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Advanced Renewable Energy Sources

A renewable sources power plant design

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Task

Advanced Renewable Energy Sources

Homework Group 10.

Design a renewable sources power plant (PV modules and wind turbines). The maximum power (sent to the grid) is limited to 60kW. Consider if energy storage could be suitable for the plant. Calculate investment cost and potential income generated.

The solution of the homework should consist of files:

1. MatLab file with calculation and additional files used for calculations (e.g., weather data).
2. A report, with
   a. a description of the problem – location and assumed energy demand,
   b. scheme and system description,
   c. real components with technical data,
   d. analysis of the working system (energy consumption),
   e. change in primary energy consumption,
   f. investment cost and potential savings/incomes,
   g. visualization of the results (graphs),
   h. conclusions.

The results files should be uploaded to the Teams platform in assignments.

Helpful links:

https://re.jrc.ec.europa.eu/pvg_tools/en/#TMY

1 Introduction

Renewable energy resources are considered clean energy resources and are critically important due to their environmental-friendly nature[8] [11]. As a result *RES* can perform an important role by addressing the issues of global warming and fossil fuel depletion[13]. The use of renewable energy resources, such as solar, wind, and biomass will not diminish their availability[14]. Because of these reasons studies on renewable energy sources (*RES*) has increased in the last years in absolute and relative terms[10].

Analysis of using wind and solar as an alternative sources of energy for desalination has shown that these two *RE* resources are complementary[15]. Solar and wind energy resources vary greatly over time and do not usually match with the time distribution of the load; thus photovoltaic (*PV*) or wind energy systems alone must be oversized if each system is used separately, leading to high electrical energy costs[9]. Integrating solar and wind energy into the same system attenuates fluctuations in the power produced, improving total system performance and reliability, and significantly reducing the size of storage required. The objective is to make production and consumption equal.

This report presents the design of a hybrid renewable energy source (solar and wind) power plant. It is organized in to 3 main sections. Section 1, this section, presents some introductory background and in the next *two* subsections it includes the objective, as well as location and detailed architecture of the system. Section 2 presents component selection process, analysis of the system including cost, and result visualization and discussions. Finally, Section 3 presents concluding remarks to finish of the report.

1.1 Objective

The primary goals of this project are to design a renewable energy power source plant that integrates photovoltaic (*PV*) modules and wind turbines, collectively contributing to a maximum power output of $60kW$. The task is divided into three main activities.

1. Design a renewable sources power plant utilizing *PV* modules and wind turbines with the following requirement.
   - The maximum power (sent to the grid) is limited to $60kW$.
2. Investigate if energy storage could be suitable for the plant.
3. Perform cost analysis by calculating the investment cost and potential income generated.

1.2 Location and System Description

1.2.1 Location

In an actual design of such a system the location has to be chosen optimally by considering environmental factors, such as, temperature, radiation, and wind speed that will result in an optimal power generation in one's country. We chose the *UK* as the location where this system will be implemented. The specific location is: Latitude (decimal degrees): 55.824, Longitude (decimal degrees): -2.469, and Elevation (m): 203.

1.2.2 System description

Our concept of a *wind–PV* hybrid energy system is shown in Figure 1. The wind energy conversion system (*WECS*) and the *PV* system are operated in parallel in order to supply electrical power to the *grid*, and the excess energy generated is supplied to batteries (Please note that the reason for including energy storage element will be discussed in the next sections).

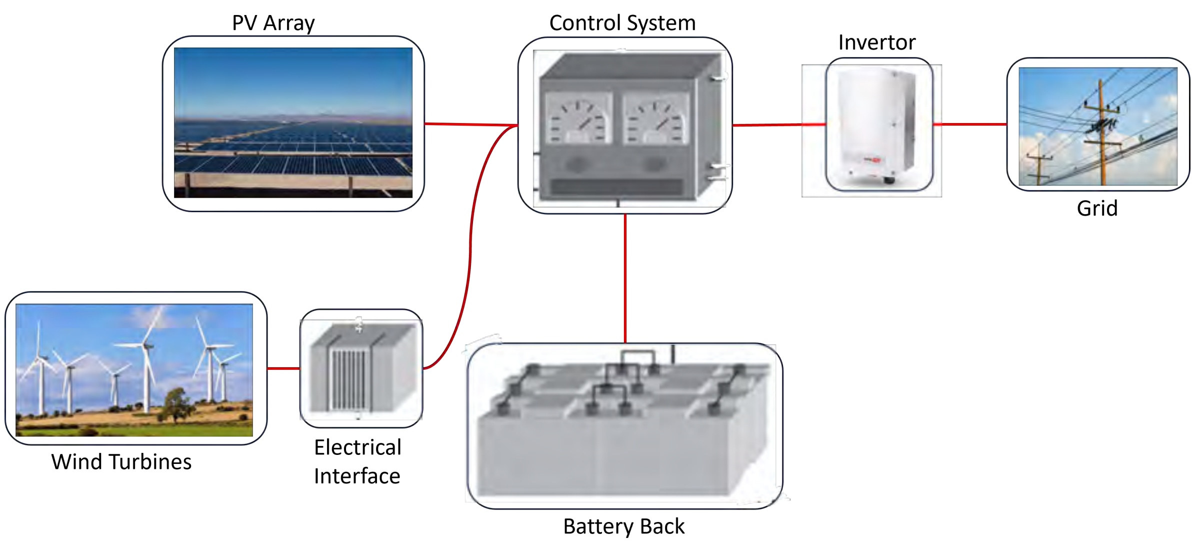


Figure 1: Proposed system architecture

The description of various components of the system is given below:

PV system

PV module performance is highly influenced by weather conditions, especially solar radiation and module temperature. The short circuit current I_{sc} and the open circuit voltage V_{oc} are the two main parameters of the $I - V$ curve shown in Figure 2.

I_{sc} is almost proportional to solar irradiance and V_{oc} increases slowly when solar irradiance increases. When the *PV* temperature increases, V_{oc} leads to a decrease of the available maximum electrical power[9].

Maximum power point tracker (*MPPT*) can be used and connected to the *PV* array to extract the maximum available power, whatever the solar irradiance is. Maximum power point tracking

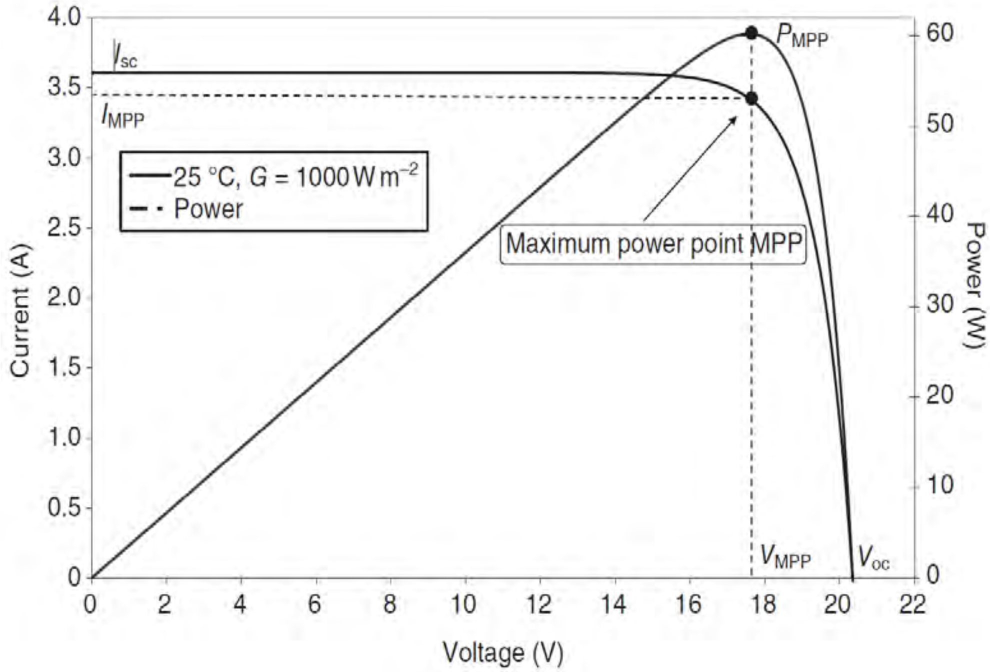


Figure 2: *I-V* and *P-V* curves of a *PV* module[9].

(*MPPT*) is a technique that allows the maximum available energy to be transferred [9] [12]. In addition, we can also design a tracking system (dual axis, single axis or inclined) to track the sun and expose the *PV* panel to the maximum radiation possible throughout the day. This of course introduces additional costs.

Small and medium power wind turbines

Since the scale of our renewable energy source power plant is relatively small, we will not be discussing about large scale wind turbines.

Different *WECS* with the same rated power can generate, at the same site, very different amount of electrical energy because of the difference of the power curve[7]. There are *three* items of data which are essential to calculate the output power of a *WECS* [9].

1. The power curve (joining aerodynamic, mechanical transmission and converting efficiencies) given by the manufacturer

2. The hourly data of wind speed for the installation site

3. the hub height.

The influence of the difference in power curve is even more important when storage is present because it introduces a lag between production and consumption, resulting in the sizing of a wind system to be strongly influenced by the wind turbine's power profile [2].

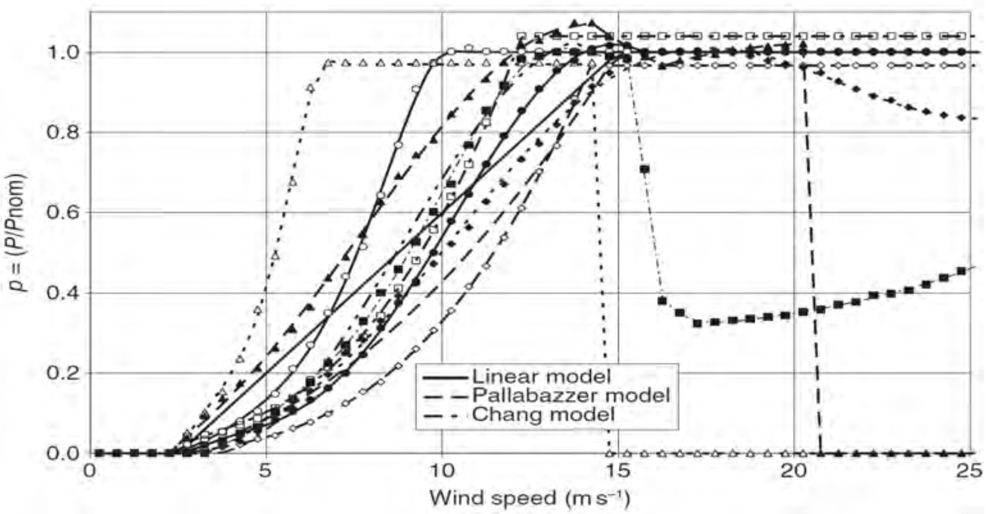


Figure 3: Eight types of *WECS* power curve $(0.2 - 20kW)$ and three well known models [9].

Battery storage

Lead–acid batteries are usually used for energy storage in hybrid systems to store surplus energy, to regulate system voltage and to supply load in case of insufficient solar radiation and/or wind [9]. Only 2 or 3 days of autonomy is required for batteries in *wind–PV* hybrid systems, while 5 to 6 days of autonomy are necessary in separate *PV* or wind systems [1][5]. Battery capacity depends on maximum depth of discharge (*DOD*), temperature and age. A battery's state of charge (*SOC*) is generally expressed as a percentage, according to the following:

During the charging process:

$$SOC(t+1) = SOC(t) \cdot [1 - \sigma(t)] + \frac{I_{\text{bat}}(t) \cdot \delta t \cdot \eta_c(t)}{C_{\text{bat}}} \tag{1}$$

During the discharge process:

$$SOC(t+1) = SOC(t) \cdot [1 - \sigma(t)] - \frac{I_{\text{bat}}(t) \cdot \delta t}{\eta_{\text{dis}}(t) \cdot C_{\text{bat}}} \tag{2}$$

with $(1 - DOD) \leq SOC(t) \leq 1$

Where $\sigma(t)$ is the hourly self-discharge rate, C_{bat} is the nominal capacity of the battery (Ah). The charge efficiency η_c depends on the SOC and the charging current and has a value between 0.65 and 0.95 and the discharge efficiency η_{dis} is generally taken equal to 1 [4][6].

For high *DOD*, phenomena such as sulfatation, freezing or stratification occur in the battery and reduce the battery lifetime, thus generally *DOD* is taken between 50 and 80% [9].

DC/AC and AC/DC converters

In a *PV–wind* hybrid system, several electrical converters can be used [9]:

- *DC/AC* converters or inverters to supply *AC* load or to grid.
- *AC/DC* converters or rectifiers, after the wind turbine.

Using inverters has three major disadvantages: a high cost depending on the quality of the output signal (square, pseudo-sinus or sinus); a decrease in the overall system performance (inverter efficiency depending on the load ratio and self-consumption); and a risk of failure.

Consequently, it can be seen that sizing an inverter correctly/well for its required purpose is important [3]: if it is undersized, there will not be enough power; demanding more than its limit will shut it off; if it is oversized, it will be much less efficient (due to standing losses) and more costly to buy and run. Moreover, some inverters operate without interruption even if no electrical charge is supplied, and thus have a significant self-consumption.

For a wind turbine with *AC* output, the use of a rectifier is necessary to charge the battery. The *AC/DC* converter efficiency is generally taken to be some percentage points lower than the equivalent inverter efficiency. Wind turbine rectifier peak power is calculated from the WECS nominal power.

2 Methods

In this section we present the overall analysis of the system. Determining the number of *PV* modules and wind turbines that is required to meet the power requirement as well as the overall power analysis is presented in Section 2.2. Section 2.4 presents the the cost analysis. This includes investment cost (for buying products and for the installation) and potential income generated.

2.1 Real components, technical data and selection process

In Section 1.2 we have chosen the location where the system is going to be installed. The next step before performing any analysis is to choose and determine the number of *PV* modules and wind turbines that is required to realize the required power demand ($60kW$ *max*) without producing excess energy.

Selecting *PV* modules, wind turbines and determining their numbers

We have used the meteorological data to determine the average value of environmental variables (*i.e.,* average temperature, average radiation and average wind speed). Here we are going to select the components based on this average value; however, detailed additional statistical analysis must be performed to choose the optimal number and rating of components.

Variables	Average Temperature (^0C)	Average Wind Speed (m/s)	Average Radiation (W/m^2)
Value	8.2049	4.6331	101.5407

Table 1: Average Value of Environmental Variables in the Year.

First we started with a $15.6kW$ rated wind turbine, manufactured by *Bergey* wind Power, the Bergey Excel 15[1] and the *MAXEON SPR-MAX3-430-R PV* module, which has a nominal power of $430W$. For these choices, in the selected location we would require the number of turbines and *PV* modules given in Table 2. However, these components are too much to install for a relatively *small* scale power plant. Therefore, we reverted and chose a more powerful wind turbine, manufactured by *Ryse* energy, *Ryse* $E-60$. This is a $60kW$ rated horizontal axis wind turbine.

Components	Quantity
Excel 15 Wind Turbine	60
MAXEON SPR-MAX3-430-R PV module	1319

Table 2: First trial, the number of components required for each to produce $60KW$ in the selected location.

The second iteration selected components and their number is presented in Table 3. Based on Table 3 we chose *Ryse* $E-60$ Wind Turbine and *MAXEON SPR-MAX3-430-R PV* module.

The next step is deciding what percentage of the maximum demand (we are calling the maximum allowable power that can be sent to the grid, $60kW$, as demand) is going to be covered by each sources.

[1] https://www.bergey.com/products/grid-tied-turbines/excel-15/

Components	Quantity
Ryse $E - 60$ Wind Turbine	14
MAXEON SPR-MAX3-430-R PV module	1319

Table 3: Second trial, the number of components required for each to produce $60KW$ in the selected location.

We decided it would be better to use wind turbine to meet 75% of the maximum power and *PV* modules for the remaining 25% of the maximum power as the location is more suitable for wind based power generation. This results in the final number of components given in Table 4.

Components	Quantity
Ryse $E - 60$ Wind Turbine	10
MAXEON SPR-MAX3-430-R PV module	330

Table 4: Final, the number of components required.

Since the distribution of the values of the environmental variables is not uniform, the 10 wind turbines alone generates more than the required power that can be sent in the year. However, a significant part of it goes to waste since we can not send all of it. We have implemented a battery storage system to prevent this problem, which will be discussed in later sections.

The technical datas and detailed description of the PV module and Wind Turbines is given in Appendix A and Appendix B respectively. For easier reference, the most important parameters are given in Table 5 and Table 6

Parameters	Value
Reference efficiency, η_{reff}, ($\%/100$)	0.227
Reference temperature, T_{reff}, (^oC)	25
Surface area, A, (m^2)	1.895
Temperature coefficient of power, β, ($\%/^oC$)	-0.27

Table 5: Parameters of the *PV* module (refer to Appendix A).

Selecting Battery

From the analysis of the system using *MATLAB*, which is presented in later section, the number of *PV* modules and wind turbines that we have specified based on the average value of the environmental variables produces more energy than what can be send to the grid. This is primarily because there are some hours in most days were the wind sped is at the optimal point. However, most of the generated energy at this point goes to waist as we can not send all of it to the grid because of the design requirement($maxPower <= 60kW$).

One solution to reduce this waste of energy is to design an energy storage system for the system. Having an energy storage element not only reduce the waste but also increases the reliability of the system. Since this is a relatively small scale power plant we decided to design a battery system.

Parameters	Value
Starting wind velocity (m/s)	2
Nominal wind velocity (m/s)	11
Maximum wind velocity (m/s)	30
Maximum power (W)	$6e^4$

Table 6: Parameters of the wind turbine (refer to Appendix B).

The capacity of the battery system is decided in such a way that decreases the cost and reduces the energy loss (hence increase reliability and efficiency).

There are a number of companies the produce battery for this kind of purpose. This includes: *LG Chem*[2], *BYD* energy[3] and others. However, the first step in selecting the battery is determining its capacity. The battery capacity can be determined using Equation 3

$$BatteryCapacity(kWh) = \frac{PowerOutput(kW)xStorageDuration(hrs)}{DepthofDischarge} \tag{3}$$

- Power Output (kW): we set this to be equal to the maximum power that can be sent to the grid, $60kW$.
- Storage Duration (hrs): The number of hours we want the battery to provide power we chose this to be $5hrs$.
- Depth of Discharge (%): This is the percentage of the battery's total capacity that you are willing to use. Here we chose 70%. This is because if we completely deplete the battery multiple times, this will decrease its performance over time.

Therefore, the battery capacity for this system should be:

$$BatteryCapacity(kWh) = \frac{60kWx5h}{0.7} = 430kWh \tag{4}$$

BYD manufactures a medium scale battery called *MC* Cube (model: *MC-B466-U-R2M01*) with capacity of $466kWh$. This battery is flexible, configurable and compliant with global energy storage standards. The spec sheet of the battery can be found in the company website[4] or in Appendix C; however this battery is relatively new and its detailed specification (*e.g.,* its efficiency and self discharge rate) are not provided by the company yet.

For this reason we chose an other battery model called *FD-LV5.0* that is also manufactured by *BDY*. This model is scalable from $5kWh$ to $160kWh$ by combining 32 packs connected in parallel. By making *three* modules each containing 32 packs we can get a battery system with a capacity of $480kWh$. Of course this system, compared to the previous one battery system, may be more susceptible to failure because of multiple contact points. However, it is also more flexible because

[2] https://www.lgessbattery.com/eu/grid/product-info.lg

[3] http://www.bydenergy.com/energy-storage

[4] http://www.bydenergy.com/product?id=35

it can still continue to work at a lower capacity if one of the modules fail. The detailed spec sheet of this battery is also given in Appendix C; nonetheless, for easier reference the main parameters of the battery are given in Table 7.

- Capacity: there are *three* modules each containing 32 packs. The capacity of one pack is $5kWh$; therefore, the total capacity is $3 * 32 * 5kWh = 480kWh$

- Maximum Power: the maximum power of the battery is not directly given. However, the datasheet provides the Max. Charge and Discharge Current as well as Charge Cut-Off Voltage from which we can calculate the maximum power as:

$$MaximumPower = modules * packs * I_{peack} * V_{peak} = 3 * 32 * 70 * 57.6 = 387.072kW$$

Parameters	Value
Capacity (kWh)	480
Maximum power (kW)	387.072
Efficiency $(\%)$	$\geq 95(we\, took\, 95\%)$
Self discharge $(\%/month)$	1

Table 7: Parameters of *FD-LV5.0* battery (refer to Appendix C).

For implementing this system other components are needed as well. This includes charge controller (invertor(s)). The detailed analysis of this topic, however, is beyond the scope of this report. Nonetheless, we have choose an invertor manufactured by *Solar Edge* just for cost analysis purpose. The details of this invertor can be found in the manufacturer website[5].

Figure 4: Three phase invertor by Solar Edge.

[5] https://www.solaredge.com/en/products/commercial/pv-inverters/three-phase

2.2 Analysis of the working system, result visualization and discussion

Based on the *PV* modules and wind turbines specifications, including their number, that we chose in Section 2.1, we performed our initial simulation. The obtained result summary is depicted in Figure 5. The detailed quantitative result is also given in Table **??**.

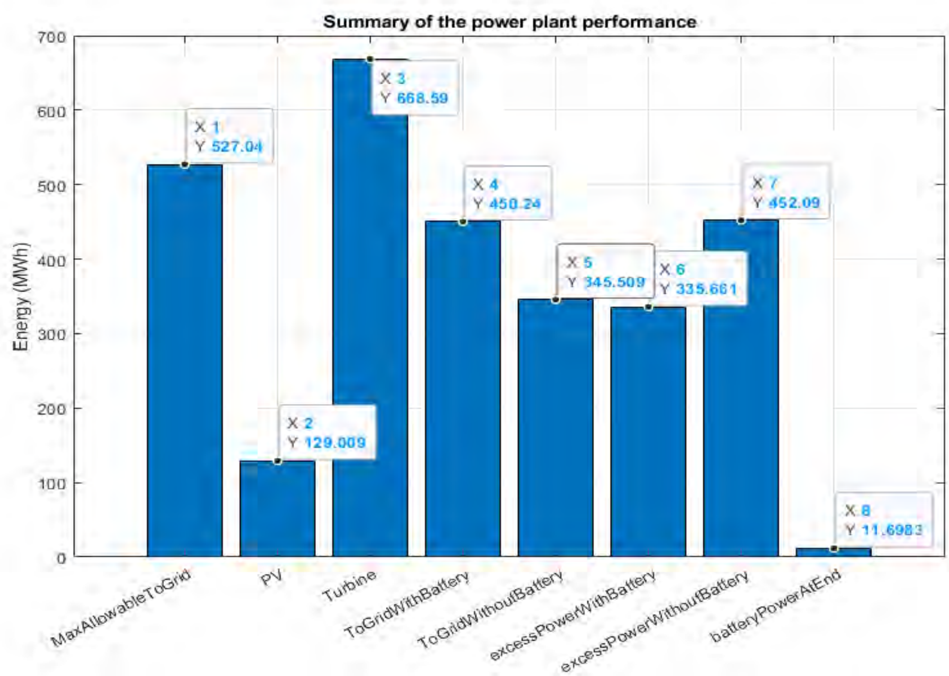


Figure 5: Summary of the power plant analysis for components specified in Table 4 and Battery capacity given at Equation 4.

As we can see from Figure 5, the wind turbine alone is generated more than what is required. This is because there is a big variation in the wind speed from the mean anual wind speed that we calculated in Table 1. During some hours of the day the speed is nominal, letting the turbine operate at its efficient point. However, most of the energy generated during those hours goes to waste as we are restricted to send only $60kW$ to the grid.

Figure 5 is our starting iteration point to select which part of the system to modify. Additionally, it is also one way of checking if the implementation of the *MATLAB* script is correct, by comparing the generated, sent and excess power.

Maximum allowable to grid (mWh)	527.04
RES, *PV* + *Turbine*, (mWh)	797.599
Actual sent to grid (mWh)	345.509
Excess (mWh)	452.09

Table 8: Summary of analysis for initial system without battery - yearly.

As we can see from Table 9 and 8, the system with battery storage were able to increase the overall yearly energy that is sent to the grid from $345.509mWh$ to $450.24mWh$. The problem with this

Maximum allowable to grid (mWh)	527.04
RES, *PV* + *Turbine*, (mWh)	797.599
Actual sent to grid (mWh)	450.24
Excess (mWh)	335.661
Battery energy at the end (mWh)	11.6983

Table 9: Summary of analysis for initial system with battery storage - yearly.

system; however, is that it is generated so much power, $797.599mWh/year$, which is greater than the maximum allowable, $527.04mWh/year$, and only sending $450.24mWh/year$.

One solution to alleviate this problem without significantly increasing the investment cost is to reduce the number of wind turbines and increase the storage capacity. The state of art presented in Section 1.2.2, indicates that 2 or 3 days of autonomy is required for batteries in *wind–PV* hybrid systems; however, in our initial iteration we only took $5hrs$ as depicted below Equation 3. If we assume an average of 3 day of autonomy, the required battery capacity that will be able to supply to the grid the maximum allowable energy for this autonomy time will be:

$$BatteryCapacity(kWh) = \frac{60kWx3dayx24h/day}{0.7} \approx 6170kWh \tag{5}$$

The capacity given in equation 5 is almost $14x$ the capacity given at Equation 4.

Using the battery capacity given at Equation 5 and reducing the number of turbines and *PV* modules from 10 to 7 and from 330 to 250 respectively results in our final system.

Components	Quantity
Ryse $E-60$ Wind Turbine	7
MAXEON SPR-MAX3-430-R PV module	250

Table 10: Finally decided number of components

The battery model have to be changed as well as the previously selected model will not be suitable for the capacity given at Equation 5. The final battery model that we chose is *MC Cube ESS*. This battery has a capacity of $5365kWh$ and its technical specification can be found at the end of Appendix C.

The results for the final system are depicted in Figure 6 and Table 11.

Maximum allowable to grid (mWh)	527.04
RES, *PV* + *Turbine*, (mWh)	565.75
Actual sent to grid (mWh)	423.8
Excess (mWh)	114.56
Battery energy at the end (mWh)	27.39

Table 11: Summary of analysis of final system performance with battery storage- yearly.

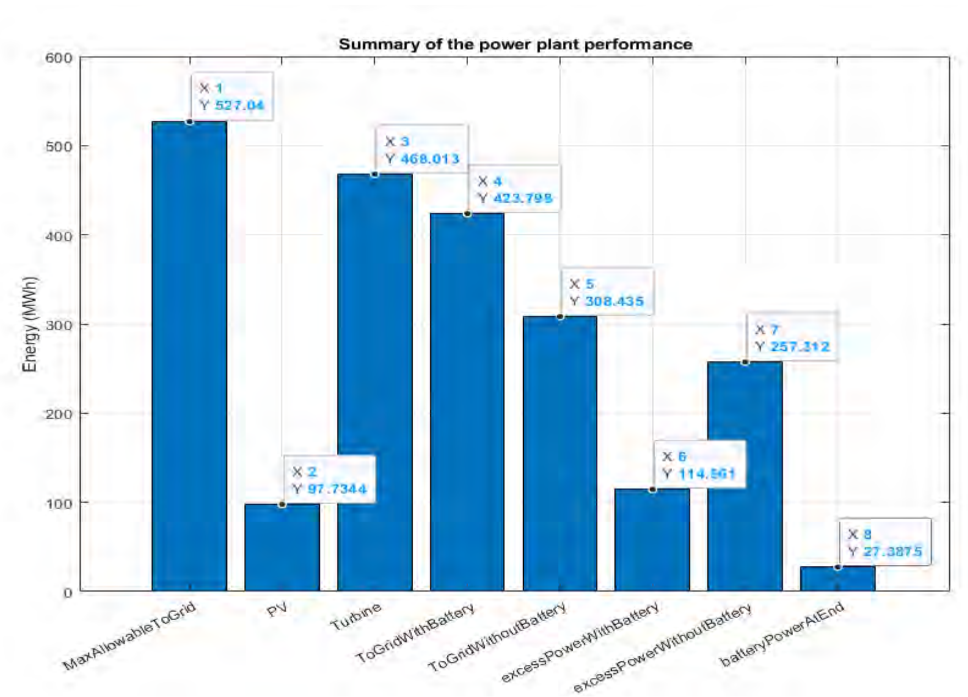


Figure 6: Summary of analysis for the final system with battery storage for parameters given in Table 10.

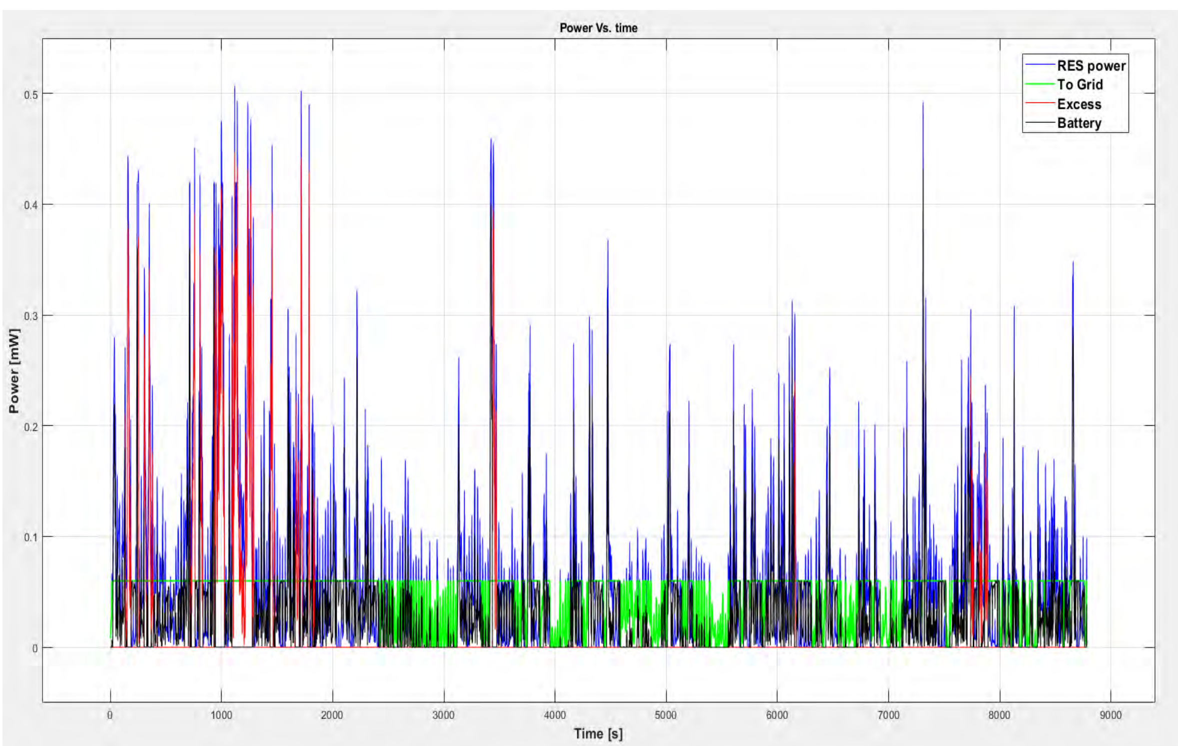


Figure 7: Hourly performance status.

As can be seen from Table 9 and 11, we were able to reduce the excess energy from $335.66 kWh/year$ to $114.56 kWh/year$. This is done by reducing the overall power generated and at the same time increasing the storage capacity. Of course this excess power is still significant, one way to reduce it is to convert it to other form of energy and store it. The yearly energy that the final system is sending is still with in the limit. However, we can make it even more close to the limit by increasing the storage capacity. For this report we decided this performance is acceptable.

The plot of the hourly performance of the system (Total generated power, battery power, excess power and power sent to grid) is depicted in Figure 7. As we can see from this figure, a much more power is being generated around the beginning which contributed to the significant portion of the excess power. However, the battery is doing well in maintaining the performance of the system as can be seen in the middle part.

2.3 Change in primary energy consumption

According to *BBC* News[6], in 2022, the majority of the primary energy consumed within the UK (78.4%) came from coal, oil and gas - fossil fuels. This highlights a critical issue, as these conventional energy sources contribute significantly to carbon emissions and environmental degradation. While our proposed hybrid renewable energy system may seem relatively small in scale compared to the overall energy demand in the UK, it has the potential to play a crucial role in mitigating this energy crisis.

The significance of the system's impact becomes more apparent when considering its environmental implications and long-term sustainability. Beyond merely addressing energy consumption, it serves as a beacon for adopting green technologies and practices. The reduction in carbon emissions and the utilization of renewable resources contribute to the broader global effort to combat climate change. In essence, our hybrid renewable energy system, though modest in comparison to national energy demands, embodies a larger vision of sustainability. It sets the stage for a future where small-scale, innovative solutions collectively make a substantial difference in the quest for cleaner, more sustainable energy practices.

[6] https://www.bbc.co.uk/news/business-63976805.amp

2.4 Investment cost and incomes

In this section we presented the investment cost, possible income generated and potential payback period.

2.4.1 Investment cost

The costs of major components that are required for the implementation of this system are listed in Table 12.

Components	Quantity	Cost/Component	Subtotal
MAXEON SPR-MAX3-430-R PV module	250	€435.31 VAT Incl. [7]	€$108,827.50$
Ryse E - 60 Wind Turbine	7	€$80,000.00$[8]	€$560,000.00$
MC Cube ESS Battery	2	€$250,000.00$[9]	€$500,000.00$
Three Phase *Solar Edge* inverter	2	€$2,569.86$[10]	€$5,139.72$
		Total	€$1,173,967.22$

Table 12: Components cost.

In addition to the cost of major components given in Table 12, we also have to consider the installation cost. The average construction cost for *PV* and wind turbine is €$1,503.54/kW$ and €$2,644.09/kW$ respectively [11].

Hence, the construction cost is:

$$Cost_{construction} = \frac{3}{4}x60kWx1,503.54/kW + \frac{1}{4}x60kWx2,644.09/kW = 107,320.65 \quad (6)$$

Therefore, the overall investment cost is:

$$Cost_{investment} = Cost_{construction} + Cost_{components} = 1,173,967.22 + 107,320.65 = 1,281,287.87 \quad (7)$$

Estimated total cost of realizing the system is: €$1,281,287.87$.

2.4.2 Income generated

Taking €$290/MWh$ as average energy price in the *UK*, the yearly income generated by the system is:

$$Income = EnergySentToGridxPrice/MWh = 423.8MWhx290/MWh = 122,902.00 \quad (8)$$

Therefore, the yearly income generated is: €$122,902.00/year$. Based on Equation 7 and 8 the estimated payback period is: $\approx 10.5years$. This payback period is only true if we exclude other costs, like cost for maintenance.

[10] https://www.planetsoarshop.com/en/products/sunpower-maxeon-3-430-wc-solar-panel
[10] We couldn't find the exact price we took approximate result.
[10] https://homeguide.com/costs/wind-turbine-cost we couldn't find the price of *Ryse E - 60*.
[10] https://www.solaris-shop.com/solaredge-three-phase-se30k-us-30kw-inverter/
[11] https://proest.com/construction/cost-estimates/power-plants/

3 Conclusions

In conclusion, our comprehensive analysis and simulation have led us to the final design of a hybrid renewable energy system, combining *Ryse E-60* wind turbines and *MAXEON SPR-MAX3-430-R PV* modules. The decision to utilize 10 wind turbines and 330 *PV* modules was initially driven by the need to meet 75% of the maximum power with wind energy and the remaining 25% with solar energy as the chosen location is more suitable for wind based energy generation.

However, due to non-uniform environmental variables and the resulting excess power generation during optimal wind conditions, we incorporated a battery storage system to enhance efficiency and reliability. The battery selection process led us to choose the *BDY FD-LV5.0* model first, providing scalability and flexibility with a capacity of $480kWh$. Our iterative simulation and analysis revealed that the initial system generated more power than could be sent to the grid. The introduction of the battery storage system significantly improved the overall energy sent to the grid, reducing waste. We further optimized the system by adjusting the number of components and selecting a battery model with a larger capacity.

The final system, consisting of 7 wind turbines, 250 PV modules, and the *MC Cube ESS* battery, demonstrated improved performance, minimizing excess energy and maximizing the energy sent to the grid. This system aligns with the need for sustainable energy solutions and showcases potential environmental impact reduction. Considering the current energy landscape, our system has the potential to contribute to the reduction of reliance on fossil fuels, addressing the environmental concerns associated with conventional energy sources. The estimated payback period of approximately 10.5 years, based on the income generated and investment cost, reflects the economic viability of the proposed system in the long run.

In conclusion, our hybrid renewable energy system presents a viable and sustainable solution, showcasing the potential for small-scale systems to make a positive impact on the energy landscape while remaining relatively economically feasible.

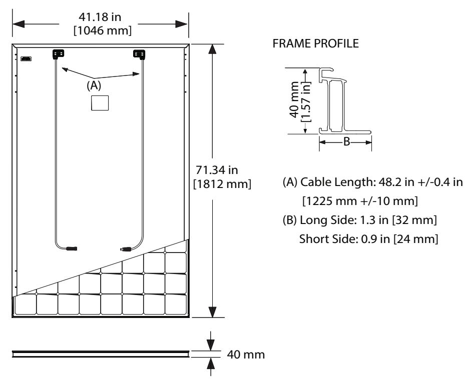
A Solar Panel Datasheet

MAXEON 3 POWER: 415–430 W | EFFICIENCY: Up to 22.7%

Electrical Data			
	SPR-MAX3-430-R	SPR-MAX3-425-R	SPR-MAX3-415-R
Nominal Power (Pnom)[2]	430 W	425 W	415 W
Power Tolerance	+5/0%	+5/0%	+5/0%
Panel Efficiency	22.7%	22.4%	21.9%
Rated Voltage (Vmpp)	35.1 V	34.9 V	34.5 V
Rated Current (Impp)	12.25 A	12.18 A	12.03 A
Open-Circuit Voltage (Voc)	40.7 V	40.7 V	40.6 V
Short-Circuit Current (Isc)	13.15 A	13.13 A	13.10 A
Max. System Voltage	1000 V UL & 1000 V IEC		
Maximum Series Fuse	25 A		
Power Temp Coef.	−0.27% / °C		
Voltage Temp Coef.	−0.236% / °C		
Current Temp Coef.	0.058% / °C		

Certifications and Compliance	
Standard Tests[3]	UL 61730, IEC 61215, IEC 61730
Quality Management Certs	ISO 9001:2015, ISO 14001:2015
Ammonia Test	IEC 62716
Desert Test	IEC 60068-2-68, MIL-STD-810G
Salt Spray Test	IEC 61701 (maximum severity)
PID Test	1000 V: IEC 62804
Available Listings	UL, TUV
IFLI Declare Label	First solar panel labeled for ingredient transparency and LBC-compliance.[4]
Cradle to Cradle Certified™ Silver	First solar panel line certified for material health, water stewardship, material reutilization, renewable energy & carbon management, and social fairness.[5]
Green Building Certification Contribution	Panels can contribute additional points toward LEED and BREEAM certifications.
EHS Compliance	RoHS, ISO 45001:2018, Recycle Scheme, REACH SVHC-163

Operating Condition And Mechanical Data	
Temperature	−40°F to +185°F (−40°C to +85°C)
Impact Resistance	1 inch (25 mm) diameter hail at 52 mph (23 m/s)
Solar Cells	112 Monocrystalline Maxeon Gen 3
Tempered Glass	High-transmission tempered anti-reflective
Junction Box	IP-68, Stäubli (MC4), 2 bypass diodes
Weight	46.7 lbs (21.2 kg)
Max. Load[6]	Wind: 50 psf, 2400 Pa back Snow: 112 psf, 5400 Pa front HVHZ:[7] 112 psf, 5400 Pa front and back
Frame	Class 1 black anodized (highest AAMA rating)



Please read the safety and installation instructions. Visit www.maxeon.com/us/InstallGuideUL. Paper version can be requested through techsupport.ROW@maxeon.com.

1 40-year warranty is not available in all countries or all installations and requires registration, otherwise our 25-year warranty applies. Service availability varies by country and installation provider. When PV Modules are used in a system over 500 kW or on a ground-mount application, such as a tracker or carport, the Product and Power Warranty Terms shall each be limited to 25 years unless written approval is provided by Maxeon and the PV Modules are digitally registered.
2 Standard Test Conditions (1000 W/m² irradiance, AM 1.5, 25° C). NREL calibration Standard: SOMS current, LACCS FF and Voltage.
3 Type 2 fire rating per UL 61730, Class C fire rating per IEC 61730.
4 Maxeon DC panels first received the International Living Future Institute Declare Label in 2016.
5 Maxeon DC panels are Cradle to Cradle Certified™ Silver - www.c2ccertified.org/products/scorecard/maxeon_solar_panels_-_maxeon_corporation. Cradle to Cradle Certified™ is a certification mark licensed by the Cradle to Cradle Products Innovation Institute.
6 As per IEC 61215-2016 tested and certified.
7 Florida High Velocity Hurricane Zone (HVHZ) or equivalent US building codes. Please refer to the Safety and Installation guide for additional details.

Made in Philippines (Cells)
Assembled in Mexico (Module)
Specifications included in this datasheet are subject to change without notice.

View warranty, patent and trademark information at maxeon.com/legal.

maxeon

545907 REV C / LTR_US
Publication Date: May 2023

B Wind Turbine Datasheet

Ryse Energy

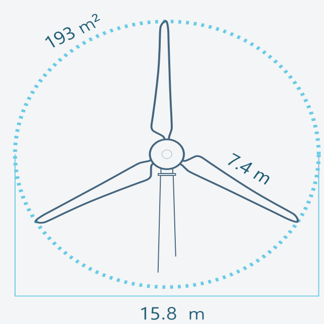
www.ryse.energy

E-60

DATA SHEET

GENERATOR	Type	Permanent Magnet
	Maximum Power	70 kW
	Rated Power	60 kW
ROTOR	Configuration	Horizontal Axis
	No. of Blades	3
	Blade Material	Glass fibre
	Blade Length	7.4 m
	Rotor Diameter	15.8 m
	Swept Area	193 m²
	Nominal Rotor Speed	120 rpm
	Pitch/Yaw	Downwind passive pitch
WIND	Cut-In Speed	2 m/s
	Rated Wind Speed	11 m/s
	Cut-Out Speed	30 m/s
	Survival Speed	59.5 m/s
WEIGHTS	Nacelle/Rotor	4,500 kg
TOWERS	Lattice	18 – 36 m
	Monopole	18 – 27 m
	Tilt-Up	18 – 27 m
DESIGN PARAMETERS	Turbine Design Class	IEC 61400-2 Class II
	Temperature Range	-20° to 50°C
	Lifespan & Servicing	20 years, subject to regular maintenance

TECHNICAL PROFILE



CLASS II

PASSIVE REGULATION

II. EXCEL 15 SPECIFICATIONS

PERFORMANCE

START-UP WIND SPEED	9 mph (4 m/s)
CUT-IN WIND SPEED	6 mph (2.5 m/s)
RATED WIND SPEED	24.6 mph (11 m/s)
AWEA RATED POWER (at 11 m/s or 25 mph)	15.6 kW
AWEA ANNUAL ENERGY (at 5 m/s average	29,800 kWh
CUT-OUT WIND SPEED	none
MAXIMUM DESIGN WIND SPEED	134 mph (60m/s)
MAXIMUM POWER	22.6 kW
ROTOR SPEED	0-150 RPM

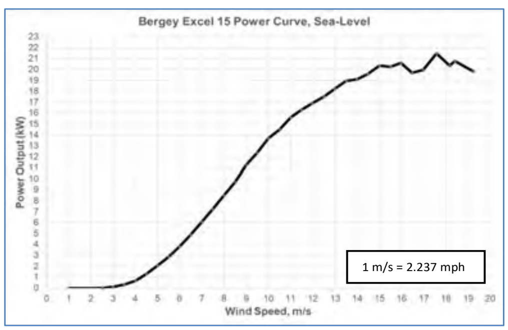
MECHANICAL

TYPE	3-Blade Upwind, Horizontal-Axis
ROTOR DIAMETER	31.5 ft. (9.2 m)
WEIGHT	1,400 lb. (636 kg)
GEARBOX	none
BLADE PITCH CONTROL	none
OVERSPEED PROTECTION	Blade stall
TEMPERATURE RANGE	-40 to 140 deg. F (-40 to 60 deg. C)

ELECTRICAL

OUTPUT FORM	240VAC, 1-Phase, 60Hz
GENERATOR	Permanent Magnet Alternator
POWER PROCESSOR	Powersync III Inverter

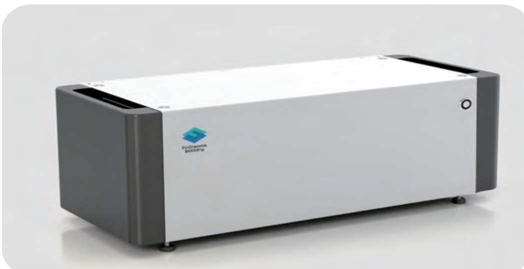
Power Output (AC kW)



Wind Speed (m/s) at Hub Height

C Battery Datasheet

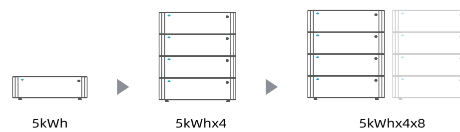
Datasheet of FD-LV5.0



- Scalable from 5 kWh to 160 kWh
- Maximum Flexibility for any Application with up to 32 Packs Connected in Parallel
- Lithium Iron Phosphate (LFP) Battery: Maximum Safety, Lifespan and Power
- High Energy Density and Operational Reliability
- Application: Residential Energy Storage

FD-LV5.0 Battery

The FD-LV5.0 Battery is a lithium iron phosphate(LFP) battery module for use with an external inverter. The communication with the inverter is established through the BMS (Battery Management System). Each battery module has a separate BMS. Furthermore, it can be expanded from 5kWh to 160kWh.



Technical Data

Usable Energy [1]	5kWh
Max. Charge and Discharge Current [2]	70A
Peak Charge and Discharge Current	200A, 10s
Dimension (H/W/D)	195mm x 595mm x 255mm
Weight	42±2kg
Nominal Voltage	51.2V
Operating Voltage	40 ~ 57.6V
Charge Cut-Off Voltage	57.6V
Discharge Cut-Off Voltage	40V
Scalability	Max. 32 in Parallel (160kWh)
Installation Mode	Floor installation
Communication	CAN / RS485
Round-trip Efficiency	≥95%
Applications	On Grid / On Grid + Backup / Off Grid
Operating Temperature	Charge 0~50℃ & Discharge -20~50℃
Protection Class	IP20
Storage Humidity	5%~95%
Altitude	< 4000m
Certification	CE / IEC62619 / UN38.3
Compatible Inverter	Solis/ Deye / Victron/ Megarevo

[1] Test conditions: 100% DOD, 0.2C charge & discharge at 25℃. System Usable Energy may vary with different inverter brands.
[2] Charge derating will occur between 0℃ and +10℃.

FinDreams Battery

System Type	MC-B536-U-R4M01	MC-B466-U-R2M01
DC Side		
Cell Type	LFP	LFP
String Type	1P416S	1P416S
System Configuration	1×1P416S	1×1P416S
Battery Capacity (BOL)	536kWh	466kWh
DC Usable Energy (BOL)@FAT	515kWh	447kWh
DC Usable Energy (BOL)@SAT	500kWh	434kWh
Battery Voltage Range	1081.6 ~ 1497.6V	1081.6 ~ 1497.6V
Nominal Power	125kW	217kW
General Parameters		
Dimensions(W×D×H)	1125×1160×2430mm	1130×1203×2521mm
Weight	≈3784kg	≈3817kg
IP Rating	IP55	IP55
Operating Ambient Temperature	-30℃~+55℃【1】	-30℃~+55℃【1】
Relative Humidity	5%~100%	5%~100%
Max. Working Altitude	<2000m	<2000m
Cooling Concept	Smart Air Cooling	Liquid Cooling
Noise	≤75dB(A)	≤75dB(A)
Fire Suppression System	With fire alarm system(Aerosol optional)	With fire alarm system(Aerosol optional)
Communication Interfaces	CAN	CAN
Communication Protocols	OD	OD
Standard Color	RAL9003	RAL9003
Compliance	UN38.3,UN3536,UL9540A,UL1973,IEC62619	

Note:
【1】Power derating is performed when the ambient temperature is below -15℃ or above 45℃.

MC Cube ESS

MC10C-B5365-U-R4M01
MC10C-B4659-U-R2M01

World's first BESS using the Blade Battery, highly integrated with ultra high energy density, flexible configuration and easy for tranportation, layout, installation, augmentation and maintenance.

SYSTEM FEATURES

Professional & Smart

Vehicle regulation Temperature control/electronic control solution compliant with vehicle standards, cloud-terminal smart battery management algorithm.

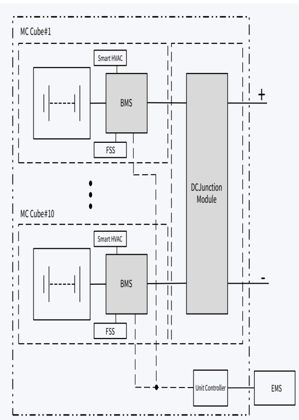
Ultra High Safety

Zero safety accident in 15 years, UL9540A certified.

Reliable & Stable

Extreme battery strength, long lifecycle. Cloud intelligent service, latest upgrading.

CIRCUIT DIAGRAM



SYSTEM PARAMETERS

System Type	MC10C-B5365-U-R4M01	MC10C-B4659-U-R2M01
DC Side		
Cell Type	LFP	LFP
String Type	1P416S	1P416S
System Configuration	10×1P416S	10×1P416S
Battery Capacity (BOL))	5365kWh	4659kWh
DC Usable Energy(BOL)@FAT	5099kWh	4428kWh
DC Usable Energy (BOL)@SAT	4946kWh	4295kWh
Battery Voltage Range	1081.6～1497.6V	1081.6～1497.6V
Nominal Power	1236kW	2147kW
General Parameters		
Dimensions(W×D×H)	6058×2438×2896mm	6058×2438×2896mm
Weight	≈41035kg	≈41385kg
IP Rating	IP55	IP55
Operating Ambient Temperature	-30℃~+55℃【1】	-30℃~+55℃【1】
Relative Humidity	5%~100%	5%~100%
Max. Working Altitude	＜2000m	＜2000m
Cooling Concept	Smart Air Cooling	Liquid Cooling
Noise	≤75dB(A)	≤75dB(A)
Fire Suppression System	With fire alarm system(Aerosol optional)	With fire alarm system(Aerosol optional)
Communication Interfaces	Ethernet	Ethernet
Communication Protocols	Modbus TCP/IP	Modbus TCP/IP
Standard Color	RAL9003	RAL9003
Compliance	UN38.3,UN3536,UL9540A,UL1973,IEC62619	

Note:
【1】Power derating is performed when the ambient temperature is below -15℃ or above 45℃.

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