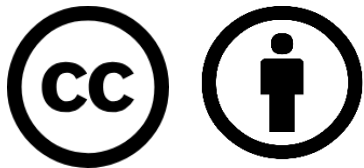


Stochastic and Modeling & Simulation Load Analysis

Electric Power Load Analysis (EPLA)

Revision of 8 June 2026

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<http://doerry.org/norbert/MarineElectricalPowerSystems/index.htm>

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Essential Questions

When should stochastic load analysis or modeling and simulation load analysis be performed?

Understand

How is stochastic load analysis performed?

Understand

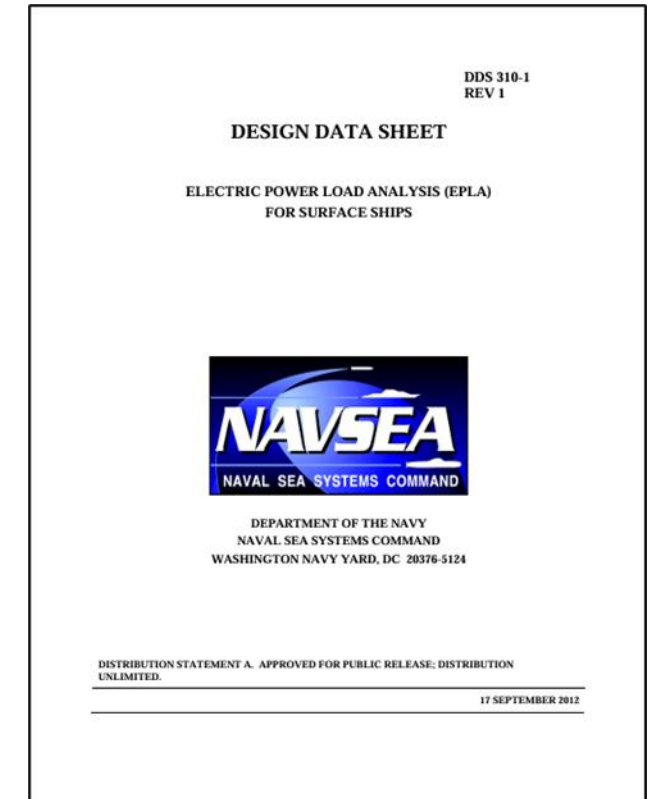
How is modeling and simulation load analysis performed?

Understand

Stochastic Load Analysis

Modeling and Simulation Load Analysis

- Stochastic Load Analysis
 - Model loads as a probability density function (PDF)
 - Correlated loads modeled together
 - Use Monte Carlo simulation to determine PDF of total load for a particular power distribution equipment.
 - Apply margin and Service Life Allowance
- Modeling and Simulation Load Analysis
 - Model loads as a function of time. May include dependence on random variables and other loads.
 - Correlated loads must communicate with each other, but do not need to be modeled together
 - Load models can incorporate time of day (meals – watch rotation, etc)
 - Use Monte Carlo simulation for random variables
 - Calculate time trace of total load
 - Apply margin and service life allowance
- Interpret results with respect to power distribution system equipment
 - Does a particular short term overload of the equipment result in a service interruption.
 - Do the service interruptions occur infrequently enough to enable meeting Quality of Service Mean Time Between Service Interruption (MTBSI)
- Process defined in DPC 310-1



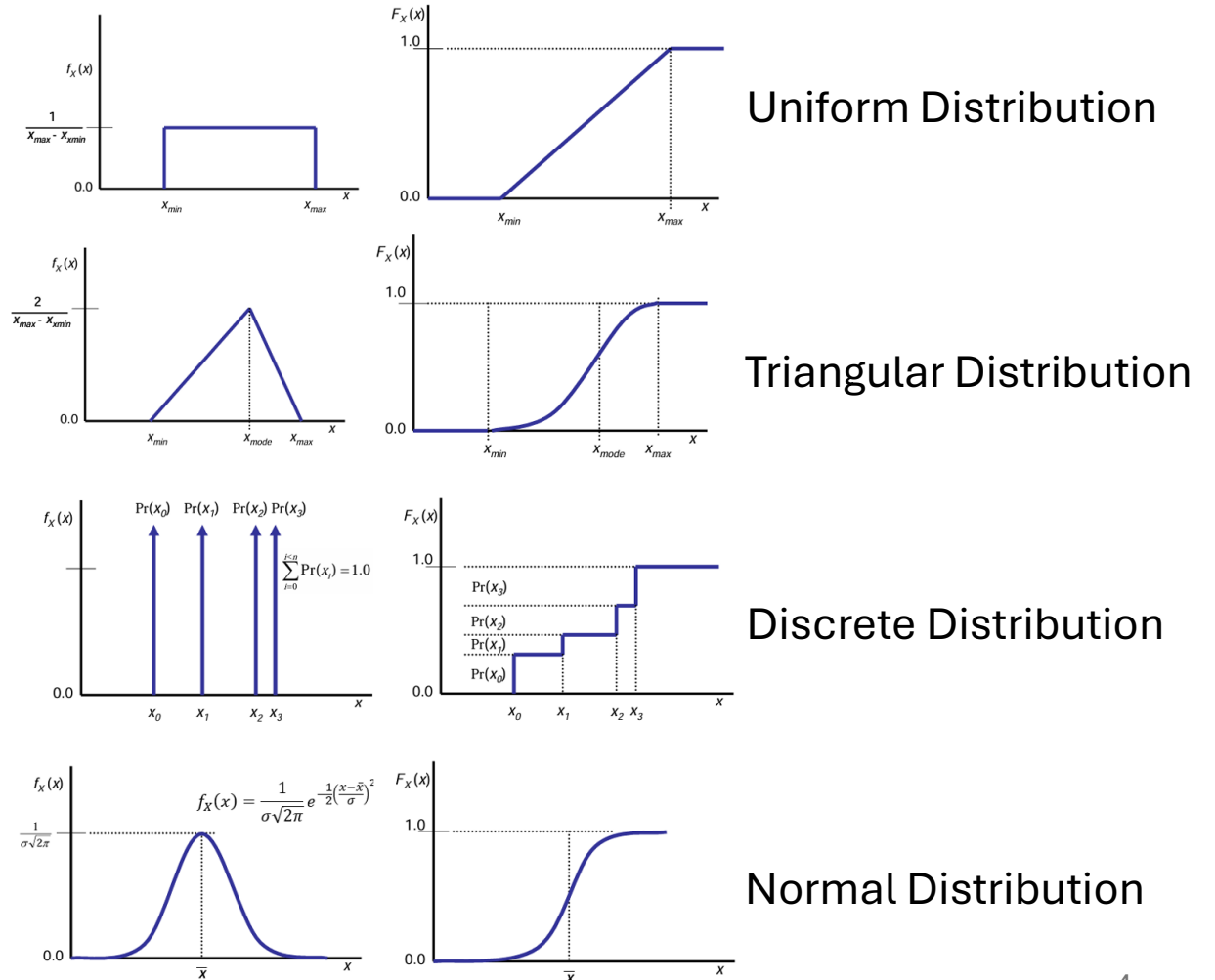
Probability Density Functions (PDF) Cumulative Distribution Function (CDF)

- The integral of a PDF over an interval of x is the probability that the random variable X will fall within the interval.
- A CDF is the probability that the random variable X will be less than or equal to x

$f_X(y)$ = PDF of X

$F_X(x)$ = CDF of X

$$F_X(x) = \int_{-\infty}^x f_X(y) dy$$



Monte Carlo simulation process

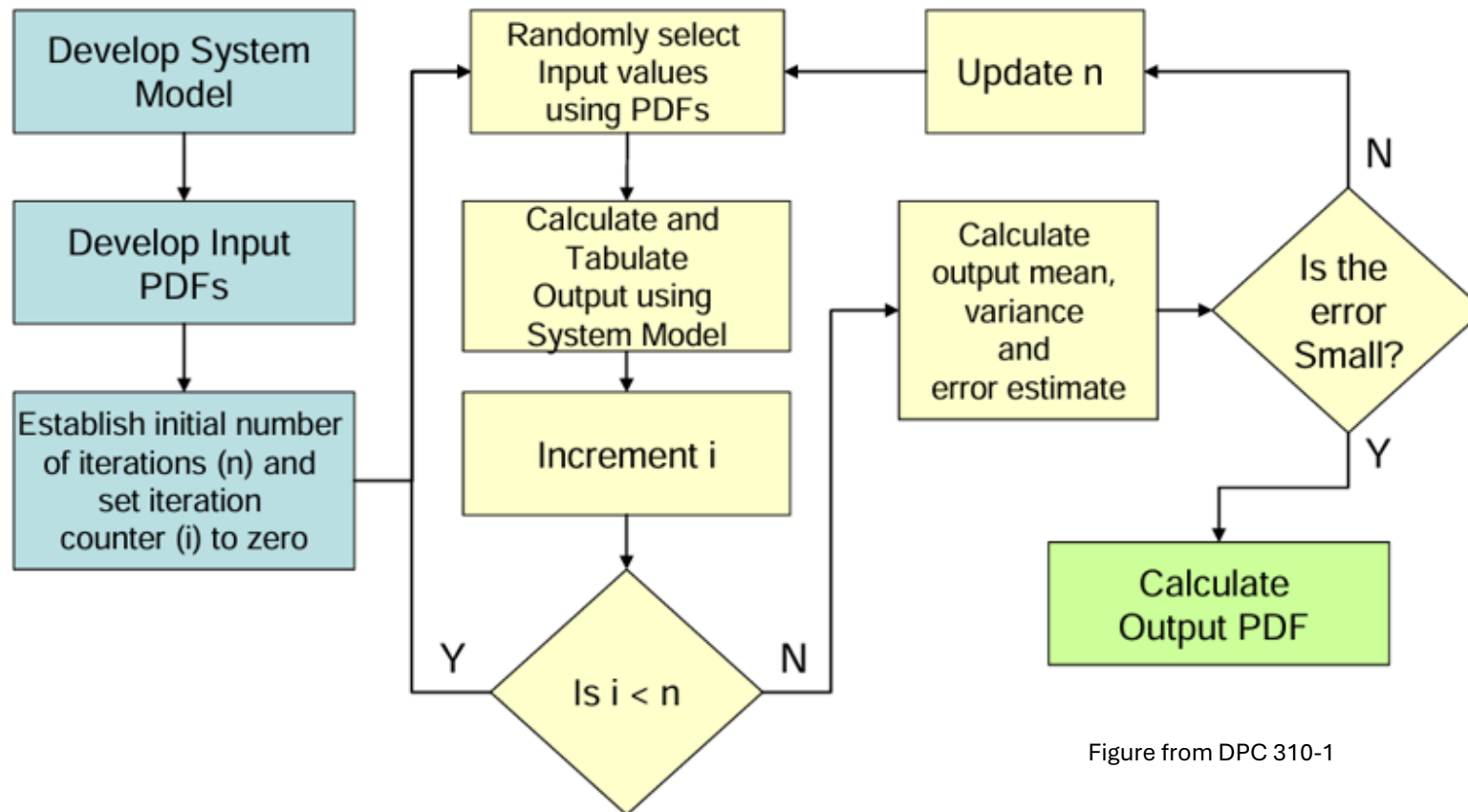


Figure from DPC 310-1

Developing a value of x that adheres to a PDF

Inverse Transform technique

- Calculate the CDF from the PDF

$$F_X(x) = \int_{-\infty}^x f_X(y) dy$$

- Create a sample u from a uniform distribution over the interval $[0:1]$
- Solve the equation for x

$$F_X(x) = u$$

- x adheres to $f_x(x)$

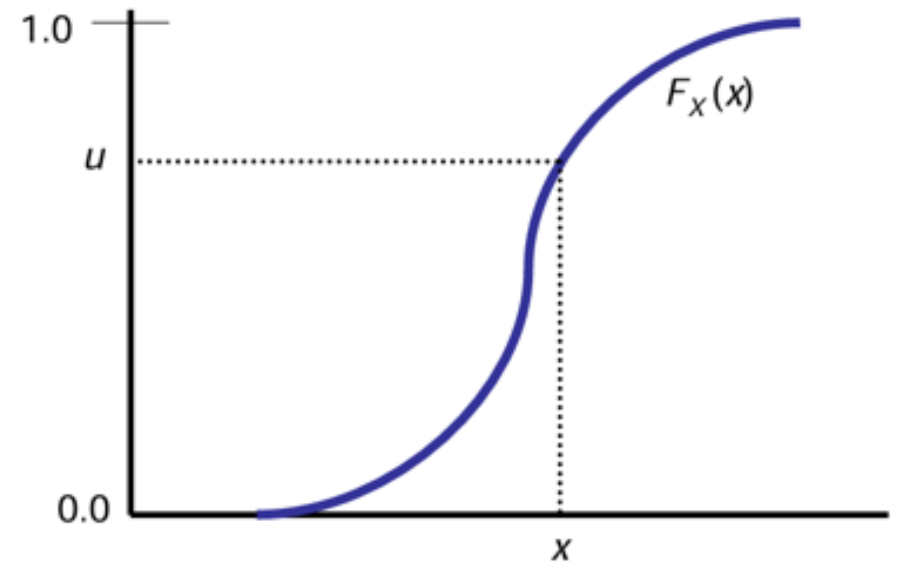


Figure from DPC 310-1

Iterating in a Monte Carlo simulation

- The total load is calculated n times by summing the applicable load values that are sampled from their respective PDFs.
- Initially n is set to a value which is believed sufficient to develop good estimates for mean values and standard deviation. Usually a number of about 500 is adequate.

- Mean Value

$$\bar{x} = \frac{1}{n} \sum_{i=0}^{n-1} x_i$$

- Variance and Standard Deviation

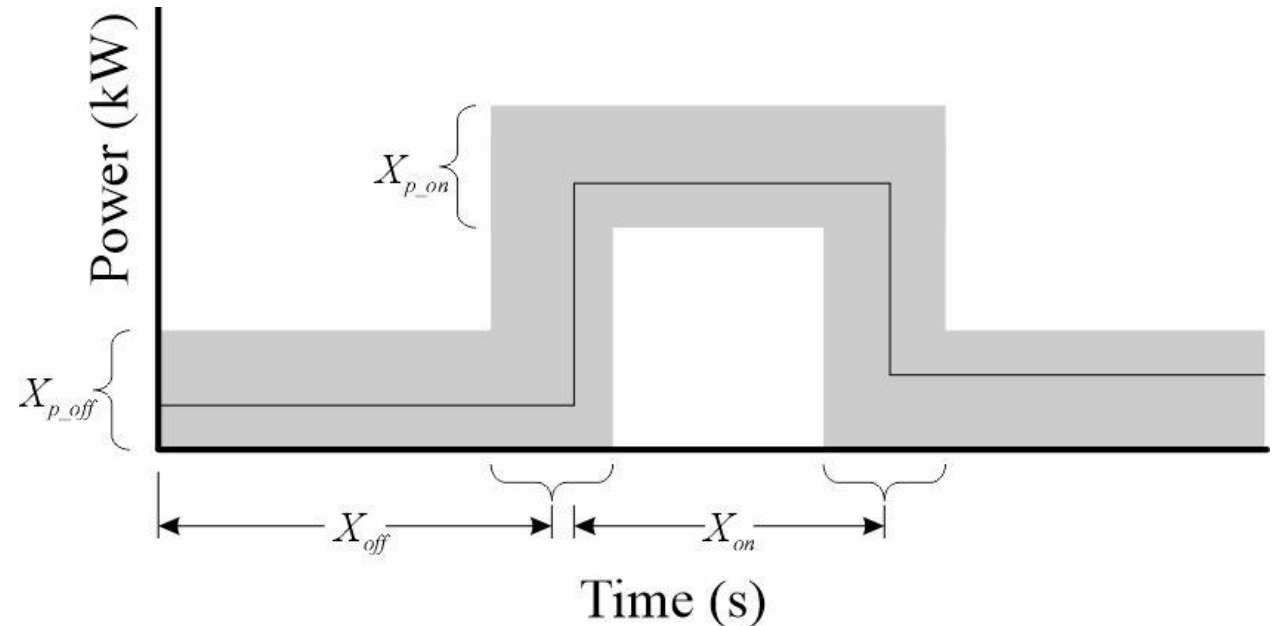
$$\sigma_x^2 = \frac{1}{n-1} \sum_{i=0}^{n-1} (x_i - \bar{x})^2$$

- Update n based on estimating the error E
 - Generally set E to no more than 0.02

$$n = \frac{9}{E^2} \left(\frac{\sigma_x}{\bar{x}} \right)^2$$

Modeling and simulation load models

- For each load, produce a waveform of power as a function of time.
- Can be completely deterministic or a function of random variables.
 - Can use measured data to calibrate models.
- Can depend on other loads or time of day.



Load model that depends on 4 random variables

Modeling and Simulation Analysis

- Time Increment
 - Generally around 1 second
 - In-rush current and transients need not be modelled (model them differently)
- Simulation Duration – Equipment Sizing
 - Generally should be about 100 times the quality of service metric for Mean Time Between Service Interruption (MTBSI)
 - Factor of 10 to limit temporary overloads contribution to MTBSI
 - Factor of 10 to develop a reasonable estimate of the number of service interruptions
 - Ensembles may be employed to enable parallel processing for increased calculation speed.
 - Example
 - MTBSI of 30,000 hours implies 10.8 billion seconds should be simulated
- Simulation Duration – 24-hour average
 - Much shorter times are likely sufficient – 2400 hours should provide a sufficiently accurate mean value estimate.

Results of analyses

- Stochastic Analysis
 - Probability Density Function of the total load
 - Service Life Allowance and Margin applied
 - Evaluation of whether exceeding the rated load of the equipment under study will lead to a service interruption.
 - Generally, meeting the rated load about 95% of the time is sufficient.
- Modeling and Simulation Analysis
 - Apply margin and service life allowance
 - Evaluation of whether exceeding the rated load of the equipment under study will lead to a service interruption.
 - Limiting the contribution to MTBSI to an allocated fraction of the allowed service interruptions.