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Reconfigurable Universal Speed Control based on Kron's Primitive Model

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Abstract

A generalization of a concept is an extension of the concept to less-specific criteria. More generally, the objective of generalization is to supply information on a content and detail level corresponding to the necessary information for correct reasoning. Generalized theory of electrical machines provides a common framework for studying, modelling, simulating and understanding the behaviour of all electrical machines. In this theory, by using Kron's primitive hypothesis machine we can simulate all kind of machines. This model is a dependent model to the reference frame that will be selected for studies. Different reference frames can be chosen depending to case. Kron' primitive model(KPM) suggests one platform for control of AC as well as DC motors. Taking a thread from KPM, we are developing a reconfigurable controller which will operate on concept of common framework as suggested by KPM. The Reconfigurable Universal Controller (RUC) will make PWM technique a universal method for any motor detected by the RUC. The RUC firstly detects the type of motor connected with it and then accordingly configures itself for the speed control. The RUC configuration parameters are passed on to the system using a software which acts as Human Machine Interface.

Keywords: KPM, RUC, PWM, Universal Control

Nomenclature:
KPM: Kron's Primitive Model
RUC: Reconfigurable Universal Controller
PWM: Pulse Width Modulation
TPS: Thermal Protection Scheme

1. Introduction

Speed control of any kind of motor is important because it enables the motor user to restrain its speed to the needed or required speed to accomplish a specific task. Before discussing about the induction motor drives we have to understand and know about induction motors. In very simple words induction motors can be described as a three phase or single phase, self starting constant speed ac motors. The reason for describing induction motor as constant speed is because normally these motors have a constant speed depending on the frequency of the supply and the number of windings. In the past it was not possible to control the speed of the induction motors according to the need.

That is why their use was limited and despite having advantages over dc motors they could not be used because of this disadvantage. But as the field of drivers have improved due to the availability of thyristors, power transistors, IGBTs and GTOs the variable speed induction motor drives have been developed. Although AC drives are costlier than DC drives they are replacing DC drives owning to their advantages.

On the other hand DC motors are easy to control as compared to AC motors. But in all industrial applications what we have readily available is AC single phase or AC three phase supply. Hence there is a great need of a universal speed controller which can reconfigure itself as per requirement and supply conditions and still perform the task of regulated speed control for AC as well as DC.

The complete idea of RUC is based on Kron's primitive model. As per KPM all rotating electrical machines work on the same basic principles.

The various types differ from each other in their winding arrangements and in the method of exciting these windings. The attempts to unify the piecemeal treatment of rotating electrical machines has led to generalized theory of electrical machines or two-axis theory of electrical machines. Gabriel Kron developed Park's Two Axis equations to deal with all rotating electrical machines in a systematic manner by tensor analysis. This unified treatment of rotating electrical machines developed by Kron, is now called generalized theory of electrical machines.

Another important factor which motivates the research in the field of RUC is "Reconfigurable computing". Reconfigurable computing is a computer architecture combining some of the flexibility of software with the high performance of hardware by processing with very flexible high speed computing fabrics like field-programmable gate arrays (FPGAs). The principal difference when compared to using ordinary microprocessors is the ability to make substantial changes to the data path itself in addition to the control flow. On the other hand, the main difference with custom hardware, i.e. application-specific integrated circuits (ASICs) is the possibility to adapt the hardware during runtime by "loading" a new circuit on the reconfigurable fabric. Gerald Estrin proposed the concept of a computer made of a standard processor and an array of "reconfigurable" hardware. The main processor would control the behaviour of the reconfigurable hardware. Once the task was done, the hardware could be adjusted to do some other task. This resulted in a hybrid computer structure combining the flexibility of software with the speed of hardware.

This paper proposes the RUC model amalgamated with KPM for building a universal controller for AC motor drives as well as DC drives. The complete concept is explained below. The prototype of model is under development. The whole task is divided in 3 modules.

1. A software platform for reconfiguration of motor drive.
2. PWM control for speed in AC and DC motors.
3. Thermal protection of motors.

2. Operation

2.1 A software platform for reconfiguration of motor drive.

Considering KRON'S primitive model, we are proposing Reconfigurable Universal Controller (RUC) and thermal motor protection circuit. According to Kron all rotating electrical machines work on the same basic principles. The various types differ from each other only in their winding arrangements and in the method of exciting these windings. Our proposed system is capable of detecting various motors such as AC motor, DC motor, stepper motor etc. Once a particular motor is detected by RUC it sends the information to the software. The software then collects all parameters like motor rating, maximum RPM, thermal cut-off temperature etc. and configures PWM speed control process for detected particular motor.

As per Kron's concept of every machine be considered as a standard machine operating with universal rotating flux technique we are proposing software on the same ground which uses universal technique of PWM for configuring and controlling AC as well as DC motors. The proposed RUC also provides thermal protection for any motor.

The RUC firstly detects the type of motor connected with it and then accordingly configures itself for the speed control. The speed control used for both AC as well as DC drives is carried out by PWM process. The basic mechanism for RUC is given by the flowchart below.

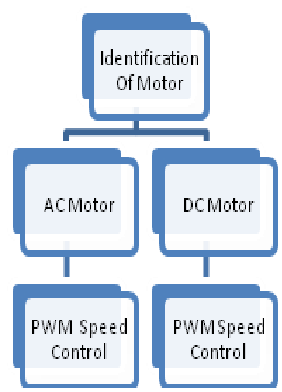

Figure 1: Basic mechanism of RUC

The RUC is planned for two types of motors. The first is single phase induction motor for AC scheme and DC motor for DC scheme. A Wi-Fi module and thermal sensor is integrated within the control panel. The Wi-Fi module is provided for wireless hassle free communication with the PC and a thermal sensor is provided for protection from thermal overload. Maximum RPM and wattage rating of motor is also provided on the control panel for user input. Speed control for the user is provided on the control panel in four different range. The speed control range for both AC as well as DC motor is same. The RUC operation for AC motor connection is shown in figure no.2 and for DC motor connection it is shown n figure no.3 .

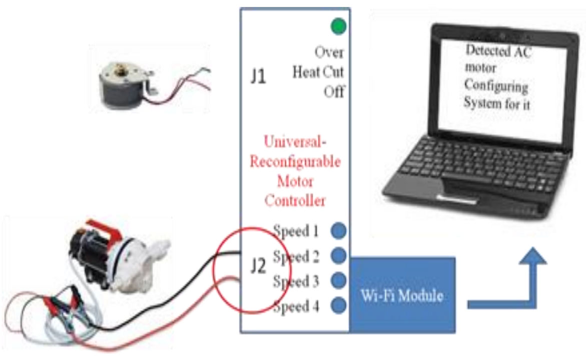

Figure 2: RUC during AC motor connection

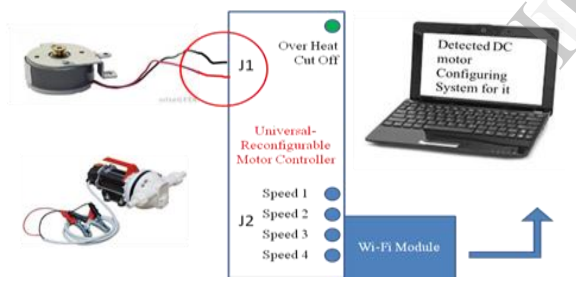

Figure 3: RUC during DC motor connection

A detailed diagram for RUC control panel is shown in figure no.4 below-

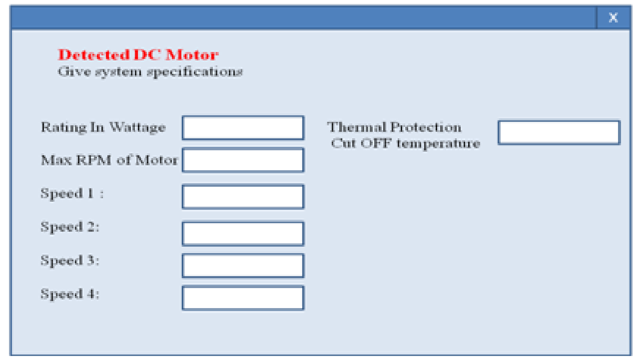

Figure 4: RUC Control Panel

2.2 PWM control for speed in AC and DC motors.

2.2.1 PWM for AC

Figure below shows a block diagram of the power conversion unit in a PWM drive. In this type of drive, a diode bridge rectifier provides the intermediate DC circuit voltage. In the intermediate DC circuit, the DC voltage is filtered in a LC low-pass filter. Output frequency and voltage is controlled electronically by controlling the width of the pulses of voltage to the motor. Essentially, these techniques require switching the inverter power devices (transistors or IGBTs) on and off many times in order to generate the proper RMS voltage levels.

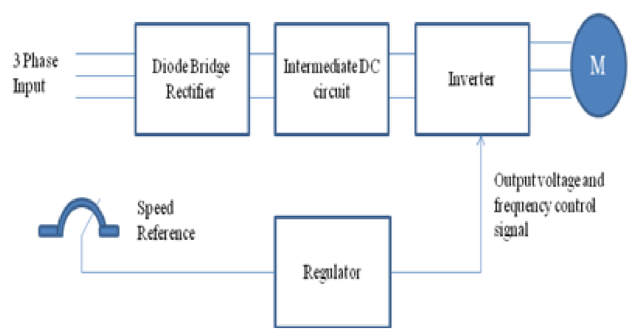

Figure 5: Power Conversion Unit(PWM)

With the use of a microprocessor, these complex regulator functions are effectively handled. Combining a triangle wave and a sine wave produces the output voltage waveform.

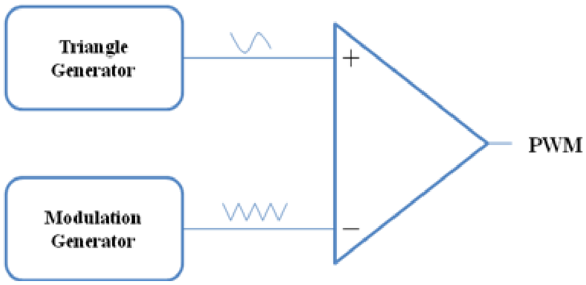

Figure 6: PWM Generator

The triangular signal is the carrier or switching frequency of the inverter. The modulation generator produces a sine wave signal that determines the width of the pulses, and therefore the RMS voltage output of the inverter.

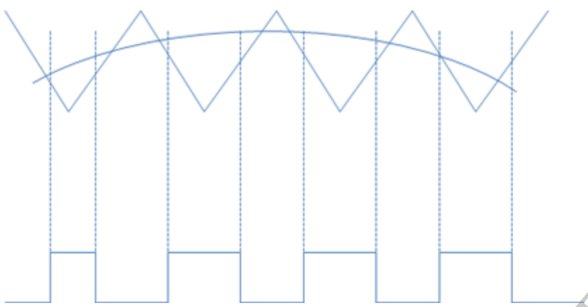

Figure 7: Output of PWM Generator

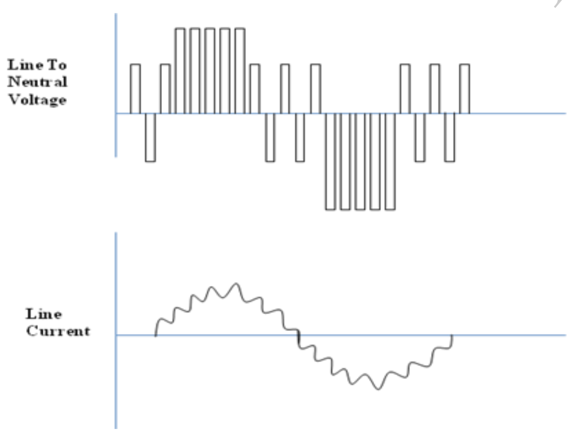

Figure 8: PWM Output Waveform

AC drives that use a PWM type schemes have varying levels of performance based on control algorithms. There are 4 basic types of control for AC drives today. These are Volts per Hertz, Sensor less Vector Control, Flux Vector Control, and Field Oriented Control.

V/Hz control is a basic control method, providing a variable frequency drive for applications like fan and pump. It provides fair speed and torque control, at a reasonable cost. Sensor less Vector control provides better speed regulation, and the ability to produce high starting torque. Flux Vector control provides more precise speed and torque control, with dynamic response. Field Oriented Control drives provide the best speed and torque control available for AC motors. It provides DC performance for AC motors, and is well suited for typical DC applications.

2.2.2 PWM for DC

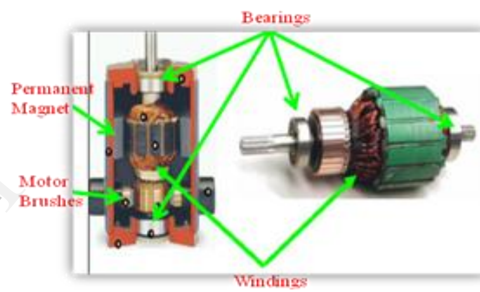

Figure 9: Armature of DC permanent magnet motor

In PWM for DC we are modulating the on/off time instead of power. We can now supply enough initial power to start the motor turning, while still conserving power after the motor is spinning. Since we are supplying the full voltage to the motor from the start, this should be enough to get the motor to a full spin from a dead stop. Since we are modulating the amount of time that full power is applied to the motor, we can use short bursts of full power to 'boost' the motor, and then let the motor 'glide' under its own inertia. By varying the amount of time the signal is 'on', the average of the signal approximates the level of the analog DC voltage needed to drive the motor at the same speed. This lets us vary the speed of the motor without 'blocking' some current and generating waste heat.

Using a function generator with a small motor, we can test this

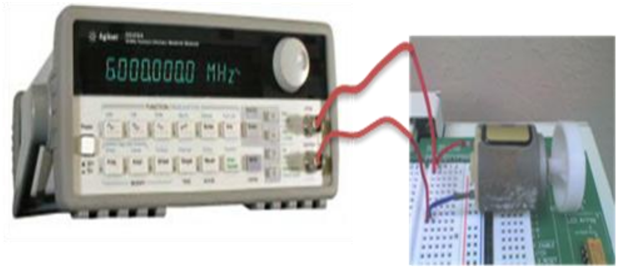

Figure 10: Function Generator with motor

2.3 Thermal protection of motors.

The term thermal protection in motors means a thermal protector placed internally within a motor which protects the motor from dangerous overheating which can cause motor failure. Thermal stress potentially can cause the failure of all the major motor parts like stator, rotor, bearings, shaft and frame insulation..The lifetime of the motor decreases by half if its operating temperature exceeds thermal limit by 10ºC for any period of time. Actually every motor does have some predetermined overload tolerance value which means every motor can run beyond its thermal limit for a specific allowable period depending on its loading condition. But if this limit is consistently crossed for specific period of time it leads to dangerous overheating.

The overheating in motors is generally caused by-

- Mechanical over loading which draws higher current from the supply leading to excessive over heating of the motor.
- Mechanical locking during which motor will draw excessively high current from the supply leading to thermal over loading of electrical motor.
- Low supply voltage which causes motor to draw high current from mains to maintain required torque.

As the thermal over loading or over heating of the motor can lead to insulation failure and damage of winding a proper motor thermal protection scheme is required.

SCHEME

We are proposing a thermal protection system(TPS) which turns the motor off when excessive heat is generated within the motor circuitry and keep it from burning up the motor. A thermistor and circuit breaker collectively forms the TPS. A thermistor is a non-linear resistance temperature detector having fast response time. They are generally used when in certain situations thermal image during motor overheating is not detected by circuit breakers. A circuit breaker protects an electrical circuit from damage caused by overload or short circuit. Its basic function is to detect a fault condition and interrupt current flow. To avoid an abrupt interruption of power supply a thermistor sensor is used with circuit breaker. The rise in the temperature is detected by thermistor which provides a signal to the user. This provides an ample amount of time for user to finish the work in hand and then trip OFF the circuit manually by circuit breaker. The motor's thermal limit is kept within an acceptable level by TPS. Precise temperature monitoring is provided to avoid overheating even in demanding motor operation. Complete motor temperature information is provided to the user.

3 . Conclusion

The KPM model has greatly helped to understand and develop the model of reconfigurable universal controller (RUC). The model will certainly reduce maintenance and other overhead costs in industrial environment. With this model, we can drive ac as well as dc motors using common controller logic and hardware.

The PC interface further enhances the potential of the RUC as different settings can be loaded for different type of motors on same drive. The software provides easy to use Human Machine Interface(HMI) which can be managed even by a layman on floor in industry.

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