OPTIMAL TUNING OF PROPORTIONAL INTEGRAL DERIVATIVE CONTROLLER FOR SIMPLIFIED HEATING VENTILATION AND AIR CONDITIONING SYSTEM

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Special thanks to my beloved Mother, Father,
Sister, Brother and especially
my lovely wife

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ABSTRACT

A Heating Ventilation and Air Conditioning system (HVAC) is an equipment that is designed to adapt and adjust the humidity as well as temperature in various places. To control the temperature and humidity of the HVAC system, various tuning methods such as Ziegler–Nichols (Z-N), Chien-Hrones-Reswick (CHR), trial and error, robust response time, particle swarm optimization (PSO) and radial basis function neural network (RBF-NN) were used. PID is the most commonly used controller due to its competitive pricing and ease of tuning and operation. However, to effectively control the HVAC system using the PID controller, the PID control parameters must be optimized. In this work, the epsilon constraint via radial basis function neural network method is proposed to optimize the PID controller parameters. The advantages of using this method include fast and accurate response and follow the target values compared to other tuning methods. This work also involves the estimation of the dynamic model of the HVAC system. The non-linear decoupling method is used to modify the model of HVAC system. The benefits of using the proposed simplification technique rather than other techniques such as the relative gain array techniques (RGA) is because of its simplification, accuracy, and reduced non-linear components and interconnection effect of the HVAC system. It is observed that the amount of integral absolute error (IAE) for temperature and humidity based on the simplified model are decreased by 18% and 20% respectively. Moreover, it is revealed that optimization of PID controller through multi objective epsilon constraint method via RBF NN of the simplified HVAC system based on non-linear decoupling method shows better transient response and reaches better dynamic performance with high precision than other PID control tuning techniques. The proposed optimum PID controller and estimation of dynamical model of the HVAC system are compared with the different tuning techniques such as RBF and Z-N based on original system. It is observed that the energy cost function due to temperature (J_T) and humidity (J_{RH}) are lowered by 15.7% and 4.8% respectively; whereas the energy cost functions reflect the energy consumptions of temperature and humidity which are produced by the humidifier and heating coil. Therefore, based on the new optimization method the energy efficiency of the system is increased. The unique combination of epsilon constraint method and RBF NN has shown that this optimization method is promising method for the tuning of PID controller for non-linear systems.

ABSTRAK

Sistem Pemanasan, Pengalihudaraan dan Penyaman Udara atau dikenali sebagai (HVAC) adalah satu sistem yang telah direka untuk mengekalkan dan melaraskan kelembapan dan juga suhu di beberapa kawasan. Untuk mengawal kadar kelembapan dan juga suhu dengan menggunakan sistem HVAC terdapat beberapa kaedah yang telah diperkenalkan antaranya Ziegler-Nichols (Z-N), Chien-Hrones-Reswick (CHR), kaedah cubaan, masa tindak balas teguh, kaedah pengoptimuman ia ini dikenali sebagai pengoptimuman kerumunan zarah (PSO) dan juga kaedah rangkaian neural (RBF-NN). Berkadaran kamiran terbitan (PID) adalah salah satu jenis alat kawalan yang sering digunakan kerana mempunyai kelebihan dari segi persaingan harga pasaran dan juga kemudahan melaraskan dan pengoperasian alat kawalan. Walau bagaimanapun, untuk mengawal sistem HVAC secara efektif dengan menggunakan alat kawalan jenis PID, pemboleh ubah untuk mengawal PID ini perlu dioptimumkan. Di dalam hasil kerja ini, pemalar epsilon dengan menggunakan kaedah rangkaian neural (RBF-NN) telah digunakan bagi mendapatkan nilai pemboleh ubah yang optimum bagi alat kawalan jenis PID. Kelebihan menggunakan kaedah ini ialah ia mempunyai kadar tindak balas yang cepat dan tepat dengan nilai yang ingin dicapai berbanding dengan kaedah yang lain. Hasil kajian ini juga melibatkan penganggaran model dinamik bagi sistem HVAC. Kaedah pengasingan secara tidak linear digunakan bagi mengubah model sistem HVAC. Kelebihan dengan menggunakan kaedah tatasusunan gandaan relatif (RGA) yang dicadangkan mempunyai ciri-ciri yang mudah, tepat dan juga meminimumkan kesan nilai yang tidak linear dan sistem penghubung di dalam model HVAC. Berdasarkan pemerhatian, nilai yang dihasilkan bagi ralat kamiran mutlak (IAE) suhu dan kelembapan bagi model yang telah dicadangkan menurun kepada 18% dan 20%. Selain daripada itu, dengan mengoptimumkan alat kawalan jenis PID menggunakan kaedah RBF-NN sistem HVAC pengasingan secara tidak linear menunjukkan hasil tindak balas seimbang yang lebih baik dan mencapai prestasi dinamik dengan kadar ketepatan yang lebih baik daripada kaedah lain. Kaedah yang dicadangkan telah dibandingkan hasil keputusannya dengan kaedah penalaan yang lain. Hasil dari keputusan menunjukkan kos fungsi yang dihasilkan bagi suhu (J_T) dan kelembapan (J_{RH}) adalah lebih rendah sebanyak 15.7% dan 4.8%; manakala fungsi kos tenaga mencerminkan penggunaan tenaga disebabkan suhu dan kelembapan yang dihasilkan oleh pelembap dan pemanasan gegelung. Oleh itu, berdasarkan kaedah pengoptimuman baru kecekapan tenaga sistem ini meningkat. Gabungan unik kekangan epsilon dan RBF NN telah menunjukkan bahawa kaedah pengoptimuman ini adalah kaedah yang berpotensi untuk penalaan pengawal PID sistem tidak linear.

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LIST OF ABBREVIATIONS

AC	-	Air conditioner
ANF	-	Adaptive neuro-fuzzy
ANN	-	Artificial neural network
AR	-	Auto regressive
ARIMA	-	Autoregressive integrated moving average
ARMAX	-	Auto regressive moving average exogenous
ASHRAE	-	American society of heating, refrigerating and air-conditioning engineers
CAS	-	Central air supply
C-H-R	-	Chein-Hrones-Reswick
CN	-	Condition number
COP	-	Coefficient of Performance
DAS	-	Discharge air system
DFL	-	Direct feedback linear
DNAC	-	Decentralized non-linear adaptive controller
EC-RBF	-	Epsilon constraint-RBF
EDE	-	Energy delivery efficiency
FS	-	Fuzzy system
FLC	-	Fuzzy logic controller
GFS	-	Genetic fuzzy system
GL	-	Genetic learning

HVAC	-	Heating ventilation air conditioning
HVAC&R	-	Heating ventilation air conditioning and research
IAE	-	Integral absolute error
IEEMS	-	Indoor environment energy management system
LD	-	Lie derivative
LR	-	Lagrangian relaxation
LS	-	Least square
MF	-	Membership function
MLP	-	Multi layered Perceptron
NFS	-	Neuro-fuzzy system
NFC	-	Neuro-fuzzy controller
NI	-	Niederlinski index
NN	-	Neural network
NTU	-	Number of transfer unit
P	-	proportional
PI	-	proportional integral
PID	-	Proportional integral derivative
PMV	-	Predictive mean vote
RB	-	Rule base
RGA	-	Relative gain array
RIA	-	Relative interaction array
RIW-PSO	-	Random inertia weight particle swarm optimization
RLS	-	Recursive least square
SFLC	-	Self-fuzzy logic controller
SISO	-	Single input single output
STFPIC	-	Self -tuning fuzzy pi controller
THC	-	Temperature-humidity control

THC1	-	Heater and thermostat-controlled fan
THC2	-	Fan and thermostat-controlled heater
T_s	-	Settling time
VAV	-	Variable air volume
Z-N	-	Ziegler-Nichols

LIST OF SYMBOLS

ρ	-	Air mass density
T_{ao}	-	Air outlet temperature
$T_2(t)$	-	Air temperature immediately following the heat exchanger
$T_1(t)$	-	Air temperature prior
T_{a_1}	-	Ambient temperature
T_a	-	Ambient temperature of outside air
$\overline{T_a}$	-	Average ambient temperature of inside and outside air
$\overline{T_c}$	-	Average conduit temperature
$\overline{T_w}$	-	Average temperature of chiller
$\overline{T_t}$	-	Average temperature of inside and outside air
K	-	Constant gain
C_p	-	Constant pressure specific heat of air
c_{pc}	-	Constant pressure specific heat of coil
K_c	-	Controller integral gain
q_{sj}	-	Cooling loads
q_{lj}	-	Cooling loads
Δk_p	-	Corrections of the k_p
Δk_i	-	Corrections of the k_i
Δk_d	-	Corrections of the k_d
Δb_j	-	Corrections of the baseband parameters
Δc_j	-	Corrections of the hidden node center
C_w	-	$c_{pc}*m_{cw}$

τ	-	Delay
τ_v	-	Delay
L	-	Delay
ρ_w	-	Density of water
p_{zj}	-	Density of zone
T_d	-	Duct surface temperature
M_{cw}	-	Effective mass of coil to outlet water temperature
M_w	-	Effective mass of coil to outlet water temperature
V_z	-	Effective of thermal space volume
V_h	-	Effective volume air exchanger
$\eta_{s,ov}$	-	Efficiency of fin tube
$\eta_{c,ov}$	-	Efficiency of fin tube
U_9	-	Energy input to the chiller
$t_{a,1}$	-	Entering air temperature
$t_{w,2}$	-	Entering water temperature
h_w	-	Enthalpy of liquid water
h_{sj}	-	Enthalpy of supply air
h_w	-	Enthalpy of water
h_{fg}	-	Enthalpy of water vapor
h_{zj}	-	Enthalpy of zone
ε	-	Epsilon boundary
η_m	-	Fan efficiency
N	-	Fan speed
u_3	-	Fan speed control
D	-	Fan wheel diameter
f_a	-	Flow rate
gpm	-	Flow rate of chilled water

C_f	-	Function of the Reynolds number and coil configuration
K_p	-	Gain
$h_{i,c}$	-	Heat coefficient between tube and chiller
$h_{i,d}$	-	Heat coefficient between air and duct
$h_{m,c}$	-	Heat coefficient between air and fin coil
$h_{mi,d}$	-	Heat coefficient between air and inside surface of duct
h_{it}	-	Heat coefficient between tube surface and chilled water
$q_h(t)$	-	Heat input to the heat exchanger
$h_{me,d}$	-	Heat loss in side duct
$h_{e,d}$	-	Heat loss inside duct
$w_{t,o,st}$	-	Heat of fin coil
h	-	Heat transfer coefficient
h_o	-	Heat transfer coefficient in the ambient
h_i	-	Heat transfer coefficient inside duct
$Q(t)$	-	Heat transfer rate
w_a	-	Humidity ratio of air
w_s	-	Humidity ratio of air supply
W_o	-	Humidity ratio of outdoor air
w_{co}	-	Humidity ratio of the air out from the coil
w_m	-	Humidity ratio of the air out the mixing box
w_{si}	-	Humidity ratio of the supply air to the humidifier
W_3	-	Humidity ratio of thermal space
w_{si}	-	Humidity ration of supply air
w_{zj}	-	Humidity ration of zone
x_r	-	Indoor absolute humidity
L_a	-	Inductance of armature
$h_{a,2}$	-	Inlet air enthalpy

$T_{a,in}$	-	Inlet air temperature
T_{in}	-	Inlet temperature of the fluid element
$h_{w,1}$	-	Inlet water enthalpy
T_{wr}	-	Inlet water temperature
η	-	Learning rate
$t_{a,2}$	-	Leaving air temperature
$t_{a,2,0}$	-	Leaving air temperature offset
$t_{w,3}$	-	Leaving water temperature
L_c	-	Lewis number
m_a	-	Mass flow rate of air
U_8	-	Mass flow rate of chilled water
m_a	-	Mass flow rate of the air stream
M_a	-	Mass flow rate of the air stream
m_w	-	Mass flow rate of water
m_{wj}	-	Mass flow rate of zone
M_c	-	Mass of conduit
m_t	-	Mass per unit for coil
m_d	-	Mass per unit for duct
m_{fin}	-	Mass per unit for tube of coil
U_{9max}	-	Maximum energy input of the chiller
U_{8max}	-	Maximum mass flow rate of chilled water
θ_{si}	-	Mixed air temperature at the inlet of air handling unit
w_{∞}	-	Moisture inside duct
$w_{d,st}$	-	Moisture inside of surface duct
M_o	-	Moisture load
B_{eq}	-	Moment of inertia of the fan wheel
j_{eq}	-	Moment of inertia of the motor wheel

η_f	-	Motor efficiency
X_o	-	Outdoor absolute humidity
f_o	-	Outdoor air flow rate
θ_o	-	Outdoor air temperature
$h_{a,3}$	-	Outlet air enthalpies
$T_{a,out}$	-	Outlet air temperature
T_{ws}	-	Outlet supply water temperature
T_{out}	-	Outlet temperature of the fluid element
$h_{w,2}$	-	Outlet water enthalpies
U_c	-	Overall heat transfer coefficient based on enthalpy potential
a_{ch}	-	Overall thermal capacitance of chiller
c_d	-	Overall thermal capacitance of humidifier
C_a	-	Overall thermal capacitance of the air
c_{ah}	-	Overall thermal capacitance of the air handling unit
c_h	-	Overall thermal capacitance of the humidifier
$(UA)_{ah}$	-	Overall transmittance area factor of the air handling unit
α_h	-	Overall transmittance area factor of the humidifier
α_d	-	Overall transmittance- area factor outside humidifier
Δq_i	-	Perturbation of input variable from the operating point
Δq_o	-	Perturbation of output variable from the operating point
Δp_f	-	Pressure rise across the fan
W	-	Product of air flow rate and specific heat of air
w_r	-	Product of return specific heat of air
h(t)	-	Rate of humid air that humidifier can produce
R_a	-	Resistance
x_{si}	-	Return air absolute humidity
f_r	-	Return air flow rate

θ_r	-	Return air temperature
T_{wo}	-	Return water temperature
θ_{co}	-	Return water temperature to storage tank
Q_o	-	Sensible heat load
c_t	-	Specific heat capacity of coil
c_f	-	Specific heat capacity of coil
c_{pd}	-	Specific heat capacity of duct
c_{pa}	-	Specific heat of air
c_p	-	Specific heat of air
c_c	-	Specific heat of conduit material
c_{pw}	-	Specific heat of water
p	-	Static pressure
T_{aoss}	-	Steady state air outlet temperature
T_{ss}	-	Steady state fluid outlet temperature
x_s	-	Supply air absolute humidity in air handling unit
x_d	-	Supply air absolute humidity in humidifier
f_s	-	Supply air flow rate
θ_s	-	Supply air temperature in air handling unit
θ_d	-	Supply air temperature in humidifier
T_h	-	Supply air temperature in humidifier
T_{wi}	-	Supply water temperature
θ_{ci}	-	Supply water temperature to cooling coil
A	-	Surface area of pipe or duct
A_o	-	Surface of coil
K_s	-	System gain
T_c	-	System time constant
T_{de}	-	System time delay

T_{∞}	-	Temperature inside duct
$T(x_1)$	-	Temperature of thermal space
$T_{\infty,t}$	-	Temperature of chiller
T_o	-	Temperature of outdoor air
T_2	-	Temperature of supply air
$T(x_3)$	-	Temperature of supply air
T_{si}	-	Temperature of supply air to the humidifier
T_{co}	-	Temperature of the air out from the coil
T_m	-	Temperature of the air out of the mixing box
T_m	-	Temperature of the air out of the mixing box
T_3	-	Temperature of thermal space
T_3 (t)	-	Temperature of thermal zone
$T_{t,o}$	-	Temperature of tube
λ	-	Thermal conductivity
q_z (t)	-	Thermal load
A_d	-	Thickness of the wall in duct
A_{it}	-	Thickness of tube in chilled water
T	-	Time constant
K_r	-	Total control system gain
ϕ_c	-	Varies in space and time
f_d	-	Varies in space and time
v_a	-	Velocity of air
e_a	-	Voltage
f_{sa}	-	Volume flow rate of the supply air
v_{he}	-	Volume of heat exchanger
v_d	-	Volume of humidifier
v_{ah}	-	Volume of the air handling unit

v_s	-	Volume of thermal space
v_{zj}	-	Volume of zone
f(t)	-	Volumetric air flow rate
f	-	Volumetric flow rate of air
f_{sw}	-	Water flow rate
$\dot{m}_{w,0}$	-	Water flow rate offset
$\dot{m}_{w}$	-	Water flow rate offset
f_c	-	Water flow rate through cooling coil

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CHAPTER 1

INTRODUCTION

1.1 Heating Ventilation and Air conditioner (HVAC)

At present, heating ventilation and air conditioners (HVAC) are common in our lives, especially in the tropical and subtropical regions of the world. HVAC is equipment that is designed to adapt and adjust the humidity as well as temperature in various places. One of the functions of HVAC is to capture heat and channel it outside. However, changing the temperature is not the only function of an air conditioner; the other feature is to function as a dehumidifier. Thus, HVAC can make people feel comfortable (Olesen and Brager, 2004). Two main objectives in the control of HVAC systems are control of both humidity and temperature (Arguello-Serrano and Velez-Reyes, 1999).

Moreover, HVAC mechanisms are also used for setting some environmental variables including temperature, moisture, and pressure (Khooban *et al.*, 2014). Achieving these purposes requires a suitable control system design. A survey by Kelman et al. (2012) reported that HVAC operations account for approximately 40% of the domestic energy consumption in the USA. Therefore, it is necessary to design HVAC control system that will deliver a high comfort level and more energy efficient. So far, various types of control systems have been proposed since the advent of HVAC systems (Wemhoff and Frank, 2010).

1.1.1 Concepts & Definitions

Air conditioning can be used to control certain environmental conditions including air temperature, air motion, moisture level and radiant heat energy level. Air conditioning involves the cooling of indoor air for thermal comfort, treatment of air for temperature, cleanliness and humidity, and efficient distribution of air to meet the requirements of a particular space. The fundamental targets of any HVAC systems are to provide and set interior thermal conditions that the number of residents will find suitable and sufficient. Sometimes this may need and require that air be changed at an ordinary speed to raise evaporation and transferring heat from the skin. It is mentioned that for providing occupant comfort well it needs to add or remove heat to or from spaces of building. Moreover, it is often a requirement that humidity be removed from spaces during the summer and humidity added during the winter. The foundation key system components which are provided the control functions of HVAC systems are heat and humidity. Before proceeding further, to define the character of HVAC system it is needed to describe many concepts and terms. Each building has balance point temperature, known as exterior temperature which is be able to encourage thermal comfort.

Losses and building heat gains are in equilibrium at the balance temperature. As a result, relevant interior temperature will be preserved naturally and without additionally involvement. When the air temperature of outside go downs below or exceeds, the heating system and cooling system are used, to drop or removes such excess heat, respectively to the balance point temperature (Grondzik and Furst, 2000).

Design of a sufficient controller depends on a good dynamic model of the system. An appropriate system model requires the selection of a suitable controller. The most important of this part is that modeling the components of the HVAC system makes easier to control the system. The model which is developed can be used for comparison validation, which is most important for in the design of a multivariable controller using control theory.

1.1.2 Components

Figure 1.1 shows the typical components in a HVAC system. The main HVAC system components are : boilers, cooling equipment, pump and controls (Trust, 2011).

i) Boilers ('a') create hot water to deliver to the working space. This is done either by heating coils ('b') or through hot water pipes to radiators ('c').

ii) Cooling tools ('d') cools water for pumping to cooling coils ('e'). Proceed air is then explode blown over the chilled water coils into the space to be cooled ('f') through the ventilation system. As part of the refrigeration cycle in the chiller, heat must also be rejected from the system via a cooling tower or condenser ('g').

iii) Pumps are used throughout the system to circulate the chilled and hot water to the required areas throughout the building

iv) Controls are used to make components work together efficiently. They turn tools on or off and tune boilers and chillers, air and water flow rates, temperature and pressure. A controller incorporating one or more temperature ('i') sensors inside the workspace sends a signal to the heating or cooling coils to activate.

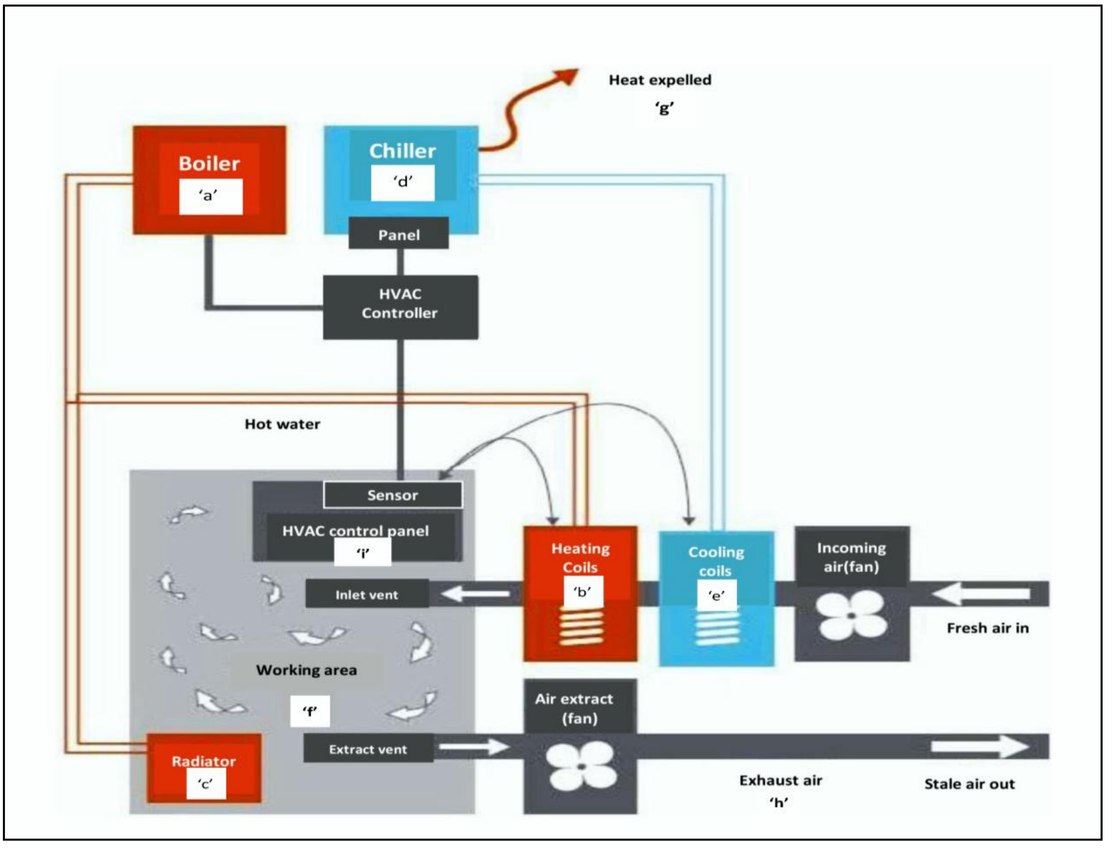

Figure 1.1: Schematic diagram of typical HVAC system (Trust, 2011)

1.1.3 Categorize of HVAC Systems

There are different methods for categorizing the HVAC system; one category of HVAC system is known as the standard or commercial system and another category is the central or local system (Anderson *et al.*, 2007). The discussion to follow will focus on different types of classified HVAC systems.

1.1.3.1 Standard HVAC System

In a standard HVAC system, shared water heaters (or water chillers) supply hot (or cold) water to multiple discharge air system (DAS) air handling units. In such systems, the supply water temperature is not locally controlled.

To each DAS controller, the water supply temperature must be regarded as constant, with any deviation a disturbance. This leaves the water flow rate and input air temperature as the only free parameters that can be locally varied (independent of the air flow rate) to achieve the desired discharge air temperature. Thus, the overall controller for the DASs typically consists of multiple, SISO control loops. For each loop controller, only one system parameter is regulated (Anderson *et al.*, 2007).

1.1.3.2 Commercial Systems

In a commercial HVAC system, a central air supply (CAS) typically provides air at a controlled temperature and flow rate for use in heating (or cooling) a space. A heating (or cooling) coil within the discharge air system (DAS) is used for heating (or cooling) the discharged air. The temperature of the discharged air is controlled by regulating the rate at which hot (or chilled) water flows through its heating (or cooling) coil(s). The flow rate of the discharged air is regulated to maintain a predetermined static air pressure within the temperature controlled space. The heat flow rate from a heating coil is a function of the flow rates of both the hot water and air, as well as the temperatures of the air and water flowing through the coil. In such a DAS, it is common to employ four separate single input single output (SISO) controllers to independently control these four parameters.

In a DAS, the temperature of the air leaving the mixing box, and subsequently going into the coil, is determined by the temperatures of the external and return air and the ratio at which they are mixed. Typically, the external and return air dampers are controlled in a coordinated manner so that the airflow rate is unaffected while the external-to-return air mix is varied to achieve a predetermined input air temperature (within the range limited by the return and external air temperatures). In general, the temperature of the water supplied to the heating coil is maintained at a constant temperature. The flow rate of the hot water through the coil is the primary parameter manipulated to control the heat flow rate and hence the discharge air temperature (Anderson *et al.*, 2007).

1.1.3.3 Central HVAC System

A central HVAC system has its major components which are located near building and may control and serve one or more thermal zones. The character of central HVAC system to transfer thermal energy is categorized in three types. In the first type system is termed an all-air system, which is conveyed only by means of cooled or heated air. In the second type system is called an all-water system, which is transferred only by means of cooled or hot water. Finally the system is phrased an air-water system which is moved by mixing of heated/cooled air or water.

By using of central HVAC systems there are a various benefits and advantages which are allowed and enabled important components to be separated in a mechanical room which is caused to take place limitation of interruption to building functions. In addition, it is caused to reduce noise and aesthetic impacts on building occupants. Other benefits of using central HVAC systems are economies of scale and reduction of building energy consumption. For the inner one larger system can achieve and improve system efficiencies in many climates by using of cooling towers. The later one in central system is also controlled to centralized energy management control schemes that, is made to reduce the energy consumption of building. Moreover, by using central HVAC system can be more suitable rather than climate control perspective which is active smoke control. Nevertheless, the disadvantages of central HVAC systems can be as a non-distributed system, which is affecting an entire building by failure of any components of equipments. Moreover, the repairing of system will be difficult if the system size and sophistication are increased (Grondzik and Furst, 2000). Figure 1.2 shows the diagram of the central HVAC system.

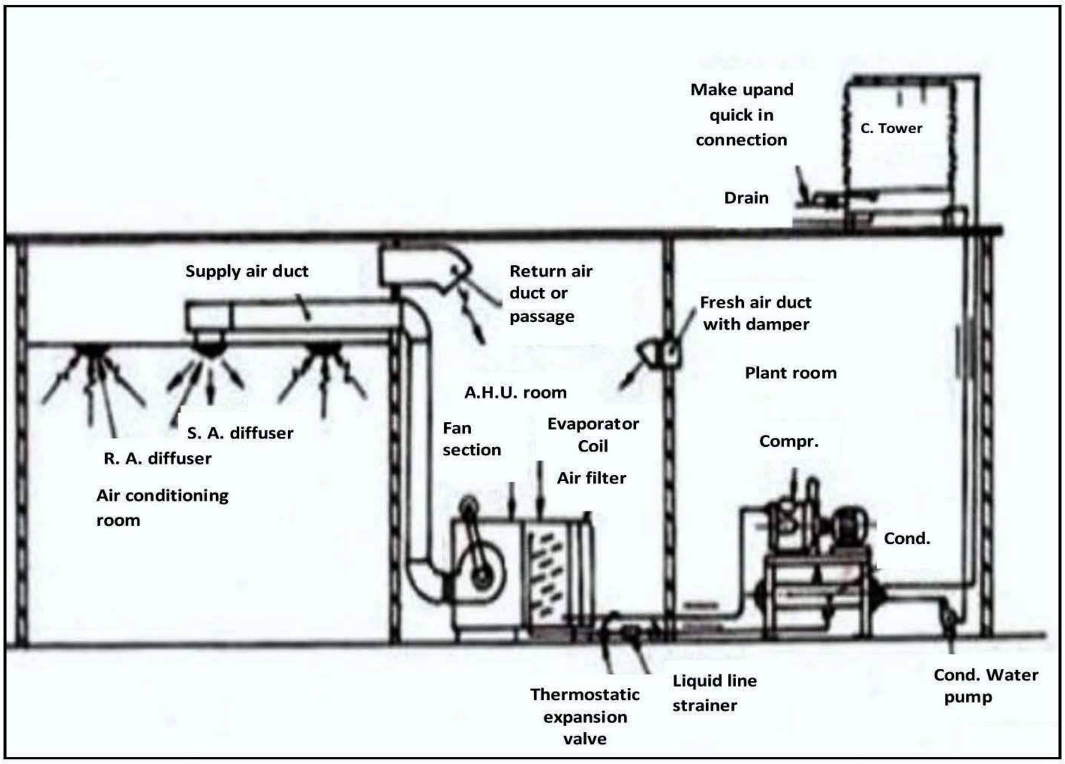

Figure 1.2: Diagram of central HVAC system (Jones, 2004)

1.1.3.4 Local HVAC System

A local HVAC system has important components which are located near the thermal zone itself, or on the boundary between the zone and exterior environment. This HVAC system controls a single thermal zone. Serving only as a single zone, local HVAC systems will have only one point of control; typically a thermostat for active systems. Each local system generally performs as a standalone system, without consider to the performance of other local systems. There are a many advantages of using local HVAC systems. Local systems tend to be distributed systems. Distributed systems prefer to provide greater collective reliability than do centralized systems.

Since local systems are likely to be of small capacity and are not complex and complicated by interconnections with other units. In addition, the maintenance of local systems tends to be routine and simple. Moreover, in a building which is unoccupied and has unused space the local system can be turn off and makes energy saving.

Nonetheless, local systems have some disadvantages. For example local system units cannot be smoothly joined together to allow for management operations of centralized energy. Moreover, local systems can normally be centrally controlled with reference to on-off functions through electric circuit control, but it is not possible to use more sophisticated central control such as night-setback or economizer operation. In addition, local HVAC system has the low capacity coefficient of performance (COP). Therefore, they cannot benefit from economies of scale (Grondzik and Furst, 2000). Figure 1.3 shows the diagram of the local HVAC system.

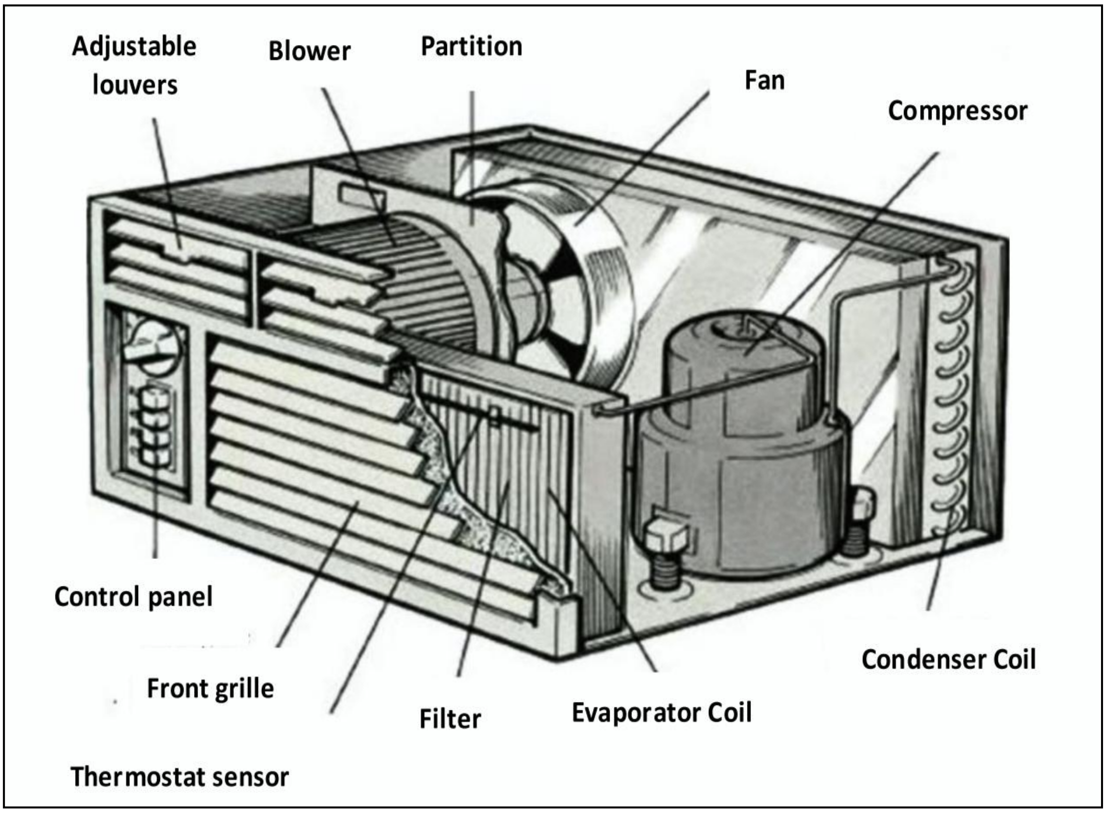

Figure 1.3: Diagram of local HAVC system (Jones, 2004)

The comparison of different types of HVAC systems which consist of advantages and disadvantages are tabulated in Table 1.1.

Table 1.1: Categories of different types of HVAC system

Type of system	Advantage	Disadvantage
Local System	-Distributed systems maintenance tends to be simple, ordinary and available. -Produce suitable occupant comfort through totally individualized control options.	-Cannot be easily connected together to let centralized energy management operations. -Be centrally controlled with respect to on-off functions through electric circuit control. -Low capacity. -Cannot suitable from economies of scale.
Central HVAC system: 1.Air system; 2. water system; 3.Air-water system	-Major equipment components to be isolated in a mechanical room. -Reduce noise and aesthetic impacts. -Offer opportunities for economies. -Improve system efficiencies in many climates. -Can reduce building energy consumption via energy management control.	-Failure of any key equipment component may affect an entire building as a non-distributed system. -Maintenance may become more difficult as system size and sophistication increase. -Transferring of conditions such as air or water imposes space and volume depends on building.
Commercial HVAC system	-Important tools are separated in a mechanical room. -Reduce noise and aesthetic impacts.	-Maintenance may become more difficult based on system size and sophistication increase.
Standard HVAC system	-Overall controller for the DASs Typically consists of multiple, SISO control loops.	-Supply water temperature is not locally controlled.

In this project, the central HVAC system, which consists of air water system, is considered as a result, of having more benefits and advantages than the other types of HVAC systems.

1.2 Problem Statements

HVAC systems are a permanent part of everyday life in our industrial society. In developing countries the use of energy is increased which influences the economy and way of life. One of the most important pieces of equipment which influences energy consumption is HVAC system. It is important to mention that the rate of energy consumption is high; therefore, optimizing and developing air conditioning systems have become more and more important (Piao *et al.*, 1998).

It is noticed that the HVAC system is a highly non-linear system which means the input signal and output signal have no proportional relation. However, the HVAC system has played a very important role in the modern world, so identification and simplification of the dynamic model and control of HAVC system have significant justification. However, the basic PID controller which is commonly used to control the parameters of HVAC system is not sufficient based on the structure and characteristics of HVAC system. Therefore, to effectively control the HVAC system using the PID controller, the PID control parameters must be optimized. The problems of this study can be divided in three sections as follows:

i) HVAC construction

ii) Difficulty in control design due to complete math model of the HVAC

iii) Tuning of PID controller to improve performance of the HVAC system

1.3 Objectives of Research

The present study investigates the effect of optimization of PID controller on humidity and temperature of simplified model of HVAC system. Regarding to the structure, complexity and non-linearity of the HAVC system simplification and optimization of HVAC system must be considered. The accomplishment obtained from this investigation will be use full in enhance the performance of HVAC system with improved energy efficiency and human comfort. The adjustment of humidity and temperature are aimed to reduce energy consumption and increase human comfort, respectively.

The specific objectives of this research are:

i) To examine the effect of non-linear decoupling method on HVAC system

ii) To carry out the effect of optimization PID controller regarding to new algorithm on parameters of simplified HVAC system

iii) To study the effect of optimized PID controller regarding to new algorithm on energy efficiency and human comfort.

1.4 Scopes of Research

In this project, a non-linear decoupling method is used to investigate the structure of a mathematical model of, humidifier and heating coil which are describing relative humidity as well as temperature responses of full mathematic dynamic model of the HVAC system, respectively. It is noticed that in mathematical model of HVAC system the CO_2 and air velocity models are ignored.

Epsilon constraint redial basis function of neural network has been used to control and optimized the parameters of PID controller with reference to overcome the non-linearity and convexity problem of the system. To obtain the optimization tuning method, the epsilon constraint algorithm and redial basis function neural network has been combined to produce the multi objective optimization method to control the parameters of HVAC system. In addition, following results are obtained:

i) The performance, transient response and human comfort of system are determined by integral absolute error (IAE) formulation based on new optimization algorithm

ii) The energy efficiency of system is described by using the cost function formulation based on new optimization algorithm

1.5 Significance of Study

In this research, a novel optimization method based on epsilon constraint through the radial basis function is considered to optimize the PID controller to control the parameters of the HVAC system. It is important to mention that the combination of redial basis function and epsilon constraint is used because of handling the non-linearity of the system and overcome the convexity problems of weighted sum techniques normally used in multi objective optimization.

It is noticed that a study on optimization technique based on epsilon constraint algorithm through the radial basis function is not reported yet. Based on the new algorithm these goals are achieved:

i) Transient response of the system is improved.

ii) Energy consumption of the system is decreased.

iii) Performance of the system is increased.

1.6 Thesis Outline

The thesis is divided into 5 chapters.

Chapter 1 presents background of the different types of HVAC system, problem statements, objectives and scope of the study, and outline of the thesis.

Chapter 2 focuses on the literature review. The literature review contains 2 main parts. In the first section the basic principles as well as different models of HVAC systems are introduced. In the second part the different types of tuning PID controller which had been used to control the parameters of HVAC system to achieve energy efficiency and target values are introduced.

In chapter 3, the methodology explains in detail. It consists of 2 main parts. First different types of decoupling method are described. Then different types of tuning method of PID controller are explained. Regarding to the tuning of PID controller based on the new algorithm, the parameters of humidity and temperature of HVAC system are controlled.

Chapter 4 reports the influence of simplified model and tuning of PID controller which are being used in full mathematical dynamic model of HVAC system. This chapter also discusses different decoupling techniques as well as comparison of simplified and original model. Moreover, different types of controllers which are used to control the parameters of the HVAC system are compared and the best result which is validated by MATLAB is displayed.

In chapter 5 the conclusion of the thesis and suggestions for future work are presented.

epsilon constraint method is considered because of ability to overcome the convexity problem of weight sum techniques which is normally used in multi objective optimization method and multi parameters that must be optimized to control the parameters of PID controller. Regarding to new optimization of PID controller based on EC-RBF neural network the performance of the system is increased. In addition, based on EC-RBF neural network the energy cost function, robustness as well as stability of the system for both humidity and temperature are improved. Improving the energy cost function and transient response of system it makes to increase the energy efficiency and improve the human comfort, respectively.

5.2 Future Recommendation

In this study, whereas some assumptions such as CO2 and air velocity that are influenced the humidity and temperature are ignored. A few suggestions for future work will be considered in two parts as mentioned below:

In modeling part:

Employing mathematical model of CO2 and air velocity are suggested.

In controlling part:

Based on new structure that is found in modeling part optimization of PID controller regarding to the multi objective and neural network algorithm is suggested.

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