Hybrid power plants

Course 31778 - lecture 07
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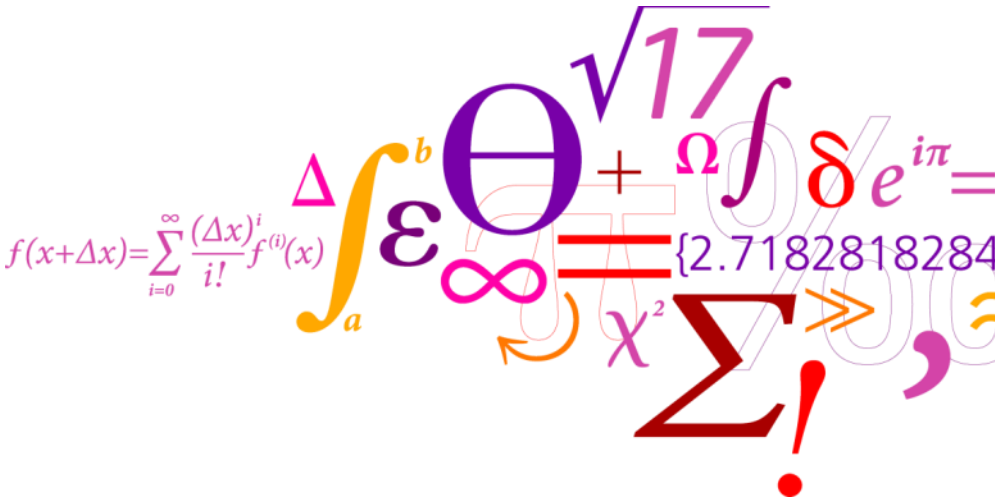


DTU Electrical Engineering
Department of Electrical Engineering

Lecture Outline & Learning Objectives

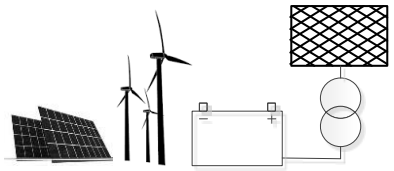
- Hybrid power plants (and microgrids)
- Possible AC vs DC configurations
- Plant controller

- Investigate different energy technologies including electric vehicles, storage and photovoltaic systems
- Perform physical modelling of energy technologies

Wind&Solar integrated hybrid power plants… and microgrids

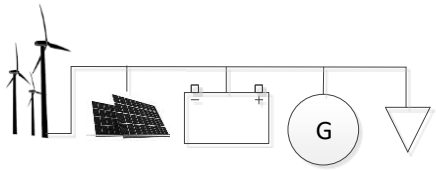
- A hybrid power plant is a (small) power system, using one renewable and one conventional energy source OR more than one renewable with or without conventional energy sources, that works in 'stand-alone' or 'grid-connected' mode.

On-Grid Hybrid Power Plant



→ grid-integrated power plant unit

Off-Grid Hybrid Power Plant



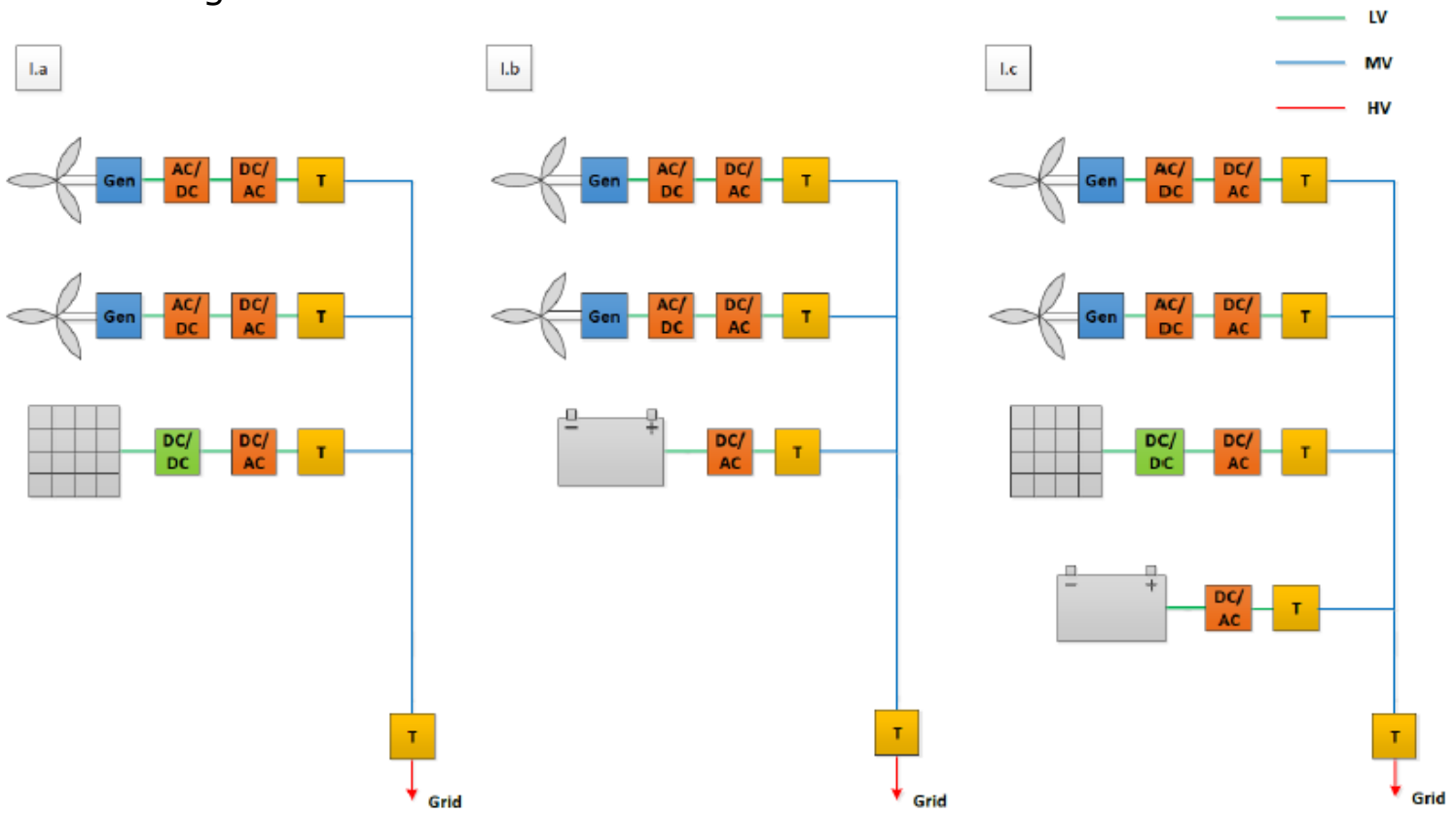
→ consumer-directed stand-alone unit (isolated microgrid)

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

- Microgrids are electricity distribution systems containing loads and distributed energy resources, (such as distributed generators, storage devices, or controllable loads) that can be operated in a controlled, coordinated way either while connected to the main power network or while is landed. (Cigre' definition)

AC-coupled hybrid power plants configurations

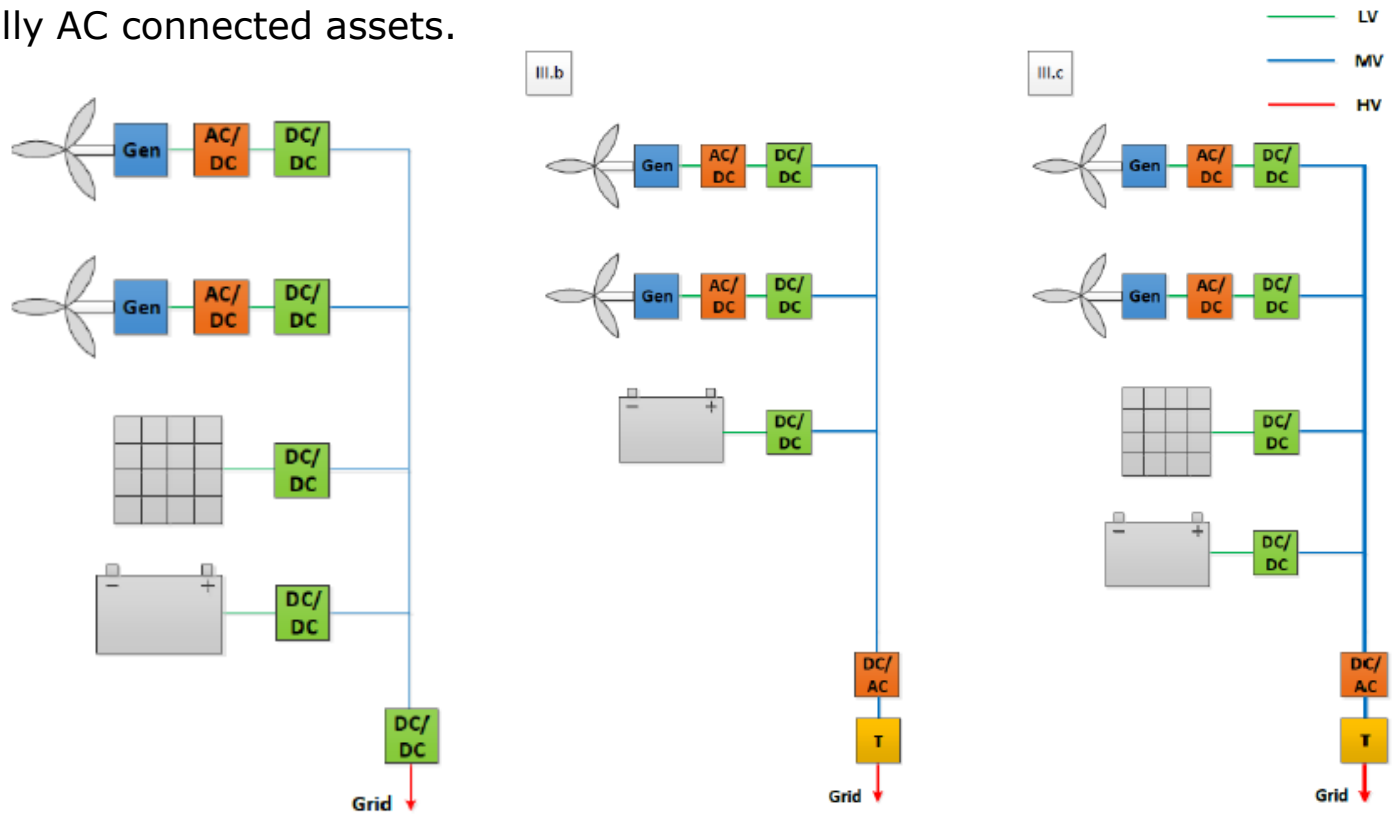
- A co-located HPP is a system, where all assets have individual Points of Connection (PoCs), but are connected to **the same substation**, which is the interconnection point between HPP and external grid.



L. Petersen, et al. "Vestas Power Plant Solutions Integrating Wind, Solar PV and Energy Storage" 3rd International Hybrid Power Systems Workshop – May 2018

DC-coupled hybrid power plants configurations

- A DC-coupled system at grid level is where the collector system is based on DC technology. Here, the individual assets are connected to a DC collector system. It is obvious that different control schemes at asset level are required as compared to traditionally AC connected assets.



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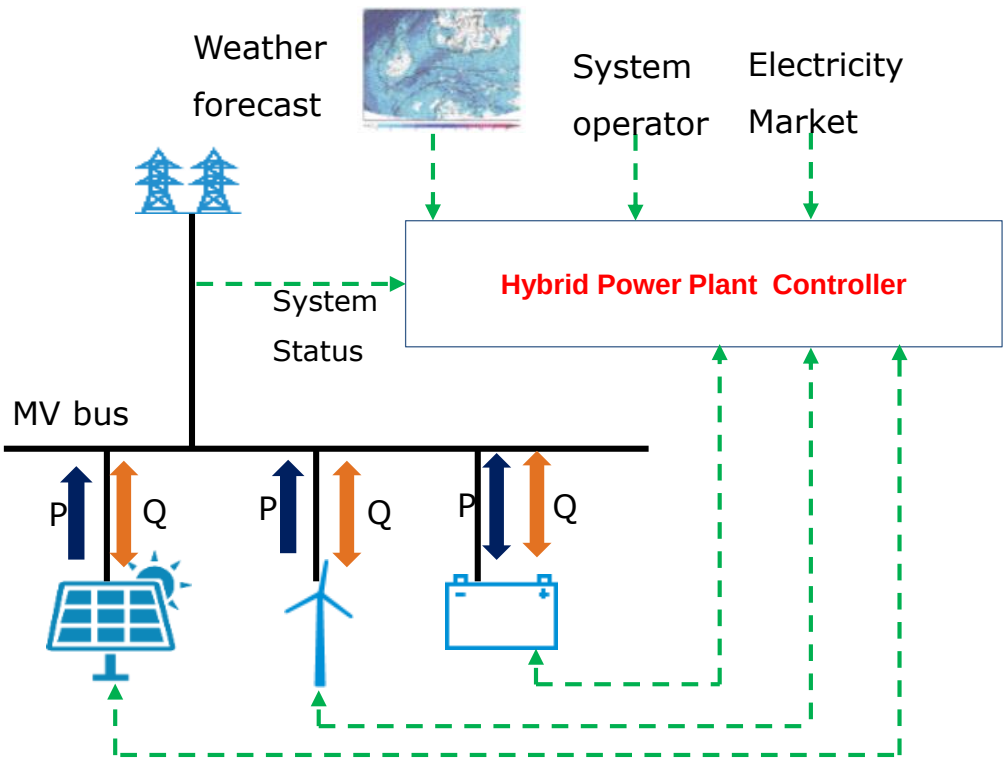
Control architecture of a hybrid power plant



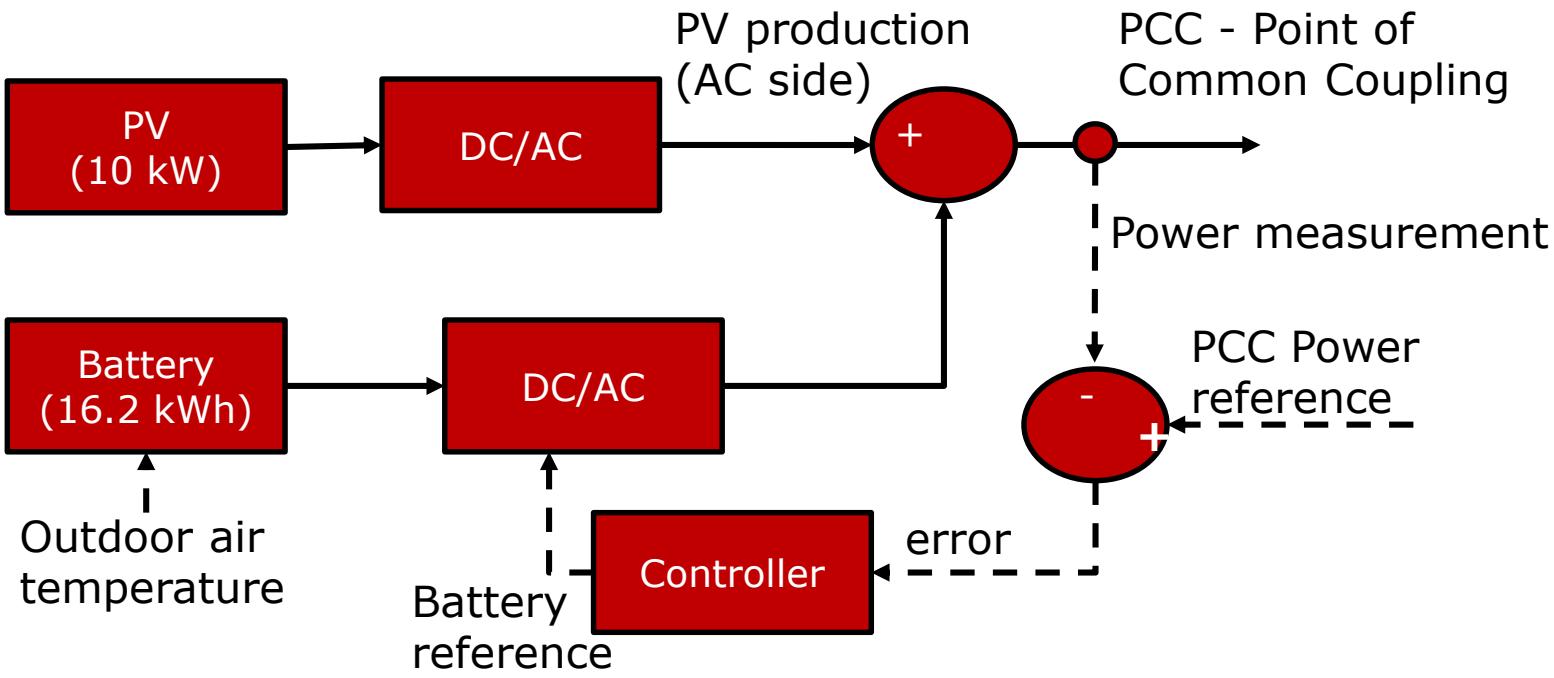
- It allows control and dispatch of the assets as being one virtual unit to the grid
- One of the keys is to account for multiple requested services which also demonstrates one of the biggest challenge of hybrid power plants

- **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

Class/home exercise (based on the content of Assignment 2)

- Starting conditions: mat files including a daily pattern for a 10 kW (on the AC side) PV plant production in May (86400 second-values); air temperature and power reference for the hybrid plant (25 hourly-values, from midnight to midnight). Simulink file including the NMC battery model built in Lecture 04-05. Note, interpolate in Simulink the PV power profile and air temperature. Do not interpolate the power reference instead (otherwise you will lose the step characteristic).
- Starting from the NMC battery model provided (10.8 kWh), scale the model to have the following characteristics: 16.2 kWh and nominal DC voltage 540 V. Scale with reasonable factors also the thermal parameters.
- Design (and tune) in Simulink a controller necessary to smoothen the power output of the combined system (PV+storage). Ensure a constant power output equal to 6.5 kW for 10 hours at the PCC (point of common coupling), between 7 AM (=25200 s) and 5 PM (=61200 s), as per power reference given (see block diagram next slide).
- Assume 0.5 seconds as measurement&communication delay on the power output of the hybrid plant (remember the inverter has a 0.1 s latency). What is a feasible initial SOC for the storage in order to ensure proper operation throughout the day? Is the power/energy size sufficient? Is it fast enough (you could try to see how small the latencies need to be to reach a "reasonably" smooth power profile)?
- Assess the energy lost throughout the day, the Ah throughput of the battery and equivalent cycles. Compare the numbers with the produced PV production and overall energy flow towards the grid.

Class/home exercise (based on the content of Assignment 2)



References

- 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.
- L. Petersen, B. Hesselbæk, A. Martinez, R. M. Borsotti Andruszkiewicz, G. C. Tarnowski, N. Steggel, D. Osmond "Vestas Power Plant Solutions Integrating Wind, Solar PV and Energy Storage" 3rd International Hybrid Power Systems Workshop – May 2018.
- M. Marinelli, F. Sossan, G. T. Costanzo, H. W. Bindner, "Testing of a Predictive Control Strategy for Balancing Renewable Sources in a Microgrid," Sustainable Energy, IEEE Transactions on, vol. 5, no. 4, pp. 1426-1433, Oct. 2014