Dispatchable Solar Power

May 2017

www.pvhstorage.com
• **Introduction to Gransolar Group**
  - History
  - Global Installation Footprint

• **Market Status**
  - Current vs Projection

• **Electricity Terminology**
  - Time of Use Tariffs

• **Technology**
  - Introduction to PV & Storage
  - Design Examples

• **Operating Modes**
  - Oversizing
  - Alternative configuration of EMS

• **Business Models**
  - Cash & PPA Structures

• **PVH Energy Storage**
  - Product Line-up
  - Pipeline
Key milestones of the year:

- **2009**
  - Development of 70 MW in Italy
  - 2 new plants in Spain

- **2010**
  - 30 MW installed in Italy
  - Incorporation of GRS Chile and US
  - 10 MW concession contracts awarded in Portugal

- **2011**
  - 32 MW installed in Italy
  - PVH incorporated in the US
  - Incorporation of Hypesolar to develop 12 MW in Portugal

- **2012**
  - Construction of 12 MW in Portugal
  - Construction of 150 MW in South Africa
  - Incorporation of GRS Centro America

- **2013**
  - 10 MW concession contracts awarded in Portugal
  - Construction of 70 MW in Italy
  - Construction of 12 MW in Spain

- **2014**
  - Development of 70 MW in Italy
  - PVH incorporated in the US
  - Incorporation of GRS in the US
  - Construction of 25 MW in New Mexico (US)
  - Award of 25 MW in New Mexico (US)
  - Construction of 6 MW Sibo (Guatemala)
  - Construction of El Paseo and Cangrejera (El Salvador)

- **2015**
  - Incorporation of GRS in Centro America
  - Construction of 50 MW in Philippines (Project management and PVH supplier)
  - Construction of 12 MW in Portugal
  - Construction of 150 MW in South Africa

- **2016**
  - 800 MW awarded in Dubai
  - 43 MW awarded in USA
  - 120 MW awarded in Chile
  - Construction of Camargo (Mexico)
  - Construction of Mont Choisy (Mauritius)
  - Capital increase
Market Projection

- Load shifting taking form with hybrid business cases of price arbitrage and capacity/demand reduction as main drivers
- Large PV and Wind projects being planned with storage
- Large utility capital investment deferral projects with storage to avoid grid upgrades
- Industrial clients taking lead on storage (data centres, mines, large users)

Current Status

- Traditional clients: off grid lead acid <30 kW size in remote or rural locations
- Load Levelling (Li-Ion) 2016 increase with multiple EU tenders
- Catastrophes driving storage implementation (South African load shedding, South Australia blackout)
- Islanded grid first users of load shifting (2 x PV w/storage on Hawaii 2016-17)
Electricity Terminology

Base Load

Typical Season Load Profile
Electricity Terminology

Seasonal Load
Electricity Terminology

Peak Load

The graph illustrates the peak load throughout the year, with significant spikes in August, indicating high energy consumption during this month.
Electricity Terminology

Capacity

- Base Load
- Seasonal Load
- Peak Load
- Capacity
Electricity Terminology

Unused Capacity

- Base Load
- Seasonal Load
- Peak Load
- Capacity
- Unused Capacity
Electricity Terminology

Load Shifting

Load Shifting spreads out peak demand to lower the capacity need.
Illustrative Load Profile over 24 hours
Photovoltaic System Sizing

• Imagine a car:
  • 300HP is the MAXIMUM horsepower the 3.7L V6 engine can deliver at its peak power output / performance \((\text{power} = \text{kW})\)
  • 1000kWp PV System refers to the 1MWp peak MAXIMUM output the system will produce in full sunlight \((\text{kWp} - \text{Kilowatt Peak})\)

• System sizing is described as the PEAK output in full sunlight under ‘Standard Test Conditions’ and can refer to AC \((\text{kW})\) or DC \((\text{kWp})\)
**Type 1: Self Consumption.**
Solar System dimensioned to 20-30% of client consumption
No interference with Grid
Can be larger depending on load profile analysis

**Type 2: Excess to be injected in the grid**
Optimize solar system with production excess injected back to the grid
Requires Net Metering and agreement with Utility

**Type 3: Solar + Storage**
Solar System + Storage ideal for large base loads
Capture high tariffs during peak hours 18:00 to 20:00
Imagine another car:

- The **power** is the horsepower of the engine, the bigger engine the faster acceleration (**power = kW**).
- The range you can drive is determined by the size of the fuel tank (or for EV's the size/capacity of battery), the bigger the tank, the longer the range (**capacity = kWh**).

- Traditional PV Plants: **kW** defines **power output** only. **kWh** defines the **volume of power output** delivered over **time**.
- Energy Storage Plants: **kW** defines **charge/discharge power**. **kWh** defines the **time** one can deliver a set **kW power output**.
Technology

Introduction to Storage

Rechargeable Batteries
- Lead Acid
- NiCd, NiMh
- Li-Ion
  - Lithium Iron Phosphate
  - Lithium Manganese Oxide
  - Lithium Nickel Manganese Cobalt Oxide

Flow Batteries
- Vanadium
- Zinc Bromide
- Iron
- Future Technology - Organics (Hydrocarbon)

Fuel Cell (Chemical)
- Hydrogen & Oxygen

Fig. 2. Schematic of a PEM fuel cell operation. Source: World Fuel Cell Council.
### Spinning Reserve

**10% Power @ 15 minutes**

**Value Proposition:**
Off-grid applications – allows generators to start up or be taken off line. Ramp rate control – Fill solar PV production gaps on cloudy days.

### Load Levelling

**10-25% Power @ 2-4 hours**

**Value Proposition:**
Intermittency - Day time PV plant production levelling (ramp rate control). Therefore offsets daytime consumption only. Helps increasing renewable penetration.

### Load Shifting (Base Load Plants)

**25-40% Power @ 4-6 hours**

**Value Proposition:**
Solar + Storage offers a stable output for up to 16 hrs/day acting as a base load. Helps increase renewable penetration.

### Peak Hour Plants

**>50% Power @ 4-6 hours**

**Value Proposition:**
Offers a priority of early evening feed in from the Storage, typically after sunset. Includes Dual Cycling capability of day time charging with solar and off-peak night time charging from the grid.
Technology

Design Examples

Spinning Reserve

Load Levelling

Load Shifting (Base Load)

Peak Hours Plant
Slide shows 7th of May production with average solar output; no cloud cover but reduced output in the morning and afternoon and below the baseload requirement at midday peak.

Bell shaped production curve

No evening production

A majority of days would have no intermittency and a large evening production.

Operating Modes

Oversizing
Intermittency Prioritized

Both graphs show April 25th production; a below average day with low solar production due to early-midday and an afternoon cloud cover reducing output significantly (50% reduction).

When Intermittency is prioritized the battery discharges most of its power during normal sun hours to avoid variations in daytime production.

Evening Prioritized

When evening is prioritized the plant has intermittent daytime production but a stable and predictable evening production.

Flexibility in operations: the prioritization can be changed as required by the off taker (daily).
<table>
<thead>
<tr>
<th>Business Models</th>
<th>CASH vs Power Purchase Agreement</th>
</tr>
</thead>
</table>

### Flat Rate
- Rate based on stable baseload consumption applications
- Daytime production is prioritised (no intermittency)
- Storage reacts to poor day time weather conditions caused by cloud cover.

### Peak Hours
- Rate based on peak hour consumption applications
- Evening (peak hours) production is prioritised (no intermittency)
- Storage does not react to poor day time weather conditions caused by cloud cover.
**PVH Energy Storage Product Line-up**

**Containerized**
- 200 kW power
- 1000 kWh capacity
- Ideal for off grid or C&I projects
- Matches well with 400-500 kW solar PV plant
- Simple installation on site
- Delivered complete with DC/AC inverters and SCADA system
- Life expectancy >20 years or 20,000 cycles
- Temperature range without cooling/heating: -5 to 50 degrees

**Large Scale**
- 500 - >1000 kW power
- 4000-6000 kWh capacity
- Ideal for large scale PV plants and utility interconnections (substations)
- Requires rodent proof and water tight building (simple industrial building)
- AC MV connection, SCADA included in EMS
- Life expectancy >20 years or 20,000 cycles
- Temperature range without cooling/heating: -5 to 50 degrees