NEURO MODELLING AND CONTROL OF AN AUTOMOTIVE AIR CONDITIONING SYSTEM

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To my beloved wife

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ABSTRACT

Air Conditioning system is very important in our world nowadays. Air conditioning system provide the temperature comfort not only in building but also inside car. The objective of this study is to identify the dynamic model for an Automotive Air Conditioning (AAC) system by using Recursive Least Square (Traditional Method) and Artificial Neural Network (Intelligent Method). Beside that, both model are also to design a self tuning PID controller for variable speed of AAC compressor system by using Matlab-SIMULINK software. In the project, system identification techniques (Traditional Method) namely Recursive Least Square (RLS) and Artificial Neural Network (Intelligent Method) was use do estimate dynamic model of AAC system. The input and output of the data used to estimate the dynamic model of AAC system were obtained from the experimental. The system identification techniques were used with (ARX) model structure and the Intelligent techniques were used with (NARX) model structure. The validation of the RLS and ANN models were based on the Mean Square Error (MSE). Comparative performance of the RLS and ANN model in this project were discussed. From the discussion, it found that RLS model with order number of 2 give a better performance with minimum value of MSE. For the ANN model, number of neuron in hidden layer of 10 and delayed input/output data of 6 have been optimized as the best model with the minimum value of MSE. After that, the best model of RLS and ANN are used with PID controllers. The PID controllers are tuned using Auto tuned and heuristic tuning method. From this research, it found that, RLS model using PID controller tuned using Heuristic tuning method had shown the best performance, but on other hand, for the ANN model it was shown that Auto tuned PID have a better performance in comparison to Heuristic tuned PID.

ABSTRAK

Sistem hawa dingin adalah sangat penting di dalam kehidupan di dunia ini. Sistem hawa dingin digunakan untuk menyediakan keselesaan bukan sahaja untuk bangunaan tetapi untuk kereta. Tujuan kajian ini adalah untuk menganggarkan model dinamik sistem hawa dingin automotif (AAC) dengan menggunakan teknik pengenalan sistem *Least Square (LS) secara* tradisional dan *Artificial Neural Network (ANN)* cara moden. Daripada ini, kedua-dua model ini juga direka dengan self pengawal PID kawalan untuk kawalan kelajuan AAC kompressor dengan *Matlab-SIMULINK*. Dalam projeck ini, teknik pengenalan sistem iaitu *Recursive Least Square* (Tradisional Cara) dan *Artificial Neural Network* (Moden Cara) digunakan untuk menganggarkan model dinamik sistem AAC. Data masukan dan keluaran yang digunakan untuk menganggar model dinamik system AAC diperolehi secara ujikaji darapada kajian. Sebelum ini teknik pengenalan sistem digunakan untuk *(ARX)* model struktur dan moden teknik digunakan untutk *(NARX)* model struktur. Kesahilan model disiasat berdasarkan *Mean Square Error (MSE)*, keputusan di antara *LS* dan *ANN* yang telah dibangunkan dalam penyelidikan ini telah dibentangkan dan dibincangkan. Dalam perbincangan, didapati bahawa *RLS* dengan nombor pesanan 2 adalah pemodelan berparameter yang terbaik dengan *MSE* yang paling rendah. Untuk *ANN* model, lapisan tersembunyi 10 dan ditangguhkan 6 adalah pemodelan berparameter yang terbaik dengan MSE yang paling terrendah. Dengan model terbaik, gunakan cara *Auto Tuned PID* kawalan dan *Heuristic PID* kawalan untuk mengawal *RLS* model dan *ANN* model. Dalam kajian tersebut, *RLS* model dikawal dengan *Heuristic Tuned PID* kawalan memberikan pretasi terbaik. Manakala *ANN* model dikawal oleh *Auto Tuned PID* kawalan akan memberikan prestasi terbaik berbanding dengan *Heuristic Tuned PID* kawalan.

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LIST OF ABBREVIATIONS

$u(k)$	-	Input data
$y(k)$	-	Output data
$\varepsilon(t)$	-	Zero mean
n	-	Order of model
a_n b_n	-	Model parameters
b	-	Bios of neuron
p_i	-	Input vector
w_i	-	Connection weight
K_p	-	Proportional controller
K_i	-	Integral controller

CHAPTER 1

INTRODUCTION

1.1 Research Background

Nowadays, the climate is change. The weather become hotter, people are suffering for the hot weather especially for Asian countries. The air conditioning system are become very important in our life. People are using air conditioning system not only inside the building but also in vehicle. The Heating, Ventilation and Air Conditioning (HVAC) systems are widely to be used in different industry, building, vehicle and etc. Originally, HVAC system is mainly use in building.

Vehicle air conditioners are much less efficient than residential air conditioners, and in the US consume about 0.9 quadrillion BTUs(quads) per year, compare to 2.3 by air conditioners in residences. Vehicle heating, in contrast, is a model of efficiency, running as a combined heat and power system using waste heat from the motor. The electricity use from appliance such as DVD players, Laptops, and refrigerators remain modest, although stand-by power use is growing. Technology and policy approaches used for buildings can address similar types of energy use in cars (Thomas et.al, 2011).

Whilst air conditioning systems increase thermal comfortableness in vehicles, they also raise the energy consumption of vehicles. Achieving thermal comfort in an energy efficient way is a difficult task requiring good coordination between engine and air conditioning system. A coordinated energy management system to reduce the energy consumption of vehicle air conditioning system while maintaining the thermal comfortableness. The system coordinates and manages the operation of evaporator, blower and fresh air and recirculation gates to provide the desired comfort temperature and indoor air quality, under the various ambient and vehicle conditions, the energy consumption can then be optimized (Khayyam et.al, 2011).

The factors that have influence on the energy consumption of a small air conditioning system that are worth mentioning are the efficiencies of the compressor, evaporator and condenser, the form that the refrigerant flow is controlled, the fan model used, and climatic conditions. Within the climate issue, an interesting factor is that relative humidity when it comes to the effect that it causes, especially in the performance of air condenser, which generally is not considered. The aims is to evaluate the influence of humidity on the coeficient of system performance (COP), seeking to quantify their influence when it happens. The tests were performed on a testing bench, mounted at Laboratory for Energy Efficiency (LAMOTRIZ) UNESP-Campus Guaratinguetu. The results, there was a significant influence, particularly when comparing high humidity conditions with low humidity, noting that only over 65% relative humidity is that significant changes are observed in COP of the system (Sobrinho et.al, 2013).

Vehicle Air Conditioning (AC) systems consist of an engine powered compressor activated by and electrical clutch. The AC system imposes an extra load to the vehicle's engine increasing the vehicle fuel consumption and emissions. Energy management control of vehicle air conditioning is a nonlinear dynamic system, influenced by uncertain disturbances. In addition, the vehicle energy management control system interacts with different complex systems, such as engine, air conditioning system, environment, and driver, to deliver fuel consumption improvements. The energy management control of vehicle AC system coupled with vehicle engine through an intelligent control design. The Intelligent Energy Management Control (IEMC) system presented in this research includes an intelligent algorithm which uses five exterior units and three integrated fuzzy controllers to produces desirable internal temperature and air quality, improved fuel consumption, low emission, and smooth driving. The three fuzzy controller includes a fuzzy cruise controller to adapt vehicle cruise speed via prediction of the road ahead using look ahead system, a fuzzy air conditioning controller to produce desirable temperature and air quality inside vehicle cabin room via a road information system and a fuzzy engine controller to generate the required engine torque to move the vehicle smoothly on the road. This research optimized the integrated operation of the air conditioning and the engine under various driving patterns and performed three simulations. Results show that the proposed IEMC system developed based on the fuzzy Air Conditioning Controller with Look Ahead(FAC-LA) method is more efficient controller for vehicle air conditioning system than the previously developed Coordinated Energy Management Systems(CEMS) (Abawajy et.al, 2012).

Increasing power requirements a long with weight and space constrains requires implementation of more intelligent thermal management systems. The design and development of such systems can only be possible with a thorough understanding of component and system level thermal loads. The present work implements 1-D and 3-D unsteady CFD based simulation tools in a military ground vehicle design process. Both power train cooling and HVAC systems are simulated in various operating conditions on a HPC Computer Cluster using multiple fidelity tools. HVAC system variables are optimized with gradient based optimization libraries. The simulation result are compared and validated with experimental results (Bayraktar, 2011).

The investigates analysis and modeling of vehicular thermal comfort parameters using a set of designed experiments aided by thermograph measurement. The experiments are conducted using a full size climate chamber to host the test vehicle, to accurately assess the transient and steady state temperature distributions of the test vehicle cabin. Further investigate the thermal sensation (overall and local) and the human comfort states under artificially created relative humidity scenarios. The thermal images are calibrated through a thermocouples network, while the outside temperature and the relative humidity are manipulated through the climate environmental chamber with controlled soaking periods to guarantee the steady state conditions for each scenario. The relative humidity inside the passenger cabin is controlled using a Total Humidity Controller (THC). The simulation uses the experimentally extracted boundary condition via a 3-D Berkeley model that is set to be fully transient to account for the interactions in the velocity and temperature fields in the passenger compartment, which included interactions from turbulent flow, thermal buoyancy and the three modes of heat transfer conduction, convection and radiation. The model investigates the human comfort by analyzing the effect of the in-cabin relative humidity from two specific perspectives; firstly its effect on the body temporal variation of temperature within the cabin. Secondly, the Local Sensation (LS) and Local Comfort (LC) are analyzed for the different body segments in addition to the Overall Sensation (OS) and the Overall Comfort (OC). Furthermore, the human sensation is computed using the Fanger model in terms of the Predicted Mean Value (PMV) and the Predicted Percentage Dissatisfied (PPD) indices. The experimental and simulation results show that controlling the RH levels during the heating and cooling processes (winter and summer conditions respectively) aid the A/C system to achieve the human comfort zone faster than the case if the RH value is not controlled. Also, the measured the predicted transient temperatures are compared and found to be in good agreement (Alahmer et.al, 2011).

1.2 Problem Statement

In most of the automotive air conditioning systems, the compressor continuously cycles on and off to meet the cooling load of the evaporator. It also does so to avoid condensate from freezing on the airside of the evaporator. Many other refrigeration systems, for example normal household refrigerators, cycle the compressor on and off in order to match the system capacity to the thermal load. Unfortunately, compressor cycling creates additional thermodynamic losses, that is, mechanical and thermal dissipation, above and beyond the losses generated during steady-state operation. This is to investigates the experimental performance of an automotive air conditioning (AAC) system for the cases of employing fixed and variable capacity compressors (FCC and VCC). An experimental system consisting of original components from an HFC134a AAC system has been set up and instrumented. For each compressor case, the system has been tested under steady-state operating conditions by varying the compressor speed, temperatures of the air streams entering the condenser and evaporator as well as the velocities of these air streams. The energy and energy analysis had been applied to the experimental system, and its performance for both compressor operations has been evaluated. The results show that the operation with the VCC usually yields a higher COP than the operation with the FCC in expense of a lower cooling capacity. Furthermore, the cooling capacity and the rate of total energy destruction in the VCC operation remain almost constant after a certain compressor speed, while both parameters increase continually with the compressor speed in the FCC operations (Alkan et.al, 2009).

In the majority of automotive air conditioning systems, the compressor continuously cycles on and off to meet the steady-state cooling requirements of passenger compartment. Since the compressor is a belt-driven accessory device coupled to engine, its cycling rate is directly related to the vehicle speed. The refrigeration system's losses increase with increasing vehicle speed and thus with increasing compressor cycling. This research to identifies and quantifies individual losses in an automotive vapor- compression refrigeration system during compressor cycling. The second law of thermodynamics, in particular, non-dimensional entropy generation, is used to quantify the thermodynamic losses of the refrigeration system's individual components under steady driving conditions at idle, 48.3 kph (30 mph), and 96.6 kph (60 mph). A passenger vehicle containing a cycling-clutch orifice-tube vapor±compression refrigeration system was instrumented to measure refrigerant temperature and pressure, and air temperature and relative humidity. Data were collected under steady driving conditions at idle, 48.3 kph(30 mph), and 96.6 kph (60 mph). A thermodynamic analysis is presented to determine the refrigeration system's performance. This analysis shows that the performance of the system degrades with increasing vehicle speed. Thermodynamic losses increase 18% as the vehicle speed changes from idle to 48.3 kph (30 mph) and increase 5% as the vehicle speed changes from 48.3 kph (30 mph) to 96.6 kph (60 mph). The compressor cycling rate increases with increasing vehicle speed, thus increasing the refrigeration system's losses. The component with the greatest increase in thermodynamic losses as a result of compressor cycling is the compressor itself. Compressor cycling reduces the compressor's isentropic efficiency, and thus the system's thermodynamic performance. The individual component losses of the refrigeration system are quantified. The redistribution of these losses is also given as a function of increasing vehicle speed (i.e. increasing compressor cycling). At 96.6 kph (60 mph), the thermodynamic losses, based on the ratio of entropy generation to entropic load, are 0.22, 0.10, 0.07, and 0.02 in the compressor, the condenser, the evaporator-accumulator, and the orifice tube, respectively. The compressor losses dominated the overall system performance. The overall system efficiency could be significantly improved by increasing the compressor's efficiency. The compressor's efficiency could be improved by reducing or eliminating cycling, such as could be accomplished by using a variable capacity compressor or by not directly coupling the compressor to the engine. Another way to increase the compressor's volumetric efficiency during cycling would be to reduce the compressor operating range. This could be accomplished by using two compressors such as is done in two-stage cascade refrigeration systems (Ratts et.al, 2000).

This thesis discusses the effect of manipulating the Relative Humidity RH of in-cabin environment on the thermal comfort and human occupants' thermal sensation. The study uses thermodynamic and psychometric analyses, to incorporate the effect of changing RH along with the dry bulb temperature on human comfort. Specifically, the study computes the effect of changing the relative humidity on the amount of heat rejected from the passenger compartment and the effect of relative humidity on occupants comfort zone. A practical system implementation is also discussed in terms of an evaporative cooler design. The results show that changing the RH along with dry bulb temperature inside vehicular cabins can improve the air conditioning efficiency by reducing the heat removed while improving the Human comfort sensations as measured by the Predicted Mean Value PMV and the Predicted Percentage Dissatisfied PPD indices (Omar et.al, 2011).

A test system is initially built in order to investigate the instability of the automotive air conditioning (AAC) system with a variable displacement compressor (VDC), and hunting phenomena caused by the large external disturbance in the AAC system with a VDC and a thermal expansion valve, and in the AAC system with a VDC and a fixed-area throttling device are investigated experimentally in part 1 of this paper. The experimental results indicate that there also exist the hunting phenomena in the AAC system with a fixed-area throttling device. The system stability is found to be dependent on the direction of the external disturbance, and the system is apt to cause hunting when the condensing pressure decreases excessively since it may cause two-phase state at the throttling device inlet and make a large disturbance to the system. The piston stroke length will oscillate only when the oscillation amplitudes of forces acting on the wobble plate are great enough, otherwise the piston stroke length will be kept invariable, and then the system instability rule is also suitable for the AAC system with a fixed displacement compressor. From the experimental results, it is concluded that the two-phase flow at the throttling device inlet or at the evaporator outlet is the necessary condition but not sufficient condition for system hunting. Finally, a new concept, conservative stable region, is proposed based on the experimental results and theoretical analysis (Tian, 2005).

Air conditioning systems are an accessory component of vehicles whose utilization provides comfort to vehicle occupants. However, they significantly increase the energy consumption of vehicles and negatively influence their performances. (Lambert et.al, 2006) reported that the mechanical compressor of the air conditioning system could increase the fuel consumption of the vehicle by 12 17% for subcompact to mid-size vehicles. Growing calls for reduction of fuel consumption in vehicles are helping the advancement of energy management systems for vehicles and their accessory components. The energy management systems are expected to have the ability to take into account the effects of several parameters that are important contributors to the energy balance in the vehicle cabin room. These parameters are mainly associated with the vehicle itself, environment, occupants, and driving strategy. Air conditioning systems (A/C) significantly increases the energy consumption of a vehicle and negatively influences its performance. A/C can be considered as the main auxiliary load on a vehicle engine when it is operating. According to a study by the National Renewable Energy Laboratory (Rugh et.al, 2007), the United States uses 26.4 billion litres of fuel per year to operate light-duty vehicle A/C systems. This is equivalent to 5.5% of the total light-duty vehicle fuel use in this country. According to ASHRAE (ASHRAE, 2007), general considerations for air conditioning design should include such factors as cabin indoor air quality and thermal comfort, ambient temperatures and humidity, the operational environment of components, vehicle and engine parameters, electrical power consumption, cooling capacity, number of occupants, insulation, solar effect, vehicle usage profile, and so on. In recent years, extensive studies have been carried out on various aspects of vehicle air conditioning systems and of management of energy utilization. These efforts have resulted in further improvements in the efficiency of the air conditioning system.

1.3 Research Objectives

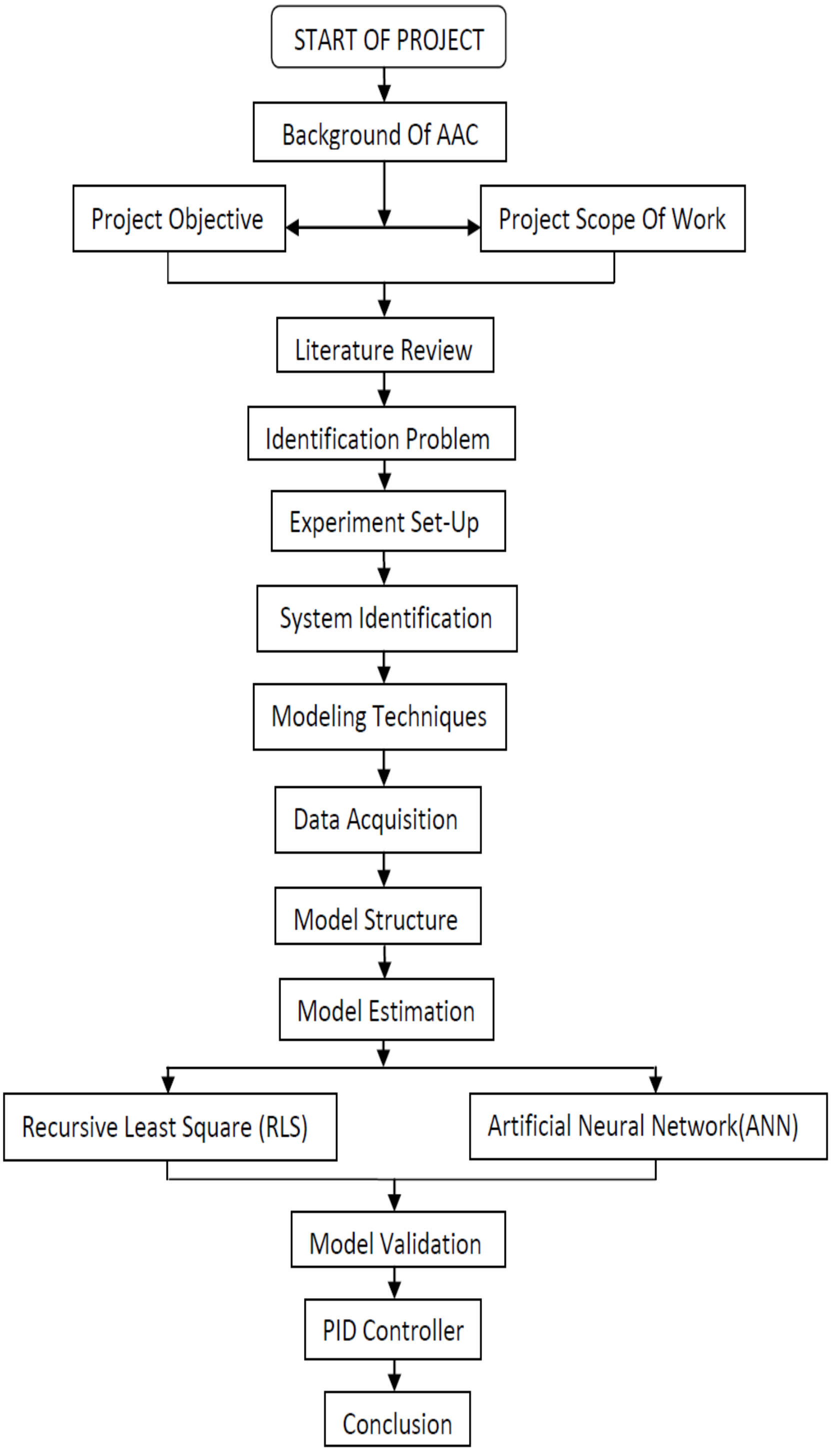
The Objective of this study is to model the dynamic of an Automotive Air-Conditioning (AAC) using system identification techniques via non parametric Neural Network structure in comparison to conventional method and to design a simple auto tuned PID controller.

1.4 Scope of Research

The scope of work for this project are below:

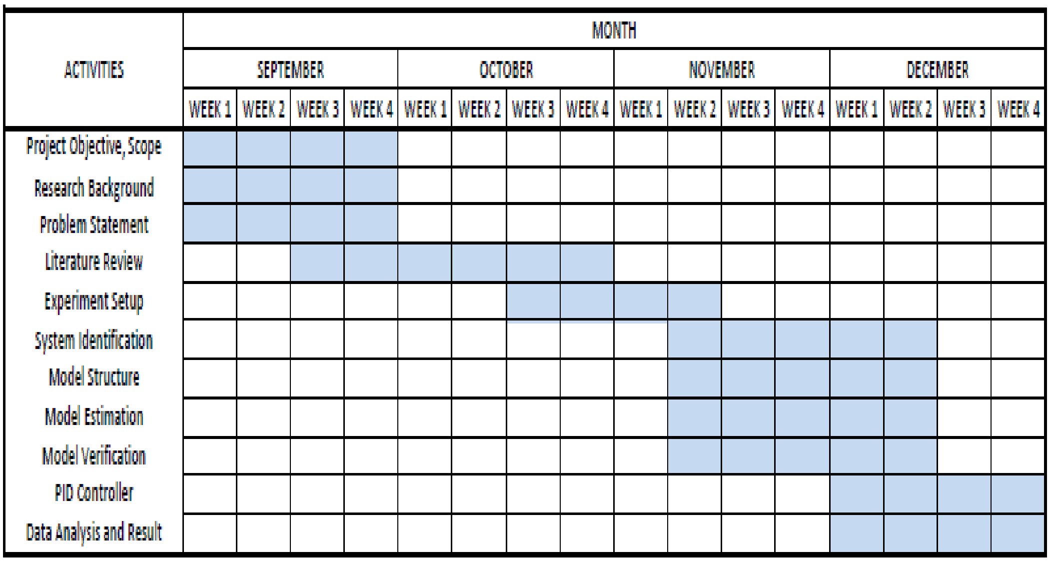
1. Literature review of an automotive air conditioning system, modeling techniques and Neural Network algorithm.
2. Modeling of an automotive air conditioning system by using conventional nonlinear ARX and Neural Network model within Matlab SIMULINK environment.
3. Design and simulate an auto tuned PID controller for automotive air conditioning system.
4. Validation, verification and analysis of the thus develop intelligence model via the PID controllers' performance in comparison with conventional model.

1.5 Flow Chart of Work Conducted

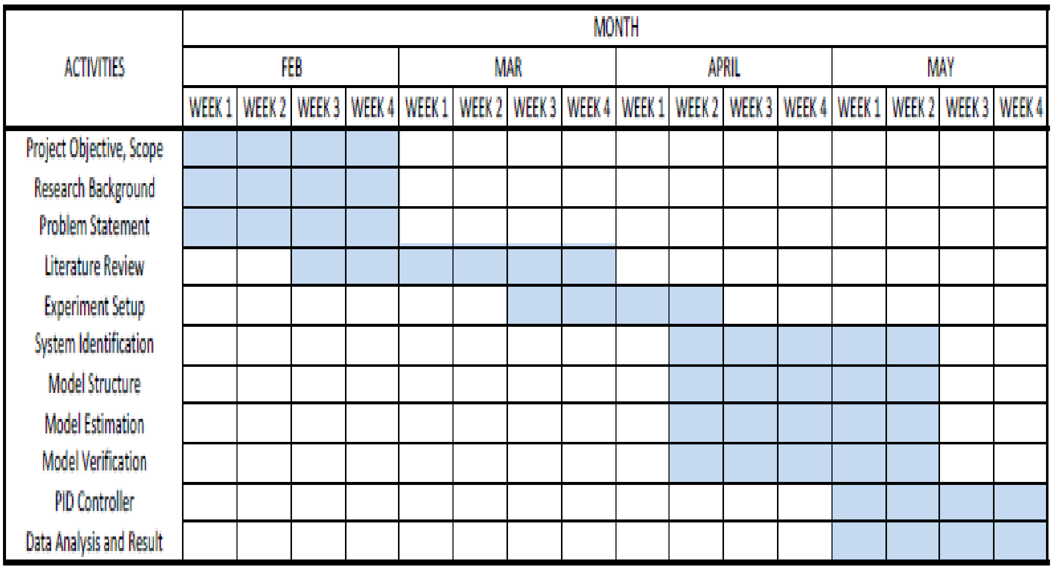


1.6 Gantt Chart for Project

Gantt Chart for Project 1



Gantt Chart for Project 2



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