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FEASIBILITY STUDY OF UTILIZING SOLAR ENERGY IN AUTOMOBILE AIR CONDITIONING

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ABSTRACT:

Air conditioner is the primary accessory of a passenger car which is used to maintain the vehicle cabin temperature and humidity at comfortable levels for a passenger. But this system consumes a lot of power and negatively affects the fuel efficiency of a car. Depleting natural oil resources, increasing oil prices and environment pollution increases the awareness about the need to use renewable sources. In past years, lot of efforts are being spent towards the application of solar energy to electric and hybrid cars, but a limited work is done on particularly air conditioning case. In the present work, feasibility study of solar operated hybrid vehicles has been discussed using fossil fuel and supplementary solar energy. Solar energy is used to run air conditioner or may be for other accessories. A break even cost analysis has also been carried out by taking a particular case of Maruti-Suzuki Alto car.

KEYWORDS

Hybrid vehicles, air conditioner, cost analysis.

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INTRODUCTION

Auto air conditioner consists of compressor, condenser, evaporator and expansion valve. These parts work in a cyclic process which is called vapour compression refrigeration cycle. Compressor is the most power consumable part of the air conditioner. In the present fossil fuel operated cars, compressor runs by directly belt connected with the engine. So put extra burden on the car engine.

The earth receives more energy from the Sun in just one hour than the world's population uses in a whole year. The total solar energy flux intercepted by the earth on any particular day is 4.2×10^{18} Watt hours or 1.5×10^{22} Joules (6.26×10^{20} Joules per hour). This is equivalent to burning 360 billion tons of oil (toe) per day or 15 Billion ton per hour. Solar power can be converted directly into electrical power in photovoltaic (PV) cells, commonly called solar cells. The sun has a surface temperature of about 6,000°C, and its hot gases at this temperature emit light that has a spectrum ranging from the ultraviolet, through the visible, into the infrared. Photovoltaic cells generally consist of a light absorber that will only absorb solar photons above certain minimum photon energy. This minimum threshold energy is called the “energy gap” or “band gap”, photons with energies below the band gap passes through the absorber, while photons with energies above the band gap are absorbed. Different materials have different band gap range and give different efficiency. Monocrystalline, polycrystalline and amorphous silicon are the main types of solar panel which are used for commercial purpose.

In stand-alone photovoltaic system, the electrical energy produced by the PV array cannot always be used when it is produced because the demand for energy does not always coincide with its production. Electrical storage batteries are commonly used in PV system. A battery is a device that converts chemical energy into electrical energy and vice versa. The primary functions of a storage battery in a PV system are: Energy Storage Capacity, Autonomy and voltage current Stabilization.

A solar panel may be installed of the roof of the car and generated electricity is stored in the battery. This stored battery power is used to run the compressor of auto air conditioner with the help of electric motor. Use of solar driven auto air conditioner system reduces the load of engine and it directly improves the fuel mileage of the car and less fuel consumption means less air pollution, so it is an eco-friendly system. It reduce the dependency of air conditioner on car engine i.e. there is no need to start the engine for air conditioner operation, this may helpful for many situations like on red lights. It may also enhance the life of air conditioner system by reducing the fluctuation of air conditioner parts. Installation of solar panel on the roof of the car reduces the amount of heat transmitted through the roof. Because those solar heat radiations are absorbed by the solar panel. Major advantage of this AC system is that there is direct relation between solar irradiance and cooling load requirement i.e. more the sunshine more will be the requirement of cooling (say in summer) and less the sunshine less will be the requirement of cooling (say in winter or monsoon). Extra solar energy power can also be used for power the other car accessories like music system, light, 12 V car battery etc.

REVIEW OF LITERATURE

A little work has already done on such kind of hybrid vehicles.

G.Rizzo (2010), studied the photovoltaic efficiency and cost relation with the time and shows a steep drop in photovoltaic power cost curve with time. The integration of photovoltaic panels in

electric and hybrid vehicles is becoming more feasible, due to the increasing fleet electrification, to the increase in fuel costs, to the advances in terms of PV panel technology, and to the reduction in their cost.

R. Farrington and J. Rugh (2010), studied the impact of vehicle air-conditioning on fuel economy, tailpipe emissions, and electric vehicle range. Conventional air-conditioning loads can reduce EV range and HEV fuel economy by nearly 40% depending on the size of the air-conditioner and the driving cycle. The peak cabin soak temperature must be reduced if a smaller air-conditioning system is to be used. Advanced glazing and cabin ventilation during soak conditions are effective ways to reduce the peak cabin temperature.

Nathan S. Lewis (2005), presented a detailed report on solar energy conversion and conclude several facts like the challenge in converting sunlight to electricity via photovoltaic solar cells is dramatically reducing the cost/watt of delivered solar electricity — by approximately a factor of 5–10% to compete with fossil and nuclear electricity and by a factor of 25–50% to compete with primary fossil energy.

B.D. Sharma (2011), studied the capacity utilization factor for different parts of India and estimated capacity factor varies from 16 to 20% in various parts of the country. At most locations in Rajasthan and Gujrat it is around 20%. In this study designed CUF is calculated for a plant is 20.8 and actual CUF is calculated 16.8.

Ahmad and Tiwari (2009), studied the variation of tilt angle with solar radiation in India. In this study angle of surface slope from the horizontal (ß) varies from 56 degree for January to 0 degree for May and June, again 58 degree for December.

INTEGRATION SYSTEM REQUIRED

Maruti Suzuki 1000 CC Alto car is particularly considered for this study. This car uses five cylinder swash plate reciprocating compressor for air conditioner, which is having pressure range from 1.3MPa (inlet) to 2.7MPa (outlet).

Power required to run this compressor at peak load = 738 Watt.
A 240V single phase alternative current motor of one horse power is required to run this compressor

Car's roof and hood available area is measured for the installation of solar panel:

Available Roof area= 148×85 = 12580cm^2
Available Hood area = 68×120 = 8160 cm^2
Total area = 20740cm^2 or 2m^2

Solar panel specifications:

Type = polycrystalline silicon panel
Power = 280 Watt
Voltage = 24 V

Polycrystalline silicon panels are selected for this application, because this type of solar panel shows good cost to power ratio as compare to monocrystalline and amorphous silicon panels. Generally polycrystalline panel give an efficiency of 15%, but in this kind of automobile application, angle between solar radiation and solar panel cannot be maintained ideally. And if a mechanism is made for variable sun tracking, then one should have to compromise with the aerodynamic shape of the vehicle. That may cause little improvement and major harm to the vehicle performance. So panel should be placed as the vehicle aerodynamic shape. Due to lack of possibility of ideal angle formation between sun rays and solar panels, panels may work with less effectiveness, so a lower photovoltaic efficiency of 13% is taken for this system design calculations.

Average sunshine received in India = 5.4 kWh/m^2

Power generated when panel receive whole day sunshine = 5.4 kWh/m^2 ×2 m^2×0.13
= 1.404kWh

Generated power is stored battery, having following specifications
Battery type = VRLA lead acid
Capacity = 3.0 kWh (50 % depth of discharge)
Voltage = 24V

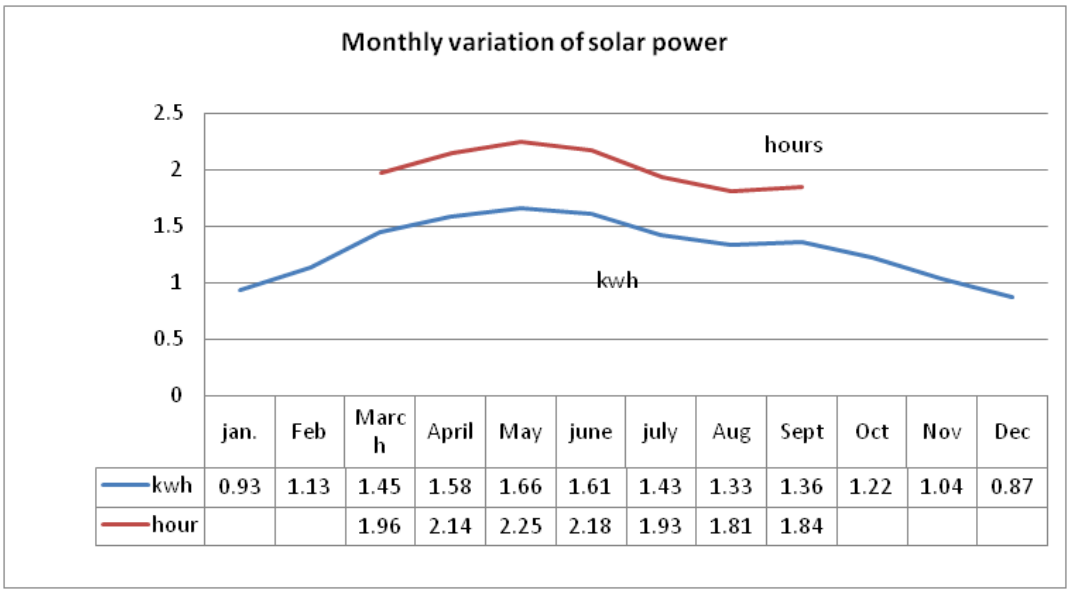
A 20ampere current rating solar charge controller is placed between panel and battery for the safety issues of battery.

Inverter is required to supply 240V AC current to the motor from the battery

RESULTS AND DISCUSSION

I.Power generated and load run time:

Polycrystalline panel is able to generate 1.404kWh energy in alto car, if it takes whole day sunshine and car air conditioner needs 0.738 kW power at peak load. Hence it can be calculated that using polycrystalline panel, it can generate power which is sufficient to run car air conditioner for nearly 2 hours.



	jan.	Feb	March	April	May	june	july	Aug	Sept	Oct	Nov	Dec
kwh	0.93	1.13	1.45	1.58	1.66	1.61	1.43	1.33	1.36	1.22	1.04	0.87
hour			1.96	2.14	2.25	2.18	1.93	1.81	1.84			

Fig.1.1: Monthly power generated and load run time

Solar energy varies from day to day. So the graph shows the monthly variations of solar power generation by using polycrystalline solar panel on the roof of the car. Air conditioner running hours are also shown up to which it can be run at full load. In India like country air conditioner is used six to seven months of a year. The biggest advantage of this system is that availability of solar energy has a direct relation with the cooling load of air conditioner. In other months of the year this solar power may be used for heating application or other accessories.

II.COST COMPARATIVE ANALYSIS:

Solar operated auto air conditioner system is eco friendly as compare to the present engine driven AC system. Generally combustion of one litre of petrol emits 240 gm of carbon mono oxide, 2.5 kg of carbon Di oxide, 1 gm of hydro carbons, and 0.1 gm of nitrogen oxide.

But for successful implementation of this system, it should be cost effective also. So a cost comparison is made between the present system and solar operated system. Break even analysis (BEP) is made for this cost analysis.

Following are some assumptions which are used for this cost analysis

i)The vehicle is run maximum 2 hour daily.
ii)Car takes complete day sunshine that may be during running or parking time.
iii)Car gives 20km/litre mileage without air conditioner work and 16km/litre with air conditioner work.
iv)Fuel price is 70Rs/litre
v)A car runs nearly one lakh km in 10 years of life.

Fixed cost:

Cost of panel: There is installation capacity of 280 Watt solar panel space on Maruti Suzuki Alto car, and the cost of large polycrystalline panels is generally taken as 40 Rs/watt, hence

Panel cost = 280×40= 11200 Rs
Cost of Lead acid battery = 18000 Rs

There are requirement of some other equipments like solar charge controller, AC motor, inverter etc.

So balance of system (BOS) cost is taken as 5000 Rs.
Total initial cost i.e fixed cost = 34200 Rs

Variable cost: In this system the only variable cost is battery replacement cost. As already mentioned, VRLA lead acid batteries are having a life of 1200 cycles. Generally a car uses 250 days of a year. Then battery replacement is required after 5 years or after 50,000 km of run. Generally battery has a 40% resale value. Hence battery maintenance cost is Rs 10800 on 50000km use.

Variable cost per unit km run: Rs 10800/50000= 0.216 Rs /km
Total cost: Fixed cost + Variable cost × km run

Fuel saved value by solar air conditioner:

As we have already assumed that car gives the mileage of 20km/litre when car run without air conditioner operation and 16 km/litre with air conditioner operation.

$$\text{Fuel saved using solar energy} = \left[\frac{x}{16} - \frac{x}{20}\right] \text{ litre}$$

Here x, is the distance travelled by the car with Air conditioner

$$\text{Now, saving in rupees} = 70 \times \left[\frac{x}{16} - \frac{x}{20}\right]$$

We can plot a graph using all the data that is calculated above

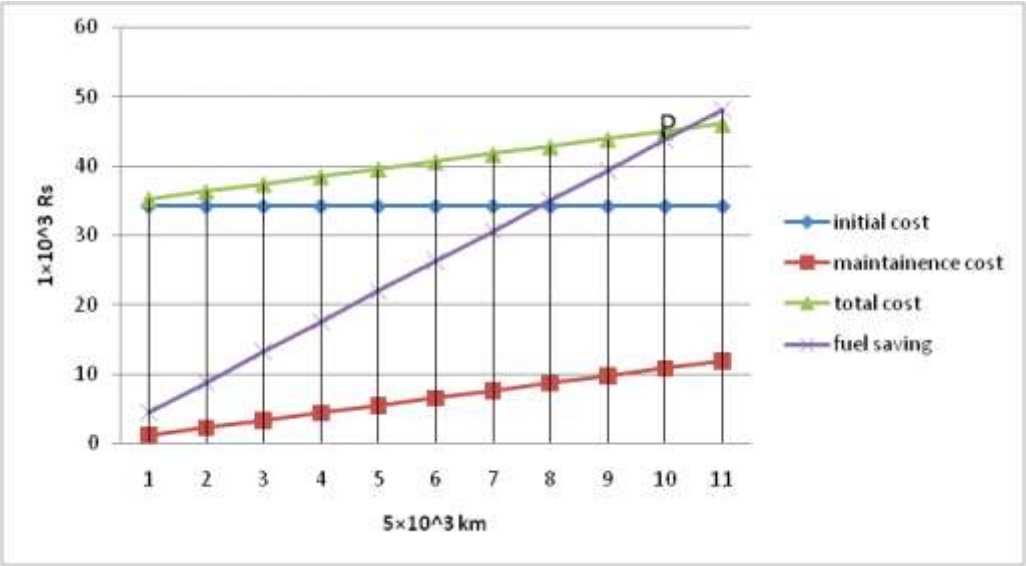


Fig.1.2: Cost analysis through breakeven point

In the above graph point 'p' is the breakeven point, which shows the point at which there is no profit and no loss.

Calculation of BEP:

X co-ordinate shows the car total km run and y co-ordinate shows the cost

Fixed cost (F): y = 34200 (1)
Variable cost or maintenance cost (V): y= 0.216 x (2)
Total cost (T): y= 34200 + 0.216 x (3)

Value of fuel saved by this solar operated system after x km:

$$y = 70 \times [\frac{x}{16} - \frac{x}{20}]$$

or y = 0.875 x (4)

At breakeven point:

34200 + 0.216 x = .875 x
x= 51897 km

At this point, if car runs 51897 km, owner of car can get his spent cost of solar system back in the form of fuel saving and any over running of car from this point gives him profit.

CONCLUSIONS

Feasibility of the solar driven auto air conditioner is checked under different working conditions and following conclusions are determined through the appropriate calculations and practical consideration with reasonable assumptions:

- There is direct relation between solar energy and AC requirement i.e. more the sunshine more will be the requirement of cooling(say in summer) and less the sunshine less will be the requirement of cooling (say in winter or monsoon). This relation gives the major strength to this project feasibility.
- Air conditioner compressor can be run with the help of 230 V, AC motor of power 738 watt.
- Sufficient solar power to run the motor can be generated by installing a solar panel on the roof of the car. This solar energy can run the motor nearly 2 hour a day at peak load.
- Polycrystalline solar panel and VRLA lead acid battery are advised for such a system work. Because this combination makes a good compromise between cost and work performance.
- This solar operated Air conditioner system is both eco friendly and cost effective. It reduces the dependency of Air conditioner on car engine i.e. air conditioner can be run without engine working like on red light etc.
- Extra solar energy can also be used for power the other car accessories like music system, light, 12 V car battery etc.

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