

POWEL SMART GENERATION

Hydro-electric power is precious and unique in many respects. It is pollution free, it is renewable and it can be stored at low cost simply by holding back water. And the short response time of hydro turbine regulation make hydro-electric systems extremely flexible and suitable to meet variations in power demand and power prices. Large gains can be made in optimizing the generation plans and schedules in a hydro power system to take advantage of changing demand, changing precipitation (water inflow), changing market conditions and variable energy prices.

The software suite Powel Smart Generation provides tools for the entire planning and scheduling process, ranging from long term plans for several years ahead, to autopilot-based execution of power generation in near real time. This paper describes these opportunities in more detail.

THE HYDROPOWER PLANNING CHALLENGES

Hydroelectric power generation is unique in that the level of generation is very easy to adjust quickly. While large thermal power stations are most economically operated at a steady base load, hydropower is ideal for balancing rapid variations in demand and energy prices.

Hydropower systems typically consist of several reservoirs, watercourses and power stations forming a complex hydrological system. Generation in rivers with cascaded power stations and variable time delays downstream are difficult to optimize. An increase in generation in one power station of a river during a peak price period will cause an increased water flow to arrive at stations downstream to produce energy perhaps in a low price period. Satisfying all restrictions on water levels, discharge rates, temperatures and turbidity in rivers and reservoirs at the same time, make generation planning and optimization a complex challenge.

The "fuel" supply (water) for hydropower generation is weather dependent and can only be predicted with the accuracy of meteorological forecasts and statistics.

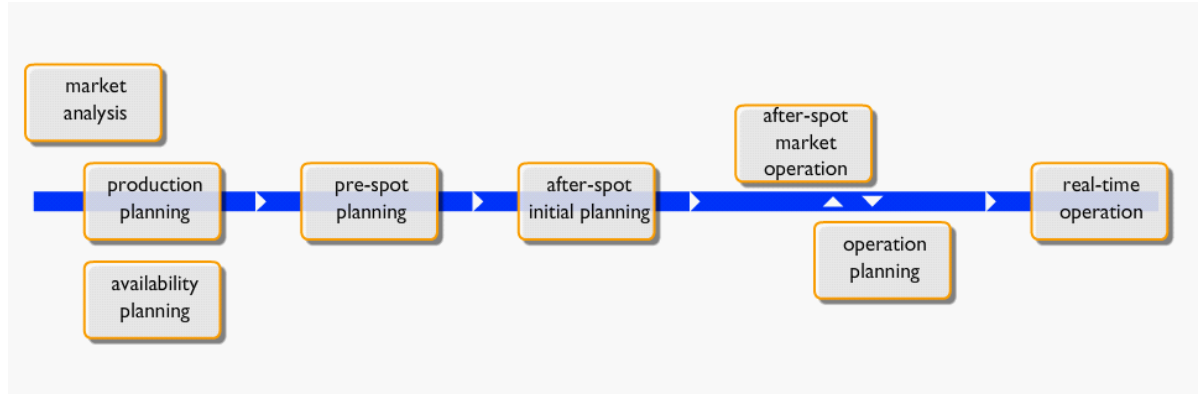
Optimal use of hydropower resources requires decision support systems able to forecast inflow, prices, and demand to maximize revenues from the generation assets while obeying all the restrictions imposed in the license. It means applying forecasts to continually revise generation plans for

both the short term (next hour and few days) and in a long-term perspective.



THE POWEL SOLUTION

The purpose of the software suite Powel Integrated Control Centre (Powel Smart Generation) is to integrate the entire planning and scheduling process, from long-term planning of 5-10 years ahead, to Autopilot-based execution of schedules in real time at the individual power station. Systems knowledge is aggregated in the model and made available to all operators, who may also perform scenario-analysis and simulations.



Generation planning process with Powel Smart Generation

SYSTEM WALK-THROUGH

The planning cycle as supported by Powel Smart Generation will be explained in the following, by first looking at the long-term planning and market analysis, then short term planning, and finally how Powel Smart Generation supports close to real-time scheduling by an operator at a control centre.

Long-term planning

The market simulator in Powel Smart Generation can plan the overall generation for months or years ahead. A model of the total energy market with its capacities, limitations and bottlenecks is combined with historical

inflow data, and estimated variations in energy generation, demand, import/export, fuel prices (the prices of available alternatives, like oil, gas, nuclear or coal) over time are included. By using different inflow scenarios, the model will:

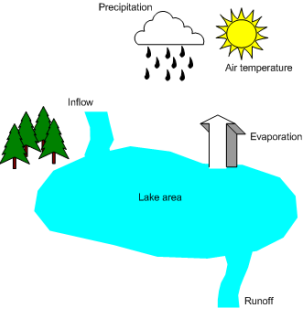
- predict the most likely market price level over the specified timeframe, with a weekly resolution
- suggest generation level per week
- estimate water values per reservoir at the end of a given planning period

Scenario analysis

One way of using the results of these models is to use the suggested weekly generation and then make the detailed plans for the generation, hour by hour (or even shorter intervals if relevant) for each generator. In this way the long-term planning determines how much water to use during the week and short-term planning determines when it should be used in each turbine to maximize profits.

Alternatively, the long-term planning may define “reservoir windows” with upper and lower limits for the end of the optimizing period, for each individual reservoir. Water values are provided for different reservoir levels within this window, and the short-term optimization is then used to find the optimal use of the various reservoirs during the planning period. This method will lead to reservoir build-up if the forecasted market price is low, and vice versa.

Water value: The expected monetary value of the water in a reservoir



Inflow forecasting

Powel Smart Generation can forecast the inflow per reservoir for the next days, based on the current state of run-off in the catchment areas, and on weather forecasts. The forecasting period may be extended beyond the end of the weather forecast by using historical weather and inflow data stored in the system.

In snowy regions the inflow contribution from snow melting in the springtime is particularly important. An accurate snow model in Powel Smart Generation keeps track of how the snow builds up during winter, and calculates the effect snow melting has on inflow.

Based on metered data like reservoir levels and generation levels, Powel Smart Generation can calculate the actual inflow per hour for the previous day. By calculating the actual inflow close to real-time, the trend in inflow changes may be monitored at any time. When this is compared with the forecasted values, utilities can react quickly to deviations from the original assumptions and keep their generation optimal.

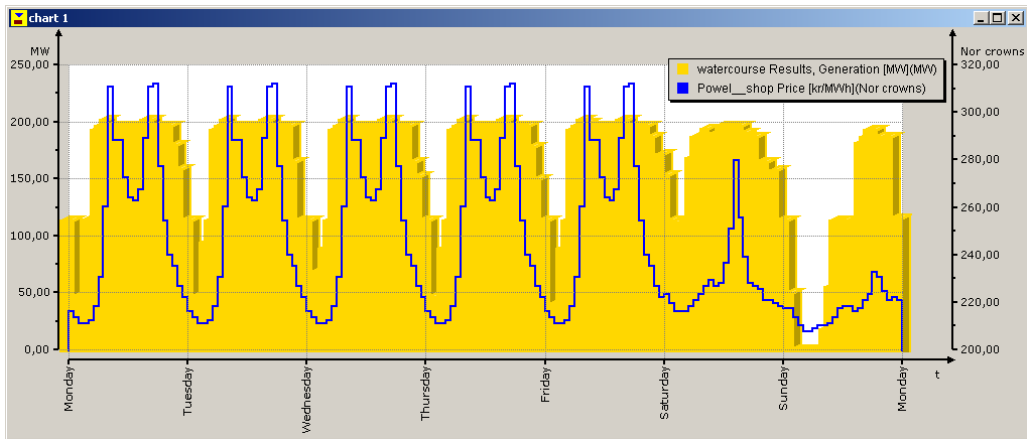
Short-term planning

The available hydrological information is combined with the short-term market expectation to optimize contracts for the spot market. Some utilities may also plan their next day generation to balance variations in local demand. The short-term local demand can be predicted using the forecasting tools of Powel Smart Generation.

Generation optimization based on market price expectations

Powel Smart Generation combines the expected inflow and current reservoir levels to produce scenarios showing optimal generation level per hour as a function of market price. The result of this price scenario analysis is used to generate spot market bids. Bids generated by Powel Smart Generation may be electronically transferred to the relevant Power Exchange.

Optimal generation (yellow bars) for given market price (blue line).



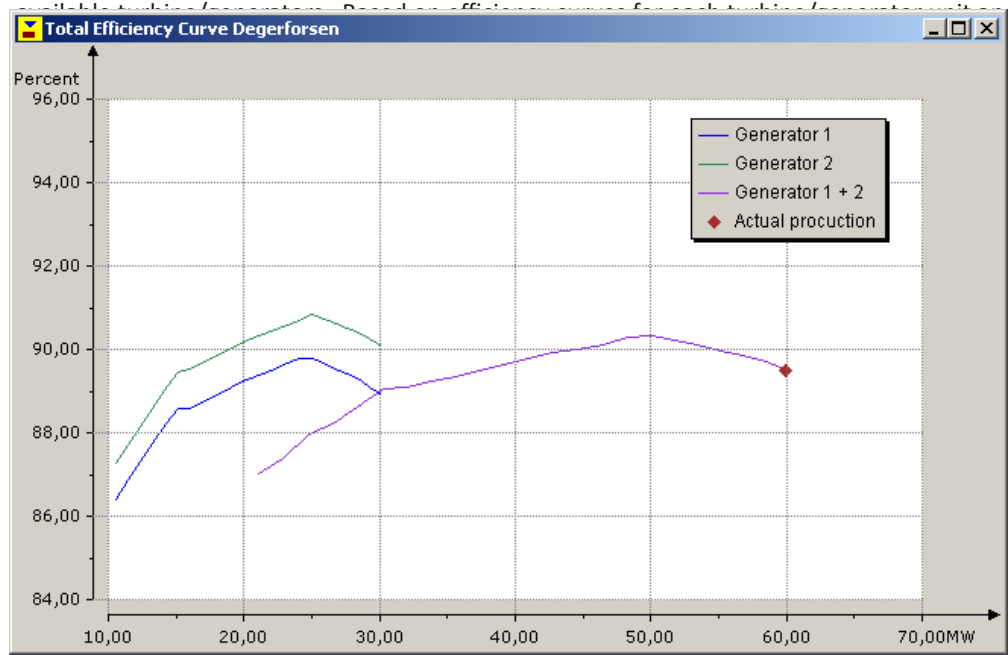
Minimize generation costs for the contracted generation volume

Generation planners re-run Powel Smart Generation’s optimizer in order to plan for the most cost-efficient generation of all contracted commitments once a market contract is settled. At this stage the optimal combination of different generation units is applied in order to generate at the lowest possible cost. The most important cost in hydropower is “fuel cost”, which is based on the water value in each reservoir at any time. All plans should be subjected to detailed simulations, where the hydrological behavior of the entire watercourse is taken into account. If the optimal solution for some reason may not be used, a change of plan may be made manually and analyzed yet again.

Creating “Scenarios” makes it easy to compare results from different simulation strategies with different input values.

The simulation results for different plans are stored as scenarios. The generation cost for each scenario is automatically calculated and can be compared to see the effect of any change of a plan. Powel Smart Generation automatically performs power station optimization, by distributing the required generation on the

The total efficiency curve for a 2-generator power station calculated by Powel Sim. Currently running above best point, due to high market prices mid-day.



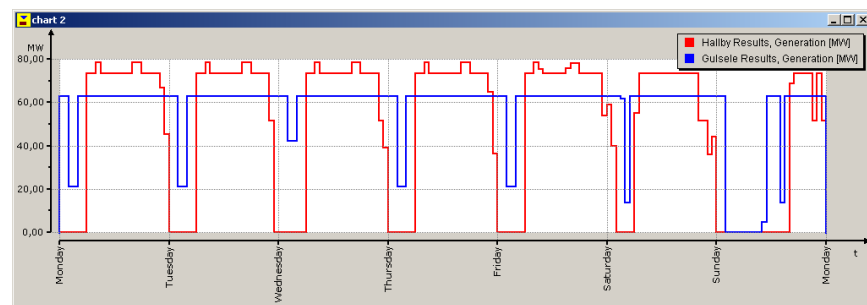
Markets for regulation and auxiliary services

Powel Smart Generation provides decision support for the very short-term markets of regulation and auxiliary services. This support includes information such as marginal costs and start-up costs for every unit, and generation cost for different levels of generation. The generation reserve requirements on both “slow” and “rotating reserve” may be included in the optimization. Bids are prepared, and may be transferred on-line to the relevant market operator.

Intra-day scheduling

An operator at a control centre will normally receive generation plans for the next day from the planning department. These plans may be detailed at the level of each turbine/generator, or be more general plans on a station or river course level. If the plans are not on a turbine/generator level, the operator may use the Powel Smart Generation to make detailed plans for next day. These short-term plans – in MW or m3/s for each turbine/generator – are normally prepared with hourly or 15 minute resolution. If situations occur which were not covered by the original assumptions, Powel Smart Generation can be re-run on the fly to get revised plans.

Powel ICC helps simplify the planning procedures and improve plans.



Typical week plan for two different power stations, displayed as a chart.

Powel Smart Generation may also be integrated with a utility’s SCADA system. In these cases, the system’s “Autopilot” will perform all changes in plans that are approved by the operator, which can then be executed automatically. The Autopilot will change generation level by sending new set points to the SCADA system, in time to allow the physical changes of gate positions, valves etc. to take place.

INTUITIVE AND FLEXIBLE MODELING OF WATERCOURSES

The generation system is modeled in Powel Smart Generation using “drag and drop” from a palette of icons for the main watercourse objects and components. When a new object is inserted, a form appears with all required attributes. The topology picture is used for several purposes.

- Easy access to the attribute form, with technical details for any object in the watercourse
- After simulation, the station and reservoir symbols in the topology picture are used to indicate the generation and reservoir level
- In normal use, spillways that are not in use are hidden. However, if a simulation gives spill from one or more reservoirs at any time during the planning period, the spillway appears in red

The main object types are reservoirs, power plants and waterways. Objects have names, topology information, attributes (like maximum generation per generator), time series (constraints, schedules, simulation results etc.), and other objects (catchments, generating units, gates etc.) connected to them. When the model is defined, it may be used for all simulations, optimizations and calculations in Powel Smart Generation.

INTEGRATION TO THERMAL POWER SYSTEMS

Through cooperation with highly experienced international partners, Powel can offer integrated solutions for coordinated optimization of both thermal and hydropower systems.

THE POWEL SMART GENERATION SOLUTION

Powel Smart Generation allows utilities to tailor the solution to their needs. The modules can be installed separately and independently of each other. The Powel Integrated Control Centre consists of the following main modules:

- **Powel Sim** – Consequence analysis, Restriction- and Water Management
- **Powel Shop** – Short Term Hydro Generation Optimizer
- **Powel Market Analyzer** – Long Term Market Analyzer and Price Forecaster
- **Powel Generation Optimizer** - Long Term Hydro Generation Optimizer with Water Value
- **Powel Inflow** – Inflow Forecaster and Analyzer
- **Powel Autopilot** – Automatic Smart Generation plan execution in SCADA systems

CONCLUSION

The software suite Powel Smart Generation covers the planning and scheduling needs of the control centre of a typical hydropower generation company. For the long-term view, Powel Smart Generation predicts market prices, suggests generation levels and estimates the monetary value of the water in the reservoirs. In the short-term perspective, inflow forecasting is based on historical data and weather forecasts. Market bidding is supported, and Powel Smart Generation optimizes the generation of contracted obligations. In the very short term, there is support for bidding in the regulation markets as well as an Autopilot for integration with SCADA systems.