WEEKLY JOURNAL-12

SUMMARY

Generation adequacy evaluation for single generation units and multiple generation units were discussed. Risk evaluation using probability method was found as useful in evaluating risk compared to reserve / capacity margin metrics.

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Power System Adequacy

Week-12

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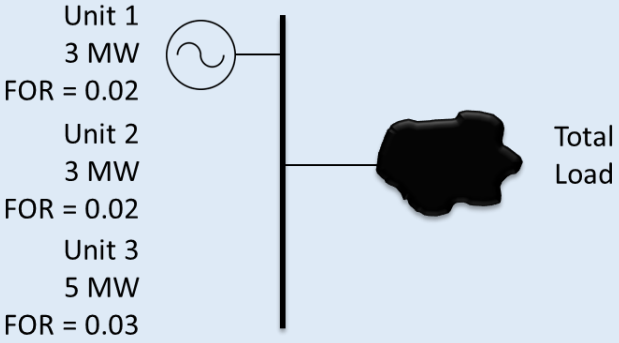
Introduction

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.



Multiple generation Units

Probability method can be used to analyze the adequacy of multiple generation units. Probability table is used to model the outage.

Units	Outage	Probability
111	0	0.98*0.98*0.97*12*10^-6
011	3	0.02*0.98*0.97*12*10^-6
101	3	0.98*0.02*0.97*12*10^-6
110	5	0.98*0.98*0.03*12*10^-6
001	6	0.02*0.02*0.97*12*10^-6
010	8	0.02*0.98*0.03*12*10^-6
100	8	0.98*0.02*0.03*12*10^-6
000	11	0.02*0.02*0.03*12*10^-6

Following metrics are used to evaluate the generation adequacy.

$$Reserve\ Margin = \frac{Capacity\ - Load}{Load} 100\%$$

$$Reserve\ Margin = \frac{120 - 100}{100} 100 = 20\%$$

Question 1

Let 3 different systems supplying 100 MW load. Determine the risk of each system.

System	No of Units	Unit Capacity	FOR
1	12	10	0.01
2	12	10	0.03
3	6	20	0.01

available Units	Outage	probability	Cumulative probability
12	120	0.886384872	1
11	110	0.107440591	0.113615128
10	100	0.005968922	0.006174538
9	90	0.000200974	0.000205616
8	80	4.56759E-06	4.64228E-06
7	70	7.38196E-08	7.46971E-08
6	60	8.69928E-10	8.77507E-10
5	50	7.53184E-12	7.5796E-12
4	40	4.75495E-14	4.77636E-14
3	30	2.13466E-16	2.14114E-16
2	20	6.46866E-19	6.48055E-19
1	10	1.188E-21	1.189E-21
0	0	1E-24	1E-24

available Units	Outage	probability	Cumulative probability
12	120	0.693842	1
11	110	0.257509	0.306158
10	100	0.043803	0.048649
9	90	0.004516	0.004846
8	80	0.000314	0.00033
7	70	1.56E-05	1.61E-05
6	60	5.61E-07	5.76E-07
5	50	1.49E-08	1.52E-08
4	40	2.88E-10	2.92E-10
3	30	3.95E-12	3.99E-12
2	20	3.67E-14	3.69E-14
1	10	2.06E-16	2.06E-16
0	0	5.31E-19	1E-24

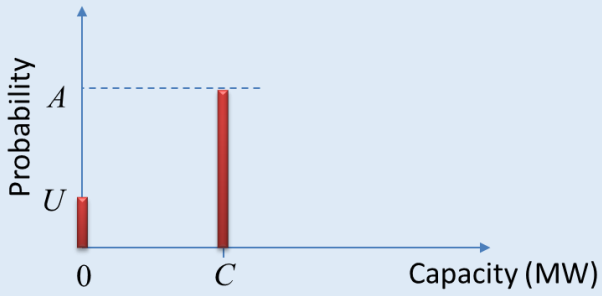
available Units	Outage	probability	Cumulative probability
6	60	0.941480149	1
5	50	0.057059403	0.058519851
4	40	0.001440894	0.001460448
3	30	1.9406E-05	1.95536E-05
2	20	1.47015E-07	1.47609E-07
1	10	5.94E-10	5.94001E-10
0	0	1E-12	1.38889E-15

System	No of Units	Unit Capacity	FOR	Risk
1	12	10	0.01	0.000205616
2	12	10	0.03	0.004846
3	6	20	0.01	0.058519851

Capacity outage

Capacity table and capacity outage table are used to evaluate the generation adequacy.

Capacity	Probability
C	A
0	U



Capacity Outage	Probability
0	A
C	U

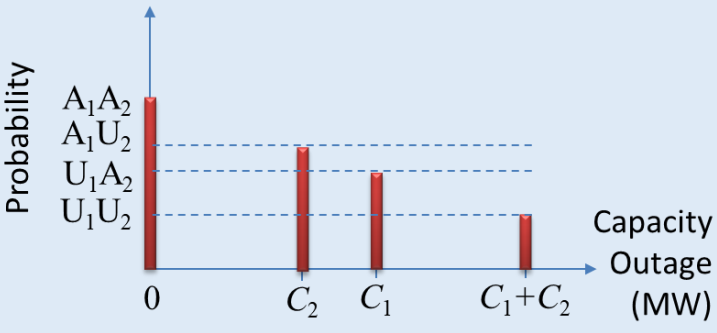
Below tables and graphs show the capacity outage table for 2 generators.

Capacity Outage	Probability
0	A_1
C_1	U_1

Capacity Outage	Probability
0	A_2
C_2	U_2

Capacity Outage	Probability
0	A_1A_2
C_2	A_1U_2
C_1	U_1A_2
C_1+C_2	U_1U_2

Capacity outage plot.



Multiple generation outage also can be evaluated in the similar way. The outage is estimated by adding one unit at a time. If there is x MW of outage, the outage is occurred due to C MW of outage by the new unit and x-C MW outage by previous units.

Question 2.

Find the outage probability for the following system.

Unit	Capacity	Unavailability
1	25	0.02
2	25	0.02
3	50	0.02

Solution

Add 1 unit at a time.

Unit 1 is added.

Outage	Recursive equitation	Cumulative Probability
0	(1-0.02)×1 + 0.02×1	1.00
25	(1-0.02)×0 + 0.02×1	0.02

Now add unit 2

Outage	Recursive equitation	Cumulative Probability
0	(1-0.02)x1+0.02x1	1.00
25	(1-0.02)x0.02+0.02x1	0.0396
50	(1-0.02)×0 + 0.02×0.02	0.0004

Outage	Recursive equitation	Cumulative Probability
0	(1-0.02)x1+0.02x1	1.00
25	(1-0.02)x0.02+0.02x1	0.0588
50	(1-0.02)x0.0004+0.02x1	0.0204
75	(1-0.02)×0 + 0.02×0.0396	0.00079
100	(1-0.02)×0 + 0.02×0.0004	0.000008

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