HydroPowerModels.jl

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Introduction: Andrew Rosemberg

- Control Engineering at Pontifical Catholic University of Rio de Janeiro (PUC-RIO), Brazil.
- Double Degree General Engineering at École centrale de Marseille, France.
- Currently enrolled in the Operations Research Masters at PUC-RIO (Electrical Department).
- Researcher at Laboratory of Applied Mathematical Programming and Statistics (LAMPS).

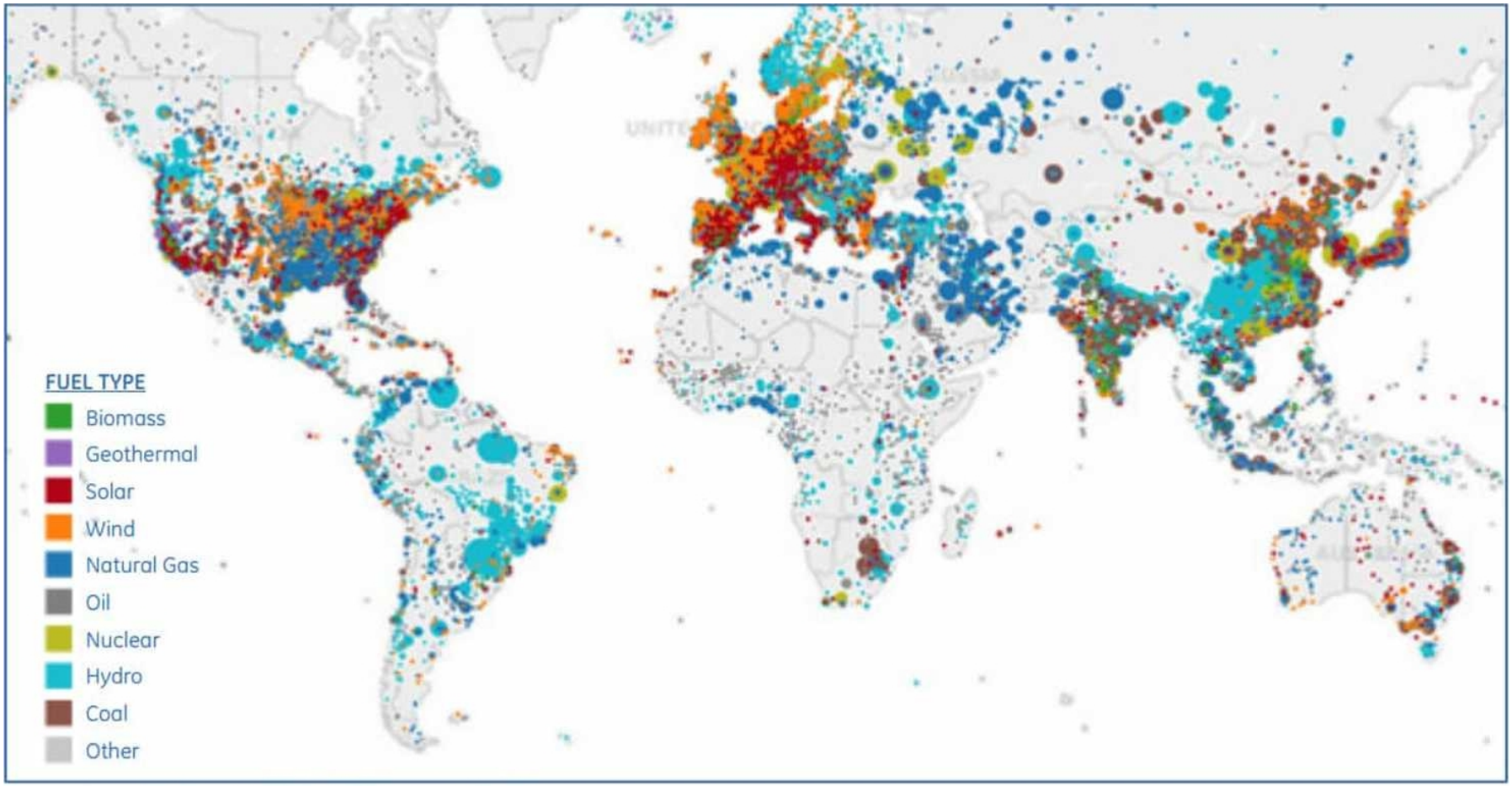
Overview

- **HydroPowerModels.jl** is a Julia Programming package for solving multistage, steady-state, hydro-dominated, power network optimization problems with Stochastic Dual Dynamic Programming (SDDP) [Pereira and Pinto, 1991].
- Mathematical programming modeling is done through **JuMP.jl** [Dunning et al., 2017].
- Optimal Power Flow (OPF) Problem Specifications and Network Formulations are handled by the **PowerModels.jl** package [Coffrin et al., 2018].
- Solution method is handled by the **SDDP.jl** package [Dowson and Kapelevich, 2017].

Hydrothermal Economic Dispatch

- Important for the planning and operation of hydro-dominated electrical systems such as the Brazilian national grid.
- Objective: Coordinate generation, energy distribution, and hydro-storage management in order to minimize the cost of operation.
- Uncertainties: Hydrology (i.e., rainfall and other inflows) of the hydroelectric plants.
- Often insufficient capacity of thermal generation to meet demand.
- Trade-off between using water for cheap generation in the present, against conserving water for future periods of drought.
- The hydrothermal dispatch problem is often modeled as a multistage stochastic problem Pereira and Pinto [1991], Maceiral et al. [2018], Philpott [2017].

Is it Relevant?



Source: Power plant data source Platts UDI Database, June 2012
Note: Circle size represents installed capacity (MW).

Optimal Power Flow

- Plan the operation of an electrical power system.
- Power Flow Equations.
- AC OPF.
- Approximations and Relaxations.

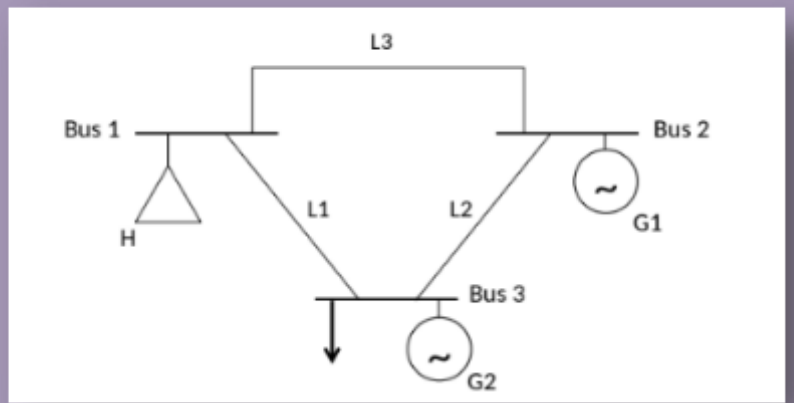
PowerModels.jl

- Steady-State Power Network Optimization Framework.
- Parsing and modifying network data .
- Enable computational evaluation of emerging power network formulations and algorithms.
- Models different Network Formulations (e.g. AC, DC-approximation, SOC-relaxation, ...).

PowerModels.jl

Network Description

Case.m



AC, DC, SOC, ...

PF,OPf, ...

Network Optimization Model

JuMP

$$\min_{x \in X} \quad f(x)$$
$$s.t. \quad g(x) \in \aleph$$

Solution Method

- Solving multistage stochastic programs is a challenging numerical problem.
- The solution of the problem is intractable.
- Common approximations (like SDP) - Curse of dimensionality.
- Overcame by SDDP.

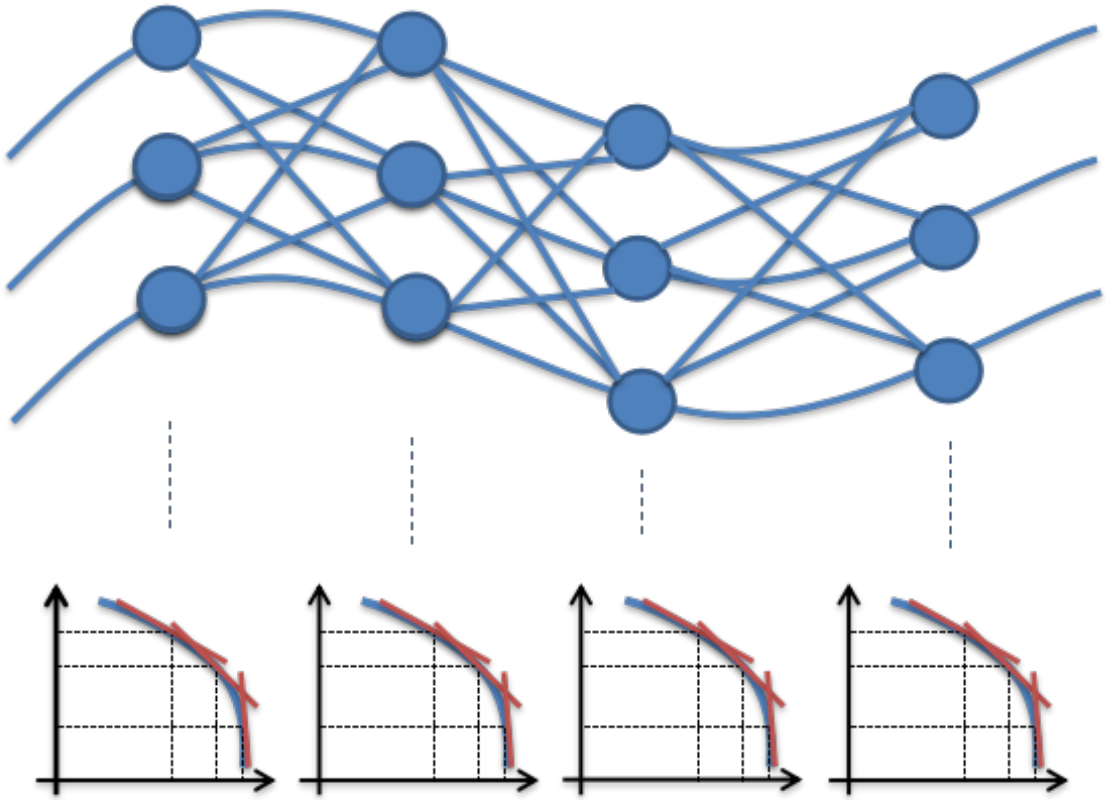
SDDP.jl

- Julia/JuMP Package for solving large multistage convex stochastic optimization problems using Stochastic Dual Dynamic Programming.
- Open source.
- Generic (Not domain specific).

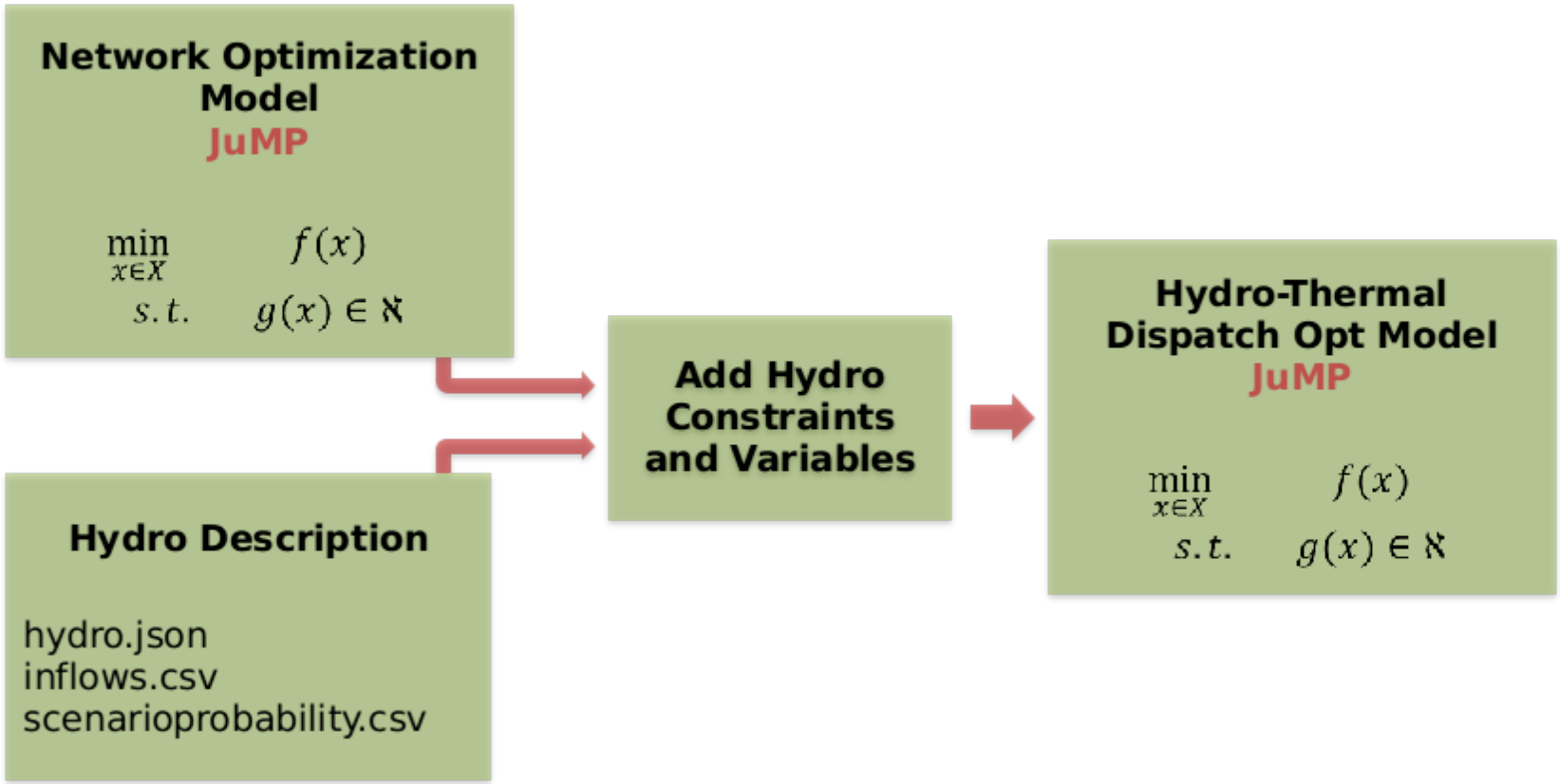
SDDP.jl

Optimization Model
JuMP

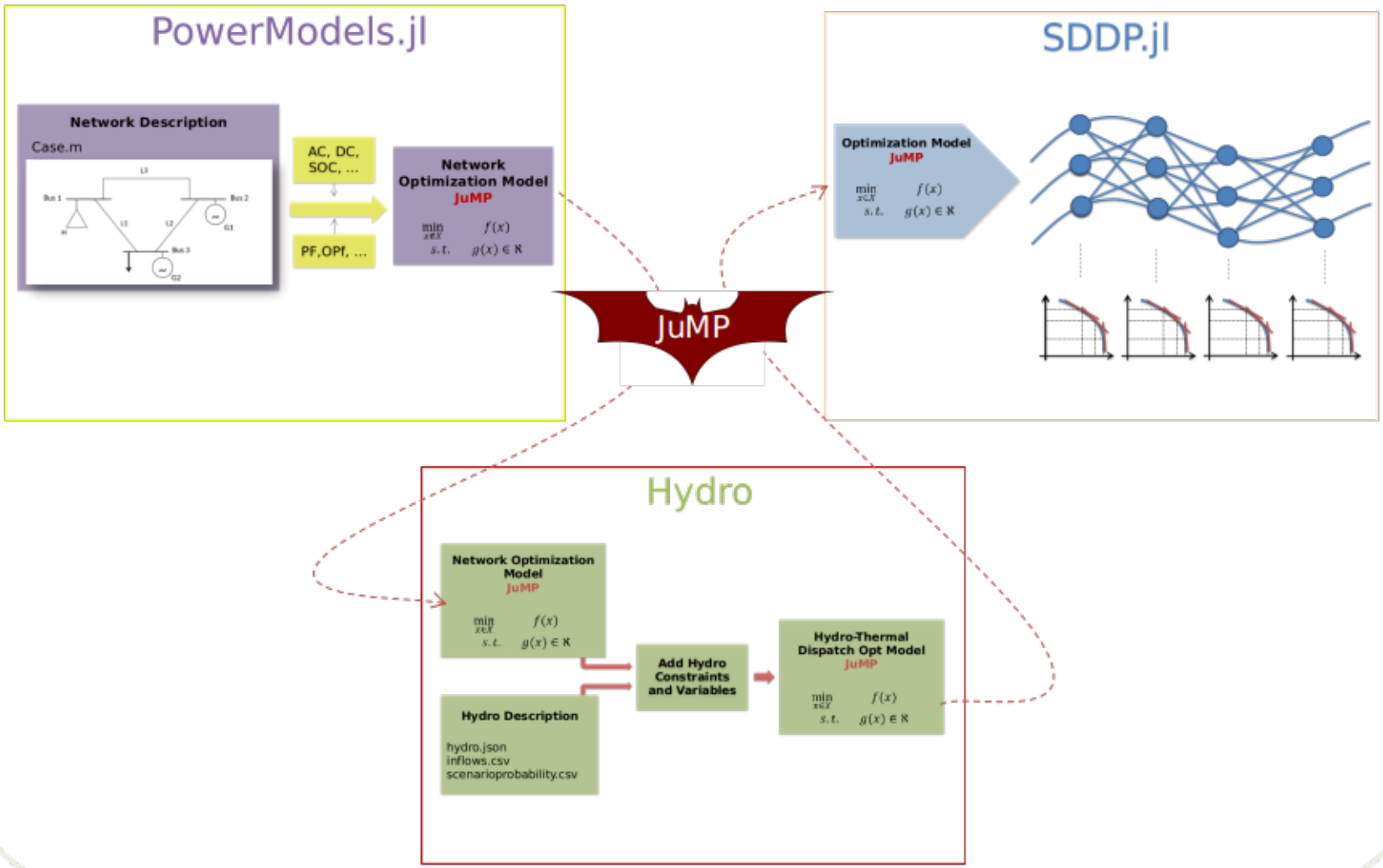
$$\min_{x \in X} \quad f(x)$$
$$s.t. \quad g(x) \in \aleph$$



Hydro


Network Optimization Model
JuMP
$\min_{x \in X} \quad f(x)$
$s.t. \quad g(x) \in \aleph$
Hydro Description
hydro.json
inflows.csv
scenarioprobability.csv
Add Hydro Constraints and Variables
Hydro-Thermal Dispatch Opt Model
JuMP
$\min_{x \in X} \quad f(x)$
$s.t. \quad g(x) \in \aleph$

HydroPowerModels.jl

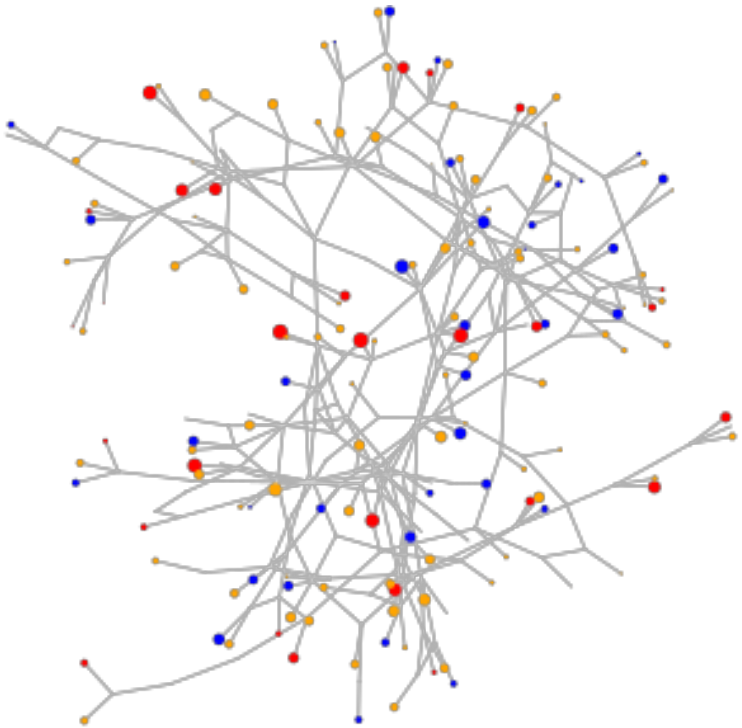


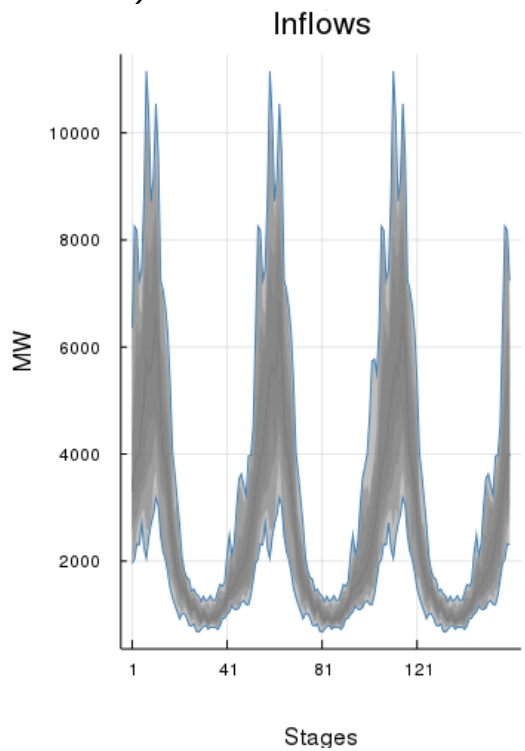
Example Case of a Realistic Hydrothermal Dispatch

Systems specifications:

- Number of buses: 166
- Number of generators: 145
- Number of loads: 286
- Number of branches: 235

In order for a qualitative view of the system, the package disposes a graph illustration plot (`plot_grid()`) and a scenarios quantile plot (`plotscenarios()`):





HydroPowerModels.jl Usage

- HydroPowerModels.jl gives you an interface to easily implement the described model.
- Once the case has been specified in the respective files (`PowerModels.json`, `hydro.json`, and `inflows.csv`) inside a case folder, a Hydrothermal Economic dispatch Operation may be planned:

First import the necessary packages:

```
> using HydroPowerModels
> using GLPK # one possible optimization solver
```

Load Case by passing the respective folder:

```
> data = HydroPowerModels.parse_folder("case3_folderpath")

Dict{Any,Any} with 2 entries:
    "powersystem" => Dict{ ...
    "hydro"       => Dict{ ...
```

Use `create_param` to create a set of problem parameters:

```
> params = create_param(
      stages          = 160,
      stage_hours     = 168.0,
      model_constructor_grid = DCPPowerModel,
      optimizer       = with_optimizer(GLPK.Optimizer))
```

Build the Model and execute the SDDP method to optimize a policy:

```
> m = hydrothermaloperation(data, params);
> HydroPowerModels.train(m)
```

Finally, simulate the performance of the policy:

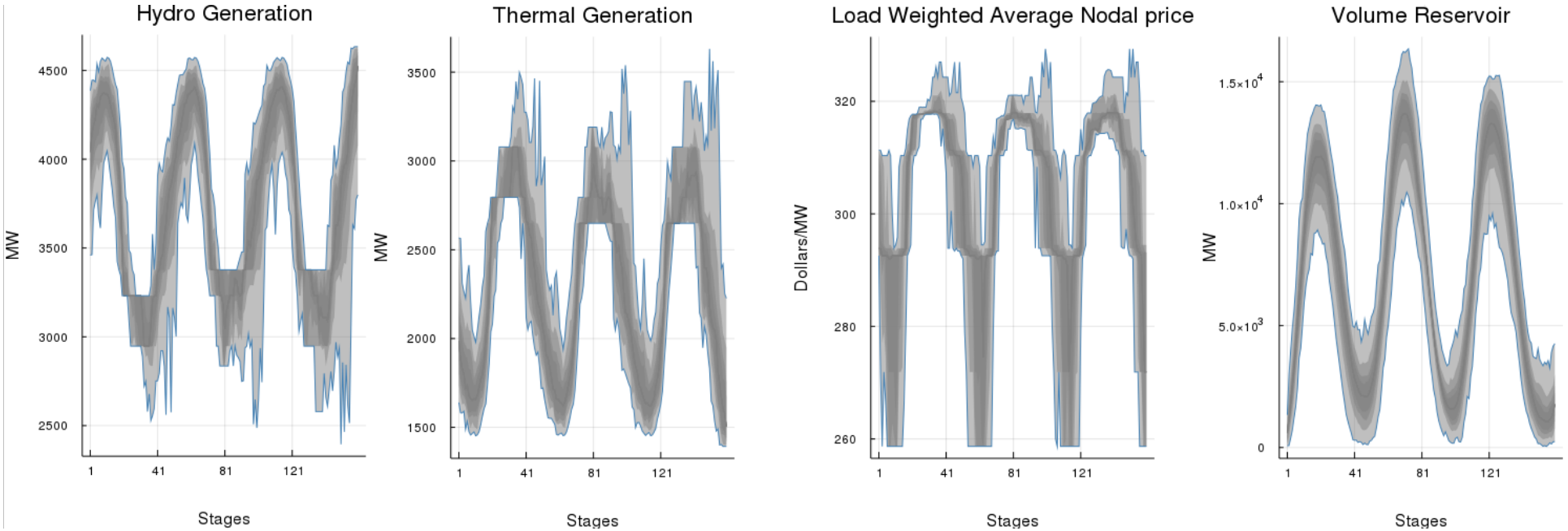
```
> results = HydroPowerModels.simulate(m, 1000);

Dict{Any,Any} with 5 entries:
    "simulations" => Dict[Dict{Any,Any}(Pair{Any,...
    "data"        => Dict{Any,Any}[Dict{Any,Any}(...
    "params"      => Dict{Any,Any}(Pair{Any,Any}(...
    "machine"     => Dict("cpu"=>"Intel(R) Xeon(R)...
    "solve_time"  => 205.31247
```

Results Case

- Ploting results is easy! The function '`plot_aggregate_results()`' receives a results dictionary and generates the most common plots for a hydrothermal dispatch:

```
> plot_aggregated_results(results)
```



Documentation and More Examples

- Detailed Documentation about installation, usage and testing of the package can be found at: **Docs HydroPowerModels.jl**
- Under Examples in the documentation there are a few Jupyter like cases and results to help discussions and learning.

Other Packages

- This is one of the many open-source projects develop by LAMPS: **LAMPSPUC Github**

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SDDP.jl

```
# Model Definition
m = SDDPModel(
                sense   = :Min,
                stages  = params["stages"],
                solver  = params["solver"],
        objective_bound = 0.0
                                    ) do sp,t

    # build eletric grid model using PowerModels
    pm = PowerModels.build_generic_model(data["powersystem"], params["model_constructor_grid"],
        params["post_method"], jump_model=sp, setting = params["setting"])

    # create reference to variables
    createvarrefs(sp,pm)

    # save GenericPowerModel
    sp.ext[:pm] = pm

    # resevoir variables
    variable_volume(sp, data)

    # outflow and spillage variables
    variable_outflow(sp, data)
    variable_spillage(sp, data)

    # hydro balance
    variable_inflow(sp, data)
    rainfall_noises(sp, data, cidx(t,data["hydro"]["size_inflow"][1]))
    setnoiseprobability!(sp, data["hydro"]["scenario_probabilities"][cidx(t,data["hydro"]["size_inflow"][1]),:])
    constraint_hydro_balance(sp, data)

    # hydro_generation
    constraint_hydro_generation(sp, data, pm)

    # Stage objective
    @stageobjective(sp, sp.obj + sum(data["hydro"]["Hydrogenerators"][i]["spill_cost"]*sp[:spill][i] for i=1:data["hydro"]["nHyd"]))
end
```

PowerModels.jl

HydroPowerModels.jl