AUTOMATIC SPEED CONTROL SUCTION FAN
FOR ELECTRIC KITCHEN HOOD

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"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering
(Control, Instrumentation, & Automation)"

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"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references."

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In the name of Allah, The Most Gracious, The Most Merciful. Peace be upon the Messenger of Allah, Prophet Muhammad s.a.w, his companions (r.a) and followers until the end of the day. Thanks to Allah, with his blessing, this final project is successful delivered.

Thanks to my beloved mom and dad, whom keep prays for me, gives me freedom and show understanding to me as a student because their loves make me moving forward.

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May Allah bless all of us.

THANK YOU.

ABSTRACT

The current economic situation has made the public realize various issues especially on the side of being thrifty in spending and to save on various aspects. These include decisions made on household items such as electrical products. There are many electrical products as well as items which are equipped with Artificial Intelligence systems. This technology is submitted and brought up in order to produce the best electrical appliances in terms of especially efficiency. In turn, this is parallel with Automatic Speed Control of Suction Fan for the Electrical Kitchen Hood by producing a kitchen suction fan which is smart and energy sufficient. Varies speed alteration depending to smoke produce while cooking is the prior specification for this suction fan. That mean, the speed of suction fan depend on the smoke quantity, more smoke faster speed. In other word, smoke is the input signal while speed of the fan is the output signal. This project will determine the suitable controller that can be use for kitchen hood suction fan. Some controller has been recognize such as, variable frequency drive (VFD), dimmer control circuit and pulse width modulator (PWM) circuit. After conducting some testing, the most suitable to use as a controller is dimmer control circuit with some modification and the input sensor can be use either heat sensor, or smoke detector or variable resistor.

ABSTRAK

Keadaan ekonomi semasa telah memaksa masyarakat sekarang untuk lebih peka terhadap isu pembaziran dan mengambil langkah penjimatan dalam pelbagai aspek termasuklah dalam pemilihan barangan elektrik untuk kegunaan di rumah. Kebanyakan barangan elektrik keluaran terkini telah dilengkapi dengan teknologi ‘Artificial Intelligent (AI)’. Teknologi ini dibangunkan bertujuan menghasilkan peralatan elektrik yang lebih jimat dan efisyen. Bertepatan dengan Projek Kawalan Kelajuan Automatik bagi Kipas Penyedut Dapur (Automatic Speed control of Suction Fan for Electric Kitchen Hood) juga dibangunkan bertujuan untuk menghasilkan sebuah kipas penyedut dapur yang pintar dan menjimatkan tenaga. Ciri utama yang perlu ada pada kipas tersebut ialah mempunyai variasi kelajuan yang sepadan dengan penghasilan asap semasa aktiviti memasak berlaku. Ini bermaksud kelajuan kipas akan bertindak balas secara langsung dengan kuantiti asap yang terhasil,semakin banyak asap semakin laju putaran kipas tersebut. Dengan kata lain, kuantiti asap adalah isyarat masukan dan kelajuan kipas adalah hasil keluaran. Beberapa kaedah yang berkemungkinan boleh digunakan di dalam projek ini akan dibincangkan terutama sekali pada bahagian kawalan kelajuan motor kipas. Motor yang digunakan adalah dari jenis motor arus ulang-alik. Pada kebiasaan terdapat beberapa jenis system kawalan yang dapat diguna pakai untuk mengawal kelajuan motor jenis arus ulang-alik, antaranya ialah pemacu frequensi boleh laras (variable frequency drive), litar kawalan (dimmer circuit) dan litar ‘pulse width modulator’ PWM. Selepas beberapa ujian dan penelitian telah didapati sebuah litar kawalan yang baru perlu direka bagi menghasilkan litar yang bersesuaian dengan jenis motor yang digunapakai.

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INTRODUCTION

1.1 Project Background

Kitchen hood is used to suck the smoke produced during cooking activity. Conventional kitchen hoods are installed with fixed speed motor. Smoke produced during cooking activity is not a constant variable, it is variously produced depends on the cooking ingredient and the capacity of cooking gas flow into the combustion chamber. So when less smoke produced, logically just low speed of sucking fan needed, but conventional sucking fan is still remain the constant speed. The rate of power-waste during this phenomenon is quite high. An automatic speed kitchen hood is the way to overcome this problem. This project is to realize the prototype of this kitchen hood. An implementation of technology and sensor to conventional kitchen hood can produce an automatic kitchen hood. Theoretically the speed of suction fan can be designed to consequence with the velocity of the gas flow into the combustion chamber. Realization of this kitchen hood can decrease electrical power waste.

1.2 Problem Statement

Some problems had been recognized due to the usage of conventional kitchen hood suction fan. Listed as follow:-

- Fix speed of kitchen hood motor are heading to the inefficiency power usage.
- Conventional kitchen hood delivered so much power waste.
- Manually speed control is not practical during cooking task.
- No such a smart technology applied to the kitchen hood.

1.3 Project Objective

First of all, the objective of this project done is to fulfill the requirements for the degree of bachelor in electrical engineering. To define controller that suit to the project, familiarize with the sensor circuit and also to design and construct an efficient and energy saving suction fan for electric kitchen hood with automatic speed control. The final objective is to make sure the project is successfully done.

1.4 Project Scope

This project is about an automatic AC motor speed controller. So the task is to find the suitable controller, then, make sure the controller circuit will work out with the sensor. Besides, we need to look for the variable that can become an input signal such as, heat, smoke particle, or the velocity of the gas flow. Simple controller circuit designed to properly work with the induction motor. This project will be implementing on the 1901-74 ELBA kitchen hood suction fan. Three big scopes in this project is research for the information, looking for the component and equipment and assemble and testing the end product.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The aim of this chapter is to review the published on the automatic ac motor speed controller, the ordinary kitchen hood and relevant literature to my project; 'Automatic Speed Control of Suction Fan for Electric Kitchen Hood '. This project is about to overcome the energy-waste of electric kitchen hood. Most commercial kitchen hoods operate at 100 percent capacity even during idle periods when ventilation systems can safely be turned down. Because hoods and associated exhaust and makeup-air fans are among the largest consumers of electricity in a commercial kitchen, the annual cost of wasted energy can amount to thousands of dollars per hood [12]. The solution to this problem is to make the suction fan work depend on smoke and heat produce during cooking activity. A new technology that reduces ventilation rates during slow periods makes it possible for restaurants and institutions to significantly reduce the amount of wasted energy [12]. The main idea to achieve this target is develop the controller for the kitchen hood suction fan motor. The motor speed must be reacting to the kitchen environment. This paper will review, summarized and analyzed the system modeling, control method, and ac motor controller design for suction fan motor. In order to achieve the goal, studied about what is the particle produced during cooking activities and studied about appropriate sensor that can use in this project and also several type of ac motor controller had done properly. All of these will be briefly explain in this chapter.

2.2 Particle Produce due to Cooking Activities.

An experiment had been done before by U.S Environmental Protection Agency, Virginia in cooperative with National Institute of Standard and Technology, Gaithersburg, Maryland under title; Source strengths of ultrafine and fine particles due to cooking with a gas stove. The selected cooking episodes (mostly frying) were capable of producing about 1014 particles over the length of the cooking period (about 15 min), more than 90% of them in the ultrafine (<0.1μm) range, with an estimated whole-house volume concentration of 50 $(\mu m/cm)^3$. More than 60% of this volume occurred in the 0.1-0.3 μm range. Frying produced peak numbers of particles at about 0.06 μm, with a secondary peak at 0.01 μm. The peak volume occurred at a diameter of about 0.16 μm. Since the cooking episodes selected were biased toward higher concentrations, the particle concentrations measured during about 600 h of morning and evening cooking over a full were compared to concentrations measured during no cooking periods at the same times. Cooking was capable of producing more than 10 times the ultrafine particle number observed during no cooking periods. Levels of $PM_{2.5}$were increased during cooking by a factor of 3. Breakfast cooking (mainly heating water for coffee and using an electric toaster) produced concentrations about half those produced from more complex dinnertime cooking. Although the number and volume concentrations observed depend on air change rates, house volume, and deposition rates due to fans and filters, the source strengths calculated here are independent of these variables and may be used to estimate number and volume concentrations in other types of homes with widely varying volumes, ventilation rates, and heating and air-conditioning practices [13]. Study shows that cooking, particularly frying, is an important source of particles indoors [13]. It can be conclude that the most of particles produce due to cooking activities are in form of gases or in the usually word called ‘smoke’.

2.3 Smoke Sensor

Sensor is use to be as input device. Studied had done about some sensors that capable to detect smoke that produced by cooking activities. There are two main types of smoke detectors: ionization detectors and photoelectric detectors [11].

2.31 Ionization Detectors

Ionization detectors have an ionization chamber and a source of ionizing radiation. The source of ionizing radiation is a minute quantity of americium-241 (perhaps 1/5000th of a gram), which is a source of alpha particles (helium nuclei). The ionization chamber consists of two plates separated by about a centimeter. The battery applies a voltage to the plates, charging one plate positive and the other plate negative. Alpha particles constantly released by the americium knock electrons off of the atoms in the air, ionizing the oxygen and nitrogen atoms in the chamber.[11] The positively-charged oxygen and nitrogen atoms are attracted to the negative plate and the electrons are attracted to the positive plate, generating a small, continuous electric current. When smoke enters the ionization chamber, the smoke particles attach to the ions and neutralize them, so they do not reach the plate. The drop in current between the plates triggers the alarm.

2.32 Photoelectric Detectors

One type of photoelectric device, smoke can block a light beam. In this case, the reduction in light reaching a photocell sets off the alarm. In the most common type of photoelectric unit, however, light is scattered by smoke particles onto a photocell, initiating an alarm. In this type of detector there is a T-shaped chamber with a light-emitting diode (LED) that shoots a beam of light across the horizontal bar of the T. A photocell, positioned at the bottom of the vertical base of the T, generates a current when it is exposed to light. Under smoke-free conditions, the light beam crosses the top of the T in an uninterrupted straight line, not striking the photocell positioned at a right angle below the beam. When smoke is present, the light is scattered by smoke particles, and some of the light is directed down the vertical part of the T to strike the photocell. When sufficient light hits the cell, the current triggers the alarm.[11]

2.33 Photoelectric Sensor Overview

Photoelectric sensors represent perhaps the largest variety of problem solving choices in the industrial sensor market. Today 's photoelectric technology has advanced to the point where it is common to find a sensor that will detect a target less than 1 mm in diameter while other units have a sensing range up to 60 m. These factors make them extremely adaptable in an endless array of applications. Although many configurations are available including laser-based and fiber optic sensors, all photoelectric sensors consist of a few of basic components. Each contains an emitter, which is a light source such as an LED (light emitting diode) or laser diode, a photodiode or phototransistor receiver to detect the light source, as well as the supporting electronics designed to amplify the signal relayed from the receiver.[11]

Probably the easiest way to describe the photoelectric operating principal is: the emitter, also referred to as the sender, transmits a beam of light either visible or infrared, which in some fashion is directed to and detected by the receiver. Although many housings and designs are available they all seem to default to the basic operating principal.

Just as the basic operating principal is the same for all photoelectric families, so is identifying their output. “Dark-On” and ”“Light-On” refers to output of the sensor in relation to when the light source is hitting the receiver. If an output is present while no light is received, this would be called a “Dark On ” output. In reverse, if the output is ON while the receiver is detecting the light from the emitter, the sensor would have a “Light-On ” output. Either way, a Light On or Dark On output needs to be selected prior to purchasing the sensor unless it is user adjustable. In this case it can be decided upon during installation by either flipping a switch or wiring the sensor accordingly.[11]

The method in which light is emitted and delivered to the receiver is the way to categorize the different photoelectric configurations. The most reliable style of photoelectric sensing is the through beam sensor. This technology separates the emitter and receiver into separate housings. The emitter provides a constant beam of light to the receiver and detection occurs when an object passing between the two breaks the beam. Even though it is usually the most reliable, it often is the least popular due to installation difficulties and cost. This is because two separate pieces (the emitter and receiver) must be purchased, wired and installed. Difficulties often arise in the installation and alignment of two pieces in two opposing locations, which may be quite a distance apart.

Through beam photoelectric sensors typically offer the longest sensing distance of photoelectric sensors. For example, units are available with a 25 m and more sensing range. Long range is especially common on newly developed photoelectric sensors such as models containing a laser diode as the emitter. Laser diodes are used to increase sensing accuracy and detect smaller objects. These units are capable of transmitting a well-collimated beam with little diffusion over the sensing ranges as long as 60 m. Even over these long distances, some through beam laser sensors are capable of detecting an object 3 mm in diameter, while objects as small as .01 mm can be sensed at closer ranges. However, while precision increases with laser sensors the speed of response for laser and non-laser through beam sensors typically remain the same, around 500 Hz.[11] An added bonus to through beam photoelectric sensors is their ability to effectively sense an object in the presence of a reasonable amount of airborne contaminants such as dirt. Yet if contaminants start to build up directly on the emitter or receiver, the sensor does exhibit a higher probability of false triggering. To prevent false triggering from build up on the sensor face, some manufacturers incorporate an alarm output into the sensor ’s circuitry. This feature monitors the amount of light arriving on the receiver. If the amount light decreases to a certain level without a target in place, the sensor sends a warning out by means of a built in LED and/or an output wire.

A very familiar application of a through beam photoelectric sensor can be found is right in your home. Quite often, a garage door opener has a through beam photoelectric sensor mounted near the floor, across the width of the door. This sensor is making sure nothing is in the path of the door when it is closing. A more industrial application for a through beam photoelectric is detecting objects on a conveyor. An object will be detected anyplace on a conveyor running between the emitter and receiver as long as there is a gap between the objects and the sensors light does not “burn through ” the object. Its sounds like we able to use this sensor in my project as long as the distance between emitter and receiver just around 740mm and it will be easy for installation and alignment.

2.4 AC Motor Speed Controllers/Variable-Speed Drive

Variable-speed drive (VSD) describes equipment used to control the speed of machinery [9] use in many industrial processes. Varying the speed of the drive may save energy compared with other techniques. A variable speed drive might consist of an electric motor and controller that is used to adjust the motor's operating speed. The combination of a constant-speed motor and a steplessly adjustable mechanical speed-changing device might also be called an adjustable speed drive. Most common VSD is variable-frequency drive. Electronic variable frequency drives are rapidly making older technology redundant.

2.41 Variable-Frequency Drive (VFD)

A variable-frequency drive (VFD) as shown in Figure 2.1 is a system for controlling the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor.[13] A variable frequency drive is a specific type of adjustable-speed drive. Variable-frequency drives are also known as adjustable-frequency drives (AFD), variable-speed drives (VSD), AC drives, microdrives or inverter drives. Since the voltage is varied along with frequency, these are sometimes also called variable voltage variable frequency (VVVF) drives.

Figure 2.1: Variable Frequency Drive (VFD)

Variable frequency drives operate under the principle that the synchronous speed of an AC motor is determined by the frequency of the AC supply and the number of poles in the stator winding, according to the relation:

Speed of motor, $RPM = \frac{120 \times f}{P}$ (2.1)

Where:
RPM = Revolutions per minute
f = AC power frequency (hertz)
p = Number of poles (an even number)

The constant, 120, is 60 seconds per minute multiplied by 2 poles per pole pair. Sometimes 60 is used as the constant and p is stated as pole pairs rather than poles. Synchronous motors operate at the synchronous speed determined by the above equation. The speed of an induction motor is slightly less than the synchronous speed.[4][5]

Let say a 4-pole motor that is connected directly to 60 Hz utility (mains) power would have a synchronous speed of 1800 RPM:

$$\frac{120 \times 60}{4} = 1800 \text{ RPM}$$

If the motor is an induction motor, the operating speed at full load will be about 1750RPM.
If the motor is connected to a speed controller that provides power at 50 Hz, the synchronous speed would be 1500 RPM:

$$\frac{120 \times 50}{4} = 1500 \text{ RPM}$$

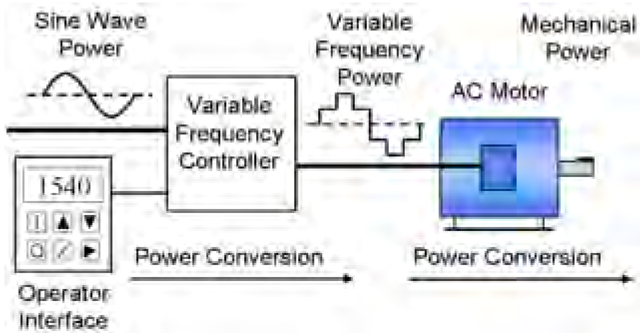

Figure 2.2: VFD System Description[13]

Figure 2.2 shows a variable frequency drive system generally consists of an AC motor, a controller and an operator interface VFD motor[7]. The motor used in a VFD system is usually a three-phase induction motor. Some types of single-phase motors can be used, but three-phase motors are usually preferred. Various types of synchronous motors offer advantages in some situations, but induction motors are suitable for most purposes and are generally the most economical choice. Motors that are designed for fixed-speed mains voltage operation are often used, but certain enhancements to the standard motor designs offer higher reliability and better VFD performance. [7][8]

Variable frequency drive controllers are solid state electronic power conversion devices. The usual design first converts AC input power to DC intermediate power using a rectifier bridge. The DC intermediate power is then converted to quasi-sinusoidal AC power using an inverter switching circuit. The rectifier is usually a three-phase diode bridge, but controlled rectifier circuits are also used. Since incoming power is converted to DC, many units will accept single-phase as well as three-phase input power (acting as a phase converter as well as a speed controller); however the unit must be derated when using single phase input as only part of the rectifier bridge is carrying the connected load.

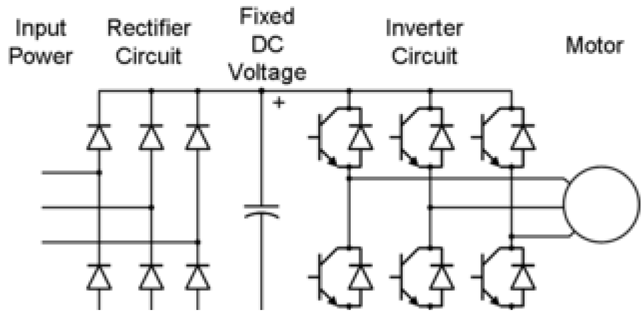

Figure 2.3: PWM VFD Diagram[13]

Figure 2.3 shows the built-in PWM VFD circuit[9]. As new types of semiconductor switches have been introduced, these have promptly been applied to inverter circuits at all voltage and current ratings for which suitable devices are available. Introduced in the 1980s, the insulated-gate bipolar transistor (IGBT) became the device used in most VFD inverter circuits in the first decade of the 21st century. [9][10]

AC motor characteristics require the applied voltage to be proportionally adjusted whenever the frequency is changed in order to deliver the rated torque. For example, if a motor is designed to operate at 460 volts at 60 Hz, the applied voltage must be reduced to 230 volts when the frequency is reduced to 30 Hz. Thus the ratio of volts per hertz must be regulated to a constant value (460/60 = 7.67 V/Hz in this case). For optimum performance, some further voltage adjustment may be necessary, but nominally a constant volt per hertz is the general rule. This ratio can be changed in order to change the torque delivered by the motor.

The usual method used for adjusting the motor voltage is pulse-width modulation (PWM). With PWM voltage control, the inverter switches are used to divide the quasi-sinusoidal output waveform into a series of narrow voltage pulses and modulate the width of the pulses.

Operation at above synchronous speed is possible, but is limited to conditions that do not require more power than nameplate rating of the motor. This is sometimes called "field weakening" and, for AC motors, is operating at less than rated volts/hertz and above synchronous speed. Example, a 100 hp, 460 V, 60 Hz, 1775 RPM (4 pole) motor supplied with 460 V, 75 Hz (6.134 V/Hz), would be limited to 60/75 = 80% torque at 125% speed (2218.75 RPM) = 100% power.

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2.42 Reasons for Using Variable speed drives

Process control and energy conservation are the two primary reasons for using a variable speed drive. Historically, adjustable speed drives were developed for process control, but energy conservation has emerged as an equally important objective.

A variable speed drive often uses less energy than an alternative fixed speed mode of operation. Fans and pumps are the most common energy saving applications. When a fan is driven by a fixed speed motor, the airflow may sometimes be higher than it needs to be. Airflow can be regulated by using a damper to restrict the flow, but it is more efficient to regulate the airflow by regulating the speed of the motor. It follows from the affinity laws that reducing fan speed to 50% results in a power consumption drop to 12.5%.