TEAM 67

Albatross Energetics

Innovative Cooling and
Dehumidification Solutions

Overview of the Problem Statement

01\.
Refrigerant Selection

02\.
Compressor Selection

03\.
Evaporator and Condenser Design

04\.
Control Logic

05\.
Cost Analysis

06\.
Results

Refrigerant Selection

Physical Properties

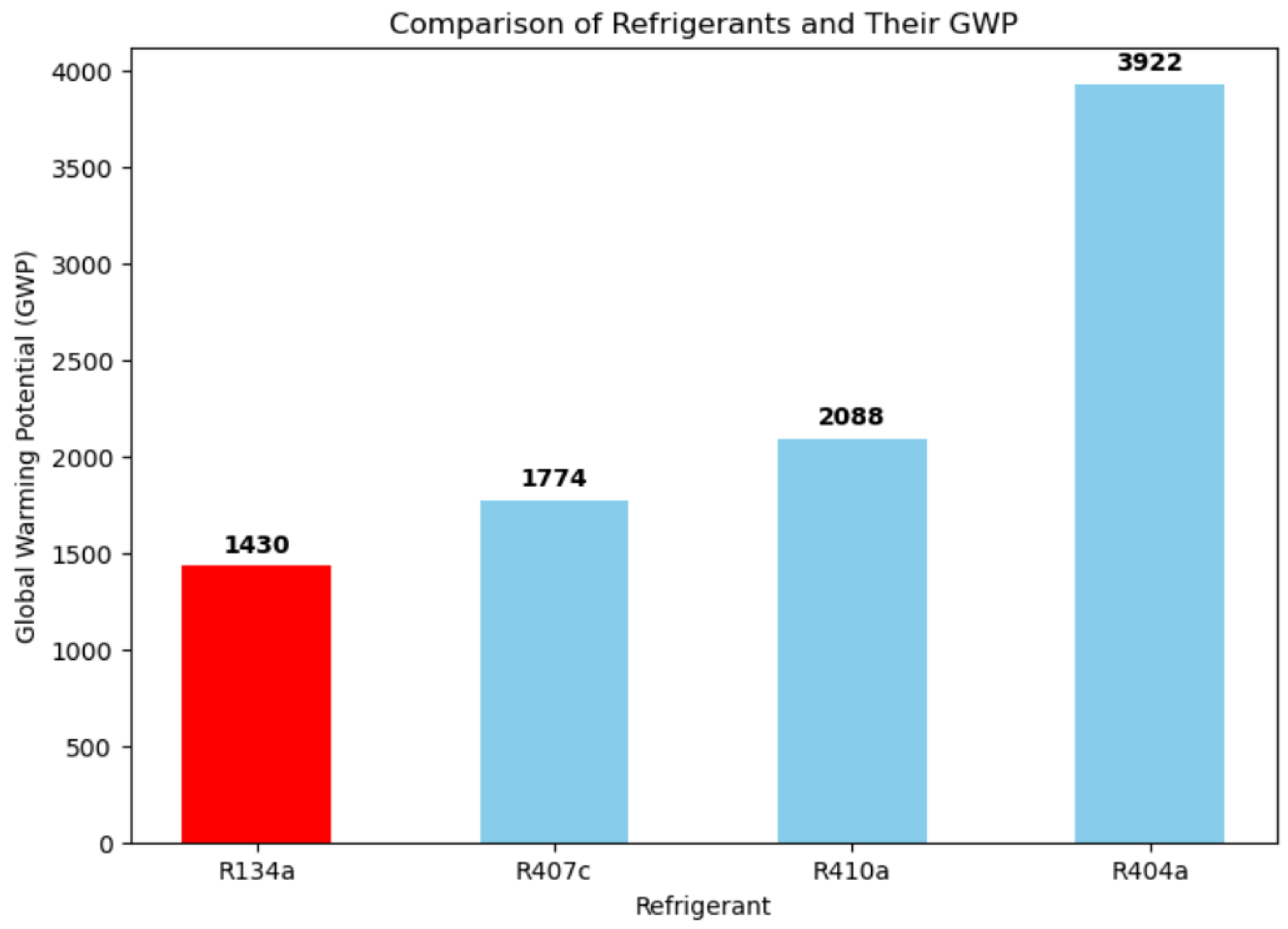
1. **R134a** has an optimal boiling point and molecular weight (102.0 g/mol).
2. Provides **efficient** cooling with lower energy consumption compared to most refrigerants.
3. **Non-flammable (A1) & low toxicity (A1)**, safer than other refrigerants -

R290	Flammable, A3
R1234yf	Flammable, A2L
R454C	Flammable, A2L

Environmental Impacts

Zero ODP, unlike older refrigerants like R22, offering better environmental protection.

Relatively better **GWP**



Exploring Low-GWP Refrigerant Options

Alternative Refrigerant: **R-513A**
GWP: **573** (Much lower than R-134a)

Potential GWP Reduction with R-1234yf using **custom blend.**

Further GWP Reduction:

By creating a **custom blend** and increasing the proportion of **R-1234yf** (even slightly), the GWP could potentially be reduced to **below 500.**

Optimized Design:

Efficiency Impact:
If the model were **designed** around this blend, the efficiency drop could have been minimized.

Why It Wasn't Used:

Resource Constraints:
Limited access to accurate thermodynamic data for the new blend prevented its inclusion in the model.

Compressor Selection

~~C1~~ C2 ~~C3~~ ~~C4~~

Isentropic Efficiency

Scroll Compressor 2 has higher isentropic efficiency than Scroll Compressor 3, making it more energy-efficient.

Displacement

Scroll Compressor 2 offers greater displacement at the same frequency compared to Scroll Compressor 3, resulting in better overall performance.

Conclusion

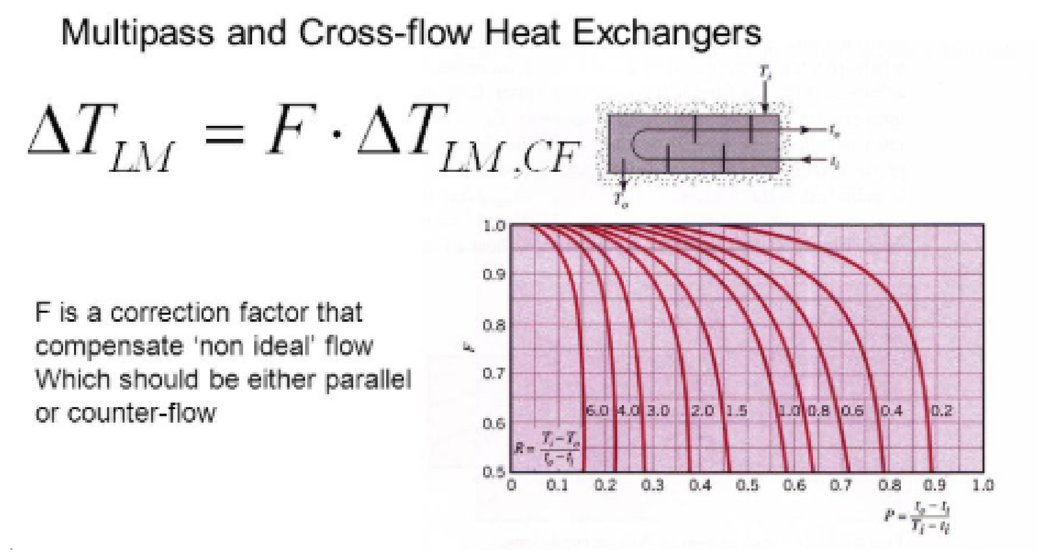
Given the factors of refrigerant compatibility, higher efficiency, and greater displacement, Scroll Compressor 2 is the most optimal choice for the HVAC system.

Evaporator and Condenser

Design Approach

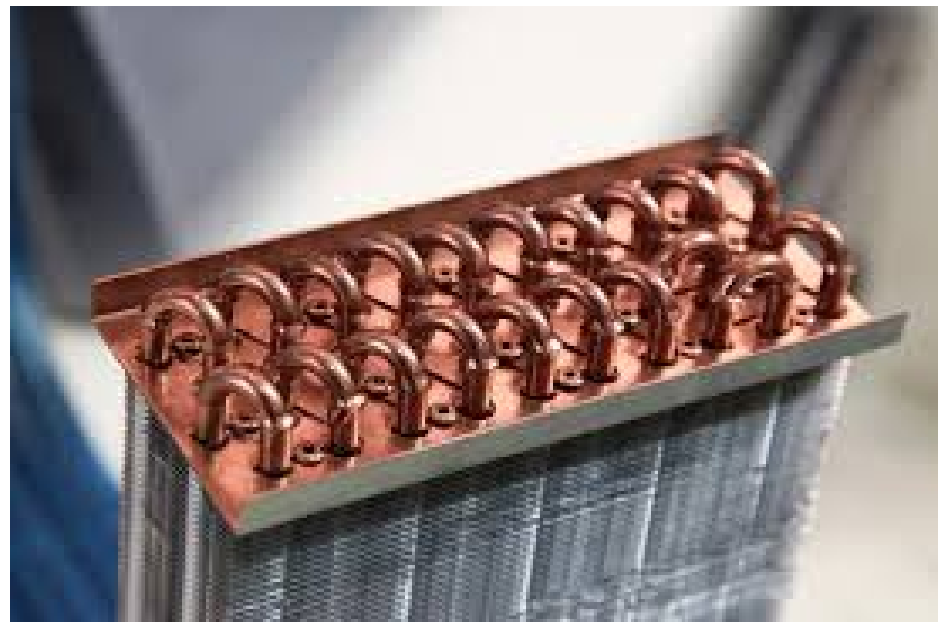
- **Heat Balance** between hot and cold fluid.
- Express heat rate using **LMTD** method.
- Convective flow parameters (**Nusselt**, **Prandtl** and **Reynold's** number) to find heat tranfer coefficients.

UA-LMTD METHOD



- **Overall heat transfer** coefficient using thermal resistance method
- **Fouling** kept part of resistance circuit

- Fin efficiency plays a role in determining the **fin surface area** on the air side.
- We get the important parameters for simulation.



Evaporator Parameters

Block Parameters: Evaporator

Condenser Evaporator (2P-MA) Auto Apply

Settings Description

NAME	VALUE	
Two-Phase Fluid 1		
Number of tubes	25	
Total length of each tube	1	m
Tube cross section	Circular	
Tube inner diameter	evap_tubeDiameter 0.01	m
Pressure loss model	Correlation for flow inside tubes	
Local resistance specification	Aggregate equivalent length	
Aggregate equivalent length of local resist...	100	m
Internal surface absolute roughness	15e-6	m
Laminar flow upper Reynolds number limit	2000	
Turbulent flow lower Reynolds number limit	4000	
Heat transfer coefficient model	Correlation for flow inside tubes	
Fouling factor	0.1	K*m^2/kW
Total fin surface area	evap_liquidFinArea*2 4.7124	m^2
Fin efficiency	0.75	
Initial fluid energy specification	Temperature	
Initial two-phase fluid pressure	0.349658607861315	MPa

Block Parameters: Evaporator

Condenser Evaporator (2P-MA) Auto Apply

Settings Description

NAME	VALUE	
Moist Air 2		
Flow geometry	Flow perpendicular to bank of circular tubes	
Tube bank grid arrangement	Inline	
Number of tube rows along flow direction	1	
Number of tube segments in each tube row	50	
Length of each tube segment in a tube row	2.5	m
Tube outer diameter	evap_tubeDiameter+2*evap_...	m
Longitudinal tube pitch (along flow directi...	evap_tubeDiameter*1.3 0.013	m
Transverse tube pitch (perpendicular to flo...	evap_tubeDiameter*1.3 0.013	m
Pressure loss model	Correlation for flow over tube bank	
Heat transfer coefficient model	Correlation for flow over tube bank	
Fouling factor	0.1	K*m^2/kW
Total fin surface area	5.5	m^2
Fin efficiency	0.75	
Initial moist air pressure	0.101325	MPa
Initial moist air temperature	T_house_init 40	degC
Initial humidity specification	Relative humidity	
Initial moist air relative humidity	0.5	
Initial trace gas specification	Mass fraction	
Initial moist air trace gas mass fraction	0.001	
Initial mass ratio of water droplets to mois...	0	
Relative humidity at saturation	1	

Condenser Parameters

Block Parameters: Condenser

Condenser Evaporator (2P-MA) — Auto Apply

Settings | Description

NAME	VALUE		Unit
Two-Phase Fluid 1			
Number of tubes	25		
Total length of each tube	evap_lengthPerTube	1	m
Tube cross section	Circular		
Tube inner diameter	0.01		m
Pressure loss model	Correlation for flow inside tubes		
Local resistance specification	Aggregate equivalent length		
Aggregate equivalent length of local resist...	100		m
Internal surface absolute roughness	15e-6		m
Laminar flow upper Reynolds number limit	2000		
Turbulent flow lower Reynolds number limit	4000		
Heat transfer coefficient model	Correlation for flow inside tubes		
Fouling factor	0.1		K*m^2/kW
Total fin surface area	evap_liquidFinArea*2	4.7124	m^2
Fin efficiency	0.75		
Initial fluid energy specification	Temperature		
Initial two-phase fluid pressure	1.31790549003734		MPa
Initial two-phase fluid temperature	73		degC

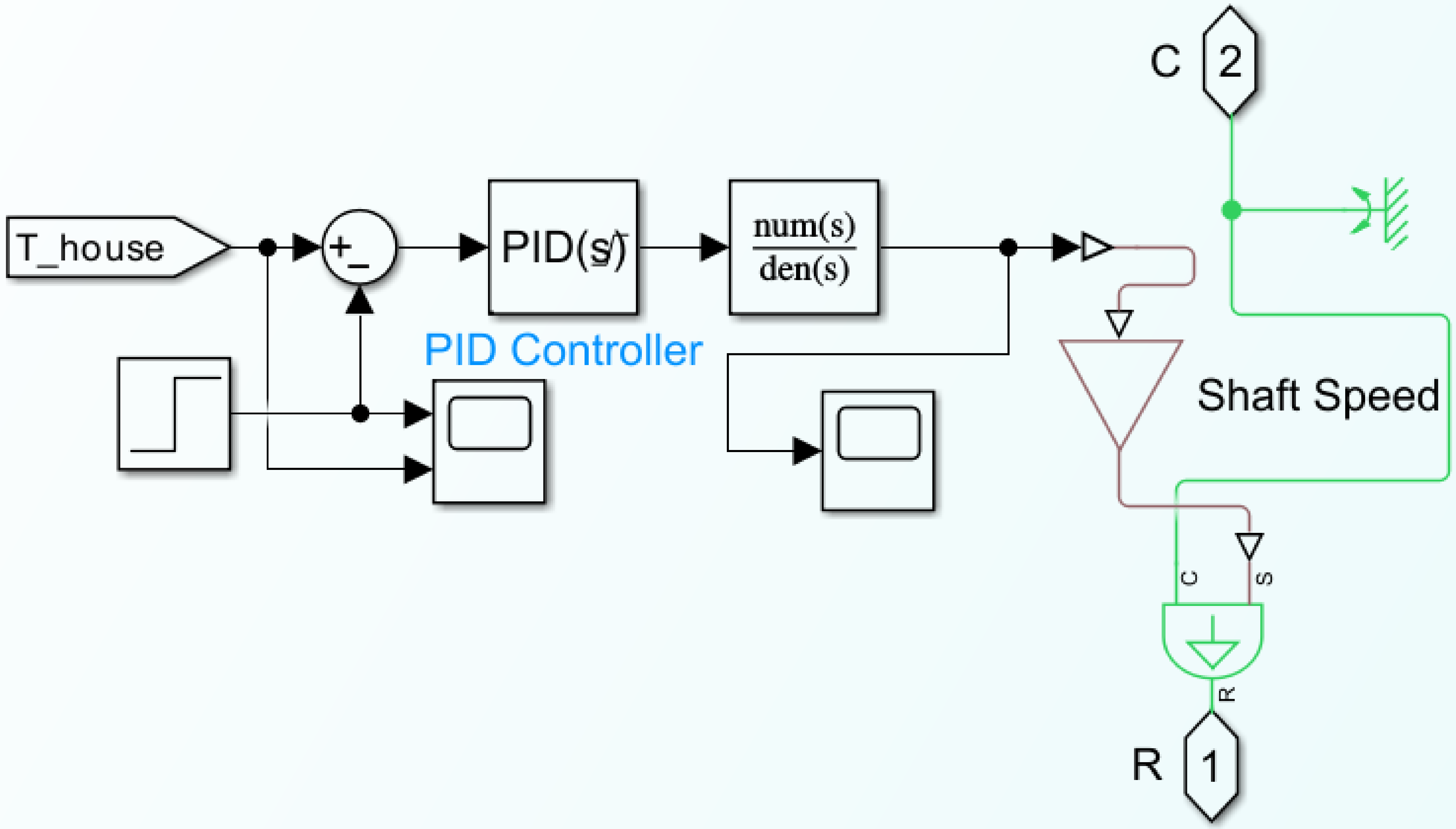
Block Parameters: Condenser

Condenser Evaporator (2P-MA) — Auto Apply

Settings | Description

NAME	VALUE		Unit
Moist Air 2			
Flow geometry	Flow perpendicular to bank of circular tubes		
Tube bank grid arrangement	Inline		
Number of tube rows along flow direction	1		
Number of tube segments in each tube row	50		
Length of each tube segment in a tube row	2		m
Tube outer diameter	evap_tubeDiameter+2*evap_...		m
Longitudinal tube pitch (along flow directi...	evap_tubeDiameter*1.3	0.013	m
Transverse tube pitch (perpendicular to flo...	evap_tubeDiameter*1.3	0.013	m
Pressure loss model	Correlation for flow over tube bank		
Heat transfer coefficient model	Correlation for flow over tube bank		
Fouling factor	0.1		K*m^2/kW
Total fin surface area	evap_airFinArea*5	3.25	m^2
Fin efficiency	0.75		
Initial moist air pressure	0.101325		MPa
Initial moist air temperature	T_env	40	degC
Initial humidity specification	Relative humidity		
Initial moist air relative humidity	0.5		
Initial trace gas specification	Mass fraction		
Initial moist air trace gas mass fraction	0.001		
Initial mass ratio of water droplets to mois...	0		
Relative humidity at saturation	1		

Transfer Function



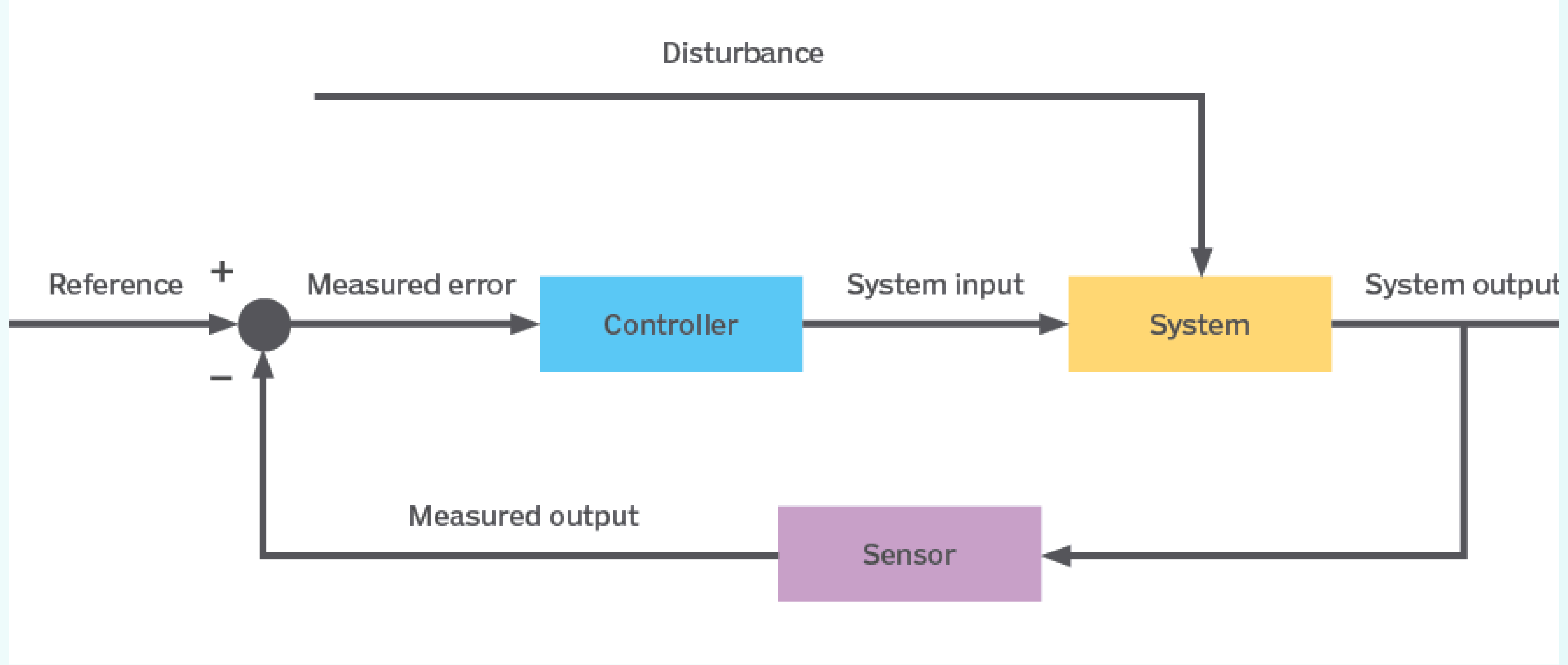
1. Mathematical modeling of temperature control in air conditioning space.
2. Determining the overall resistance from the Thermal resistance network.
3. Apply Laplace Transform

Formula:

$$\frac{T(s)}{\omega(s)} = \frac{-0.92\tau \Delta h_{evap}}{\left(\frac{MCs}{C_1} + 1\right) \Delta h_{comp}}$$

Control Logic

Hysteretic Control Strategy



Approach:

- The system ran the compressor and fans at a fixed speed.
- Temperature was the factor to switch the system on or off.

Working:

- Home temperature exceeds upper limit, compressor turns off.
- Temperature drops below the lower limit, the compressor turns back on.

Pros

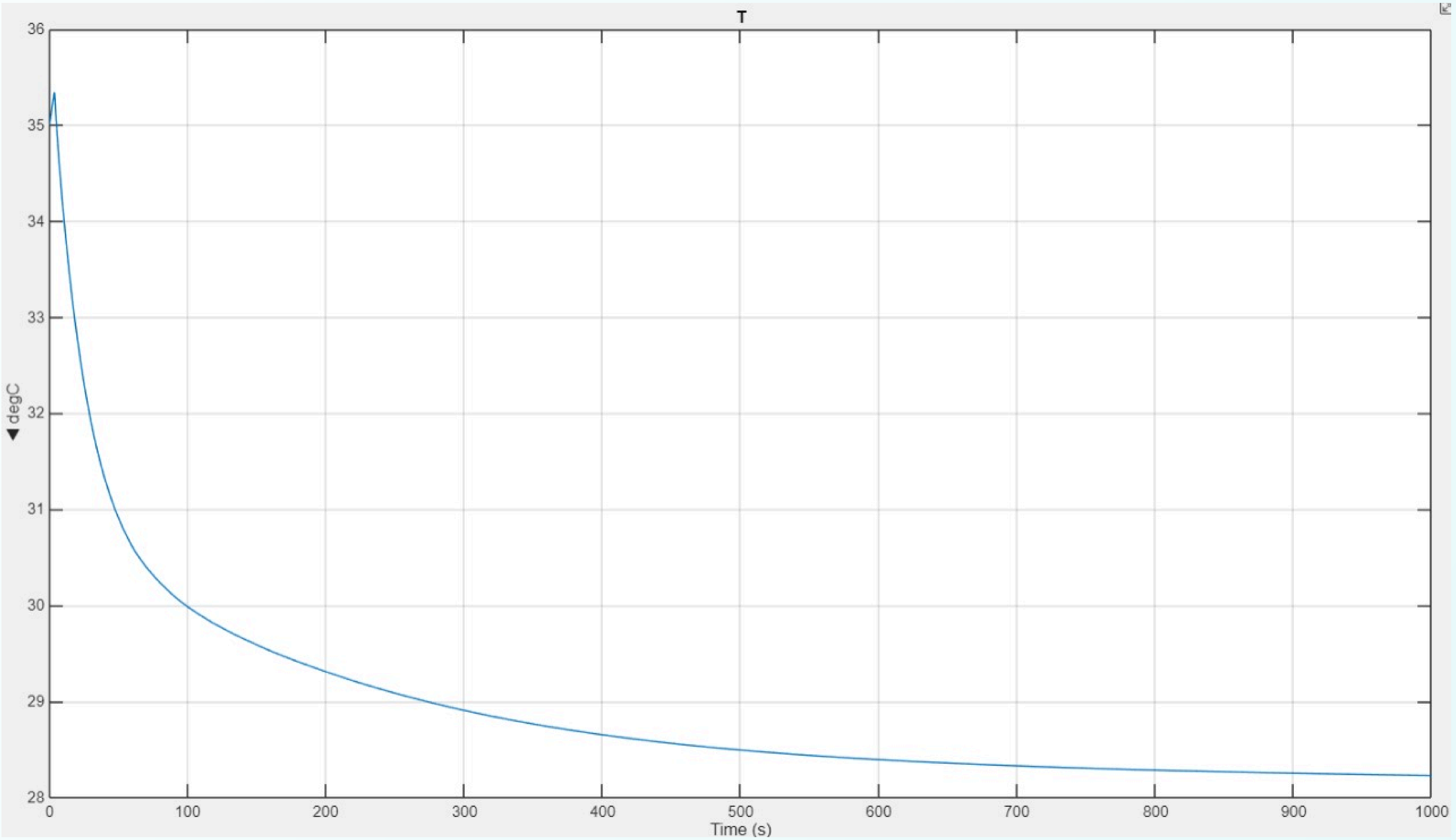
This approach was simple to implement and straightforward

Cons

It was not energy efficient and was not to able to dynamically adjust to changing temperature.

Control Logic

Hysteretic Control Strategy



Control Logic

Transition to PID Control

Switch to PID Control

- We upgraded to PID control for both the compressor and evaporator fan.
- Dynamic adjustment of compressor and fan shaft speed based on the temperature.

Phases of Operation

- Starts by increasing shaft speed to meet demand.
- Reaches a maximum speed when needed.
- Then, it gradually decreases as the temperature gets closer to the target.

Single PID Controller

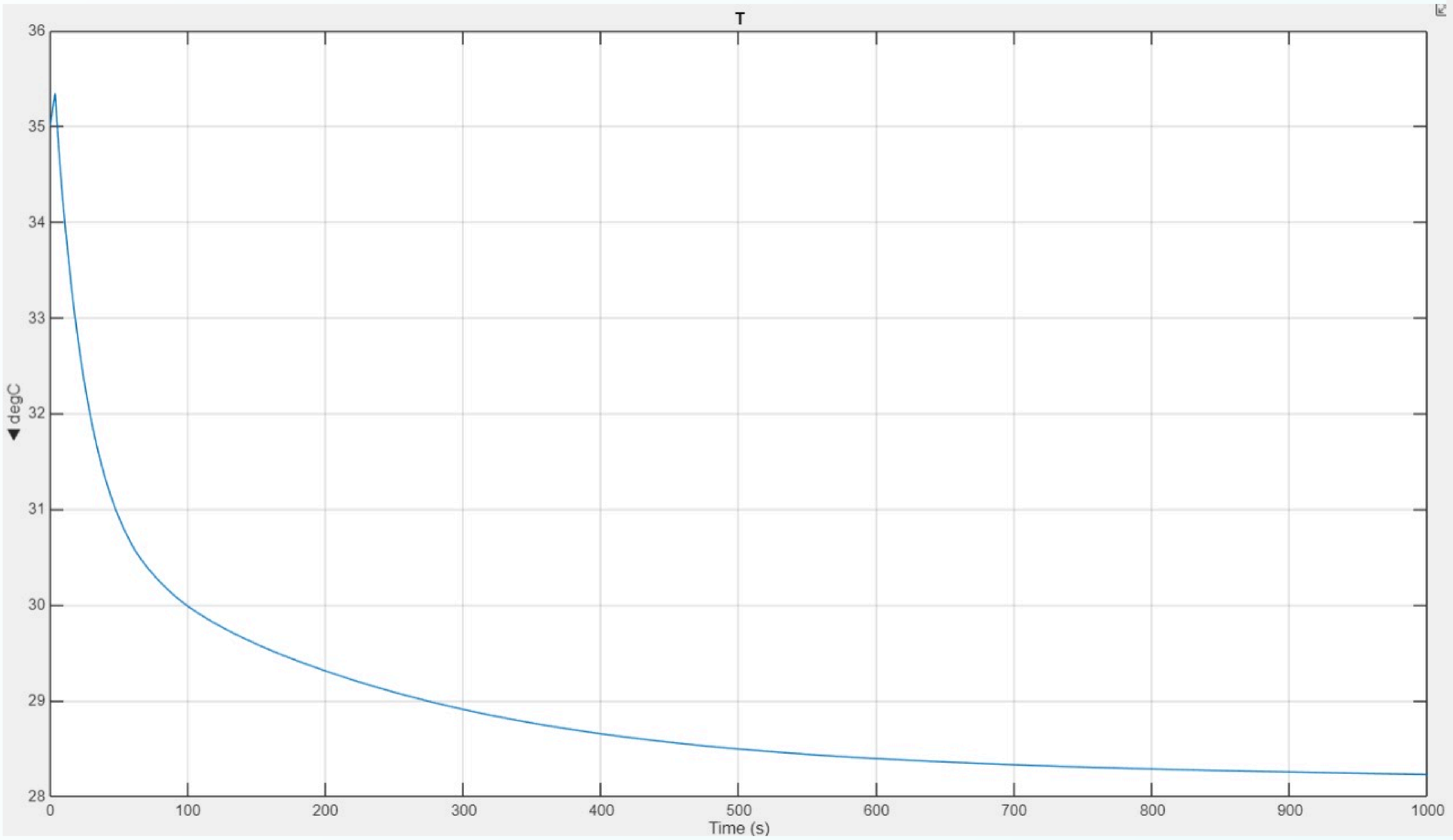
- To keep things cost-effective, we use just one PID controller to manage both the compressor and fan.

Benefits

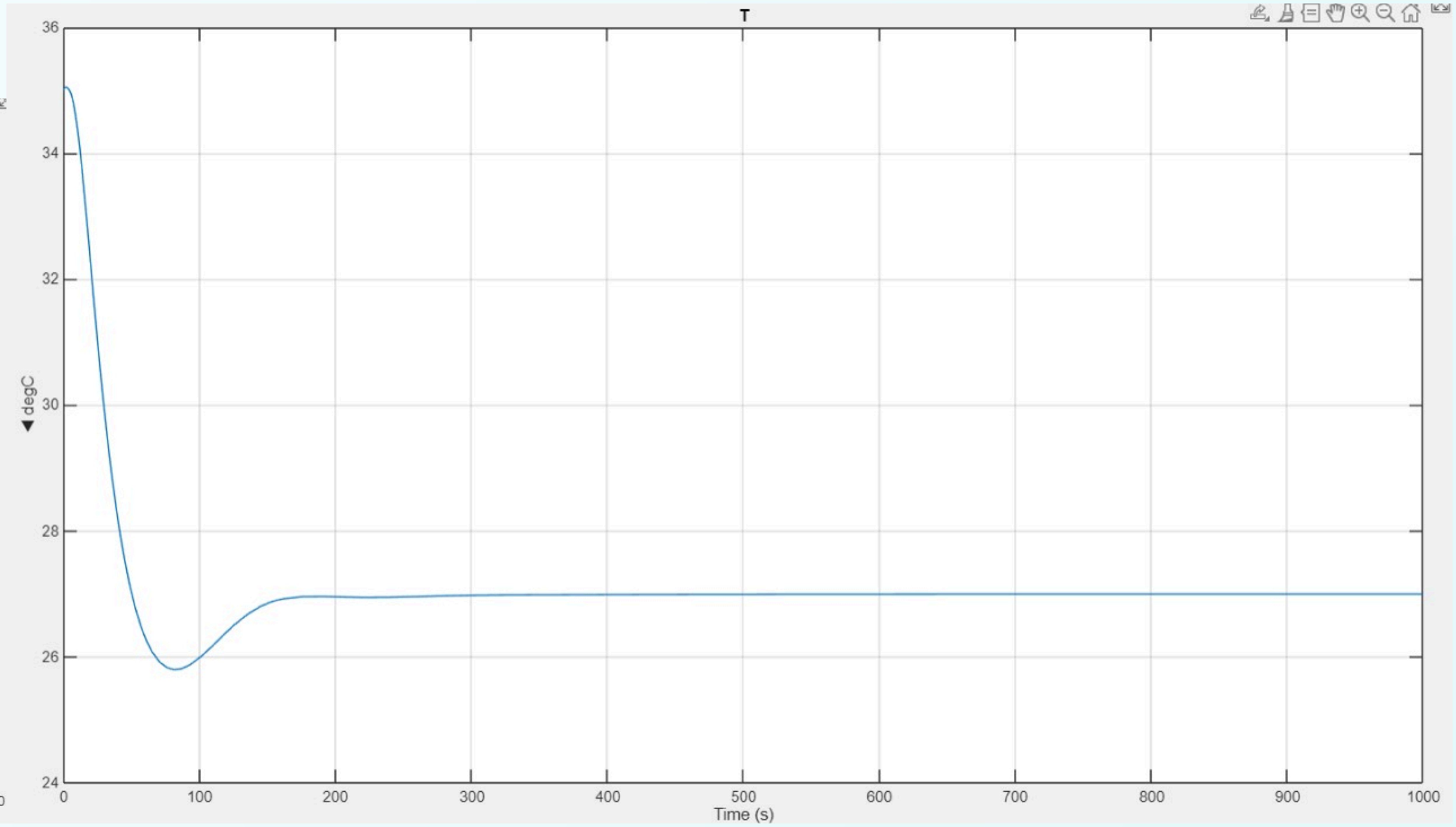
- This makes the system much more energy-efficient, lowering power consumption.
- It also ensures the system runs at optimal performance, adjusting smoothly to changes in temperature.

Control Logic

Transition to PID Control



on_off switch



PID Control

Dry bulb temperature (Kelvin) on Y-axis and time (Seconds) on X-axis

Fuzzy PID

Combines traditional PID control with fuzzy logic to adapt to system dynamics and uncertainties in real-time, improving performance in non-linear and dynamic environments.

Error Calculation:

The system calculates the **error** (difference between setpoint and current shaft speed) and the rate of change of error (derivative).

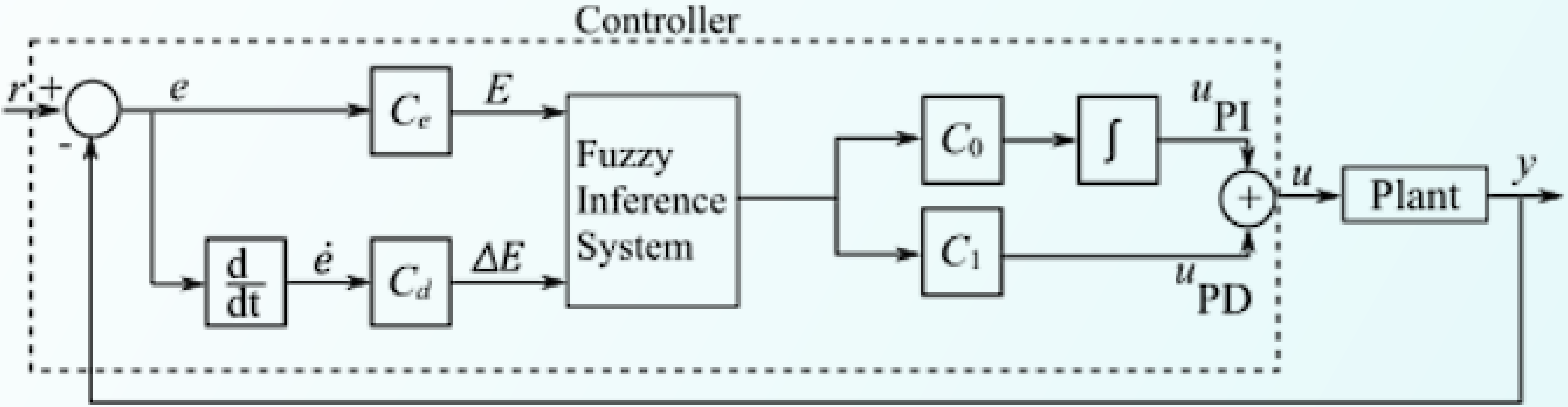
Fuzzy Logic

Fuzzy logic **processes** these inputs (error and its rate) using fuzzy rules to **dynamically adjust the PID** parameters.

PID Adjustment:

The fuzzy controller outputs the **adjusted PID gains** to control the compressor and evaporator shaft speeds.

Fuzzy PID


Controller
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Fuzzy Inference System
C_0
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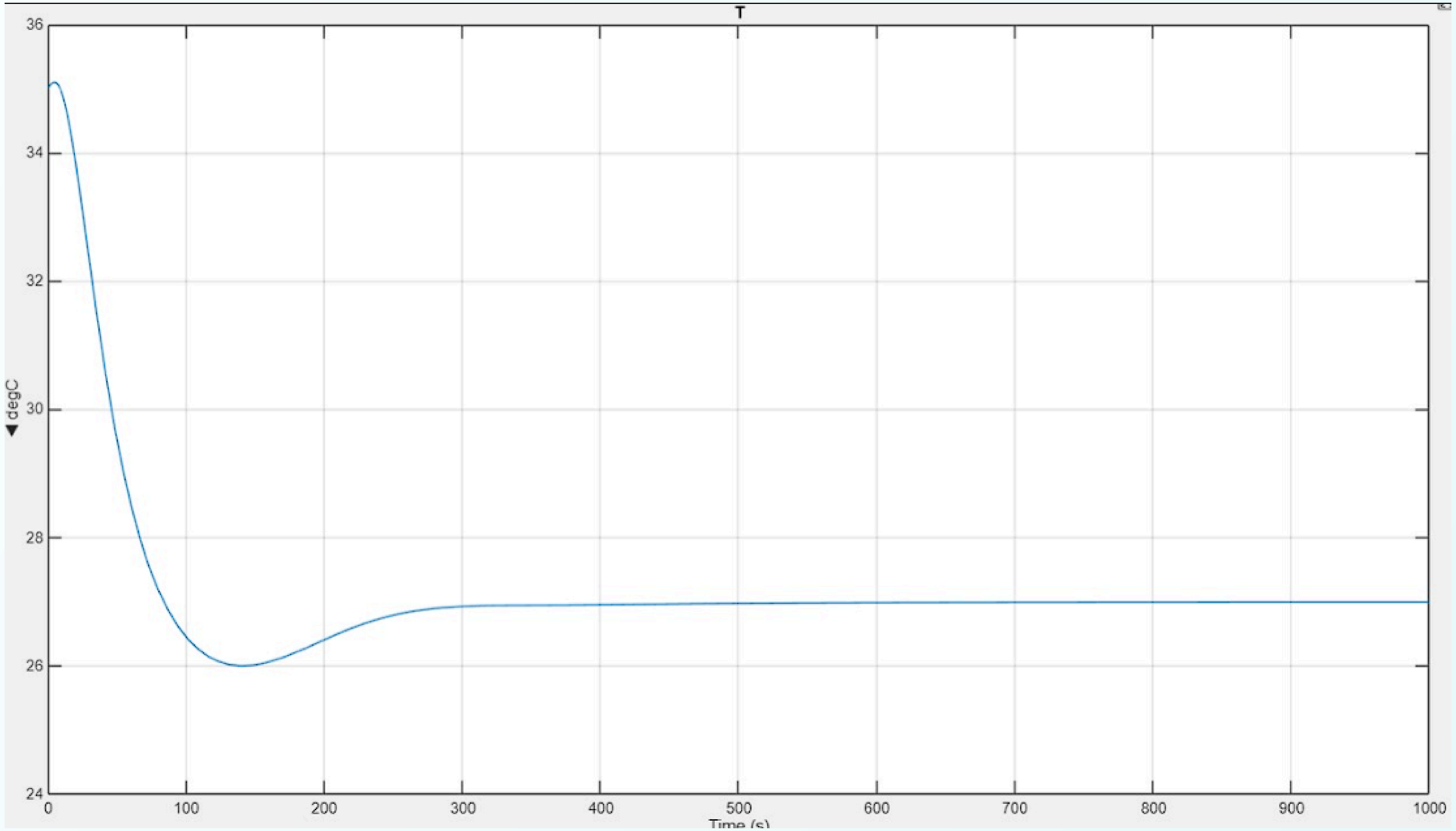
Fuzzy PID


T
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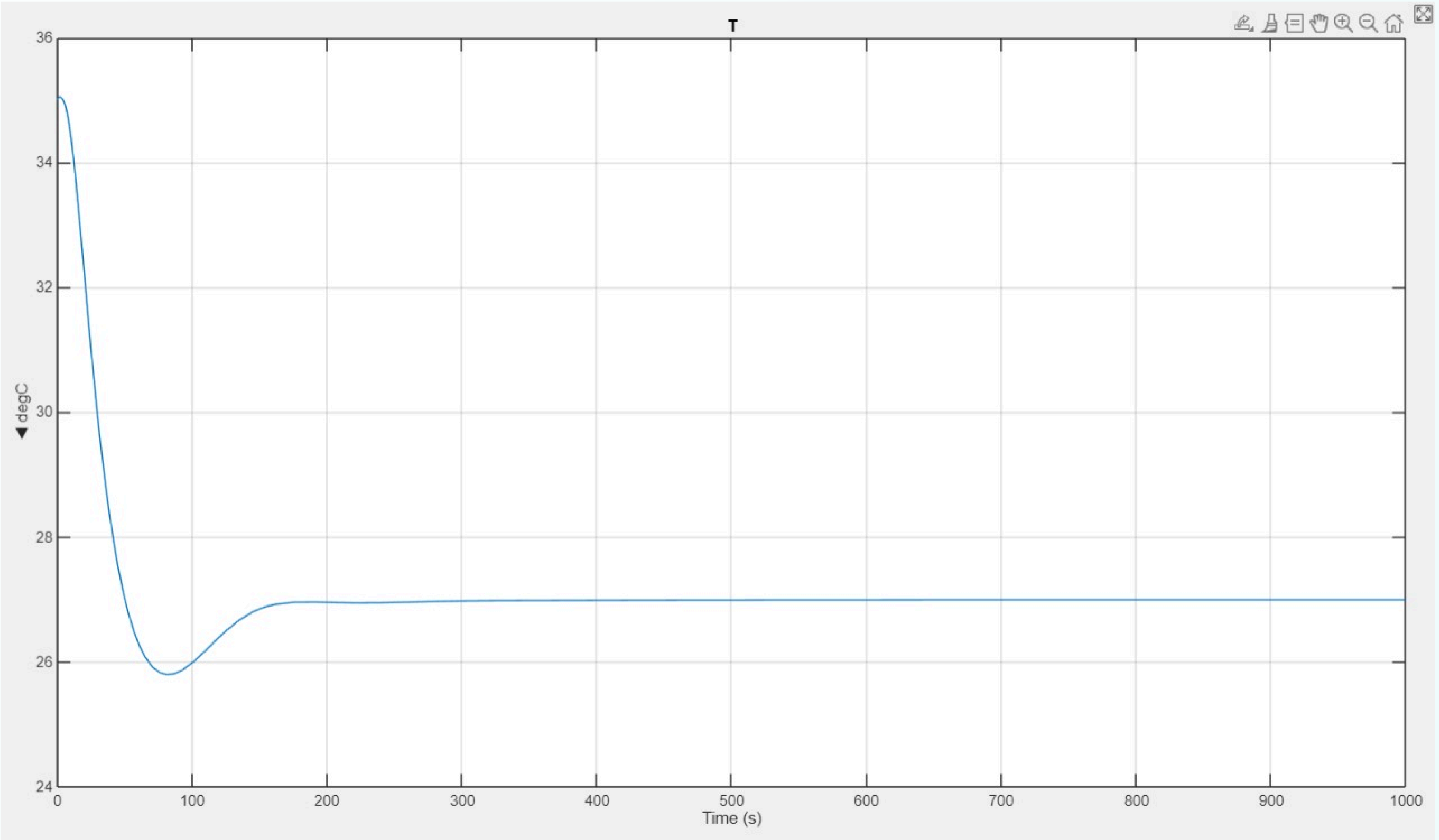
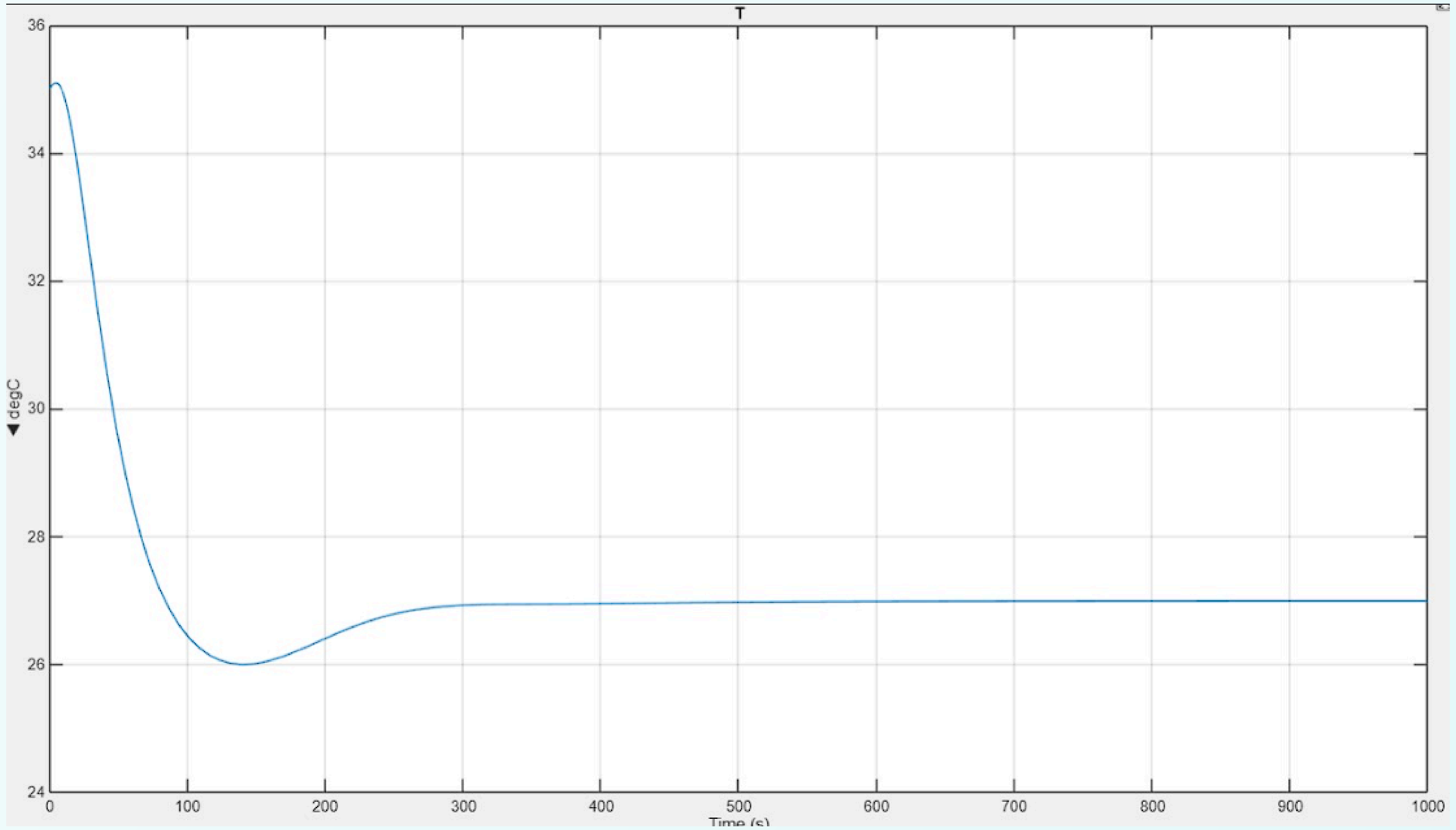
1000
Time (s)

PID



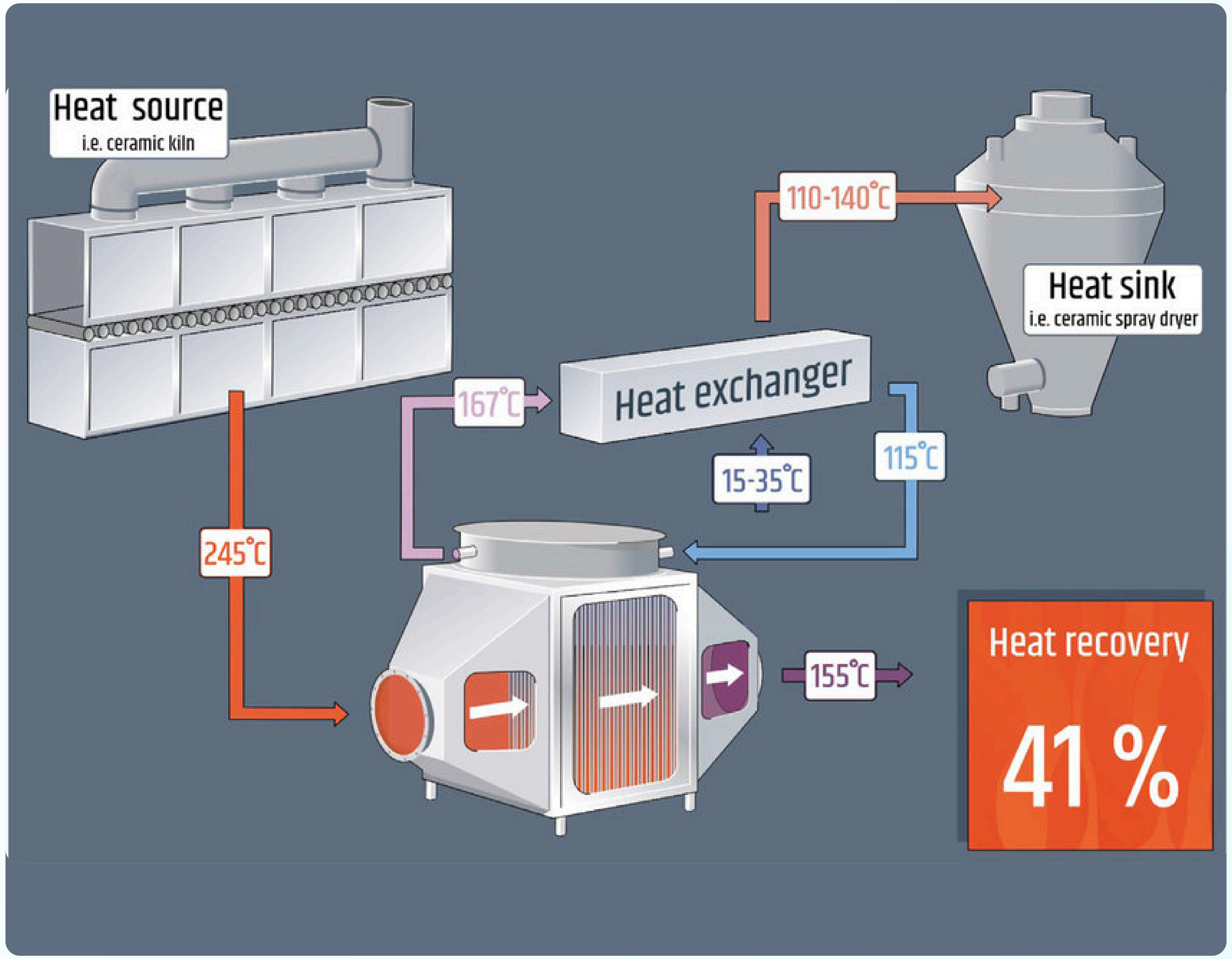
Fuzzy PID



Cost Analysis

Component	Cost (₹)
Evaporator	16,710
Condenser	15,610
Expansion Valve	3,097
Compressor	10,000
Indoor Blower	1,981
Outdoor Fan Motor	3,900
Total Cost	51,298

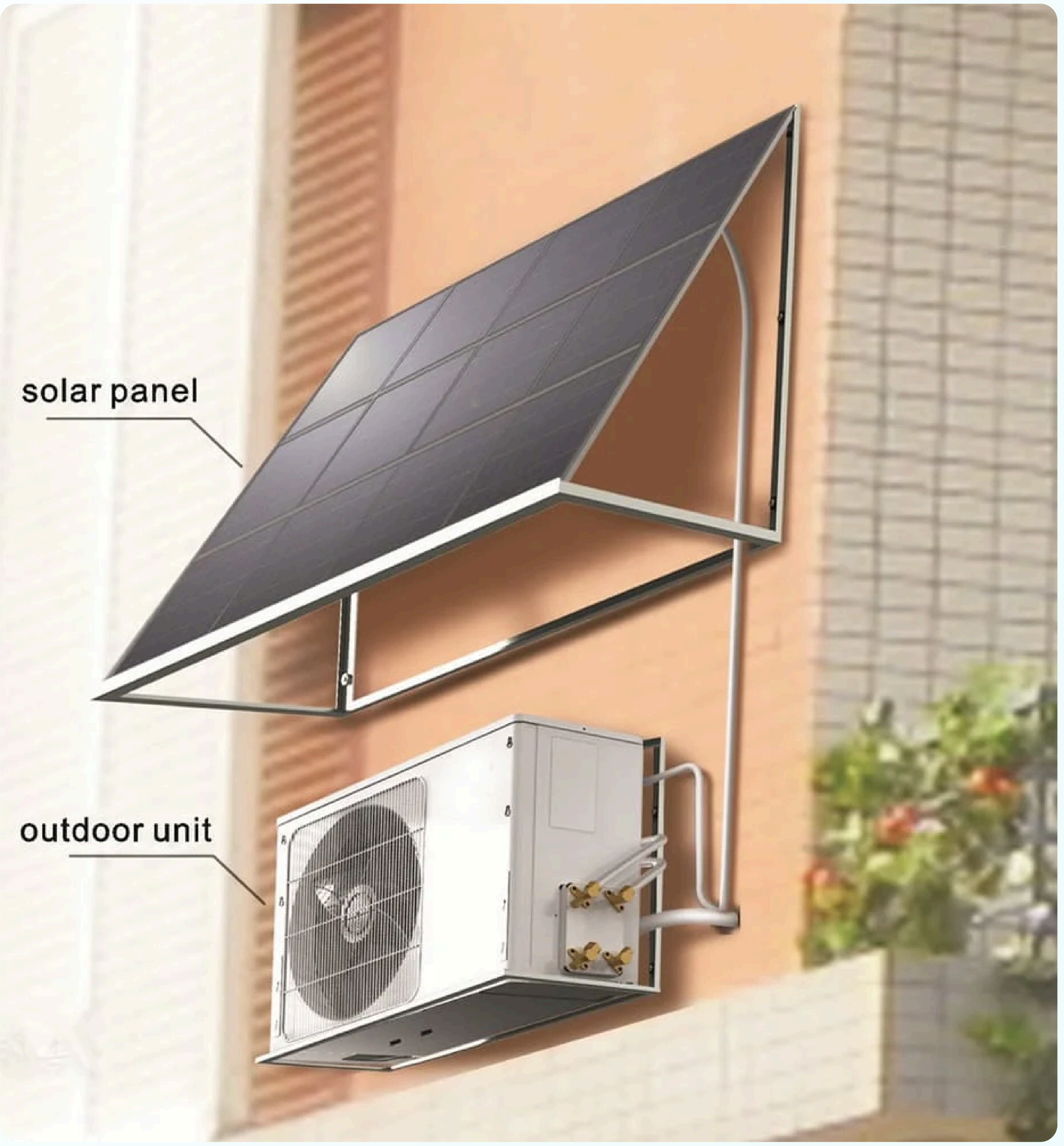
Potential Innovations



1. Waste Heat Recovery:

- **Capture** heat from the VCR cycle condenser.
- **Transfer** waste heat to water or air using a heat exchanger.
- Can be used for **domestic** hot water, space heating.
- **Higher initial cost**, but reduced running costs due to energy savings over time.

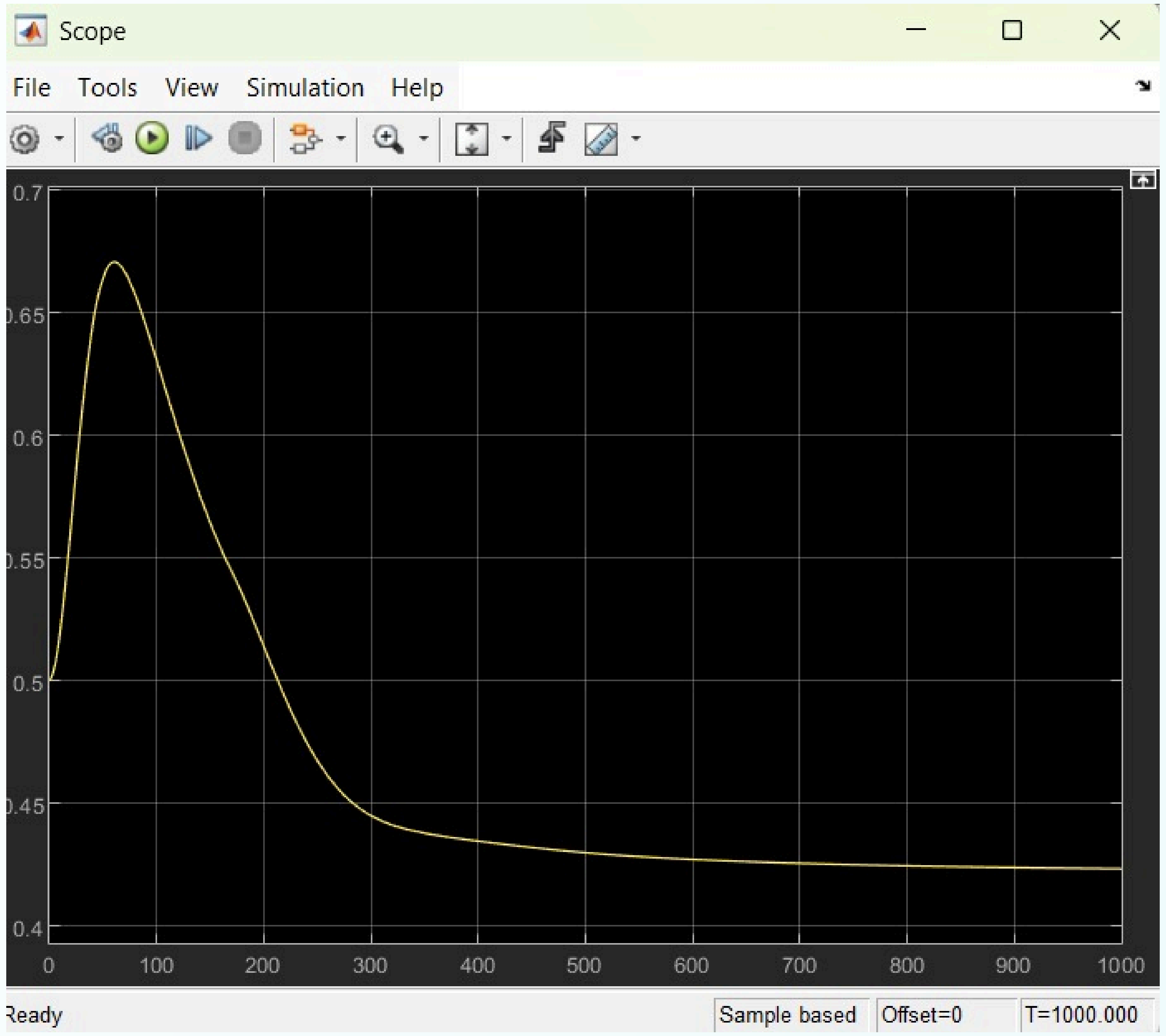
Potential Innovations



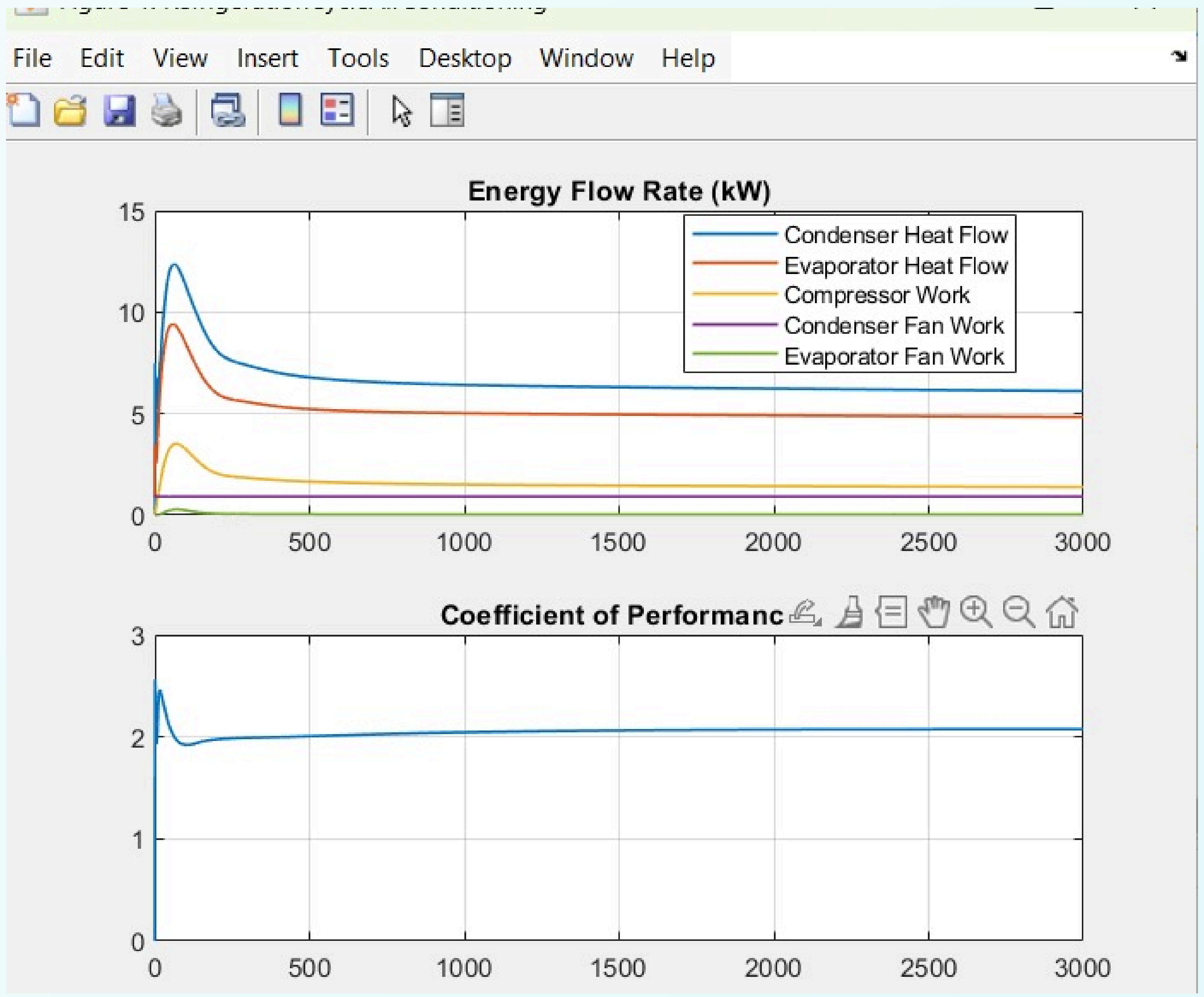
2. Solar Integration:

- Integrate **PV panels** to power the HVAC system.
- **Lower electricity** costs by using solar energy during peak hours.
- Combine renewable energy with HVAC technology for a **greener** solution.
- **Higher initial investment**, but long-term savings through reduced energy bills.

Results

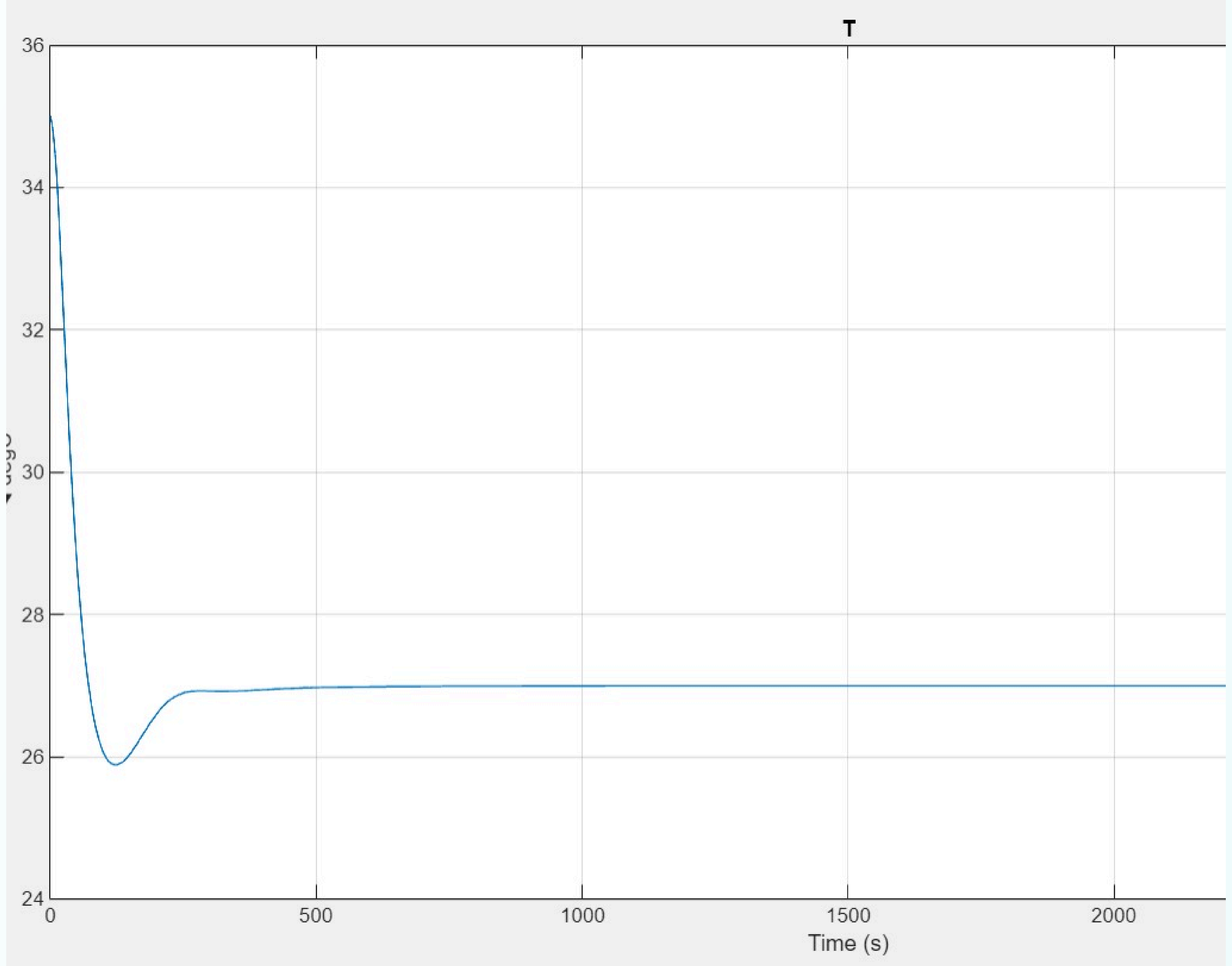


Wet bulb temperature (Kelvin) on Y-axis and time (Seconds) on X-axis

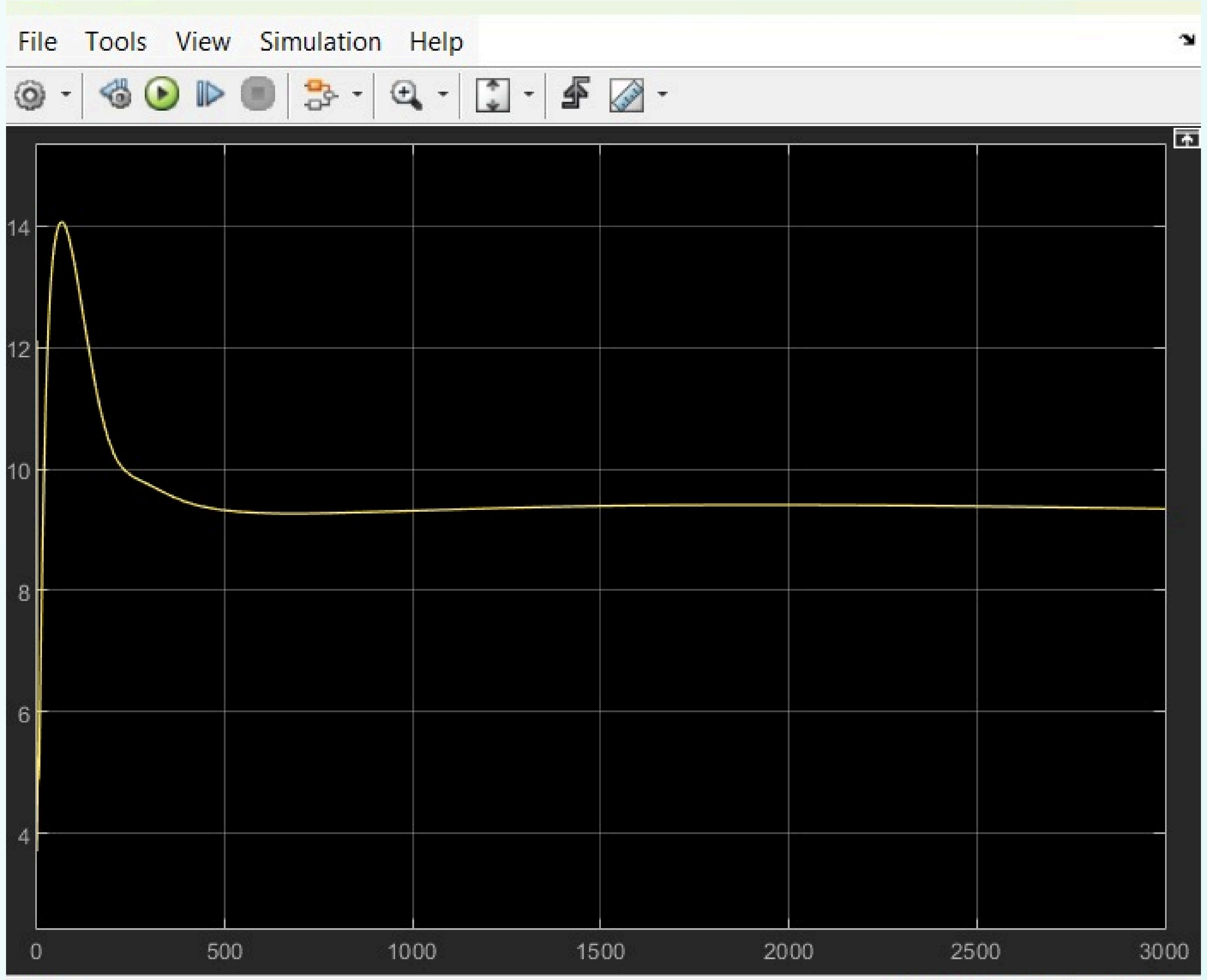


Energy Flow Rate and COP at 35∘C

Results

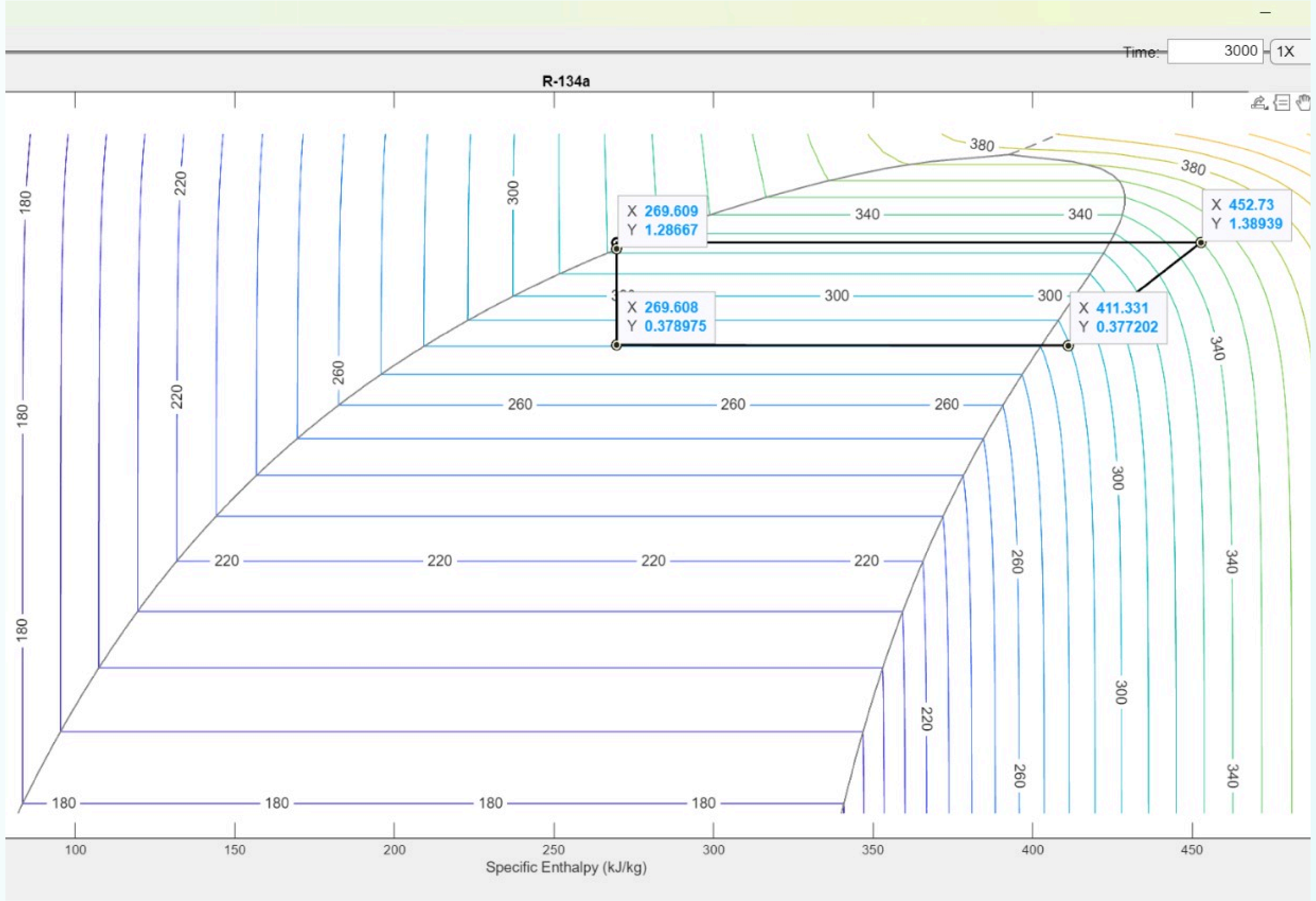


Dry bulb temperature (Kelvin) on Y-axis and time (Seconds) on X-axis



Superheat at 35 dgeree Celsius

Results



P-h Graph