Probabilistic Energy Management (PEM) – Approach and Framework

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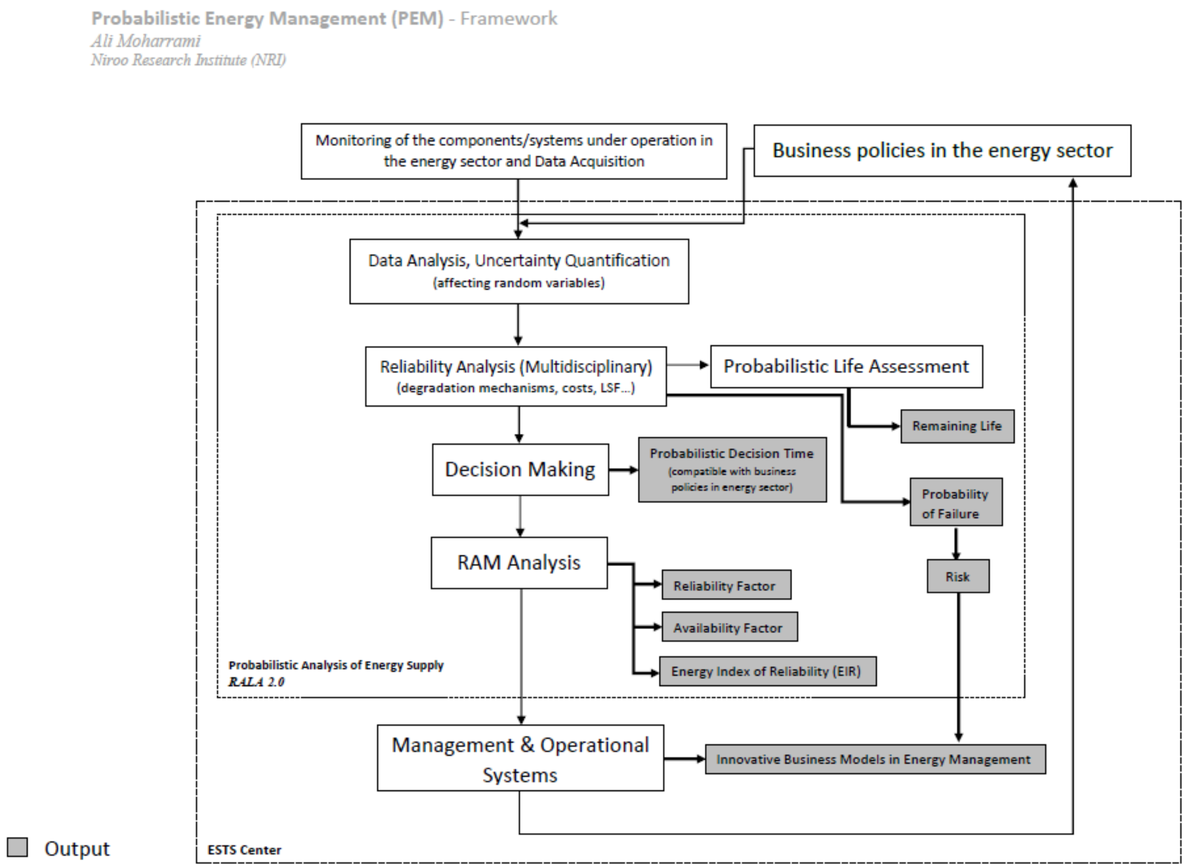
Probabilistic Energy Management (PEM) - Framework



Probabilistic Energy Management (PEM) - Approach

In *PEM* approach,

- after systems are fielded, their operation will be under monitoring to:
  - assess whether systems or components have met their RAM objectives
  - identify unexpected failure modes
  - record fixes
  - assess the utilization of maintenance resources
  - assess the operating environment
- a maintenance management database may be used for this purpose.
- in order to assess RAM, it is necessary to maintain an accurate record not only of failures but also of operating time and duration of outages.

Energy Sector Total Solution (ESTS) Center

In PEM, abovementioned monitoring, assessments and studies are carried out in a new coherent organization which we call the

"***Energy Sector Total Solution (ESTS) Center***".

Energy Sector Total Solution (ESTS) Center

This center should have an integrated data processing system that allows

- reliability data to be considered along with logistical data regarding spare parts, tools, as well as component/system's LCC allowing a total awareness of the interaction of logistical and RAM issues.

- These issues in turn must be integrated with management and operational systems to allow the plant to be profited from complete situational awareness with respect to RAM.

Energy Sector Total Solution (ESTS) Center

ESTS Services:

ESTS Center could also provide a broad range of energy solutions concerning issues in the field of

- power generation and energy supply,
- energy infrastructure integrating,
- returns on the investment, and also
- risk management

Decision Making Methodology

Limit State Function (Failure Function)

- *System Effectiveness* is defined as [2]

$$System\ Effectiveness = \frac{Effectiveness}{LCC}$$

where *Effectiveness* could be described as [2]

$$Effectiveness = Availability \times Reliability \times Maintainability \times Capability$$

Decision Making Methodology

Limit State Function (Failure Function)

- A time-based *LSF*, namely *Safety Margin*, could be defined as follows [1]:

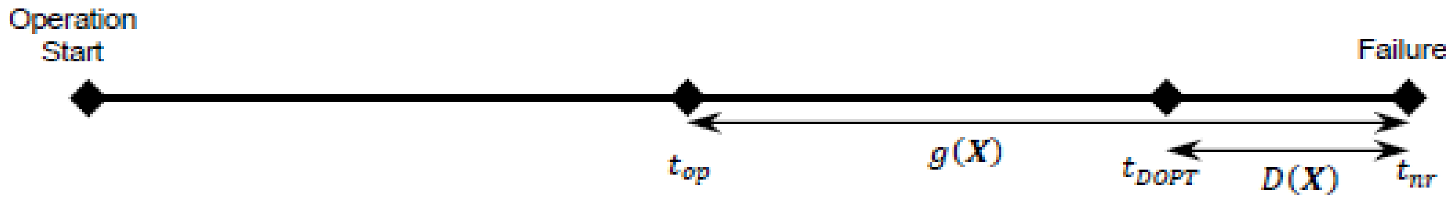
$$g(\boldsymbol{X}) = t_{nr}(\boldsymbol{X}) - t_{op}$$

- *PoF* would be

$$P_F = P[g(\boldsymbol{X}) < 0]$$

Decision Making Methodology

- We define a *Decision Making* criteria on $g(\boldsymbol{X})$ in which the appropriate decision has to be taken within the *Decision Interval*, $D(\boldsymbol{X})$.



- Inside the safe region $g(\boldsymbol{X}) > 0$, we should undertake a Decision Making process at the particular moment of operating time, t_{DOPT}, wherein

$$t_{DOPT} = t_{nr}(\boldsymbol{X}) - D(\boldsymbol{X})$$

- We call $D(\boldsymbol{X})$ the *Decision Function*.

Decision Making Methodology

- The *Decision Boundary* could be introduced as

$$0 < t_{nr}(\boldsymbol{X}) - t_{op} \leq D(\boldsymbol{X}) \rightarrow \textbf{system's abnormal operation range}$$

- Hence, *PoA* would be

$$P_A = P[0 < g(\boldsymbol{X}) \leq D(\boldsymbol{X})]$$

- Now, *Normalability* could be introduced as

$$Normalability = (1 - P_A) \times 100$$

Decision Making Methodology

- In order to have system's normal operation inside the safe region, we should consider *LSF* subjected to the following boundary condition:

$$t_{nr}(\boldsymbol{X}) - t_{op} > D(\boldsymbol{X})$$

- Taking the *Intelligent Decision Making* into account, in this model, t_{DOPT} is considered as the optimum time for making a decision regarding the upcoming failure.

Decision Making Methodology

Kernel Estimator

- To determine the *Decision Function*, $D(\boldsymbol{X})$, we take up a *Novelty Detection*-based *CM* technique.

- Using the *Kernel Estimator* as a method of *Density Estimation*, the data density $f(x)$ is defined to be [3, 4]

$$f(x) = \frac{1}{Nh^D}\sum_{i=1}^{N} K\left(\frac{x - X_i}{h}\right)$$

for kernel

$$K(x) = \frac{1}{(2\pi)^{D/2}} \exp\left(\frac{1}{2}x^2\right)$$

Decision Making Methodology

- Now, we defined a *Novelty Threshold* d on $F(x)$, the integrated form of $f(x)$, such that X_i is classified normal if $F(X_i) < d$, else X_i is classified abnormal [4].

- in *PEM* approach, we assess the *PoA* as follows:

$$P_A = P\left(\sum_{j=1}^{M} F\left(\mu_{X_j}\right) > \sum_{j=1}^{M} d_j\right)$$

- With the assumed admissible *PoA* level a, we consider the optimum decision time, t_{DOPT}, as a particular t_{op} in which $P_A = a$.
- The *Decision Function* corresponding to the obtained t_{DOPT} becomes:

$$D(\boldsymbol{X}) = t_{nr}(\boldsymbol{X}) - t_{DOPT}$$

Decision Making Methodology

- applying different analyses via *RALA* software packages and combining their results will create an ability of adjustment of $D(x)$ considering several issues related to technical matters, economic concerns, etc.

- *RALA* software package [1] is able to solve defined cases considering the appropriate *LSF* based on the acquired data for affecting random variables.

- Therefore, in this approach, $D(x)$ represents an **adjustable intelligent** *Decision Function* **compatible** with the business policies in the energy sector.

Results and Discussions

- *Decision Function* is directly a function of component/system's condition factors including affecting parameters (random vector), dominant degradation mechanisms and physics of failure due to the presence of the service rupture life term, $t_{nr}(\boldsymbol{X})$.

- Finding a logical and practical relationship applicable to making the *Rational Decision* as a function of system's condition factors will create a powerful tool for managers and also engineers working in the energy sector.

Results and Discussions

- Achieved results are in good agreement with our practical experience in the power generation sector of the electric power industry as a major part of the energy sector.

Conclusion

- *Energy Management* issues shall be well taken into consideration.
- The introduced probabilistic approach, *PEM*, could offer an effective and efficient *Total Solution* providing the modelling techniques for early detection of health data abnormalities occurring in the complex systems of the energy sector.
- A key goal of such abnormality early detections is the achievement of more reliable results for managing and economic planning of future inspection/maintenance activities that will lead to a considerable cost and energy savings as well as operational safety improvements.

Conclusion

- In terms of *RAM* analysis, providing improved level of system **availability** is the main purpose of the *Total Solution* offerings of the introduced *PEM* approach.

- From what has been discussed above, we may safely draw the conclusion that taking the introduced *PEM* approach creates a valuable process converting the energy sector's acquired **data** into information, **information** into knowledge and consequently **knowledge** into **wisdom** of effective *Energy Management*.

References

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Contact and further discussion…

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