Module 6-4
Spinning Reserve Assessment

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Background

- Planning phase (static reserve) and operating phase (spinning reserve).
- Sources of uncertainties in operation: load forecast uncertainty and generator outages.
- Reserve generation needs to be scheduled to account for these uncertainties.
- Delay to start cold units (lead time): short for gas turbines and hydro units and long for thermal units.

Spinning Reserve and Operating Reserve

- Spinning reserve: Reserve capacity that is synchronized and ready to take load.
- Operating reserve: Spinning reserve plus the quick/rapid start capacity.
- Adequate spinning/operating reserve needs to be determined to keep the risk level acceptable.

Methods for Determining Operating Reserve Requirements

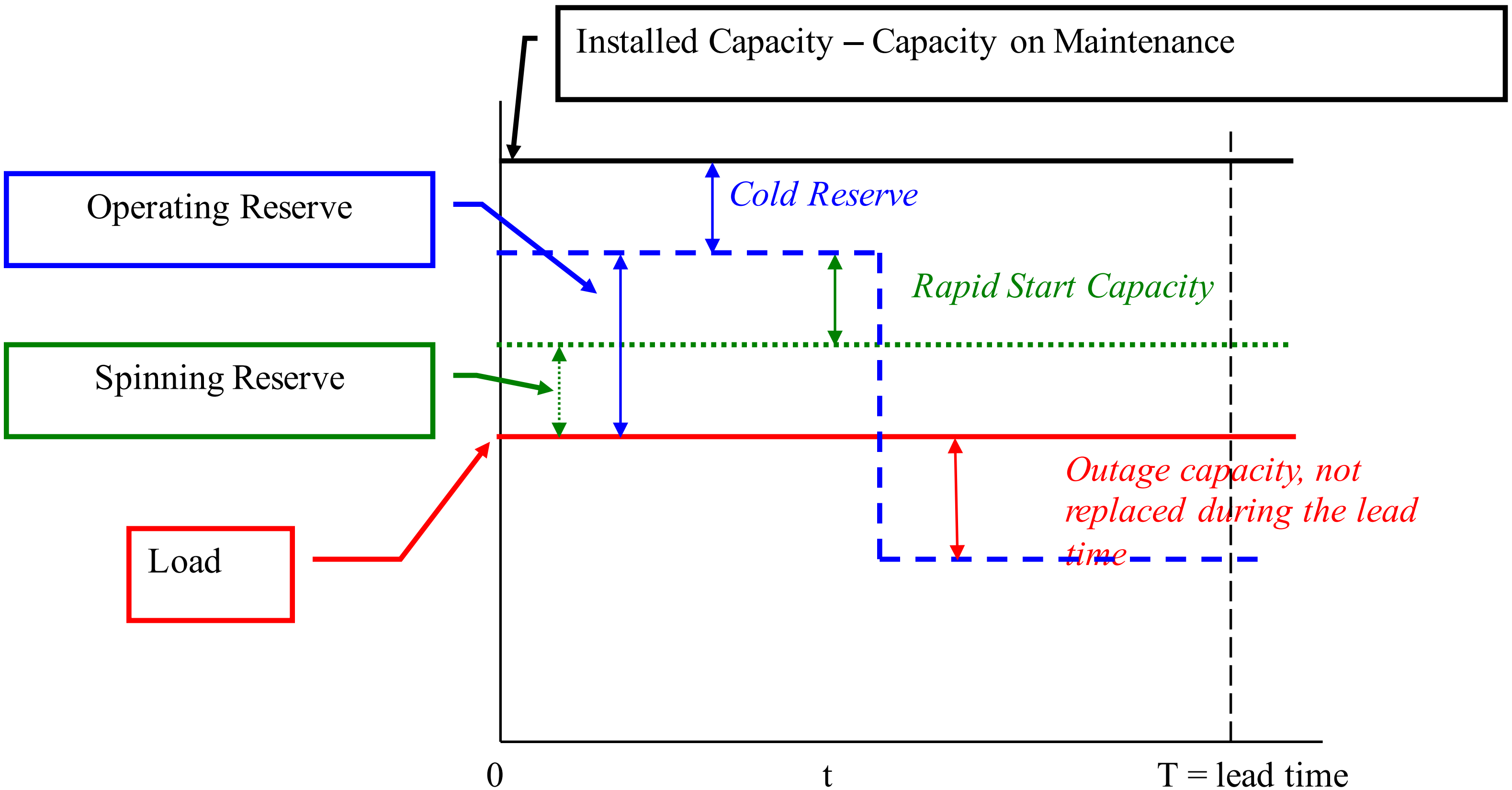
- Deterministic: such as reserve equal to the largest unit or as a percentage of the load.

- Probabilistic methods: PJM Method, Security Function Method and Frequency & Duration Method.

Basic PJM Method of Spinning Reserve Allocation

- First described in 1963 by a group of engineers from PJM.
- Computes probability of insufficient capacity in operation at a future time equal to the time needed to bring in additional generating capacity.
- Sufficient installed capacity is assumed
- The present state is assumed known and start-up time for all standby units is considered the same
- Three steps: building generation model, building load model and computing risk.
- Basically the same procedure as the static reserve calculation, essential difference is time horizon.

Reserves in Relation to Load



- # Step 1: Generation system model
- The probability of a two state unit being down at T, given it is operating at 0 is:

$$p_d(T) = \frac{\lambda}{\lambda+\mu}[1-e^{-(\lambda+\mu)T}]$$

Where λ and μ are the failure and repair rates of the unit.

- If (λ+ μ)T<<1, the expression for failure probability can be approximated:

$$p_d(T) = \frac{\lambda}{\lambda+\mu}[\lambda+\mu]T = \lambda T$$

This really means that repair time is much longer than T implying no repair during T.

- If T is the start up time of additional capacity, then λT is the probability of losing capacity and not being able to replace it. It is called ORR – outage replacement rate.
- The probability of various capacity levels of generation system at T can be computed from ORR for individual units using unit addition algorithm.

- Steps 2 &3: Load Model and Risk Calculation
- The load for the operating reserve calculation is the forecast load at T.
- Risk or the probability of insufficient capacity at T:

$$Risk = \sum_i \Pr(load\ at\ T = L_i)\Pr(Cap\ at\ T < L_i)$$

- If there is no uncertainty in forecast load:

$$Risk = \Pr(Capacity\ at\ T < Load\ at\ T)$$

- The computed risk can be compared with reference risk to decide whether scheduled capacity is adequate.
- Selection of reference risk is a management decision.

Modified PJM Method (one version)

- Includes effect of rapid start and hot reserve units – see models and start sequence.

- Denoting start up times of rapid start, hot reserve and cold reserve units by t_r, t_h, t_c, the modified method proceeds as follows:

Modified PJM Method (one version)

1. Using scheduled units at t=0

   Risk (t_r) = Probability of insufficient generation at t_r

This can be computed using the Basic PJM method

2. Assuming that hot reserve units are not failed at t_r, their failure probabilities at t_h are determined.

3. Generation model at t_h consists of units in operation at t=0 and rapid start units becoming available at t_r.

Modified PJM Method (one version)

4. Risk at t_h is given by

   Risk(t_h) = Probability of insufficient capacity at t_h

5. Also Risk(t_r^+) is computed by considering probabilities of all units in operation at time 0 and probabilities of rapid start units at t_r^+ which in fact is 0 time for these units.

6. At t_h^+ the hot reserve units are assumed to become available. The probability of insufficient capacity at t_h^+ is calculated by modifying the generation model at th by using probabilities of hot reserve units at t_h^+ which is in fact 0 time for these units.

Modified PJM Method (one version)

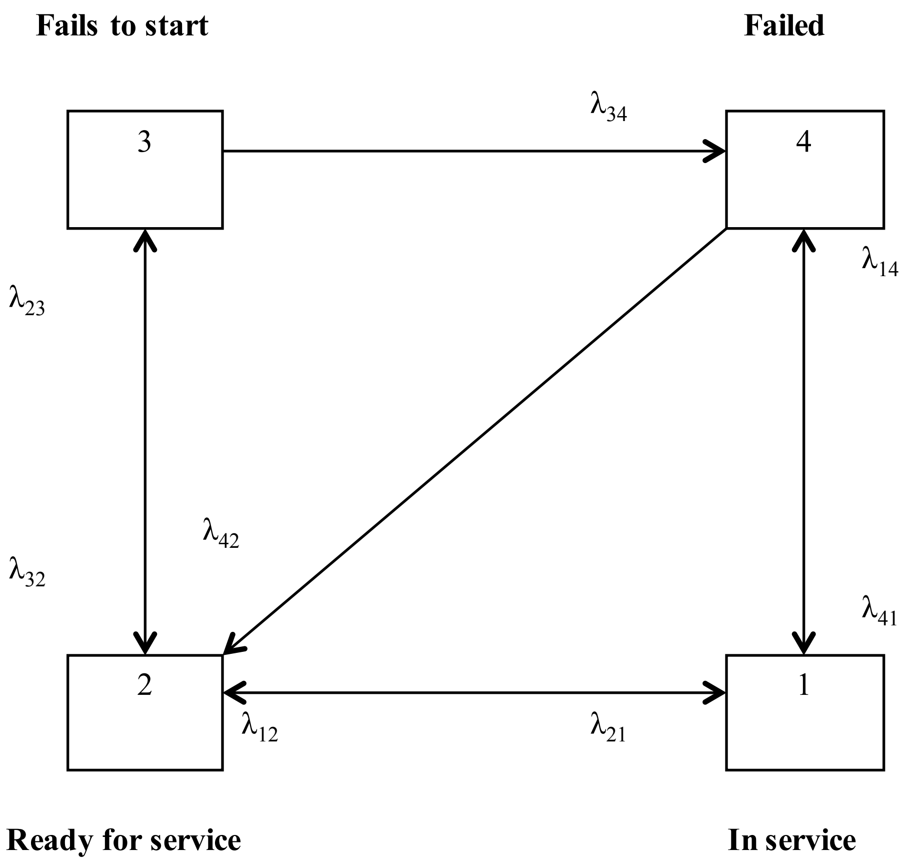
7. Next probabilities of hot reserve units at t_c are computed. The generation model at tc consists of units in operation at t=0 having operated for t_c , rapid starts having operated for $(t_c - t_r)$, and hot reserve units having operated for $(t_c - t_h)$

8. This generation model is then used to compute risk at t_c

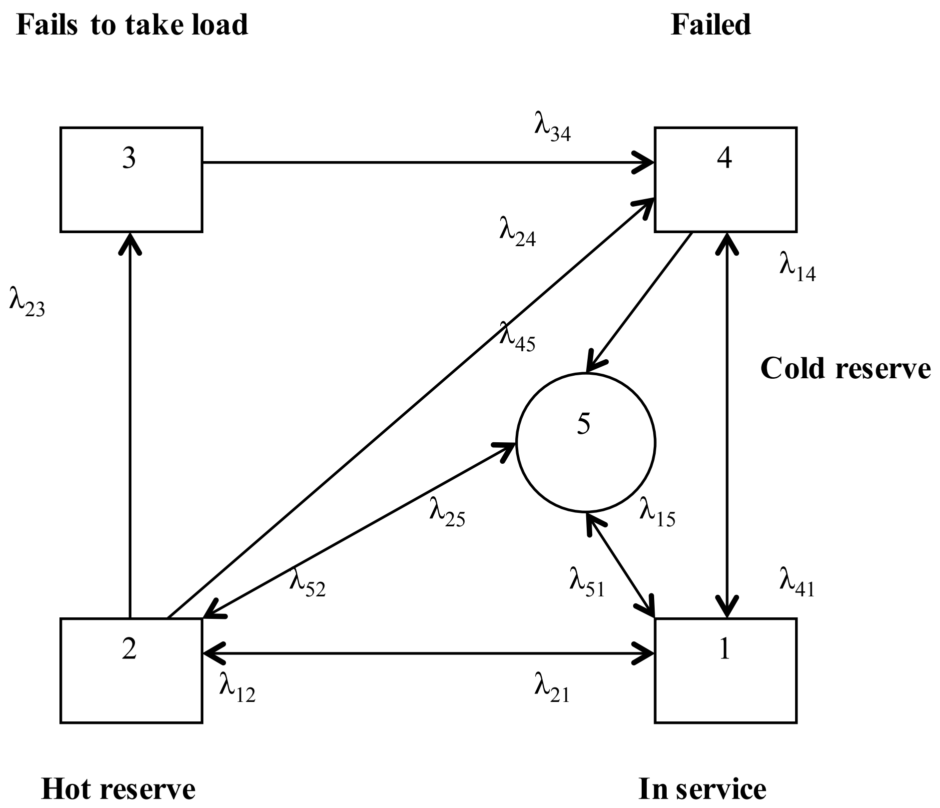
9. The following has been suggested as an index of composite risk:

Risk=Risk(t_r)+[Risk(t_h)-Risk(t_r^+)] +[Risk(t_c)- Risk(t_h^+)]

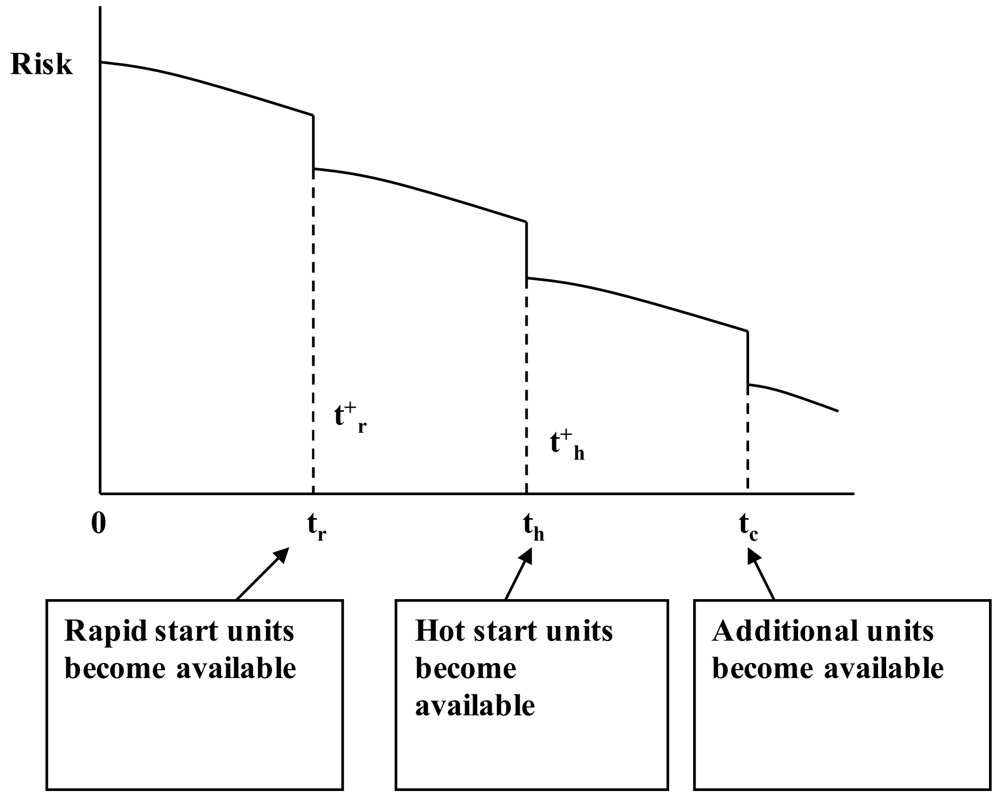
A 4-state model of a rapid start unit



A 5-state model of hot reserve unit



Starting sequence of different units



Security Function Method

- Calculates probability of system trouble as a function of time.
- Time span of computation is the lead time for modification of system configuration to achieve improved system security.
- One suggested function:

$$S(t) = \sum_i P_i(t) W_i(t)$$

$P_i(t)$=probability of system being in state i at time t

$W_i(t)$=probability that system configuration of state i leads to system trouble

- The security function is examined for time period equal to lead time. If it exceeds a predefined reference value, decision to start additional capacity can be taken. Likewise if the system is too secure, generation capacity can be taken off for economic reason.

Frequency & Duration Method

- PJM Method and Security Function Method focus on point wise probability of capacity deficiency
- The frequency and duration method, in addition to point wise probability, computes two interval based indices – interval frequency and fractional duration.
- The assumption that repair time is much longer than T, i.e., no repair during T is not made in this method.
- Interval frequency is the expected number failure events in an interval - in this case (0, T)
- Fractional duration is defined as the expected proportion of interval spent in failure state.
- Application to operating reserve problem is similar to other two methods, except that two additional indices are available.