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MODERN OPTIMIZATION TECHNIQUES FOR PID PARAMETERS OF CONTROL SYSTEM

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ABSTRACT
Effective control of dynamic processes is crucial for optimizing performance in various engineering applications. The Proportional-Integral-Derivative (PID) controller is a widely adopted control strategy due to its simplicity and versatility. However, achieving optimal PID controller parameters remains a challenging and time-consuming task, often requiring manual tuning. This research proposes an innovative approach by integrating optimization techniques into the PID controller design process to automate parameter tuning for enhanced control system performance. The study begins with the development of a detailed mathematical model representing the dynamics of the control process under consideration. This model serves as the foundation for subsequent simulation and optimization efforts. A critical aspect of the research involves the careful selection and definition of performance criteria, including overshoot, settling time, and rise time, to quantify the desired behavior of the control system.
KEYWORDS: PID controller, optimization, Control system, HVAC, Cabin subsystem.

INTRODUCTION
There is a limited amount of things like fossil fuels. Even though climate change and its effects on the environment will have bad effects, it doesn't seem like a good idea to limit how much of something you can eat if you have no other choice. The move away from fossil fuels and toward renewable energy sources is causing high investment costs. These costs go up with the amount of new capacity that is built. So, if you want to speed up the switch to a system that is powered by renewable resources and save money at the same time, you should use less energy.

Since buildings use at least 30% of all energy, it's important to look into how this can be cut down. One way to get the supply of energy to match the demand for it would be to improve the quality of the controls [1]. Most buildings are controlled by proportional-integrative (PI) systems and sometimes by proportional-integrative-derivative (PID) systems. Since industry seems slow to adopt new technologies, it might be a good idea to look into how to better tune these controllers, with a focus on building energy systems. Even though PI and PID controllers are widely used in industry and sophisticated tuning methods and software packages are available [2], there are still

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 4205-4215
a lot of poorly tuned controllers in the building automation industry and the heating, ventilation, and air conditioning (HVAC) industry.
HVAC (heating, ventilation, and air conditioning) systems are used all year long to keep offices, homes, and businesses at a comfortable temperature for people to work and live in. This lets the inside temperature be controlled all year long. Putting in HVAC systems makes it possible for people to live a life that is not only wealthy but also very healthy [3]. But in an environment that can be controlled to the right degree, a wide range of things can be made while keeping in mind how much they cost, how well they work, and how quickly they can be used. Every day of the year, people in industrialized countries around the world work to keep the air clean in residential areas, business areas, institutional settings, and industrial settings. HVAC system models use the conservation of mass and energy to figure out how much of each component is needed to heat and cool the building and how much electricity is needed. Some of the parts of the system are pumps, mixing boxes, fans, coils, chillers, humidifiers, ducts, boilers, and other HVAC equipment. When figuring out how much energy is needed, ES programmes use a wide range of complicated methods that are unique to each implementation in the system.

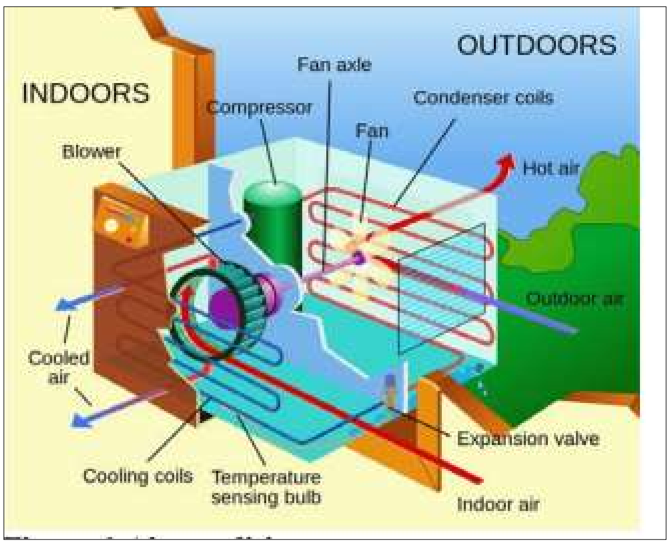

Figure 1: Air conditioner

The HVAC regulates the Room temperature, humidity of the room, air purification as well as air flow in a given room. These factors are described below:

HVAC SYSTEMS

A heating, ventilation, and air conditioning (HVAC) system's primary objective is to provide people with the desired degree of thermal comfort by regulating and altering outside air conditions to suit inhabited buildings' demands . Meeting the demands of a process and the needs of the occupants is the aim of an HVAC (heating, ventilation, and air conditioning) system. Buildings that are residential, commercial, or institutional are among those that are using HVAC (heating, ventilation, and air conditioning) systems more and more. Before being pumped through the rooms, the outside air is taken inside the structures and heated or cooled. The air is then recycled inside the system or discharged back into the atmosphere, depending on the external weather conditions. The selection of HVAC systems in a particular building will be influenced by a

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 4205-4215

number of factors, including the surrounding climate, the age of the structure, the preferences of the owner and designer, the project budget, and the architectural style of the building. .

Based on their functions and air distribution methods, HVAC (heating, ventilation, and air conditioning) and A/C systems may be categorized. Air circulation, heating, and cooling are all necessary procedures and are all significant. Two examples of processes that may be included are the dehumidification and humidification processes. To accomplish these tasks, make use of the appropriate heating, ventilation, and air conditioning (HVAC) equipment, such as dehumidifiers, air conditioners, heaters, and ventilation fans. A distribution system is necessary for heating, ventilation, and air conditioning (HVAC) systems in order to maintain the proper temperature and provide the appropriate quantity of air. The primary determinants of the distribution system's uniqueness are the kind of refrigerant and its delivery method, which may include water pipes, air handling equipment, fan coils, or air ducts.

PROPOSED MODEL AND SIMULATION RESULTS

A volume of wet air exchanging heat with the outside world is how the cabin is visualized. Before entering the cabin again, the moist air passes via a mix door, a heater, an evaporator, a blower, and a recirculation flap. The flow input from the cabin or the outside world is chosen by the recirculation flap. To regulate the temperature, the blender door redirects flow around the heater. There are two ways to mimic the model: using manual system inputs or predetermined system inputs. The System Inputs variant subsystem contains the HVAC system's control settings for specified system inputs. The dashboard controls may be used to change the control settings for manual system inputs during operation.

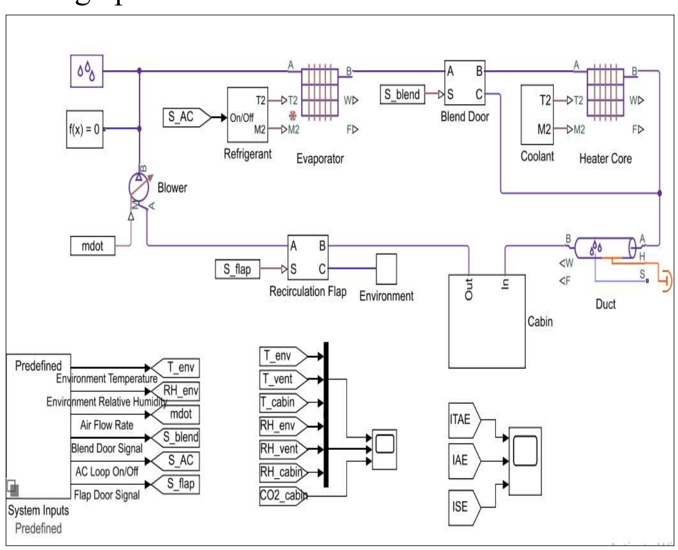

Figure 2: Proposed simulation model

The supply air pressure control loop in an HVAC system may be used using a PID controller. The water flow rate from the chiller to the heat exchanger and the air flow rate, which may be changed using a variable-speed fan, are the HVAC system's control inputs. Motor speed is adjusted by the PID controller calculations as needed to keep it at a predetermined point in relation to the system output signal. The motor speed should be regulated to maintain a set point difference for the HVAC system, taking into account factors like flow rate, ambient temperature, and the functioning of the valves and dampers. The capacity of the PID system to keep a given point and accelerate activity determines how well it performs. The non-linearity and time-variance features of big HVAC systems make tuning a difficult and time-consuming procedure. As a result, optimizing the PID controller of an HVAC system to get the best tracking control efficiency is a challenging task. Here, we suggest using to adjust the PID settings, which will expedite the HVAC system's retuning procedure as required.

Variable flap

In a moist air network, this subsystem simulates a limitation that regulates flow between paths AB and AC. Physical Signal Port S sets the relative limitation area. Path AC shuts and path AB opens when the value is 1. Path AB shuts and path AC opens when the value is 0.

Table 1: Variable flap parameters

Parameters	Value
Minimum restriction area (m^2)	1e-10
Maximum restriction area (m^2)	0.9 * duct area
Cross-sectional area at ports A, B, and C (m^2)	duct area
Discharge coefficient	0.8

Table 2: Cabin Parameters

Parameters	Value
Number of occupants	1
Moisture gain per occupant (g/s)	0.04
CO2 gain per occupant (g/s)	0.01Exhalation temperature (degC)
Exhalation temperature (degC)	30
Sensible heat per occupant (W)	70

HVAC SYSTEM MODEL

Thus far, the approach used, along with the factors and presumptions, have been revealed. The constructed model provides a simplified but functional system representation for appropriate control design while also taking into account some of the frequent thermal loads seen in real driving conditions. The system is implemented in Matlab/Simulink and is theoretically modelled. These tools may mimic the actual model, and others have been created in response

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 4205-4215

to interface the system model with various thermal disturbances.

CABIN SUBSYSTEM

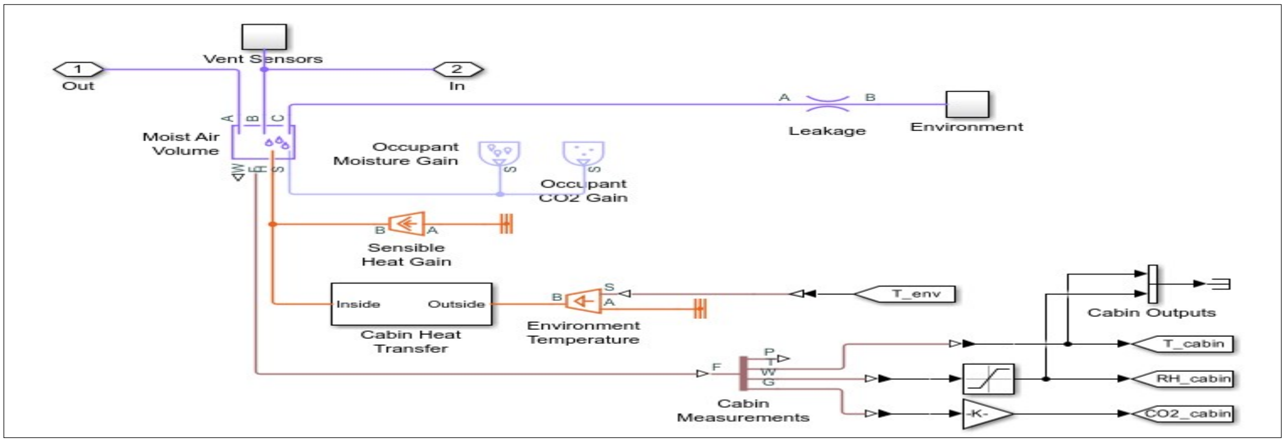

Figure 3: Cabin subsystem

Surface elements (or body) and cabin air are the two distinct thermal masses that make up the HVAC system. For them, the heat balance equation is as follows:

$\dot{Q}_{cabin} = V_{air}\, \rho_{air}\, C_{pair}\, \hat{T}_{cabin}$

* Q^\ surf = m body Cp body T ^ body

Where m body is the equivalent body mass made up of each surface element having a heat capacity, any $\dot{T}$ is the temperature fluctuation in °C, and any Cp is the specific heat in W/kg°C. Any $\dot{Q}$ is the total heat per time unit. V air is the cabin air volume in m3. ρair is the air density in kg/m3. Continuous time is used to express equations 4.2 and 4.1. Throughout the specified simulation period (ts), load calculations are carried out at time steps. Following each time step, all loads are added up, and the new cabin air and body element temperature may also be stated as follows:

JAYA OPTIMIZATION

The benchmark function of restricted and unconstrained issues has been successfully solved using the simple and effective Jaya global optimization technique. Although it employs the same parameter-free method as the TLBO, it differs in that it doesn't need a learner phase that is, it just requires the teacher phase while the TLBO operates in two phases. It is predicated on the idea that the optimal solution for a particular issue may be found by avoiding the worst one. The beauty of this algorithm is that it only needs a small number of control parameters, which are often common for all algorithms, such as the maximum number of generations and population size, as well as the number of design variables. Before starting the real computational experiments, there is no need to fine-tune any algorithm specific control settings.

Catalyst Research Volume 23, Issue 2, December 2023 Pp. 4205-4215

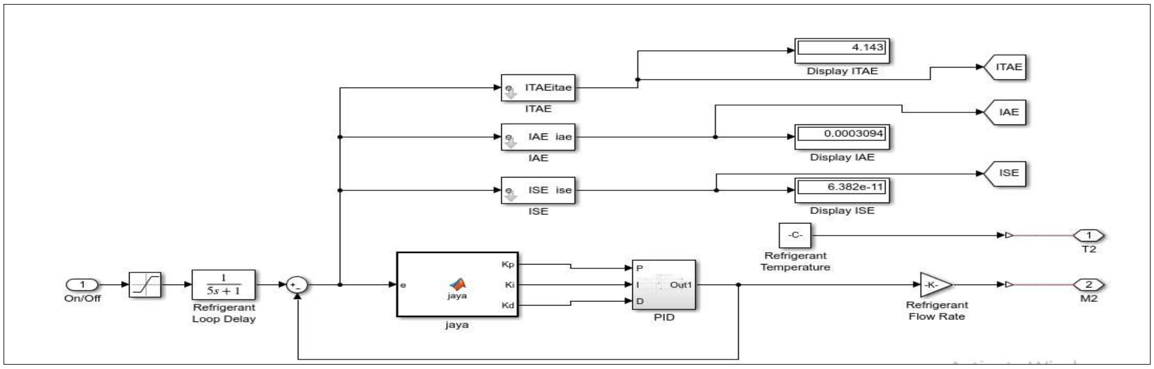

Figure 4: Jaya Optimization subsystem

SIMULATION MODEL WITHOUT CONTROLLER

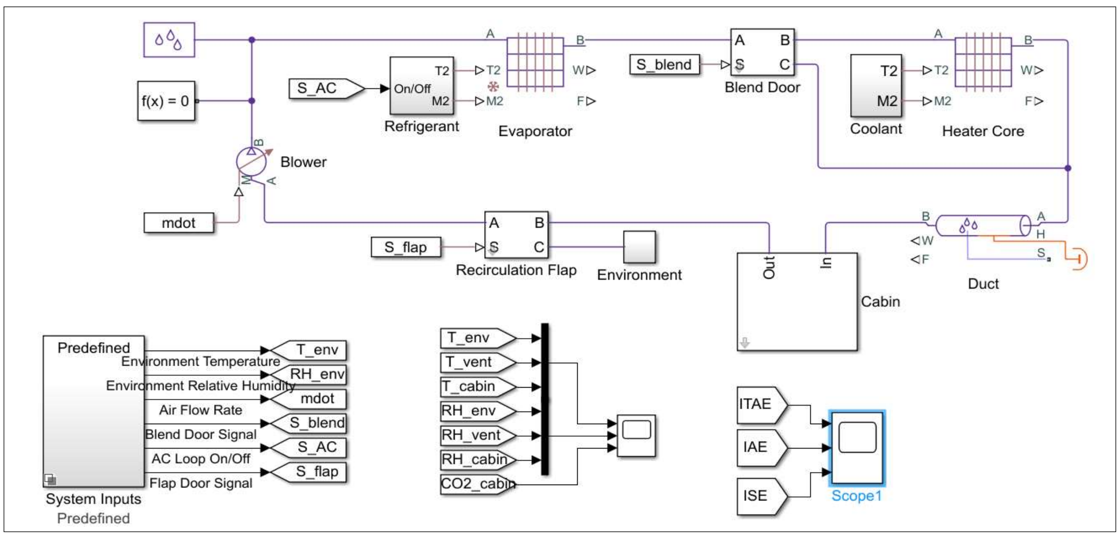

Figure 5: Simulation Model without Controller

Simulation Results

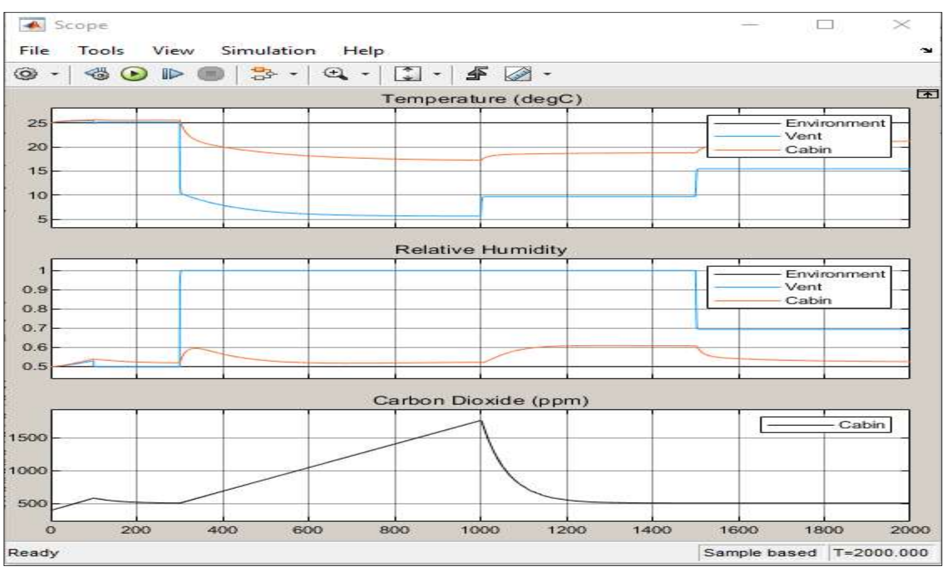

Figure 6: Temperature, relative humidity, and PPM of hybrid optimization

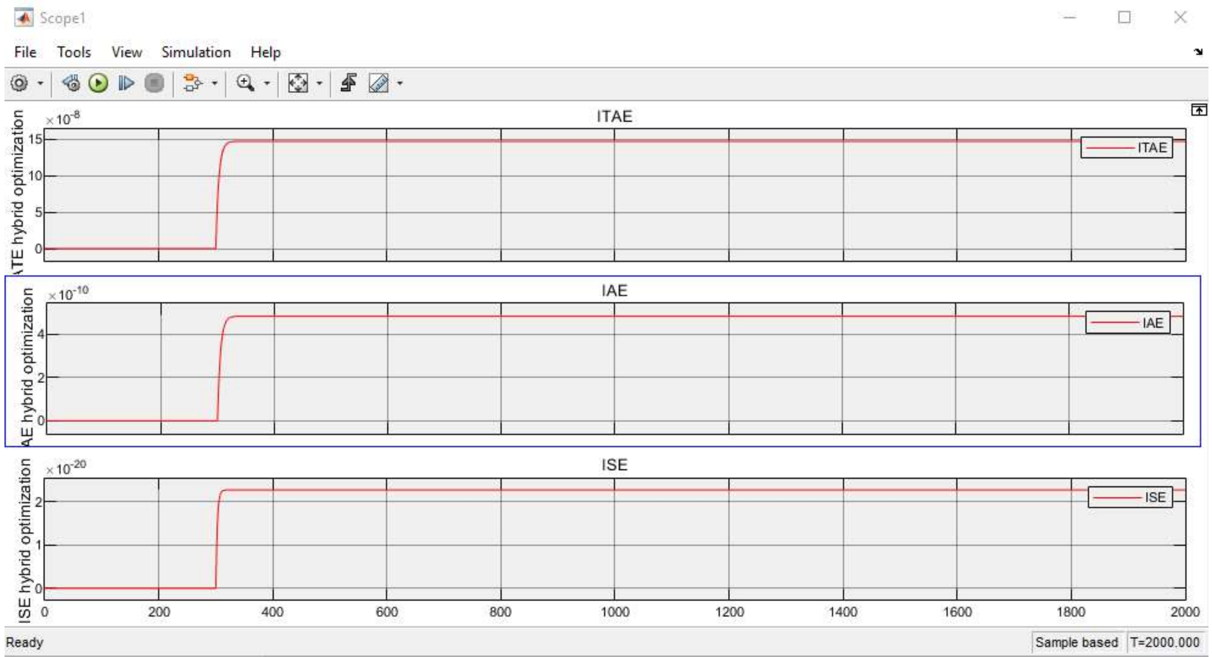

Figure 7: ITAE,IAE,ISE of hybrid optimization

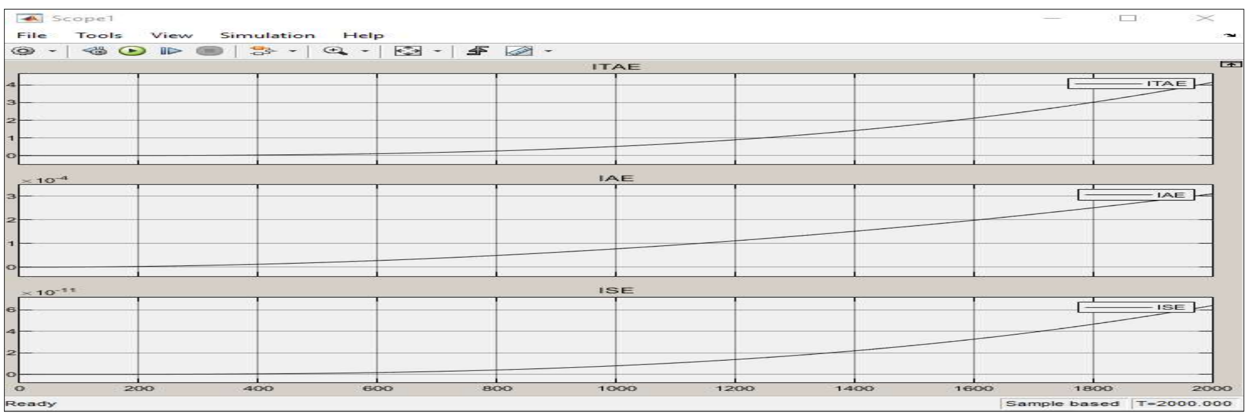

Figure 8: ITAE, IAE, ISE of JAYA optimization

Optimization

Key concept in optimization. Most optimization algorithms are designed to minimize an objective function. that maximizing a function is equivalent to minimizing its negative. So, if you want to maximize a function f(x), you can minimize −f(x).

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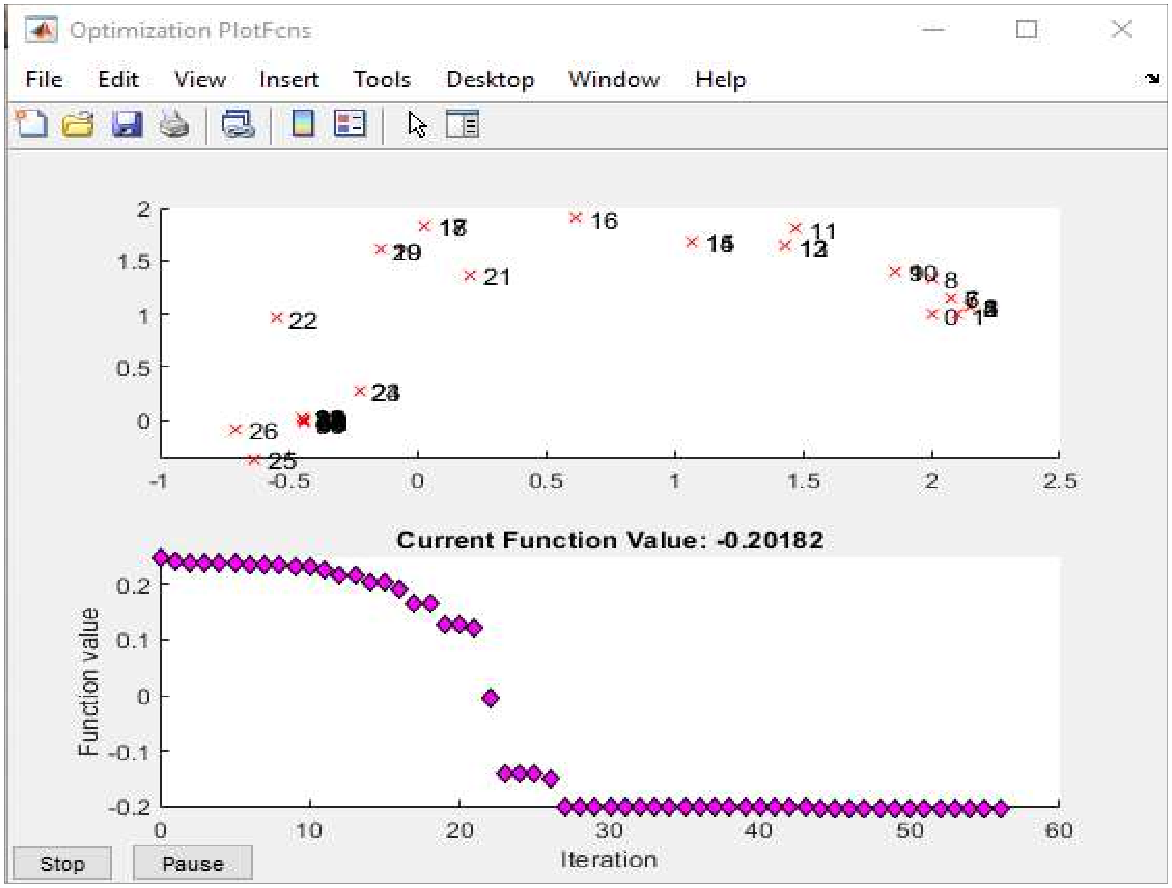

Figure 9: Optimization Function of hybrid optimization

Table 3: Optimization Function of hybrid optimization

Techniques	Optimization Function
Hybrid Optimization	-0.20
Cat And Mouse Optimization	-.4052
Jaya Algorithm	-0.28

The outcomes of optimization strategies and the values of their optimization functions. The values of the optimization function seem to represent numerical outcomes of each optimization method applied to a problem. Finding the least (or highest) value of an objective function by modifying the input parameters or variables is usually the aim of optimization algorithms.

CONCLUSIONS

In conclusion, the evaluation of optimization studies for vehicle Heating, Ventilation, and Air Conditioning (HVAC) systems represents a significant stride towards achieving energy efficiency and enhanced occupant comfort. The comprehensive exploration focused on three distinct facets: optimization of HVAC operational parameters, control system optimization, and vehicle design optimization.

The operational variable optimization approach within the HVAC system proved instrumental in identifying optimal parameter settings, minimizing overall error, and ensuring a comfortable environment for vehicle occupants. Notably, this study introduced an innovative method for swiftly tuning PID controller parameters in a second-order HVAC system using the cost-effective and fast-convergent optimization algorithms—cat and mouse optimization, jaya optimization, and a hybrid of cat and jaya optimization.

The research underscores the complexity of HVAC system optimization, emphasizing that achieving minimal overall error is contingent not only on the system's functionality but also on the structural characteristics of the building and heat dissipation dynamics. While operational variables and controller optimization methods demonstrate efficacy for current vehicles, their implementation necessitates a dynamic model of the vehicle's thermal properties and HVAC system, posing challenges for redesign. Nevertheless, the study highlights the relevance of the proposed method for building design optimization.

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