Performance Analysis of Pneumatic based Solar PV Tracking System

Jacob[1,] L.karikalan[2], S. Baskar[3], P. Prakesh[4]

[1,2,3] *Department of Automobile Engineering, VELS Institute of Science, Technology & Advanced Studies (VISTAS), Tamil Nadu, India.*

[4] *Department of Mechanical Engineering, VELS Institute of Science, Technology & Advanced Studies (VISTAS), Tamil Nadu, India.*

[1*] *Corresponding Author Email: jacob.se@velsuniv.ac.in,[2]karikalanl.se@velsuniv.ac.in,*
[3]*baskar133.se@velsuniv.ac.in*

Abstract

Renewable energy particularly, solar energy has been receiving increased focus because it's believed that solar energy is the viable option to satisfy the increasing energy demand in environmentally friendly way. One of the key is use of harvesting solar energy is an efficient use of tracking unit. In conventional solar PV tracking system the electricity is used as source medium for operation. In this project an attempt has been made to use solar energy for tracking, with the help of mechanical system. The development of pneumatic based solar PV tracking primary system consists of refrigerant tank, pneumatic actuator, PV panel and shading plate. The refrigerant stored in the tank starts evaporating with temperature difference based on various incident solar radiation intensity over a period of time which tends to actuate the pneumatic piston and this panel follows the direction of sun. Testing of the feasibility of newly developed tracking unit. System at various solar radiation intensity and finding the operating pressure and temperature are the major objectives of the present project. In this work, a pneumatic based solar PV tracking was developed through proper dynamic analysis of the unit.

Keywords: *Solar energy, Sun tracking system, RTD*

1. Introduction

The main motivation of the system is to optimize the system components for a given panel size , evaluated the performance of the newly developed tracking unit and Comparison of PV panel output with non-tracking solar PV panel for energy analysis. For the future generation the sufficient of clean energy demand is most challenges one. The Alternative renewable energy sources such as solar energy can be utilized for our energy needs El-Adawi et al. (2007). Among these renewable energy resources is solar power, which when harvested can be used to generate electric power. The 0.16 % of the land on earth will provide 20 TW of power by using efficient solar conversion systems, nearly twice the world's consumption rate of fossil energy. When implementing this technology, one can either rely on fixed or tracking panel installations Singh et al. (2014). The spectrum related to sunlight passing through the atmosphere when the sun is at a 42 degree elevation from the horizon (defined as air mass 1.5; i.e., when the path through the atmosphere is 1.5 times than that when the sun is at high noon).Because of day/night and time-of-day variations in insolation and cloud cover, the average electrical power produced by a solar cell over a year is about 20% of its Wp rating Cipriani et al. (2013).

1.1 Methodology

The following methodology can be adopted as follows.

- Identification of system components
- Procurement of system components

- Integration of system components
- Conducting experiment
- Results and discussion

A detailed literature review has been carried out for the performance of various tracking methods based on active and passive tracking ,optimum tilt angles, axis of rotation ,cloudy condition etc. have been well studied.

2. Identification of System Components

The pneumatic based solar PV tracking system consists of the following solar components 1. PV panel 2. Pneumatic actuator 3. Flow control valve 4. Refrigerant transfer hoses 5. Refrigerant (R134a) 6.Supporting Frame 7.Plummer block 8. Refrigerant tank 9.Temperature sensor 10.pressure gauge

2.1 Properties of Refrigerants (R134a)

The working fluid for tracking unit considered for the present work is considered for the present work is R134a. The reason for the selection of R134a, it is environmentally friendly refrigerant. The properties of the refrigerant is given below

Molecular Weight: 101.04 g/mole

Critical pressure: 40.5 bar

Critical density: 513 kg/m3

Critical temperature: 100.95 °C

Triple point: -102.4 °C

Specific volume: 0.235 m^3/kg

Heat capacity at constant pressure, C_p: 0.08754 kJ/ (mol.K)

3. Dynamic Design Analysis

In this analysis, the arriving of important design parameters of tracking unit is explained in details. The early design of the project is analyzed by using ADAMS (Automated Dynamics Analysis of Mechanical Systems) software. This software generally used for analysis of experimental setup like vibration analysis, flexible links, building customized modules, complex nonlinear behavior of car tires. In this project vibration analysis and pressure withstanding capacity of refrigerant tank has been performed using ADAMS software.

3.1 PV Panel

The following rating was found sufficient and optimal for the testing phase of this project keeping in mind the cost and size. Figure 1 indicates the ADAMS design model, the following dimensions are

Panel Rating: 40W

Dimensions: 600*550 mm

Weight: 5 kg

3.2 Solar Panel Mounted Shaft Design

Solar panel mounted Shaft is coupled to the crank rod which transmits the linear motion given by piston rod of into rotational motion. The shaft connected to panel will rotate the assembly depending upon the magnitude and direction of force acting on the pneumatic actuator. The assumption is Point Loading of 5kgf equally spaced from mid plane of the shaft.

The Shaft Material is C40 Steel considered here because it is more appropriate for Low power transmissions.

Length of shaft = 800 mm

Yield strength of the shaft Syt = 330 N/mm^2

Ultimate strength of the shaft Sut = 630 N/mm^2

The above values are collected from Ref 11 for C40 steel material

τ_{max} = 0.18*Syt = 0.18*330 = 99 N/mm^2

3.3 Pneumatic Actuator

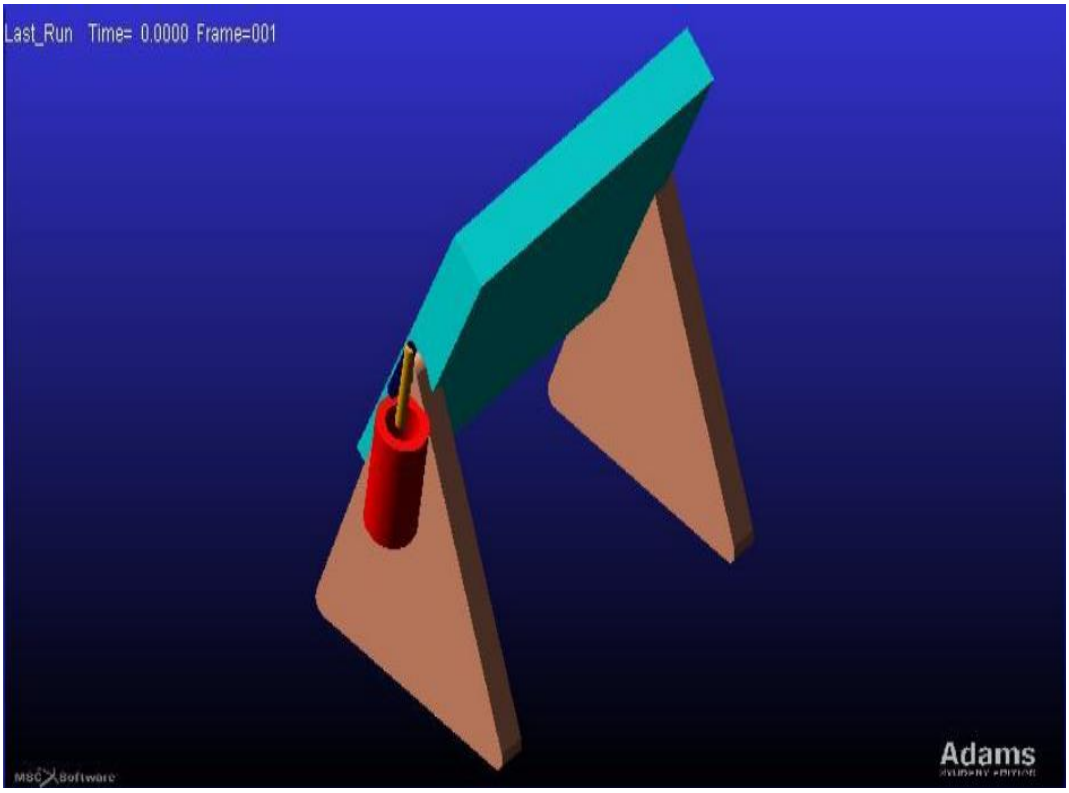

Figure 1.ADAMS Simulation Model

Pressure Range: 20 bar

3.4 Refrigerant Tanks

The refrigerant tank is used to store R134a refrigerant and the tank is made up of Copper material which is non-corrosive and inert to R134a apart from having high thermal conductivity.M Type copper was chosen because it's best suited for heating applications especially solar heating. The dimension of the tank is given as Dimensions: ϕ 25.4 mm, Length: 550 mm and Material: M Type Copper Tube.

4. Experimental setup and readings

The most crucial element of the system is the Refrigerant tank which is mounted on either side of the solar panel. The fabricated part refrigerant tank is shown Figure. It is analogous to a boiler which upon receiving heat, generates high temperature high pressure steam (gas in this case)

Figure 2. Refrigerant tank

The tanks were constructed from 110 cm. The end caps are soldered to either side and flow control valves provide into each pipe near one end and it is shown in Figure.The refrigerant temperature in tank is measured tank is measured by using RTD (Resistive Temperature Difference). Two RTD's kept inside the tank and the surface temperature of the tank is measured by another RTD. This totally six RTD's were fixed to measure the refrigerant temperature and tank surface temperature. The pressure of the refrigerant is measured by using two pressure gauge inserted in two refrigerant ranks. From this measuring system to find the operating pressure and temperature and measure the tilt angle with respect to the force acting on the pneumatic cylinder.

Figure 3. Flow control valve

The refrigerant tank connected with 3 RTDs where, 2 RTDs are used to measure the fluid temperature and RTD to measure the tank surface temperature. The pressure of the refrigerant is measured using pressure gauge connected to the refrigerant tank. Same setup of RTDs and pressure gauge is installed on the refrigerant tank present on the other side of the panel.

The ambient temperature, refrigerant temperature, pressure and solar intensity are taken at a time interval of 15 min to measure the tilt of angle of the solar panel. The volume of refrigerant is varied by 60%, 70%, 80% and 90%.

For 60% of refrigerant mass, the panel tilt was 30-72 degree. In this system requires for actuation the pressure range was 7-12.5 bar and temperature of the refrigerant reaches up to 43ºC. The panel tilt is with respect to when the high temperature at the time only it tilted suddenly. So the movement of tilt was non uniform. The tilting time was in between

the range of 12.00pm to 2.30pm when this time the solar intensity range was optimum i.e., (1050 - 1150 W/m^2)
The experimental readings were taken by varying mass of refrigerant.

Table 1.Experimental readings

Volume of Refrigerant (%)	Existing Range (bar)	Angle of Panel (Degree)
60	7 - 12	30 - 74
70	9 - 14	30 - 76
80	10 - 16	30 - 80
90	12 - 17	30 - 80

Finally the setup was assembled all the individual components together meticulously. The system components fabricated based on the design criteria is finally assembled for performance evaluation. The solar PV panel having the rated capacity of 20 watts is taken from solar lab and mounted on the supporting frame using supporting shaft. The refrigerant tank is fully coated with black paint for more solar heat absorption. The refrigerant charged tanks are placed top and bottom of the PV panel. The expansion hose is used to connect refrigerant tank and pneumatic cylinder. The assembled view of experimental setup is shown in Figure.4.

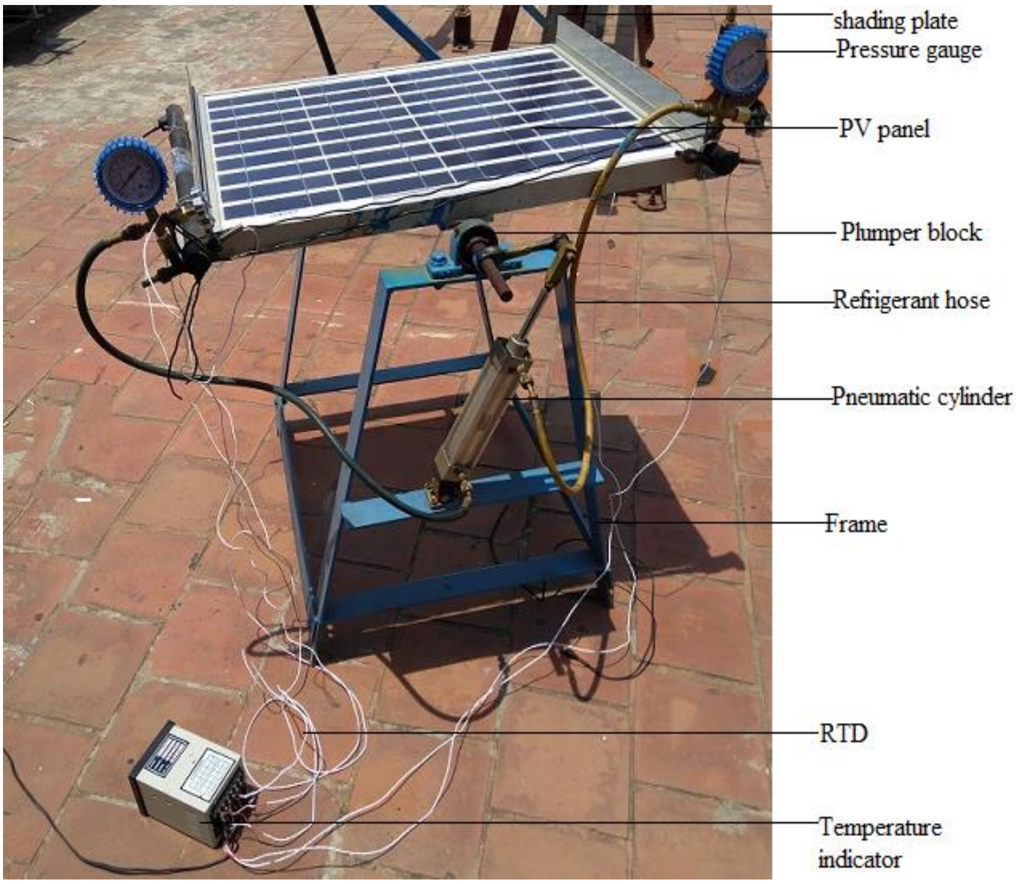

Figure 4.Assembly View of experimental setup
The principle of tracking of PV panel is based on actuation of pneumatic cylinder by the pressure gradient. The difference in pressure of refrigerant is due to difference of isolation falling on two refrigerant tanks. The refrigerant tanks are placed on the longitudinal ends of the panel and it is filled with the refrigerant (R134a). When the panel is not facing the Sun at right angles then the two tanks will be illuminated by varying degree of Sunlight.

Therefore the temperature in one tank will be higher when compared to the other, causing a pressure gradient in the two tanks. The refrigerant in the tank gets heated up and absorbs the latent heat of vaporization and changes from liquid phase to vapor phase. The refrigerant vapors being lighter than the liquid particles, rise above the liquid level. Therefore the vapor pressure increases steadily thereafter.

The Refrigerant hose connects the Refrigerant tanks with the Double acting pneumatic cylinder. The hose being connected to the bottom of the tank so that only the heavier liquid refrigerant will flow through the pipes and not the vapors. Therefore the high pressure vapor pushes the liquid refrigerant through the hoses to act on the piston. Similarly the refrigerant from the other tank acts on the rod side of the piston. The unbalanced forces actuate the cylinder such that to balance the forces. The piston of the actuating cylinder is connected to the crank which rotates the panel accordingly. The two shades on either side of the panel are crucial because they control the variation in the amount of sunlight each tank receives. Varying the shade height influences the sensitivity of the system. The hydraulic actuator is mounted onto the support frame using swivel mounting arrangement.

5. Results and discussion

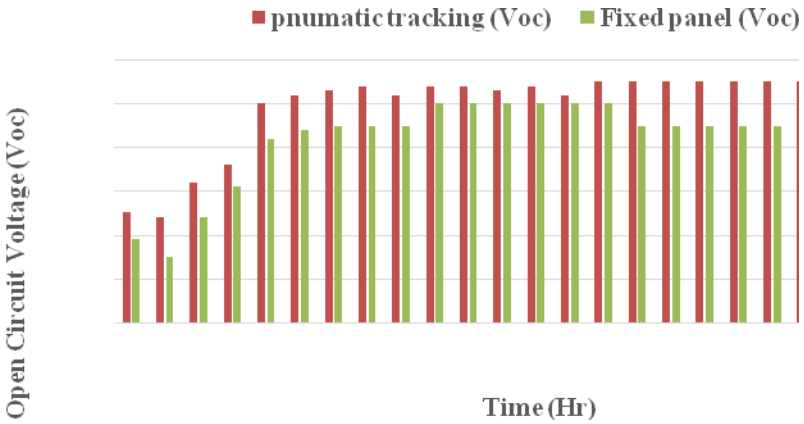

Figure 5. Open circuit voltage Vs Time

Figure 5 shows that the Open circuit voltage Vs Time. Based on variation of time the open circuit voltage is higher for pneumatic tracking than the fixed solar panel.

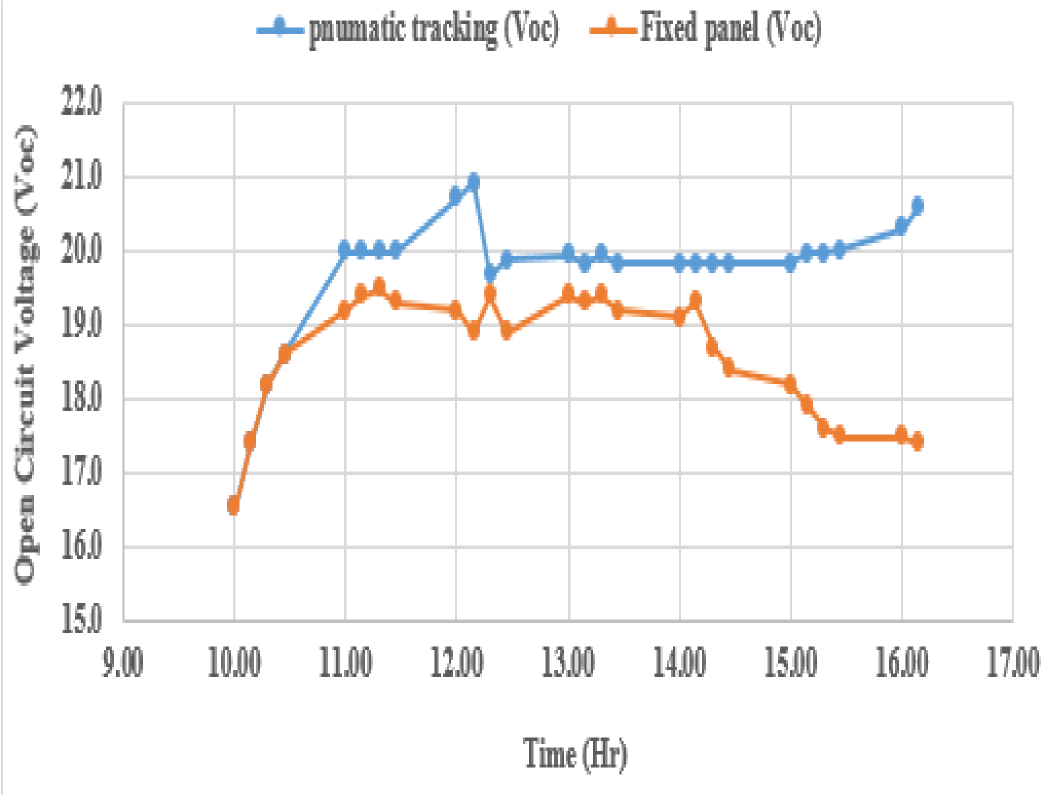

Figure 6. Open circuit voltage Vs temperature

Figure 6 shows that the Open circuit voltage Vs Time. Based on variation of time in hour basis, the open circuit voltage (voc) is increasing. Here Y axis taken Open circuit voltage and X axis taken time in hour.

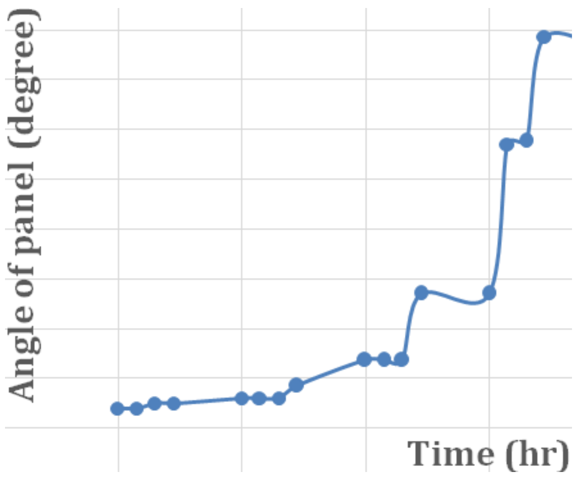

Figure 7.Time Vs Angle of panel

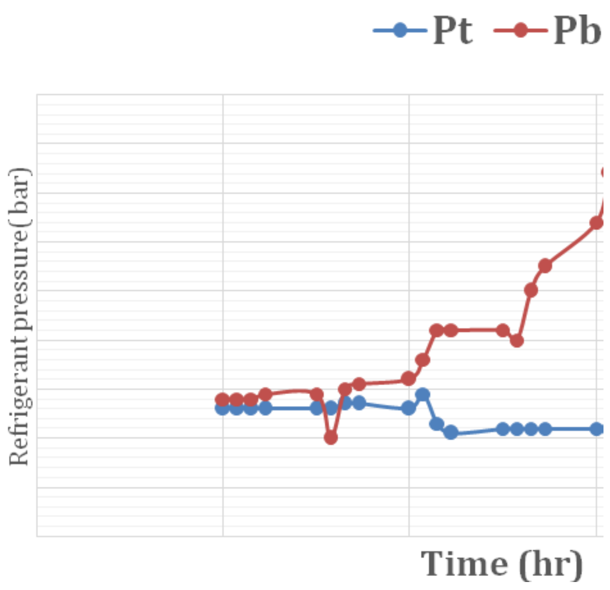

Figure 8.Time Vs Refrigerant pressure

Figure 7 shows that the refrigerant pressure Vs Time. Based on variation of time the refrigerant pressure also increasing.Here Y axis taken refrigerant pressure in bar and X axis taken time in hour.

5.1 Total output Voltage Comparison

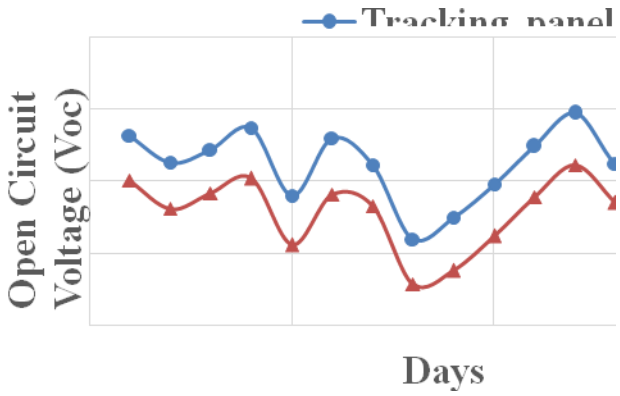

Figure 9.Open circuit voltage Vs Days

Figure 9 shows that the Open circuit voltage Vs Days. Based on number of days increasing the open circuit voltage also fluctuating. Here Y axis taken Open circuit voltage and X axis taken days.

6. Conclusion

The passive type of pneumatic based solar tracking system was designed and fabricated. The design procedure was followed by manual calculation as well as software calculations. In order to find the optimized system components the ADAMS Software was used which gave the satisfactory results. From this software simulation, the refrigerant tank withstands capacity in terms of pressure (111-191 psi) and temperature (30 ^{0}C -50 ^{0}C) was calculated. Then the refrigerating tank is inserted with three temperature sensor and one pressure gauge on each side. Then from these measuring arrangements, the pressure and temperature variation of refrigerant tested with relate to the change in solar radiation intensity. The solar PV panel is capable to track the sun path satisfactorily.

Abbreviations

PV photovoltaic

ADAMS	Automated Dynamics Analysis of Mechanical Systems
RTD	Resistance Temperature Detector

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