# DESIGN AND IMPLEMENTATION OF A HYBRID POWER PLANT CONTROLLER

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- Motivation for the Hybrid Power Plant Controller
- Controller Design
- Simulation Test Cases and Results
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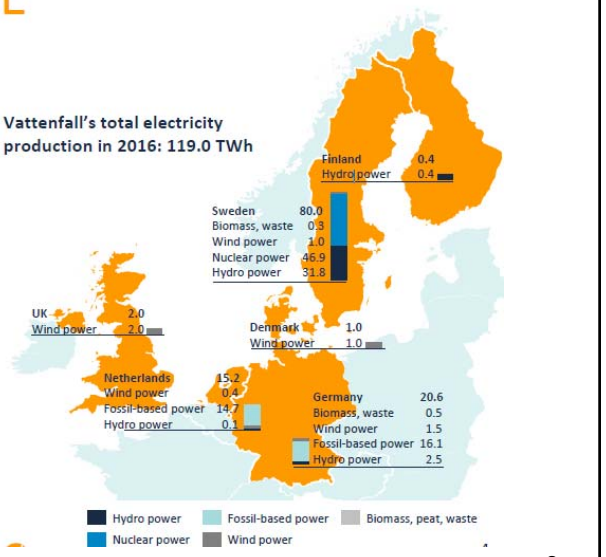
# VATTENFALL AT A GLANCE

- One of Europe's largest producers of electricity and heat
- 100% owned by the Swedish state
- Main products: electricity, heat, gas, energy services
- Main markets are Sweden, Germany, Netherlands, UK, Denmark and Finland
- 20,000 employees

**Net sales in 2016: SEK 139bn**

**Underlying operating profit[1] in 2016: SEK 22bn**

**Vattenfall's total electricity production in 2016: 119.0 TWh**

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# VATTENFALL'S VALUE CHAIN

We are striving to provide reliable and innovative energy solutions to meet our customers' needs. Vattenfall's ambition is to make a positive impact across its value chain.

**Production**
Vattenfall produces electricity from hydro power, nuclear power, coal, natural gas, wind power, solar power, biomass, and waste. Vattenfall is investing in more renewable generation and is phasing out fossil-based production.

**Electricity distribution**
Vattenfall operates electricity distribution networks in Sweden and Germany and has ongoing development of smart grid solutions which ensure security of supply. We enable customers to feed self-generated power into the network, becoming so-called "prosumers". Electricity distribution is a regulated monopoly business monitored by national authorities.

**District heating**
We are one of Europe's largest producers and distributors of district heating, supplying households and industries in metropolitan areas. In partnership with cities and regions, we are driving the transformation towards fossil-free heating solutions.

**Sales of electricity, heat and gas**
Vattenfall sells electricity, heat and gas to consumers and business customers. We focus on optimising the customer experience by offering different price and service models and by giving customers opportunities to reduce their environmental impact.

**Energy services and decentralised generation**
Vattenfall offers energy services, such as charging solutions for electric vehicles, solar panels, heat pumps and smart control of energy consumption. We also provide wholesale energy market services and access to marketplaces for customers that enable them to buy and sell electricity.

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# Motivation

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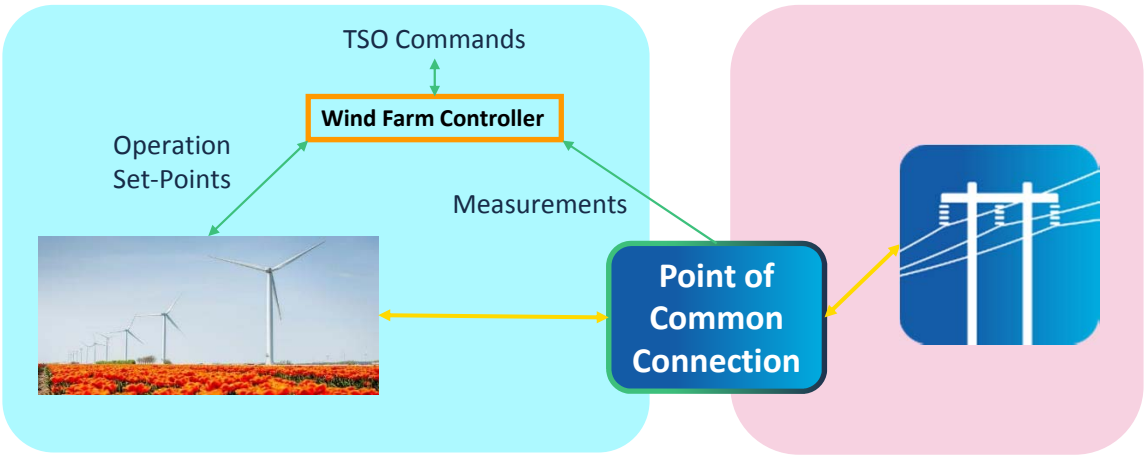
# Today‘s onshore wind farms layout

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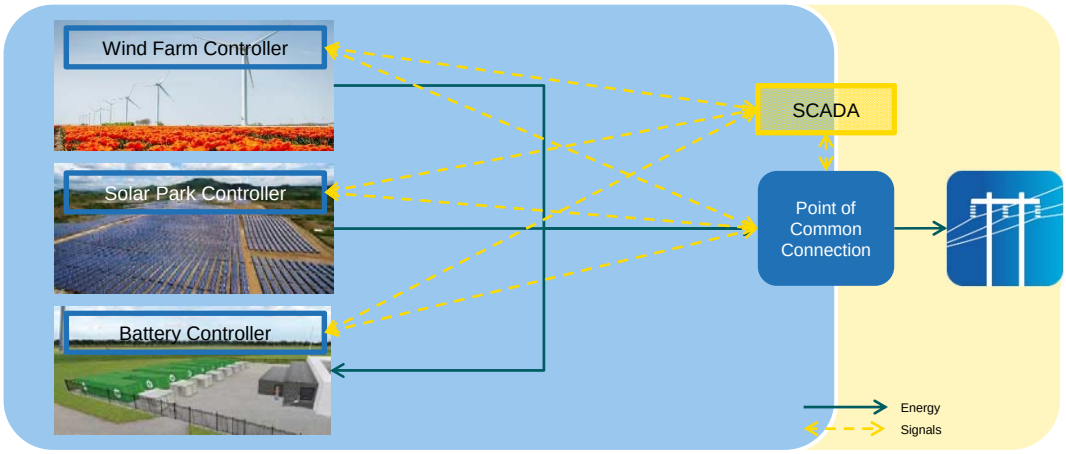
# Renewable Power Plants

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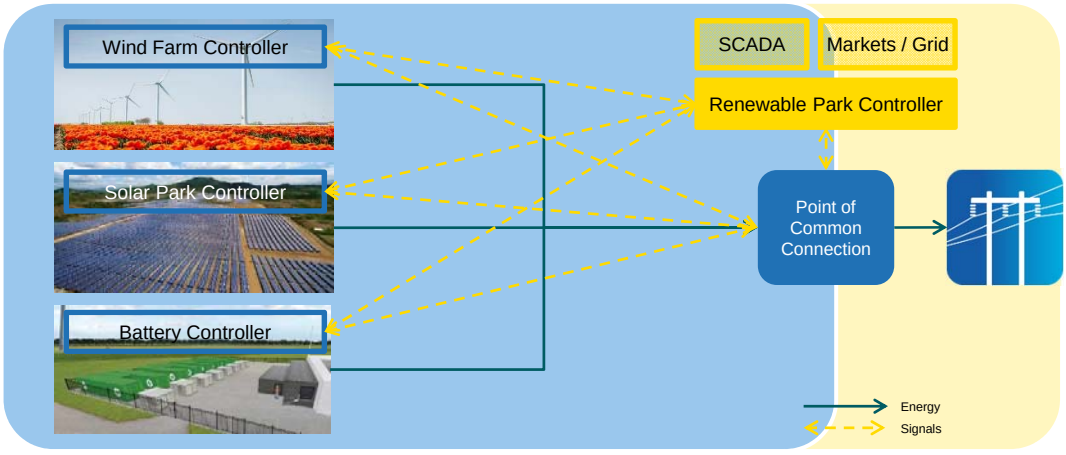
# Solution: Renewable Park Controller

Vattenfall's Renewable Park Controller - Enhanced optimization functions based on Energy market spot prices, Weather Forecast & Grid demands

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# Challenges and potential with Renewable Power Plants

- Challenges
  - Power Limitations in the Point of Common Connection
  - Increase the utilization of the grid connection point while securing against overloading
  - Synchronization of the Ancillary Services provided by different generation sources
  - Flexibility in operating different generation and/or storage units
  - Multiple systems from various suppliers to service and maintain

- Potential
  - LCoE Reduction: Increased utilization of the shared grid connection or agreements
  - LRoE Improvement: Approaching subsidy-free market enables participation in different grid services markets to enhance additional revenues
  - Hybrid Power Plants: Wind+Solar+Storage connected on a common Point of Common Connection, increased power generation flexibility
  - Vattenfall in control with different smart optimization algorithms based on the market related functions, weather conditions and spot price forecast
  - Maximize yield (revenue) while providing grid support function and minimizing fatigue loads
  - Easier Operation
  - Increased Flexibility

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# Controller Design

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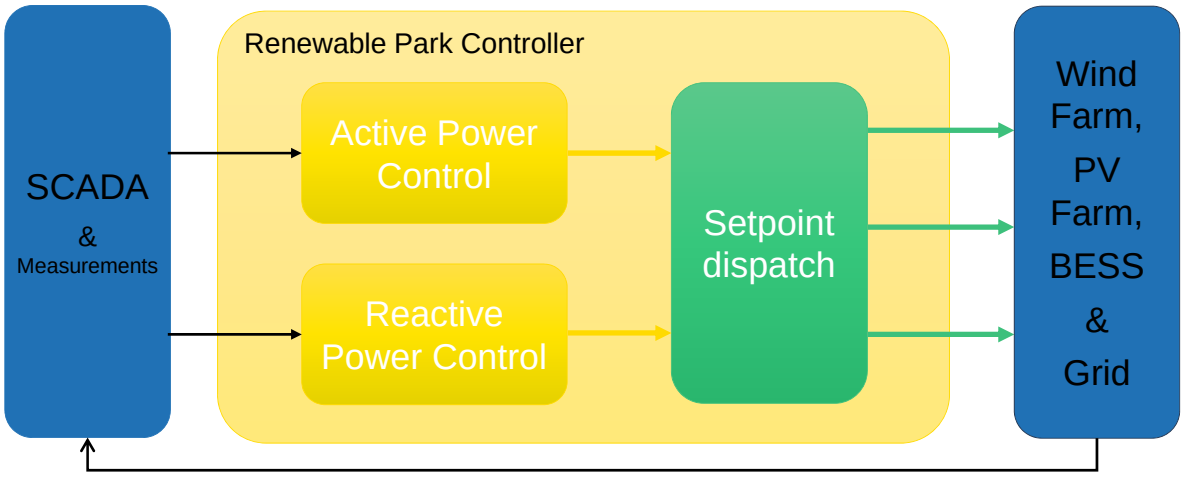
# Renewable Park Controller – Architectural Diagram

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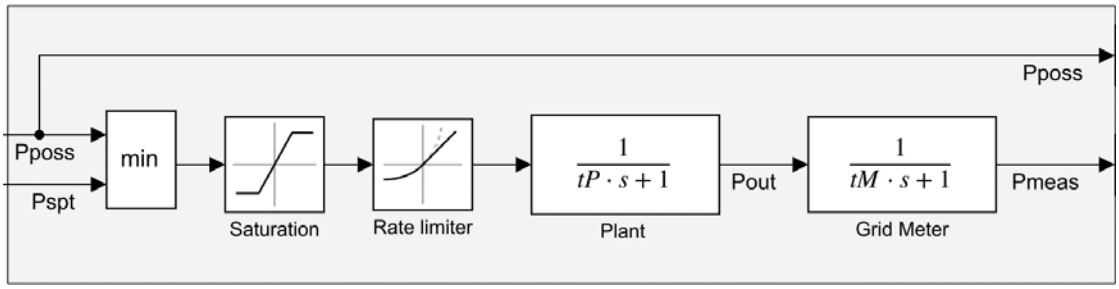
# Plant design-WPP&SPP

- *Only main dynamics of the WPP and SPP included, i.e. first order transfer functions plus delays introduced by the grid meters.*
- *Possibility to have different ramp rate limitations*

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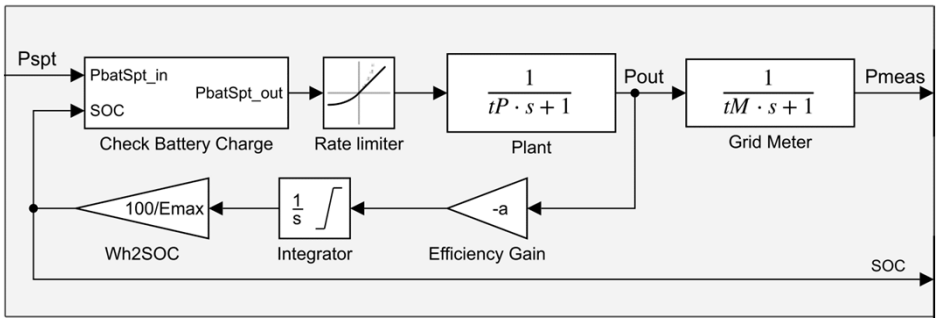
# Plant Design - BESS

- *Similar to WPP and SPP in terms of dynamic behaviour.*
- *Contains additional information regarding SOC and conversion efficiency.*






# RPC Simulations Test Cases

# Simulated Hybrid Power Plant

- Wind Power Plant : 122.4 MW
- Solar Power Plant : 40 MW
- Battery : 12 MW(h)
- Total Capacity (Base Power) : 174.4 MW
- Grid Connection Point Capacity: 130MW

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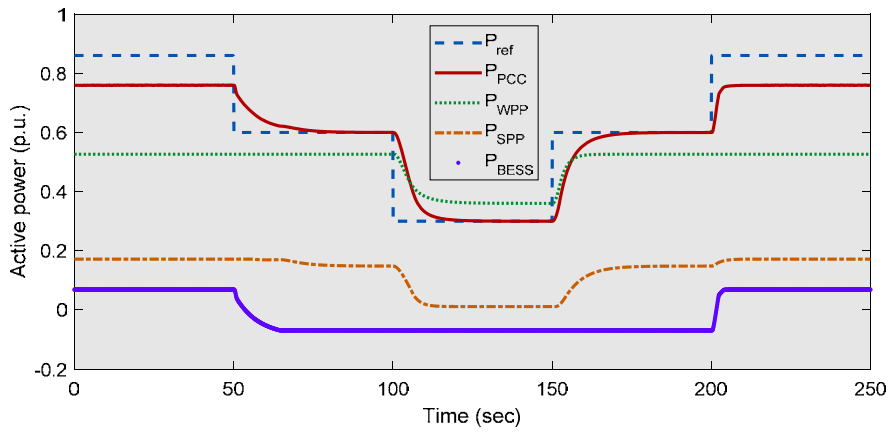
# Case 1: Step Changes in Setpoint

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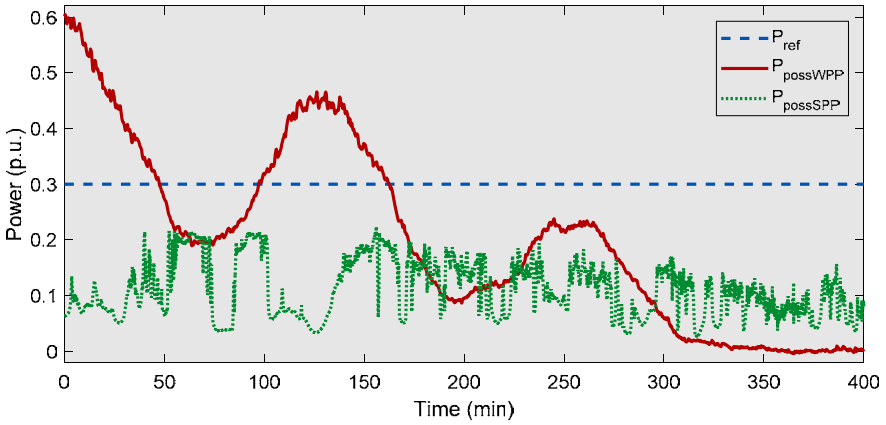
# Case 2: Varying Possible Power

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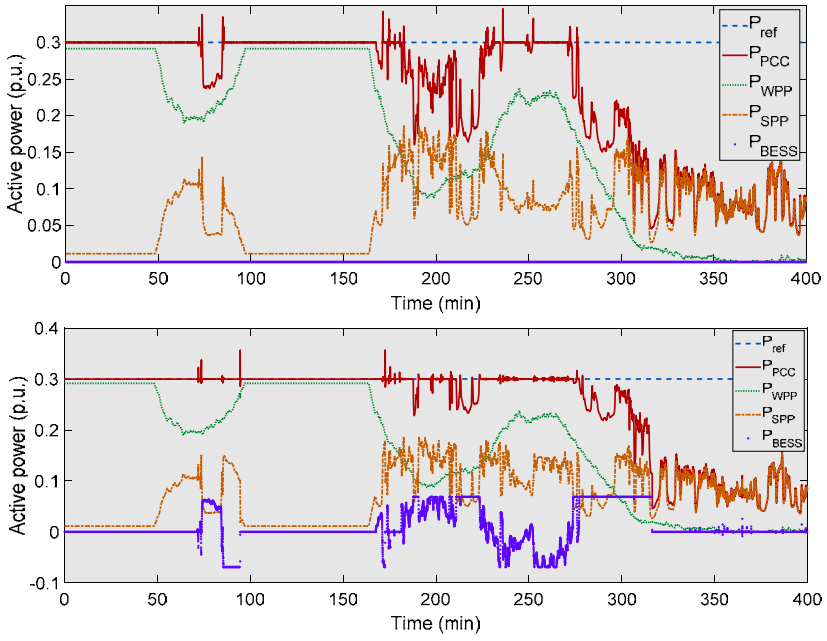
Case 2a:
Without battery support

Case 2b:
With battery support

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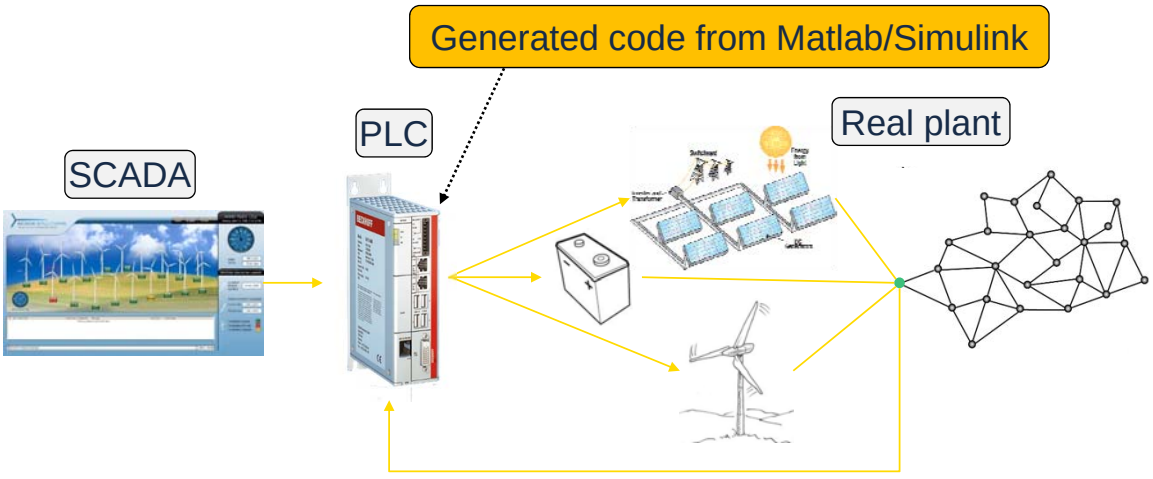
# Field Implementation



## The Field version



# Conclusions and Outlook



## Conclusions

- The solution for steering and optimization of a Hybrid Power Plant was presented
- Main challenges and potential were highlighted
- *The Renewable Park Controller design was shown*
- *For validating the controller design simulations results have been introduced*

# Outlook

- *Verification of the Renewable Park Controller prior to the field implementation in a Hardware in the Loop test setup*
- *Field Implementation*
- *Field Test and Verification*
- *Continue the initial development with Enhanced Optimization Solutions based on Energy market spot price, Weather Forecast, Ancillary Services and grid demands*



# THANK YOU!!