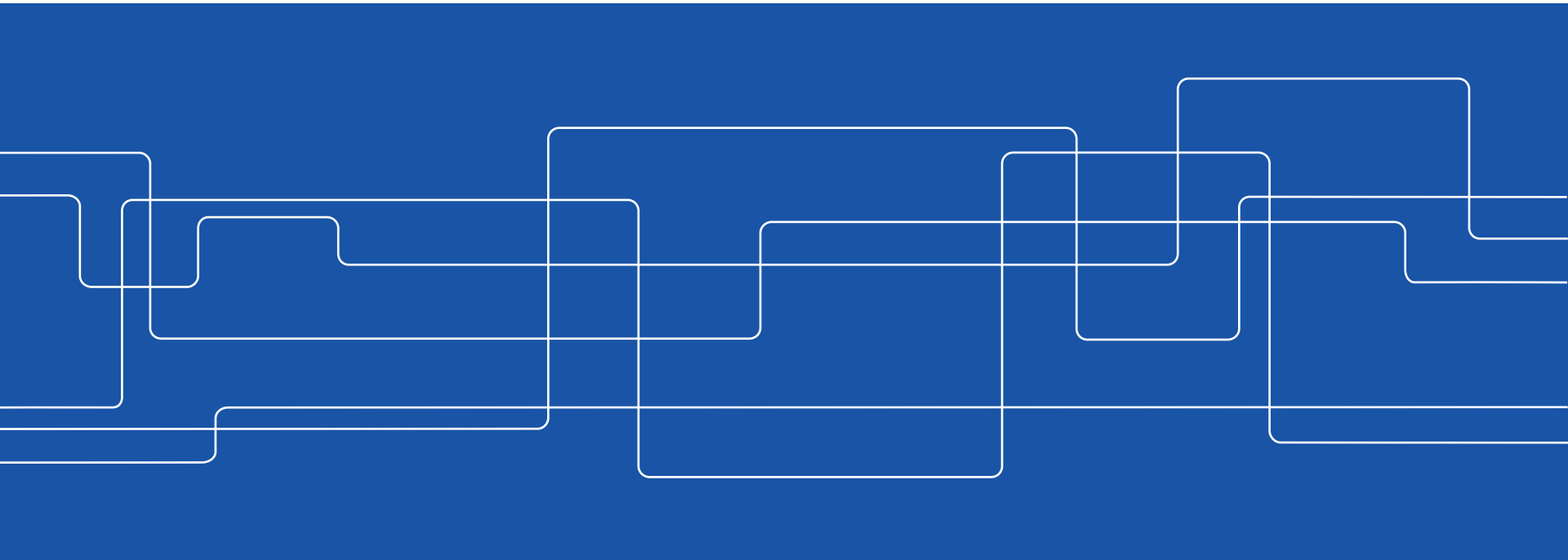
Optimal implementation of reliability centered asset management for power systems

Ebrahim Shayesteh

Risk and reliability analyses in the electric system – Sep. 2020



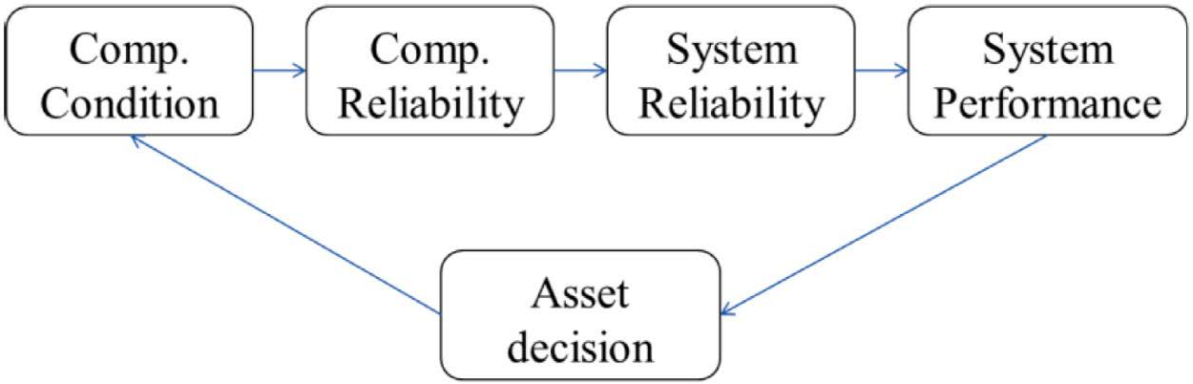
Reliability Optimization: Phase 1- Method

- **Title:** Optimal implementation of reliability centered asset management for power systems
- **Postdoctoral researcher:** Ebrahim Shayesteh (**esh@kth.se**)
- **Start date:** 2015-02-01 **End date:** 2017-07-01
- **Key persons:** Patrik Hilber
  Rajeev Thottappillil
- **Sponsor:** Riskanalysis program
  Swedish Energy Agency

Reliability Optimization: Phase 1- Method

Aims and scope:

- The aim of this project is to use the reliability chain to study how the component condition and power system reliability interact.
- For instance, what is the optimum monitoring and maintenance schedule for a component to increase the whole system reliability?
- Moreover, how the condition of the component can be translated to the power system reliability?



Reliability Optimization: Phase 1- Method

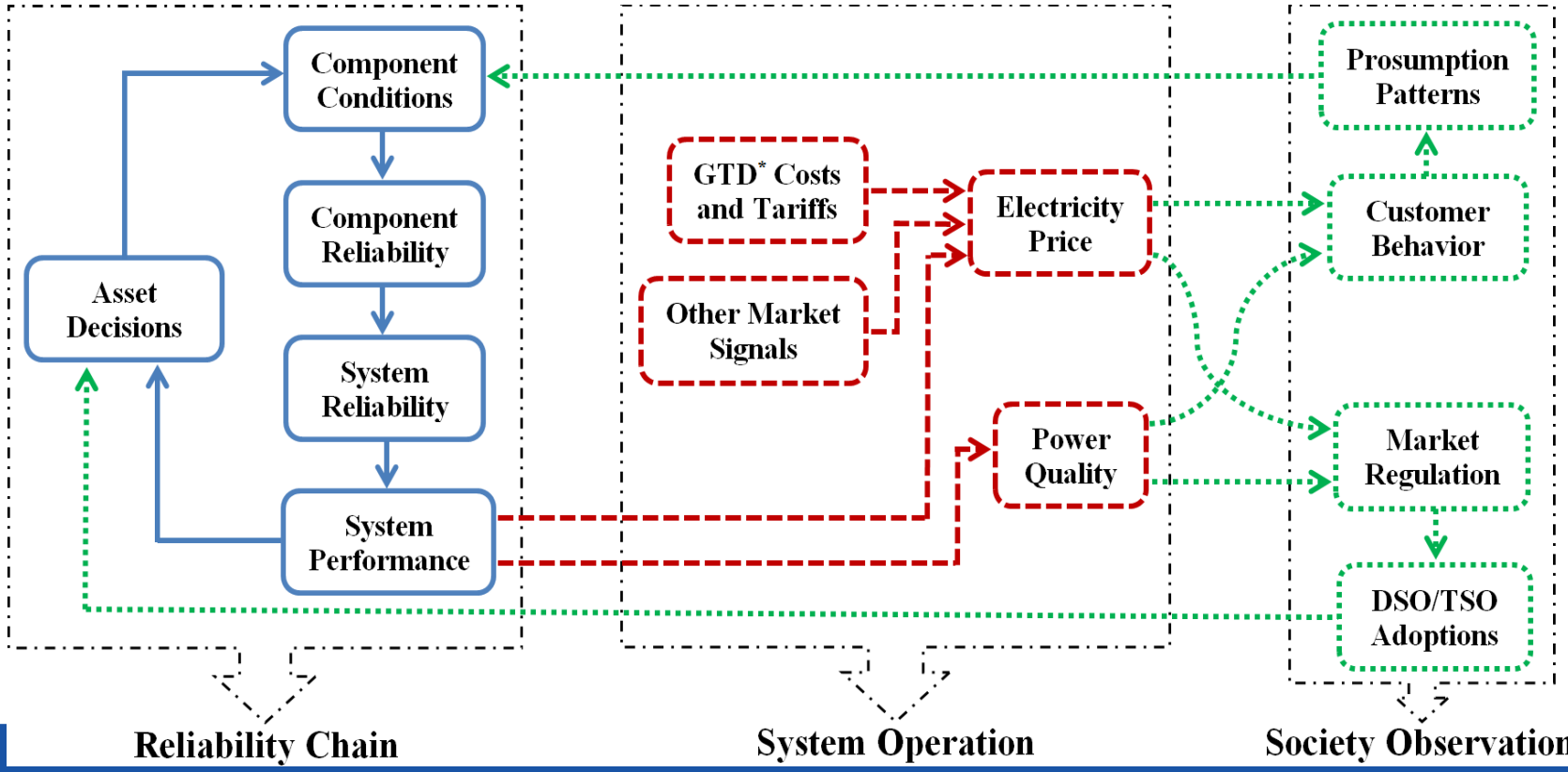
Algorithm:

- First, all the components of the system should be monitored and their initial states should be transferred into the health index and then the component reliability.
- Then, a set of possible maintenance action for each component together with the corresponding costs and impact on component reliability are provided.
- After that, a cost-benefit optimization problem is proposed to select the optimum maintenance action for all components.
- Finally, the status of each component is updated according to the assigned maintenance action.

Reliability Optimization: Phase 1- Method

Aims and scope:

- The schematic of reliability chain and its relation to system operation and society (* GTD abbreviates Generation, Transmission, and Distribution).



Reliability Optimization: Phase 1- Method

Problem formulation:

- The objective function of the cost benefit optimization problem is defined as follows:

$$\Delta TC_i = \left(\Delta C_i^{CM}\right) + \left(\Delta C_i^{PM}\right) + \left(\Delta C_i^{IC}\right)$$

$$\Delta C_i^{CM} = \Delta\lambda_i \cdot \beta_i^{CM}$$

$$\Delta C_i^{IC} = \Delta\lambda_i \cdot I_i^H \quad \Longrightarrow \quad I_i^H = exp\left(I_i^H(d,y)\right)$$

$$\Delta C_i^{PM} = x_i^{inc} - x_i^{dec}$$

Reliability Optimization: Phase 1- Method

Final formulation with TC:

$$min_{\{x_{i,a,t}\}} \quad \sum_{i=1}^{I}\sum_{t=1}^{T} TC_{i,t} \tag{7a}$$

$s.t.$

$$TC_{i,t} = (1-\omega)\cdot\left[C_{i,t}^{CM} + C_{i,t}^{IC}\right] + \omega\cdot\left[C_{i,t}^{AM}\right] \tag{7b}$$

$$C_{i,t}^{CM} = \lambda_{i,t}\cdot\beta_i^{CM} \tag{7c}$$

$$C_{i,t}^{AM} = \sum_{a=1}^{A}\left(x_{i,a,t}\cdot\alpha_{i,a}^{AM}\right) \tag{7d}$$

$$C_{i,t}^{IC} = \Delta\lambda_{i,t}\cdot\overline{I_{i,t}^{H}} + C_{i,t}^{IC0} \tag{7e}$$

$$\lambda_{i,t}^{new} = \lambda_{i,t-1}^{new}\cdot f_{inc} + \sum_{a=1}^{A}\left[x_{i,a,t}\cdot\left(\lambda_{i,t}^{fix} - \lambda_{i,t}^{var}\right)\right], t \geq 2 \tag{7f}$$

$$\lambda_{i,t}^{new} = \lambda_i^{old} + \sum_{a=1}^{A}\left[x_{i,a,t}\cdot\left(\lambda_{i,t}^{fix} - \lambda_{i,t}^{var}\right)\right], t = 1 \tag{7g}$$

$$\Delta\lambda_i = \lambda_{i,t}^{new} - \left(\lambda_{i,t-1}^{new}\cdot f_{inc}\right), t \geq 2 \tag{7h}$$

$$\Delta\lambda_i = \lambda_{i,t}^{new} - \lambda_i^{old}, t \geq 1 \tag{7i}$$

$$\sum_{a=1}^{A}\sum_{t=1}^{T} x_{i,a,t} = x_i^{max} \tag{7j}$$

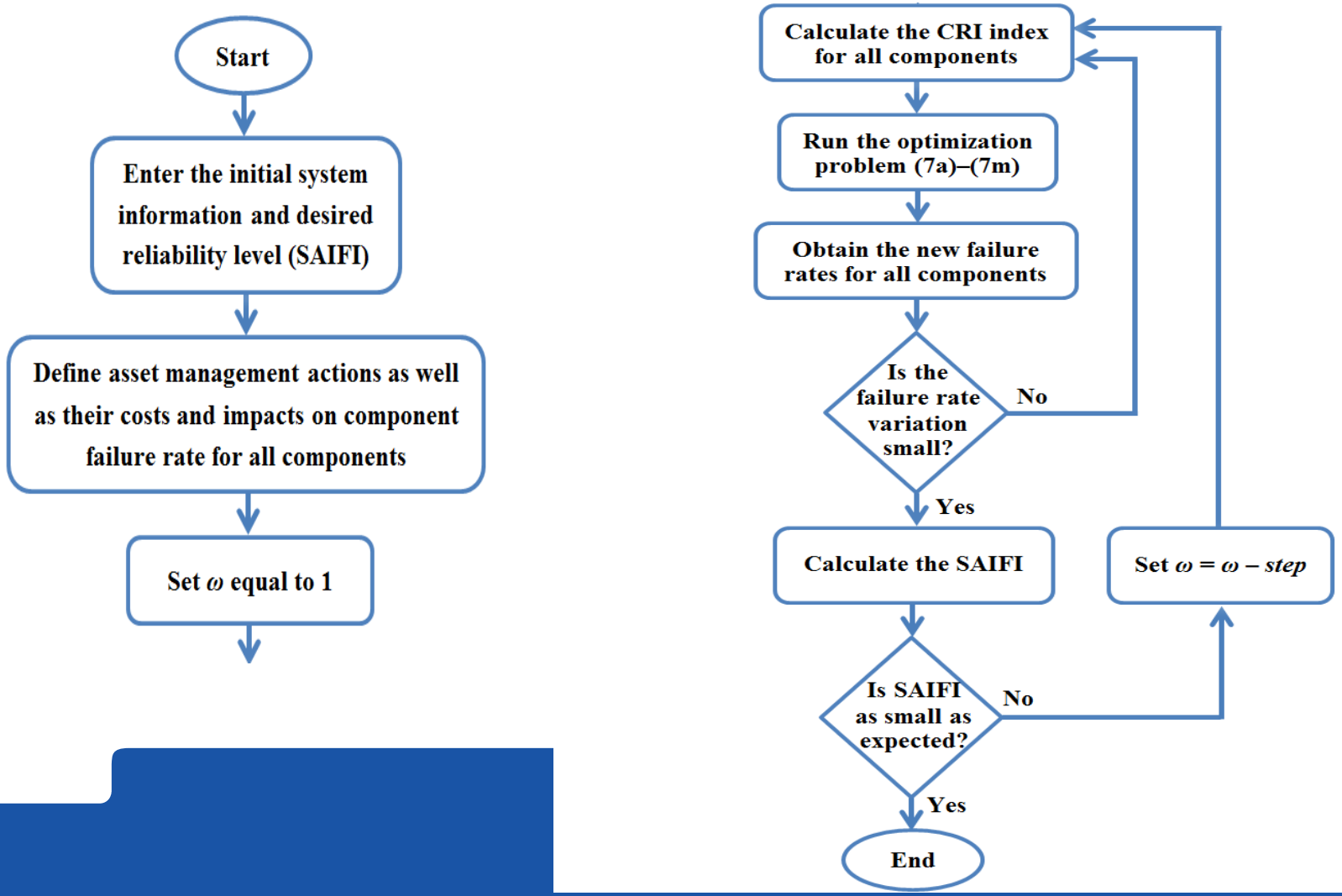
$$\sum_{a=1}^{A}\left(n_a^{max}\cdot\sum_{t=\theta}^{\theta+\tau}\sum_{i=1}^{I} x_{i,a,t}\right) \leq n_\tau^{max}, 0 \leq \theta \leq T-\tau \tag{7k}$$

$$\lambda_{i,t}^{var} = \lambda_i^{old}\cdot\left(f_{inc}\right)^{t-1} \tag{7l}$$

$x_{i,a,t}$ *is a binary variable.* (7m)

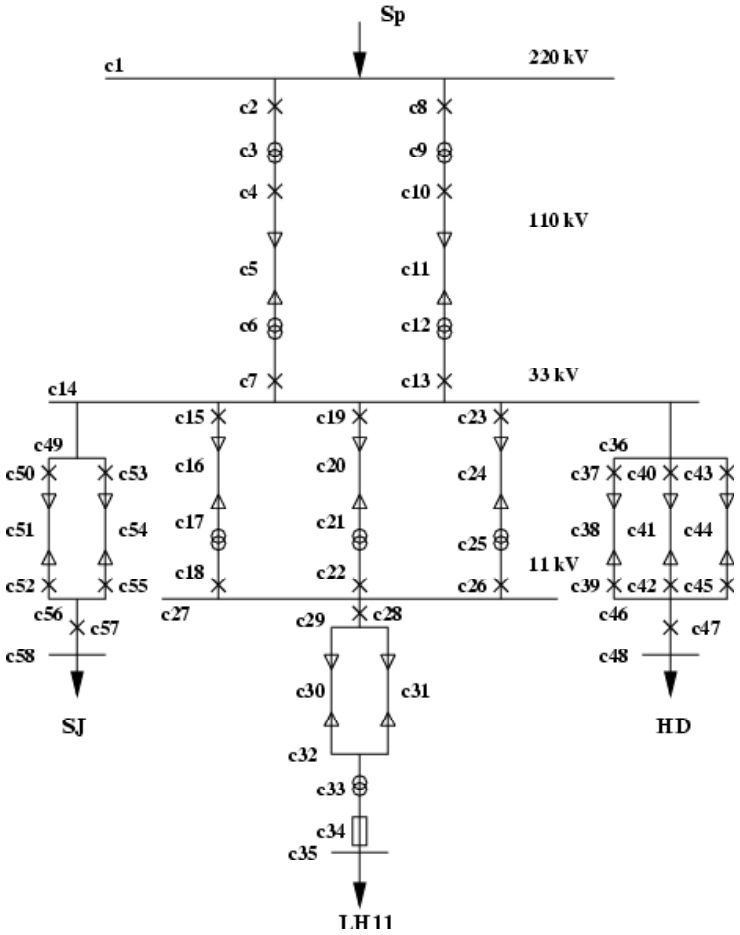
Reliability Optimization: Phase 1- Method

The flowchart of the whole model:



Reliability Optimization: Phase 1- Case

Test system:



Reliability Optimization: Phase 1- Case

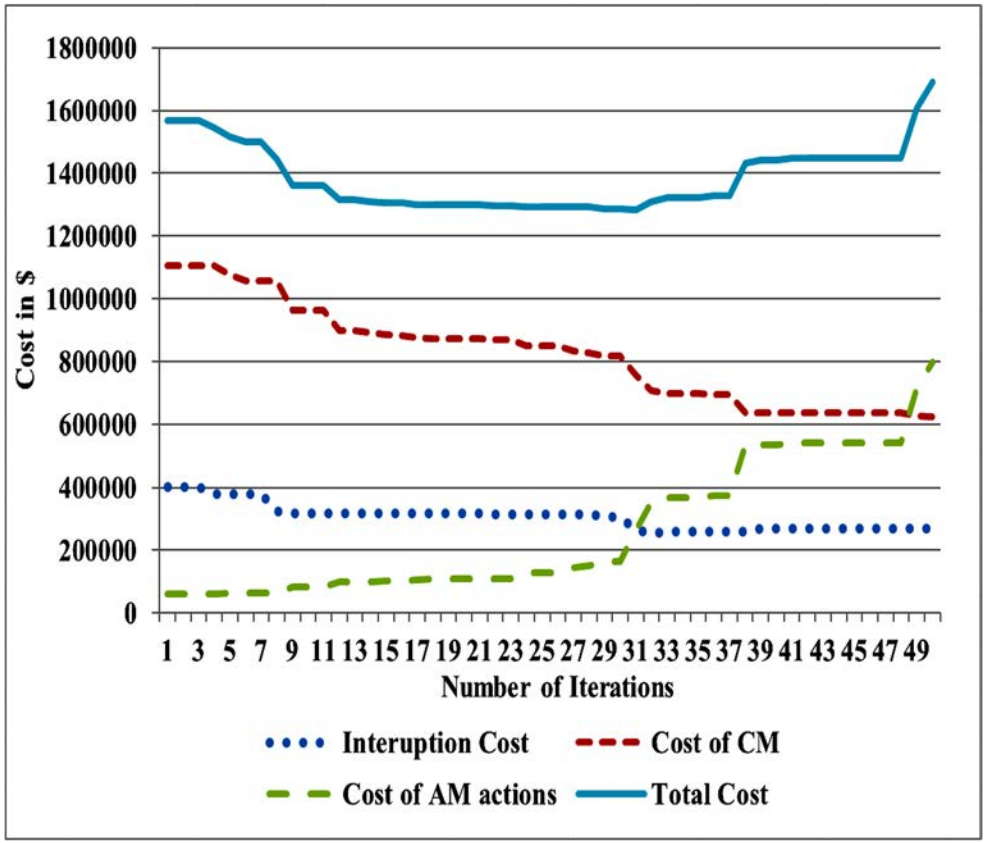
Cost of preventive and corrective maintenance actions

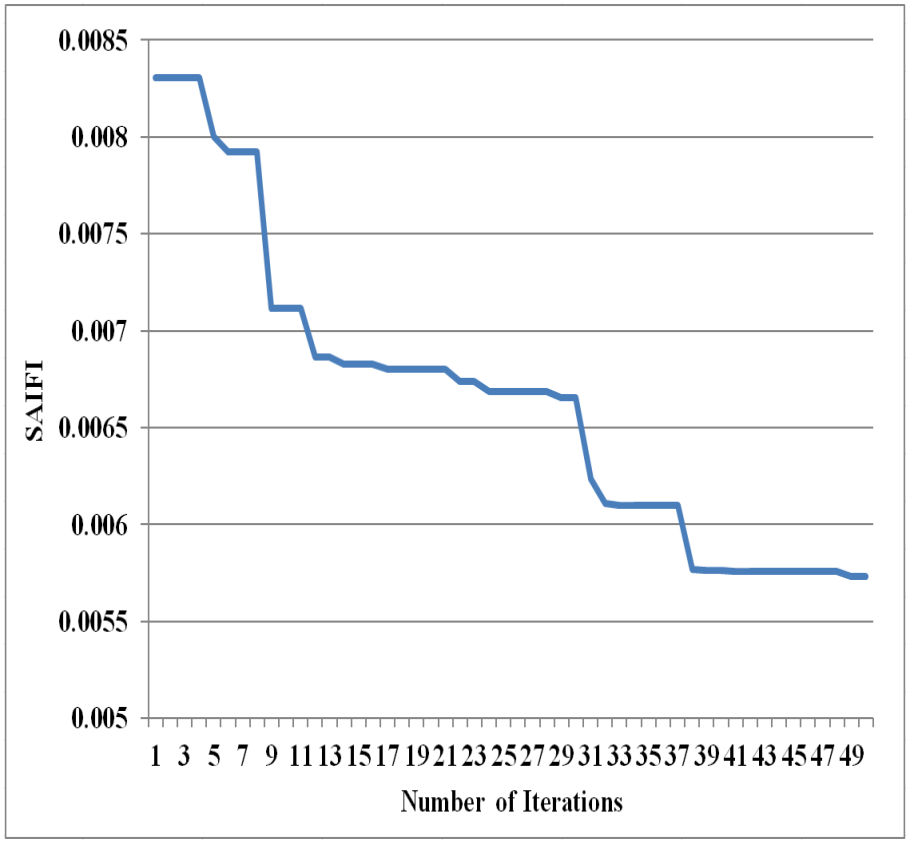
Maintenance Level	Maintenance average cost	Failure rate after PM
Minor maintenance	100 ($/m)	Remain the same
Medium maintenance	700 ($/m)	Reduced by 10%
Major maintenance	6,000 ($/m)	Reduced by 40%
Replacement	75,000 ($/m)	Reduced by 80%

Cost of corrective maintenance
204,500 ($/f)

Reliability Optimization: Phase 1- Case

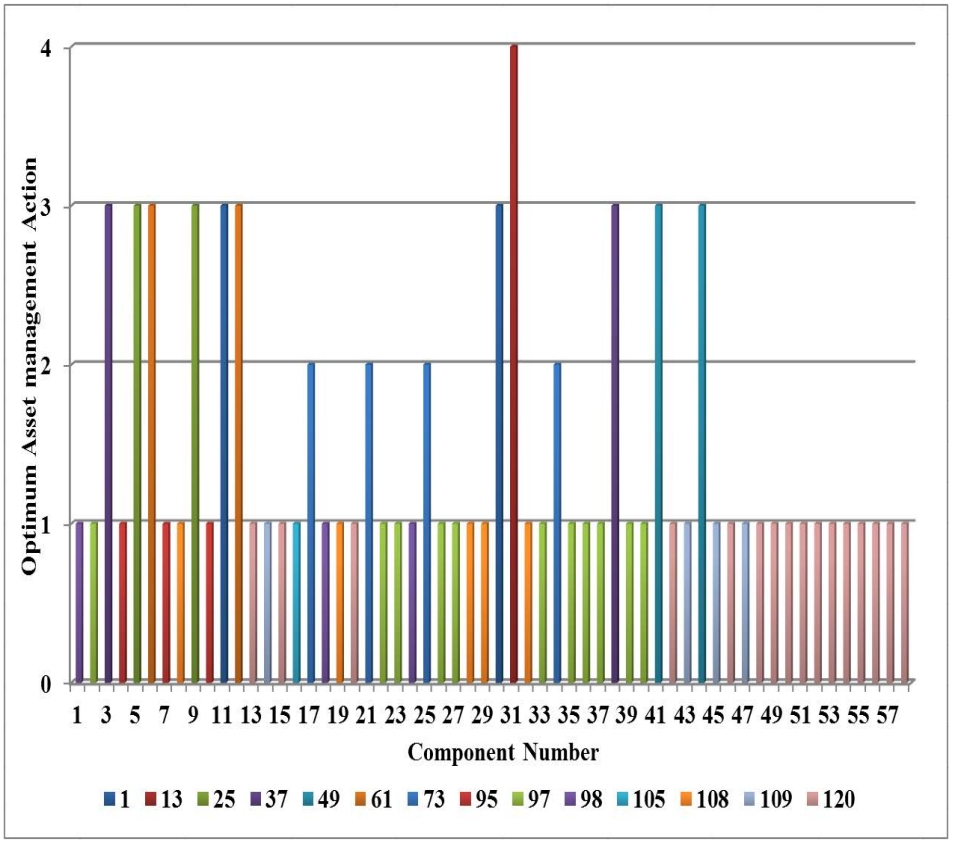
Simulation results with TC:

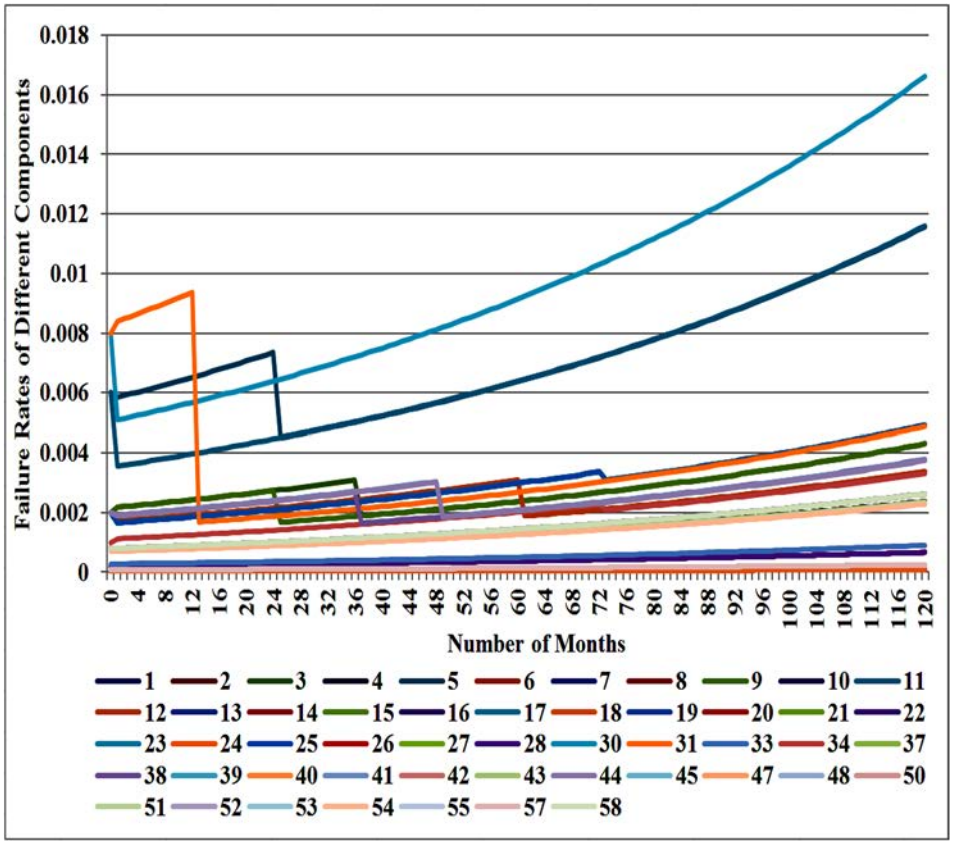




Reliability Optimization: Phase 1- Case

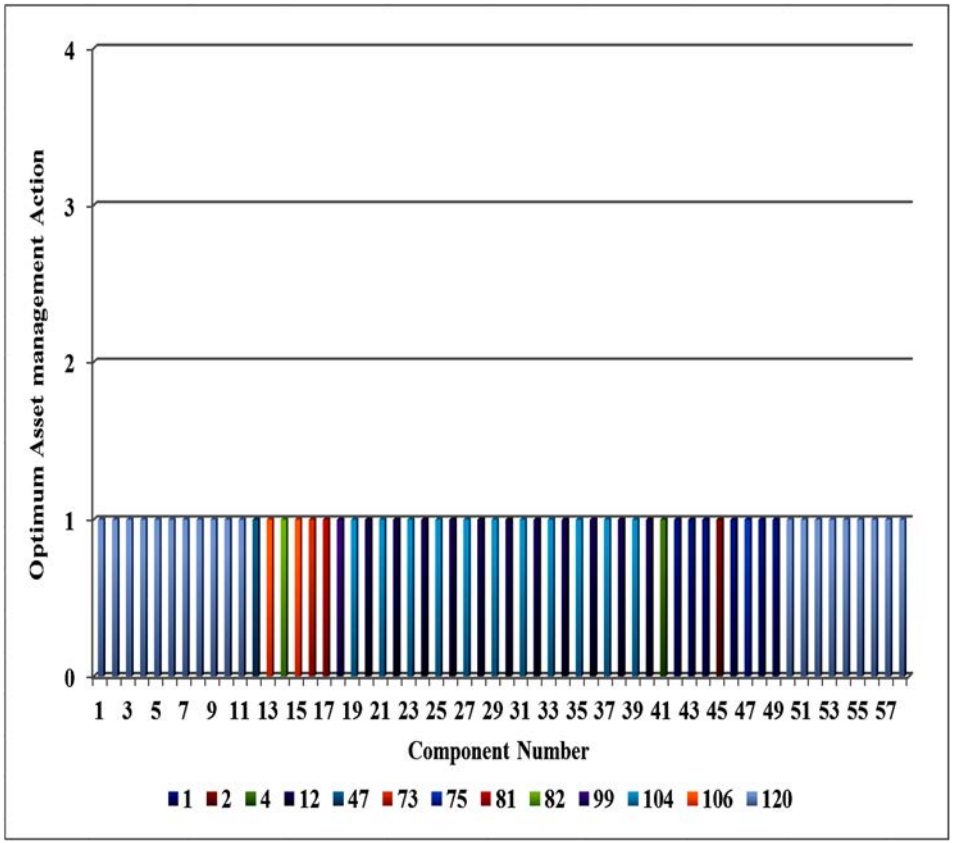
Simulation results with TC (ω equal to 0.4):

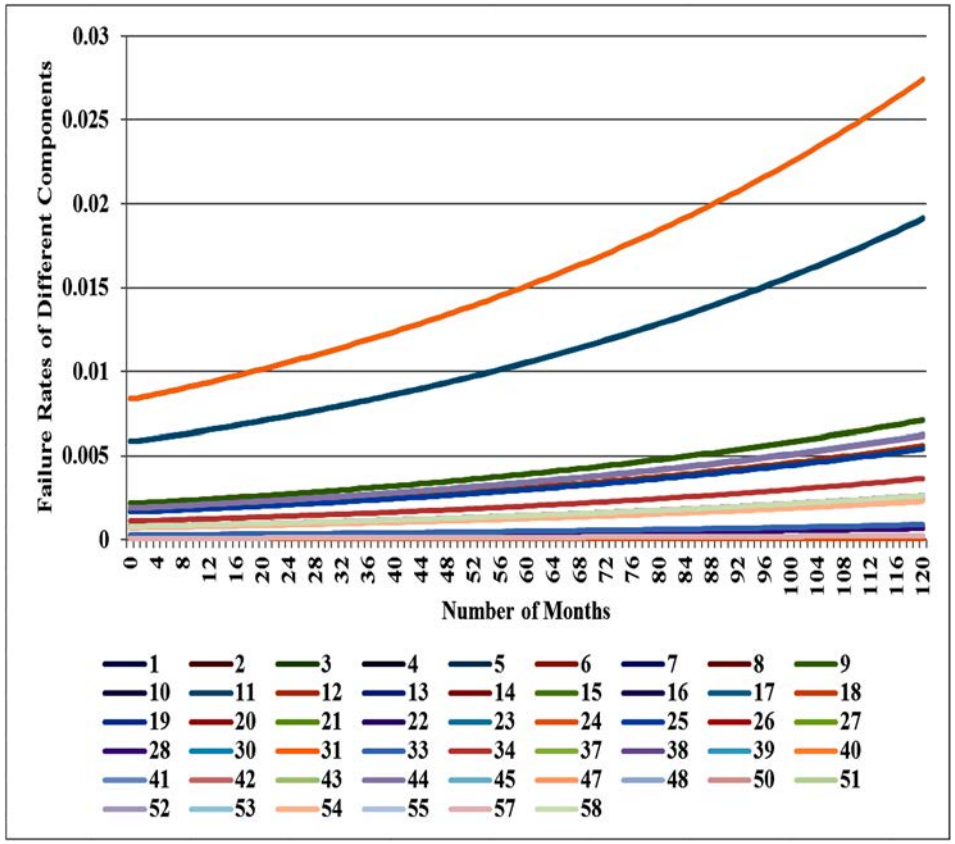




Reliability Optimization: Phase 1- Case

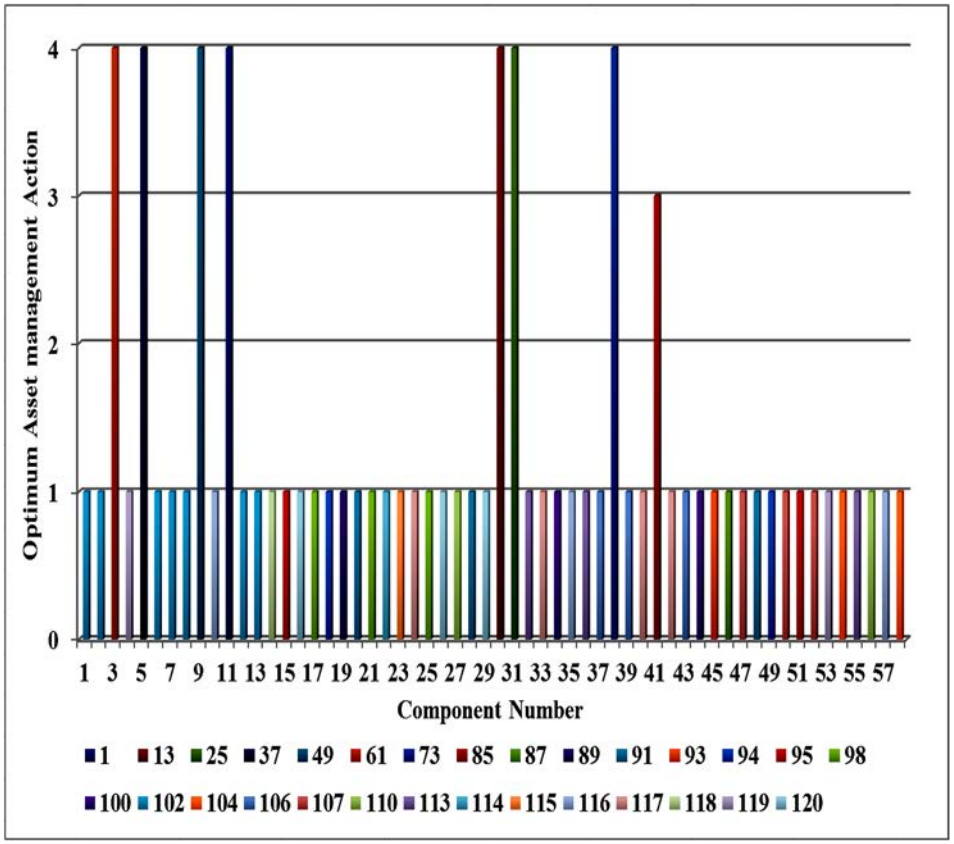
Simulation results with TC (ω equal to 1):

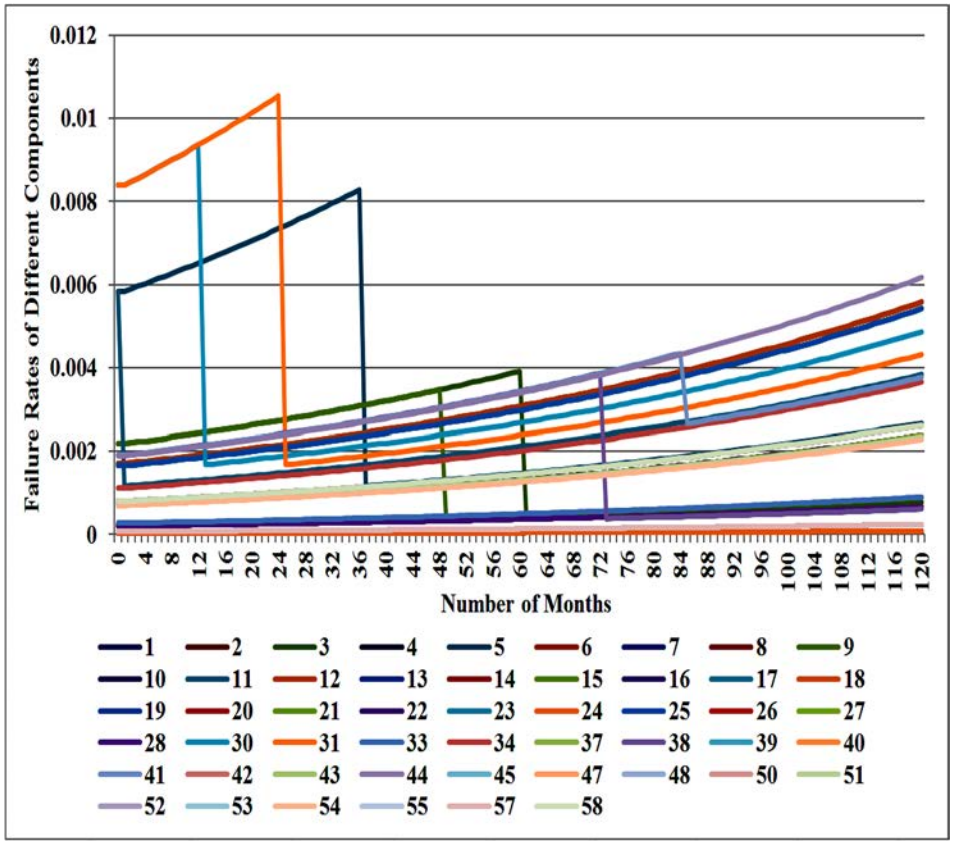




Reliability Optimization: Phase 1- Case

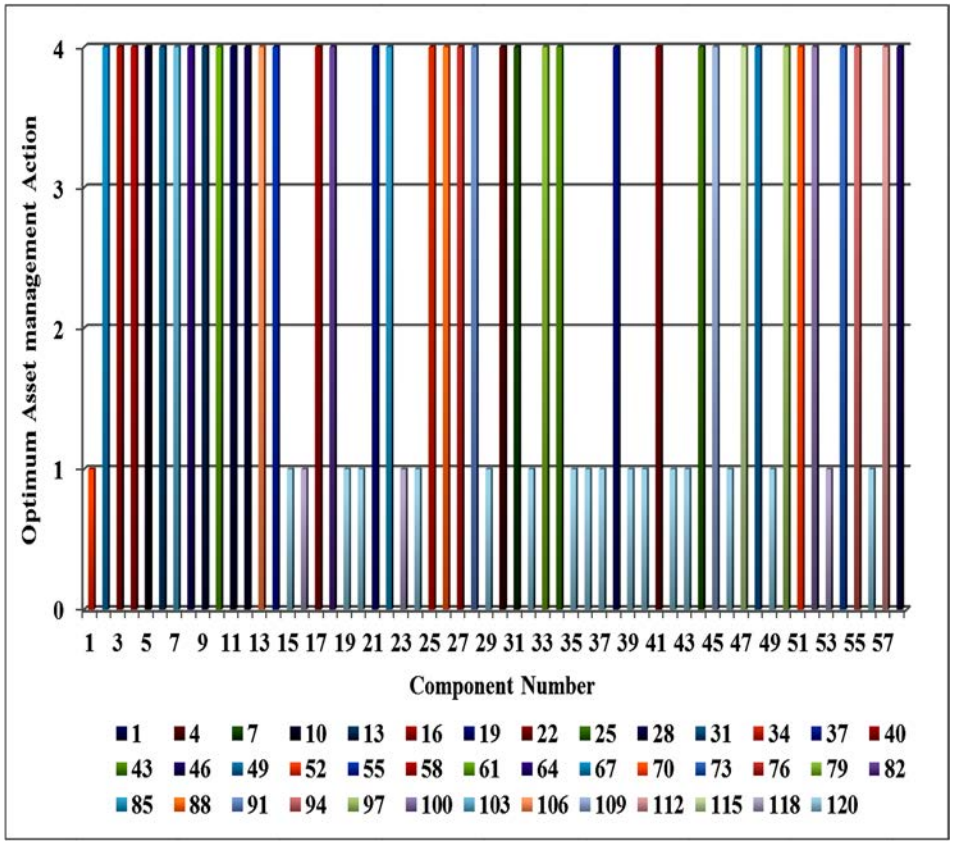
Simulation results with TC (ω equal to 0):

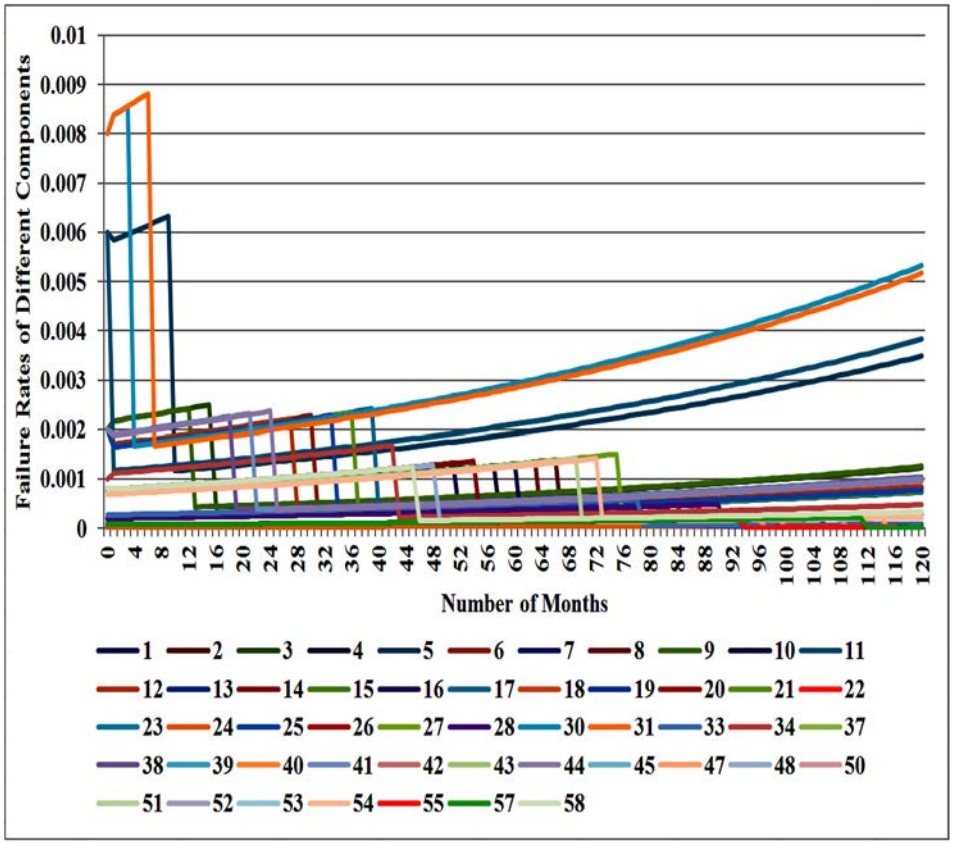




Reliability Optimization: Phase 1- Case

Simulation results with TC (ω equal to 0 + extra PM cap.):



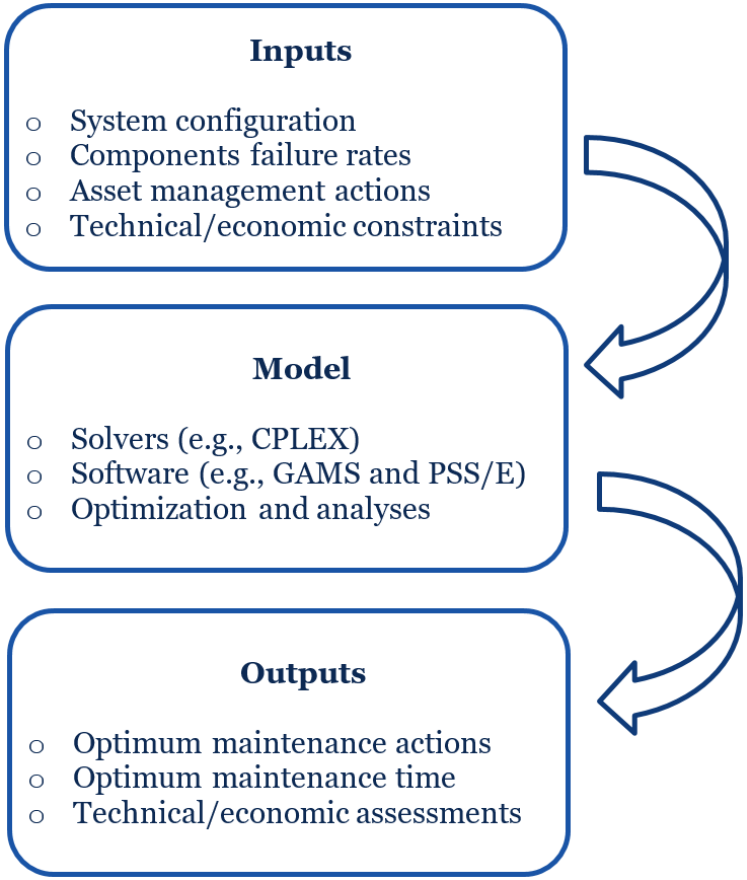


Reliability Optimization: Phase2-Toolbox

- **Title:** Maintenance optimization of reliability centered asset management for power systems – continuation: maintenance toolbox development
- **Postdoctoral researcher:** Jan Henning Jürgensen (**jhjur@kth.se**)
- **Start date:** 2018-07-01 **End date:** 2019-12-31
- **Key persons:** Patrik Hilber (KTH)
  Jenny Paulinder (GENAB)
- **Sponsor:** Riskanalysis program
  Göteborg Energi Nät AB

Reliability Optimization: Phase2-Toolbox

Aims and scope: A review on the inputs and outputs of the proposed toolboxes/software



Agenda

Thank you!