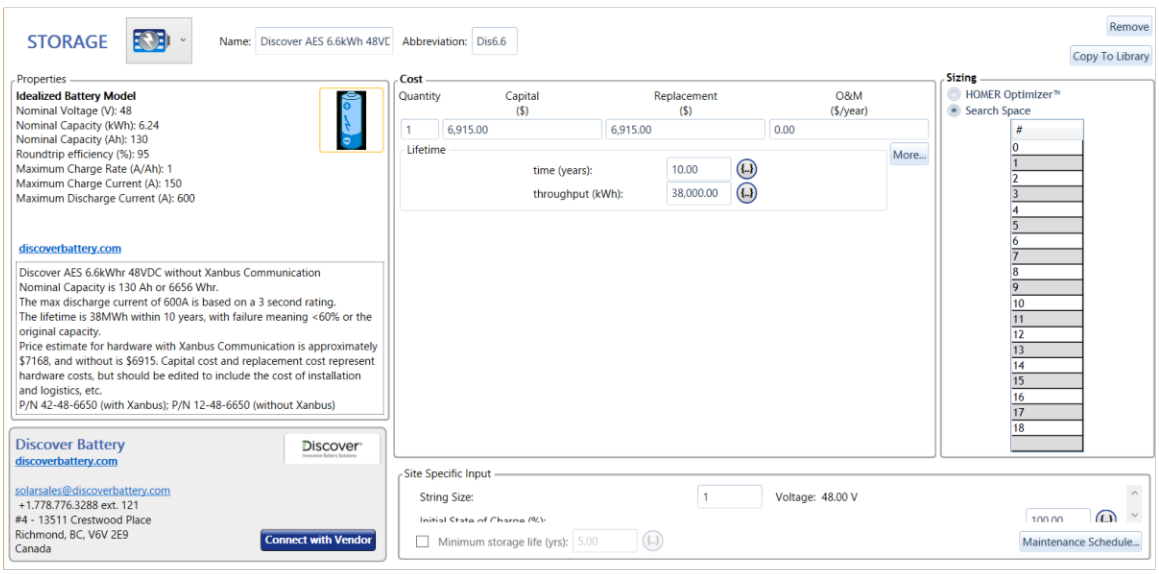


Figure 4.6: Storage calculated in the phase 2

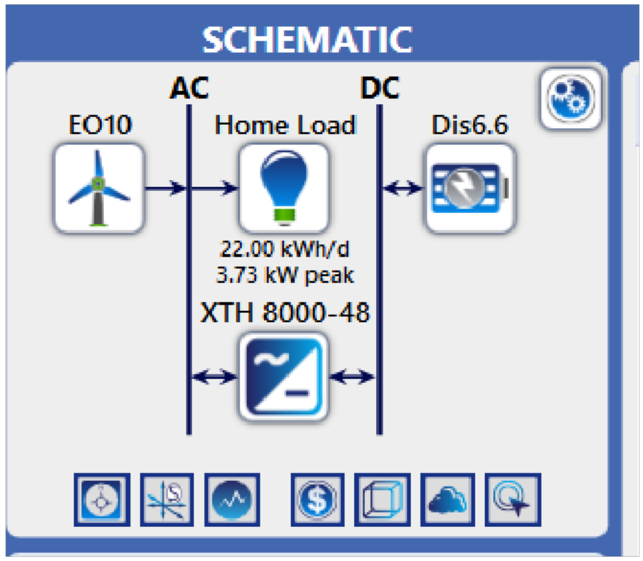


Figure 1.7: Schematic of selected Wind Turbine, Storage, Inverter and Home Load in Homer pro

Chapter 5: Cable Specifications

5.1 Cable Size and Length

The size and the length of the cables required is determined by the power output of the wind turbine. Since output power according to the wind conditions which includes losses as well has been accounted into, so this could be accomplished in this step. Selection of correct size of the wire also enhances the overall performance, reliability and safety of the system. The selection of the cable size is based upon the following factors:

5.1.1 Current carrying Capacity

The current carrying capacity of a cable is the amount of electrical current that the cable can safely carry without exceeding its temperature rating. If a cable is undersized then in that case, it might overheat and become a cause of fire. The National Electrical Code (NEC) publishes tables listing the specific requirements for the cable ampacity based on the conductor size is given below:

AWG	Diameter		Turns of wire, no insulation		Area	
	(in)	(mm)	(per in)	(per cm)	(kcmil)	(mm^2)
0000 (4/0)	0.4600	11.684	2.17	0.856	212	107
000 (3/0)	0.4096	10.405	2.44	0.961	168	85.0
00 (2/0)	0.3648	9.266	2.74	1.08	133	67.4
0 (1/0)	0.3249	8.251	3.08	1.21	106	53.5
1	0.2893	7.348	3.46	1.36	83.7	42.4
2	0.2576	6.544	3.88	1.53	66.4	33.6
3	0.2294	5.827	4.36	1.72	52.6	26.7
4	0.2043	5.189	4.89	1.93	41.7	21.2
5	0.1819	4.621	5.50	2.16	33.1	16.8
6	0.1620	4.115	6.17	2.43	26.3	13.3
7	0.1443	3.665	6.93	2.73	20.8	10.5
8	0.1285	3.264	7.78	3.06	16.5	8.37

Table 5.1: Diameter and Cross-section Table for AWG

AWG	Weight	Copper resistance		NEC copper wire ampacity with 60/75/90 °C insulation (A)
	lb/1000 ft	(??/km) (m??/m)	(??/kft) (m??/ft)	
0000 (4/0)	640.5	0.1608	0.04901	195 / 230 / 260
000 (3/0)	507.9	0.2028	0.06180	165 / 200 / 225
00 (2/0)	402.8	0.2557	0.07793	145 / 175 / 195
0 (1/0)	319.5	0.3224	0.09827	125 / 150 / 170
1	253.5	0.4066	0.1239	110 / 130 / 150
2	200.9	0.5127	0.1563	95 / 115 / 130
3	159.3	0.6465	0.1970	85 / 100 / 110
4	126.4	0.8152	0.2485	70 / 85 / 95
5	100.2	1.028	0.3133	
6	79.46	1.296	0.3951	55 / 65 / 75
7	63.02	1.634	0.4982	
8	46.97	2.061	0.6282	40 / 50 / 55

Table 5.2: Copper Ampacity and Resistance for AWG

5.1.2 Voltage Drop

Voltage regulation can impact the sizing of cable by influencing the allowable voltage drop and thus, the required size of cable to maintain acceptable voltage levels for electrical equipment. The NEC specifies a 5% limit if voltage drop for electrical power systems.

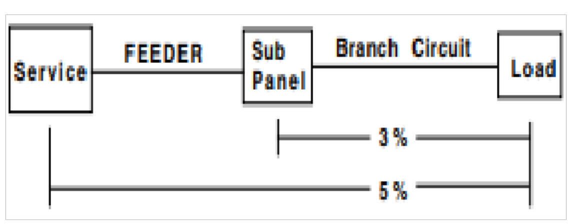


Figure 5.1: Acceptable Voltage drop across branch circuit

5.1.3 Power Loss

The selected cable size should be checked for power less and it should be less than 5%. These losses result due to I2R losses.

5.2 Calculation

The length and current must be known to correctly to determine the voltage drop across the given cable. To determine the voltage across cable coming from the wind turbine to the converter, the calculations are given below:

5.2.1 Wind Turbine to Converter

According to NEC standards, the voltage drop across feeder should be less than 5% and for branch circuits should be less than 3%. The parameters used for calculating the resistance across AC cable from turbine to converter is given below:

$$Load\ Current\ = \frac{KW}{PF\ \times V} = \frac{8201}{0.9\ \times 220} \tag{5.1}$$

$$Load\ Current = 41.41\ A$$

After calculating the load current, resistance would be calculated to compensate for temperature given by:

$$R\ = R_{ref}\left[1 + \alpha_{20}\left(T - T_{ref}\right)\right] = 0.48\ \Omega/kft \tag{5.2}$$

Where

R_{ref} at 20°C = 0.3951 Ω/kft from table

α_{20} at 20°C = 0.00393 K^{-1}

T_{ref} = 20 °C

T = 75 °C

Based on the load current, Calmont wire and cable AWG 6 (16 mm^2) is chosen from the table 1 as the suitable for the required application. The reactance for AWG 6 is chosen from the table given in appendix which is given below:

$$X = \frac{0.112}{3.28} = 0.0341\ \Omega/kft \tag{5.3}$$

$$Voltage_{drop} = \frac{2.I.l.(Rcos\phi + xsin\phi)}{1000}$$

$$= \frac{2 \times 41.41\ \times 120\ (0.387 + 0.0146)}{1000}$$

$$Voltage_{drop} = 3.99\ V$$

Where

PF = 0.9

X = 0.0341 Ω/kft

R = 0.48 Ω/kft

I = 41.41 A

L = 120 ft

$$\%Voltage_{drop} = \frac{3.99}{220} \times 100 = 1.8\% \tag{5.4}$$

$$Power_{loss} = 2.l.R.I^2 = 2 \times 120 \times \frac{0.387}{1000} \times 41.41^2 = 159.26\ Watt$$

$$\%Power_{loss} = \frac{159.26}{8201} \times 100 = 1.94\%$$

The voltage drop across it is **1.88%** which falls under 3% for branch circuits as per NEC standards. Also, the load current is less than for the selected gauge. Power loss is found to be 1.94% which is less than the maximum limit of 5%. Calmont wire and cable AWG 6 is selected.

5.2.2 Converter to Batteries

The voltage drop across cables connecting converter and batteries is given by:

$$Load\ Current\ = \frac{KW}{V} = \frac{8201}{48} = 170\ A$$

For these cables, AWG 3/0 cable is selected according to the load current requirement.

$$Voltage_{drop}\ = \frac{2.I.l.R}{1000} = \frac{2 \times 170\ \times 20\ (0.0719)}{1000} \quad (5.5)$$

$$Voltage_{drop} = 0.48\ V$$

Where

L = 20 ft

R = 0.0719 Ω/kft from table in appendix

$$\%Voltage_{drop}\ = \frac{0.48}{220} \times 100\ = 0.22\% \quad (5.6)$$

$$Power_{loss}\ = \ 2.l.R.I^2\ = 2 \times 20 \times \frac{0.0719}{1000} \times 170^2 = 83.1\ Watt$$

$$\%Power_{loss} = \frac{83.1}{8201} \times 100\ = 1.01\%$$

Voltage drop comes about to be 1.33% which falls under the condition of less than 2% for DC branch circuits. Also load current is less than the ampacity. So the power loss also falls with the required parameters. Calmont wire and cable AWG 3/0 is selected.

5.2.3 Converter to House Load

The AWG 6 is selected for this purpose. The calculation for this are given below:

$$X = \frac{0.112}{3.28} = 0.0341\ \Omega/kft \tag{5.7}$$

$$Voltage_{drop} = \frac{2.I.l.(Rcos\phi + xsin\phi)}{1000} = \frac{2 \times 41.41 \times 20\ (0.387 + 0.0146)}{1000}$$

$$Voltage_{drop} = 0.66\ V$$

Where

PF = 0.9

X = 0.0341 Ω/kft

R = 0.48 Ω/kft

I = 41.41 A

L = 20 ft

$$\%Voltage_{drop} = \frac{0.66}{220} \times 100 = 0.3\% \tag{5.8}$$

$$Power_{loss} = 2.l.R.I^2 = 2 \times 20 \times \frac{0.387}{1000} \times 41.41^2 = 26.54\ Watt$$

$$\%Power_{loss} = \frac{26.54}{8201} \times 100 = 0.32\%$$

The percentage voltage drop falls under the NEC regulations of under 3% for branch circuits. Power loss is calculated as 0.32% which is less than the maximum limit of 5%. Calmont wire and cable AWG 6 is selected.

Chapter 6: Wiring Diagrams

6.1 Detailed Wiring Diagram

The detailed wiring diagram for the off-wind wind turbine with battery storage is given below:

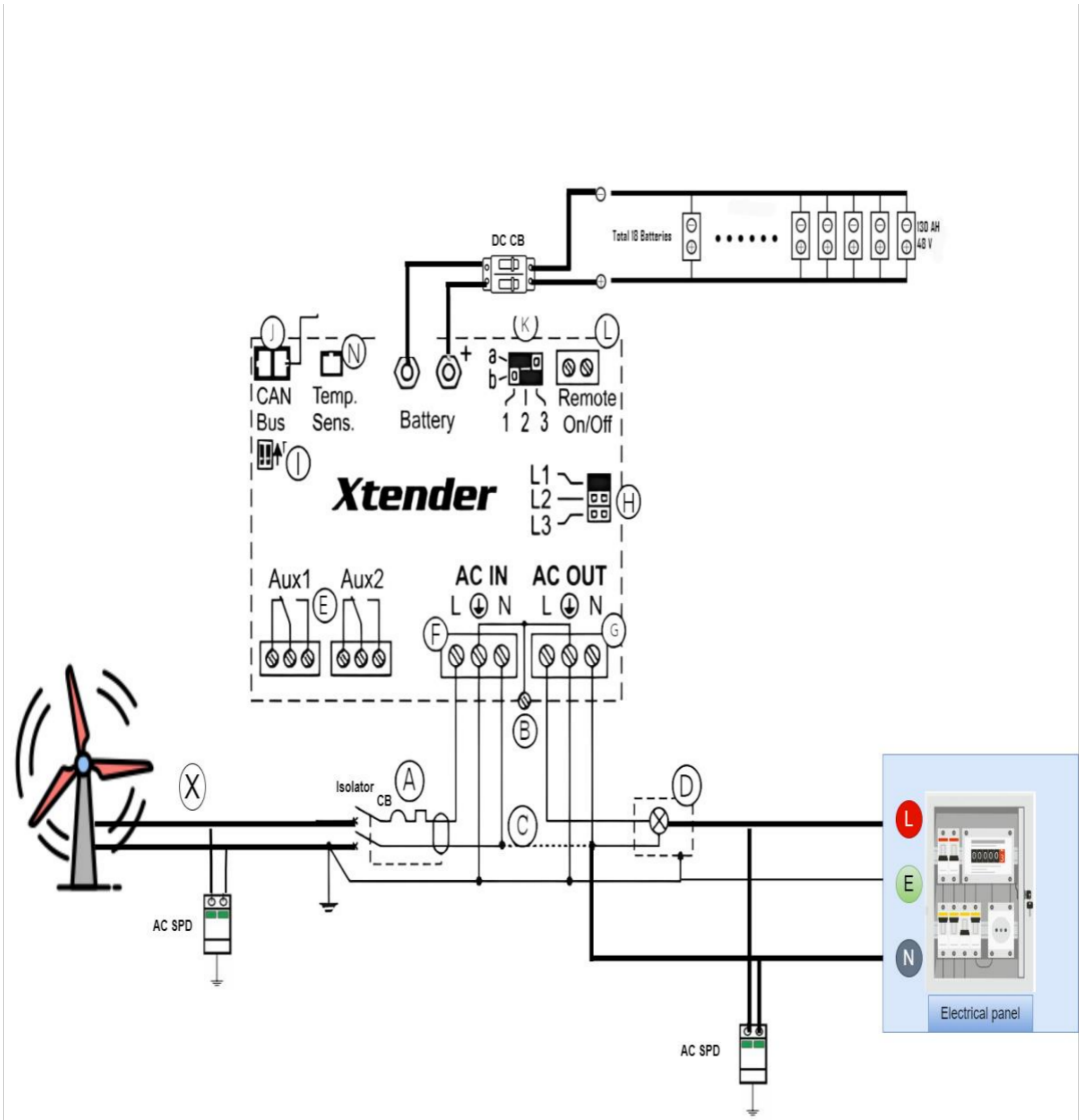


Figure 6.1: Detailed Diagram for Wiring

Figure Elements

Element	Description	Comment
A	Differential Circuit Breaker	The protection device can be installed downstream of the source
B/G	Output Supply	AC 240V 50 Hz is the output given through this terminal.
C	Connect of Neutrals	In a fixed installation where the neutral is connected to the earth at a single installation point upstream of the Xtender, it is permissible to carry out a connection of the neutrals in order to preserve an unchanged earthing system downstream, independent of the operating mode of the Xtender.
D	Electrical Panel	AC output out of the converter is connected with the electrical panel.
E	Aux Contact	Auxiliary contact for use with module ARM-2
F	AC IN	Input power supply from the source
H	Phase Jumper	Phase selection jumper with default at L1 position
I	Open/Terminated	Switch for terminating the communication bus.
J	Comm Bus	Double connector communication bus
K	jumper	Jumper for programming on/off switch by dry contact
L	Command Entry	Remote command module entry
N	Temp sens	Connector for the battery temperature sensor
X	Regulated voltage	Voltage regulated by ABB ACS800-11 installed inside wind turbine to AC supply 220V 50Hz.

Appendices

Appendix A

A.1 Datasheet for Discover AES 6.65kWh 48VDC Battery

48-6650 TECHNICAL SPECIFICATIONS

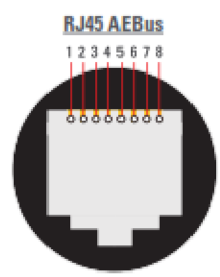
Discover
Innovative Battery Solutions

Electrical Specifications		
Nominal Voltage		51.2 V
Charge Voltage		54.4 V
Maximum Voltage		58.4 V
Minimum Voltage		40 V
Nominal Capacity		130 Ah
Nominal Energy		6656 Wh
Max Continuous Charge Current		130 Adc
Max Continuous Discharge Current		130 Adc
Fuse - Provides backup over-current protection	Hardware 0.0.0.1	150 A
	Hardware 0.0.0.2	200 A
Cell Chemistry		$LiFePO_4$
Cell Modules		16S 26P
Self-Discharge 25°C / 77°F		< 3% per month (battery off)

Fault Limits	
Over Temperature - Discharge Protection	> 60°C/140°F for 5s
Over Temperature - Charge Protection	> 60°C/140°F for 5s
Low Temperature - Discharge Protection	< -20°C/-4°F for 5s
Low Temperature - Charge Protection	< 0°C/32°F for 5s
Over Voltage Protection	> 3.65 V in any cell module for 5s
Under Voltage Protection	< 2.5 V in any cell module for 5s
Over Current Protection	Based on Fuse (Section 2.2)

Mechanical Specifications	
Battery Dimensions (HxWxD)	375 x 347.5 x 471.5 mm
Battery Weight	87 kg
Shipping Dimensions (HxWxD)	570 x 440 x 570 mm
Shipping Weight	98.9 kg
Terminal	M8
Terminal Hardware	M8 Stainless Steel Bolt, Flat Washer, Lock Washer (Supplied)
Terminal Torque	9.0 Nm +/- 3
Case Material	Powder Coated Cold Rolled Steel
Enclosure IP Rating	IP 55
Charge Temperature Range	0°C/45°C (32°F/113°F)
Discharge Temperature Range	-20°C/50°C (-4°F/122°F)
Storage Temperature Range	-20°C/45°C (-4°F/113°F)

Operational Specifications	
Battery Management System (BMS)	Integrated, with Solid State Relay (SSR)
Cell Balancing	Passive balancing when Cell Voltage > 3.35 V
Non-Volatile Memory	Yes
Lifetime Logged Data	• Time • High/low average cell module voltage • Balancing, Fault and Relay State • Battery SOC, Current, Voltage, Temperature • Charge Energy In/Out
Communication Ports	• Isolated USB • Isolated CAN (AEBus) • Isolated XANBUS
Communication Connectors	USB Type A Female RJ45 Jack x2



Pin 1*	AEBus +12 V
Pin 2*	AEBus +12 V
Pin 3	AEBus GND
Pin 4	AEBus CAN Low
Pin 5	AEBus CAN High
Pin 6	AEBus +5V
Pin 7*	AEBus GND
Pin 8*	AEBus GND

*0.0.0.2 Hardware only

Regulatory Approvals	UN 38.3, IEC62133, UL 2271, UL 1973

UN38.3 PASSED
TRANSPORT SAFETY CERTIFIED

FUNCTIONAL SAFETY c UL us LISTED

FUNCTIONAL SAFETY c UL us LISTED

A.2 Datasheet for Inverter Xtender XTH 8000-48

Xtender series

Model	XTS 900-12	XTS 1200-24	XTS 1400-48	XTM 1500-12	XTM 2000-12	XTM 2400-24	XTM 2600-48	XTM 3500-24	XTM 4000-48	XTH 3000-12	XTH 5000-24	XTH 6000-48	XTH 8000-48
Inverter													
Nominal battery voltage	12Vdc	24Vdc	48Vdc	12Vdc		24Vdc	48Vdc	24Vdc	48Vdc	12Vdc	24Vdc	48Vdc	
Input voltage range	9.5 - 17Vdc	19 - 34Vdc	38 - 68Vdc	9.5 - 17Vdc		19 - 34Vdc	38 - 68Vdc	19 - 34Vdc	38 - 68Vdc	9.5 - 17Vdc	19 - 34Vdc	38 - 68Vdc	
Continuous power @ 25°C	650**/500VA	800**/650VA	900**/750VA	1500VA	2000VA	2000VA	2000VA	3000VA	3500VA	2500VA	4500VA	5000VA	7000VA
Power 30 min. @ 25°C	900**/700VA	1200**/1000VA	1400**/1200VA	1500VA	2000VA	2400VA	2600VA	3500VA	4000VA	3000VA	5000VA	6000VA	8000VA
Power 5 sec. @ 25°C	2.3kVA	2.5kVA	2.8kVA	3.4kVA	4.8kVA	6kVA	6.5kVA	9kVA	10.5kVA	7.5kVA	12kVA	15kVA	21kVA
Maximum load	Up to short-circuit												
Maximum asymmetric load	Up to Pcont.												
* Load detection (stand-by)	2 to 25 W												
Cos φ	0.1-1												
Maximum efficiency	93%	93%	93%	93%		94%	96%	94%	96%	93%	94%	96%	
Consumption OFF/Stand-by/ON	1.1W/1.4W/7W	1.2W/1.5W/8W	1.3W/1.6W/8W	1.2W/1.4W/8W	1.2W/1.4W/10W	1.4W/1.6W/9W	1.8W/2W/10W	1.4W/1.6W/12W	1.8W/2.1W/14W	1.2W/1.4W/14W	1.4W/1.8W/18W	1.8W/2.2W/22W	1.8W/2.4W/30W
* Output voltage	Pure sine wave 230Vac (±2%) / 120Vac (1)												
* Output frequency	45Hz - 60Hz (1) ± 0.05% (crystal controlled)												
Harmonic distortion	<2%												
Overload and short-circuit protection	Automatic disconnection with 3 time restart attempt												
Overheat protection	Warning before shut-off - with automatic restart												
Battery charger													
* Charge Characteristic	6 steps: Bulk-Absorption-Floating-Equalization-reduced floating-periodic absorption Number of steps, thresholds, end current and times completely adjustable with the RCC-02/-03												
* Maximum charging current	35A	25A	12A	70A	100A	55A	30A	90A	50A	160A	140A	100A	120A
* Temperature compensation	With BTS-01 or BSP 500/1200												
Power Factor Correction (PFC)	EN 61000-3-2												
General data	**XTS 900-12**	**XTS 1200-24**	**XTS 1400-48**	**XTM 1500-12**	**XTM 2000-12**	**XTM 2400-24**	**XTM 2600-48**	**XTM 3500-24**	**XTM 4000-48**	**XTH 3000-12**	**XTH 5000-24**	**XTH 6000-48**	**XTH 8000-48**
* Input voltage range	150 to 265Vac / 50 to 140Vac (1)												
Input frequency	45 to 65Hz												
Input current max. (transfer relay) / Output current max.	16Aac/20Aac			50Aac/56Aac									50Aac/80Aac
Transfer time	<15ms												
Multifunction contacts	Module ARM-02 with 2 contacts, in option			2 independent contacts (potential free 3 points, 16Aac/5Adc)									
Weight	8.2 kg	9 kg	9.3 kg	15 kg	18.5 kg	16.2 kg		21.2 kg	22.9 kg	34 kg	40 kg	42 kg	46 kg
Dimension hxwxl [mm]	110x210x310			133x322x466						230x300x500			
Protection index	IP54			IP20									
Conformity	Directive EMC 2004/108/EC: EN 61000-6-1, EN 61000-6-3, EN 55014, EN 55022, EN 61000-3-2, 62040-2 Low voltage directive 2006/95/EC: EN 62040-1-1, EN 50091-2, EN 60950-1												
Operating temperature range	-20 to 55°C												
Relative humidity in operation	100%			95% without condensation									
Ventilation	Optional cooling module ECF-01			Forced from 55°C									
Acoustic level	<40dB / <45dB (without/with ventilation)												
Warranty	5 years												
Accessoires													
Remote control RCC-02 or RCC-03	•	•	•	•	•	•	•	•	•	•	•	•	•
Module XCOM-232i	•	•	•	•	•	•	•	•	•	•	•	•	•
Internet based communication sets Xcom-LAN, Xcom-GSM	•	•	•	•	•	•	•	•	•	•	•	•	•
Remote Control Module RCM-10 (3 m)	•	•	•	•	•	•	•	•	•				
2 aux. contacts module ARM-02	•	•	•										
Cooling Module ECF-01	•	•	•										
Battery temp. sensor BTS-01 (3 m)	•	•	•	•	•	•	•	•	•	•	•	•	•
Communication cable for 3ph and // CAB-RJ45-8-2	•	•	•	•	•	•	•	•	•	•	•	•	•
Mounting frame X-Connect										•	•	•	•

v 1.2.0

* Adjustable with the RCC-02/-03 ** These features are valid only when using the cooling module ECF-01. (1) With -01 at the end of the reference, means 120V/60Hz. Available for all Xtenders except XTH 8000-48 Data may change without any notice.

A.3 Resistance and Reactance per Unit of length of copper cables (ABB Electrical Handbook)

2.2 Installation and dimensioning of cables

2 Protection of feeders

Table 1: Resistance and reactance per unit of length of copper cables

S [mm²]	single-core cable r[Ω/km] @ 80 [°C]	single-core cable x[Ω/km]	two-core/three-core cable r[Ω/km] @ 80 [°C]	two-core/three-core cable x[Ω/km]
1.5	14.8	0.168	15.1	0.118
2.5	8.91	0.156	9.08	0.109
4	5.57	0.143	5.68	0.101
6	3.71	0.135	3.78	0.0955
10	2.24	0.119	2.27	0.0861
16	1.41	0.112	1.43	0.0817
25	0.889	0.106	0.907	0.0813
35	0.641	0.101	0.654	0.0783
50	0.473	0.101	0.483	0.0779
70	0.328	0.0965	0.334	0.0751
95	0.236	0.0975	0.241	0.0762
120	0.188	0.0939	0.191	0.074
150	0.153	0.0928	0.157	0.0745
185	0.123	0.0908	0.125	0.0742
240	0.0943	0.0902	0.0966	0.0752
300	0.0761	0.0895	0.078	0.075

Table 2: Resistance and reactance per unit of length of aluminium cables

S [mm²]	single-core cable r[Ω/km] @ 80 [°C]	single-core cable x[Ω/km]	two-core/three-core cable r[Ω/km] @ 80 [°C]	two-core/three-core cable x[Ω/km]
1.5	24.384	0.168	24.878	0.118
2.5	14.680	0.156	14.960	0.109
4	9.177	0.143	9.358	0.101
6	6.112	0.135	6.228	0.0955
10	3.691	0.119	3.740	0.0861
16	2.323	0.112	2.356	0.0817
25	1.465	0.106	1.494	0.0813
35	1.056	0.101	1.077	0.0783
50	0.779	0.101	0.796	0.0779
70	0.540	0.0965	0.550	0.0751
95	0.389	0.0975	0.397	0.0762
120	0.310	0.0939	0.315	0.074
150	0.252	0.0928	0.259	0.0745
185	0.203	0.0908	0.206	0.0742
240	0.155	0.0902	0.159	0.0752
300	0.125	0.0895	0.129	0.075

58 ABB SACE - *Electrical devices*

A.4 Specific Voltage drop (ABB Electrical handbook)

2 Protection of feeders

The following tables show the ΔU_x [V/(A·km)] values by cross section and formation of the cable according to the most common cosφ values.

Table 3: Specific voltage drop at cosφ = 1 for copper cables

	cosφ = 1			
	single-core cable		two-core cable	three-core cable
S[mm²]	single-phase	three-phase	single-phase	three-phase
1.5	29.60	25.63	30.20	26.15
2.5	17.82	15.43	18.16	15.73
4	11.14	9.65	11.36	9.84
6	7.42	6.43	7.56	6.55
10	4.48	3.88	4.54	3.93
16	2.82	2.44	2.86	2.48
25	1.78	1.54	1.81	1.57
35	1.28	1.11	1.31	1.13
50	0.95	0.82	0.97	0.84
70	0.66	0.57	0.67	0.58
95	0.47	0.41	0.48	0.42
120	0.38	0.33	0.38	0.33
150	0.31	0.27	0.31	0.27
185	0.25	0.21	0.25	0.22
240	0.19	0.16	0.19	0.17
300	0.15	0.13	0.16	0.14

Table 4: Specific voltage drop at cosφ = 0.9 for copper cables

	cosφ = 0.9			
	single-core cable		two-core cable	three-core cable
S[mm²]	single-phase	three-phase	single-phase	three-phase
1.5	26.79	23.20	27.28	23.63
2.5	16.17	14.01	16.44	14.24
4	10.15	8.79	10.31	8.93
6	6.80	5.89	6.89	5.96
10	4.14	3.58	4.16	3.60
16	2.64	2.28	2.65	2.29
25	1.69	1.47	1.70	1.48
35	1.24	1.08	1.25	1.08
50	0.94	0.81	0.94	0.81
70	0.67	0.58	0.67	0.58
95	0.51	0.44	0.50	0.43
120	0.42	0.36	0.41	0.35
150	0.36	0.31	0.35	0.30
185	0.30	0.26	0.29	0.25
240	0.25	0.22	0.24	0.21
300	0.22	0.19	0.21	0.18

A.5 AWG KCMILL and DC resistance at 75℃ as per NEC

		Diameter		Cross Sect. Area			D.C. Resistance (Ohms/1000 feet)			
							Copper		Aluminum	
AWG	Stranding	in	mm	in²	mm²	Circular Mils	@ 68°F (20°C)	@ 167°F (75°C)	@ 68°F (20°C)	@ 167°F (75°C)
20	solid	0.032	0.81	0.001	0.52	1,020	10.150	11.953	-	-
20	10	0.037	0.94	0.001	0.69	1,020	10.900	12.836	-	-
19	solid	0.036	0.91	0.001	0.65	1,200	8.051	9.481	-	-
18	solid	0.040	1.02	0.001	0.82	1,620	6.390	7.770	-	-
18	7	0.046	1.17	0.002	1.07	1,620	6.538	7.950	-	-
16	solid	0.051	1.29	0.002	1.31	2,580	4.021	4.890	-	-
14	solid	0.064	1.63	0.003	2.08	4,110	2.525	3.070	-	-
12	solid	0.081	2.06	0.005	3.32	6,530	1.587	1.930	-	-
10	solid	0.102	2.59	0.008	5.27	10,380	0.995	1.210	-	-
8	solid	0.128	3.25	0.013	8.30	16,510	0.628	0.764	-	-
6	7	0.184	4.67	0.027	17.16	26,240	0.404	0.491	0.661	0.808
4	7	0.232	5.89	0.042	27.27	41,740	0.253	0.308	0.416	0.508
2	7	0.292	7.42	0.067	43.20	66,360	0.160	0.194	0.261	0.319
1	19	0.332	8.43	0.087	55.85	83,690	0.127	0.154	0.207	0.253
0	19	0.372	9.45	0.109	70.12	105,600	0.100	0.122	0.165	0.201
00	19	0.418	10.62	0.137	88.53	133,100	0.080	0.097	0.130	0.159
000	19	0.470	11.94	0.173	111.93	167,800	0.063	0.077	0.103	0.126
0000	19	0.528	13.41	0.219	141.26	211,600	0.050	0.061	0.082	0.100
250MCM	37	0.575	14.61	0.260	167.53	250,000	0.042	0.052	0.069	0.085
300MCM	37	0.630	16.00	0.312	201.11	300,000	0.035	0.043	0.058	0.071
350MCM	37	0.681	17.30	0.364	234.99	350,000	0.030	0.037	0.050	0.061
400MCM	37	0.728	18.49	0.416	268.55	400,000	0.026	0.032	0.043	0.053
500MCM	37	0.813	20.65	0.519	334.92	500,000	0.021	0.026	0.035	0.042
600MCM	61	0.893	22.68	0.626	404.07	600,000	0.018	0.021	0.029	0.035
700MCM	61	0.964	24.49	0.730	470.88	700,000	0.015	0.018	0.025	0.030
750MCM	61	0.998	25.35	0.782	504.68	750,000	0.014	0.017	0.023	0.028
800MCM	61	0.114	2.90	0.010	6.59	800,000	0.013	0.016	0.022	0.027
900MCM	61	1.094	27.79	0.940	606.45	900,000	0.012	0.014	0.019	0.024
1000MCM	61	1.152	29.26	1.042	672.45	1,000,000	0.011	0.013	0.017	0.021

A.6 Calmont Wire and Cable Solid and Stranded Conductor AWG Chart

CALMONT
Wire & Cable

420 East Alton Avenue,
Santa Ana, California 92707
Toll Free: (800) 905-7161
Phone: (714) 549-0336
Fax: (714) 549-4028
www.calmont.com

Solid and Stranded Conductor AWG Chart

AWG Size	Total Strands/ Strand Size	Type	Construction	Nominal Diameter		Circular Area		Approximate Weight		Nom. Break Strength		Maximum DC Resistance	
				Inches	mm	Mils	mm2	Lbs/ 1000'	Kg/ Km	Lbs	Kg	Ohms/ 1,000'	Ohms/ Km
14	37/30	C	37/30	0.0700	1.78	3700	1.88	11.5	17.2	102	46.10	2.95	9.69
14	37/30	C	37/30	0.0700	1.78	3700	1.88	11.3	16.9	96.2	43.60	3.44	11.3
14	41/30	B	41/30	0.0740	1.88	4100	2.08	12.7	18.8	113	51.10	2.63	8.64
14	42/30	RB	7x6/30	0.0823	2.09	4200	2.13	13.6	20.3	115	52.40	2.70	8.85
14	49/30	RC	7x7/30	0.0900	2.29	4900	2.48	16.0	23.9	135	61.10	2.34	7.66
14	105/34	RB	7x15/34	0.0820	2.08	4168	2.11	13.5	20.1	115	52.00	2.75	9.03
14	105/34	B	105/34	0.0746	1.89	4168	2.11	12.9	19.1	115	52.00	2.62	8.60
14	168/36	RB	7x24/36	0.0823	2.09	4200	2.13	13.6	20.3	115	52.40	2.75	9.04
14	266/38	RB	7x38/38	0.0829	2.11	4256	2.16	13.8	20.5	117	53.10	2.75	9.01
14	413/40	RB	7x59/40	0.0800	2.03	3969	2.01	12.9	19.2	109	49.50	2.99	9.50
14	441/40	RB	7x3x 21/40	0.0902	2.29	4238	2.15	14.4	21.5	116	52.80	2.94	9.64
14	462/40	RB	7x66/40	0.0847	2.15	4440	2.25	14.4	21.4	122	55.40	2.67	8.77
14	665/42	RB	7x95/42	0.0819	2.08	4156	2.11	13.5	20.0	114	51.80	2.90	9.51
14	1050/44	RB	7x3x50/44	0.0898	2.28	4200	2.13	14.3	21.3	115	52.40	3.08	10.10
14	1078/44	RB	7x7x22/44	0.0910	2.31	4312	2.19	14.7	21.8	119	53.80	3.00	9.83
14	1176/44	RB	7x3x56/44	0.0951	2.42	4704	2.38	16.0	23.8	129	58.70	2.75	9.01
12	49/0.0116	RC	7x7/0.0116	0.104	2.64	6,593	3.34	20.55	30.6	181	82.1	1.6	5.25
12	63/30	RB	7x9/30	0.102	2.59	6,331	3.21	20	29.8	174	78.9	1.7	5.57
12	259/36	RB	7x37/36	0.102	2.59	6,475	3.28	20.38	30.4	178	80.7	1.6	5.25
10	133/0.0893	RC	19x7/0.0893	0.134	3.4	10,600	5.37	32.9	49	291	132	1.1	3.61
10	49/0.0146	RC	7x7/0.0146	0.128	3.25	10,445	5.29	32.56	48.5	287	130	1.1	3.61
8	1	S	Solid	0.129	3.26	16512	8.37	50.0	74.4	454	206.00	0.64	2.10
8	7/16	C	7/16	0.152	3.87	18064	9.15	56.3	83.8	497	225.00	0.60	1.98
8	19/21	C	19/21	0.143	3.62	15433	7.82	48.1	71.6	424	192.00	0.71	2.32
8	37/24	C	37/24	0.141	3.57	14948	7.58	46.6	69.4	411	186.00	0.73	2.39
8	49/25	RC	7x7/25	0.161	4.09	15760	7.96	51.4	76.5	432	196.00	0.73	2.40
8	133/29	RB	7x19/29	0.170	4.31	16983	8.61	55.6	82.7	467	212.00	0.87	2.21
8	133/29	RC	19x7/29	0.170	4.31	16983	8.61	58.4	86.9	467	212.00	0.71	2.32
8	152/30	RB	19x8/30	0.157	3.98	15200	7.70	51.7	77.0	418	190.00	0.78	2.57
8	168/30	RB	7x24/30	0.165	4.18	16800	8.51	54.5	81.0	462	209.00	0.67	2.21
8	245/32	RB	7x35/32	0.159	4.04	15680	7.95	50.8	75.6	431	196.00	0.73	2.38
8	301/33	RB	7x43/33	0.157	3.98	15173	7.69	49.2	73.2	417	189.00	0.75	2.47
8	413/34	RB	7x59/34	0.163	4.13	16392	8.31	53.1	79.0	451	204.00	0.70	2.30
8	602/36	RB	7x86/36	0.156	3.96	15050	7.63	48.8	72.6	414	188.00	0.77	2.52
8	665/35	RB	7x95/36	0.164	4.16	16625	8.43	53.9	80.2	457	207.00	0.70	2.28
8	1050/38	RB	7x150/38	0.165	4.18	16800	8.51	54.4	81.0	462	209.00	0.70	2.28
8	1666/40	RB	7x7x34/40	0.175	4.46	16010	8.11	54.5	81.1	440	200.00	0.78	2.55
8	1715/40	RB	7x7x35/40	0.178	4.52	16481	8.35	56.1	83.5	453	206.00	0.76	2.48
6	1	S	Solid	0.162	4.11	26244	13.3	79.4	118	721	327.00	0.40	1.32
6	7/14	C	7/14	0.192	4.88	28762	14.6	89.7	131	791	359.00	0.38	1.24
6	19/19	C	19/19	0.180	4.56	24487	12.4	76.3	114	673	305.00	0.45	1.46
6	37/22	C	37/22	0.186	4.72	23683	12.0	73.9	110	651	295.00	0.46	1.52
6	49/23	RC	7x7/23	0.203	5.17	25027	12.7	81.9	122	688	312.00	0.46	1.50
6	133/27	RB	7x19/27	0.213	5.41	26818	13.6	87.8	131	737	334.00	0.42	1.39
6	133/27	RC	19x7/27	0.213	5.41	26818	13.6	92.2	137	737	334.00	0.45	1.46
6	259/30	RB	7x37/30	0.205	5.19	25900	13.1	84.0	125	712	323.00	0.44	1.44
6	427/32	RB	7x61/32	0.210	5.33	27328	13.9	88.6	132	751	341.00	0.42	1.37
6	665/34	RB	19x35/34	0.206	5.24	26394	13.4	89.8	134	726	329.00	0.46	1.50
6	665/34	RB	7x95/34	0.206	5.24	26394	13.4	85.5	127	726	329.00	0.43	1.43
6	1050/36	RB	7x150/36	0.206	5.23	26250	13.3	85.1	127	722	327.00	0.44	1.45
6	1078/36	RB	7x7x22/36	0.228	5.78	26950	13.7	91.8	137	741	336.00	0.45	1.48

B – Bunch stranded wire. Wires are twisted without a geometric relationship to each other.

C – Concentric stranded wire. Each layer of the stranding has all strands in the same direction and position.

RB – Rope construction with Bunch stranded groups. Similar to concentric for the groups of strands. Each Bunch Stranded strands.

RC – Rope construction with Concentric stranded groups. Similar to concentric stranding for both the final stranding and each group.

S – Solid wires.

The maximum resistance values are for the wire as a single conductor. Additional allowances have to be made when the wires are cabled into a multi conductor cable.

CALMONT
Wire & Cable

420 East Alton Avenue,
Santa Ana, California 92707
Toll Free: (800) 905-7161
Phone: (714) 549-0336
Fax: (714) 549-4028
www.calmont.com

Solid and Stranded Conductor AWG Chart

AWG Size	Total Strands/ Strand Size	Type	Construction	Nominal Diameter		Circular Area		Approximate Weight		Nom. Break Strength		Maximum DC Resistance	
				Inches	mm	Mils	mm2	Lbs/ 1000'	Kg/ Km	Lbs	Kg	Ohms/ 1,000'	Ohms/ Km
6	1666/38	RB	7x238/38	0.207	5.27	26656	13.5	86.4	129	733	332.00	0.44	1.44
6	1813/38	RB	7x7x37/38	0.236	6.00	29008	14.7	98.7	147	797	362.00	0.42	1.39
6	2744/40	RB	7x7x56/40	0.225	5.72	26370	13.4	89.8	134	725	329.00	0.47	1.55
6	6517/44	RB	7x7x19/44	0.224	5.68	26068	13.2	89.5	133	717	325.00	0.50	1.64
4	7/12	C	7/12	0.242	6.16	45700	23.2	142	212	1256	570.00	0.24	0.78
4	19/17	C	19/17	0.227	5.75	38990	19.8	122	181	1072	486.00	0.28	0.92
4	37/20	C	37/20	0.224	5.69	37888	19.2	118	176	1042	472.00	0.29	0.94
4	49/21	RC	7x7/21	0.257	6.52	39800	20.2	130	194	1094	496.00	0.29	0.94
4	61/22	C	61/22	0.228	5.78	39045	19.8	121	179	1073	487.00	0.28	0.91
4	133/25	RC	19x7/25	0.269	6.82	42615	21.6	146	218	1171	531.00	0.28	0.93
4	133/25	RC	7x19/25	0.269	6.82	42615	21.6	140	208	1171	531.00	0.27	0.88
4	259/28	RB	7x37/28	0.258	6.54	41119	20.8	133	198	1130	513.00	0.27	0.90
4	259/28	RC	37x7/28	0.265	6.72	41119	20.8	141	210	1130	513.00	0.29	0.95
4	413/30	RB	7x59/30	0.258	6.56	41300	20.9	134	199	1135	515.00	0.27	0.90
4	437/30	RB	19x23/30	0.266	6.75	43700	22.1	149	221	1201	545.00	0.27	0.89
4	1050/34	RB	7x3x50/34	0.283	7.19	41675	21.1	142	211	1146	520.00	0.29	0.95
4	1064/34	RB	19x56/34	0.261	6.63	42230	21.4	144	214	1161	527.00	0.29	0.94
4	1078/34	RB	7x7x22/34	0.287	7.28	42786	21.7	146	217	1176	533.00	0.28	0.92
4	1666/36	RB	7x7x34/36	0.283	7.19	41650	21.1	142	211	1145	519.00	0.29	0.96
4	1672/36	RB	19x88/36	0.260	6.60	41800	21.2	142	212	1149	521.00	0.29	0.95
4	1813/36	RB	7x7x37/36	0.295	7.50	45325	23.0	154	230	1246	565.00	0.27	0.88
3	7/11	C	7/11	0.272	6.91	57585	29.2	180	267	1583	718.00	0.19	0.62
3	19/16	C	19/16	0.254	6.45	49032	24.9	153	227	1348	611.00	0.22	0.73
3	37/19	C	37/19	0.251	6.38	47686	24.2	149	221	1311	595.00	0.23	0.75
3	61/21	C	61/21	0.257	6.52	49547	25.1	154	230	1362	618.00	0.22	0.72
2	7/10	C	7/10	0.306	7.76	72585	36.8	227	337	1998	906.00	0.15	0.49
2	19/15	C	19/15	0.286	7.25	61948	31.4	193	287	1703	772.00	0.18	0.58
2	37/18	C	37/18	0.282	7.17	60091	30.5	187	279	1652	749.00	0.18	0.60
2	49/19	RC	7x7/19	0.323	8.21	63152	32.0	207	308	1736	787.00	0.18	0.60
2	61/20	C	61/20	0.288	7.32	82464	31.7	195	290	1717	779.00	0.17	0.57
2	133/23	RC	7x19/23	0.339	8.61	67931	34.4	222	331	1867	847.00	0.17	0.55
2	133/23	RC	19x7/23	0.339	8.61	67931	34.4	233	347	1867	847.00	0.18	0.58
2	259/26	RB	7x37/26	0.325	8.26	65478	33.2	212	316	1800	816.00	0.17	0.57
2	259/26	RC	37x7/26	0.334	8.48	65478	33.2	225	335	1800	816.00	0.18	0.61
2	637/30	RB	7x7x13/30	0.350	8.88	63700	32.3	217	323	1751	794.00	0.19	0.61
2	665/30	RB	19x35/30	0.328	8.32	66500	33.7	226	337	1828	829.00	0.18	0.59
2	665/30	RB	7x95/30	0.328	8.32	66500	33.7	216	321	1828	829.00	0.17	0.56
2	1666/34	RB	7x7x34/34	0.356	9.05	66124	33.5	225	335	1818	824.00	0.18	0.60
2	2646/36	RB	7x7x54/36	0.357	9.06	66150	33.5	225	335	1818	825.00	0.18	0.60
2	2891/36	RB	7x7x59/36	0.373	9.46	72275	36.6	246	366	1987	901.00	0.17	0.55
2/0	37/15	C	37/15	0.400	10.15	120635	61.1	376	560	3316	1504.00	0.09	0.30
2/0	61/17	C	61/17	0.457	11.61	157419	79.8	191	730	4327	1963.00	0.07	0.23
2/0	133/20	RC	19x7/20	0.480	12.19	136192	69.0	468	697	3714	1698.00	0.09	0.29
2/0	133/20	RC	7x19/20	0.480	12.19	136192	69.0	446	664	3744	1698.00	0.08	0.28
2/0	259/23	RB	7x37/23	0.462	11.74	132287	67.0	429	638	3636	1649.00	0.09	0.28
2/0	259/23	RC	37x7/23	0.475	12.05	132287	87.0	155	677	3636	1649.00	0.09	0.30

B – Bunch stranded wire. Wires are twisted without a geometric relationship to each other.

C – Concentric stranded wire. Each layer of the stranding has all strands in the same direction and position.

RB – Rope construction with Bunch stranded groups. Similar to concentric for the groups of strands. Each Bunch Stranded strands.

RC – Rope construction with Concentric stranded groups. Similar to concentric stranding for both the final stranding and each group.

S – Solid wires.

The maximum resistance values are for the wire as a single conductor. Additional allowances have to be made when the wires are cabled into a multi conductor cable.

References

1. https://electrical-engineering-portal.com/cable-selection-application
2. https://www.rapidtables.com/calc/wire/voltage-drop-calculator.html
3. https://up.codes/viewer/illinois/nfpa-70-2020/chapter/3/wiring-methods-and-materials#310.15
4. https://www.engineersedge.com/copper_wire.htm
5. https://odposp.blob.core.windows.net/media/documents/Catalogue/products/1060/106001_BA_EN.pdf
6. https://library.e.abb.com/public/e7db50d2e351a1e6c125704b00296284/1SDC010001D0203.pdf
7. https://www.thoughtco.com/physics-of-air-density-373328
8. https://www.engineeringtoolbox.com/air-density-specific-weight-d_600.html
9. https://paspk.org/wp-content/uploads/proceedings/51,%20No.1/decf3cd5Wind%20Speed%20Analysis%20of%20Some.pdf
10. https://eocycle.com/eocycle-wind-turbine-certification-solidifies-status-efficient-small-wind-turbines-world/
11. https://www.calmont.com/wp-content/uploads/calmont-eng-wire-gauge.pdf
12. https://www.siechem.com/wp-content/uploads/2017/02/conductor-Resistance.pdf