Promotion of higher penetration of distributed PV through storage for all (StoRES Project) in Italy

Susanna Mocci
Dept. of Electrical and Electronic Engineering
University of Cagliari
Cagliari, Italy
susanna.mocci@diee.unica.it

Andrea Rubiu
Municipality of Ussaramanna
Ussaramanna (VS), Italy

***Abstract*— In the paper the Italian contribution in the progress of the European project StoRES - Promotion of higher penetration of distributed PV through storage for all - is presented. The primary challenge is to achieve increased penetration of Renewable Energy Sources (RES) and predominantly photovoltaics (PV), in the energy mix of islands and rural areas in the Mediterranean (MED) region without compromising grid stability. The main objective of StoRES is to boost self-consumption in the MED region with the integration of optimal storage solutions, by integrating PV and energy storage systems (ESS) under an optimal market policy in order to remove the barriers concerning grid reliability with higher RES deployment. Coupled PV-ESS solutions will be tested in different pilot sites by taking into account local particularities for optimization. Sardinia is a good region for testing PV-ESS solutions, and ESS will be installed in different pilot sites in the Municipality of Ussaramanna (Sardinia, Italy). The selection of different residential units with existing rooftop PV has been completed. The design of joint technical solution has been applied to the local situation.**

Keywords*— Photovoltaics, Energy Storage Systems, Residential storage, Energy management, Self-consumption.

I. Introduction

The European Union (EU) has fixed ambitious targets for the RES share aiming at reaching a resilient Energy Union. The main objective is the decarbonisation of the distribution network, and the integration of higher shares of distributed generation through the deployment of innovative and flexible energy management strategies. However, significant restructuring of the electricity network with the adoption of new technologies is now needed in order to allow further RES penetration. Europe has put forward the “Clean Energy For All Europeans” (Winter Package) [1].

The implementation of innovative technologies such as smart energy management systems and battery storage solutions to support RES will be established. For this reason and also due to the reduced prices of RES, consumers will be encouraged to further utilize RES with benefits such as the right to produce and self-consume electricity as well as feed any excess back to the grid.

The project StoRES “Promotion of higher penetration of distributed PV through storage for all”, funded by the European Regional Development Fund (2016-2019), addresses the development of an optimal policy for the effective integration of RES and Energy Storage Systems (ESS). The motivation behind StoRES project is the promotion of photovoltaic (PV) installations in the MED region using smart, optimised and innovative solutions that lift the concerns of all the involved stakeholders of the energy sector. In fact, testing coupled PV-ESS solutions in different pilot sites and taking into account local particularities for optimization, current barriers concerning grid reliability with higher RES deployment will be eliminated.

StoRES foresees the development of an optimal policy for the effective integration of PV and ESS via testing smart solutions in 5 MED islands and rural areas. The challenge is how to achieve high PV penetration in those MED areas, while solving all market/technical/grid/tariff issues without compromising grid stability or security of supply, by boosting levels of PV self-consumption within the MED through an optimal storage solution. A number of residential pilots will be selected in each of the participating pilot regions (Cyprus, Greece, Italy, Spain and Portugal) where distinctive particularities, needs and requirements will be taken into consideration for the optimal development of common technical solutions. Regarding the pilots sites, they consist of domestic consumers with PV systems on their rooftops with private or social ESS (only in Cyprus). The private ESS will be installed at the house level and will serve the needs of the household under a smart self-consumption policy with Demand Side Management (DSM) capabilities.

StoRES is expected to change the current situation concerning grid reliability with higher RES deployment in islands/rural areas giving a cost-effective option to the public on more affordable and sustainable energy supply. The project will highlight the barriers in islands and rural networks preventing the increased penetration of PV systems. These barriers can be related to the existing infrastructure (electric network, storage facilities, transferability of energy, smart-metering etc.) and policy framework (flexibility, adaptability, bureaucracy, costs etc.).

Moreover, the real costs related to the tariff accompanying the energy policy are identified, in order to adapt the policy into the market rules as applied globally. Also, the problems and barriers regarding the introduction of ESS taking into account the current situation are identified such as financial, administrative, and technical.

In the first phase of StoRES the Italian partner has worked on the wide dissemination of the StoRES main objectives at local and regional level, in order to involve the community to joint the project and to promote the expressions of interest. Then, the main steps reached in the StoRES project are:

- The preliminary study, technical and policy barriers, current status and market: the state-of-art analysis of the RES, PV and ESS in Italy has been carried out and compared with the other partners' studies. The study of policies, framework and barriers has been implemented, with particular attention to the storage, since it is a developing solution in Italy and very few installations are available.
- The selection of pilot sites representing typical consumers, using production/consumption data: the selection of different residential units with existing rooftop PV system as pilot locations has been completed, and the energy consumption of the different pilot households has been studied in order to suitably size the storage units that will be installed.
- Finalising ESS technical solution for the selected pilots (Lithium ion, or lithium iron phosphate, or other Lithium technology): The design of joint technical solution has been applied to the local situation, and the stage of tender preparation for the purchase of equipment is in progress.

II. State of the Art and Barriers in Italy

A. RES And PV targets

A priority for Italy is to resume sustainable growth – sustainable from both the economic and the environmental perspective. The energy sector has a fundamental role to play in the growth of the economy and of the country, and achieving a more competitive and sustainable energy is therefore one of the most significant challenges in Italy. That is mainly why the Government has drawn up a National Energy Strategy (SEN) [2] that sets out clearly the main goals to be pursued in the coming years, as well as describes the basic decisions to be taken and establishes the priorities of action. Moreover, consumers drive the energy transition. The distributed nature of RES, the competitive costs of RES technologies, and new developments in smart grids and battery storage solutions make it possible for energy consumers – both at a domestic and an industrial level - to become active players on the market.

Italy has adopted national renewable energy action plans to meet its renewables targets (including electricity, heating and cooling and transport), and to achieve its EU target for final energy consumption from RES by 2020. If the SEN energy efficiency target (126 Mtoe of final energy consumption in 2020) is reached, 21.4 Mtoe of final energy consumption should come from renewables in 2020. Moreover, Italy has reached its objectives on RES share (17%) five years in advance, thanks mainly to a sharp increase in non-hydro power production capacity between 2008 and 2012. In 2016 the provisional share of RES in the gross final consumption of energy reached 17.6% [3]. In the past years, the number and capacity of PV plants in Italy grew at a very sustained pace. In 2008 PV capacity was about 2% of the total renewable capacity installed in Italy. In 2016 this share became 37% [4],[5]. In fact, until July 2013, under the "Fifth energy account" (Conto Energia) PV plants with a minimum capacity of 1 kWp and connected to the grid could benefit from a feed-in-tariff (FiT), based on the electricity produced. The tariff differed depending on the capacity and type of plant and was granted over a period of 20 years. The "Fifth energy account" also had a premium dedicated to self-consumption.

According to the GSE (Gestore Servizi Energetici) by the end of 2016 more than 730,000 PV plants were installed in Italy, for a total power of 19.3 GWp (preliminary data in Fig. 1). The new PV installations in 2016 reached about 373 MWp, whereas 300 MWp was achieved in 2015. In 2016 Italy met 7.3% of its electricity needs with solar. Despite this outcome, the rate of new PV installations in Italy has declined compared with the past years, with the majority of solar being added through the Italian net-metering scheme (Scambio sul Posto, SSP). GSE has the role of managing net-metering and paying the related contribution to the customer, based on injections and withdrawals of electricity in a given calendar year and on their respective market values.

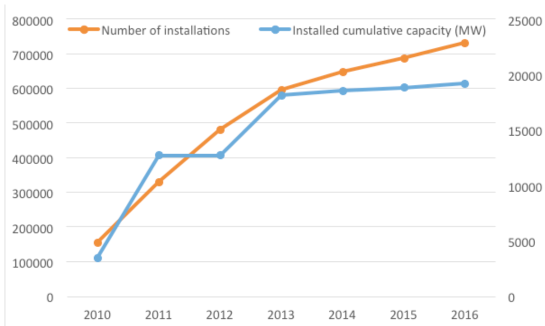

Fig. 1 Number and capacity of PV plants in Italy (2010-2016).

The majority of PV plants (91%) have size below 20 kWp, with average capacity of 5 kW (626,472 plants, 20% of overall capacity). Moreover, 98% of PV plants are below 200 kW (676,705 plants, 40% of overall capacity). Almost all PV power plants installed in Italy are connected to the low voltage network (97%).

Italy is also defining 2030 renewable energy targets [5]. PV will play a strategic role in 2030 energy scenario, depending on the adopted assumptions (price of electricity and CO_2) and policies (Fig. 2). The continuously increasing PV penetration in the energy mix combined with the intermittent nature of RES impose significant challenges to the electricity system operation. Therefore, the adoption of new technologies is urgently needed in order to achieve further RES deployment and eliminate the barriers related to grid stability.

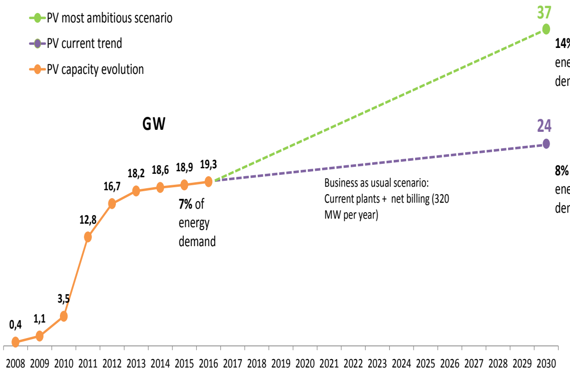

Fig. 2 Evolution of PV capacity and possible future trends in Italy [5].

B. ESS potential and barriers

Energy storage is considered as a technology that will bring higher rates of self-consumption from RES electricity and potentially solve the issues related to high PV penetration. However, technological and safety issues arise with the integration of ESS to the distribution grid. In addition to the aforementioned barriers, the lack of financial compensation mechanisms along with high capital costs are the main obstacles to ESS deployment.

Owing to the relatively high PV capacity of 19 GW, the concept of storing energy is becoming very interesting in Italy. Moreover, energy storage has emerged in energy discussion due to the large number of net-metered installations. However, there are some uncertainties about the contribution of storage to the income statement of a PV plant and also about the payback time. For instance, the current payback period for a residential PV system under the net-metering scheme is around seven years. Therefore, the combination of storage for on-site utilisation is not yet viable. In order to tackle these barriers, the Italian Regulator (AEEGSI) is now focused on distribution storage in order to identify a cost-effective solution for storage installations [6].

AEEGSI is committed to reform the Italian electricity market and has released two important resolutions aimed at developing the usage of electrochemical energy storage systems. These are resolutions n. 574 [7] and n. 642 [8], introduced in 2014. Resolution n. 574/2014 defines how storage systems can access and use the electricity grid, and resolution n. 642/2014 complements the n. 574/2014 by defining the grid services to be provided by storage systems. Furthermore, the Italian Electro-technical Committee (CEI) has released the technical standard CEI 0-16 for HV and MV applications [9], and CEI 0-21 for LV applications [10]. These requirements define the connection diagrams of the power plants and storage systems to the grid, with relative measurement and protection systems, and the grid services required for effective integration of the same. The AEEGSI resolutions n. 574/2014 and n. 642/2014 are significant for the development of a domestic storage market because, together with CEI technical requirement documents, they have set the rules for storage installations. The AEEGSI resolutions and the CEI requirements are driving the cost reduction of storage systems.

In April 2017 ANIE Energia and RSE - Research on the Energy System published a White Paper on "*Prospects and opportunities for Electrochemical Storage*", including selected best-case projects in Italy that integrate electrical storage systems and RES plants [11].

III. Selection of Pilot Locations

The procedure of identifying the pilot sites in each participating region in order to maintain the selection phase transparent and homogeneous was discussed. A similar methodology has been followed in each participating region for the identification of the pilot locations and it was of utmost importance to ensure the transparency of the selection process. As a consequence, the main guiding principle that has been taken into account includes the homogeneous selection since all pilots must be identified as an output of a common procedure. The sites must consist of existing residential prosumers with typical energy profile, ideally to have a balanced energy profile. Finally, local specificities and technical needs such as the maximum allowable system capacity, system connection, storage sizing and data collection availability have been considered for the selection procedure and the finalization of the joint technical solution.

In Italy, dissemination activities were carried out for the selection of pilots, such as the publication of an official call that was released through the local press, mailed to citizens and published through the Municipality website. In order to choose the pilots in line with the project scope, the selection criteria enlisted in Table I were taken into account for the evaluation of the interested applicants. The main criteria for the selection is the higher potential of self-consumption of the PV owners, deriving by the comparison between the energy delivered to the distribution network during the daylight hours by the prosumer and the consumption absorbed by the network during evening-night hours. In Sardinia, the on-site inspection and the evaluation of the consumption/production data provided by the prosumers have led to the selection of eleven (11) households, which have been selected to operate as pilot sites for the purpose of the StoRES project. The systems are typical residential premises with an existing rooftop PV system (rated at 3-12.5 kW) and two smart meters. The general information of the eleven selected PV pilots is outlined in Table II, whereas the map location of each pilot is shown in Fig. 3.

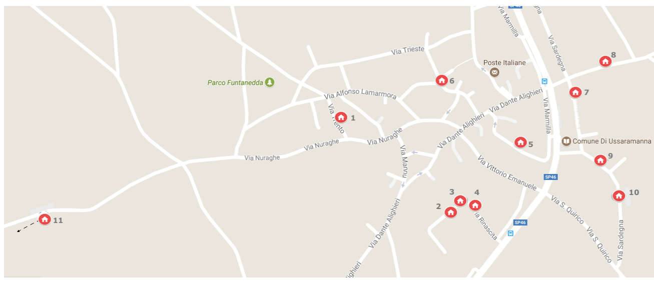

Fig. 3 Selected Pilot Locations in Municipality of Ussaramanna – Italy.

TABLE I. CRITERIA FOR THE PILOT SELECTION IN ITALY

Requirement	Fit criterion
Participant needs to have potential optimization of self-consumption	Existing prosumer with some kind of net-metering/premium/billing
System connection	1PH – 3PH
Nearly-zero energy house	PV production more or less equal to consumption. The potential self-consumption rate of each prosumer is one of the selection criteria that have been considered.
If DC-coupled system	a. Available space about 1.5 times the existing inverter to mount the new Hybrid Inverter (approximation). b. Enough space for batteries should be available (typical cabinet style battery HxWxD: 100x60x60cm).
If AC-coupled system	a. Enough space for Battery Inverter (assume the same size as the PV Inverter). b. Battery Inverter ideally next to existing PV Inverter (need to consider wiring capacity if placed away from PV Inverter). c. Enough space for batteries should be available (typical cabinet style battery HxWxD: 100x60x60cm).
Batteries location/space	a. Location close to Battery/Hybrid Inverter b. Enough space (typical cabinet style battery HxWxD: 100x60x60cm).
Batteries ventilation	Batteries will be sealed, mobile and electrically protected. However, the following is common practice to follow: a. If surrounding space >10m^3 → no additional ventilation required. b. If surrounding space <10m^3 → ventilation towards a space of >10m^3 is required.

TABLE II. GENERAL INFORMATION OF THE PILOT SITES IN ITALY

	Premise Type	PV System Capacity	Supply	Map Position
1	Typical household	3 kWp	1-PH	1
2	Typical household	4,9 kWp	1-PH	2
3	Typical household	5,9 kWp	1-PH	3
4	Typical household	4,6 kWp	1-PH	4
5	Typical household	3 kWp	1-PH	5
6	Typical household	6 kWp	1-PH	6
7	Typical household	6 kWp	1-PH	7
8	Typical household	12,5 kWp	3-PH	8
9	Typical household	5 kWp	1-PH	9
10	Typical household	3 kWp	1-PH	10
11	Typical household	4,9 kWp	1-PH	11

IV. DESIGN OF JOINT TECHNICAL SOLUTION

The different technologies and configurations available on the market for both residential and community storage applications are identified and analysed. In addition, regional requirements and needs that have been taken into consideration for each country are outlined, aiming at the development of the technical specifications of the solution and the optimal storage utilisation.

Among several different technologies available on the market for energy storage, electrochemical storage solutions are preferable for PV applications since they have suitable storage capacity range for small residential and community applications. Batteries lie in this category and are desirable for supplying energy for relatively short duration and also have very fast response time making them preferable for medium and low-voltage connection in comparison to other storage technologies. The main battery types available on the market for the scope of the project are Lead-acid and Lithium-ion. However, Lead-acid battery type has low energy density and short lifetime compared to other technologies, thus making it less competitive for long-life applications. Lithium-ion batteries have a unique structure as shown in Fig. 4, where a positive electrode (cathode) consists of lithium metal oxide and a negative electrode (anode), which is a graphite layer. In order for Lithium Ion cells to migrate into the cell and charge the battery, the cell is filled with an electrolyte. Lithium-ion technologies are considered as one of the fastest growing battery technologies since they can offer fast responding time and long lifetime [12]. Although different technologies have a wide range of applications, the battery type will be selected based on the requirements of all pilot sites and the scope of StoRES project.

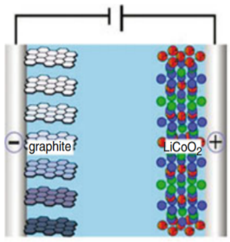

Fig. 4 Schematic representation of the Lithium-ion battery technology [13].

Two main configuration types can be distinguished depending on the PV system and the battery connection, namely the DC-Coupled and AC-Coupled systems. The schematic diagram for the DC-Coupled system is shown in Fig. 5 where the energy storage system is placed on the DC-side between the PV array and the DC-AC inverter.

Two different types of DC-coupled systems exist. The first one utilizes a typical string inverter and a charge controller, which is responsible for the battery charge and protection from overvoltage. This system can be easily fitted to existing grid-connected applications, but it involves various limitations to the system. In fact, the solar string inverter allows only uni-directional power flow (from the DC to the AC side), and the coupled PV-ESS system does not permit electricity to be stored from the public network, but only from the PV system. Moreover, the back-up supply to the household load is not supported, since the solar string inverter is designed to operate when the grid is in operation.

The deployment of a bi-directional hybrid inverter can solve these limitations. Despite the higher cost of hybrid inverters, various services are available to benefit the consumer and also support the public grid. For example, battery charging can be achieved with renewable and nonrenewable energy since electricity from the grid can be stored in the battery. Moreover, DC-coupled hybrid storage systems offer support for backup power supply in case of grid outage. Finally, ancillary services such as voltage regulation and frequency control can be achieved since active and reactive power can be absorbed or fed back to the grid.

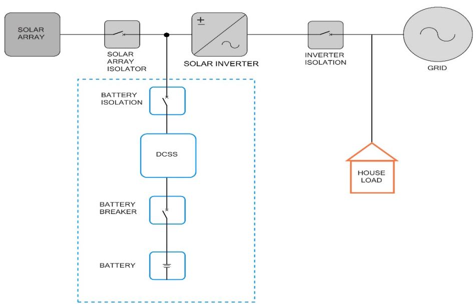

Fig. 5 Schematic diagram of a residential DC-Coupled storage system with a hybrid inverter.

In the AC-coupled system type, shown in Fig. 6, a PV inverter directly converts the PV generation to AC and is also connected to the public grid. The energy storage unit is facilitated by an additional bi-directional battery inverter to the AC-side, responsible for the energy flow between the battery unit and the household load. The AC-Coupled configuration offers great system flexibility and can also store energy from both directions (grid, PV array). Also, it can support UPS mode, which can provide backup from the battery system when grid failure occurs. For both cases, an Energy Management System (EMS) that ensures communication with the battery charge controller and the hybrid/solar inverter is responsible for optimal energy flow through the system based on the current PV production, the battery state of charge and the prosumer energy demand.

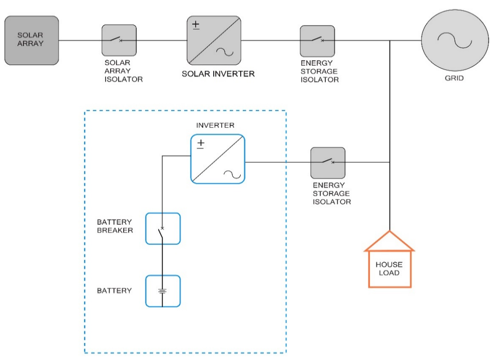

Fig. 6 Schematic diagram of a residential AC-Coupled storage system.

In Italy, the technical solution is designed accordingly so as to fulfill the energy needs of each pilot and at the same time size the battery approximately in order to ensure the optimal utilization of the integrated storage system. Considering the supporting storage technology, several different electrochemical battery technologies are available on the Italian market. However, state-of-art Lithium Ion batteries or Lithium Iron Phosphate or other Lithium technologies will be considered for all pilot sites in Italy since these technology types offer high-energy conversion performance, long lifetime and low self-discharge rate (preferable for long-life PV applications).

Since the daily load curves for the selected prosumers were not available, it has been necessary to refer to typical daily load/production curves. In Fig. 7 typical PV production and energy consumption profile for a representative household in Italy is shown for a winter working day, delivered by ATLANTIDE Project [14]. The data reported comes from a measurement campaign carried out by ENEL in 2008 of about 5000 customers (3400 residential users).

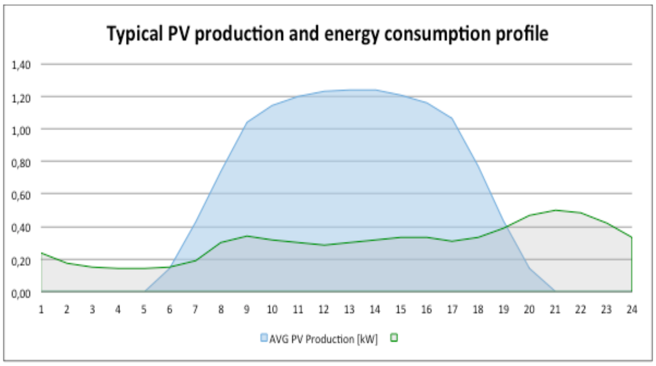

Fig. 7 Typical PV production and energy consumption profile in Italy.

The self-consumption rate of a typical household in Italy is moderate, and PV generation and load consumption occur at different time slots. So, the electricity is delivered from the public grid to cover the demand during the periods where PV production is low.

By analyzing the pilots data, the average daily energy yield for a 3 kWp PV system is 13 kWh, and the household daily energy consumption reaches up to 7 kWh (average energy consumption during daylight is 5 kWh). Similarly, for the 5 kWp PV system, the daily energy yield is close to 18 kWh and the daily consumption close to 9 kWh. Nevertheless, the theoretical ESS capacity range of 8-12 kWh is strongly overestimated if properly considering consumption out of daylight, and thus a range of 4-8 kWh is considered suitable for the selected pilots. Modular 2 kWh batteries are under consideration to reach the suitable capacity (4-6-8 kWh). The AC-coupled system solution is chosen to avoid impact in the production of PV systems considered for the FiT recognition.

Finally, taking into consideration the national standards for grid-connected systems, the detailed technical specifications of the joint residential solution have been developed accordingly and are listed in Table III.

V. Conclusions

The paper summaries the progress and targets of StoRES project. For this purpose, coupled PV-EES residential storage systems will be developed aiming at optimizing the utilization of storage towards achieving higher PV penetration. The process of selecting the pilot sites in Italy is analyzed highlighting the importance of the selection criteria developed. The installation of the systems in all pilot locations will be completed within the final quarter of 2017.

The participation of public authorities in the project serves the purpose of mobilizing them, through gaining expertise, towards making interventions to eliminate obstacles limiting higher contributions of RES in the MED area. It is expected that the project results, policy recommendations and adaptation of new technologies will be transferable to all MED regions.

TABLE III. TECHNICAL SPECIFICATIONS

Battery Inverter	
Support charging technology	Lithium Ion/ Lithium Iron phosphate/other Lithium battery packs
Nominal Voltage	1PH: 230VAC ±10% 3PH: 400VAC ±10%
Nominal Power	3-6 kVA
Nominal Frequency	50Hz
Total harmonic distortion	< 5%
Power factor (cosφ)	0.85 – 1 inductive / capacitive
Ingress protection	IP55 (at least)
Inverter design	Transformerless
Cooling	Regulated air cooling
Installation	Indoor and outdoor installation
Permitted humidity	0 - 100 %
Ambient temperature range	-15°C to +60°C
AC Voltage Regulation (Batt. Mode)	1PH: 230VAC ± 5% 3PH: 400VAC ± 5%
Peak Efficiency	>95%
Communication with EMS or external controller	Ethernet or CAN or RS485 (anything compatible with the EMS)
Communication with battery	Ethernet or CAN or RS485 (anything compatible with the battery)
Communication with electricity meter	RS485 (or anything compatible with the meter)
Battery Unit	
Technology	Lithium Ion/ Lithium Iron phosphate/other Lithium
Usable Capacity	4-8 kWh (for residential applications)
Nominal Voltage	48 VDC preferable
Ingress protection	IP34 (preferable); IP24 (acceptable)
Cooling	Regulated air cooling
Installation	Indoor installation
Ambient temperature range	0°C to +50°C
Efficiency @ 0.3C, 25°C	>90%
Battery lifetime @ 25°C	10 years
Battery cycles @ 0.5C, 100% DOD of usable capacity, 25°C	>5000

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