WEEKLY JOURNAL-11

SUMMARY

Generation adequacy evaluation indices were discussed. Simplified two state, 4 state space diagrams for a single generating unit were discussed

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Power System Adequacy

Week-11

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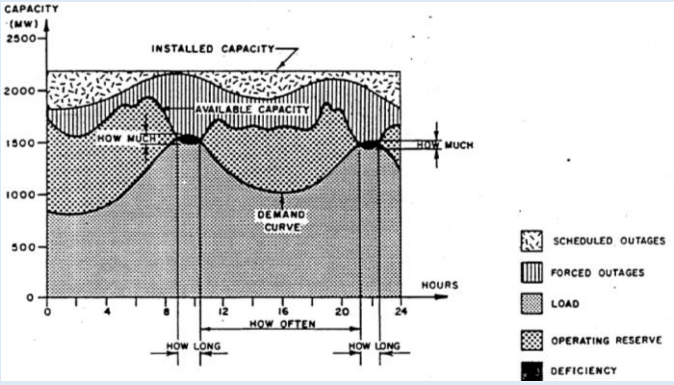
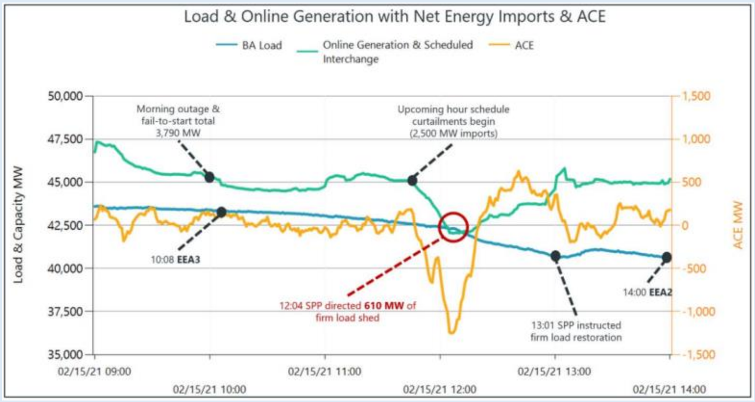
Introduction

Power system reliability can be analyzed in 3 levels of hierarchy. They are, Level- 1:- Generation only, Level-2:- Generation and Transmission, and Level-3:- Generation, Transmission and distribution.

Generation adequacy for long term is evaluated based on installed capacity. Short term adequacy is evaluated based on operating capacity. Static capacity should be able to handle planned outage, unplanned outage and load growth.



Above figure shows the relationship between installed capacity and available capacity. Below figure shows a major power outage caused in February 2021 across Midwest.

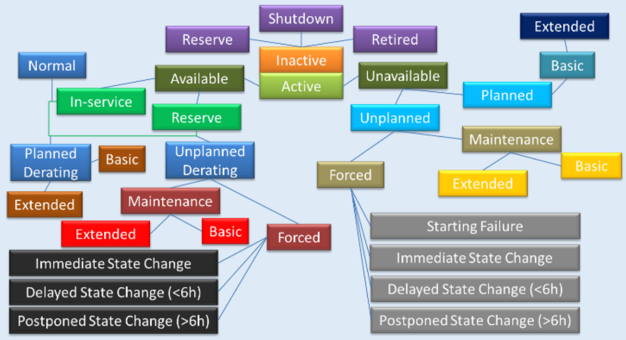


Probabilistic based and deterministic approaches are used for reliability evaluation. Reserve margin and capacity margin are examples of those analysis.

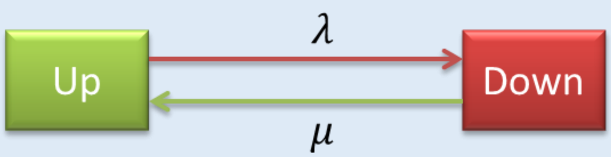
$$\text{Reserve Magin} = \frac{\text{Capacity} - \text{Load}}{\text{Load}} * 100$$

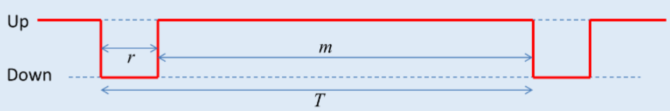
$$\text{Capacity Magin} = \frac{\text{Capacity} - \text{Load}}{\text{Capacity}} 100$$

It is harder to analyze the reliability by considering all the possible causes of failure. because there are several causes for the failure.



State space diagram for a single generation unit can be drawn as in below figure.



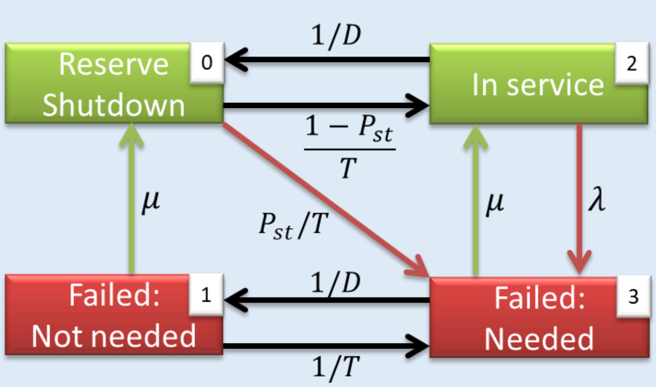


$$Availability = \frac{m}{m+r} = \frac{m}{T} = \frac{f}{\lambda} = \frac{ex.d\ failurerate}{cycle\ frequency}$$

FOR (Forced Outage Rate) is , a performance index , used to estimate the ratio between number of hours spent on unplanned outages over total cycle time.

$$FOR = \frac{FOH}{FOH+SH} * 100 = \frac{r}{r+m} = U$$

Below figure shows the four-state space diagram of a generator.



Here, T- average shutdown time.
D-Average in-service time per occasion of demand.
P_{st} -probability of starting failure.

State transition matrix

$$\boldsymbol{P} = \begin{bmatrix} -\frac{P_{st}}{T} - \left(\frac{1-\boldsymbol{P_{st}}}{\boldsymbol{T}}\right) & \mu & \frac{1}{D} & 0 \\ 0 & -\mu - \frac{1}{T} & 0 & \frac{1}{D} \\ \frac{1-P_{st}}{T} & 0 & -\lambda - \frac{1}{D} & \mu \\ \frac{P_{st}}{T} & \frac{1}{T} & \lambda & -\mu - \frac{1}{D} \end{bmatrix}$$

For steady state

$$\dot{\boldsymbol{P}} = 0$$

$$\begin{bmatrix} -\frac{P_{st}}{T} - \left(\frac{1-P_{st}}{T}\right) & \mu & \frac{1}{D} & 0 \\ 0 & -\mu - \frac{1}{T} & 0 & \frac{1}{D} \\ \frac{1-P_{st}}{T} & 0 & -\lambda - \frac{1}{D} & \mu \\ \frac{P_{st}}{T} & \frac{1}{T} & \lambda & -\mu - \frac{1}{D} \end{bmatrix} \begin{bmatrix} P_0 \\ P_1 \\ P_2 \\ P_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

However, 4[th] row is not an independent row. Therefore, we use general property.

$$P_0 + P_1 + P_2 + P_3 = 1$$

$$\begin{bmatrix} -\frac{1}{T} & \mu & \frac{1}{D} & 0 \\ 0 & -\mu - \frac{1}{T} & 0 & \frac{1}{D} \\ \frac{1-P_{st}}{T} & 0 & -\lambda - \frac{1}{D} & \mu \\ 1 & 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} P_0 \\ P_1 \\ P_2 \\ P_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

State 1 and 3 are fail states therefore forced outage hours will be $(P_1 + P_3) * Total\ time$. FOH plus SH is equal to 1- reserve state probability times total hours. Therefore

$$FOR = \frac{FOH}{FOH+SH} = \frac{P_1 + P_3}{P_1 + P_3 + P_2}$$

Problem of the week

A system consists of four generating units with the following data.

Unit	Capacity	FOR
1	50 MW	0.01
2	30 MW	0.02
3	50 MW	0.015
4	25 MW	0.03

Develop a probability table for capacity outage for the given system.

	0.01	0.02	0.015	0.03		
	50	30	50	25		
outage amount	G1	G2	G3	G4	Probability	Cumulative
0	1	1	1	1	0.92697759	1
25	1	1	1	0	0.02866941	0.07302241
30	1	0	1	1	0.01891791	0.044353
50	0	1	1	1	0.00936341	0.02543509
50	1	1	0	1	0.01411641	0.01607168
55	1	0	1	0	0.00058509	0.00195527
75	0	1	1	0	0.00028959	0.00137018
75	1	1	0	0	0.00043659	0.00108059
80	0	0	1	1	0.00019109	0.000644
80	1	0	0	1	0.00028809	0.00045291
100	0	1	0	1	0.00014259	0.00016482
105	0	0	1	0	0.00000591	0.00002223
105	1	0	0	0	0.00000891	0.00001632
125	0	1	0	0	0.00000441	0.00000741
130	0	0	0	1	0.00000291	0.000003
155	0	0	0	0	0.00000009	0.00000009