

# StochasticPowerModels

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**Part I**

**Home**

## Chapter 1

# StochasticPowerModels.jl Documentation

### 1.1 Overview

StochasticPowerModels.jl is a research-grade Julia/JuMP package for experimentation with Steady-State Power Network Optimization under uncertainty, extending PowerModels.jl.

### 1.2 Installation

For now, StochasticPowerModels is unregistered. Nevertheless, you can install it through

```
| ] add https://github.com/timmyfaraday/StochasticPowerModels.jl.git
```

At least one solver is required for running StochasticPowerModels. The open-source solver Ipopt is recommended, as it is fast, scaleable and can be used to solve a wide variety of the problems and network formulations provided in PowerModels. The Ipopt solver can be installed via the package manager with

```
| ] add Ipopt
```

Test that the package works by running

```
| ] test StochasticPowerModels
```

**Part II**

**Manual**

## Chapter 2

# Getting Started

### 2.1 Quick Start Guide

Once StochasticPowerModels is installed, Ipopt is installed, and a network data file (e.g. "case5\_spm.m" ) has been acquired, an stochastic AC Optimal Power Flow can be executed with,

```
using StochasticPowerModels
using Ipopt

result = run_ac_sopf("matpower/case5_spm.m", Ipopt.Optimizer)
```

## Chapter 3

# Mathematical Model

### 3.1 The StochasticPowerModels Mathematical Model

#### Sets and Parameters

StochasticPowerModels implements a generalized polynomial chaos expansion version of the AC Optimal Power Flow problem from [Matpower](#). The core generalizations of the deterministic OPF problem are,

- Support for multiple load ( $S_k^d$ ) and shunt ( $Y_k^s$ ) components on each bus  $i$
- Line charging that supports a conductance and asymmetrical values ( $Y_{ij}^c, Y_{ji}^c$ )

sets:

$N$  - buses

$R$  - reference buses

$E, E^R$  - branches, forward and reverse orientation

$G, G_i$  - generators and generators at bus  $i$

$L, L_i$  - loads and loads at bus  $i$

$S, S_i$  - shunts and shunts at bus  $i$

data:

$S_k^{gl}, S_k^{gu} \quad \forall k \in G$  - generator complex power bounds

$c_{2k}, c_{1k}, c_{0k} \quad \forall k \in G$  - generator cost components

$v_i^l, v_i^u \quad \forall i \in N$  - voltage bounds

$S_k^d \quad \forall k \in L$  - load complex power consumption

$Y_k^s \quad \forall k \in S$  - bus shunt admittance

$Y_{ij}, Y_{ij}^c, Y_{ji}^c \quad \forall (i, j) \in E$  - branch pi-section parameters

$T_{ij} \quad \forall (i, j) \in E$  - branch complex transformation ratio

$s_{ij}^u \quad \forall (i, j) \in E$  - branch apparent power limit

$i_{ij}^u \quad \forall (i, j) \in E$  - branch current limit

$\theta_{ij}^{\Delta l}, \theta_{ij}^{\Delta u} \quad \forall (i, j) \in E$  - branch voltage angle difference bounds

(3.1)

### Stochastic Optimal Power Flow in Current-Voltage Variables

A variable  $I_{ij}^s$ , representing the current in the direction  $i$  to  $j$ , through the series part of the pi-section, is used. The mathematical structure for a current-voltage formulation is conceived as:

variables:

$$\begin{aligned} I_k^g \quad \forall k \in G \\ V_i \quad \forall i \in N \\ I_{ij}^s \quad \forall (i, j) \in E \cup E^R \text{ - branch complex (series) current} \end{aligned} \quad (3.2)$$

$$I_{ij} \quad \forall (i, j) \in E \cup E^R \text{ - branch complex (total) current} \quad (3.3)$$

$$\text{minimize: } \sum_{k \in G} c_{2k} (\Re(S_k^g))^2 + c_{1k} \Re(S_k^g) + c_{0k}$$

subject to:

$$\begin{aligned} \angle V_r = 0 \quad \forall r \in R \\ S_k^{gl} \leq \Re(V_i(I_k^g)^*) + j\Im(V_i(I_k^g)^*) \leq S_k^{gu} \quad \forall k \in G \end{aligned} \quad (3.4)$$

$$\begin{aligned} v_i^l \leq |V_i| \leq v_i^u \quad \forall i \in N \\ \sum_{k \in G_i} I_k^g - \sum_{k \in L_i} (S_k^d/V_i)^* - \sum_{k \in S_i} Y_k^s V_i = \sum_{(i,j) \in E_i \cup E_i^R} I_{ij} \quad \forall i \in N \end{aligned} \quad (3.5)$$

$$I_{ij} = \frac{I_{ij}^s}{T_{ij}^*} + Y_{ij}^c \frac{V_i}{|T_{ij}|^2} \quad \forall (i, j) \in E \quad (3.6)$$

$$I_{ji} = -I_{ij}^s + Y_{ji}^c V_j \quad \forall (i, j) \in E \quad (3.7)$$

$$\frac{V_i}{T_{ij}} = V_j + z_{ij} I_{ij}^s \quad \forall (i, j) \in E \quad (3.8)$$

$$|S_{ij}| = |V_i| |I_{ij}| \leq s_{ij}^u \quad \forall (i, j) \in E \cup E^R$$

$$|I_{ij}| \leq i_{ij}^u \quad \forall (i, j) \in E \cup E^R$$

$$\theta_{ij}^{\Delta l} \leq \angle(V_i V_j^*) \leq \theta_{ij}^{\Delta u} \quad \forall (i, j) \in E$$

### Stochastic Optimal Power Flow in Power-Voltage Variables

A complete mathematical model is as follows,



variables:

$$S_k^g \quad \forall k \in G \text{ - generator complex power dispatch} \quad (3.9)$$

$$V_i \quad \forall i \in N \text{ - bus complex voltage} \quad (3.10)$$

$$S_{ij} \quad \forall (i, j) \in E \cup E^R \text{ - branch complex power flow} \quad (3.11)$$

$$\text{minimize: } \sum_{k \in G} c_{2k} (\Re(S_k^g))^2 + c_{1k} \Re(S_k^g) + c_{0k} \quad (3.12)$$

subject to:

$$\angle V_r = 0 \quad \forall r \in R \quad (3.13)$$

$$S_k^{gl} \leq S_k^g \leq S_k^{gu} \quad \forall k \in G \quad (3.14)$$

$$v_i^l \leq |V_i| \leq v_i^u \quad \forall i \in N \quad (3.15)$$

$$\sum_{k \in G_i} S_k^g - \sum_{k \in L_i} S_k^d - \sum_{k \in S_i} (Y_k^s)^* |V_i|^2 = \sum_{(i,j) \in E_i \cup E_i^R} S_{ij} \quad \forall i \in N \quad (3.16)$$

$$S_{ij} = (Y_{ij} + Y_{ij}^c)^* \frac{|V_i|^2}{|T_{ij}|^2} - Y_{ij}^* \frac{V_i V_j^*}{T_{ij}} \quad \forall (i, j) \in E \quad (3.17)$$

$$S_{ji} = (Y_{ij} + Y_{ji}^c)^* |V_j|^2 - Y_{ij}^* \frac{V_i^* V_j}{T_{ij}^*} \quad \forall (i, j) \in E \quad (3.18)$$

$$|S_{ij}| \leq s_{ij}^u \quad \forall (i, j) \in E \cup E^R \quad (3.19)$$

$$|I_{ij}| \leq i_{ij}^u \quad \forall (i, j) \in E \cup E^R \quad (3.20)$$

$$\theta_{ij}^{\Delta l} \leq \angle(V_i V_j^*) \leq \theta_{ij}^{\Delta u} \quad \forall (i, j) \in E \quad (3.21)$$

## **Part III**

## **Library**

## Chapter 4

# Network Formulations

### 4.1 Network Formulations

#### Type Hierarchy

We begin with the top of the hierarchy, where we can distinguish between current-voltage and power-voltage formulations

```
AbstractACPModel <: AbstractPowerModel  
AbstractIVRModel <: AbstractPowerModel
```

#### Power Models

Each of these forms can be used as the model parameter for a PowerModel:

```
ACPPowerModel <: AbstractACPForm  
IVRPowerModel <: AbstractIVRModel
```