INVESTIGATING THE PEAK DEMAND REDUCTION CAPABILITY OF PV: A CASE STUDY IN FLORIANÓPOLIS, SOUTH BRAZIL

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ABSTRACT: Many studies have shown that, under favorable conditions, particularly when load requirements are driven by commercial air conditioning, PV power is available at peak time, and therefore, can effectively contribute to generating capacity. To investigate this contribution, we analyzed the demand curves of 14 feeders with daytime demand peak that supply the city of Florianópolis – Brazil (27ºS, 48ºW) during a period of 21 months. In a first step we considered that the PV power generation was *ideal*, that is, all days were clear days. With this assumption we determined the maximum capacity of a PV power plant to reduce the peak demand for all the analyzed feeders. In a second step we recalculate all hourly points of Demand minus PV generation with actual values for the 21 months, to determine how often the PV generation could not reduce the load curve to the expected value. We found that, only in very specific situations, for example, when a summer storm interrupted abruptly the solar irradiation, the PV generation failed and the established demand limit was exceeded.
Keywords: Grid-Connected, Demand-Side

1 INTRODUCTION

The effective capacity of a generating resource is its effective contribution to the generating capacity available to meet electrical demand. Because solar electrical generation is not dispatchable, it is generally assumed to have no effective capacity, and is considered strictly as energy producer. However, it has been shown that there may exist a substantial degree of correlation between load requirements and PV output. This correlation has been associated with loads driven by commercial activity and air conditioning requirements and includes not only utility-wide generating capacity value, but also localized transmission and distribution (T&D) benefits [1,2]. It is know also that, the best load matching opportunities were not found in "traditional" high solar resource locations, but in areas with high daytime summer peak loads and low winter loads, often corresponding to metropolitan areas.

Florianópolis is located in south Brazil, having the lowest solar irradiation level of all its territory (4500 Wh/m²/day where the maximum value is 6300 Wh/m²/day in northeastern region). However, while the city receives a great number of tourists in summer time and, therefore, the electrical consumption is more than twice the winter consumption and, also while, in the central region of the city is localized the commercial center with a high midday air-conditioning demand, we expected that the load is a good match to PV's power output.

To analyze the capability that PV power plants have to reduce the demand peak in Florianópolis, we investigated the behavior of the demand in comparison with the solar availability, or PV generation, for a period of 21 months, with hourly coincident PV generation and demand values. For this period, we analyzed the demand curves of the 56 feeders that supply the city and found that 24 have daytime demand peak. From these 24 feeders we selected 14 that are distanced no more than 10 Km from de solar plant. The university region, where the solar plant is installed, has also a daytime demand peak, so we considered that the demand and PV generation values were coincident.

2 USED METODOLOGY

To determine the maximum capacity of a PV power plant to reduce the peak demand for the 14 feeders, we considered that the PV power generation was ideal, that is, all days, of the 21 months analyzed, were clear days. With this assumption we obtain the limit value of PV peak reduction capability, that is, the maximum reduction of the demand peak value that can be expected for a specific feeder in one entire year of PV operation (in this case 21 months). We selected 12 clear days, one for each month of the year, from the solar plant data described in [3]. We worked with 10% PV penetration level. The PV output values were normalized for a 1000 W/m^2 solar irradiation level at the largest historical PV power value.

For each feeder, the hourly demand and coincident PV (clear days) output data for the 21 months were compared and the maximum demand minus PV output value was obtained. This value is assumed as the PV peak reduction capability limit. Table 1 shows the obtained values in percentage of the assumed PV power.

The obtained results show a good relation between demand and PV generation, with peak demand reduction factors values within 49.35% and 87.36%.

Table 1: Obtained values of demand peak reduction (% of PV power) for the 14 analyzed feeders, considering ideal PV generation (clear days) for 21 monitoring months.

Feeder	Historical Demand Peak (kW)	PV Power (kW)	Demand Reduction (kW)	Date of Demand Peak	Hour of Demand Peak	Percentage of Peak reduction (%)
CQS_01	5879	587.9	389.93	03/12/2002	16:00	66.32
CQS_10	8078	807.8	645.00	03/11/2002	17:00	79.84
CQS_11	9536	953.6	832.44	03/13/2002	14:00	87.29
CQS_12	8030	803.0	501.18	11/23/2001	15:00	62.41
CQS_TT1	26792	2679.2	2.127.00	03/12/2002	17:00	79.39
ICO_03	6931	693.1	342.07	12/07/2001	16:00	49.35
ICO_07	9536	953.6	812.58	03/19/2002	15:00	85.21
ICO_08	8963	896.3	782.25	03/12/2002	14:00	87.27
ICO_09	5019	501.9	432.11	11/16/2000	10:00	86.09
ICO_10	9273	927.3	604.19	10/27/2000	15:00	65.15
ICO_11	9369	936.9	781.11	03/11/2002	16:00	83.37
ICO_LI	6429	642.9	561.65	03/14/2002	16:00	87.36
ICO_TT2	30759	3075.9	2.500.28	03/19/2002	15:00	81.28
TDE_07	9512	951.2	830.29	03/12/2002	14:00	87.29

3 RESULTS

With actual PV output values, we have recalculated demand minus PV output, to see how many times, in 21 months, the PV generation could not reduce the load curve to the expected values. For a specific feeder (TDE 07), which supplies the university region where the solar plant is installed, from approximately 15,000 hourly demand values, only 41 were greater than the expected value and occurred on summer time. This shows the high-energy consumption in summer time. From these 41 values, 36 were supplied by the PV generation, remaining only 5 that exceed the expected value. These 5 failure events occurred in very specific situations, where, in a high demand moment, the PV generation was abruptly interrupted by the presence of clouds (see Figure 1).

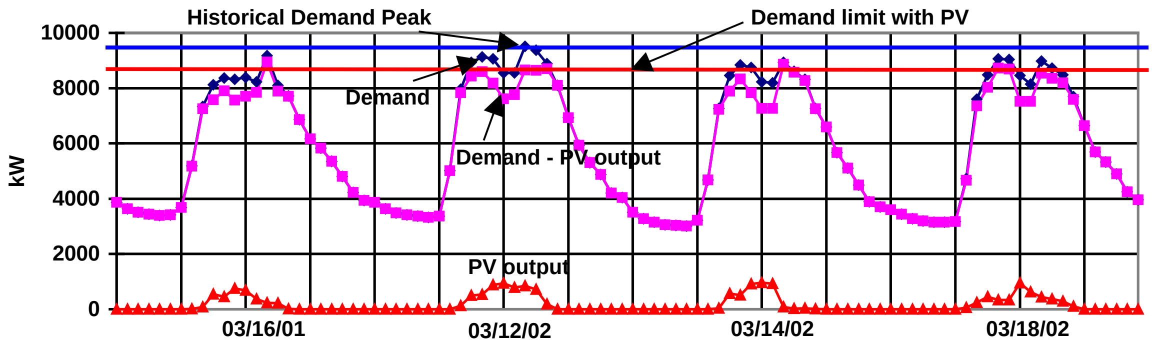

Figure 1: TDE 07 feeder, 21 months monitoring. Only in 4 days the PV generation did not supply the demand with the expected value.

The five times where the PV supply failed, occurred under following situations:

03/16/01: unexpected increase in the demand value at 14:00h with low PV output level.

03/12/02: at 16:00h, with high demand value, the solar irradiation is interrupted.

03/14/02: at 14:00h a summer storm interrupted abruptly the solar irradiation in a moment of high demand.

03/18/02: two failure events occurred in the morning, at 10:00h and 11:00h, when the demand was increasing.

Solar Load Control (SLC) devices [4] should be used to reduce the demand when the PV generation fails, as occurred in the five cases described above. The SLC is an energy end-use control device designed to increase the effective capacity, hence the value, of grid-connected PV applications.

The high correlation between demand and solar availability explains why, with actual data of PV generation, so few points are not satisfactory supplied by PV generation. To see better this correlation we selected three consecutive days with different characteristics. Figure 2 shows, for the TDE 07 feeder, demand, PV output and demand minus PV output for the days: Monday 03/04/02, Tuesday 03/05/02 and Wednesday 03/06/02. The straight line represents the demand value that should not be exceeded. This figure shows the high correlation between demand and solar availability. On Monday morning, with an overcast sky, the demand is in a low level. In the afternoon, with higher values of sun irradiation, the demand increased, but was compensated by the enhanced PV generation. On Tuesday, a clear day with high solar irradiation, the demand is high and the solar generation is also high. On Wednesday, a heavily overcast day, the demand reduces to values under the PV penetration level of 10%. These three days show the high correlation between demand and solar availability. This can explain why, in 21 months, only five times the demand was not supplied by the solar generation.

Table 2 shows the number of failure events occurred in the PV supply and the fraction of demand reduction for the 14 feeders.

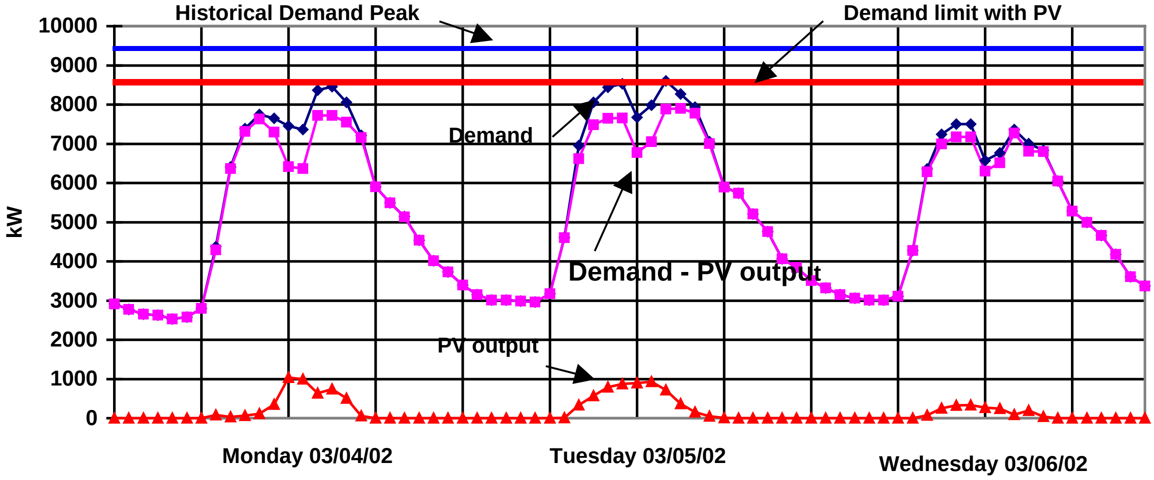

Figure 2. Demand behavior of three consecutive days with distinct solar radiation.

Table 2: Obtained values of demand peak reduction (% of PV power) for the 14 analyzed feeders, using actual PV generation data for 21 monitoring months.

Feeder	Historical Demand Peak (kW)	PV Power (kW)	Demand Reduction (kW)	Date of Demand Peak	Hour of Demand Peak	Percentage of Peak reduction (%)	Number of failures
CQS_01	5879	587.9	167.76	03/14/2002	14:00	28.53	8
CQS_10	8078	807.8	257.92	03/14/2002	14:00	31.92	11
CQS_11	9536	953.6	700.11	03/14/2002	14:00	73.41	1
CQS_12	8030	803.0	244.51	11/22/2001	15:00	30.44	2
CQS_TT1	26792	2679.2	1178.27	03/14/2002	14:00	43.97	4
ICO_03	6931	693.1	265.11	11/27/2001	14:00	38.24	2
ICO_07	9536	953.6	573.00	12/12/2000	15:00	60.08	7
ICO_08	8963	896.3	505.33	03/14/2002	14:00	56.37	13
ICO_09	5019	501.9	209.36	11/16/2000	10:00	41.71	2
ICO_10	9273	927.3	574.26	10/27/2000	16:00	61.92	1
ICO_11	9369	936.9	169.10	02/12/2001	14:00	18.04	12
ICO_LI	6429	642.9	17.21	02/12/2001	14:00	2.67	9
ICO_TT2	30759	3075.9	1832.01	03/14/2002	14:00	59.56	11
TDE_07	9512	951.2	568.94	03/16/2001	14:00	59.81	5

On 03/14/02, when a summer storm occurred, six feeders showed the worst failures. Also in this extreme case, high values of peak reductions are obtained, from 28.53% to 73.41%. The worst case occurred with the ICO_LI feeder, where only 2.67% of the demand peak was reduced.

3 CONCLUSIONS

We can conclude that, for the 14 analyzed regions, the use of PV power plants can contribute significantly to the reduction of demand peaks. The high demand values that occur in summer time, with daytime demand peaks, are favorable to the use of PV power plants in Florianópolis central region. The use of Solar Load Controller could guarantee 100% of PV peak demand reduction, achieving the equivalent of firm peaking PV capacity.

4 REFERENCES

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