National Infrastructure Simulation & Analysis Center

State Utility Forecasting Group (SUFG)

Reliability & Security Constrained Hydrothermal Scheduling

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Overview

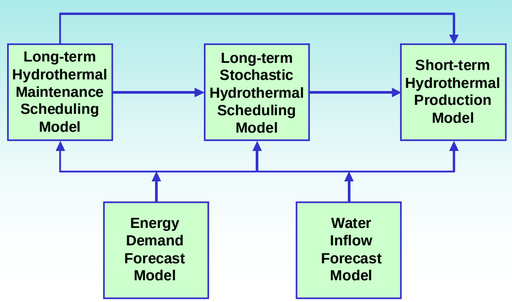
Reliable and secure operation of Pacific Northwest ports is crucial to the region and the nation.

Port operation is reliant on the Northwest electric power infrastructure. A power system failure can cause a major shutdown of the ports. It is therefore critical for the power system to operate reliably and in a secure fashion, and to achieve economical efficiency at the same time.

Purdue has developed a series of optimization-based models, focused on various aspects of the operation of the electric power infrastructure in the Pacific Northwest, leveraging past work in Africa and the upper Midwest.

The Models

Several models are used to address problems with differing time scales.



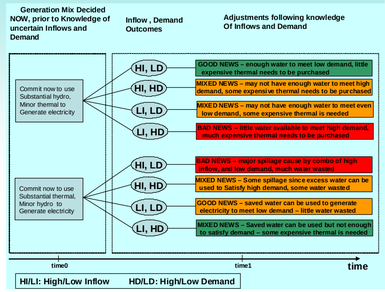
Long-term hydrothermal maintenance scheduling model

The objective of maintenance scheduling is to minimize both operational and maintenance costs. To ensure both reliability and security of the power system, we set a reserve margin for each node for each time period, and respect inter-nodal transmission capacity. This will prevent the event that too many plants are shutdown for maintenance at any node during any time period.

Hence, the reliability is balanced and the system is secure. In this model, all hydrological and major river management constraints are considered. The clock of this model is "half month". This is based on the maintenance manual for small gas turbine plants that usually require about 15 days for scheduled maintenance each year. It often takes about one month to complete the scheduled maintenance for large plants however.

Long-term stochastic hydrothermal scheduling model

The objective of the hydrothermal scheduling model is to determine the sequence of hydro releases over the planning horizon that will minimize total expected thermal operational cost. It considers water inflow and demand uncertainty and takes maintenance schedules from the long-term hydrothermal maintenance scheduling model as input. This model's output will be used as input to the short-term hydrothermal production model.



Short-term hydrothermal production model

This model uses the water storage levels from the long-term hydrothermal scheduling model as targets and the maintenance schedules from the long-term hydrothermal maintenance scheduling model for capacity availability. In general, this model is similar to the long-term maintenance model.

Supplemental Models

Energy demand forecast model

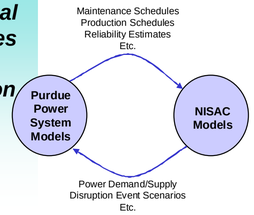
In this model, we use historical demand data to predict the demands of the major utilities in the region. Forecasts are based on the assumption that a 2% demand growth will sustain for the next few years for the region.

Water inflow forecast model

We calculate the mean inflows for the major rivers of the region. The mean inflows are used as forecasts in a longer term (6 months and beyond). As for the shorter term inflow forecasts (less than 6 months), we used forecasts done by others (see References).

SUFG's models provide inputs to NISAC models

- *Optimal hydrothermal maintenance schedules*
- *Optimal short-term hydrothermal operation schedules*
- *Other inputs to be determined*



Results

Forecast hourly demand data is listed in Table 1 and hydrothermal schedules from the short-term model for a period of 24 hours are listed in Table 2. We only list the on/off status of the plants that are scheduled for optimal production. Four nodes are modeled: Washington East (WaE), Washington West (WaW), Oregon (OR) and California (as a demand node).

Table 1. Nodal demand

	WaE	WaW	OR
hr0	58.860	7092.535	2493.605
hr1	57.864	6904.234	2377.902
hr2	57.564	6819.059	2375.377
hr3	58.140	6852.715	2359.145
hr4	59.520	7008.120	2421.360
hr5	62.316	7365.471	2525.213
hr6	65.688	7843.478	2697.834
hr7	69.768	8516.458	2951.774
hr8	71.904	8971.224	3129.872
hr9	71.172	8986.557	3203.271
hr10	68.892	8744.627	3161.481
hr11	66.900	8476.025	3099.075
hr12	63.576	8073.406	3010.018
hr13	62.580	7907.105	2921.315
hr14	62.040	7775.990	2843.970
hr15	60.816	7650.596	2854.588
hr16	61.392	7721.252	2882.356
hr17	63.228	7918.843	2930.929
hr18	64.860	8195.035	2985.105
hr19	68.232	8701.042	3158.726
hr20	66.816	8502.096	3065.088
hr21	63.660	8072.335	2883.005
hr22	59.976	7534.306	2700.718
hr23	56.976	7045.556	2497.468

Table 2. Generation Schedules (on/off status).

	Hydro unit commitment							
	WaE					OR		
	Stat2	Stat3	Stat4	Stat5	Stat6	Stat1	Stat2	Stat3
hr1	1	1	0	0	0	1	1	0
hr2	1	1	1	1	0	1	1	0
hr3	1	1	1	1	0	1	1	0
hr4	1	1	1	1	0	1	1	0
hr5	1	1	1	1	0	1	1	0
hr6	1	1	1	1	0	1	1	0
hr7	1	1	1	1	1	1	1	0
hr8	1	1	1	1	1	1	1	0
hr9	1	1	1	1	1	1	1	0
hr10	1	1	1	1	1	1	1	1
hr11	1	1	1	1	0	0	1	1
hr12	1	1	1	1	1	1	1	1
hr13	1	1	1	1	1	0	1	1
hr14	1	1	1	1	1	1	1	1
hr15	1	1	1	1	0	0	1	1
hr16	1	1	1	1	0	0	1	1
hr17	1	1	1	1	1	1	1	1
hr18	1	1	1	1	1	0	1	1
hr19	1	1	1	1	1	1	1	1
hr20	1	1	1	1	1	1	1	1
hr21	1	1	1	1	1	1	1	1
hr22	1	1	1	1	1	0	1	1
hr23	1	1	1	1	1	1	1	0

References

Hydro Research Group, University of Washington, 2002.

Z. Yu, F.T. Sparrow, B. Bowen, F. Smardo, "On convexity issues of hydrothermal scheduling," Journal of Electrical Power and Energy Systems, Vol. 22 (6), Aug.2000, pp. 451-457.

Demand data - FERC FORM 714.

Transmission data - http://www.transmission.bpa.gov/OASIS/BPAT/outages/oasisContent.shtm

Water inflow data - http://waterdata.usgs.gov/.

Hydro plant data - http://www.bpa.gov/power/ , etc.

Thermal heat rate and capacity data – FERC FORM 860.

About SUFG

The State Utility Forecasting Group (SUFG), hosted at Purdue University, was established in 1985 by Indiana state code to forecast electricity demand for Indiana and to study power supply needs for both Indiana and the Midwest. For the past 8 years, it has also engaged in deregulation analysis, natural gas systems, modeling energy system security, and international power pool studies.

NISAC's core partners are Sandia National Laboratories and Los Alamos National Laboratory.
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.
Los Alamos National Laboratory is operated by the University of California for the United States Department of Energy under contract W-7405 ENG-36.