Modelling and quantification of uncertainties in power systems: Probabilistic analysis using PowerFactory

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April 20, 2018

Uncertainties in power systems

weather renewables

consumption contingencies

Probabilistic Analysis

Uncertainties	Calculation	Probability distributions
weather	power grid	distribution

Probabilistic Analysis

Problem definition

$X: \Omega \to \mathbb{R}^s$: Random input defined on some probability space Ω
$f: \mathbb{R}^s \to \mathbb{R}^d$: Function to be studied probabilistically
$f(X)$: Observed random quantities

Goal: Determine the distributon of $f(X)$.

Major challenges

- Precision
- Performance
- Generic modelling

Calculation methods

Non-intrusive	Intrusive
Monte Carlo method	Cumulants
Quasi-Monte Carlo method	Convolutions
Point estimate	Stochastic Galerkin

Overview of calculation methods

Cumulants

- Approximation of distribution functions using series expansion, similar to Taylor
- Linearization at the operating point
- Result: Moments

Convolution method

- Support of discrete variables difficult
- Linearization at the operating point
- Problematic: Momory consumption / performance / resolution
- Independent random input variables required

Point estimate

- Requires many executions of analysed calculation
- Independent random input variables required
- Result: Moments

The (Quasi-) Monte Carlo method

Given a sequence $(X_n)_n$ of samples of the random input X.

Estimation of the expectation of some function f:

$$\frac{1}{N}\sum_{n=1}^{N} f(X_n) \to E[f(X)] \text{ as } N \to \infty. \tag{1}$$

Questions

- Convergence
- Rate of convergence

Answer depends on ...

- Type of the sequence of samples
- Properties of f (continuous, ...)
- Dimensionality of the problem

$(X_n)_n$ identically and independently distributed (i.i.d) samples from X.

Convergence rate:

$$O(1/\sqrt{N}). \tag{2}$$

Pro:

- Convergence rate is independent of input dimension
- May be applied to ‚any' integrable function f
- Convergence with probability 1

Con:

- Relatively slow convergence
- We do not know the constants (depend on the realization)

Quasi-Monte Carlo method

$(X_n)_n$ specific 'space exploring' sequence.

Convergence rate:

$$O((\log N)^s/N), \tag{3}$$

where s is the number of random inputs.

Pro:

- Convergence rate is relatively fast.

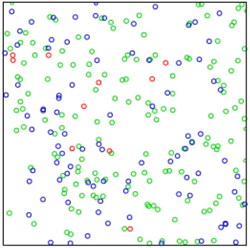
Con:

- Rate of convergence depends on input dimension.
- Valid for uniform distributions on the unit cube $[0, 1]^s$.
  Therefore, transform of distributions is required.
- Requires some assumptions on f.

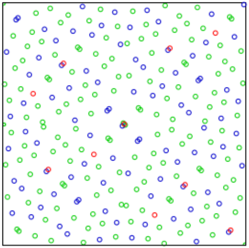
Note:

- Still topic of research.
- Dependence on input dimension $\log(N)^s$ is worst case scenario.
- Usually not much dependence on input dimension observed.

Monte Carlo



Quasi-Monte Carlo

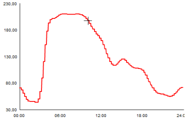


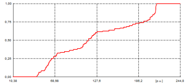
Source: Wikipedia

Modelling randomness

Distributions

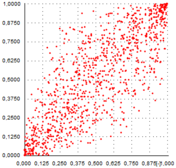
- Predefined distributions
- Estimated distributions based on measurement data

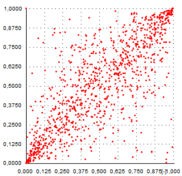




Dependencies

- Predefined copulae
- Estimated copulae based on measurement data





Thank you for your attention ...