GENESYS Redevelopment Requirements Specifications

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# Introduction

The GENESYS model was developed to test the adequacy of the regional power supply, given that future conditions, such as load and generation, are uncertain. GENESYS is also the primary analytical tool the Council uses for understanding the impacts of changes in the hydroelectric system’s operation on the regional power system.

## Purpose

The GENESYS redevelopment project is intended to enhance the analytical capabilities for both adequacy assessment and hydro-based analysis and to structure the code base to simplify future development and maintenance. This document comprehensively describes what a redeveloped GENESYS will encompass, including the functionality contained in the current code base.

## Intended Audience

This document provides a sufficient level of detail to describe the scope of the redevelopment process that is targeted for the members of the Council’s advisory committees and other interested stakeholders. It is also intended to lay out requirements for future developers who will be implementing the requirements in this document.

## Scope

GENESYS will simulate the coordinated operation of dispatchable resources. The simulations will cover a wide spectrum of uncertainty in: load (due to temperature and economic conditions), natural stream flows, thermal availability, energy efficiency and demand response achievement and variable energy resource output (wind and solar). Outputs will provide data that allows calculation of adequacy measures and basic statistics on operations and the marginal prices implied by the operations.

# Overall Description

GENESYS, **GEN**eration **E**valuation **SYS**tem, is a constrained economic dispatch model that uses Monte Carlo sampling to simulate short-term load uncertainty, and uncertainty in streamflows, wind, solar and forced outages for thermal generation plants. The current version of the model performs a detailed constrained dispatch of the regulated hydroelectric power projects in the watershed of the Columbia River Basin and of Pacific Northwest regional thermal plants against an extra-regional import market, on a 14 period per year basis, on a user defined window (2 to 7 days) basis, and on an hourly basis.

## History

In 1999, the deterministic load-resource balance in the region, as assessed by the Bonneville Power Administration, was nearly 4,000 aMW deficit. GENESYS was developed as a dispatch model to evaluate adequacy in a single year by dispatching resources within user defined nodes within and outside of the region. A distinguishing characteristic of GENESYS from predecessor production cost models was the ability to utilize stochastic and deterministic input variables and perform a hydro and thermal generation dispatch. Unlike predecessor models GENESYS was not designed to test long-term load uncertainty and utilize system expansion logic. In the Council’s modeling portfolio, GENESYS is used to provide adequacy thresholds, in the form of adequacy reserve margins, to the Regional Portfolio Model (RPM) which considers long-term load uncertainty and performs regional power system expansion studies.

##  Functions

GENESYS will be able to simulate the operation of the region’s power system on an hourly basis, including the simulation of individual hydroelectric facilities, while meeting system requirements for energy, capacity and ancillary services. It will also adhere to all non-power constraints for all resources, in particular, hydroelectric operations mandated in the Council’s Fish and Wildlife Program and by the Biological Opinion. It will appropriately dispatch non-hydro resources based on dispatch price parameters and determine when economics would dictate that stored water should be used to dispatch hydroelectric resources in coordination with these resources.

 It will also be able to identify when it is not possible to meet load while satisfying all constraints and determine/illustrate the underlying cause. It will be able to track metrics or functions of the underlying dispatch and produce summary results in a simple format that can either be read directly or easily imported into other programs such as Excel.

## Description of Anticipated Users

Users are anticipated to be Council staff, BPA staff, other utility IRP planners or specialized regional stakeholders with a desire to participate in regional or utility specific adequacy assessments.

While the program should be adaptive by changing inputs, there will also be users that can alter source code as needed. Thus, the source code will need to be in a managed repository, e.g. GitHub, with the exception of BPA’s HYDSIM module.

## Design and Implementation Constraints

GENESYS will need to be capable of using distributed computing, but the install should be kept simple enough that it does not cause issues for utility users. Depending on the approach to redevelopment, it may need to have access to a database server.

## Documentation Approach

Documentation should be developed concurrently with the model and should be posted to the Council’s website and updated and maintained in that location.

## Assumptions and Dependencies

GENESYS will depend on HydSim for monthly regulation of natural flows. That is, the model will simulate operations that are consistent with the results from the HydSim model that estimate required flows to meet non-power constraints. It will likely also require a mathematical programming solver, e.g. Gurobi, Xpress/Mosel, CPLEX, etc. for the hourly dispatch.

# External Interface Requirements

## User Interfaces

The user interface should accommodate changing input assumptions or any switches to turn on or off model logic. While it would be possible for the interface to be quite basic, it would be preferred that there be a clean and simple GUI for initiating GENESYS runs. Larger changes may be better accomplished with database editors or other tools.

## Hardware Interfaces

The program should be capable of interfacing with cluster computing either through the Message Passing Interface (MPI) standard or another technology. Expandability to AWS (Amazon Web Service) or a similar service would be ideal.

## Software Interfaces

There should not be a need for direct interface with other software, but the inputs to GENESYS should be coordinated with the inputs for HYDSIM, RPM and AURORA. Further, GENESYS should create outputs that are better coordinated with the needs of other programs or post-processing applications.

## Communication Protocols and Interfaces

The main communication protocol will be the requirements for distributed computing. This will likely be some sort of MPI interface.

# System Features

## Feature – Coordinated Resource Dispatch

The dispatch should be a function of the regional load net must-take generation ( for each node) and an external electricity price. It should include dispatch of demand response when needed and the effects of energy efficiency savings and renewable resource generation. It should include all non-power constraints for hydro; see hourly hydro dispatch for more detail.

### Outputs

The model should be capable of outputting the hourly dispatch for any plant or aggregation of plants. In some cases higher resolution may be desirable if it is possible.

## Feature - Multi-Stage Unit Commitment

The unit commitment should have a multi-stage approach starting at a (1) monthly level to coordinate with a monthly volume forecast for the regional hydro generation, then a (2) weekly or alternate window commitment preference, then a (3) day ahead commitment preference, then a (4) hour ahead commitment and finally (5) an after-the-hour true up for reserve deployment. See Figure 1.

### Outputs

The model should be capable of outputting the data used to support the commitment decisions and the associated stage.

### Required Elements

* Monthly and hourly hydro regulated dispatch
* Load forecast and error assumptions
* Hydro forecast and error assumptions
* Renewable forecast and error assumptions
* External market supply and pricing, i.e. how much power outside the region can be depended upon
* External market demand and pricing, i.e. what external requirements are likely to impact the regional generation
* Reserve requirements
* Fuel constraints and price
* Minimum up and down time for plants
* Ramp rates
* Reserve Requirements
* Heat rates and efficiency curve assumptions
* Variable O&M costs
* Demand Response/DSG/Emergency Resource dispatch price
* Maximum and minimum plant capacities (any other operating states)

Figure 1 - Multi-Stage Resource Commitment

## Feature – Dynamic Fuel Constraints

The fuel constraints should be able to be a function of the dispatch and commitment. For hydro this can be reflected as constraints such as dissolved gas constraints that limit bypass spill. For natural gas this could be a limit on deviations from day-ahead fuel elections.

### Required Elements

* Upper rule curve limits on hydro
* Refill requirements on hydro
* Drafting rights limitations (elevations)
* Limit on ability to draft below drafting rights for short periods of time
* Size of reservoirs
* Other non-power constraints for hydro
* Natural gas supply or contract constraints

## Feature - Internal Hydro Fuel Supply and Forecast Error

Forecasting the supply of fuel includes water forecasts for runoff that feeds the hydroelectric system.

### Required Elements

* Side-flows data, currently 24 period data is available, will need to estimate volatility and create synthetic weekly and daily flows
* Forecast side-flow error parameters – Autocorrelation and variance
* Flood control elevation targets (storage targets) as a function of anticipated side-flows and/or a range of acceptable elevations as a function of time
* Will also need refill elevation targets (to use as a starting point for the monthly dispatch)
* And, also critical elevation targets (or drafting rights elevation)
* Limits on borrowed hydro (drafting below the drafting rights elevation)

## Feature - Hourly Hydro Dispatch

The hourly hydro dispatch should select projects to use for hourly hydro generation based on daily and weekly flow or generation preferences. It should also identify the price by project for deviating from a planned or preferred generation schedule.

### Required Elements

* Plant parameters including:
	+ Number of Units
	+ Minimum and Maximum Generation by Unit
	+ Ramp Limits
	+ Tables of Storage vs Elevation, discharge vs. tailwater, and head vs. H/K
	+ Lag Time to next plant and/or functional description of when lagged water arrives into the downstream plants pool
	+ Full Gate Flows
	+ Size of reservoirs
* Projected hourly project side-flows which are inflows into a reservoir not released by an upstream project
* Projected reserve deployment
* Non-power constraints:
	+ Elevation constraints
	+ Bypass Spill constraints
	+ Flow constraints
	+ Rate of change limits on fore-bay and tail-water

## Feature – Integrating Storage into Dispatch Decisions

The integration of generic storage into the dispatch means that the model will have to decide at appropriate time steps, whether to store, generate or take no action based on projected system conditions. Alternately, storage could be tied to reserve requirements and should be accounted for during the after-the-hour true-up.

### Required Elements

* Efficiency parameter needed
* Ramp rates
* Energy Limit
* Capacity Limit
* Losses

## Feature - Load and Renewable Forecast Error Simulation

Forecast error for both load and renewable generation, as well as corresponding actions that would be taken, including the modification of operations given the forecast error, should be incorporated into the model.

### Required Elements

* Forecast error parameters for various forecast horizons

## Feature – Incorporate Reserve Requirements

Balancing, contingency and other potential operating reserves should be directly incorporated into the dispatch and commitment algorithms of the model. This should include the reserves held out for forecast error.

### Required Elements

* Fuel Consumption from Reserve Provision
* Load and variable energy resource reserve requirements
* Contingency Reserve Requirements
* Unplanned outage parameter assumptions

## Feature - Direct Conservation Input

The model should have the ability to have a direct input for forecast conservation and uncertainty in its acquisition. Currently energy efficiency savings are subtracted from the hourly load forecast, which means that those savings have a fixed seasonal and hourly pattern.

### Required Elements

* Conservation forecast
* Relation of conservation forecast to load forecast
* Uncertainty parameters

# Other Nonfunctional Requirements

## Performance requirements

GENESYS should be able to produce a full scenario run in 12 hours or less. A “full” scenario at the very least would be a study that simulates the operation over every combination of wind and temperature years, currently 6,160 games. In the future a full scenario might mean running with random combinations of all uncertain variables, which would require many more simulations, perhaps as many as 10,000 or more.

## Project documentation

Project documentation should be incorporated into the source code repository and include both functional specifications and technical discussions for the model.

## User documentation

User documentation should be included in the software install as either HTML help or as a Word Document.

# Other Requirements

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