

POWEL SHOP

Powel Shop is the program for short-term optimization of hydropower generation within the Powel Smart Generation concept. The program offers excellent decision support during the process of making price dependant production bids at day-ahead spot markets, like Nord Pool. The target for this optimization is to utilize the available water resources in a way that creates maximum income. When the day-ahead spot contract has been settled, Powel Shop is used to find how to generate the contracted energy at lowest possible cost. And during the day, Powel Shop can be used to re-plan the entire watercourse e.g. after a regulation power trade or an unexpected outage.

Powel Shop is tightly related to Powel Nimbus and Powel Sim (see separate Product Fact sheets), hence the three products should be considered together. In daily operative use, Powel Nimbus acts as the user interface and the input/output server for Shop. During system configuration and prototyping, Shop may also be used from Powel Sim.

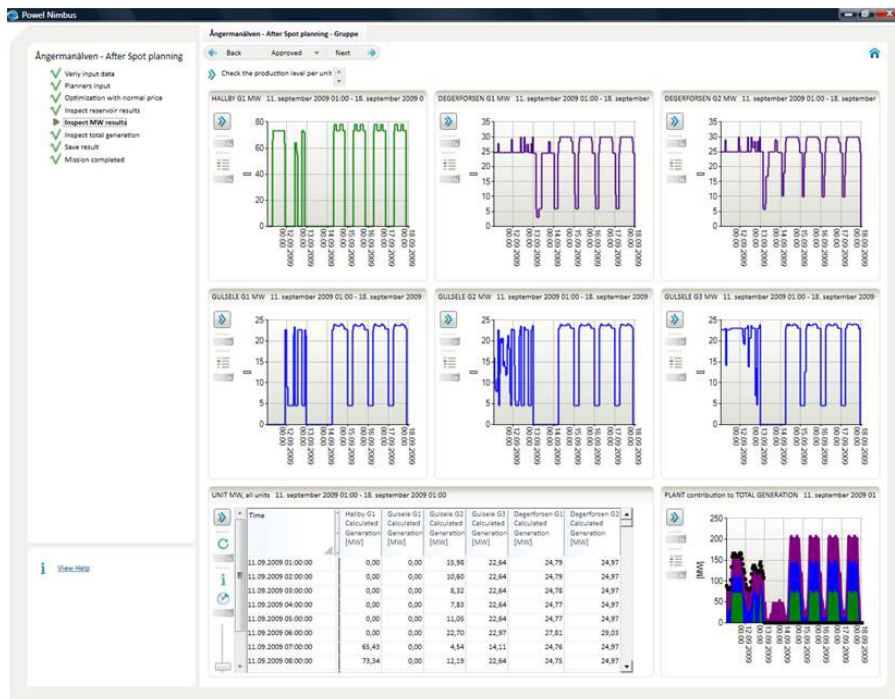
ally prepare a set of very robust and profitable bids. These bids combine the wish to sell more when price is high and less when price is low, with the current hydrological constraints in the watercourse as well as the targets from seasonal, mid-term planning.

When the day-ahead spot contract has been received from the Power Exchange, Powel Shop is used to find optimal generation plans for every unit in the hydropower system. At this stage, the criterion is to generate the contracted energy at lowest possible cost.

Thanks to the Smart Generation concept of Balance Groups, Shop is able to combine several watercourses in one single optimization in order to fulfill the total contract. Hydrological conditions, constraints and water values for the different reservoirs in the total system are considered by Shop in order to find the optimal contribution from each power plant, hour by hour.

When performing a task as part of a predefined work process in Powel Nimbus, Shop is invoked every time the user reaches an optimization step. Powel Nimbus extracts all required input data from the database, and transfers this to Shop together with model data for the

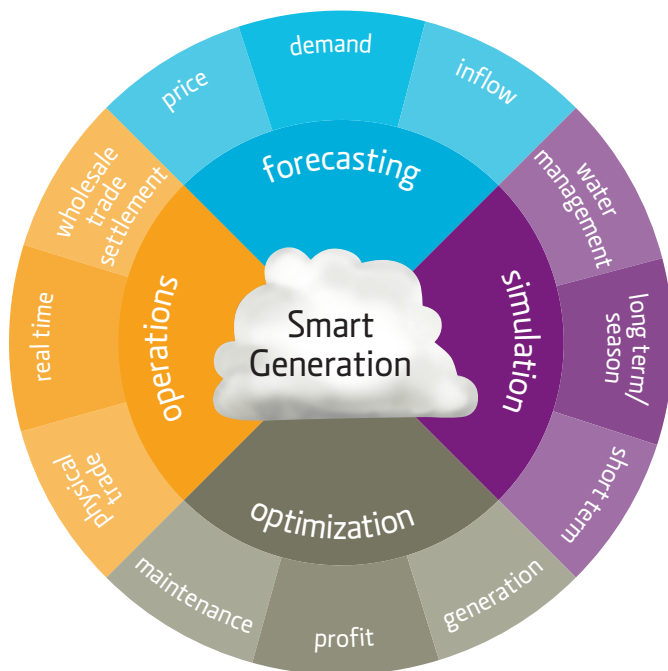
hydropower system(s) in use. By using different Input Data-sets when defining the Powel Nimbus tasks, e.g. with different price or inflow forecasts, a set of different optimizations may easily be executed.



Optimal generation plans per unit from Powel Show, as displayed in Powel Nimbus

During preparation of the spot market bid, Powel Shop is used to find the optimal hydropower generation at many different price levels. Based on the optimal results from Shop with 10-20 different price curves as input, the customer can methodi-





When Shop has successfully finished the optimization, Powel Nimbus makes the results available for the user. The user may inspect the results as tables or charts, by using predefined, easily customized Custom Screens. If the results are satisfactory, the user will normally store the results into the Powel database as a Scenario.

The entire process of running multiple optimizations with different input and storing the results in different time series in the database may be fully automated. The user simply makes a list of Input Datasets, and a corresponding list of Scenarios where the results should be stored. Once this is setup, the user can execute the whole bunch of optimizations with one command. This is very useful when Shop is used to prepare bids for the spot market, by running multiple optimizations with a full range of price curves.

When optimizing, Powel Shop considers the majority of constraints defined in Powel Availability (see separate Product Fact Sheet). Revisions or outages are of course taken into account, together with a wide range of other restriction types.

Some of the most useful restriction types are:

- Time dependant min/max restrictions for discharge, production and reservoir levels
- Tactical reservoir limits, where Shop is allowed to pass the limit in periods with high or low prices - but at the cost of a user defined penalty (soft limits)
- Maximum rate of change e.g. of discharge or reservoir level (ramping)
- Block restrictions, where Shop finds the optimal generation level for each block but keeps the generation level constant for a given number of time steps
- Average restrictions, where Shop utilizes price variations in the market but still ensures that the user specified average discharge is reached, e.g. allowing daily or weekly averages to be used for planning
- Min/max end-reservoir restrictions– defining a reservoir end-level “window” (reservoir slack)

The results from Shop include optimized generation plans for each power plant, down to unit level and with hourly or 15 minutes resolution. The optimization period is normally 1-3 weeks.

In order to decide how much water that should be drained from each reservoir during the optimization period, Shop compares the market price during the period with a calculated value of each m3 of water. This important input parameter – the water value - is normally calculated by a seasonal planning model like Powel Long-Term Generation Optimizer. This model calculates variable water values for each individual reservoir. These water values depend on the hydrological situation in the entire watercourse, and is a function of reservoir level at end of the optimization period. This causes the water value to increase if a lot of water is drained, and to decrease if the reservoir gets close to spilling water.

Powels seasonal planning model is not a prerequisite to use Powel Shop. Powel Shop can also use water values that are imported from other systems as a time series, or simply typed in manually by the user. Other methods to give end-conditions for water usage are to apply average discharge restrictions, or to define soft constraints on reservoir levels.

Other important input parameters to Shop are inflow forecasts for each reservoir, and an hourly market price forecast for the entire optimization period. Powel also offers a very accurate model for inflow forecasting, Powel Inflow, see separate Product Fact Sheet.

OTHER FACTS ABOUT POWEL SHOP

- Shop is able to consider start/stop costs per unit for a configurable number of days in the start of the period
- Shop uses an optimization algorithm (CPLEX), based on mixed integer programming when start /stop costs are considered, otherwise based on linear programming (which is faster)
- Timestep length for optimization is from 15 minutes to several hours, may vary during the period
- The program can handle many hydraulically coupled hydropower reservoirs, ponds, power plants, pumps or other components connected to the hydropower system
- Shop is deterministic, i.e. assumes that all input is known – however uncertainty in e.g. price or inflow forecasts are managed by running multiple optimizations in an automated manner
- On multi-CPU servers or workstations, many optimization runs may be run in parallel to save time (requires additional CPLEX licenses)