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PV OPERATED HVAC FOR SOUTHWEST STATES

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ABSTRACT

This report analyzes energy usage and associated utility capacity requirements for compressor based air-conditioning compared to evaporative cooling supplied by electricity from photovoltaics (PV). Two novel scenarios are presented, two stage evaporative coolers with grid tied PV, and two stage evaporated coolers supplied with direct current (DC) electricity from PV. The two scenarios are complimentary; where a grid tied system can tap DC for air-conditioning purposes (see Figure 1). 8% PV system gains can be achieved by eliminating the inverter for powering such a DC heating, ventilating and air-conditioning (HVAC) system. A PV system directly coupled to high efficiency evaporative cooler can remove the air-conditioner peak demand from a utilities load profile. Typical cities energy comparisons are presented. Incentive and public goods programs are not necessarily designed for this optimized, direct utilization of DC approach.

1. INTRODUCTION

Utilities like the Sacramento Municipal Utility District (SMUD) have a very expensive peak demand. With its service area located in the hot Central Valley of California, SMUD faces a difficult situation of having intense "needle peak" demands, which are driven primarily by high summer temperatures. Southwest utilities have primarily air-conditioner based peak electricity demands. This paper presents the advantages in using the source of the problem, the sun, and supplying the energy needed to run market-available HVAC systems.

High efficiency evaporative coolers are becoming well understood, with limited HVAC market share. Water usage for high efficiency evaporative coolers can be less than the water used to cool central station utility generators that are supplying the electricity for conventional compressor based cooling. Instead of peak demands of 3 to 5 kilowatts (kW) (or more) for compressor based direct expansion (DX) air conditioning, typical demands for mid-size evaporative coolers are on the order of 1 kW.[1]

High efficiency evaporative coolers operate through the evaporation of water. They employ a heat exchanger to separate most of the moisture from the ventilation supply air, provide continuous ventilation with fresh outside air, are quieter, and use up to 70 percent less energy than the standard compressor based air-conditioning.

2. COMBINING PV AND HIGH EFFICIENCY EVAPORATIVE COOLERS

A DC motor installed on high efficiency evaporative coolers can be sized to use the additional electrical production of summer months directly from PV system; corresponding to when building cooling is most needed. This energy can be supplied from a modest PV system. Directly coupling the DC output from a PV system can eliminate the need for inefficiencies of DC to alternating current (AC) inverters. Because inverters are not used, potentially 8% more useful PV generated electricity can be utilized based on a 92% inverter weighted efficiency. PV system voltage and motor voltage can theoretically be matched during times of maximum PV outputs, the same time HVAC is needed. Electronically commutated, brush-less DC motor systems are now used as drives for blowers and fans in many evaporative coolers. These DC motors are known for their reliability and high efficiency.

Table 1 shows the hours of operation for a two stage evaporative cooler in various cities, operating in a low or high speed setting depending upon the need for cooling. In addition, Table 1 shows data from a separate study comparing conventional air conditioning compressor based DX cooling and high efficiency evaporative cooling.

This referenced study assumed the DX systems have an energy efficiency rating (EER) of 11.1 (roughly corresponding to a seasonal energy efficiency rating, SEER, of 12.9) and a thermostat set point of 76 degrees F. This study also assumed a run time of the evaporative coolers to exceed that of the replaced conventional air conditioning systems by 43% at an average power consumption of 800 watts.[1] A PV system

TABLE 1. HOURS OF COOLING & ENERGY COMPARISON OF DX AND EVAP [1] & [2]

City	Yearly Hours Evap [2]	Cooling Energy DX kWh/yr [1]	Cooling Energy Evap kWh/yr [1]	Evap / DX % [1]
Albuquerque	1,404	2,487	334	13.4%
Las Vegas	1,587	4,722	497	10.5%
Phoenix	1,648	6,043	574	9.5%
Salt Lake City	1,375	2,839	357	12.6%
Sacramento	1,342	*	*	*
Denver	*	1,935	279	14.4%
Table Average:	1,471	3,605	408	11.3%

* Not Available

TABLE 2. 3 kW_{PTC} PV EVALUATION FOR VARIOUS SOUTHWEST CITIES

City	3 kW_{PTC} PV (kWh)	Latitude/ Slope	3 kW_{PTC} Minus Evap (kWh)	Evap w/extra energy (kWh)	Total Useful Energy (kWh)	Total Useful Energy kWh/Kw_{PTC}
Albuquerque	5,706	35.0	5,372	361	5,732	1,911
Las Vegas	5,654	36.0	5,157	537	5,694	1,898
Phoenix	5,436	33.0	4,862	620	5,482	1,827
Salt Lake City	4,730	40.5	4,373	386	4,759	1,586
Sacramento*	4,711	38.3	4,303	386	4,689	1,563
Boulder *	4,976	40.0	4,567	441	5,008	1,669
Table Average:	5,382		4,973	441	5,417	1,806

Note: Boulder Colorado weather data and latitude used, not Denver;
Sacramento evaporative energy extrapolated from Salt Lake City.

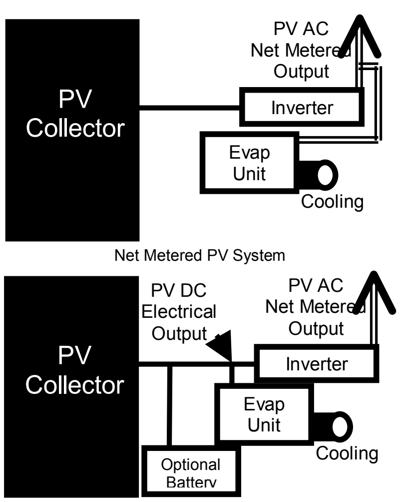

Figure 1. Net Metered PV, AC & DC HVAC.

could eliminated the demand for electricity to run HVAC equipment, providing a utility the peak reduction benefits.

Figure 1 illustrates airflow, DC and AC power for high efficiency evaporative coolers in a net metered PV system, and the DC powered version with an optional battery for voltage control or night time usage.

A south facing, latitude tilt, rack mounted 3 kW_{PTC} crystalline silicon PV system would produce an estimated annual energy shown in Table 2 for the various cities. Initial study based on calculations from BIPV Designer shareware (Google "BIPV" for software [3]). Design parameters are a 3-meter by 9 meter PV array, tilted at latitude, ground reflectivity is 20%. Other parameters are system efficiency; 80% for normal AC power, (88% for the directly coupled commutated DC motor on the evaporative cooler), module efficiency at 12.3% and temperature correction at 0.0047/ ^{o}C (ASE-300-DGF/17-300, 269.1 watts PTC {CEC}, 2.42 m^2). Figure 2 shows available variables in BIPV Designer. Subtracting the energy used for evaporative coolers, with an 8% efficiency gain for no DC to AC losses is also shown in Table 2.

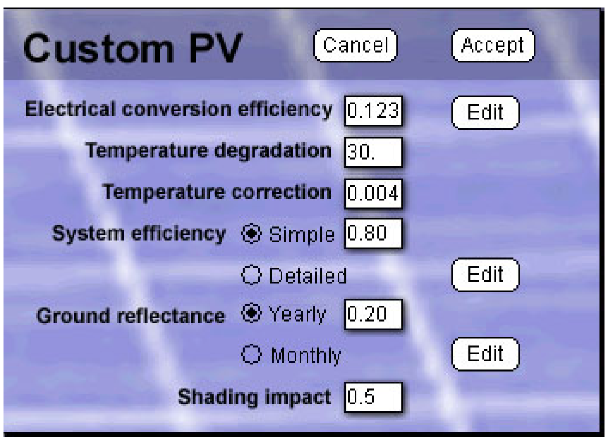

Fig. 2: Interactive variables available in BIPV Designer.

3. ECONOMICS

A Denver based PV installation of 3 kW_{PTC}, would receive an Amendment 37 rebate of \$5.09 / kW_{PTC} or \$15,270; plus \$1,719 tax savings from the 2005 Federal Energy Policy. A 3 kW_{PTC} system is estimated to cost \$7 per PTC watt to install, for a total out of pocket cost of \$4,011 including the PV rebate and tax savings.

In 2005, Xcel provided rebates for evaporative coolers up to \$200 (Pacific Gas and Electric is \$500 for high efficiency systems). A system of only 1 kW_{PTC} would be needed to provide a ¾ HP (559 Watts) electronically commutated DC motor with the electricity needed, still assuming some losses from the PV system. However, a 3 kW_{PTC} system would provide additional economics by optimizing the inverter for non-summer months, operating more hours in optimal inverter conditions. A 2.5 kW inverter would suffice for 3 kW_{PTC} PV modules that used DC to run an evaporative cooler during summer daylight hours. The system would be better optimized for the fall, winter and spring sun hour operation because the inverter would more likely operate in an efficient manner. Figure 3 shows a typical inverter efficiency curve, this one for the SMA Sunny Boy 2500U.

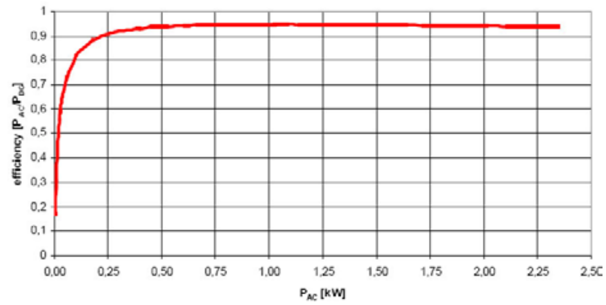

Figure 3. Efficiency curve for the Sunny Boy 2500U (courtesy of SMA-America).

High efficiency evaporative coolers installed costs are \$400 to \$850 more than DX systems, depending upon efficiency; and use about as much water as a compressor based air conditioner when considering water usage at the power plant.[1]

Fig. 4. High efficiency evaporative coolers (image courtesy of Coolerado).

An image of a high efficiency heat and mass exchanger cooler is shown in Figure 4. The Coolerado R600 delivers 1,500 CFM of conditioned air. 1,500 CFM is also discharged as saturated exhaust air. There is 0.7 inches of water column pressure drop across the heat and mass exchangers at this flow rate. The fans are designed to take another 1/2 inch of pressure drop downstream from the air conditioner. The system uses an electronically commutated motorized impeller from EBM that draws 800 watts of power at full speed. The R600 provides about 5 tons of cooling when operated in the western US, and has an EER of 60+ (Not an EER equivalent, an actual EER since no moisture is added to the conditioned air stream). This tonnage and EER can be directly compared to vapor compression systems operating in a 100% makeup air environment. When comparing to a residential or recirculation environment, this equates to about 3 tons of cooling at an EER of 40+. The conditioned air will be within a couple degrees of the entering air's wet bulb temperature (again, without adding moisture to it). [4]

2003 energy costs to run DX HVAC average $335/year in the Southwest; in Phoenix costs are $502/year .[5] Rebates for PV and high efficiency evaporative coolers, combined with decades of complete removal of escalating energy costs, provide attractive economics for directly coupling DC from PV systems to high efficiency evaporative coolers. All rebate fine print needs to be investigated for adherence to the constantly changing rules for mechanical and PV equipment incentives.

4. POLICY

Many utilities are providing rebates for customers who install PV systems [6]. Reasons for this policy vary from environmental to jobs creation to utility system benefits. Some Southwest state utilities are recognizing benefits in providing rebates for evaporative coolers in place of compressor based air conditioning systems. Combining these two technologies might provide an even higher profit margin to those utilities with intense HVAC driven peak electrical usage. Utility energy efficiency, renewable portfolio standards, utility system benefits and local jobs creation goals can be combined with an appropriate combination of end-use energy products, and distributed generation renewable energy technologies, like PV.

Theoretically, for people who will be installing PV anyway, an incentive could be created that justified an additional 500 watts of PV for running DC based high efficiency evaporative coolers for Southwest states. The additional cost for installation is estimated to be $5 per PTC watt (2006) because transaction, labor and balance of systems costs for the additional 500 watts of PV would be minimal.

5. CONCLUSION

This paper attempts to show advantages in combining PV with high efficiency evaporative cooling technologies. High efficiency evaporative coolers do not cost much more to install, and use about as much water as a compressor based air conditioner when considering water usage at the power plant. They use one quarter of the energy, and provide substantial savings to utilities in Southwest states in reducing peak electricity needs. By providing the electricity to an evaporative cooler directly from a PV system, the total HVAC load is removed from the grid. Additional savings come from the direct use of the DC electricity provided by PV systems.

6. ACKNOWLEDGEMENT

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