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SPEED CONTROL AND MONITORING SYSTEM FOR SINGLE PHASE INDUCTION MOTOR USING LABVIEW WITH MOTOR PROTECTION

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ABSTRACT
This paper deals with the realization of a proposed system involving the speed control of induction motor and monitoring of its parameters coupled with overload and overcurrent protection. The applications of induction motors are almost too numerous to mention and hence functioning of these machines at proper speed is necessary to ensure good productivity and safety at affordable costs. Monitoring simplifies the outcomes of complex analysis through detailed diagnosis thereby preventing unscheduled downtimes that result in lost production. Speed control is carried out using Direct Torque Control Space Vector Modulation (DTC-SVM) and monitoring is achieved using LabVIEW software. This paper profoundly explains the vector control diagram of SVM as well as the LabVIEW software which generates flexible and scalable design, control and test applications at minimal cost supplemented with overload and overcurrent protection, This proposed system improves the adaptability of prevailing systems.

KEYWORDS: DTC, SVM, Voltage vectors, LabVIEW, H-Bridge.

INTRODUCTION
In recent years, AC motors have been employed for most applications such as elevators, pumps, printers, robots etc due to is numerous advantages like simple and extremely rugged construction, low cost, high reliability, minimum maintenance costs, and high efficiency. But the main disadvantage that promoted the use of DC motors, despite their demerits in comparison with induction motors in the olden days was that, speed decreases with the increase in load and necessitates the speed control of induction motors thereby endangering its efficiency. Induction motors are commonly known as constant speed motors and hence its speed control is in fact inevitably significant.

The equation governing the speed of an induction motor is given by,

$$N_S = 120 f / P$$

Where, 'Ns' is the synchronous speed of the machine

'f' is the supply frequency and,

'P' is the number of poles.

The methods to control speed of induction motors may be subdivided as follows:

1. Control from stator side:

(a)By changing the applied voltage

(b)By changing the applied frequency

(c)By changing the number of stator poles

2. Control from rotor side:

(a)Rotor rheostat control

(b)By injecting an emf in the rotor circuit

(c)By operating two motors in cascade

But these methods of speed control are outdated due to difficulty and low efficiency. Certain factors need to be taken into consideration for choice of new methods of speed control. They are:

1. Affordable cost

2. Improvement in efficiency

3. Ease of implementation

4. Adaptability to incorporate complex algorithms

The promotion in the power electronics field increased the availability of thyristors, power transistors, IGBTs and GTOs which in turn gave better chances of inventing effective speed drives for induction motors. The speed control algorithm presented in this paper is Direct Torque Control Space Vector Modulation (DTC-SVM) which will be discussed in detail later on.

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Besides employing speed regulation in motors, it should also be made sure that the system operates efficiently at all times. This can be achieved by real time monitoring of the parameters of the induction motor like speed, temperature, motor current, motor voltage etc. The monitoring system aids in the prevention of problems and keeps track of the operations that are performed by the system.

Virtual instruments is a software that truly provides the leverage to build on the powerful hardware foundation to create virtual instruments, providing better ways to innovate and significantly reduce cost. It represents a fundamental shift from traditional hardware-centred instrumentation systems to software-centred systems. With virtual instruments, engineers and scientists build measurement and automation systems that suit their needs exactly (user-defined) instead of being limited by traditional fixed-function instruments).

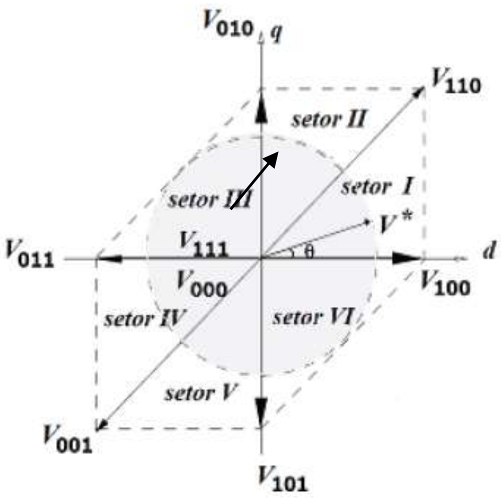

Fig.1. Reference Voltage Vector Synthesis

DIRECT TORQUE CONTROL (DTC)

Direct Torque Control was presented by I. Takahashi and T. Noguchi for the torque control of induction motor. It established to be a promising method of speed control offering simple structure and good dynamic behaviour. As discussed earlier, the speed of the induction motor can be maintained at a constant value as long as the magnitude and frequency of the voltage driving the induction motor is modified accordingly. This modification should be a function of the error between the actual motor speed and the desired motor speed.

A. Overview of the System

From fig.2 it can be seen that the main elements of a DTC system are as follows:

(a)Flux Estimator

The stator flux maybe controlled if a proper choice of the stator voltage is made. This is because the stator flux varies with the change in applied stator voltage with time. The estimated stator flux is decreased or increased to be made equal to the desired or reference stator flux. The flux error which is the difference between the estimated and desired stator flux is fed to the hysteresis comparator which in turn produces the flux error status.

(b)Torque Estimator

The instantaneous value of torque is a sinusoidal function of the angle between the stator and rotor fluxes given by the relation,

$$T \; \alpha \; \phi . I_2 . \mathrm{Cos}\Theta$$

Where, 'T' is the torque of the motor
'ϕ' is the stator flux
'I_2'is the rotor current at standstill and,
'CosΘ' is the angle between stator and rotor fluxes.

This angle will change to a great extent, if the stator flux changes quickly, causing a large variation in the output torque. Thus, the voltage vectors of the inverter must be properly chosen in order to obtain a constant speed so that the desired performance is achieved. Similar to the flux control, torque is controlled within the tolerance band.

(c)Voltage Source Inverter

A voltage source inverter (VSI) converts the DC to AC through power electronic devices such as an IGBT. It is this inverter that carries out the command from the switching algorithm to vary the stator voltage as required in order to control the speed. Thus in order to get the desired stator flux, the technique of space vector modulation is applied.

The value of stator flux and torque calculated are compared with the desired values in the hysteresis comparators. This output is then fed to a switching table to select an appropriate voltage vector at the inverter. The switching table determines the voltage vector to be applied, which depends on the required changes in stator flux and torque. The selected voltage vector will be applied to the induction motor to run the machine at the required speed.

B. Why DTC Is Not Self-Adequate

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Rudimentarily, in DTC, only one vector is applied for a particular sampling period. This may cause the stator flux and torque to go beyond their tolerance limits which introduces high torque ripples and distortions in the stator flux and current. This is the main disadvantage of the conventional DTC method.

So a second algorithm that can be used in conjunction with the basic DTC system is the Space Vector Modulation, which eliminates the common disadvantages of the traditional DTC method.

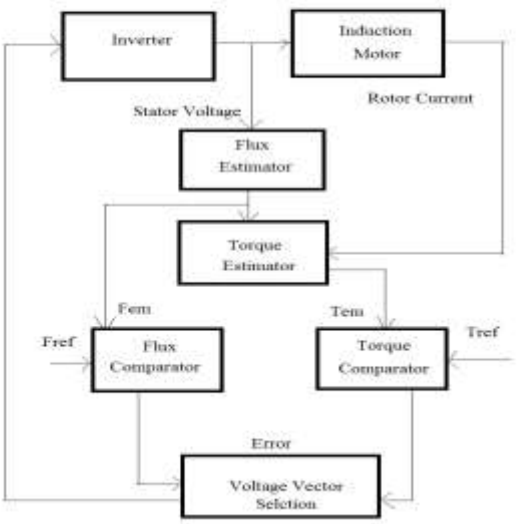

Fig.2. Block Diagram of DTC Method

DIRECT TORQUE CONTROL SPACE VECTOR MODULATION (DTC-SVM)

The modification of the voltage waveforms to maintain the motor at constant speed is done by employing SVM algorithm in a Voltage Source Inverter (VSI) but the extent of the alteration is determined by the DTC algorithm. In the voltage source inverter, conversion of DC power to AC power is performed in the switched mode. The actual power flow in each motor phase is controlled by the duty cycle of the respective switches. To obtain a suitable duty cycle for each switch, the technique of Pulse Width Modulation (PWM) is used.

An H-bridge inverter consisting of several power electronic switches is used as the voltage source inverter here. The switching power devices can be constructed using power BJTs, GTOs, IGBTs, etc. The choice of switching devices is based on the desired operating power level, required switching frequency, and acceptable inverter power losses. The ON and OFF states of the lower switches are complementary to the upper ones. Two switches on the same leg cannot be closed or opened at the same time. The switch combinations can be represented as binary codes that correspond to the equivalent switches and the eight inverter states can transformed into eight corresponding space vectors.

Thus, SVM defines a space vector table that represents the states (ON or OFF) of the individual switches. In a three phase system, eight voltage vectors maybe defined, out of which two are null vectors and six are active vectors. In a single phase system there would be only four voltage vectors as shown in table 1. The space vector table or the switching table is shown in table 1. The reference voltage vector is realized by the sequential switching of active and zero vectors.

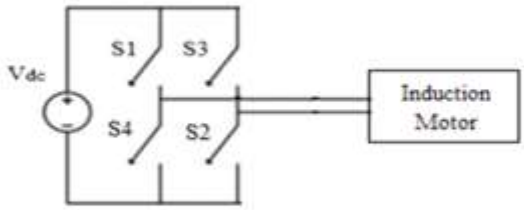

Fig.3. Schematic Diagram of Voltage Source Inverter

The basic step is the selection of stator voltage vectors are selected from the switching table to minimize the error signal that comes from the DTC section. Once the voltage vectors are selected, the switches of the inverter are switched ON and OFF with the required duty cycle such that the average output voltage of the inverter is obtained by using a weighted average of the three closest switching states. This way, a sine wave of the right magnitude and frequency to bring the motor to its normal speed is made by a series of DC pulses. The first pulse has a very short ON time, followed by longer ON period until the widest pulse appears at the centre of the sine wave.

Table I. Switching Table in SVM

Space Vectors		Switching State	ON-State Switches
Zero Vectors	V0	[0 0]	S4 S2
	V3	[1 1]	S1 S3
Active Vectors	V1	[0 1]	S4 S3
	V2	[1 0]	S1 S2

LABVIEW MONITORING SYSTEM

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LabVIEW stands for Laboratory Virtual Instrumentation Engineering Workbench that exploits the computing power, productivity, display, and connectivity capabilities of popular desktop computers. One of the most powerful features that LabVIEW offers is its graphical programming environment. With LabVIEW, we can design custom virtual instruments by creating a graphical user interface on the computer screen.

We can customize front panels with knobs, buttons, dials, and graphs to emulate control panels of traditional instruments, create custom test panels, or visually represent the control and operation of processes.

A. Overview of the System

Fig.4 shows the block diagram of a LabVIEWbased monitoring system.

(a)Data Acquisition System (DAS)

The data acquisition system takes information signals from sensor outputs. All the motor parameters like temperature, speed, voltage and current are physical quantities which are in the form of analog signals. These analog signals are changed to its digital value which maybe further processed.

(b)Signal Conditioning Circui

The output of the sensors maybe low level signals, containing a large amount of noise as well. To be compatible with the DAQ, this signals need to be amplified to the right intensity. Hence the signal conditioning system has the functions of amplification, filtering and isolation of the signals from the sensors.

(c)*Connector Accessory*

The output of the signal conditioning circuit needs to be connected with the DAQ card, which cannot be done directly. Hence a connector accessory is employed to establish a link between the signal conditioner and the pin configuration of the DAQ card.

(d)LabVIEWProgramming

The programming method used in LabVIEW is G programming, which is defined for graphical programming. It is also known as data flow programming as it is depending on the structure of the graphical block diagram to execute the user-designed program. When comparing with text-based programming, LabVIEW is user friendly as the user can design the program by simply arrange and wiring the relevant icons together. LabVIEW programs are also named as virtual instruments, or VI, because their appearance and operation mimic the physical instruments, such as oscilloscopes and multi-meters.

(e)Server VI & Client VI

Client programs request service from a server by sending it a message, and server programs process client requests by performing the tasks requested by clients. Client-server applications are not limited to transferring data but can store data for future references and even run the simulation on the client VI. Many applications require more than one client to access data from the server. The server must handle multiple connections and respond to each and every client.

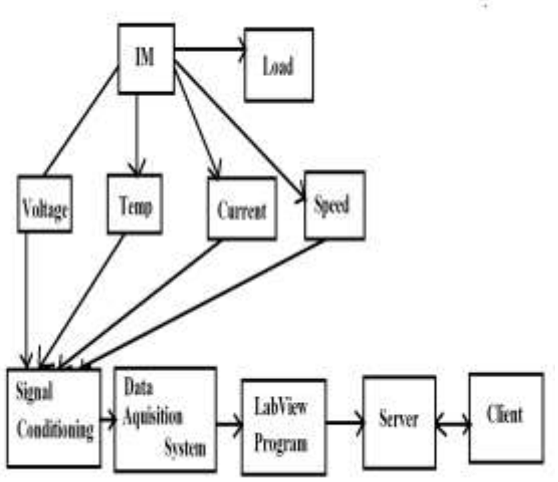

Fig.4. Block Diagram of LabVIEW Monitoring System

MOTOR PROTECTION

Protection of the motor as well as the personnel operating the motor is very crucial. Motor protection safeguards the motor, the supply system and personnel from various operating conditions of the driven load, the supply system or the motor itself. Motor protection categories in this paper include:

- Overcurrent Protection
- Overload Protection

Overload protection is installed in the motor circuit to protect the motor from damage from mechanical overload conditions when it is operating. The effect of an overload is an excessive rise in temperature in the motor windings due to current higher than full load current. The larger the overload, the more quickly the temperature rises to a point that damages the insulation and lubrication of the motor.

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Overcurrent protection interrupts the electrical circuit to the motor upon excessive current demand on the supply system from either short circuits or ground faults. It is required to protect the motor branch circuit conductors and control equipment from these large currents.

The block diagram of the motor protection system is as shown in fig.5.

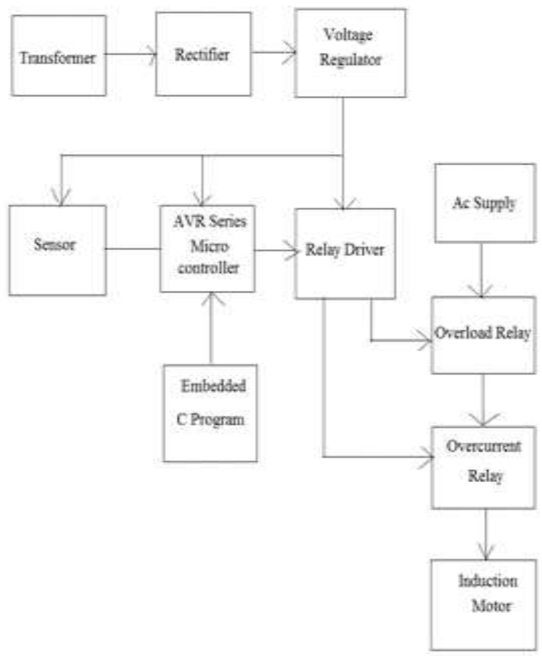

Fig.5. Block Diagram of Motor Protection System

After the single phase AC supply is stepped down using a transformer, it is converted into DC using a rectifier and prevented from any variations using a voltage regulator. A current sensor keeps track of the motor current, which when goes beyond the limit, makes the microcontroller to trigger off the relay driver. At the time of overload or overcurrent, the respective relay disconnects the motor from supply and thus protection is ensured. After the situation is taken care of, the motor regains its state of operation.

CONCLUSION

In this paper, with reference to the traditional DTC method, a most convenient industrial control scheme for voltage source inverter-fed induction motor drives was presented, A very important feature of DTC-SVM is that it has a simple structure. Hence it can be analyzed and implemented in a simple way. This is . This method would provide operation in a wide power range.

Industrial system designers of LabVIEW continue to push for higher performance and functionality relying on its promising features. LabVIEW monitoring would ensure a highly accurate monitoring system. A simplified operational block diagram of the LabVIEW based monitoring system was discussed, pointing out the advantages as well.

Also, the need for motor protection and the method to overcome the conditions of downtimes was examined. Thus this paper proposes a reliable, all in one motor conditioning system using microcontrollers that is capable of replacing complicated circuits by a single, efficient unit.

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