ESTIMATING THE CAPACITY VALUE AND PEAK-SHAVING POTENTIAL OF PHOTOVOLTAICS IN ONTARIO: A CASE-STUDY FOR THE CITY OF TORONTO

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ABSTRACT

Hourly electric power demand data in Toronto from 2000 to 2006 was analyzed along with coincident, simulated hourly photovoltaic (PV) power generation to quantify PV capacity value and seasonal peak-shaving. Three different methods were used to assess PV capacity value, and their results were compared. Results indicate that PV power generation is strongly correlated with demand: PV output increases with increasing demand, reaching about 45% of its nominal value during peak demand hours. Likewise, the PV capacity value obtained for low grid penetration is about 40% for all three methods, considerably higher than the 11% yearly average capacity factor. Yearly variations in capacity value show a strong correlation with variations in the demand summer to winter peak ratio (SWPR).

1. INTRODUCTION

In November 2006, the government of the province of Ontario (Canada) introduced a $0.42/kWh tariff for PV-generated electricity. This study examined two key aspects of increased PV grid penetration in Ontario, namely PV capacity value and seasonal peak-shaving. The city of Toronto was used for this case study since it is Ontario's (and Canada's) largest urban centre, and since peak load management is a major concern there.

2. DATA

2.1Electric power demand data for the Toronto zone

Hourly electric power demand data for the Toronto zone was obtained from the Ontario Independent Electricity System Operator (IESO) [1]. Full-year data was available for 5 years: 2000, 2001 and 2004-2006. This will be referred to as "2000-2006".

2.2 PV electric power production data

Watsun-PV 6.1 was used to simulate the hourly power generated by a grid-connected PV system in Downsview, Toronto (43.75ºN, 79.48ºW). Weather data for the simulation consisted of hourly average irradiance, temperature, humidity and wind speed data, and daily average albedo. The hourly data was provided by Environment Canada meteorological stations in Toronto. Data was interpolated from Eastern standard time to Downsview local solar time as required, using the conversion in [2]. Gaps in the data were filled using data from nearby weather stations in Mississauga and Elora, or by linear interpolation. Finally, a monthly value of daily average albedo was constructed using a RETScreen International algorithm [3].

Three PV system orientations were modeled: South-facing (S), Southwest-facing (SW) and West-facing (W) orientations with 30° tilts. PV system losses were tuned to achieve performance ratios of ~0.75, the most common value in an international database [4].

3. METHODOLOGY

Three approaches to calculating PV capacity value were considered in this study (for a review, see [5]). In all cases, capacity values were computed for each year separately, then averaged over 2000-2006.

3.1 ELCC and the Garver approximation

A generator's effective load-carrying capability (ELCC) is a standard measure of capacity value. It is defined as the load increase that can be supported by the generator, without changing system reliability. Here, the Garver approximation [5] was used to estimate PV's ELCC. The Garver characteristic capacity (m) was set to m=3% of peak load, based on IESO analyses of forecast data yielding m values between 2.5 and 3.5% of peak load [6].

3.2 Mean PV output during peak intervals

Since PV capacity is most valuable during peak loads, capacity value is sometimes equated with average generator output during "high demand" intervals. Two approaches were considered here.

The first approach considers average PV output over all hours where the load is within a given percent deviation from the peak. With this approach, there is no consensus on what percent deviation corresponds to a given grid penetration level.

The second approach equates yearly capacity value with average PV output during some fixed peak time window. In this study, an interval corresponding to summer "on-peak hours" in Ontario was chosen: 11AM to 5PM from June to August. This approach has approximated ELCC well in some wind studies [7], but recent PV results [5] give contrary evidence.

4. RESULTS AND DISCUSSION

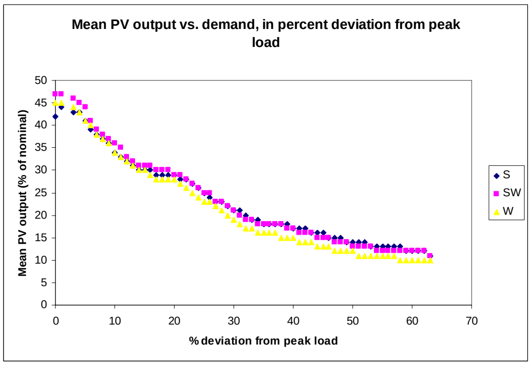

Fig. 1 Mean PV output (% of nominal/nameplate value) over all hours with loads within a given % deviation from the peak.

4.1 Mean PV output during peak intervals

Fig. 1 shows the average PV output over all hours where loads are within a given deviation from the peak. The figure shows a clear correlation between PV power generation and demand: PV output reaches about 45% for peak loads, and decreases steadily to reach typical yearly PV capacity factor values of ~11% when all loads are included. For peak loads, the SW and W orientations give higher average PV outputs than the S orientation, which has the highest yearly capacity factor.

The average PV output over hours within 10% of the peak is approximately 35% for all orientations; this corresponds to PV capacity value as defined in a recent Ontario wind integration study [8]. Meanwhile, the 2000-2006 average values for the 11AM-5PM summer period are ~43% for all orientations.

These results can be compared to those of Rowlands [9], who estimated a PV capacity value of 52.1% for loads within 10% of the peak in Guelph, Ontario by examining insolation values in July-August (no losses were included). Another investigation of PV peak shaving based on a real 75kW PV array in Toronto yielded a much lower value for the PV capacity credit during summer peak periods, namely 25% [10].

4.2 ELCC using the Garver approximation

Fig. 2 shows ELCC for the SW orientation at different grid penetration levels (2, 5, 10, 20%), plotted against the summer to winter peak load ratio (SWPR) associated with each year and with the 2000-2006 average. ELCC decreases slowly as grid penetration increases, in agreement with [5]. The 2000-2006 average ELCC ranges from 25% to 37%, for grid penetration levels between 20% and 2%, respectively. At low grid penetration levels, all three methods of calculating PV capacity value yield results of 40±5%.

ELCC results vary considerably from year to year, ranging from 30% to 44% at 2% grid penetration. There is a strong correlation between yearly variations in ELCC and in SWPR, in agreement with the results of [5]. No such correlation was found when comparing yearly variations in ELCC and insolation. This suggests that yearly variations in PV ELCC will be predicted better by variations in SWPR than in the solar resource.

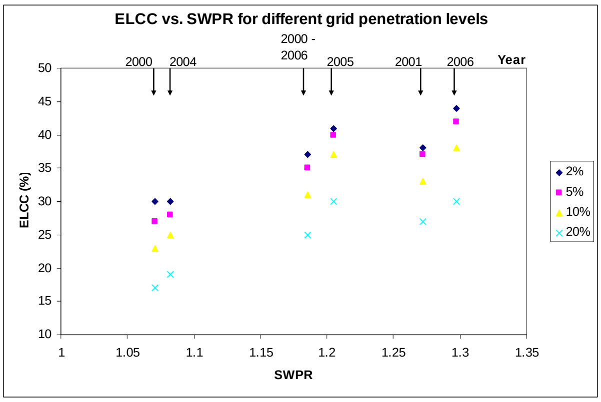

Fig. 2 ELCC vs. summer to winter peak load ratio (SWPR) at different grid penetration levels for the SW orientation.

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