**Problem Description:**

i want to develop R code, there is complete description in the file, i want to develop thermal model for analysis of lower concentrating pv/t, i am using pv panel with dimensions of 510mm x 1200 mmm, pv efficiency of 17.4%. I have data of optical efficiency of cpc to calculate concentrated solar irradiance at pv surface at concentration ratio of 1.7. I am using rectangular spiral double loops of copper pipe that start from corner of pv panel and ends at center, dia of pipe and spacing between pipes of each loops needs to be optimized. The copper pipes are attached to pv back surface with thermal paste and pipes are embedded in nano-pcm (RT-42+1% graphene) for heat transfer enhancement. then the whole assembly (spiral copper pipes and nano-pcm) is insulated from back and sides.

**Thermal Model:**

The rays falling on the PV Panel, only part of it is converted to electricity while the rest of it is dissipated as waste heat. The waste heat generated from the solar cell can be modelled as the inward heat flux given by equation (19) where q is the heat generated by the solar cell, Areapv is the area of the absorber, ηopt is the optical efficiency of the concentrator, S is the inward heat flux and ηel is the electrical efficiency of the solar cell.

q=(1-ηel)×ηopt×S×Areapv (equation 19).

Where electrical efficiency is a function of temperature and thus given by equation (20) where T is in ◦C, η0 is the base efficiency of the solar cell, and β is the rate of degradation of the solar cell.

ηel=η0(1 β(T 25) (equation 20) Since the heat generation takes place in solar cells, it is conducted to the top portion of the PV panel and then lost to ambient via convection

heat transfer and radiation as given by Equations (21), (22) and (23). Thus, on the top face of the PV/T module, convective heat transfer boundary condition is set where hconv is the convective heat transfer coefficient and u is the wind speed.

hconv=2.8+3u (21)

Qconv=hconv(Tpv -Tamb) (22)

Qrad = hrad. (Tpv – Tsky) (23)

where

where fn represents the cloudiness factor, taking values within the range of 1 (completely overcast day) to 0 (perfect clear sky). Our findings indicate that under clear sky conditions (fn=0).

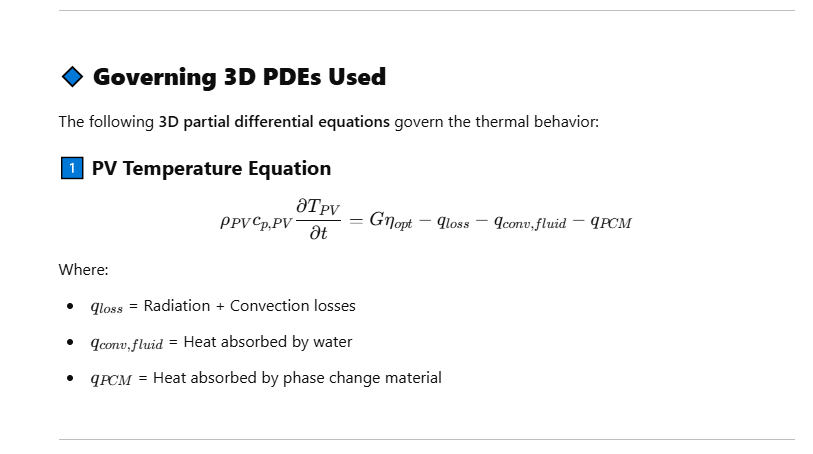
**🔹 Inputs Used**

The model takes the following **inputs**:

1. **Time Range:** 8:00 AM - 6:00 PM (5-minute interval)
2. **Environmental Inputs:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Time | Ambient Temp (°C) | Wind Speed (m/s) | Irradiance | ***ηopt*​ (%) (Ref 72%)** |
| **8:00** | 27.12 | 1.12 | 587 | 4.2 |
| 8:05 | 27.62 | 1.16 | 601.7 | 2.3 |
| 8:10 | 28.12 | 1.2 | 616.3 | 0.5 |
| 8:15 | 28.62 | 1.24 | 631 | 1.2 |
| 8:20 | 29.12 | 1.28 | 645.7 | 2.9 |
| 8:25 | 29.62 | 1.32 | 660.3 | 4.6 |
| **8:30** | 30.12 | 1.36 | 675 | 6.2 |
| 8:35 | 30.62 | 1.4 | 689.7 | 7.8 |
| 8:40 | 31.12 | 1.44 | 704.3 | 9.4 |
| 8:45 | 31.62 | 1.48 | 719 | 10.9 |
| 8:50 | 32.12 | 1.52 | 733.7 | 12.3 |
| 8:55 | 32.62 | 1.56 | 748.3 | 13.7 |
| **9:00** | **29.69** | **1.3** | **763** | 15.1 |
| 9:05 | 30.47 | 1.34 | 777.7 | 16.4 |
| 9:10 | 31.25 | 1.38 | 792.3 | 17.7 |
| 9:15 | 32.03 | 1.42 | 807 | 19 |
| 9:20 | 32.81 | 1.46 | 821.7 | 20.2 |
| 9:25 | 33.59 | 1.5 | 836.3 | 21.4 |
| **9:30** | **32.25** | **1.49** | **851** | 22.6 |
| 9:35 | 32.75 | 1.53 | 865.7 | 23.8 |
| 9:40 | 33.25 | 1.57 | 880.3 | 54.7 |
| 9:45 | 33.75 | 1.61 | 895 | 55.5 |
| 9:50 | 34.25 | 1.65 | 909.7 | 56.3 |
| 9:55 | 34.75 | 1.69 | 924.3 | 57 |
| **10:00** | **34.81** | **1.67** | **939** | 57.7 |
| 10:05 | 35.02 | 1.72 | 948.8 | 58.3 |
| 10:10 | 35.23 | 1.77 | 958.7 | 58.9 |
| 10:15 | 35.44 | 1.82 | 968.5 | 59.4 |
| 10:20 | 35.65 | 1.87 | 978.3 | 60 |
| 10:25 | 35.86 | 1.92 | 988.2 | 60.5 |
| **10:30** | **36.24** | **1.89** | **1019** | 60.9 |
| 10:35 | 36.42 | 1.94 | 1027.3 | 61.4 |
| 10:40 | 36.6 | 1.99 | 1035.7 | 61.8 |
| 10:45 | 36.78 | 2.04 | 1044 | 62.1 |
| 10:50 | 36.96 | 2.09 | 1052.3 | 62.5 |
| 10:55 | 37.14 | 2.14 | 1060.7 | 62.8 |
| **11:00** | **36.87** | **2.15** | **1099** | 63.1 |
| 11:05 | 37.29 | 2.12 | 1096.8 | 63.3 |
| 11:10 | 37.71 | 2.09 | 1094.5 | 63.6 |
| 11:15 | 38.13 | 2.06 | 1092.3 | 63.8 |
| 11:20 | 38.55 | 2.03 | 1090 | 64 |
| 11:25 | 38.97 | 2 | 1087.8 | 64.1 |
| **11:30** | **38.01** | **2.08** | **1084.5** | 64.3 |
| 11:35 | 37.83 | 2.11 | 1079.5 | 64.4 |
| 11:40 | 37.65 | 2.14 | 1074.5 | 64.5 |
| 11:45 | 37.47 | 2.17 | 1069.5 | 64.6 |
| 11:50 | 37.29 | 2.2 | 1064.5 | 64.7 |
| 11:55 | 37.11 | 2.23 | 1059.5 | 64.7 |
| **12:00** | **37.66** | **2.34** | **1070** | 64.8 |
| 12:05 | 37.64 | 2.32 | 1064 | 64.7 |
| 12:10 | 37.62 | 2.3 | 1058 | 64.7 |
| 12:15 | 37.6 | 2.28 | 1052 | 64.6 |
| 12:20 | 37.58 | 2.26 | 1046 | 64.5 |
| 12:25 | 37.56 | 2.24 | 1040 | 64.4 |
| **12:30** | **37.77** | **2.34** | **1034** | 64.3 |
| 12:35 | 37.72 | 2.33 | 1028 | 64.1 |
| 12:40 | 37.67 | 2.32 | 1022 | 64 |
| 12:45 | 37.62 | 2.31 | 1016 | 63.8 |
| 12:50 | 37.57 | 2.3 | 1010 | 63.6 |
| 12:55 | 37.52 | 2.29 | 1004 | 63.3 |
| **13:00** | 38.52 | 2.08 | **998** | 63.1 |
| 13:05 | 38.42 | 2.09 | 994.3 | 62.8 |
| 13:10 | 38.32 | 2.1 | 990.7 | 62.5 |
| 13:15 | 38.22 | 2.11 | 987 | 62.1 |
| 13:20 | 38.12 | 2.12 | 983.3 | 61.8 |
| 13:25 | 38.02 | 2.13 | 979.7 | 61.4 |
| **13:30** | 37.66 | 2.34 | **947** | 60.9 |
| 13:35 | 37.55 | 2.39 | 933.2 | 60.5 |
| 13:40 | 37.44 | 2.44 | 919.3 | 60 |
| 13:45 | 37.33 | 2.49 | 905.5 | 59.4 |
| 13:50 | 37.22 | 2.54 | 891.7 | 58.9 |
| 13:55 | 37.11 | 2.59 | 877.8 | 58.3 |
| **14:00** | **37.72** | **2.12** | **896** | 57.7 |
| 14:05 | 37.69 | 2.14 | 891.1 | 57 |
| 14:10 | 37.66 | 2.16 | 886.3 | 56.3 |
| 14:15 | 37.63 | 2.18 | 881.4 | 55.5 |
| 14:20 | 37.6 | 2.2 | 876.5 | 54.7 |
| 14:25 | 37.57 | 2.22 | 871.7 | 23.8 |
| **14:30** | **37.23** | **2.57** | **860.5** | 22.6 |
| 14:35 | 37.11 | 2.56 | 853 | 21.4 |
| 14:40 | 36.99 | 2.55 | 845.5 | 20.2 |
| 14:45 | 36.87 | 2.54 | 838 | 19 |
| 14:50 | 36.75 | 2.53 | 830.5 | 17.7 |
| 14:55 | 36.63 | 2.52 | 823 | 16.4 |
| **15:00** | **36.87** | **2.15** | **825** | 15.1 |
| 15:05 | 36.68 | 2.23 | 814.7 | 13.7 |
| 15:10 | 36.49 | 2.31 | 804.3 | 12.3 |
| 15:15 | 36.3 | 2.39 | 794 | 10.9 |
| 15:20 | 36.11 | 2.47 | 783.7 | 9.4 |
| 15:25 | 35.92 | 2.55 | 773.3 | 7.8 |
| **15:30** | **35.24** | **2.51** | **740.99** | 6.2 |
| 15:35 | 35.11 | 2.49 | 723 | 4.6 |
| 15:40 | 34.98 | 2.47 | 705 | 2.9 |
| 15:45 | 34.85 | 2.45 | 687 | 1.2 |
| 15:50 | 34.72 | 2.43 | 669 | 0.5 |
| 15:55 | 34.59 | 2.41 | 651 | 2.3 |
| **16:00** | **34.99** | **2.39** | **656.98** | 4.2 |
| 16:05 | 34.82 | 2.36 | 643 | 6.1 |
| 16:10 | 34.65 | 2.33 | 629 | 8 |
| 16:15 | 34.48 | 2.3 | 615 | 9.9 |
| 16:20 | 34.31 | 2.27 | 601 | 11.9 |
| 16:25 | 34.14 | 2.24 | 587 | 14 |
| **16:30** | **34.3** | **2.26** | 573 | 16 |
| 16:35 | 34.21 | 2.25 | 559 | 18.1 |
| 16:40 | 34.12 | 2.24 | 545 | 20.2 |
| 16:45 | 34.03 | 2.23 | 531 | 22.3 |
| 16:50 | 33.94 | 2.22 | 517 | 24.3 |
| 16:55 | 33.85 | 2.21 | 503 | 26.4 |
| **17:00** | **33.76** | **2.2** | 489 | 28.4 |
| 17:05 | 33.56 | 2.17 | 475 | 30.3 |
| 17:10 | 33.36 | 2.14 | 461 | 32.1 |
| 17:15 | 33.16 | 2.11 | 447 | 33.8 |
| 17:20 | 32.96 | 2.08 | 433 | 35.3 |
| 17:25 | 32.76 | 2.05 | 419 | 36.6 |
| **17:30** | **32.56** | **2.02** | 405 | 37.6 |
| 17:35 | 32.36 | 1.99 | 391 | 38.3 |
| 17:40 | 32.16 | 1.96 | 377 | 38.5 |
| 17:45 | 31.96 | 1.93 | 363 | 38.3 |
| 17:50 | 31.76 | 1.9 | 349 | 37.6 |
| **17:55** | **31.56** | **1.87** | 335 | 36.2 |
| **18:00** | **31.36** | **1.84** | **320.9** | 34.1 |

1. **System Parameters:**
   * **PV Panel & PCM Geometry:**
     + PV dimensions (510 mmm x 1200 mm)
     + Nano-PCM RT-42 with 1% graphene
     + Double rectangular spiral loop (corner to center flow)
   * **Fluid Properties (Water):**
     + Density ρ=997\rho = 997ρ=997 kg/m³
     + Specific heat cp=4184c\_p = 4184cp​=4184 J/kg·K
     + Thermal conductivity k=0.6k = 0.6k=0.6 W/m·K
     + Viscosity μ=8.9×10−4\mu = 8.9 \times 10^{-4}μ=8.9×10−4 Pa·s
   * **Pipe Parameters:**
     + Inner Diameter Di​ (10, 12, 15 mm for parametric analysis)
     + Outer Diameter Dc​ (assume)
     + Length L (according to 2 loops used on back of PV)
     + Mass flow rate m 0.08 kg/s
   * **Heat Transfer Parameters:**
     + Convection & Radiation losses

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**Results to be shown**

1. Parametric Analysis (in parallel flow and opposite flow separately) using fixed values of 1000 watt/m2 solar irradiance, ambience temperature of 38.92 degree Celsius, wind spend of 2.92 m/s,
2. Optimal dia from given variables (10, 12 and 15 mm) of pipe for both flows based on max outlet temperature, for 6 hours of simulation
3. Optimal spacing given variables (18, 36 and 72 mm) between pipes for both flows based on max outlet temperature, for 6 hours of simulation
4. Nano-PCM thickness given variables (12,18 and 24 mm) for both flows, based on Delay time in peak PV temp, Melt fraction of Nano-pcm for 6 hours of simulation
5. Hydraulic Analysis
6. Nusselt num of designed absorber for both parallel and Opposite flow b) Pressure Drop for designed absorber for both parallel and Opposite flow.
7. PV temperature evolution wrt time 8 am to 6 pm (in parallel flow and opposite flow separately)
8. PCM temperature wrt time 8 am to 6 pm (in parallel flow and opposite flow separately)
9. Outlet temperature from both loops 8 am to 6 pm (in parallel flow and opposite flow separately)
10. Temp dependent Electrical Efficiency of PV from 8 am to 6 pm (in parallel flow and opposite flow separately).

I want all these 6 results based on transient analysis from 8 to 6 pm with 5 mins interval.