Optimal scheduling of hybrid power plants

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Hybrid power plants

- Future energy supply will be based on renewable technologies: wind, solar and hydro...
- Solar and wind are becoming cost-competitive, but lack important capabilities in terms of storage, reliability and supplying ancillary services
- By combining the cheap energy from solar and/or wind with the regulating capabilities of hydropower, hybrid power plants have a vast potential for supplying affordable, secure and robust energy globally.
Comparing characteristics of renewables

- LCOE
- Development cost
- E&S complexity
- Time to COD
- Lifetime
- Predictable
- Seasonality
- Dispatchability
- Flexibility

- PV
- Wind
- Hydro Storage
- PV + BESS
Floating-PV and hydro hybrid power plants

- Efficient use of land areas and resources
  - Surface area of hydro reservoir is "free"?
  - Common grid connection point
  - Inflow and irradiation - correlation and seasonality?
- Floating-PV limits evaporation from hydro reservoirs
  - But how will it affect other environmental/eco-system/biology aspects of the reservoirs and rivers?
- Constantly balancing PV will lead to more wear on hydro equipment and rapid changes in water flows
  - Battery storage may help
- Hybridization for single systems or through the market?
  - Each producer balancing their own portfolio may lead to lower liquidity in the market?
  - But very good in areas where the power market/grid is still under development
Typical scheduling challenges

**For hydro alone:**
- Complex hydro systems with varying sized reservoirs in series/parallel or other complex configurations
- Complex hydraulic couplings, flow patterns in rivers and tunnels
- Wear, costs and reduced lifetime of equipment due to balancing/flexible operations
- Tight environmental constraints in cascaded systems – minimum flows, ramping, reservoir level, state-dependent constraints...
- Complex market commitments – energy, balancing, reserves...
- Uncertainty in inflow and prices, forecasting accuracy, historical data and models vs climate change

**For hybrid plants:**
- All of the above!
- Uncertainty for solar (both seasonal, short-term and very-short term) and also joint/correlated uncertainty for solar/inflow/prices/load
- Short-term variability of solar necessities more frequent re-optimizations, i.e. Larger potential for autonomous scheduling

**Hypothesis:** Large PV capacity compared to hydro capacity will amplify the problems?
Example cases

- **Simple Cascade**
  - Reservoir
  - Plant

- **Complex cascade + pump**
  - Reservoir
  - Plant
  - Reservoir
  - Plant + Pump

- **Jumbo PV**
  - Small PV
  - Medium PV
  - Large PV
SINTEF's hydropower models

- We have set up analysis for hybrid plants using SINTEF's hydropower models
  - STM: SHOP
  - LTM/seasonal: ProdRisk
- Modelled PV as a "solar market" where energy can be bought at zero cost
- Solar market + hydro production = cover market load
Initial POC for short-term scheduling (SHOP)
Initial POC for seasonal scheduling (ProdRisk)
More robust and flexible model coupling between SHOP and ProdRisk

[1]:

```python
from pyshop import ShopSession
```

[2]:

```python
shop = ShopSession()
```
More robust and flexible model coupling between SHOP and ProdRisk

[1]:
```python
from pyprodrisk import ProdriskSession
from pyshop import ShopSession
```

[2]:
```python
prodrisk = ProdriskSession()
shop = ShopSession()
```

Technology for a better society
• Same (running) kernel
• Same environment
• Same user interface
• Easier debugging
• Better data handling
• More flexible
• More robust
Future work

• Project period: 2021-2024

• Need for scheduling models to be updated more frequently in order to re-plan closer to real-time

• The optimal hydro-PV hybrid scheduling system will realize the complementation of energy generation over seasons, days, hours, and seconds

• Establish a new reservoir trajectory curve that includes inflow, power generation as well as solar generation effect

• PhD + MSc students also involved
Technology for a better society

This presentation is based on work by
Jiehong Kong, Hans Ivar Skjelbred, Hans Olaf Hågenvik, Benjamin Trondsen, Bjørnar Fjelldal and Ellen Krohn Aasgård