Photovoltaic Project Summary

Solar Resource-Utility Load Matching Assessment

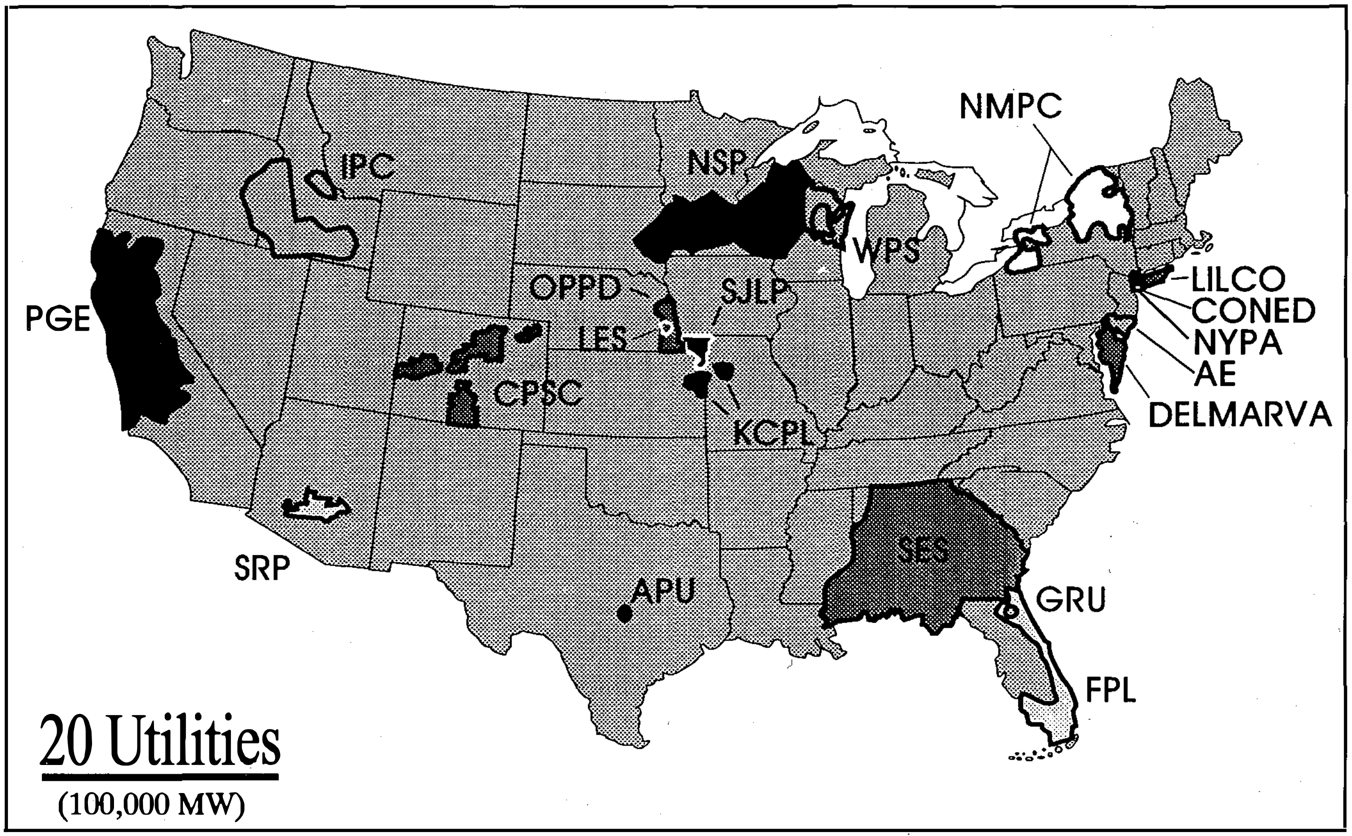

Figure 1. Service areas of the considered utilities. Atlantic Electric (AE); City of Austin Power & Light (APU); Consolidated Edison (ConEd); Delmarva Power (DELMARVA); Florida Power & Light (FPL); Gainesville Regional Utilities (GRU); Idaho Power Corp. (IPC); Kansas City Power & Light (KCPL); Lincoln Electric System (LES); Long Island Lighting Co. (LILCO); New York Power Authority (South NY Sector) (NYPA); Niagara Mohawk Power Corp. (NMPC); Northern States Power (NSP); Omaha Public Power Dist. (OPPD); Pacific Gas & Electric Co. (PGE); Public Service Co. (Colorado) (CPSC); Salt River Project (SRP); Southern Electric System (SES); St. Joseph Light & Power Co. (SJLP); Wisconsin Public Service Corp. (WPS).

Introduction

Many utility planners may be unfamiliar with the potential for the development of photovoltaics (PV) in their service areas. The goal of the research summarized in this document is to provide information on the match existing between the output of PV power plants and the load requirements of U.S. utilities (Fig. 1). This material indicates whether or not the effective capacity (hence the value) of this renewable resource should be higher than that traditionally assigned to an intermittent resource.

Using Satellite Resources to Quantify Load Matching

Actual time-coincident utility load and PV output data covering a statistically significant period (at least 1 year) are necessary to quantify load matching. System load data are often available from utilities, while site/time-specific insolation data required to simulate PV output often are not. In this work, we use a proxy measurement of solar radiation with wide geographical coverage provided by geostationary satellites to simulate PV output at arbitrary times and locations in the United States.

A pilot study at the State University of NewYork at Albany for the New York Power Authority and the International Energy Agency (IEA) demonstrated and confirmed the accuracy of this method of simulation. Geostationary satellites have the potential to provide the data needed for an initial estimate of PV's load-matching potential for American utilities. We note, as demonstrated in the IEA study, that (1) satellite data constitute the most accurate option beyond 50 km (30 mi) of a ground-based measuring station and (2) currently operational satellite-to-irradiance procedures provide a conservative assessment of the ultimate potential of satellite-aided solar resource monitoring.

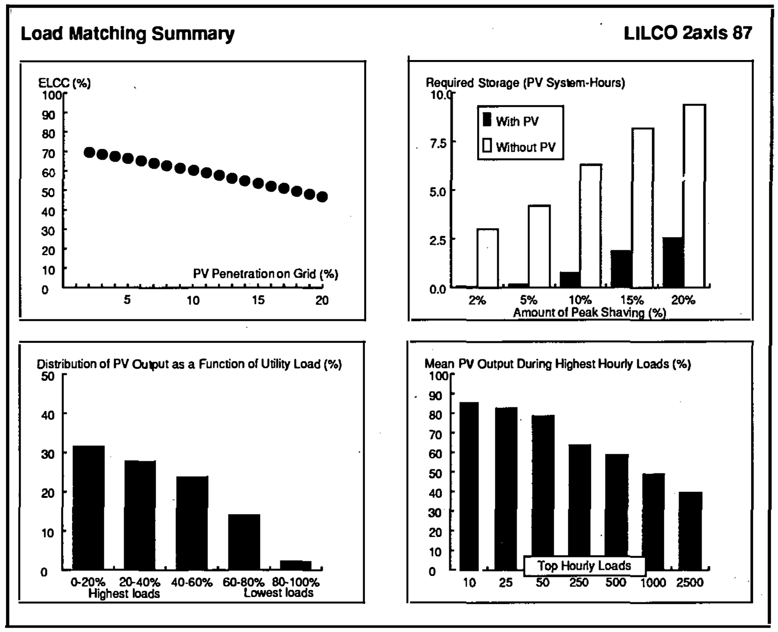

Figure 2. A graphical summary presenting each load-matching benchmark for a given utility (NEW is inferred from the distribution of PV output as a function of utility load).

Quantifying Load Matching for 20 U.S. Utilities

Load matching of PV is quantified using four complementary benchmarks (ELCC, NEW, MOHL, and MBES; see Glossary) derived from experimental data.

We considered two array configurations: (1) fixed tilt at site latitude; and (2) two-axis tracking. All ratings were done in terms of summer ac output. For a given utility, PV output was considered to be that of systems dispersed over its entire service area. The study noted that the differences in summer production across the United States were not considerable, while differences were much more pronounced in the winter.

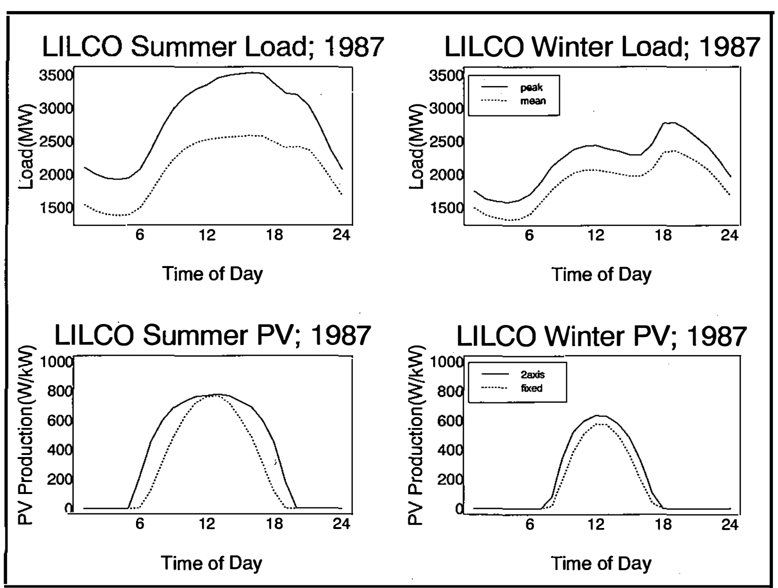

Figure 3. Summary of utility summer and winter peak loads and correlated PV output for a given utility.

Results

Twenty utilities elected to participate in the study. Graphic load-matching and resource summaries (see Fig. 2 and 3) were prepared for each utility and may be obtained from the report *Solar Resource—Utility Load Matching Assessment*, by Richard Perez, Robert Seals, and Ronald Stewart.

We summarize these findings through two of the load-matching benchmarks:

Effective Load Carrying Capability (ELCC) and Minimum Buffer Energy Storage (MBES).

The relative ELCC of two-axis tracking PV systems is plotted in Fig. 4 against utility summer-to-winter peak-load ratios. The quasi-logarithmic growth of PV's ELCC as a function of the ratio is remarkable: all the utilities studied, from winter peaking to highly summer peaking, fit the pattern.

In Fig. 5, the MBES needed to guarantee a firm 10% peak load reduction is compared to the Total Energy Storage (TES) required to accomplish the same reduction without PV. The PV resource considerably reduces energy storage requirements in all cases, including winter peaking NMPC.

High Load-Matching Opportunities:
Results in Fig. 4 show that the effective capacity of PV is considerably higher than "conventional" PV capacity factors for many utilities. Results for a composite of all four benchmarks are presented in Fig. 6. In geographical distribution, the gradient used to fill the service area of each utility on the map in Fig. 1 relates to the load-matching capability as summarized in Fig. 6. Based on the limited evidence gathered, the zones of highest load-matching capability include the southwestern seaboard, the heartland, and, to a lesser extent, the eastern seaboard. By contrast, the two areas traditionally considered as prime for solar development (the Florida peninsula and the southwest arid lands) did not fare as well on the load-matching scale. In comparing fixed-versus-tracking PV, on average, the non-tracking option results in a 10%-15% reduction of load-matching capability.

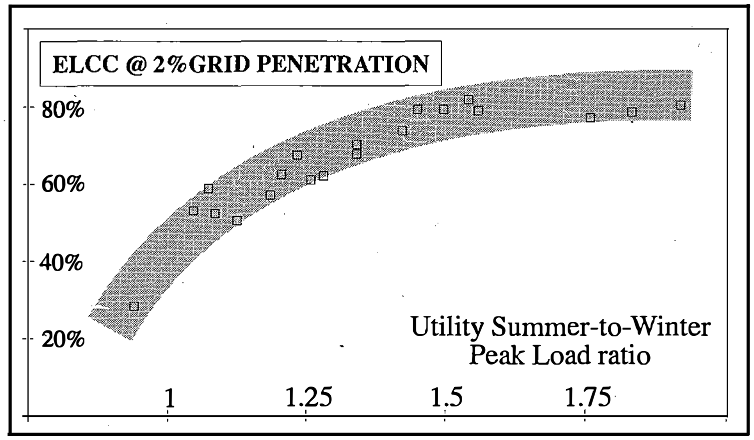

Figure 4. ELCC as a function of utility summer-to-winter peak load ratio. Each point represents one utility.

Note that a strong match at the utility-wide level will very likely correspond to load-matching occurrences at the transmission/distribution level for that utility and, hence, to possible high-value transmission and distruibution (T&D)/PV-Demand-Side Management (DSM) development opportunities. However, less utility-wide matching does not preclude localized T&D/PV-DSM development opportunities.

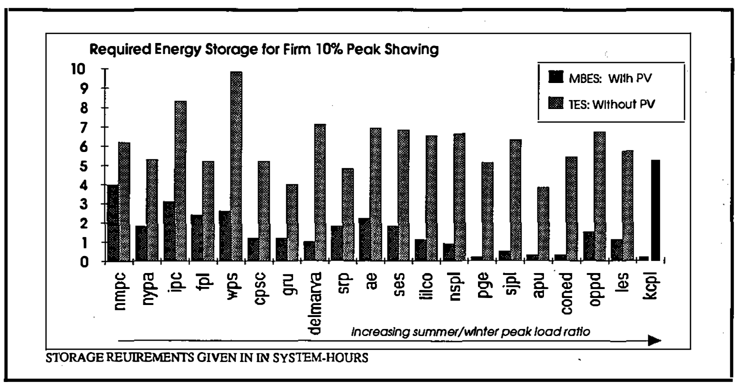

Figure 5. MBES required to guarantee a firm 10% peak load reduction with PV, compared to TES without PV.

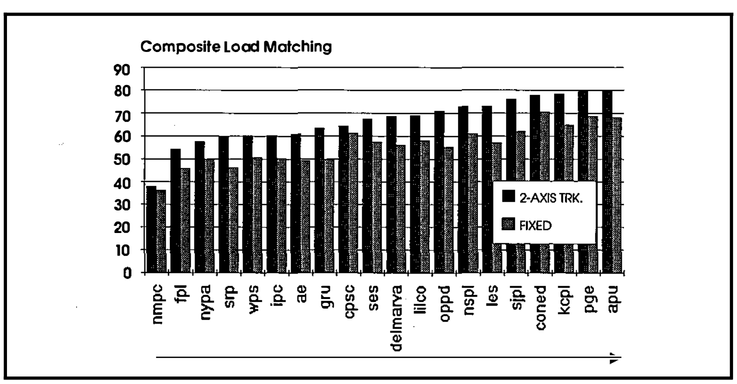

Figure 6. Composite PV load-matching results.

Little Coincidence with Overall Solar Resource:
Comparing the load-matching map in Fig. 1 and the solar resource map in Fig. 7, it is apparent that the distributions are not strongly related. The resource is critical, but less so in its overall magnitude than in terms of its feed-back relationship with load requirments.

Conclusions

The load-matching capability of PV, as quantified with four independent benchmarks, was found to be substantial for many of the 20 considered utilities. Thus, a PV-based resource, either on the demand or the supply side, could effectively contribute to meet these utilities' capacity requirements. Also, a well-defined relationship was observed between a utility's summer-to-winter peak load ratio and the load-matching capability of PV for that utility. Should this trend be confirmed (and refined/quantified), its implications may be very important and useful for utility planners. In particular, if this relationship is found to persist at the sub-utility (T&D) level, then knowing the SWP ratio would be sufficient to estimate the corresponding PV capacity value.

Finally, with the exception of California, most of the best PV load-matching opportunities were found for locations not traditionally targeted for solar energy development—the central United States and the Mid-Atlantic seaboard. In contrast, the load matching potential of traditional solar energy regions (Florida, Arizona) was found to be more limited.

Acknowledgments
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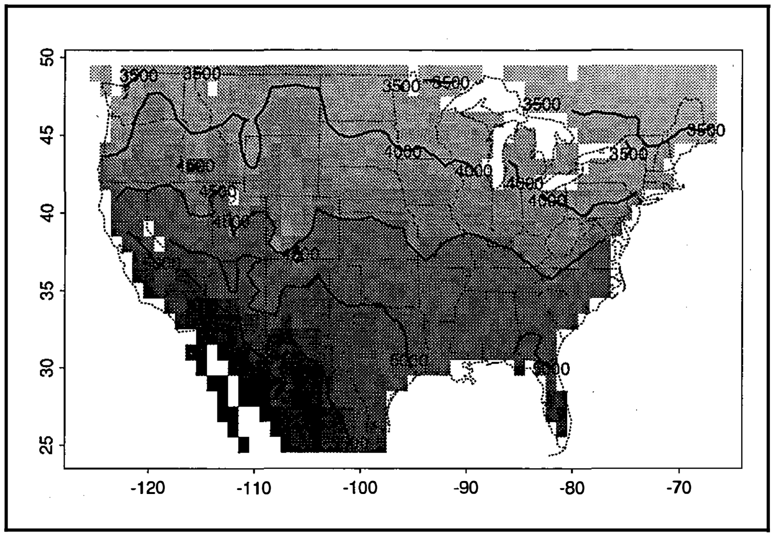

Figure 7. U.S. solar resource—1987/1988 global irradiance (Wh/m^2/day).

GLOSSARY

DSM Demand-Side Management
ELCC Effective Load Carrying Capability: the effective increase in a utility's usable capacity due to the added resource, at constant loss of load probability (LOLP)
End-use accuracy The difference between PV-utility load-matching quantified from satellite data and from ground-based data
LOLP Loss of Load Probability
MBE Mean Bias Error
MBES Minimum Buffer Energy Storage: The minimum storage required to guarantee a firm fixed peak load reduction
MOHL Mean Output during Highest hourly Loads: the mean PV output during the 'n' highest observed hourly loads on the considered grid
NEW Normalized Energy Worth: the mean value of PV-generated energy using a normalized energy rate scale based on each utility's load duration curve
Physical accuracy The difference between solar irradiance estimated from the satellite and ground-measured irradiance
RMSE Root Mean Square Error (short-term errors)
SWP Summer-to-Winter Peak (load ratio)
TES Total Energy Storage: Storage to accomplish the same firm MBES peak-load reduction without PV

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The second phase of this work is in progress. Utilities can participate at no cost to themselves and should contact

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