AN INTEGRATED DESIGN APPROACH TO OPTIMIZE PHOTOVOLTAIC SYSTEMS

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ABSTRACT

This paper describes an energy saving case study utilizing an integrated design approach, retrofitting a commercial site. All concerned parties realized a fairly novel outcome – they all achieve their objectives.

Commercial photovoltaic (PV) system design based upon available footprint, past energy consumption and the client's budget is not an optimal approach. This myopic practice will most likely result in higher capital cost with marginal energy savings. This was the case for a self-service carwash located in the Imperial Valley of California, which resulted in the previous owner's bankruptcy.

1. INTRODUCTION

IF you are frustrated with poor photovoltaic designs that reflect poorly on the industry as a whole, an integrated approach to optimize photovoltaic design may be the solution we are seeking. Make no mistake, poorly defined basis of design have a significantly negative impact on the industry. By educating and promoting an integrated design approach with a rational analysis results in the best solution for the particular situation making it a win for the customer, for the utility, for the contractor, and the industry. An industry design standard ensuring the best basis of design will contribute significantly to the success of photovoltaic.

2. PROBLEM STATEMENT

Photovoltaic system designed based upon available footprint, past energy consumption and the client's budget is not an optimal approach. This myopic practice will most likely result in higher capital cost with marginal energy savings. It has become the industry practice for photovoltaic design/build contractors to rely on pre-engineered, pre-packaged designs rather than performing a detailed engineering analysis to provide the best design. It is important to note that these practices can be successful with good judgment, but unfortunately some practicing lack the experience, guidance or expertise to demonstrate sound judgment; having a detrimental effect on the industry. These are complicated systems that require sound engineering practices for the public safety and should never be simplified to a "cookie cutter approach". Practices have been developed through standards to ensure public safety, however these standard do not protect against insufficient designs that often result in less than optimal results. Such practice defeats the advantage of photovoltaic, which is to reduce the economic burden on the end user.

3. OBJECTIVES AND SCOPE OF STUDY

The objective of an integrated design approach is to 1) eliminate misunderstandings between the manufacturer, installer and the end user and 2) assist the end user in selecting and obtaining the proper system for a particular need.

4. METHOD

The integrated design approach includes the following:

1) Project Definition - Understand your client and their needs; identify constraints, boundary conditions.
2) Set Criteria – capacity (future needs through Energy audit), appearance, durability and cost.
3) Analyze possible alternative solutions – potential solutions may involve a phased approach.
4) Endorse the Project - Make a decision with the client.
5) Basis of Design – system performance specifications defined through the client/contractor partnership project endorsement.

4.1 Project Definition

The key to defining the project is to understand your client's issues and/or concerns. Listen to their needs and wants and define the project objective and scope around that. Project definition will differ from one client to the next.

This process defines 1) the client's requirements and expectations and 2) baseline criteria for function, performance and maintainability.

4.2 Set Criteria

Criteria or the limits of scope are set by project definition. Understanding the client's needs and wants assures a successful scope of work definition that achieves the client's objectives. These objectives are the project drivers that measure its success.

4.3 Analyze possible alternative solutions

There are multiple solutions but the best is dependent upon the most significant driver identified through the process of previous steps.

4.4 Endorse the Project

This is the final step in the planning phase of the process. The client/contractor partnership is developed by effective communication and involvement through the process. Endorsement is the commitment of this partnership to successful project performance. To achieve an efficient project endorsement the partnership works from an informed knowledge base devolved in the previous steps of the process.

4.5 Basis of Design

The Basis of Design is a narrative presentation of facts sufficiently complete to demonstrate that the project concept is fully understood and that subsequent design details and their ultimate presentation in the final drawings and specifications will be based on sound engineering decisions. Its function is to translate the project needs into physical components from which the system will be built. It describes the technical approach planned for the project as well as the design parameters to be used.

This is facilitated through standards, codes, and sound engineering judgment.

5. CASE STUDY

5.1 Executive Summary

This was the case for a self-service carwash located in the Imperial Valley of California, which resulted in the previous owner's bankruptcy.
The new owner retained the services of a PV contractor to evaluate the benefit of replacing the portion of the PV system removed by the previous owner. A comprehensive energy audit was conducted as part of the engineering analysis. The findings of the analysis were:

- Facility power consumption followed a diurnal cycle with peak demands occurring twice a day during hours of minimal or non-PV production.
- Average daily energy consumption of 234 kWh.
- Average peak power demand of 20.6 kW, with an annual maximum of 23 kW.
- Facility load factor of 0.48.

Through the energy audit, measures were taken to improve efficiency of the following systems:

- Reclaimed water treatment.
- Pressure stations.
- Lighting.

After incorporating these energy efficiency improvements, the portion of the PV system removed by the previous owner was replaced, the lighting system was upgraded and the pressured water and reclamation systems were retrofitted. The results of this integrated design approach were:

- Peak demand shaving below 20 kW allowing the facility to operate in a non-demand rate schedule.
- 30-percent reduction in average daily energy consumption.
- 60-percent reduction in utility bill.
- Return on investment (ROI) of approximately 7 ½ years.

An integrated design approach with rational analysis provided the best solution for the particular situation making it a win for the client, for the utility, for the contractor, and the industry.

5.2 Background

The Facility is a coin-operated self-service carwash located in Imperial Valley of California. The Facility has eight (8) large bays, each equipped with a trigger gun and wand (sprayer) and a scrub foam-brush. After a customer parks their vehicle inside one of the eight large bays they insert coins or tokens into the controller. They can choose options such as soap, tire cleaner, wax or rinse (all dispensed from the sprayer), or scrub the vehicle with the foam-brush. The number of coins or tokens inserted determines the amount of time customers have to operate the equipment. The Facility is equipped with separate vacuum stations that allow customers to clean their upholstery and carpets.

During the summer season, typical peak hour operation occurs before 9:00AM and after 5:00PM, Monday through Friday. Power consumption follows a diurnal cycle peaking twice a day, once in the morning and once in the evening. Average daily energy consumption was 234 kWh, or approximately 29 kWh per bay per day, with a total monthly average of 7,200 kWh for the facility.

Electrical utilities charge commercial customers based not only on the amount of energy used (kWh) but also on peak demand (kW). Peak demand is very important to the utility so that they may properly size the requisite electrical service and insure that sufficient peak generating capacity is available to that given facility/service area.

In order to determine the peak demand during the billing period, the utility establishes short periods of time called the demand interval (15 minutes). The billing demand is defined as the highest average demand recorded during any one demand interval within the billing period.

Prior to improvements the Facility was in the GS-2 TOU-B rate schedule.

- GS – General Service
- 2 – Demand
- TOU – Time Of Use
- B – Option B Pricing

This rate schedule is applicable to single- and three-phase general service customers whose monthly maximum demand registers above 20 kW and below 200 kW. Under this rate schedule the facility is being charged for demand on both delivery and generation side. Delivery demand charges are assessed year round while generation demand charges are only assessed during the summer. Facility historical peak demand power range was between 19 and 23 kW, with an average of 20.6 kW.

This average 3% of power over the demand threshold of 20 kW accounted for approximately 38% of the utility billing due to demand charges. During the summer season, the demand charge component increased to approximately 48% of the utility billing, on average.

5.3 Implementing the Approach

The first step in the process was to assess the Facility's performance to determine what needed improvement. The comprehensive energy audit included an energy balance and recommended improvement projects with costs. The energy balance was performed by looking at all of the energy coming into the Facility and monitoring the power consumption to find out how that energy is used within the Facility. This provided a baseline to measure the Facility performance and identified the major energy consumers. From this an energy management plan was developed.

Energy Efficiency Improvements:

Reclaimed Water Treatment:

- Installed soft starts on pumps and VFDs on pumps that where throttled and or had bypasses.
- Piped pumps in parallel.
- Reduced system pressure losses where possible.
- Downsized pumps that where oversized.
  - Achieved through impeller size reduction
- Added energy recovery systems to replace pressure reducing valves, which waste pumping energy.
- Repaired leaks in distribution systems.
- In storage tanks, replaced oversized pumped mixing with laminar flow mixers.

Pressure Stations:

- For stations with highly variable flows installed pony pumps to handle base loads.
- Installed improved pump controls.
- Installed premium efficiency pumps/motors instead of rewinding older pumps.
- Varied tank levels to reduce loads, especially during peaks.
- Install motion-detecting lights or lights on timer switches in infrequently-used stations.

Lighting:

- Replaced High Intensity Discharge (HID) and T12 or T8 lighting with high efficiency T5 fluorescent lighting.
- Installed occupancy sensors in areas that are frequently unoccupied.
- Installed photo controls and dimming systems.
- Used daylight wherever possible.

Solar Energy System:

- Installed module support system on the roof of the structure.
- Installed (58) 200 Watt Panels on the roof of the structure.
- Installed (2) 6,000 Watt grid-tied inverters.

- Installed wiring, disconnects, overcurrent protection, and ground-fault protection.
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6. CONCLUSION

Through energy efficiency improvements the peak demand was shaved below 20 kW allowing the Facility to operate within GS-1 schedule. The advantage of this schedule is that demand charges are eliminated; however the rates per kWh are higher. By reinstalling the portion of the PV system removed by the previous owner, 25% of energy usage has been offset.