NEPP
north european power perspectives

June 2013

Wind Power Capacity Credit

In a power system there must be enough power plants in order to meet the demand with an acceptable reliability. The level of reliability can never be 100 percent since extreme events that the system is not dimensioned for can happen. The level to which a power plant can contribute to this requirement is defined as the capacity credit of the power plant, sometimes also called the capacity value. In order to compare the capacity credit for different sources it is important that exactly the same definition is used. The basic theory for this was developed in the 1960s by Garver. Wind power also has a capacity credit and the level is dependent on the amount of installed wind power capacity, the wind resource and correlation with the demand.

In any power system there is always a certain risk of capacity deficit, measured as Loss of Load Probability, LOLP. The level of this is in Sweden extremely low, and an indication of this is that we have not had forced load disconnection caused by lack of available capacity for decades.

However, the risk for capacity deficit has not been considered negligible and because of this we have in Sweden introduced a system with certain legislation where up to 2000 MW of capacity, production or voluntary load reduction, is procured every year by the TSO, Svenska Kraftnät.

Definition of Capacity Credit

The capacity credit is defined as the possibility for a certain power plant to increase the reliability, measured as decreased LOLP, of the power system with a certain level. There are some slightly different definitions:

- *Equivalent Load Carrying Capability- ELCC*: If X MW of a power plant result in that the demand can increase with Y MW at the same LOLP, then the *capacity credit as ELCC* of the X MW power plant is Y MW
- *Equivalent Firm Capacity-EFC*: If X MW of a power gives the same decrease of LOLP as a 100 percent reliable Y MW power plant, then the *capacity credit as EFC* of the X MW power plant is Y MW
- *Equivalent Conventional Capacity*: If X MW of a power gives the same decrease of LOLP as a conventional, not 100 percent reliable, Y MW power plant, then the *capacity credit as ECC* of the X MW power plant is Y MW

The basic theory of this was presented by Garver in IEEE Transactions on Power Apparatus and Systems in August 1966 in a paper with the title Effective Load Carrying Capability of Generating Units. The method and definition has also been applied to wind power since the end of the 1970s.

Capacity needs in Sweden

It is important that there is enough capacity during peak load situations. In the basic ELCC method, as stated above, one should consider many high load situations, trading capabilities with other areas and also outages in units. Here an analysis of the availability of wind and nuclear power during peak load situations is presented. One way of presenting the results is to show the actual capacity of the specific technology during peak load, compared to the installed capacity of this technology. Another alternative is to relate the capacity contribution during peak load to the yearly energy production. The reason for this is that the consequences of different technologies often are compared for a certain yearly energy production, e.g. 10 TWh wind energy compared to 10 TWh nuclear power. Below the availability of wind power and nuclear power during peak load situations are presented.

Wind power in Sweden during peak load

An important issue is the wind availability during peak load. The yearly peak loads (column 3 in Table 1) and when they occurred have been taken from yearly reports from Svensk Energi. In the report “Production variation from wind power, Elforsk report 04:34”, a possible installation of 4000 MW of wind power in Sweden has been studied. The report is based on real wind data for the period 1992-2002 and presents hourly MW levels for 56 sites and 10 years. In Table 1, column 4, the production during the reported Swedish peak load situations is studied. The data corresponds to in installation of 4000 MW of wind power, with an average production of 10 TWh/year, i.e. a mean production of 1142 MW.

The analysis shows that the mean capacity contribution for wind in this case is 1137,9/4000 = 28% of installed capacity. If the capacity contribution during peak load is related to yearly energy production the conclusion is that the mean production during the peak load situation is around the same as yearly mean (99,7%). (This was also the conclusion from an earlier study of wind availability in Sweden during eight load peaks (“Vindkraftens tillgänglighet vid hög last, Söder, KTH, 1987)).

*Table 1: Wind Power during peak load (*for year 2000, date is confirmed but not hour)*

Date	time	Peak load [MW]	Wind power [MW]	Share of installed capacity [percent]	Share of yearly mean [percent]
1992-01-20	08-09	23900	459,9	11,5	40,3
1993-12-14	16-17	24400	468,0	11,7	41,0
1994-02-14	08-09	24400	1134,8	28,4	99,4
1995-12-21	08-09	24400	1312,1	32,8	114,9
1996-02-07	08-09	26300	549,8	13,8	48,2
1997-02-17	08-09	25500	1941,1	48,5	170,0
1998-12-07	16-17	24600	2253,0	56,3	197,4
1999-01-29	08-09	25800	823,7	20,6	72,2
2000-01-24	08-09*	26000	520,5	13,0	45,6
2001-02-05	17-18	26800	1915,8	47,9	167,8
Average value:			**1137,9**	**28,4**	**99,7**

Nuclear power in Sweden during peak load

In order to get a comparison with another technology, the Swedish nuclear power production in the 10 today (2013) existing reactors during 10 Swedish peak load situations is studied. (There have been changes in the installed capacity which is shown in Table 2, right column.)

Table 2: Nuclear Power in Sweden during ten peak load situations.

Date	time	Peak load [MW]	Nuclear power [MW]	Share of installed capacity [percent]	Share of yearly mean [percent]	Yearly prod. [TWh]	Yearly mean [MW]	Installed capacity [MW]
2003-01-31	08-09	26400	8840	93,6%	118,2%	65,5	7477,2	9441
2004-01-22	08-09	27300	9432	99,6%	110,2%	75	8561,6	9471
2005-03-03	08-09	25800	8182	91,3%	102,7%	69,8	7968,0	8961
2006-01-19	17-18	26300	8928	99,6%	120,3%	65	7420,1	8961
2007-02-21	18-19	26200	7083	78,1%	96,5%	64,3	7340,2	9074
2008-01-23	17-18	24500	9000	100,7%	128,6%	61,3	6997,7	8938
2009-01-16	08-09	24800	8741	93,6%	153,1%	50	5707,8	9342
2009-12-21	16-17	24800	5330	57,1%	93,4%	50	5707,8	9342
2010-12-22	17-18	26700	8691	95,0%	136,9%	55,6	6347,0	9151
2011-02-23	08-09	26000	7931	84,7%	119,8%	58	6621,0	9363
Average value			**8215,8**	**89,3%**	**118,0%**	**61,5**	**7014,8**	**9204,4**

The analysis shows that the mean capacity contribution in this case is 8214,8/9204,4 = 89% of installed capacity. If the capacity contribution during peak load is related to yearly energy production the analysis shows that the mean production during peak load situation is around 20% higher than the yearly mean (118,0%).

Although wind power has a peak load contribution of merely 28%, compared to 89% for nuclear power, the difference in peak load power contribution for a given yearly energy production is significantly smaller. Here wind power, as an average, contributes with the same capacity during peak load as the yearly average, while nuclear power, as an average, contributes with 118% of the yearly average during peak load.

If we, for example, compare the peak load contribution of 10 TWh wind power (data from Table 1) with 10 TWh nuclear power (data from Table 2) we find that 10 TWh (4000 MW) of wind power has a peak contribution of 1137,9 MW. 10 TWh nuclear power provides a peak contribution of 10/61,5*7014,8*1,18=1345,9 MW. 10 TWh of nuclear power therefore can be expected to contribute with a larger capacity during peak load than wind power, but the difference is smaller than the identified share of installed capacity indicates; 28% for wind power, compared to 89% for nuclear power. The explanation is that nuclear power has significantly higher equivalent full load hours than wind power.

If the same average capacity contribution during peak load is expected then the wind power case would have to add 1345,9-1137,9=208,0 MW of 100 percent reliable capacity. A rough estimate, based on costs for gas turbine power, indicates that this difference in peak load capacity contribution would correspond to an additional electricity generation cost for wind power of around 0,65 öre/kWh. But one first have to estimate whether these 208 MW are needed or not.

This analysis only considers peak load situation and provides a magnitude of the capacity credit difference between two technologies. However:

- Only peak load situations are studied, and not all possible situations with possible challenges
- Only ten situations are used in the evaluation for both wind and nuclear.
- Only Swedish peak load is considered, while at least the Nordic system should be studied to obtain a better view.
- True calculations of capacity credit should consider the risk of capacity deficit.
- There are other methods to solve a capacity deficit situation, e.g. flexible demand which should be implemented when this solution has a lower cost. Here only one specific solution was selected.

For further information: Lennart Söder, KTH Royal Institute of Technology