ISSN: 0974-5823 Vol. 7 No. 4 April, 2022

International Journal of Mechanical Engineering

Modeling and Design of Pneumatic Actuator System for Solar PV Tracking

Dhanya T[1] and Gopal P M[2]

[1]Research Scholar, Department of Mechanical Engineering, Karpagam Academy of Higher Education, Coimbatore – 641021

[2]Assistant Professor, Department of Mechanical Engineering, Karpagam Academy of Higher Education, Coimbatore – 641021

Abstract: Solar energy has gotten a lot of attention recently since it's thought to be a realistic solution for meeting rising energy demand while also being environmentally benign. Solar energy collecting is one of the most important aspects. The tracking unit was used effectively. A conventional solar PV tracking system generates the electricity. a material that is used to operate as a source In this project, an attempt was made to make use of Solar energy is employed for tracking with the help of a mechanical mechanism. A refrigerant tank, a solar PV tracking system, and a solar PV tracking system are all part of the core system of a solar PV tracking system based on pneumatics. Pneumatic actuator, PV panel, and shade plate As a result of temperature changes produced by varying incidence solar radiation strength over time, the refrigerant in the tank begins to evaporate, forcing the pneumatic piston to actuate and the panel to track the sun's route. The newly built tracking equipment is being put to the test. The main goals of this project are to test the system at various levels of solar radiation and to determine the operating pressure and temperature.

Keywords: *Solar PV system, Pneumatic Actuator, Refrigerant, Solar tracking, solar radiation, open circuit voltage.*

1. INTRODUCTION

Pneumatic actuators [1], often known as man-made or artificial muscles, have been the subject of several previous research publications in the robotics field Pneumatic control systems are efficient equipments that are frequently used in manufacturing industries and automation processes. These systems have plenty of merits that includes, cheaper in cost, higher efficiency and higher weight to force ratios [2]. Pneumatic actuators are now used in medical gadgets as well as industrial machines to help us in our daily lives. Pneumatic actuators are safer and more reliable to use than hydraulic servomotors in terms of environmental and employee safety [3]. The design procedures of Pneumatic actuators are somewhat complex due to non linearity in their dynamics, air compression and some frictional effects. Also when compared to hydraulic systems, pneumatic systems provide less harmfulness with the environmental aspects and less cost [4]. In the nuclear power generation systems, pneumatic actuators are extensively used because of their consistent operational performances [5]. In pneumatic actuators due the absence of liquid or gases, provides complete cleanliness with their operation. This will improve the pollution atmosphere to low less pollution atmosphere. Due to the aforesaid advantages, pneumatic actuators are extensively used in many industries now a day [6].

The system's primary goal is to optimize system components for a certain panel size, test the performance of a newly built tracking unit, and compare PV panel output to non-tracking solar PV panels for energy analysis [7-10]. The most difficult task for future generations is meeting the need for sustainable energy. Solar energy, for example, is an alternative renewable energy source that can be used to meet our energy needs. Solar power is one of these renewable energy sources that, when harvested, may be used to generate electricity. Fixed or tracking panel installations can be used to achieve this technology [11-14]. The solar reflection is at a 40-degree angle to the horizon, the 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 roughly about 15-20% of its actual rating [15-17].

2. PROPOSED METHODOLOGY

The proposed pneumatic actuator system for solar PV tracking is illustrated in Figure 1. The pneumatic actuator based solar PV tracking system consists of the following solar components. They are PV panel, Pneumatic actuator, Flow control valve, Refrigerant (R134a) with Refrigerant transfer hoses, Supporting Frame and Plummer block, Refrigerant tank with temperature sensor and pressure gauge.

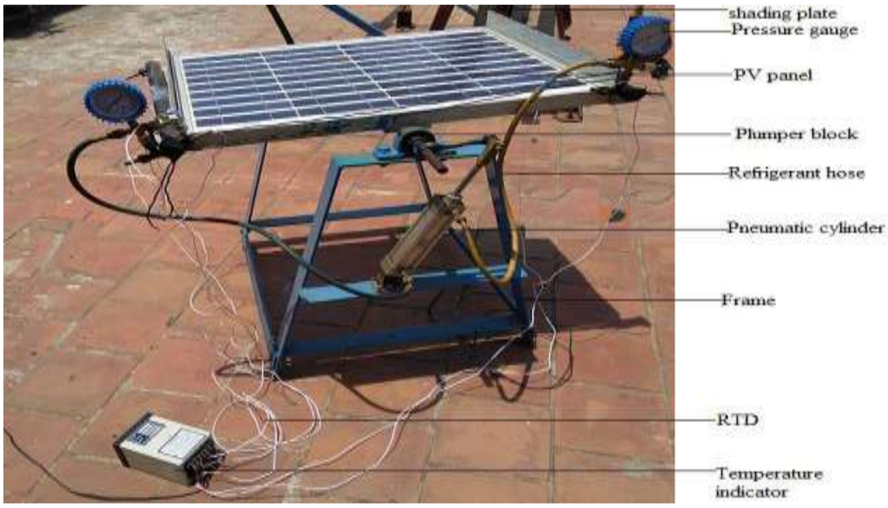

Fig. 1 Proposed Pneumatic Actuator system for Solar PV panel tracking

Solar PV Panel

A 40 W solar PV panel is utilized in this proposed research work. The specifications of the solar panel are given in Table 1.

Table 1 Typical 40 W solar PV panel specifications.

Details	Specifications
Power at maximum radiation	40W
Percentage of Tolerance	± 5%
V_{oc}	25.5V
I_{sc}	2.25A
V_{max}	19.4V
I_{max}	2.4A
Efficiency of the Module	15.35%
Efficiency of Solar Cell	18.6%
Fuse Rating (series(	15A
Water proof rating	IP65
system voltage (max)	1000V DC
Panel Operating Temperature	- 40°C to 85°C
Dimensions	450mm x 650mm x 25mm
Weight	4.3 kg

Mounted solar panel, a shaft is connected to the crank rod, which converts the piston rod's linear motion into rotating motion. Depending on the magnitude and direction of force acting on the pneumatic actuator, the shaft linked to the panel will rotate the assembly. The assumption is that a 5kgf point load is evenly distributed across the shaft's mid plane.

Pneumatic Actuator

Pneumatic cylinders are also named as pneumatic actuators which provide linear or angular moments attached with the apparatus or the automated system equipments. The force created in the pneumatic actuators easily controls the linear or rotational moments in any difficult environments like high pressure and high temperature surroundings.

Fig. 2 Pneumatic actuator cylinder

The pneumatic actuators are cost effective equipments since they are light in weight and require very less maintenance with continuous operations. Fig. 2 illustrates the pneumatic actuator utilized in this research workA single-piston pneumatic cylinder or actuator has only one port through which air enters and moves the piston in only one direction. The piston is then returned to its original position by a spring. These pneumatic cylinders are suited for slower operations due to their short stroke length. They also use less air, resulting in higher efficiency and lower operating costs.

Refrigerant tank and Flow control valve

The refrigerant tank fitted with pressure gauge and RTD's is illustrated in Fig.2 and the flow control valve is illustrated in Fig.4.

Fig. 3 Refrigerant tank

Fig.4 Flow control valve for Refrigeration control

The R134a refrigerant tank is built of copper, which is non-corrosive and inert to R134a and has a high thermal conductivity. M Type copper was chosen for its suitability for heating purposes, particularly solar heating. Dimensions: 25.4 mm, Length: 550 mm, Material: M Type Copper Tube are the specifications for the tank. The Refrigerant tank, which is located on either side of the solar panel, is the most important component of the system. Figure depicts a partially built refrigerant tank. It's like a boiler that produces high-temperature, high-pressure steam after receiving heat (gas in this case)

The tanks were made of thick steel. End caps are soldered on both sides, and flow control valves are installed near one end of each pipe, as shown in Fig.3. RTD (Resistive Temperature Difference) is used to determine the temperature of the refrigerant in the tank. Two RTDs are kept inside the tank, while another RTD measures the surface temperature. The temperature of the refrigerant and the temperature of the tank surface were both measured using a total of six RTDs. Two pressure gauges put in two refrigerant ranks are used to measure the refrigerant's pressure. Measure the tilt angle with relation to the force exerted on the pneumatic cylinder using this measuring device to determine the operating pressure and temperature. The refrigerant tank is connected to three RTDs, two of which are used to detect fluid temperature and one of which is used to measure the temperature of the tank surface. A pressure gauge linked to the refrigerant tank is used to gauge the refrigerant pressure. The refrigerant tank on the other side of the panel has the same setup of RTDs and pressure gauge. 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 actuation of a pneumatic cylinder by a pressure gradient is the basis for PV panel tracking. The difference in refrigerant pressure is caused by the isolation between two refrigerant tanks being different. The refrigerant tanks are installed on the panel's longitudinal ends and filled with refrigerant (R134a). The two tanks will be lighted by varied degrees of Sunlight if the panel is not facing the Sun at straight angles. As a result, the temperature in one tank will be higher than in the other, resulting in a pressure gradient between the two tanks. The refrigerant in the tank heats up, absorbs the latent heat of vaporization, and transforms from liquid to vapour. Because refrigerant vapours are lighter than liquid particles, they ascend above them. As a result, the vapour pressure gradually rises.

The refrigerant hose links the refrigerant tanks to the pneumatic cylinder with double action. Only the heavier liquid refrigerant will flow through the pipes, not the vapours, thanks to the hose being linked to the tank's bottom. As a result, the high-pressure vapour forces liquid refrigerant through the hoses, acting on the piston. The refrigerant from the opposite tank acts similarly on the rod side of the piston. The imbalanced forces actuate the cylinder, which brings the forces back into balance. The actuating cylinder's piston is connected to the crank, which rotates the panel accordingly. The two shutters on either side of the panel are crucial because they control the amount of sunlight that each tank receives. Changing the shade height has an impact on the system's sensitivity. The hydraulic actuator is secured to the support frame using a swivel mounting method.

3. EXPERIMENTAL RESULTS AND DISCUSSION

To measure the tilt of angle of the solar panel, the ambient temperature, refrigerant temperature, pressure, and solar intensity are taken every 15 minutes. The volume of refrigerant is varied by 45, 60, 75, and 90 percent. The panel tilt was 30-75 degrees for 60% of the refrigerant mass. The pressure range for actuation in this system was 6-12.5 bar, and the refrigerant temperature reached 43°C. The panel tilt is in relation to when the temperature was really high at the time, and it tilted abruptly. As a result, the tilt movement was not consistent. The tilting time was in between the range of 12.00 pm to 3.00 pm when this time the solar intensity range was optimum; the test results noted and are tabulated in Table 2.

Table 2 Experimental results

Refrigeration Value	45%	60%	75%	90%
Existing Range (bar)	6-10	9-14	12-16	15-20
Angle of Panel (Degree)	30-70	30-75	30-80	30-80

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.

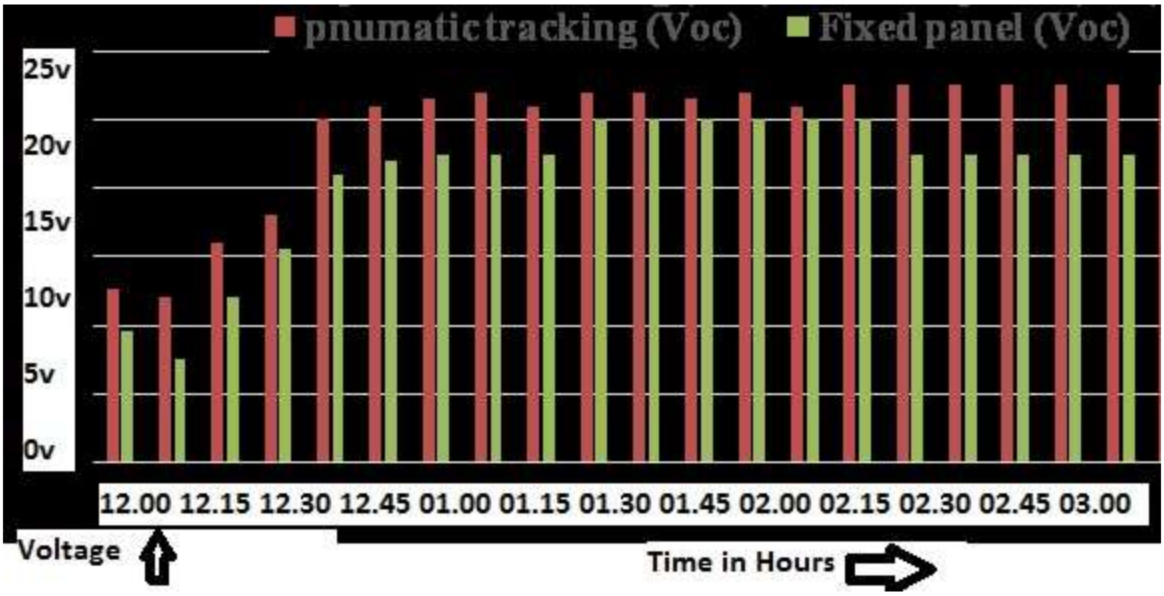

Fig.5 Pneumatic tracking voltage Vs Time

Form the fig.5 it is clear that during pneumatic adjustments made in the solar panel, the optimal voltage values are obtained in the solar panel when compared to fixed panel voltages under open circuit voltage conditions. The proposed pneumatic tracking system for solar PV system provides better tracking efficiency.

4. CONCLUSION

A passive solar tracking device based on pneumatics was conceived and built. Following the design process, manual and digital calculations were performed. A refrigerating tank with three temperature sensors and one pressure gauge is placed. The pressure and temperature variations of the refrigerant tested are then linked to changes in solar radiation intensity using these measuring devices. The solar PV panel can successfully track the sun's path.

REFERENCES

[1] Baskar S, Karikalan L, "Performance Study and Characteristic on a Domestic Refrigeration System with Additive of Zirconium Oxide (Zro2) Nano-Particle as Nano-Lubricant", International Journal for Research in Applied Science & Engineering Technology (IJRASET), ISSN: 2321-9653; IC Value: 45.98; Volume 5 Issue X, October 2017.

[2] Baskar, Karthikeyan, "Heat transfer characteristics of acetone/water mixture in a tubular heat exchanger with turbulator", International Conference on Advanced Nano-materials and Emerging Engineering Technologies (ICANMEET) 2013, pp.627 - 630, 24-26 July 2013.

[3] Berenguel, M., Rubio, F.R., Valverde, A., Lara, P.J., Arahal, M.R., Camacho, E.F. and López, M. (2004) "An Artificial Vision-Based Control System for Automatic Heliostat Positioning Offset Correction in a Central Receiver Solar Power Plan"t. Solar Energy, 76, pp.563-575.

[4] Cipriani, G., Di Dio, V., La Manna, D., Massaro, F., Member, R.M.I. and Zizzo, G. (2013) "Economic Analysis on Dynamic Photovoltaic Systems in New Italian "Feed in Tariffs" Context. Proceedings of the 4th International Conference on Clean Electrical Power: Renewable Energy Resources Impact, Alghero, 11-13 June 2013, pp.584-590.

[5] El-Adawi, M.K. and Al-Nuaim, I.A. (2007) "The Temperature Functional Dependence of VOC for a Solar Cell in Relation to Its Efficiency New Approach. Desalination", 209, pp.91-96.

[6] Huang, B.J., Ding, W.L. and Huang, Y.C. (2011) "Long-Term Field Test of Solar PV Power Generation Using One-Axis 3-Position Sun Tracker". Solar Energy, 85, pp. 1935-1944.

[7] Jeong, B.H., Park, J.H., Kim, S.D. and Kang, J.H. (2013) "Performance Evaluation of Dual Axis Solar Tracking System with Photo Diodes". Proceedings of the International Conference on Electrical Machines and Systems (ICEMS), Busan, 26-29 October 2013, pp. 414-417.

[8] Khalifa, A.J.N. and Al-Mutawalli, S.S. (1998) "Effect of Two-Axis Sun Tracking on the Performance of Compound Parabolic Concentrators". Energy Conversion and Management, 39, pp. 1073-1079.

[9] L.Karikalan, M.Chandrasekran, S.Ramasubramanian, S.Baskar, "Hybridization of Composites using Natural and Synthetic Fibers for Automotive Application", IJSRST | Volume 3 | Issue 7 | September-October 2017 | Print ISSN: 2395-6011 | Online ISSN: 2395-602X.

[10] of Al2O3, Aluminium Alloy and Fly Ash for Making Engine Component", International Journal of Mechanical Engineering and Technology (IJMET), ISSN print: 0976-6340 and ISSN Online: 0976- 6359, IAEME Publication, Journal homepage: http://www.iaeme.com/IJMET/index.asp, Vilume 9, Issue 12, December 2018, pp. 91-96, Article ID: IJMET 09-12-011.

[11] Poulek, V. (1994) "Testing the New Solar Tracker with Shape Memory Alloy Actors". Proceedings of the Conference Record of the IEEE Photovoltaic Specialists Conference, Waikoloa, 5-9 December 1994, pp. 1131-1133.

[12] S. Baskar, M. Chandrasekaran, T. Vinod Kumar, P. Vivek& L. Karikalan, "Experimental Studies on Convective Heat Transfer Coefficient of Water/Ethylene Glycol-Carbon Nano Tube Nanofluids", International Journal of Ambient Energy, ISSN: 0143-0750 (Print) 2162-8246 (Online), 16 Mar 2018, DOI:10.1080/01430750.2018.1451381.
[13] S. Baskar, M. Chandrasekaran, T. Vinod Kumar, P. Vivek& S. Ramasubramanian, "Experimental Studies on Flow and Heat Transfer Characteristics of Secondary Refrigerant Based CNT Nanofluids for Cooling Applications", International Journal of Ambient Energy, ISSN: 0143-0750 (Print) 2162- 8246 (Online), DOI: 10.1080/01430750.2018.1456970.
[14] S.Jacob, L.Karikalan, S.Baskar and S.Venugopal, "Performance Analysis of Automobile Radiator Using Nano Fluid and Water Mixture as Coolant", International Journal of Modern Trends in Engineering and Research (IJMTER) Volume: 5, Issue: 03, [March– 2018] ISSN (Online):2349– 9745; ISSN (Print):2393-8161.
[15] S.Jacob, L.Karikalan, S.Venugopal, C.Gnanavel, S.Baskar, "Thermal analysis of fatty acid in heat exchanger with the addition of Phase Change Materials" |International Journal of Recent Trends in Engineering & Research (IJRTER) | Volume 04 | Issue 03 | March- 2018 [ISSN: 2455-1457].
[16] Singh, P. and Ravindra, N.M. (2012) "Temperature Dependence of Solar Cell Performance – An Analysis. Solar Energy Materials and Solar Cells", 101. pp. 36-45.
[17] Zeroual, A., Raoufi, M., Ankrim, M. and Wilkinson, A.J. (1998) "Design and Construction of a Closed Loop Sun-Tracker with Microprocessor Management". International Journal of Solar Energy, 19, pp. 263-274.