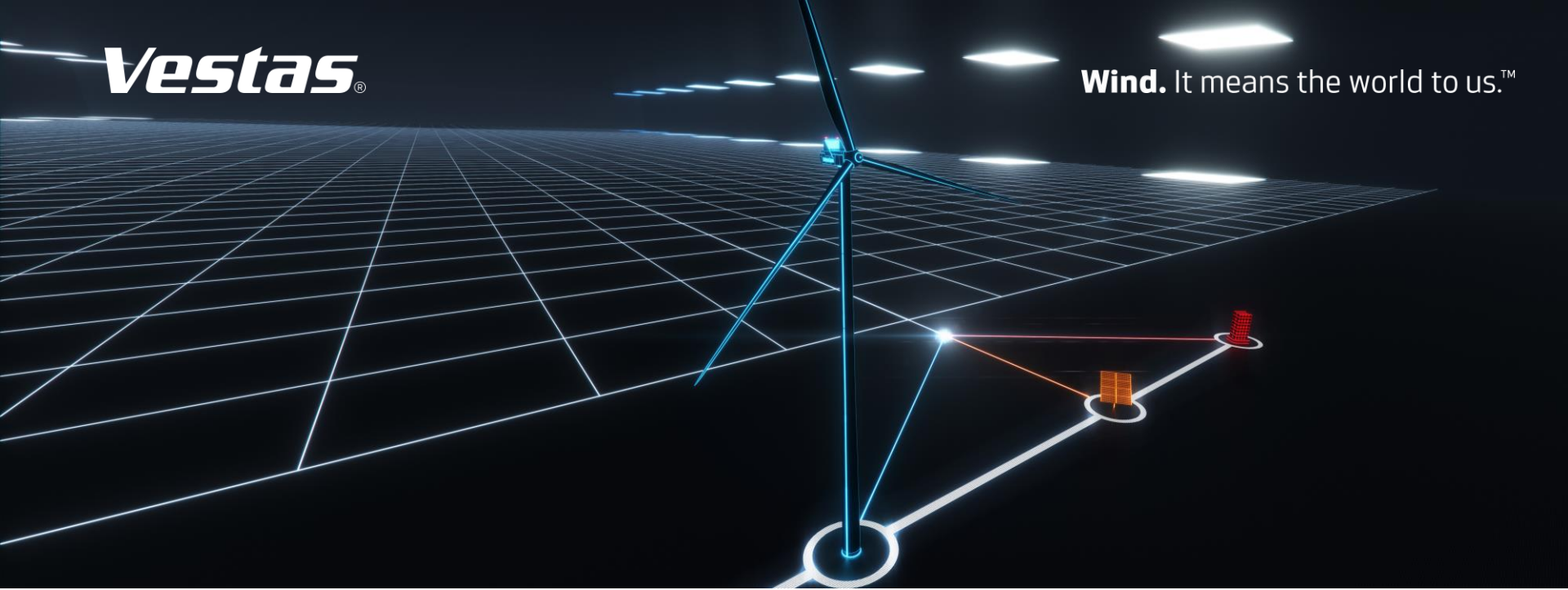


Vestas Power Plant Solutions Integrating Wind, Solar PV and Energy Storage

Public

L. Petersen, B. Hesselbæk, A. Martinez, R. M. Borsotti Andruszkiewicz, G. C. Tarnowski

Vestas

N. Steggel, D. Osmond

windlab

Profile

Lennart Petersen

- M.Sc. Electrical Power Systems
- Industrial PhD student

- Working on Hybrid Solutions (Configuration, Control & Operation)
- Presentation about PhD work in *Session 5B – System Design Aspects* (Wed., 8.45)

Wind Integrated Hybrid Power Plant

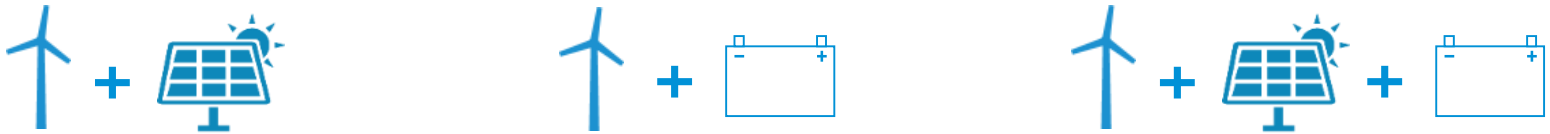
Definitions

General definition of hybrid power plants with renewables [1]:

This is a power system, using one renewable and one conventional energy source OR more than one renewable with or without conventional energy sources, that works in 'stand-alone' or 'grid-connected' mode.

Vestas definition of a grid-connected wind integrated hybrid power plant:

*A wind integrated hybrid power plant, is a **sustainable energy solution** in which wind energy is complemented by solar energy and/or energy storage.*



1. I. Lazarov, V. D., Notton, G., Zarkov, Z., Bochev, "Hybrid power systems with renewable energy sources types, structures, trends for research and development.," *Int. Conf. ELMA*, 2005

Wind Integrated Hybrid Power Plant

Definitions

General definition of hybrid power plants with renewables [1]:

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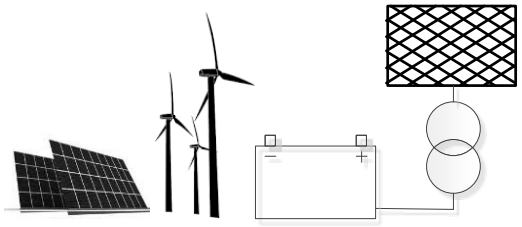
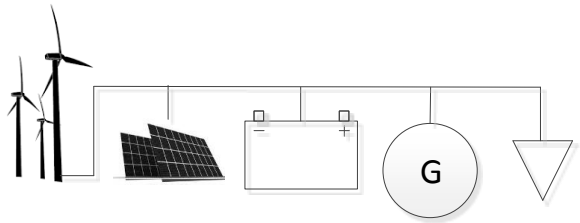
On-Grid Hybrid Power Plant



→ grid-integrated power plant unit

Off-Grid Hybrid Power Plant



→ consumer-directed stand-alone unit (isolated microgrid)

1. I. Lazarov, V. D., Notton, G., Zarkov, Z., Bochev, "Hybrid power systems with renewable energy sources types, structures, trends for research and development.," *Int. Conf. ELMA*, 2005

Agenda

Value Proposition

- Combining Wind and Solar
- Combining Wind (& Solar) and Storage

System Topologies & Plant Control

- WTG-coupled vs. Co-Located
- Hybrid Power Plant Controller

Kennedy Energy Park (Australia)

- Operational use cases
- Weak grid connection

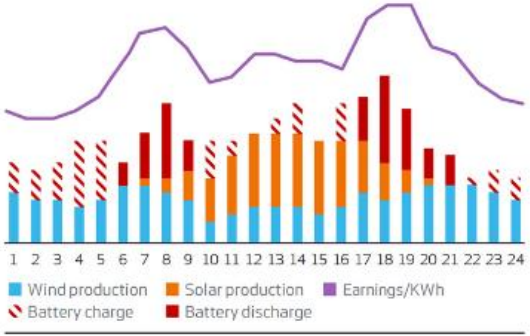
Shift in Energy / Power Sector

Maturity of renewable energy pushes governments to reduce and phase out incentives

MARKET

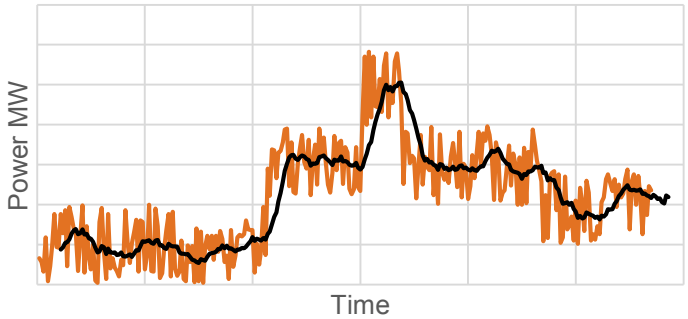
Fixed
Power Purchase Agreements

Three tier
Power Purchase Agreements



Merchant
pricing

GRID



Increased power fluctuations and decreased control

Making **control** and **predictability** contribution towards the power & energy system can enable higher penetration of renewable energy!

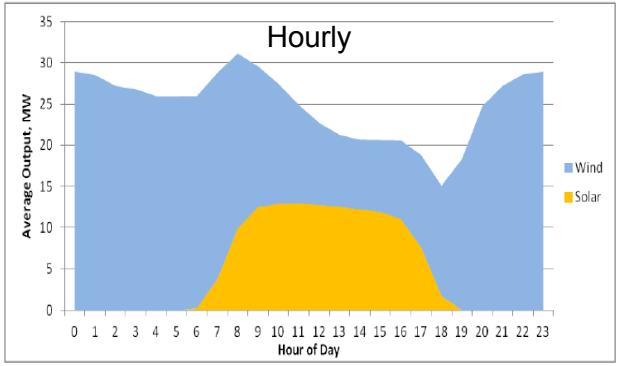
Vestas

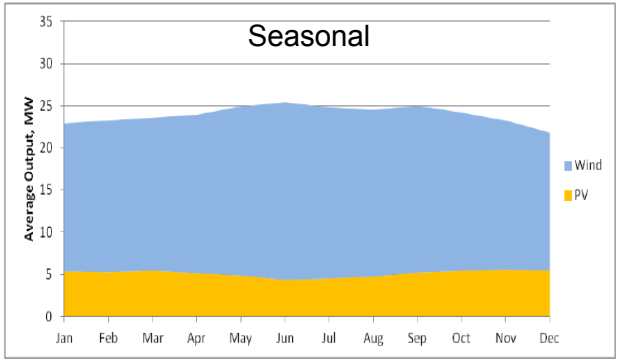
Value Proposition – Wind + Solar + Storage

Potential for overall LCOE reduction

Example

Complementarity of generation profiles





- Increased Annual Energy Production (AEP) and Capacity Factor (CF) per substation capacity
  → by complementarity of generation profiles
  → store excess power (curtailment reduction)

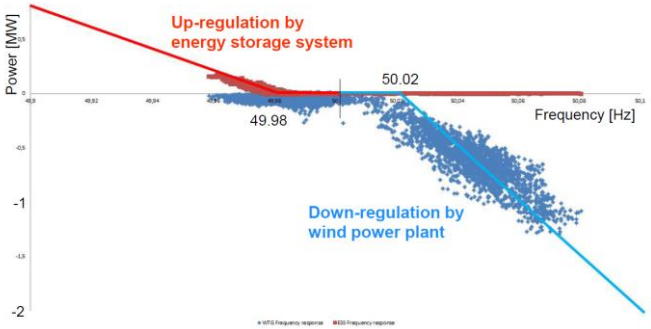
- CAPEX reduction
  → El. Infrastructure (“overplanting”)
  → Financing (higher P-value = lower project discount factor)

- OPEX reduction
  → Simultaneous maintenance
  → Share control & operation
  → deliver power despite shut-down WTG

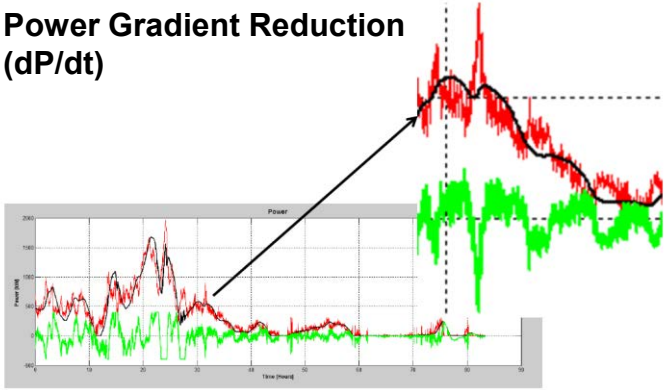
Value Proposition – Wind (& Solar) + Storage

Grid services: License to operate in new markets, comply to country specific grid codes

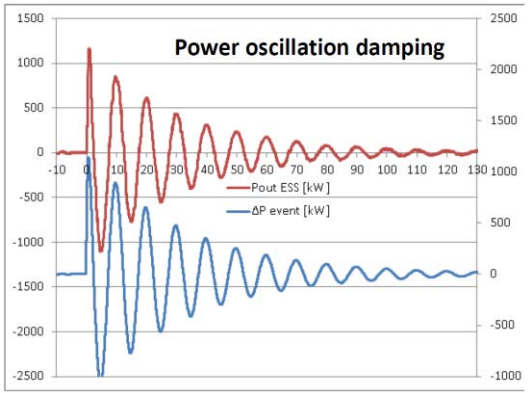
Frequency Support



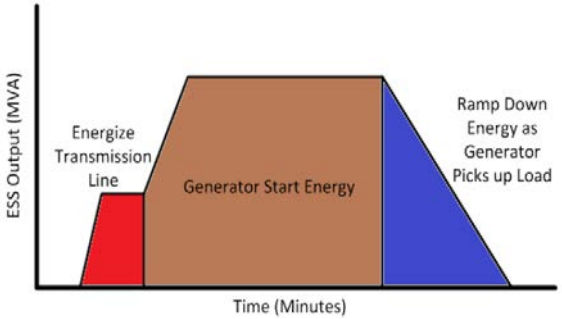
Power Gradient Reduction (dP/dt)



Power Oscillation Damping



Black Start

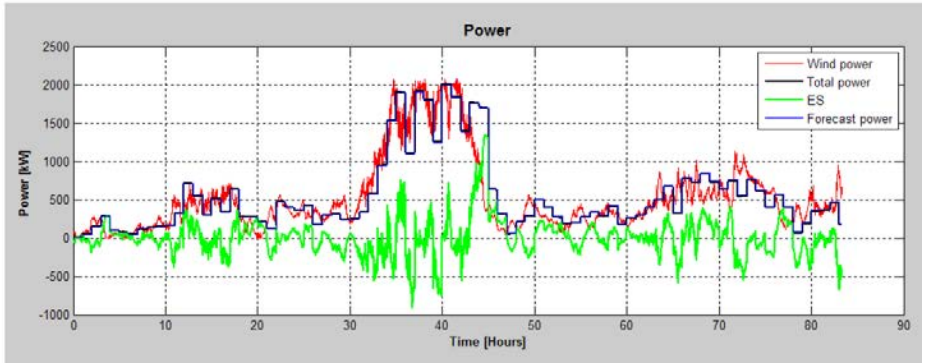


J. Eyer, G. Corey: Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide (2010)

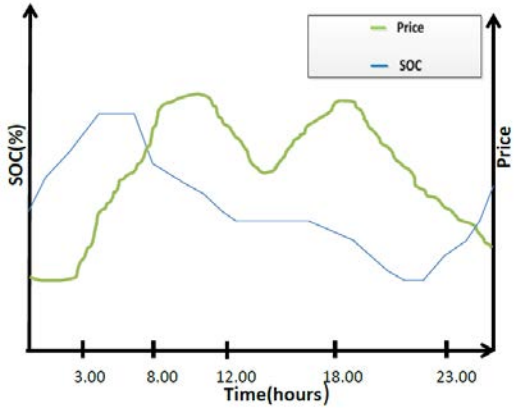
Value Proposition – Wind (& Solar) + Storage

Energy services: Enter into new markets, allow to capture additional revenue streams

Forecast Error Reduction

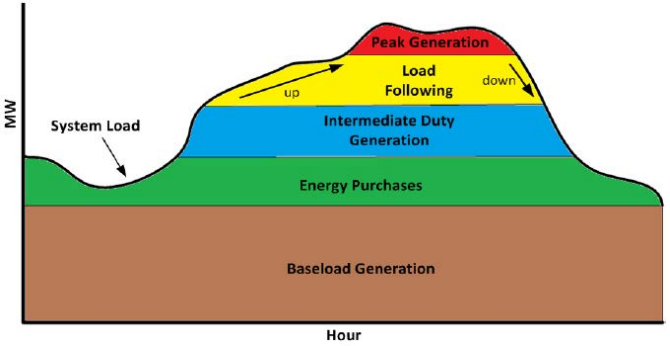


Energy Arbitrage



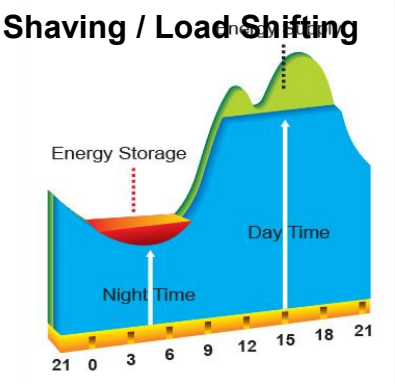
A. A. Akhil, G. Huff et al.: DOE/EPRI Electricity Storage Handbook in Collaboration with NRECA (2015

Load / Demand Following



J. Eyer, G. Corey: Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide (2010)

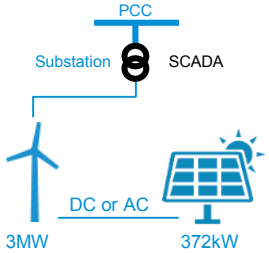
Peak Shaving / Load Shifting



Hybrid Power Plant Topologies

Small plants
Low solar/wind ratio

WTG-coupled

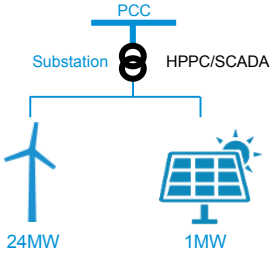


Wind and PV

Demonstrator in Spain

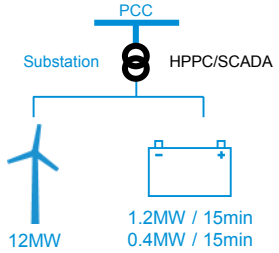
Large plants
Hybrid Power Plant Controller (HPPC)

Co-Located (sharing substation and infrastructure)



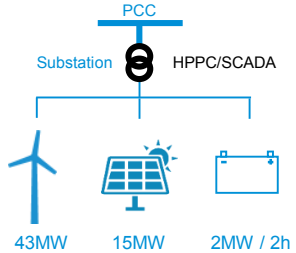
Wind and PV

Louzes, Greece



Wind and storage

Lem Kær, Denmark



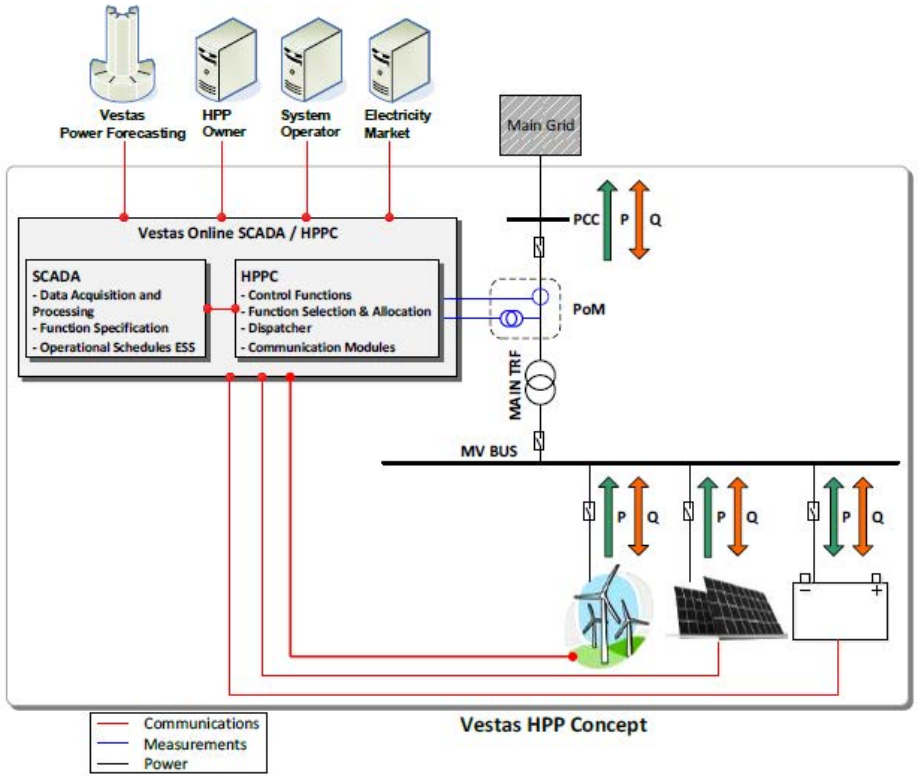
Wind, PV and storage

Kennedy, Australia

Vestas scope of work: **Full EPC & Service**

Controlling the Hybrid Power Plant

Plant level control and optimisation of individual assets



Exemplary HPPC functionalities

1. Grid/Power services

- Voltage Control (V / Pf / Q)
- Frequency Control
- Power Gradient Reduction
- Power dispatch

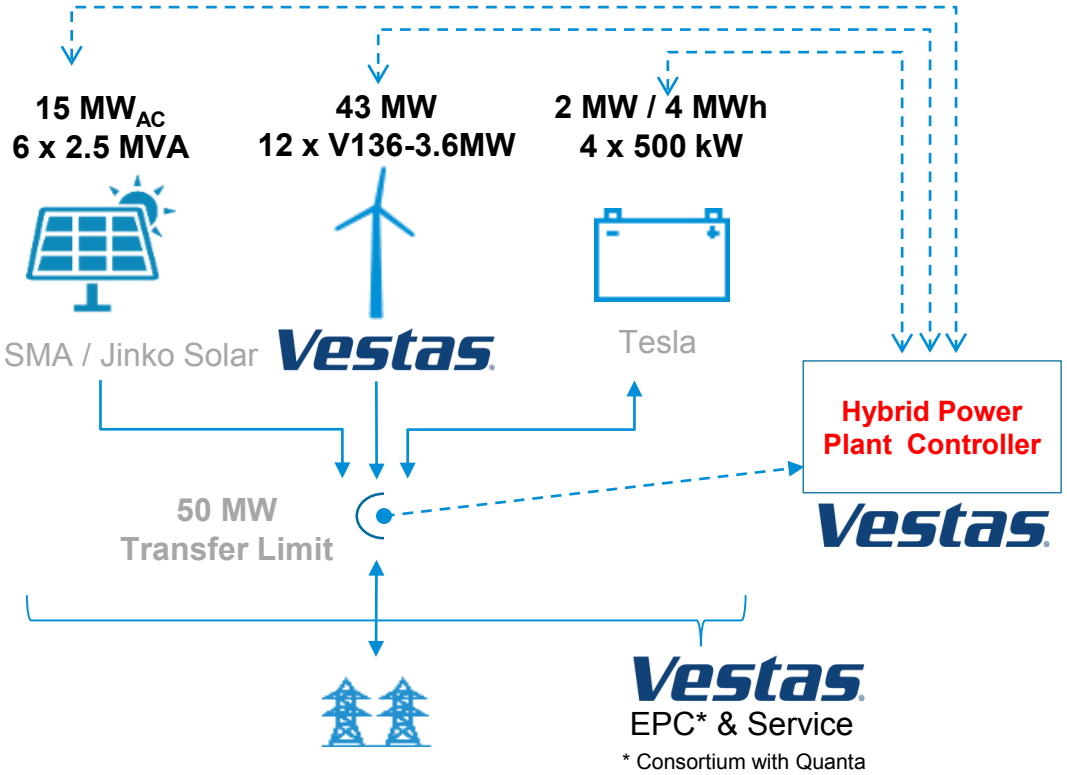
2. Energy/Market services

- Firming / Reduce forecasting error
- Peak-shaving / Set schedule
- Energy Arbitrage
- Load/ Demand following

Kennedy Energy Park (Australia)

World's first utility-scale hybrid power plant combining wind, solar & storage

KENNEDY ENERGY PARK



KEY BENEFITS

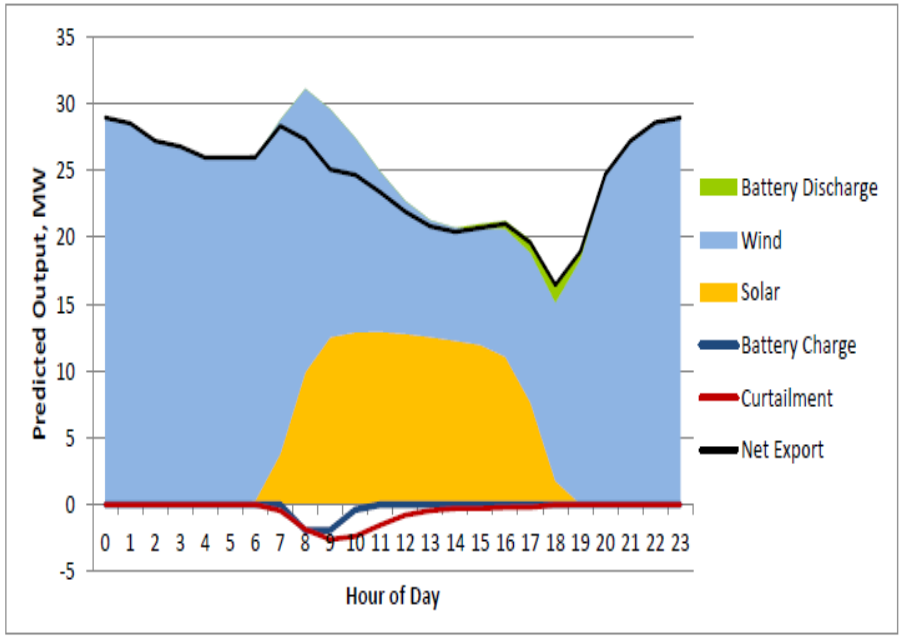
- Increased Energy Production
- Improved Capacity factor
- Reduced cost
- Fulfillment of Grid Requirements & enable new earning opportunities

KEY CHALLENGE

- Controlling & operating the Hybrid Power Plant

Use Cases with Battery Energy Storage System

Complementing Wind and Solar Energy at Kennedy Energy Park



Curtailment Reduction ("Store curtailed energy")

- Charge the battery at time when the available energy resource from wind and solar is above the allowed power transfer at the connection point (8-11am)

Energy Arbitrage

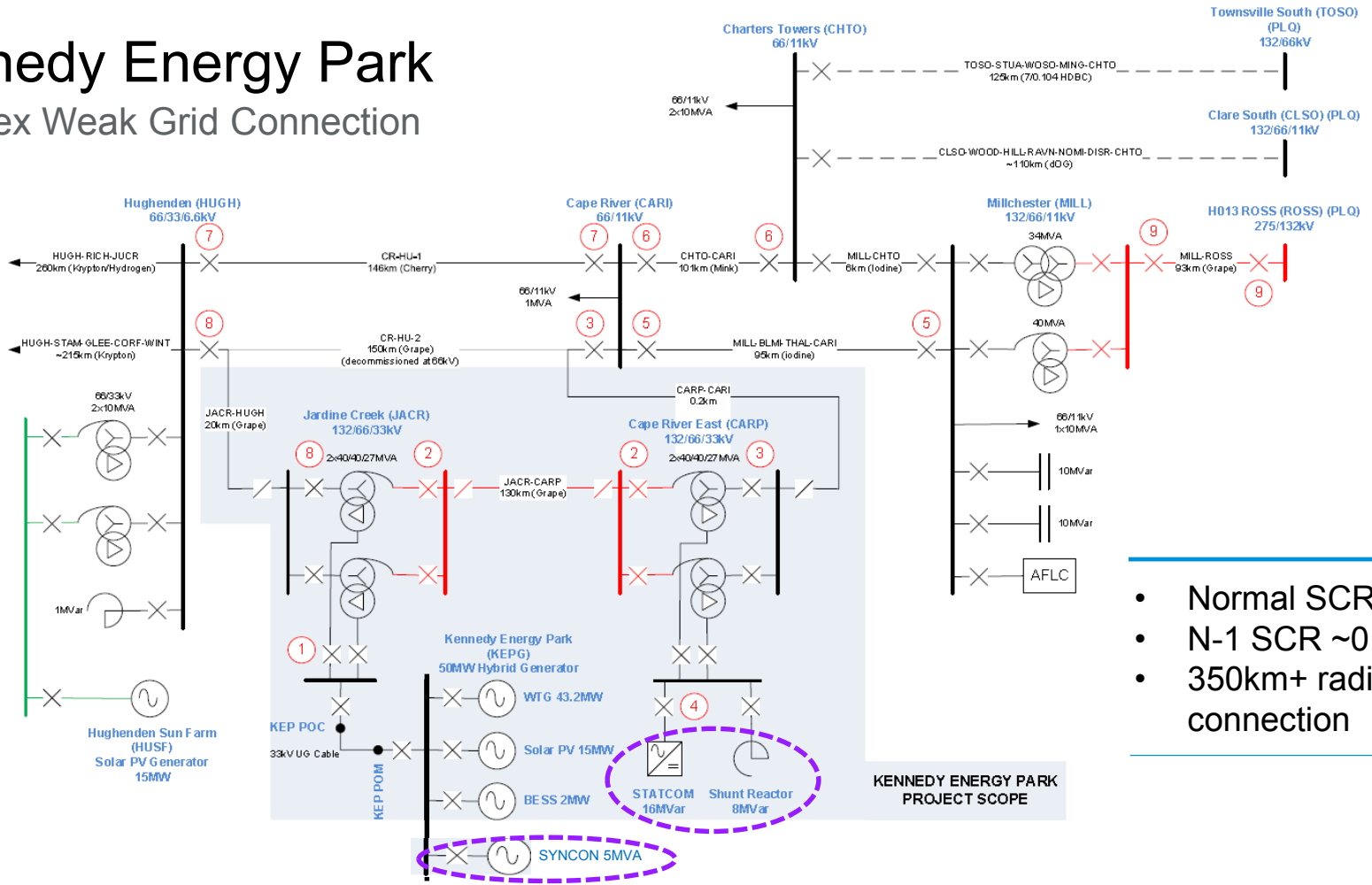
- Charge the battery at times of low energy prices (typically 8-11am)
- Discharge the battery at times of high energy prices (3-8pm depending on the month of year)

Frequency Support (FCAS)

- Contingency FCAS for the periods of time outside arbitrage and curtailment periods of operation.

Kennedy Energy Park

Complex Weak Grid Connection

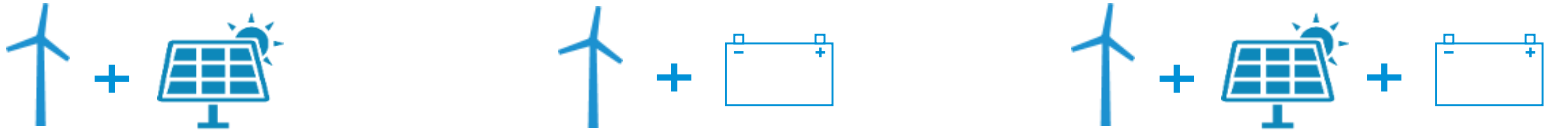


- Normal SCR ~1.5
- N-1 SCR ~0.7
- 350km+ radial connection

Vestas

Summary

- Hybrid power plants as **sustainable energy solutions** in which wind energy is complemented by solar energy and/or energy storage.



- Value proposition by:

Business Case Certainty	Complementarity & Flexibility	Infrastructure utilization	Fulfill grid codes and enter new revenue streams

- WTG-Coupled vs. Co-Located Hybrid power plant solution
- Main challenges: Right-sizing of assets & Hybrid power plant control
- Kennedy Energy Park as world's first utility-scale hybrid power plant combining wind, solar & storage

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