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Research Article

A general overview of Solar Thermal Applications and Solar Photovoltaics Applications.

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Abstract: This paper represents the modern investigation on incredible solar energy in real World. The Sun is the ultimate source of energy. Here we are focusing on ‘Village Electrification by Photovoltaic Micro Grid Using Solar Energy’ i.e. micro grid using solar/photovoltaic cell as renewable energy source Solar Energy. This Paper also deals with the various utilities of Solar energy and make life comfortable & nature friendly. Model of Solar/Photovoltaic Micro Grid is made using Simulink/MATLAB. Solar energy is an important, clean, cheap and abundantly available renewable energy. This Paper also deals with the various utilities of solar energy and makes life comfortable & nature friendly.

INTRODUCTION

***Solar Energy*:** The sun radiates about 3.8 x 1026 W of power in all the directions. Out of this about 1.7 x 1017 W is received by earth. The average solar radiation outside the earth’s atmosphere is 1.35 kW/m2 varying from 1.43 kW/m^2 (in January) to 1.33 kW/m^2 (in July). It is received on Earth in cyclic, intermittent and dilute form with very low power density 0 to 1 kW/m^2 .Solar energy received the ground level is affected by atmospheric clarity, degree of latitude, etc. For design purpose, the variation of available solar power, the optimum tilt angle of solar flat plate collectors, the location and orientation of the heliostats should be calculated.

Solar energy is the most readily available and free source of energy since prehistoric times. It is estimated that solar energy equivalent to over 15,000 times the world's annual commercial energy consumption reaches the earth every year. Renewable energy sources also called non-conventional energy, are sources that are continuously replenished by natural processes**.** For example, solar energy, wind energy, bio-energy - bio-fuels grown sustain ably), hydropower etc., are some of the examples of renewable energy sources. Energy is expressed in Joule. 1 Cal = 4.186 J

For solar energy calculations, the energy is measured as an hourly or monthly or yearly average and is expressed in terms of kJ/m2/day or kJ/m2/hour. Solar power is expressed in terms of W/m^2 or kW/m^2.

Solar Thermal Energy Application: In solar thermal route, solar energy can be converted into thermal energy with the help of solar collectors and receivers known as solar thermal devices. The Solar-Thermal devices can be classified into three categories:

(I), Low-Grade Heating Devices - up to the temperature of 100°C.

(II).Medium-Grade Heating Devices -up to the temperature of 100°-300°C

(III).High-Grade Heating Devices -above temperature of 300°C

Figure- 1: Solar Flat plate collector

Figure -2: Box Type Solar

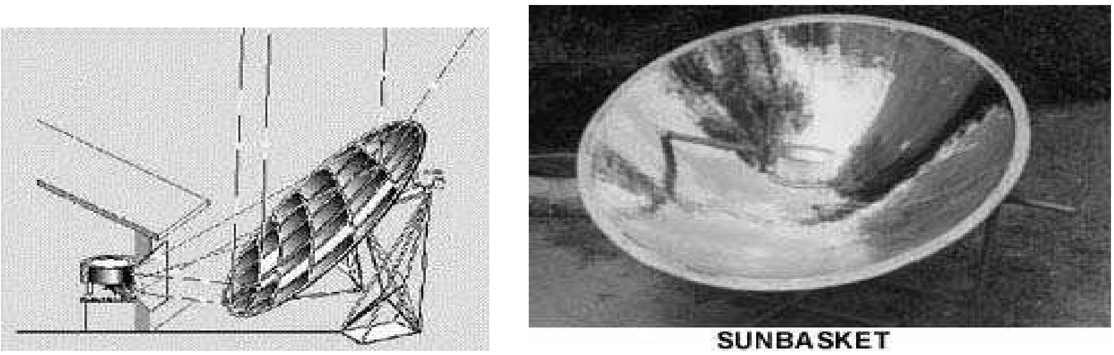

Figure -3: Photavoltaic sun baskets

Solar Photovoltaic (PV): Photovoltaic is the technical term for *solar electric*. Photo means "light" and voltaic means "electric". PV cells are usually made of silicon, an element that naturally releases electrons when exposed to light. Amount of electrons released from silicon cells depend upon intensity of light incident on it. The silicon cell is covered with a grid of metal that directs the electrons to flow in a path to create an electric current.

***Solar Photovoltaic Array*: G**uided into a wire that is connected to a battery or DC appliance. Typically, one cell produces about 1.5 watts of power. Individual cells are connected together to form a solar *panel* or *module*, capable of producing 3 to 110 Watts power. Panels can be connected together in series and parallel to make a solar *array* (**Figure -4**), which can produce any amount of Wattage as space will allow. Modules are usually designed to supply electricity at 12 Volts. PV modules are rated by their peak Watt output at solar noon on a clear day.

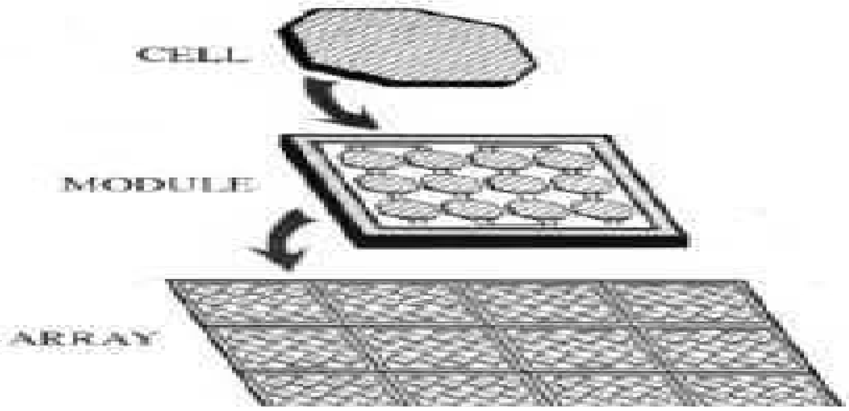

Figure -4: Solar Photovoltaic Array

(iii)Solar Water Pumps: In solar water pumping system, the pump is driven by motor run by solar electricity instead of conventional electricity drawn from utility grid. A SPV water pumping system consists of a photovoltaic array mounted on a stand and a motor-pump set compatible with the photovoltaic array. It converts the solar energy into electricity, which is used for running the motor pump set. The pumping system draws water from the open well, bore well, stream, pond, canal etc.

Figure -5: Solar Water Pumps

The density of power radiated from the sun (referred to as the ‘‘solar energy constant’’) at the outer atmosphere is 1.373kW/m2. Part of this energy is absorbed and scattered by the earth’s atmosphere. The final incident sunlight on earth’s surface has a peak density of 1kW/m2 at noon in the tropics. The technology of photovoltaic’s (PV) is essentially concerned with the conversion of this energy into usable electrical form. The basic element of a PV system is the solar cell. Solar cells can convert the energy of sunlight directly into electricity. The paper presents a hybrid PV/FC renewable energy scheme for supplying an isolated community with electrical energy. In order to obtain electricity from the hybrid green system at an economical price, its topology and control design must be optimized in terms of coordinated operation and layout configuration. Many topologies are currently available for integrated green system configurations, depending on the use of interface converters based on common DC/common AC bus interface architecture. Solar panels can be connected in parallel or in series to obtain required photovoltaic power rating. The power obtained by this way is DC in nature and it should be converted to AC for some AC type loads. Therefore, DC to AC converters are required for such load types. Electrical energy is not only required during day time, but also at night. This key requirement puts forwards the possible use of other renewable green energy sources, such as fuel cells in integrated micro co-generation schemes[8,9]. The Electrochemical voltage behavior of the fuel cell is commonly modeled using the simple equivalent first order (RC). This circuit consists of three passive circuit elements that result in a first order approximation of the dynamic response of the electrochemical capacitor. The circuit includes the double layer capacitance RC in series with ohmic resistance. The equivalent series resistance that represents the energy lost due to the distributive resistance of the electrolyte, electronic contacts and the porous separator[5,6]. Hydrogen itself is a clean and emission free fuel. Currently Hydrogen technology is concentrating on the storage methods, efficient and safe Fuel Cell Batteries. Enhancing the output efficiency and improving the performance of fuel cell are among main research topics.

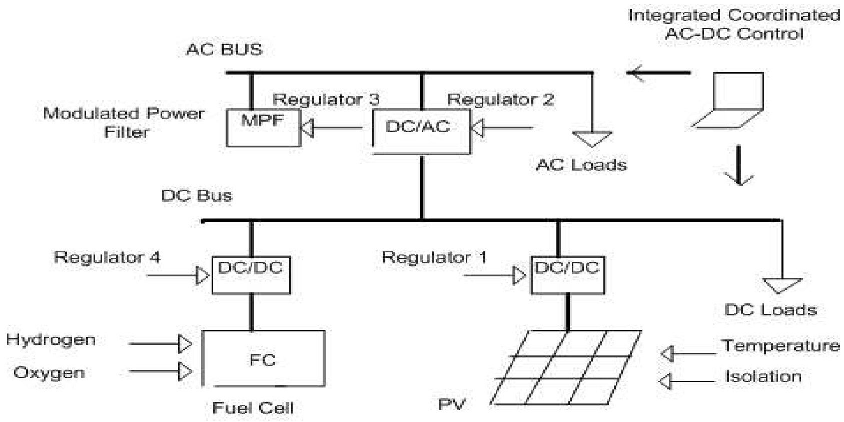

Figure -6: Green Energy Scheme for Electricity Supply

The industrial applications of fuel cell technology are still limited to hybrid electric vehicles. Little papers are dealing with the power system application of fuel cell and system interactions. Therefore, the interaction of fuel cell with power system components and switching electronic drives, choppers and controllers are crucial. The generated electrical energy in fuel cell could be directly connected to the common DC bus through DC-DC-Chopper to convert the stored energy in hydrocarbon to DC electrical energy[4,5]. In integrated green energy power system, Fuel cell and solar are fully used as the main energy sources to supply the hybrid DC and AC type loads. India receives solar energy in the region of 5 to 7 kWh/m^2 for 300 to 330 days in a year. This energy is sufficient to set up 20 MW solar power plant per square kilometer land area.
Fig.(6) Integrated (FC-PV) Green Energy Scheme for Electricity Supply Figure (6) shows the scheme of the studied system with common DC/ common AC collection bus interface. The scheme uses a primary common DC bus collection with an added secondary common AC bus for feeding any AC loads and public grid interface. The proposed hybrid green energy scheme is digitally simulated for different operation conditions and load excursions. The proposed control scheme comprises multi-loop dc-coupled coordinated dynamic error driven controllers with supplementary regulation loops to control the different subsystems[6,7].

COORDINATED ERROR DRIVEN TRI-LOOP CONTROLLER

Figure-7 shows the general four regulator coordinated control structure. The hybrid system was digitally simulated and validated using MATLAB/Simulink–SimPower software environment in order to test the controller performance for interfacing devices of PV panels and wind generator under changing weather conditions and load disturbances. The simulation results show that the effects of the change in solar radiation and ambient temperature are compensated by controlling the DC-DC chopper, which interfaces the PV panel to the common DC bus. Similarly the effect of wind speed variations is compensated by controlling the AC-DC rectifier converter, which interfaces the wind generator to the common DC bus. The controller of pulse width modulated inverter reduces the effect of AC load disturbances. Voltage stabilization is achieved by installing the modulated power filter on the AC common bus[10, 11].

Essential subsystems in a solar energy plant:

1. **Solar collector or concentrator**: It receives solar rays and collects the energy. It may be of following types:

a) Flat plate type without focusing

b) Parabolic trough type with line focusing

c) Paraboloid dish with central focusing

d) Fresnel lens with centre focusing

e) Heliostats with centre receiver focusing

2. **Energy transport medium**: Substances such as water/ steam, liquid metal or gas are used to transport the thermal energy from the collector to the heat exchanger or thermal storage. In solar PV systems energy transport occurs in electrical form.

3. **Energy storage**: Solar energy is not available continuously. So we need an energy storage medium for maintaining power supply during nights or cloudy periods. There are three major types of energy.

4. **Energy conversion plant**: Thermal energy collected by solar collectors is used for producing steam, hot water, etc. Solar energy converted to thermal energy is fed to steam-thermal or gas-thermal power plant.

5. **Power conditioning, control and protection system**: Load requirements of electrical energy vary with time. The energy supply has certain specifications like voltage, current, frequency, power etc. The power conditioning unit performs several functions such as control, regulation, conditioning, protection, automation, etc.

6. **Alternative or standby power supply**: The backup may be obtained as power from electrical
Network or standby diesel generator.

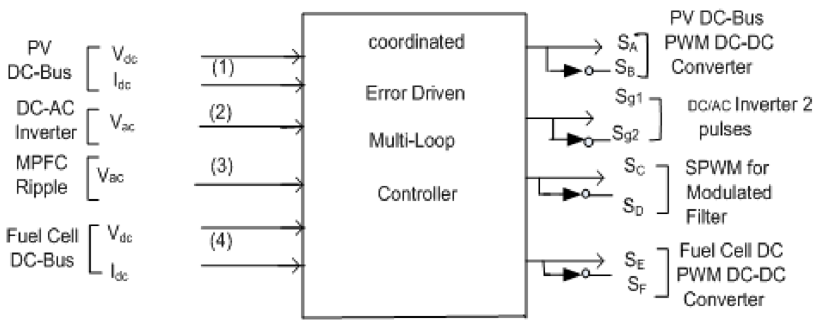

Fig.7.0

PV Charge Controllers: Blocking diodes in series with PV modules are used to prevent the Batteries from being discharged through the PV cells at night when there is no sun available to generate energy. These blocking diodes also protect the battery from short circuits. In a solar power system consisting of more than one string connected in parallel, if a short-circuit occurs in one of the strings, the blocking diode prevents the other PV strings from discharging through the short-circuited string. The battery storage in a PV system should be properly controlled to avoid catastrophic operating conditions like overcharging or frequent deep discharging. Storage batteries account for most PV system failures and contribute significantly to both the initial and the eventual replacement costs. Charge controllers regulate the charge transfer and prevent the battery from being excessively charged and discharged.

Three types of charge controllers are commonly used:

1. Series charge regulators
2. Shunt charge regulators
3. DC–DC Converters

Series Charge Regulators: In the series charge controller, the switch S1 disconnects the PV generator when a predefined battery voltage is achieved. When the voltage falls below the discharge limit, the load is disconnected from the battery to avoid deep discharge beyond the limit. The main problem associated with this type of controller is the losses associated with the switches. This extra power loss has to come from the PV power, and this can be quite significant. Bipolar transistors, MOSFETs, or relays are used as the switches.

Shunt Charge Regulators: In Shunt Charge Regulators when the battery is fully charged the PV generator is short-circuited using an electronic switch (S1). Unlike series controllers, this method works more efficiently even when the battery is completely discharged, as the short circuit switch need not be activated until the battery is fully discharged [1]. The blocking diode prevents short-circuiting of the battery. Shunt charge regulators are used for small PV applications (less than 20 A). Deep-discharge protection is used to protect the battery against deep discharge. When the battery voltage reaches below the minimum set point for the deep discharge limit, switch S2 disconnects the load. Simple series and shunt regulators allow only relatively coarse adjustment of the current flow and seldom meet the exact requirements of PV systems.

DC–DC Converter Type Charge Regulators: Switch mode DC-to-DC converters are used to match the output of a PV generator to a variable load. There are various types of DC–DC converters:

(i) Buck (step-down) converter

(ii) Boost (step-up) converter

(iii) Buck-boost (step-down/up) converter

PV System Characteristics and Impacts

Today's grid-connected residential and commercial systems typically have the following characteristics and associated impacts:

The PV system and the inverter are connected to the grid in parallel with the load.

The load is served whenever the grid is available.

Energy produced by the PV system decreases the apparent load. Energy produced in excess of the load flows into the distribution system.

The PV system has no storage and cannot serve the load in the absence of the grid.

The PV system produces power at unity power factor and utility supplies all Volt Ampere reactive power.

The inverter meets the requirements of IEEE 1547-2005.

There is no direct communication or control between the utility and the inverter.

If the inverter senses that utility service has fallen outside set boundaries for voltage and/or frequency or utility service is interrupted, the inverter will disconnect from the utility until normal conditions resume. The load remains connected to the utility.

For residential and small-commercial systems, the grid interconnection is typically net-metered at a flat rate.

• The price of energy is constant throughout the day and there is no demand charge.

• When excess energy is produced, the meter spins backwards.

Energy is bought and sold at the same price.

Over the course of a month or a year, if energy produced exceeds energy used, the utility will not pay for the excess above the amount used.

If the grid is not available, grid-tied PV inverters (without energy storage and load transfer capability) cannot serve the load, even when sunlight is present and the PV modules are able to produce power.

For large-scale commercial systems, rate structures are more complex.

Time-of-use rates often apply, with cost of energy being higher during periods of peak demand.

Demand charges may apply with a significant portion of the utility bill derived from the highest power requirement (kW) measured over a 15 to 30 minute interval during the monthly billing period.

A charge for VARS (reactive power) may apply.

Net metering is less common, and some systems are not permitted to deliver any power back to the utility. In this case, the load must always exceed the energy generated by the solar system.Other systems have dual meters and power is purchased by the utility at a lower rate than the rate charged for power supplied by the utility to the customer.

Solar energy can be utilized through two different routes, as solar thermal route and solar electric (solar photovoltaic) routes. Solar thermal route uses the sun's heat to produce hot water or air, cook food, drying materials etc. Solar photovoltaic uses sun’s heat to produce electricity for lighting home and building, running motors, pumps, electric appliances, and lighting.

A renewable energy system converts the energy found in sunlight, wind, falling-water, sea-waves, geothermal heat, or biomass into a form, we can use such as heat or electricity. Most of the renewable energy comes either directly or indirectly from sun and wind and can never be exhausted, and therefore they are called renewable. However, most of the world's energy sources are derived from conventional sources-fossil fuels such as coal, oil, and natural gases. These fuels are often termed non-renewable energy sources. Although, the available quantity of these fuels are extremely large, they are nevertheless finite and so will in principle ‘run out’ at some time in the future Renewable energy sources are essentially flows of energy, whereas the fossil and nuclear fuels are, in essence, stocks of energy.

Distribution of Solar Energy System: As deployment of distributed PV systems increases, many customers are likely to be subject to time-of-use rates and demand charges, and will be paid less for energy delivered to the utility at a particular time of day than they will be charged for energy delivered by the utility at that same time. However, by employing control strategies that optimize value, a SEGIS can mitigate the effects of these rate structures or even exceed the value received by today’s net-metered flat-rate customers. The SEGIS will need to manage power flows to and from the utility so that power is purchased from the utility mainly when rates are low, peak demand is minimized, and power is sold to the utility mainly when rates are high.

A first step in optimizing value is to consider the rate structure when establishing the orientation (azimuth and tilt) of the PV modules. At least for regions where utility demand peaks in the summer and time-of-use rates apply, having a portion of the array facing west may provide more value to the customer, even though total energy delivered may be lower.

A second step in optimizing value is to dispatch loads to operate in concert with the availability of solar energy and/or cheap utility power. This could occur by direct communication between the inverter and smart loads via standardized protocols or via inverter communication with an energy management system. Note that some loads may have their own storage and thus are particularly suited to dispatch. For example, tank-type electric water heaters store hot water and can be controlled to heat more water only when either excess solar energy or cheap utility power is available. Even the thermal mass of a building can be used to minimize evening demand, as illustrated by a Florida Solar Energy study of a home with south and west facing PV and a multi-speed air conditioner, shown in Figure 3.4 This study illustrates the importance of building system design in optimizing solar system value. If PV had been added to the control home, peak daytime demand would have been reduced, but demand after 6 pm would have remained high. On the other hand, if the energy-efficient home had been built without PV, there still would have been significant daytime peak demand (the sum of the red and blue lines). It is the combination of PV and building system design that results in nearly complete elimination of the evening peak. Note that optimizing the performance of a system with more than one orientation for the PV array requires either multiple inverters or inverters with multiple maximum power point tracking inputs.

A third step in optimizing value is to add energy storage so excess solar energy or cheap utility power can be stored for later use when building demands dictate and excess or cheap power is not available. For buildings with demand charges, addition of storage has been shown to add value to the PV system5, as shown in Figure 4. Storage can have the added benefit of enabling the building to continue to operate critical loads during a utility outage.

To maximize the benefit of the PV system without an undue burden on the building owner/operator may require a control system with adaptive logic. Such a controller would monitor demand, solar energy supply, and utility rates to optimize the flow of energy based on time of day, day of the week, and time of year by controlling dispatch able loads and storage operation. The controller might also communicate with utility smart-metering devices to obtain real-time pricing, and via the internet would monitor weather trends and forecasts to anticipate the availability of the solar resource as well as the real-time price of solar power.

PV tracking systems is an alternative to the fixed, stationary PV panels. PV tracking systems are mounted and provided with tracking mechanisms to follow the sun as it moves through the sky. These tracking systems run entirely on their own power and can increase output by 40%.

Back-up systems are necessary since PV systems only generate electricity when the sun is shining. The two most common methods of backing up solar electric systems are connecting the system to the utility grid or storing excess electricity in batteries for use at night or on cloudy days.

PERFORMANCE

The performance of a **sol**ar cell is measured in terms of its efficiency at converting sunlight into electricity. Only sunlight of certain energy will work efficiently to create electricity, and much of it is reflected or absorbed by the material that makes up the cell. Because of this, a typical commercial solar cell has an efficiency of 15%—only about one-sixth of the sunlight striking the cell generates electricity. Low efficiencies mean that larger arrays are needed and higher investment costs. It should be noted that the first solar cells, built in the 1950s, had efficiencies of less than 4%.

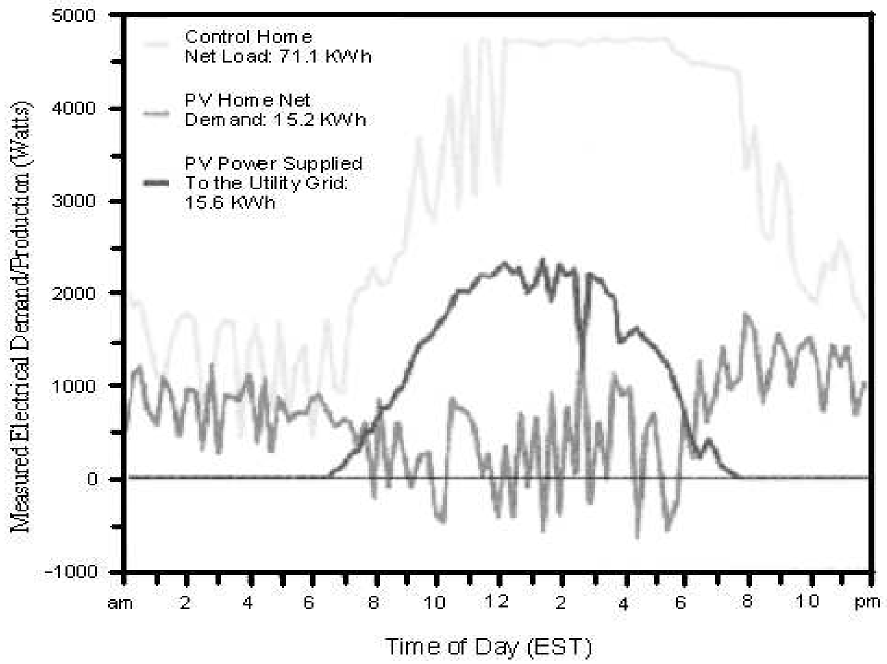

Fig.8: Peak Reduction from Combined Use of Solar Energy and Demand Management in a Residential Application4

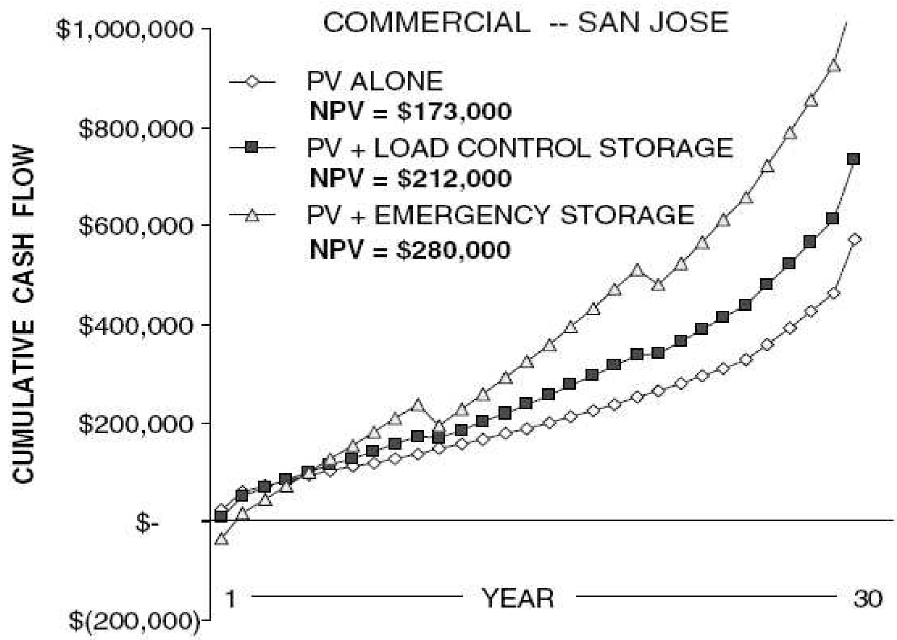

Fig.9: Cumulative Cash Flow for Commercial Customers – Comparing PV-alone, PV + Local Load Management (MBES) Storage and PV + Emergency Storage Options.5

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