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A Review of Solar Air Conditioning System

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Abstract*— Solar air conditioning can be done through solar thermal energy conversion and photovoltaic conversion (sunlight to electricity). The U.S. Energy Independence and Security Act of 2007[1] created 2008 through 2012 funding for a new solar air conditioning research and development program, which should develop and demonstrate multiple new technology innovations and mass production economies of scale. Solar air conditioning might play an increasing role in zero-energy and energy-plus buildings design.

Index Terms*— solar energy, thermal energy collector, free energy, radiant cooling.

I. INTRODUCTION

In the late 19th century, the most common fluid for absorption cooling was a solution of ammonia and water. Today, the combination of lithium bromide and water is also in common use. One end of the system of expansion/condensation pipes is heated, and the other end gets cold enough to make ice. Originally, natural gas was used as a heat source in the late 19th century. Today, propane is used in recreational vehicle absorption chiller refrigerators. Hot water solar thermal energy collectors can also be used as the modern "free energy" heat source.

Photovoltaics can provide the power for any type of electrically powered cooling be it conventional compressor-based or absorption-based, though the most common implementation is with compressors. For small residential and small commercial cooling (less than 5 MWh/a) PV-powered cooling has been the most frequently implemented solar cooling technology. The reason for this is debated, but commonly suggested reasons include incentive structuring, lack of residential-sized equipment for other solar-cooling technologies, the advent of more efficient electrical coolers, or ease of installation compared to other solar-cooling technologies (like radiant cooling).

Since PV cooling's cost effectiveness depends largely on the cooling equipment and given the poor efficiencies in electrical cooling methods until recently it has not been **cost** effective without subsidies. Using more efficient electrical cooling methods and allowing longer payback schedules is changing that scenario.

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For example, a 100,000 BTU U.S. Energy Star rated[note 1] air conditioner with a high seasonal energy efficiency ratio (SEER) of 14 requires around 7 kW of electric power for full cooling output on a hot day. This would require over a 7 kW solar photovoltaic electricity generation system (with morning-to-evening, and seasonal solar tracker capability to handle the 47-degree summer-to-winter difference in Sun elevation angle). The photovoltaics would only produce full output during the sunny part of clear days.

A solar-tracking 7 kW photovoltaic system would probably have an installed price well over $20,000 USD (with PV equipment prices currently falling at roughly 17% per year). Infrastructure, wiring, mounting, and NEC code costs may add up to an additional cost; for instance a 3120 watt solar panel grid tie system has a panel cost of $0.99/watt peak, but still costs ~$2.2/watt hour peak. Other systems of different capacity cost even more, let alone battery backup systems, which cost even more. Due to the advent of net metering allowed by utility companies, a photovoltaic system can produce enough energy in the course of the year to completely offset the cost of the electricity used to run air conditioning, depending on the amount of electric costs one wishes to offset.

A more efficient air conditioning system would require a smaller, less-expensive photovoltaic system. A high-quality geothermal heat pump installation can have a SEER in the range of 20 (±). A 100,000 BTU SEER 20 air conditioner would require less than 5 kW while operating.

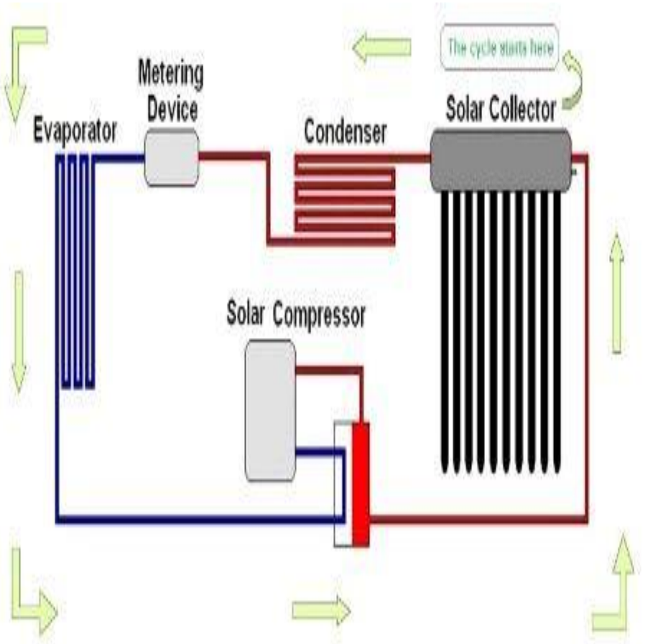

Fig. 1. Block diagram of solar air conditioner

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Newer and lower power technology including reverse inverter DC heat pumps can achieve SEER ratings up to 26. There are new non-compressor-based electrical air conditioning systems with a SEER above 20 coming on the market. New versions of phase-change indirect evaporative coolers use nothing but a fan and a supply of water to cool buildings without adding extra interior humidity (such as at McCarran Airport Las Vegas Nevada). In dry arid climates with relative humidity below 45% (about 40% of the continental U.S.) indirect evaporative coolers can achieve a SEER above 20, and up to SEER 40. A 100,000 BTU indirect evaporative cooler would only need enough photovoltaic power for the circulation fan (plus a water supply).

A less-expensive partial-power photovoltaic system can reduce (but not eliminate) the monthly amount of electricity purchased from the power grid for air conditioning (and other uses). With American state government subsidies of $2.50 to $5.00 USD per photovoltaic watt,[2] the amortized cost of PV-generated electricity can be below $0.15 per kWh. This is currently cost effective in some areas where power company electricity is now $0.15 or more. Excess PV power generated when air conditioning is not required can be sold to thepower grid in many locations, which can reduce (or eliminate) annual net electricity purchase requirement. (See Zero-energy building)

II. WORKING PRINCIPLE

Superior energy efficiency can be designed into new construction (or retrofitted to existing buildings). Since the U.S. Department of Energy was created in 1977, their WeatherizationAssistance Program[3] has reduced heating-and-cooling load on 5.5 million low-income affordable homes an average of 31%. A hundred million American buildings still need improved weatherization. Careless conventional construction practices are still producing inefficient new buildings that need weatherization when they are first occupied.

It is fairly simple to reduce the heating-and-cooling requirement for new construction by one half. This can often be done at no additional net cost, since there are cost savings for smaller air conditioning systems and other benefits.

Earth sheltering or Earth cooling tubes can take advantage of the ambient temperature of the Earth to reduce or eliminate conventional air conditioning requirements. In many climates where the majority of humans live, they can greatly reduce the buildup of undesirable summer heat, and also help remove heat from the interior of the building. They increase construction cost, but reduce or eliminate the cost of conventional air conditioning equipment.

Earth cooling tubes are not cost effective in hot humid tropical environments where the ambient Earth temperature approaches human temperature comfort zone. A solar chimney orphotovoltaic-powered fan can be used to exhaust undesired heat and draw in cooler, dehumidified air that has passed by ambient Earth temperature surfaces. Control of humidity and condensation are important design issues.

Ambient earth temperature is much lower than peak summer air temperature, and much higher than the lowest extreme winter air temperature. Water is 25 times more thermally conductive than air, so it is much more efficient than an outside air heat pump, (which becomes less effective when the outside temperature drops in Winter).

The same type of geothermal well can be used without a heat pump but with greatly diminished results. Ambient Earth temperature water is pumped through a shrouded radiator (like an automobile radiator). Air is blown across the radiator, which cools without a compressor-based air conditioner. Photovoltaic solar electric panels produce electricity for the water pump and fan, eliminating conventional air-conditioning utility bills. This concept is cost-effective, as long as the location has ambient Earth temperature below the human thermal comfort zone

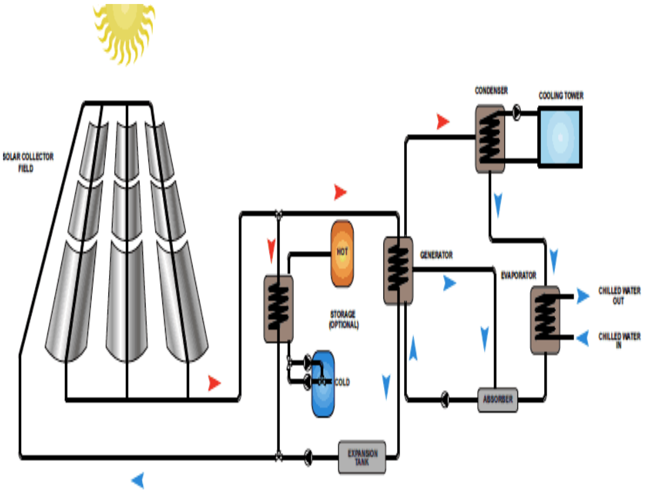

Fig. 2. Flow chart of solar AC process

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