

DTU



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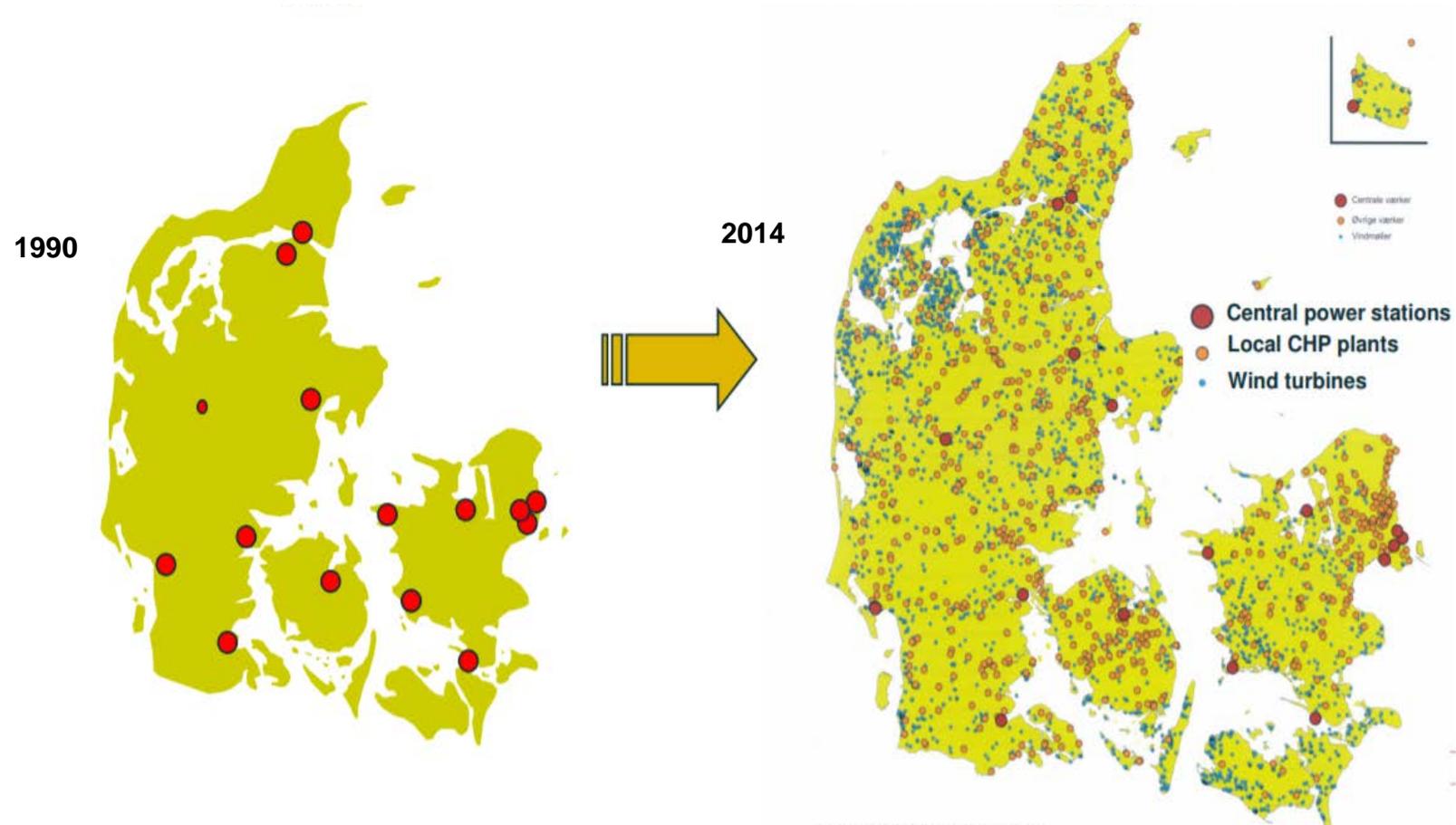
Integration of Distributed Wind to the Power System

Definition of Distributed Wind in IEA Task 41

- Wind turbines deployed in a distributed application
- Connected at a distribution voltage (nominally 70 kV) or below
- Behind the meter, in front of the meter, or in an off-grid application.
- In this context, DW is inclusive of all scales of wind turbine technologies and is agnostic to business model, although in some instances, such as technology standards, more specific industry segregation is included.

RES generation in distribution systems

Centralized Plants Vs Distributed Generations



Henning Parbo, "Distributed Generation Trends and Regulation: The Danish Experience", EPRG Workshop on Distributed Generation and Smart Connections

Integration Challenges/Opportunities for DW stakeholders

- **From System Operator's perspective:**

- Loss minimization, TSO/DSO co-ordination, voltage profile management etc.
- Might also be (market) opportunities for DW turbines owners

- **From DW Turbine Manufacturers' Perspective:**

- Stricter requirements for DW turbines in grid connection code
 - In terms of frequency support, volt/var control, harmonics etc.
- Evolving system support capabilities for all wind turbines such as grid forming capabilities, blackstart, load following, power oscillation damping etc.
 - Many of these services are relevant and useful for DW mainly with respect to minigrid, microgrid and islanded systems
- Evolving global markets for DW turbines connected to weak grids
 - Advanced control and operational strategies need to be developed
- Evolving technologies such as hybrid systems with storage and/or solar

A project case study from System Operator's perspective

NetVind project

Using wind power plant control in distribution grid operation

Objective

- to improve the operation of a real distribution network with a high penetration of wind power by exploiting the WPP control capabilities.

DSO's challenges

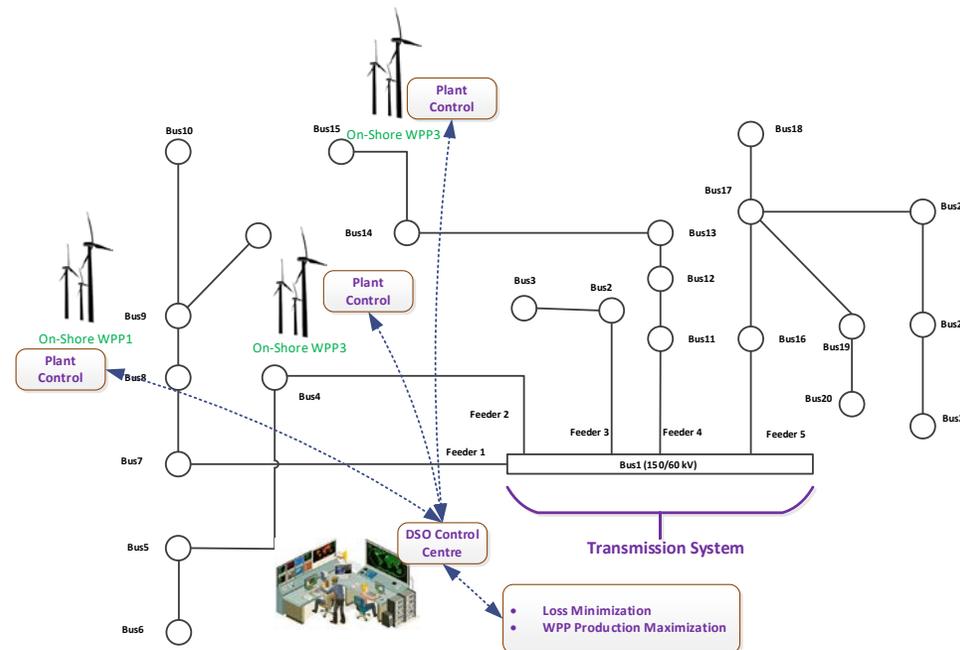
- how to operate the distribution systems by using WPPs as controllable components

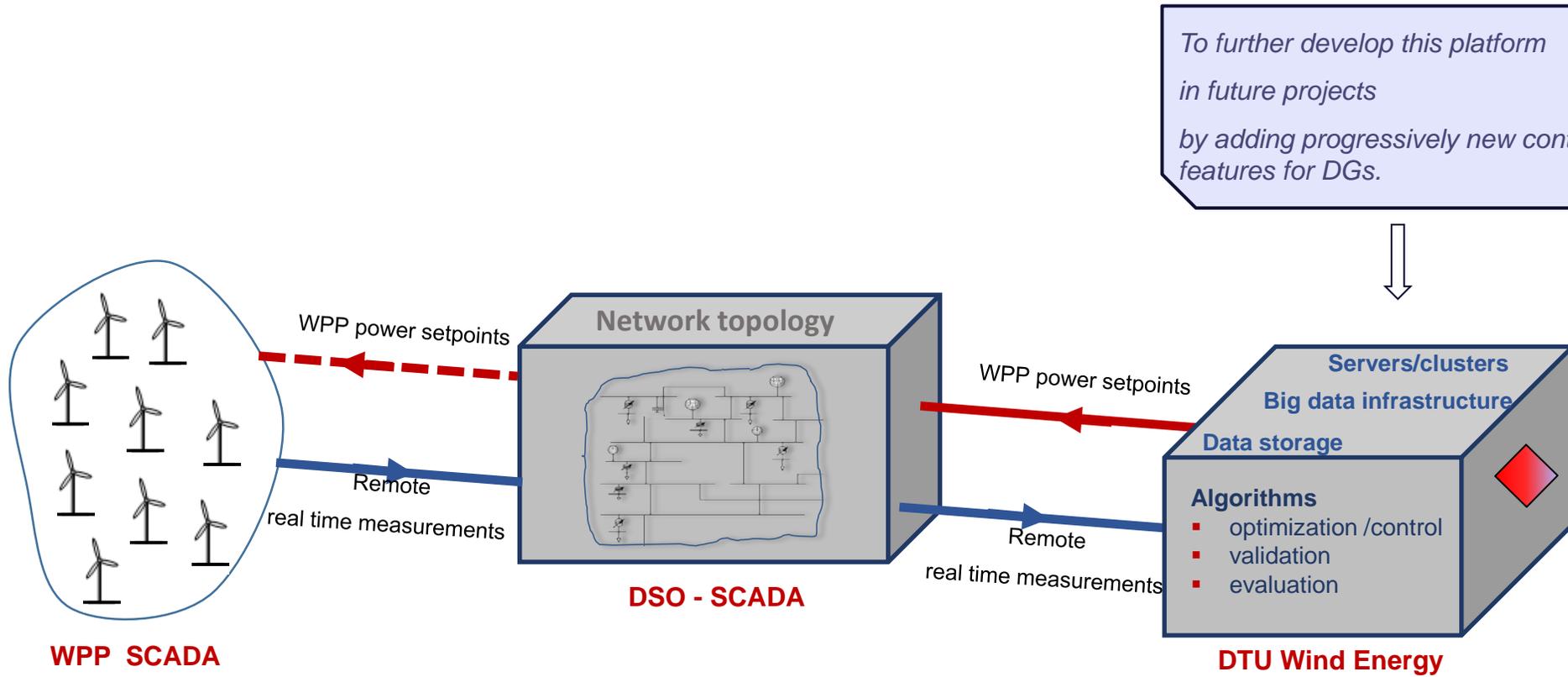
Partners

ENIIG Forsyning A/S (leader)
 DTU Wind Energy
 Dansk Energi

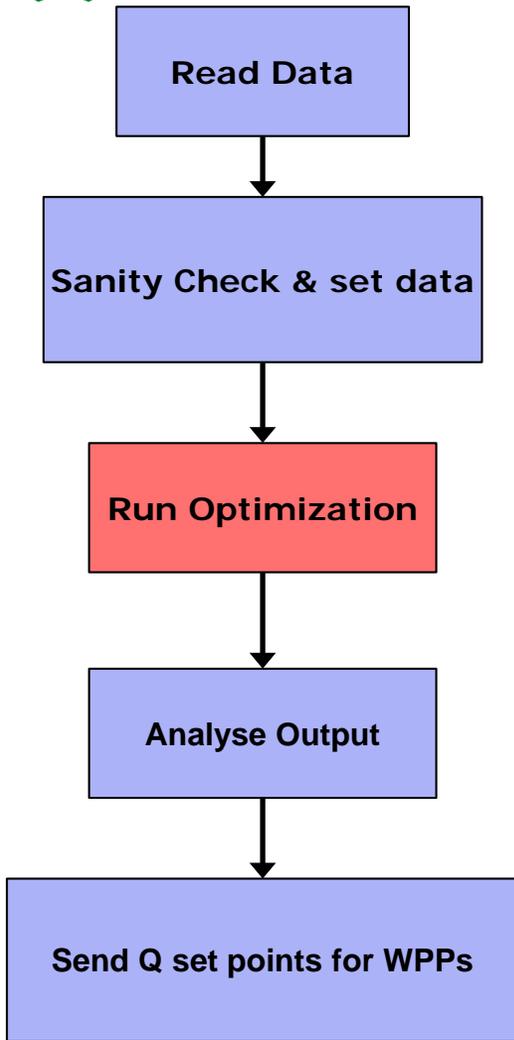
Project period:

Sep, 2016 – Sep, 2018





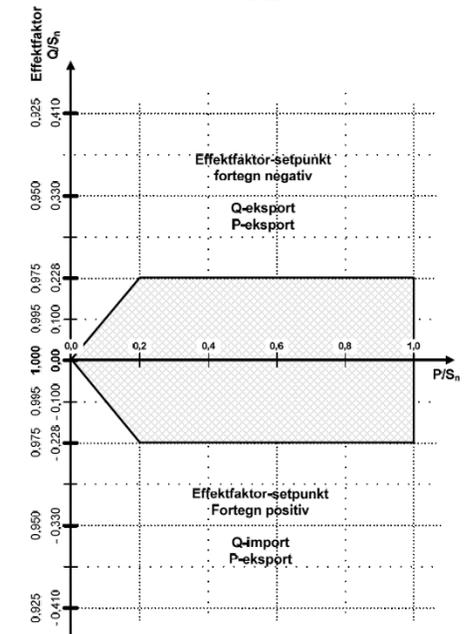
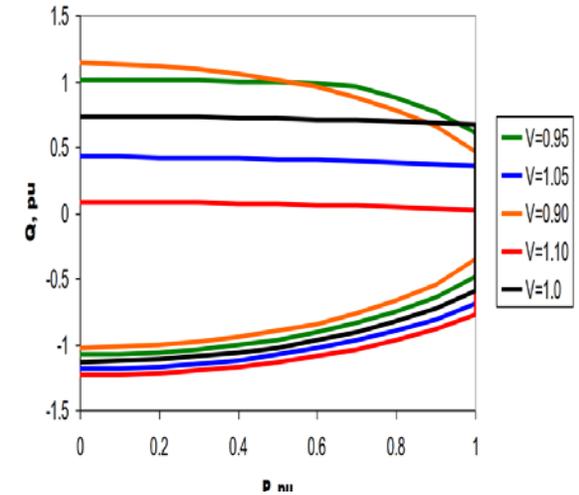
Optimization



- **Control variables:**
 - Reactive power set point of WPPs

- **Objective:**
 - Minimize active power loss in 60 kV feeders

- **Constraints**
 - Network constraints
 - Reactive Power Flow Limit to the Transmission Network
 - Power loading limit of the feeders
 - Power loading limits of the transformers
 - Voltage Limits
 - WPP constraint
 - WPP capability / Grid code requirements



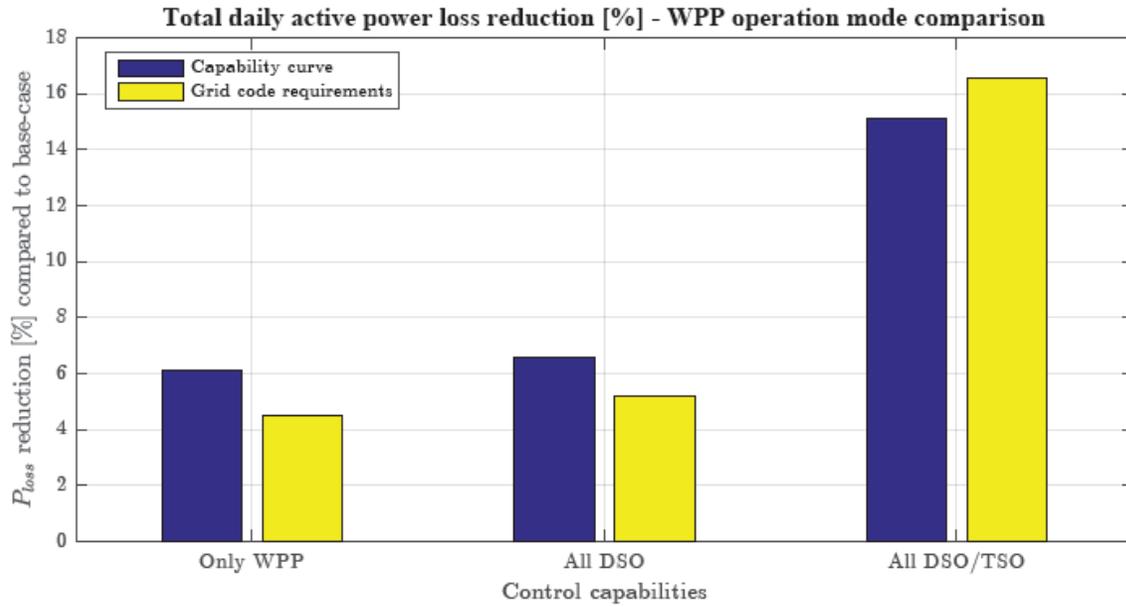
Loss Minimization Results

Without Optimization			With Optimization		
			Loss reduction [%]		Energy Saving [MWh]
Power loss [MW]	Number of Hrs	Energy loss [MWh]	Mean	Uncertainty	
0-500	6321	949	6.18%	0.25%	58.6 ± 2.38
500-1000	967	695	1.42%	0.10%	9.9 ± 0.69
1000-1500	674	833	2.93%	0.11%	24.4 ± 0.92
>1500	798	1539	4.63%	0.08%	71.3 ± 1.23
Sum	8760	4016			164.2 ± 2.92

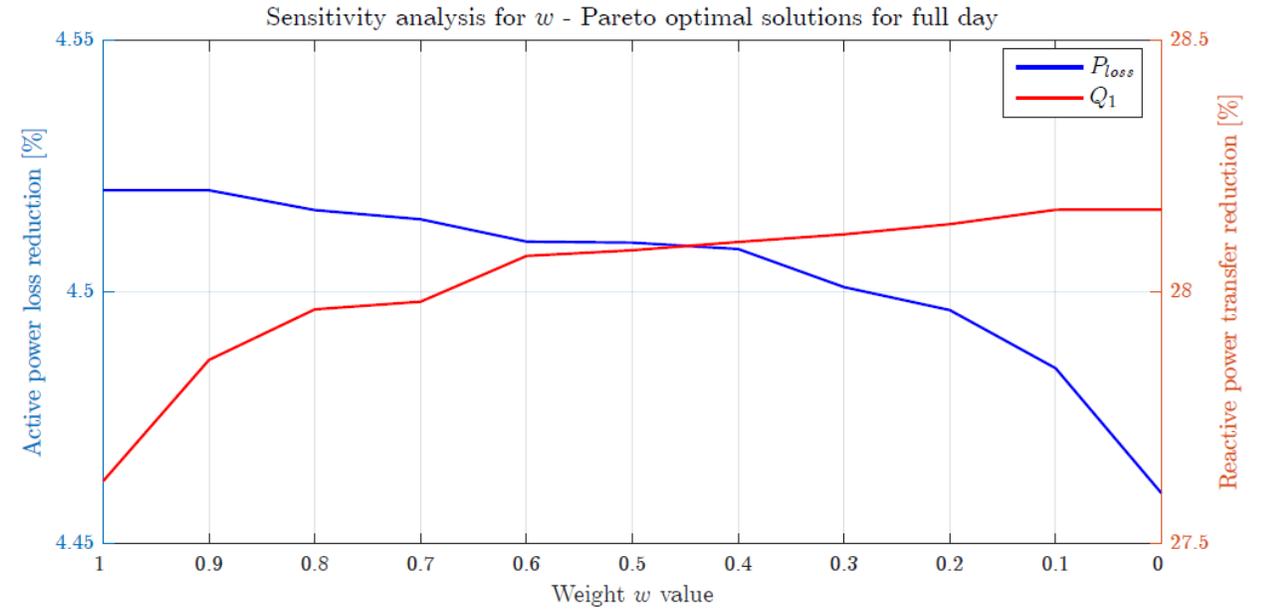
Using optimization method, estimated energy saving is 164.2 + 2.92 MWh for 1 year based on the representative data only using reactive power capability of DW

Looking Beyond

What is the impact of co-ordinating the control of tap-changing transformers together with DW?



Does loss minimization impact the reactive power transfer between TSO and DSO?



Observability and Controllability of all the voltage levels are required considering all the assets

Ongoing PhD project within EU Marie Curie WindGrid :

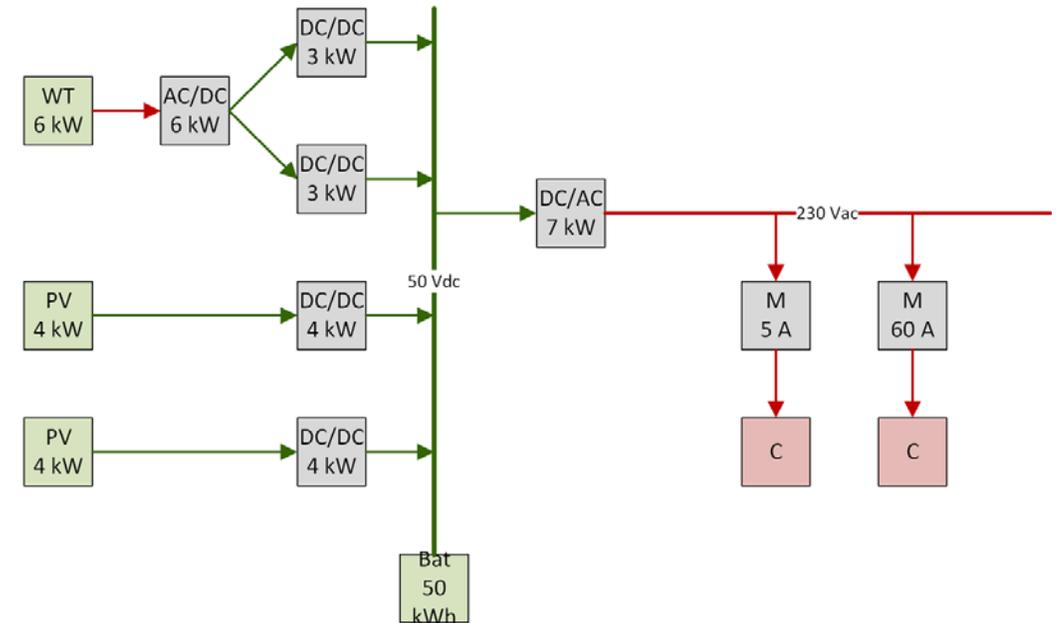
- Incorporate forecast uncertainty from weather dependent generation & loads (using weather data/models, AMR, SCADA) in observability of the distribution network
- Investigate the impact of forecast uncertainty for WPPs and loads on the performance of the whole distribution networks
- Develop enhanced control method for controlling the DW to improve performance of the whole distribution network

A project case study from DW Turbine manufacturer's perspective

The concept of a mini-grid

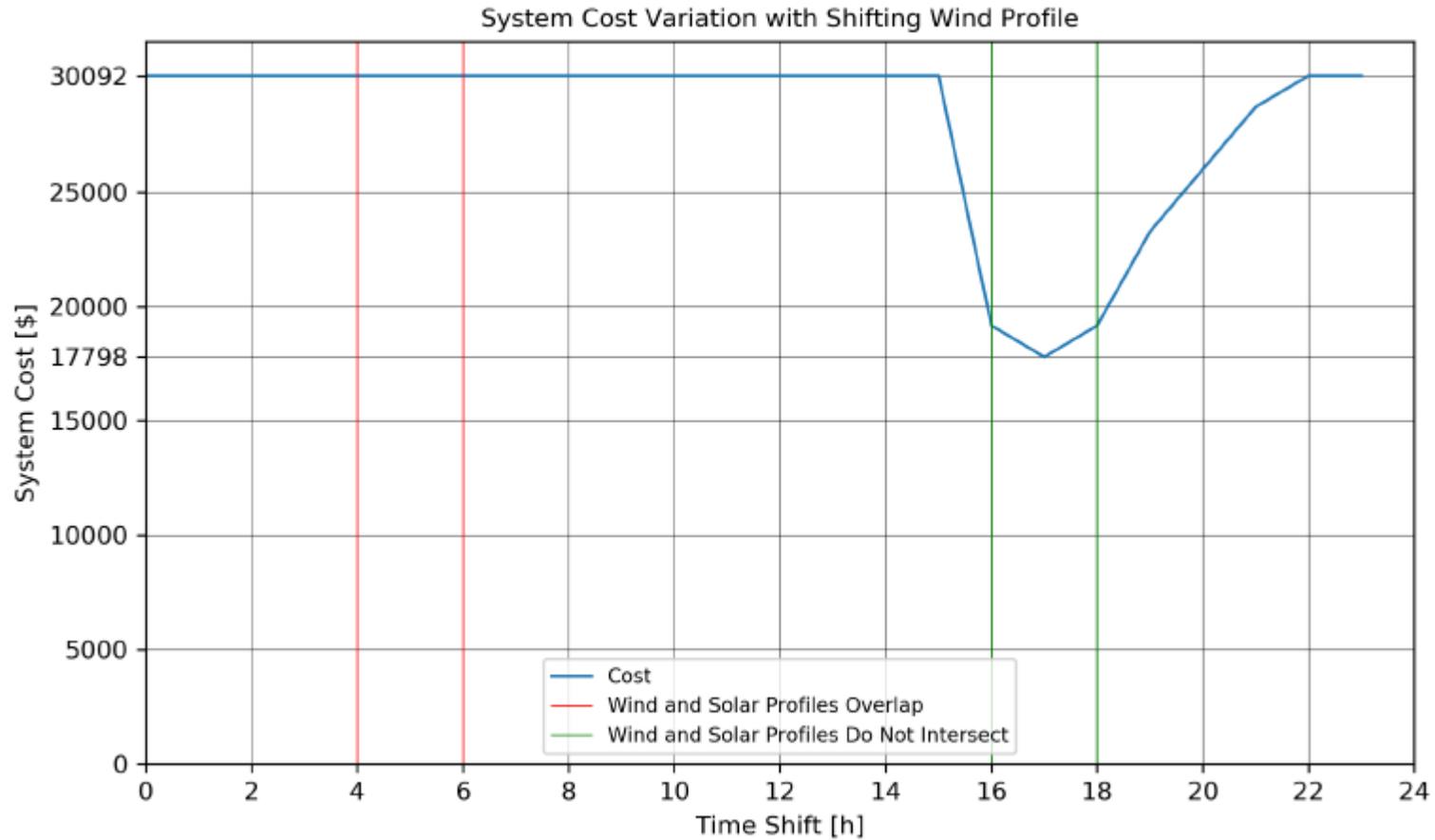
A collection of components in a power system:

- Consumption (consumers)
- Generation
(conventional and renewable)
- Balancing components
(e.g. dump load and storage)
- Control system
(local and supervisory)





Simulation results for system costs



Breakout stakeholders' sessions - DW integration

- What is the biggest challenge seen by you in order to integrate more distributed wind into the power system?
- Which support (tool, knowledge, seminars) from IEA Task 41 /DTU Wind Energy would help your business?
- Which specific grid services, do you think, distributed wind can provide and in which markets?