

# Coral



## Composite reliability analysis

### Overview

Coral evaluates the static reliability of a hydrothermal generation-transmission system, providing system and bus reliability indices such as LOLP and EENS for each stage of a study horizon. A probabilistic simulation (Monte Carlo) of generator and circuit outages is adopted, also taking into account the effect of scheduled maintenance of power plants and uncertainties regarding inflows to hydro plants.

Coral uses the detailed modelling of the hydro system adopted by SDDP, used to simulate the schedule of power plants and produce scenarios of hydro plant's available power.

For each sampled state of plants and circuits, Coral uses an optimal power flow (OPF) to assess the minimum load shedding required to comply with the transmission limits. The simulation uses variance reduction techniques that provide good estimates for reliability indices using a moderate sample size, therefore speeding up the computational effort.

Coral has a graphical user interface, used to run the model and analyse results presented in spreadsheets and graphed according to user choice of reliability indices.

Coral is a powerful tool that is currently in use by different system operators and utilities. Coral runs on standard PCs using Windows 2000 or later.

## Methodology and modelling

The objective of Coral's OPF is to minimise the load shedding while respecting both transmission and generating unit-level constraints, considering

- DC power-flow model, including circuit flow limits and active power balance for each bus and load block
- Maximum generation levels of the power plants
- Outages of power plants and circuits
- Scenario of available power of hydro plants
- Maintenance schedule for the power plants and the circuits or the use of outage rates

The OPF is formulated as a large scale linear programming (LP) model and solved by Xpress - a state of the art commercial package developed by Dash Optimisation.

The outages of plants and circuits are simulated using the Monte Carlo method. Availability of each unit or circuit is modelled as a Markov Chain; the user must specify its forced outage rate. The load curve is discretized in load blocks.

The contribution of the generation and transmission failures to system reliability is assessed during the simulation of equipment outages, providing the corresponding generation and transmission estimates of reliability indices besides the composite reliability indices whose contribution for each sampled state is calculated by the OPF.

Estimates of system and bus reliability indices are obtained for each stage and load block, as well as their uncertainties for the chosen sample size of the simulation.

## Model Input and Output

Coral has several Excel compatible output files, such as:

- Composite System LOLP and EENS
- Composite Bus LOLP and EENS
- Generation System LOLP and EENS
- Transmission Bus LOLP and EENS
- Bus Power Marginal Cost
- Circuit marginal sensitivity
- Yearly averaged indices

## Graphical User Interface

Coral a friendly graphical user interface that facilitates the input of several of the modelling options, as well as the executions parameters.

A companion graph module, similar to the one used by SDDP, allows the user to select the required output and plot results using Excel.

## Integration with external models

- Coral is integrated with SDDP model. It shares with SDDP input data, such as demand, inflows and technical data for the power plants and network.
- Coral uses scenarios of hydro plant available power simulated with SDDP.

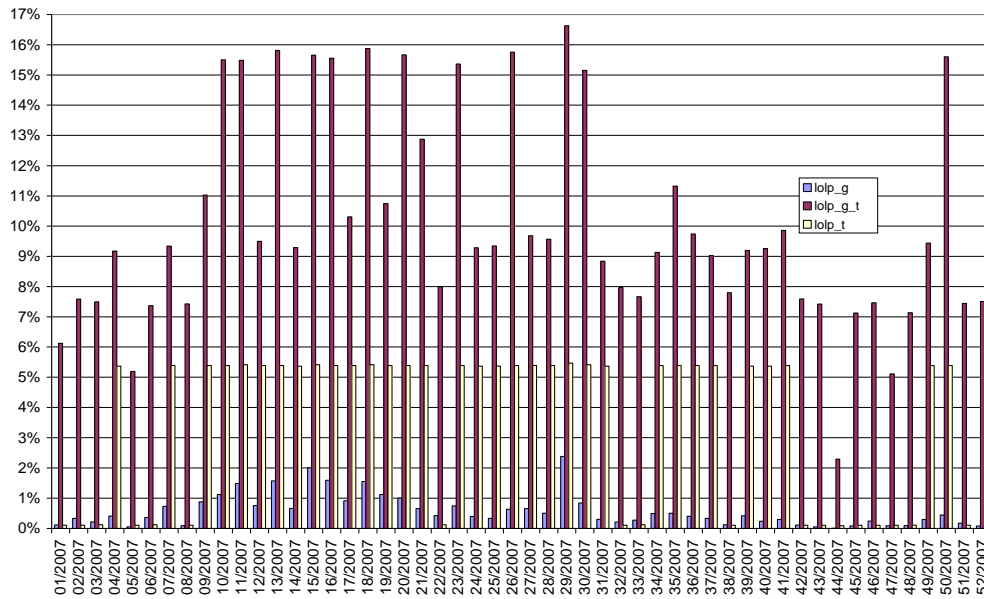
## Applications of the model

- Coral is the official reliability model of the National Dispatch Centre of Panama (ETESA) since 2006.

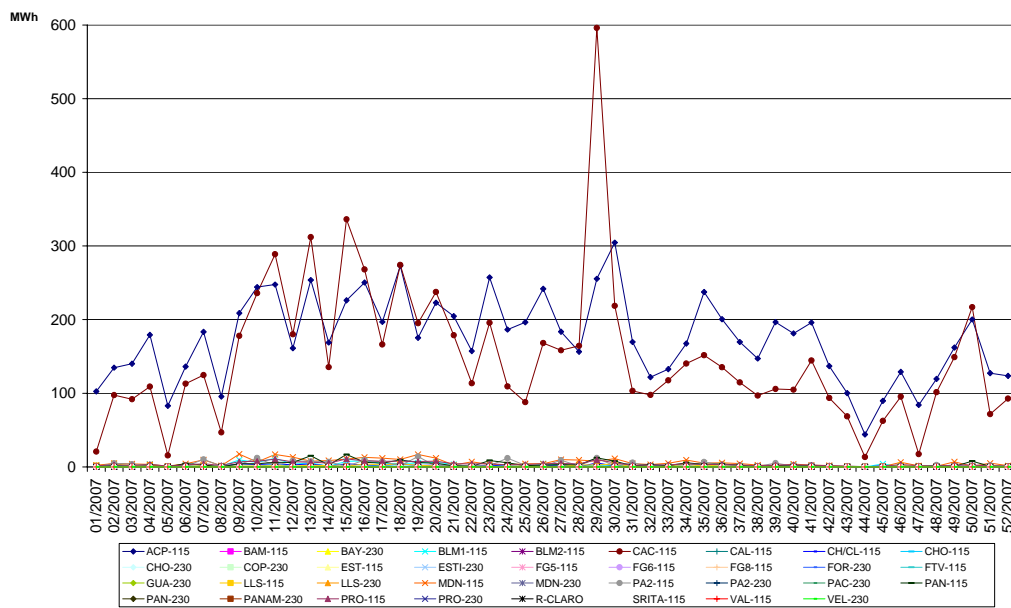
## Example Case Study

Coral is used by the National Dispatch Centre of Panama (ETESA) for determining the mid-term power reserve requirements. Weekly reliability estimates for the next year are also calculated using Coral.

The figure below illustrates the system weekly LOLP for the year of 2007.



The following figure presents bus weekly EENS indices along 2007.



### Contact

**Address:**  
 PSR  
 Rua Voluntários da Pátria 45, Suite 1402  
 Botafogo, 22270-000  
 Rio de Janeiro – RJ, BRAZIL  
**Tel:** +55-21-3906.2100  
**Fax:** +55-21-3906.2121  
**E-mail:** psr@psr-inc.com  
**URL:** www.psr-inc.com