Study on Improved Efficiency of Photovoltaic Cell using Optimization of Optical Filters using Nano-Fluids

[1]Shaik. RasoolSaheb, [2]K. Krishna Murthy
[1]S&H (Physics), TKR Engineering College, Meerpet, Saroor Nagar, Hyderabad, Telangana, India
[2]Dept. of Electronics, PG Center, P.B. Siddartha Arts & Science College, Vijayawada, AP, India

Abstract
This paper has presented band pass filters with low ss and high pass filters integrated with operational amplifiers in advanced integrated communication circuits over wide range of the affecting parameters. Filter gain, filter bandwidth, and filter resonance frequency are the major interesting parameters in the current study. Filter circuit can be designed over optical transmission spectrum regions.

Keyword
Operational Amplifiers, Band Pass Filters, Low Pass Filters, Filter Gain, Filter Bandwidth, and High Pass Filter

The negative impact of human activities on the environment receives tremendous attention, especially on the increased global temperature. To combat climate change, clean and sustainable energy sources need to be rapidly developed. Solar energy technology is considered as one of the ideal candidates, which directly converts solar energy into electricity and heat without any greenhouse gas emissions. In both areas, high-performance cooling, heating and electricity generation is one of the vital needs. Modern nanotechnology can produce metallic or nonmetallic particles of nanometer dimensions which have unique mechanical, optical, electrical, magnetic, and thermal properties. Studies in this field indicate that exploiting nanofluid in solar systems, offers unique advantages over conventional fluids. In this paper, the applications of nanofluids on different types of solar collectors, photovoltaic systems and solar thermoelectrics are reviewed. Beside the wide range of energy conversion, the efforts done on the energy Storage System (ESS) have been reviewed. In the field of economics, nanotech reduces manufacturing costs as a result of using a low temperature process.

I. Introduction

The most important consideration in choosing a filter type is the intended use of the filter. Forexample, if the requirement is to attain optimum behavior with square wave signals, togetherwith good frequency limiting, then the Bessel lowpass filter is the logical choice [1- 2]. This filterprovides the least overshoot as a response to transients, when compared with Tschebyscheff or Butterworth low pass filters. The disadvantage of this filter is the less abrupt kink in theamplitude frequency response. If, however, square wave behavior is of less importance than theattenuation of sine wave signals, then the decision will be in favor of Tschebyscheff orButterworth filters.From the cutoff frequency onward, the Tschebyscheff filter has a strongly accentuated reductionin amplification. However, the amplitude frequency response within the pass band is notmonotone, but instead features ripples with constant amplitude. The higher the permitted rippleof the order in question, the greater the attenuation above the cutoff frequency. The advantageof the greater reduction in amplificationmust be set against the higher ripple before the cutofffrequency[3]. In contrast, the Butterworth filter features an almost linear amplitude frequencyresponse up tothe cutoff frequency. It is used mainly when a minimum distortion of the inputsignal is required; only the part of the ignal above the cutoff frequency will be attenuated[4] Continuing the discussion of Op Amps, the next step is filters. There are many different types of filters, including low pass, high pass and band pass. We will discuss each of the following filters in turn and how they are used and constructed using Op Amps[5]. When a filter contains a device like an Op Amp they are called active filters. These active filters differ from passive filters (simple RC circuits) by the fact that there is the ability for gain depending on the configuration of the elements in the circuit. There are some problems encountered in active filters that need to be overcome. The first is that there is still a gain bandwidth
limitation that arises. The second is the bandwidthin general. In a high pass filter there is going to be high frequency roll off due to the limitations of the Op Amp used. This is very hard to overcome with conventional op amps. The mathematical operations discussed in the previous lab (the integrator and differentiator) are both types of active filters. As for now, the discussion will focus mainly on the Low Pass (LP), High Pass (HP) and Band Pass (BP) filters. There is also a band stop filter that can be created from the band pass filter with a simple change of components [6].

II. Modeling Analysis

The final type of filter to be discussed here is that of a band pass filter. The band pass filter takes advantage of thelow pass configuration as well as the high pass configuration. The two of these combine to for a range of frequencies that is called the pass band. Below the lower cutoff frequency the signals are stopped as well as above the higher cutoff frequency. The difference between these two frequencies is called the bandwidth of the filter [6].

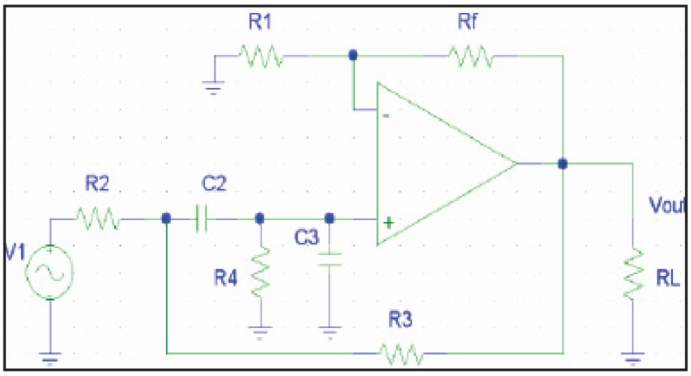


Fig. 1: Band Pass Filter With Low Pass and High Pass Connection [7]

The logic behind the cutoff frequencies is a little misleading. The lower cutoff frequency is controlled by the high pass filter part of the band pass filter. On the same type ofidea, the upper cutoff frequency is controlled by the low pass filter part of the band pass filter. The circuit shown in fig. 6 is that of a basic pass band filter. Notice the combination of the low pass and high pass connections. The combination of a 1storder HP and a 1storder LP creates a

2ndorder band pass. If the trend were to continue a 2ndorder HP and a 2nd order LP create a 4thorder band pass. Based on the corner or cutoff frequency chosen and the values of resistors available, the values ofthe capacitors can be calculated [8]:
Where c is the speed of light (3x108m/sec), R is the resistance and λc is the corner wavelength. These values again arise from the transfer function and then solving for each of the coefficients. To obtain a higher order filter the cascade technique will have to be used. Therefore to make a 4th order high pass (HP)filter two 2nd orderHP filters need to be cascaded [9].
To obtain a higher order filter the cascade technique will have to be used. Therefore to make a 4th order bandpass (BP) filter two 2nd order BPfilters need to be cascaded, thereforethe resonant frequency can be given by [10]:

$$f_0(BPF) = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}} \qquad (1)$$

The lower and higher frequencies of BP filters can be described by the following formula [11-12]:

III. Simulation Results and Performance Analysis

The model has presented low pass, high pass and band pass Filters Integrated with operational amplifiers in advanced Integrated circuits under the set of the wide range of the operating parameters as shown in Table 1 is listed below.

Table 1: Proposed Operating Parameters in [2,5,12,15]

Operating parameters	Value
Near infrared corner wavelength, λ_{NIR}	1200 nm-2000 nm
Resistance, R	1 MΩ-10 MΩ
Capacitance, C	10 pF-100 pF

Based on the model equations analysis, assumed set of the operating parameters as listed in the Table 1 above, and based on the series of the Figs. (2-9), the following facts are assured:

1. Figs. (2, 3) have assured that near infrared wavelength increases this leads to increase in filter capacitance values and decreases with increasing filter resistances values at the assumed set of the operating parameters.
2. Figs. (4, 5) have assured that near infrared wavelength increases this leads to increase in filter resistance values and decreases with increasing filter capacitance values at the assumed set of the operating parameters.
3. Figs. (6-9) have indicated that the filter resonance frequency, filter bandwidth, and lower and higher filter frequencies decreases with increasing near infrared operating optical signal wavelength. As well as the filter gain increases with increasing near infrared operating optical signal wavelength.

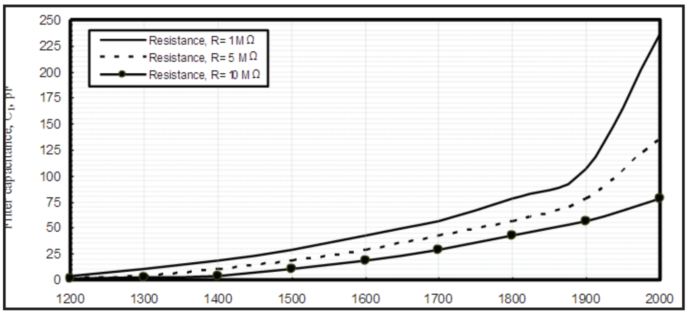


Fig. 2: Filter Capacitance Versus Near Infrared Corner Wavelenth and Filter Resistance at the assumed set of the Operating Parameters

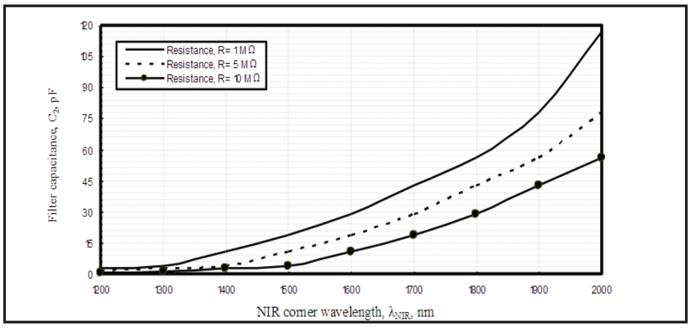


Fig. 3: Filter Capacitance Versus Near Infared Corner Wavelenth and Filter Resistance at the Assumed set of the Operating Parameters

The model has been investigated based on the different filters types categories with the integration role of operational amplifiers in advanced optical communication systems over wide range of the affecting parameters. It is theoretically found that the increased operating optical signal wavelength, this results in the increased of filter gain and the decreased of filter resonance frequency, lower and higher filter frequencies, and filter resonance frequency. It is our success to design the filters circuits with operational amplifiers under study considerations.

A group of literatures investigated the effects of nanoparticle size and volume fraction on the heat transfer [18–25]. Wongcharee and Eiamsa-ard[26]studied CuO-water nanofluid in three differ-ent volume fractions of 0.3%, 0.5%, 0.7% for a laminar regime. The reults exhibited an improvement of Nusselt number as nanofluid concentration rose. Santra et al. [27]in their assessment of copper-water nanofluid for a range of Reynolds numbers (Re¼5 to 1500) and solid volume fraction between 0.00 and 0.05 assuming the fluid in two phases (Newtonian and non-Newtonian), observed theenhancement of heat transfer with enrichment in solid volume fraction. Fotukian and Nasr-Esfahany[28]investigated the heat transfer features of γ-Al_2O_3/water nanofluid in a circular tube with a solid volume fraction less than 0.2%. By adding nanoparticles to water, thermal conductivity augmented. Meanwhile, increasing solid volume fraction beyond 0.2% caused no change in the heat transfer rate. Arani and Amani [29]in an experimental research examined TiO2-water nanofluid with Reynolds numbers between 8000 and 51000 and volume fraction in the range of 0.002–0.02. Heat transfer was improved with increasing of nanoparticles volume fraction. They also observed that at high Reynolds num-bers, more power is needed to overcome the pressure drop of nanofluid, so it is not beneficial to use nanofluid at high Reynolds numbers compared to low Reynolds numbers. Sebdani et al. [30] investigated Al_2O_3-water in mixed convection in a square cavity at constant Rayleigh numbers, the results demonstrated the heat transfer reduction for low Reynolds number (Re¼1) while volume fraction was more than 0.05, but in high Reynolds number (10–100), increasing of nanoparticles percentage, enhanced heat transfer. Also, for a constant Reynolds number, the effect of adding nanoparticles on heat transfer was correlated to Rayleigh number, so that augmentation of heat transfer continued until Ra¼103 while for Ra¼104 and Ra¼105 heat transfer decreased with adding more nanoparticles [30].

The reports on the effect of nanoparticles size on the thermal conductivity are antagonist. A numerical modeling research by Lelea [31]showed that at constant Reynolds numbers in a microchannel heat sink, the enhancement of heat transfer reduces as Al_2O_3 nanoparticle diameter increased in base fluid. Teng et al. [32] surveyedthe changes in heat transfer of Al_2O_3-water nano-fluid at different diameter size of nanoparticles and a variety oftemperatures; they declared better thermal conductivity in smaller nanoparticle diameter. The interesting aspect of this study was that the heat transfer enhanced considerably at higher temperatures. In contrary, Beck et al. [33] observed reduction of thermal conductivity for water-based and ethylene glycol-based alumina with decreasing in particle size. The same results were obtained for water-gold nanofluid by Shalkevich et al. [34].

Nanofluid may be utilized as a coolant for electronic devices. Recently they are used in heat sinks to improve thermal conductivity [35–41]. Ijam and Saidur [42]investigated the influence of SiC-water and TiO_2-water nanofluids as the coolant in a minichannel heat sink, the results exhibited an improvement in thermal conductivity compared to base fluid. In another study by Selvakumar and Suresh [43]on CuO-water nanofluids in an electronic heat sink, the same results were obtained. Hung and Yan [44] researched on a double-layered microchannel heat sink and demonstrated that adding Al_2O_3 nanoparticles to water raises the thermal performance. Nanofluid is also capable to improve oil recovery, Suleimanov et al. [45]demonstrated that an aqueous solution of anionic surface-active agents with addition of light non-ferrous metal nanoparticles permitted a 70–90% reduction of surface tension on an oil boundary in comparison with surface-active agent aqueous solution and is characterized by a shift in dilution.

II. Applications of Nanofluids in Solar Energy

A. Solar Collector

In solar collectors, the absorbed incident solar radiation is converted to heat. The working fluid conveys the generated heat for different applications. Solar collectors are categorized in tow types, non-concentrating and concentrating collectors [46]. Non-concentrating solar collectors are usually used for low and med-ium temperature applications such as space heating and cooling, water heating, and desalination. While concentrating solar collec-tors are exploited in high temperature applications such as electricity generation. However these systems are acquiring more and more attention, prevailing to low efficiency is still a big deal. Nanofluid has shown a good ability in enhancing the efficiency of solar systems. In this part, the research over employing nanofluid in solar collectors are reviewed.

Tyagi et al. [47]theoretically investigated the performance of a Direct Absorption Solar Collector (DAC) exploiting aluminum-water nanofluid as the absorbing medium. Fig. 1shows the schematic of a nanofluid-based DAC of their study with glass surface on the top and completely isolated at the bottom side. They supposed a steady-state two-dimensional model for heat transfer. By using the following equation, the collector efficiency is obtained:

$$H \; ¼ \; \frac{\text{useful gain}}{\text{available energy}} \; ¼ \; \frac{\dot{m} C_p (\bar{T}_{out} - \bar{T}_{in})}{A G_t}$$

where m is the mass flow rate flowing through the collector, cp is the specific heat, T_{in} and T_{out} are the mean fluid inlet and outlet temperatures respectively, A is the area of the collector and Gt is the solar flux incident on the solar collector. Fig. 2 depicts the collector efficiency versus the variation of particles size in the range of 1–20 nm. The collector efficiency increased gradually with ascendance of nanoparticle size. They attributed this to the enhancement of absorption coefficient which is directly affected by the term D2. From Fig. 3, the augmentation of collector efficiency is obvious as the volume fraction increases. This is due to the enhanced attenuation of sunlight passes through the collector. Since the attenuation varies exponentially with volume fraction, the efficiency initially increases rapidly at low concen-trations and then reaches an asymptotic value in higher concen-trations more than 1%. The result revealed that, under similar

Fig. 2. Collector efficiency (Eq. 1)as a function of the particle size (D) (f_v ¼0.8%)[47]. Fig. 2. Collector efficiency (Eq.1)as a function of the particle size (D) (f_v ¼0.8%)[47].

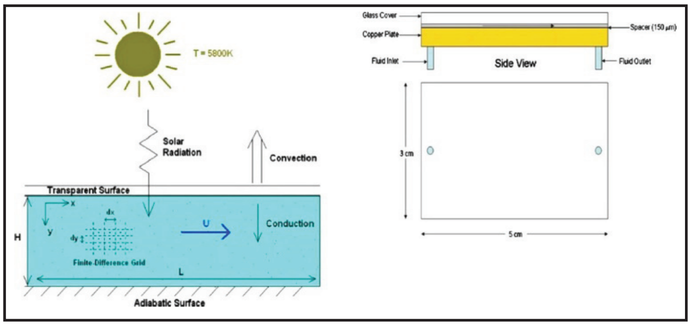


Fig. 4:

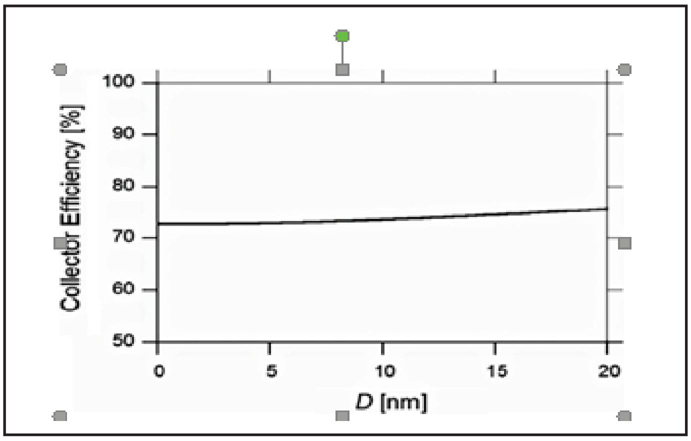


Fig. 5: Collector Efficiency (Eq. 1)as a Function of the Particle Size (D) (f_v ¼0.8%) [47].

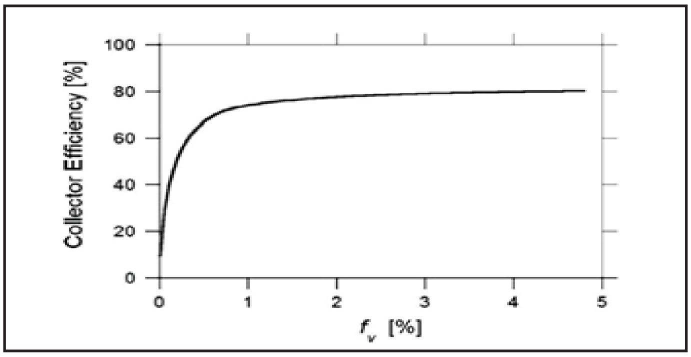


Fig. 6: Collector Efficiency (Eq.1) as a Function of the Particle Volume Function ((f_v) (D¼5nm)

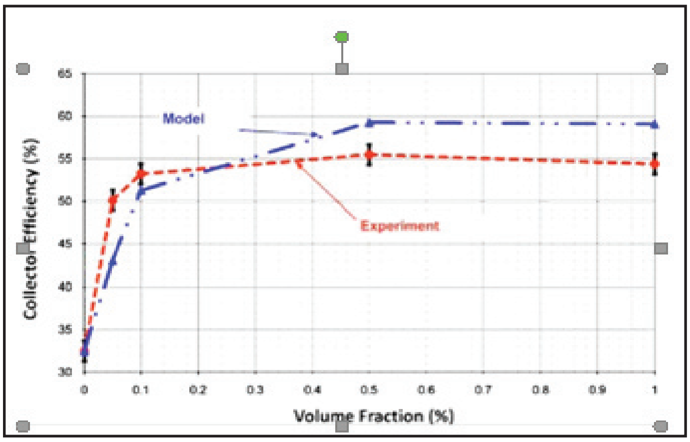


Fig. 7: Comparison of Modeling and Experimental Result for 30nm Graphite Spheres [48]

Otanicar et al. [48]examined the effect of different nanofluids (carbon nanotubes, graphite and silver) on the performance of a direct absorption collector experimentally and compared the results with numerical models. Fig. 4 demonstrates the schematic of the setup which is a micro solar-thermal collector with a 35 cm^2 surface area and 150 μm channel depth; they used a Super PAR64 lamp to simulate the solar spectrum. The same equation of Tyagi's study (Eq. (1)) was applied to evaluate the experimental efficiency of the collector. In the numerical model, they modified the work of Tyagi et al. [47] using radiative transport equations (RTE) coupled to the energy equations which involved emission term compared to the previous work. Fig. 5 exhibits the efficiency of the model and experiment for 30 nm graphite spheres with a 5% discrepancy in comparison. Fig. 6 demonstrates the experimental results of collector efficiency versus volume fraction variations for different nanoparticles. As it is shown, the efficiency ascended with enhancement of particles concentration but, after a volume fraction of 5%, the efficiency diminished slightly. The reason is that the transmittance of water is approached at low particle concentrations and little heating occurs, while at high particle concentrations we expect high absorption of solar incident for the nanofluid. All in all the enhanced efficiency is due to three reasons, modification of the optical properties of the fluid, heat loss reduction as the peak temperature places away from surface, and thermal conductivity enhancement. According to the new model expectation, the influence of particle size on the efficiency was in contrast with heat transfer modeling for different nanofluids,

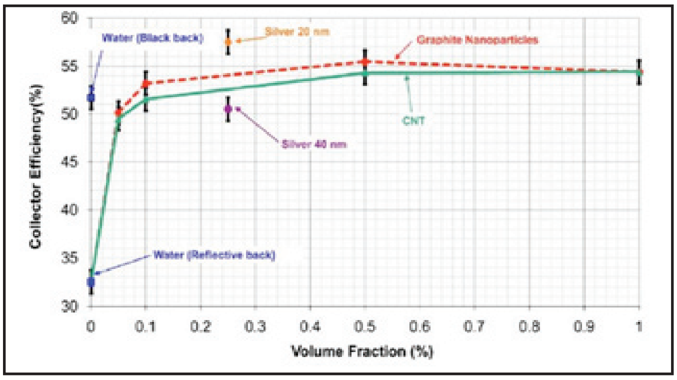


Fig. 8: Steady-state Collector Efficiency for Experimental Nicro Solar Thermal Collector

they also investigated the heat transfer enhancement for Al_2O_3/synthetic oil nanofluid in a parabolic trough collector tube numerically [58].

Solar energy conversion to heat or electricity mainly utilizes surface absorbers. Temperature difference between absorber and heat transfer fluid is a common imperfection in these systems which happen due to thermal resistance at interfaces. One of the solutions to reduce heat loss is volumetric absorption. In volumetric absorption, solar radiation is absorbed by a volume of heat transfer fluid directly. Attaining better properties through adding small solid particles to base fluid was firstly suggested by Abdel-rahman et al. [59]. Some researchers declared utilizing the concept of volumetric absorption in solar power collectors [60-61]. Veer-aragavan et al. [62] made an analytical model for volumetric solar flow receivers, which employed nanoparticles suspended in thebase fluid and displayed an improvement in solar conversion efficiency by decreasing the temperature differences between the absorber and fluid. Lenert and Wang [63] studied the influence of different variations in nanofluid volumetric receivers theoreti-cally and experimentally. In their theoretical part, a one dimen-sional transient heat transfer model was supposed and the enhancement of receiver efficiency with augmentation of nano-fluid height (H) and incident solar flux was proved. The schematicof this model is shown in Fig. 8. In the experimental part, carbon coated cobalt nanoparticles were added to Therminols VP-1in a liquid-based volumetric receiver. For the temperatures below 700 K, enhancement of nanofluidheight lowered the receiver's efficiency. For the temperatures between 800 and 1200 K, the efficiency enhanced while no effect was observed for the temperatures above 1300 K.

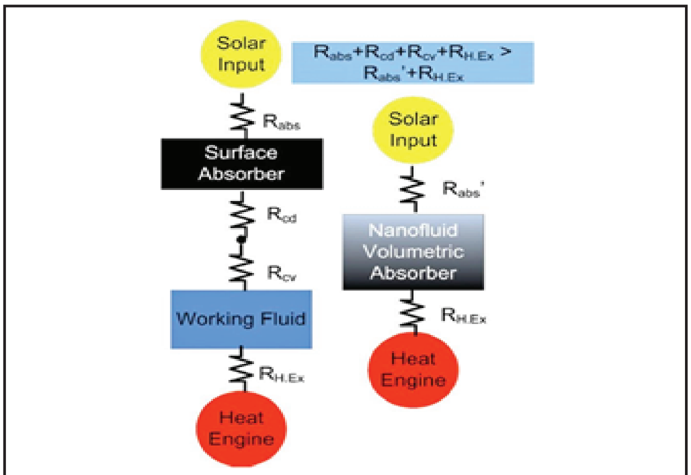


Fig. 9. Thermal resistance network - comparison between a conventional solar thermal plant and a nanofluid solar thermal plant. R_{abs}, R_{cd}, R_{cv}, $R_{H.Ex}$, and R_{abs}' refer to the thermal resistance of solid surface absorption, conduction, convection, fluid-to-fluid heat exchange, and volumetric solar absorption heat transfer steps, respectively [52].

Fig. 9:

Resistances for a surface-based and for a volumetric-based collector in a solar plant, so its obvious that the thermal resistances are clearly lower for a volumetric-based collector.

Otanicar et al. [48] in their study on a DAC, observed that volumetric absorption causes the maximum temperature to take place in the vicinity of the center rather than the collector surface; hence heat loss would be minimum. This is an important mechanism in volumetric receivers that causes efficiency enhancement.

C. Photovoltaic Thermal Systems

Hybrid photovoltaic thermal systems consist of two parts, PV modules and heat extraction part which cools PV module. These systems are capable of producing electrical and thermal energy simultaneously; hence the overall efficiency of PV/T systems is greater than PV systems [89–92]. Consequently the effective costs for PV/T systems are lower. Usually, the heat is rejected by air or water in PV/T systems [93]. PVT/water systems take the advantage of a higher efficiency in comparison with PVT/air systems [94]. Optimizing optical properties of the working fluid in PV/T systems can improve the efficiency, it means that the more transmission of the visible light and the more absorption of the solar infrared radiation, improve the performance of PV/T systems.

Zhao et al. [95]employed a damped oscillator Lorenz–Drude model to investigate the optical properties of working fluid in a PV/T system which satisfied the Kramers–Kronig relations. The inverse method based on genetic algorithm was applied to obtain the refraction from the transmittance on the absorption. The optimization includes maximizing both transmittance of solar incidents owning wavelength between 200 nm and 800 nm and absorption of infrared part of solar radiation for wavelength between 800 nm and 2000 nm which leaded to 92% absorption of the solar radiation and 89% transmittance of the visible light for the optimized working fluid.

Proper spectral tuning for optical properties of working fluid in PV/T systems can be done by Nano fluids. Taylor et al. [67] investigated the optimization of Nano fluid-based optical filters theoretically for PV/T systems. Five kinds of PV cells were chosen in their study (InGaP, CdTe, InGaAs, Si, Ge) to inquire the versatility of Nano fluidfilters over the solar spectrum. The purpose was to attain an optimized model for working fluid to have maximum transmittance between absorption spectrum of each cell and maximize the absorption out of this range. Table 4demonstrates the optimum absorption spectrum for each PV cell. They focused on core/shell nanoparticles. In these materials, the optical features are controllable by changing the shell to core radius ratio. They used the following equation to obtain the nanoparticles volume.

Table 4
Estimated PV cell spectral response parameters [67].

Cell type	Short λ response edge (nm)	Long λ response edge (nm)
InGaP	444	666
CdTe	500	750
InGaAs	589	884
Si	751	1126
Ge	1270	1906

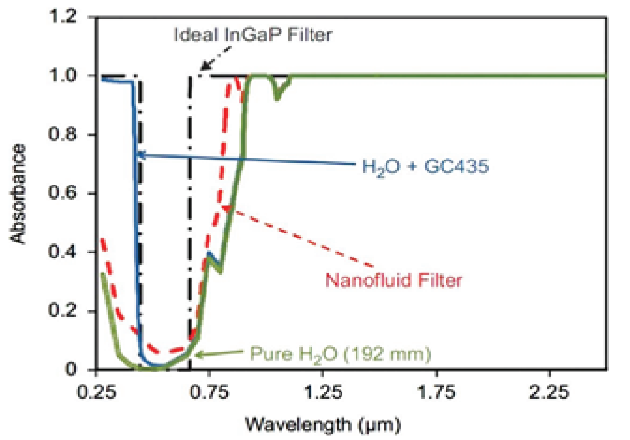


Fig. 13. Indium gallium phosphate cell filter comparison. Absorptance is shown for: an ideal filter (arbitrary thickness), a 'good' pure fluid (192 mm H_2O), a conven-tional thin film filter (w/200 mm H_2O) and a nanofluid filter (20 mm thickness) [67].

Fig. 10:

D. Thermal Energy Storage

Obtaining electricity from solar energy is applicable by using photovoltaic or solar-thermal energy conversion systems which is more reliable and cost effective in large scales comparing to photovoltaic systems. A storage medium plays the key role in solar-thermal power plants which should take advantage of high thermal conductivity, also capable of operating at high tempera-tures. Some of materials used as heat transfer fluid in high thermal-energy storage are Na-K eutectics and alkali metal salts eutectics [97]. Usually these materials have poor thermo-physical characteristics [98]. Increasing the thermal conductivity, the specific heat capacity of the storage medium also the operating temperature of these materials will improve the thermodynamic efficiency of system. Importing gaseous working fluid of small

Nano fluids at 1% concentration weight and different size of nanoparticles, the enhancement of the SHC was observed. Consequently, solar electricity cost degradation is expected due to reduced amount of requiring storage medium and reduced size of thermal transport system. Nelson and Banerjee [103]observed 50% enhancement in SHC of Nano fluids over neat polyalphaolefin in their experiment.

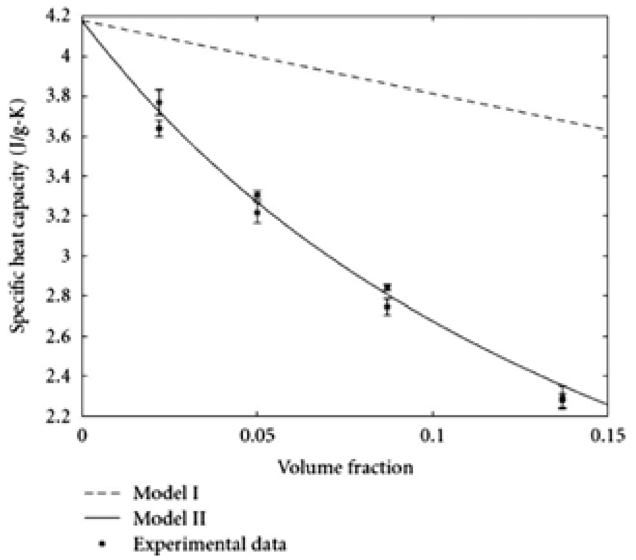


Fig. 19. Variation of specific heat capacity versus volume fraction for copper oxide-water at 35 1C [103].

Fig. 11:

Cells which elevated conversion efficiency of solar energy. Fig. 21 showsa schematic of a solar-thermoelectric module.

E. Solar cells

The cooling improvement of solar cells leads to the better performance of solar panels. Elmir et al. [118]simulated cooling for a solar cell by forced convection in the presence of a Nano fluid. The physical properties were chosen for Al_2O_3-water Nano fluid. The results unveiled that changing the solid volume fraction from 0.0% to 10% causes 27% increase of the heat transfer at low Reynolds numbers (Re¼5) which leads to better performance of the cell. In contrary, Cui and Zhu [96]mentioned the reduction in electrical

ISSN : 2230-7109 (Online) | ISSN : 2230-9543 (Print)

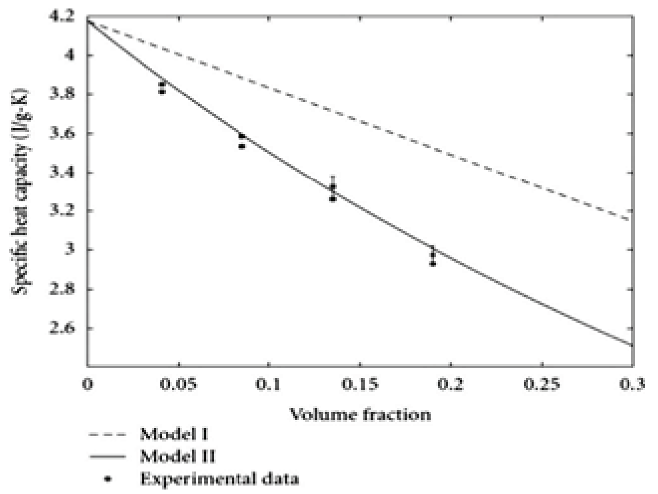


Fig. 20. Variation of specific heat capacity versus volume fraction for silica-water at 35 1C [103].

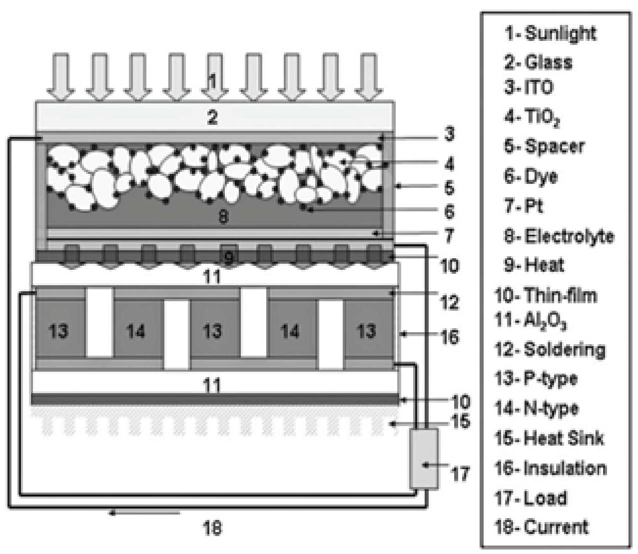


Fig. 21. Schematic diagram of a solar-thermoelectric module [116].

efficiency of PV through adding MgO nanoparticles to water in comparison with exploiting water as the coolant.

In a different application, Chen et al. [119]used TiO2-water Nano fluid for coating TiO2 nanoparticles on the photo electrodes of DSSC utilizing Electric-Discharge Nanofluid-Process. Chang et al. [120] employedTiO2Manuelito create the anode of DSSC viaelectrophoresis deposition. To evaluate the effects of Nano fluid on solar cells more studies are needed regarding newer temperature-dependent or temperature-independent models to evaluate thermochemical properties of Nano fluid. For example using the models presented by Maiga et al. [121], Nguyen et al. [122], Koo and Kleinstreuer[123], and Duangthongsuk and Wongwises[124], Chon et al. [125]can be beneficial to estimate the viscosity and thermal conductivity of Nano fluid.

III. Economical and Environmental Aspects

Both economical and environmental aspects are important criterions that define the acceptability of utilizing nanofluid in solar

Table 8
Economic comparisons for conventional and nanofluid-based solar collectors [125].

	Conventional solar collector ($)	Nanofluid solar collector ($)
Capital costs		
Independent costs	200	200
Area based costs	397.8	327.8
Nanoparticles		188.79
Total capital (one time cost)	597.8	716.59
Total maintenance (for 15 year life)	96.23	115.35
Total costs	694.03	831.94
Electricity cost savings per year	270.13	278.95
Years until electricity savings¼costs	2.57	2.98
Natural gas cost savings per year	80.37	83.02
Years until natural gas savings¼costs	8.64	10.02
Electricity price		
November–March (per kWh)	0.08	0.08
May–October (per kWh)	0.09	0.09
Daily service charge	0.25	0.25
Gas price rate (per term)	0.74	0.74
Monthly service charge	9.70	9.70

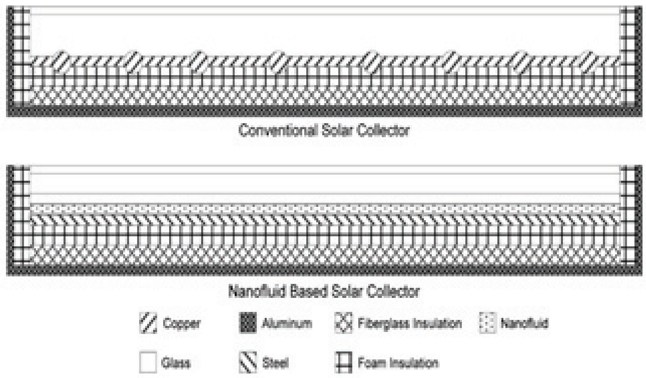
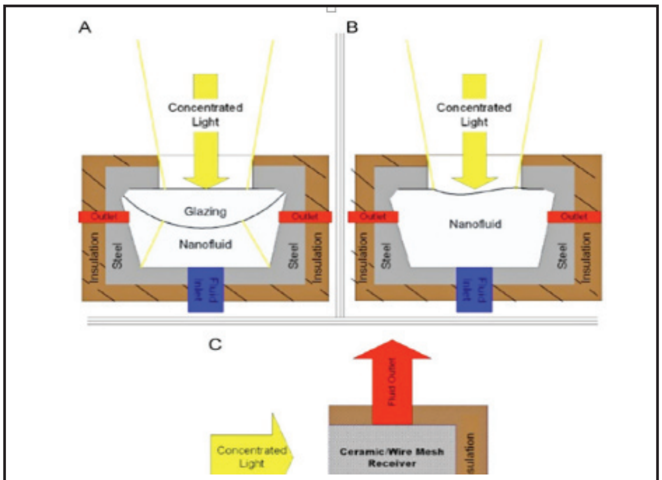


Fig. 22. Conventional solar collector (top) and nanofluid-based direct absorption collector (bottom) [125].

Table 9
Yearly avoided damage costs for conventional andnanofluid-based solar collectors [125].

	Cost ($/kg)	Damage costs avoided ($)	
		Conventional solar collector	Nanofluid based solar collector
Carbon dioxide (CO_2)	0.03	48.72	50.45
Sulfur oxides (SO_x)	12.13	9.60	9.95
Nitrogen oxides (NO_x)	18.40	27.13	28.12
Total		85.45	88.52



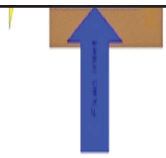


Fig. 23. (a) Conceptual design of a nanofluid concentrating collector with glazing. (b) Conceptual design of a nanofluidconcentrating collector without glazing. (c) Conceptual drawing of a conventional power tower solid surface absorber [52].

Concluding remarks and directions for future work

Based on the literatures, the improved thermal conductivity of Nano fluid is the most important factor for enhancing the efficiency in solar systems but a higher solid volume fraction does not always enhance the efficiency.

The results on the effect of nanoparticle size for solar collector efficiency are antagonist (see Refs. [47-48]), which needs more experimental research to do on the particle size effect. Volumetric absorption of Nano fluid in solar collectors reduces the thermal resistance at interfaces and minimizes temperature difference between absorber and heat transfer fluid; hence a higher efficiency is expected.

As the pH value of Nano fluid diverges positively or negatively from the isoelectric point, less agglomeration appears and consequently leads to better thermal conductivity. The experimental study [82]exhibited the influence of this mechanism in improvement of efficiency for a flat plate collector.

Utilizing Nano fluid in solar systems comprises many environmental and economical beneficial aspects such as reducing of CO2 emission through enhancing the efficiency, also less emission in manufacturing process of Nano fluid-based collectors. As mentioned in the literature, Taylor [52]declared $3.5 million more in the yearly revenue for a 100 MW power tower solar plant exploiting Nano fluid as the heat transfer medium.

This work focused on the characterization of various Nano fluids in solar systems, however further research is needed for better understanding the effects from the Low pass and high pass and band pass width

References

[1] Choi SUS. Enhancing thermal conductivity of fluids with nanoparticles. In: Siginer DA, Wang HP, (Eds.), Developments and applications of non-New-tonian Flows, FED-vol. 231/ MD-Vol. 66. ASME Publications, pp. 99-105, 1995.

[2] Mahmoodi M, Hashemi SM.,"Numerical study of natural convection of ananofluid in C-shaped enclosures", Int J Therm Sci 2012;55, pp. 76–89.

[3] Keshavarz Moraveji M, Haddad SMH, Darabi M. Modeling of forced con-vective heat transfer of a non-Newtonian nanofluid in the horizontal tubeunder constant heat flux with computational fluid dynamics. IntCommunHeat Mass Transf 2012; 39: 995–9.

[4] Ghadimi A, Saidur R, HSC Metselaar."A review of nanofluid stability proper-ties and characterization in stationary conditions", Int J Heat Mass Transf2011;54: 4051–68.

[5] Roy G, Gherasim I, Nadeau F, Poitras G, Nguyen CT. Heat transfer perfor-mance and hydrodynamic behavior of turbulent nanofluid radial flows. Int JThermSci2012;58:120–9.

ShailRasool has been working as a Asst.professor. in TKR Engineering , Hyderabad. He receive M.Sc. Degree from Andhra University and pursuing Ph.D from Acharya Nagarjuna University. He published many papers in various journals. He having good command in Physics.

Prof.K.Krishna Murthy is a Professor in Dept. Electronics in P.G. Center, P.B. Siddartha Arts and Science College Vijayavada. He has published many papers.

- Member of BOS, ANU, Guntur.
- Member of BOS, K.U Machilipatnam.
- Member of BOS, JMJ College, Tenali
- Member of BOS, SDMS Mahila Kalasala, Vijayawada, AP, India.