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B.E. PROJECT REPORT

On

"Machine Tool Monitoring Using Electric Current Analysis of the Spindle Motor in CNC Machine."

Submitted by,

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UNDER THE GUIDANCE OF

Prof. Pallavi Wadkar (Internal Guide)

IN PARTIAL FULFILMENT OF
B.E.(ELECTRONICS AND TELECOMMUNICATION)
SAVITRIBAI PHULE PUNE UNIVERSITY 2023-2024

MARATHAWADA MITRA MANDAL'S COLLEGE OF ENGINEERING, PUNE- 52

DEPARTMENT OF ELECTRONICS AND TELECOMMUNICATION

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COLLEGE OF ENGINEERING, PUNE

CERTIFICATE

This is to certify that the seminar report entitled

"Machine Tool Monitoring Using Electric Current Analysis of the Spindle Motor in CNC Machine."

Submitted by,

Avnish Raj	Exam No: - B190453005
Purva Jiwane	Exam No: - B190453060
Om Pokharkar	Exam No: - B190453113

is Bonafide work carried out by them under the supervision of Prof. Pallavi Wadkar and it is approved for the partial fulfilment of requirement of Savitribai Phule Pune University for award of the degree of Bachelor of Engineering (Electronics and Telecommunication).

This seminar report has not been earlier submitted to any other Institute or University for the award of any degree or diploma.

Prof. Pallavi Wadkar	**Dr. G. S. Gawande**	**Dr. V. N. Gohokar**
Department of E&TC	**Head of Department of E&TC**	**Principle**

INDEX

ABSTRACT

Computer Numerical Control (CNC) is a manufacturing process in which pre-programmed computer software observes the movement of factory tools and machinery. This process can be used to control a range of complex machinery, from CNC routers.
The electric current drawn by the spindle motor is a critical parameter to monitor. It provides insights into the load and conditions under which the motor operates. By analyzing this current, you can assess various aspects of machine tool performance.
To analyze the current of the spindle motor, you can follow these steps:

1. Equipment:

Use a current probe or a multimeter capable of measuring current.

Ensure the equipment is rated for the current levels expected in spindle motor.

2. Safety Precautions:

Power off the spindle motor before connecting any measurement equipment.

Follow safety guidelines to avert electric shock.

3. Connection:

Connect the current multimeter in series with the spindle motor power supply.

Ensure a secure and proper connection to avoid measurement errors.

4. Measurement:

Power on the spindle motor.

Measure and record the current values at different operating conditions, such as startup, idle, and various load levels.

5. Analysis:

Compare the recorded current values with the motor's specifications.

Look against abnormal spikes, fluctuations, or patterns that may indicate issues.

Consider the relationship between load and current – higher loads typically result in higher currents.

6. Temperature Consideration:

Monitor the motor's temperature during the assessment, as excessive current can lead to overheating.

Check if there's a correlation between increased current and elevated temperature.

7. Documentation:

Document your findings and observations.

Note any deviations from scheduled behavior or specifications.

8. Troubleshooting:

If you observe unusual current patterns, consult the motor's documentation or seek advice from the manufacturer.Investigate potential issues with the motor or its control system.

ORGANIZATION OF REPORT

Our project "Machine Tool Monitoring Using Electric Current Analysis of the Spindle Motor in CNC Machine" is thoroughly explained in all the chapters in this report. Planning and organization of this subject has been done with curiosity and as per the given deadline. So, this project gives the entire overview of this subject.

The report is divided into various chapters to understand each aspect of the subject technically and separately.

Chapter1:

Gives brief introduction of this project. This consist of introduction and scope of project, objective of this project.

Chapter 2:

Gives brief review of the related Literature and present scenario of proposed system.

Chapter3:

Describes System Schematic & Specification and block diagram with its detailed explanation.

Chapter4:

Describes the implementation of the project with its hardware and software description that is detailed analysis of each component.

Chapter5:

Conclusion, Future Scope and Project Planning.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Computer Numerical Control (CNC) is a manufacturing process in which pre-programmed computer software observes the movement of factory tools and machinery. This process can be used to control a range of complex machinery, from CNC routers.

The electric current drawn by the spindle motor is a critical parameter to monitor. It provides insights into the load and conditions under which the motor operates. By analyzing this current, you can assess various aspects of machine tool performance

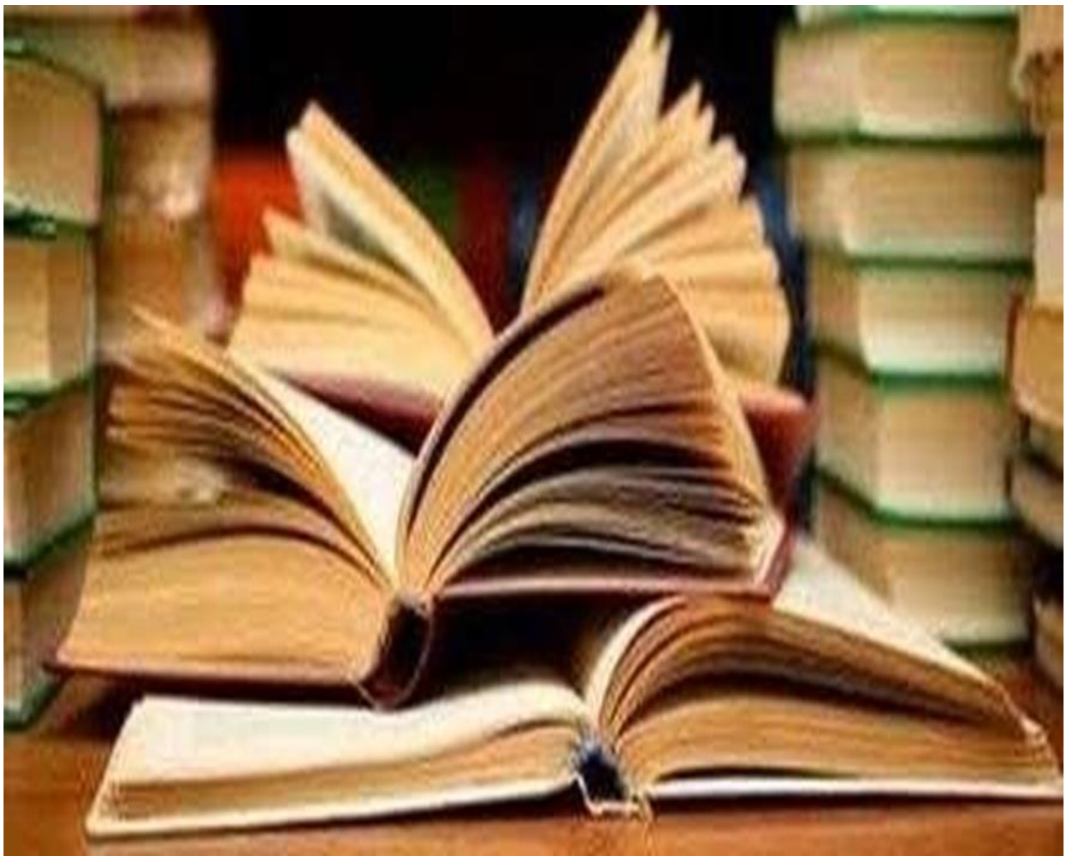
With CNC machining, 3-D cutting tasks can be done in a single set of prompts.The automatic nature of CNC machines allows the production of precised products and high accuracy, simple parts and cost-effectiveness products.By continuously monitoring the spindle motor's current, user can predict when and where the maintenance is required.

For example, an increase in current over time might indicate that the spindle motor's bearings and deteriorating need replacement. Hence the timely maintenance can be done with the real time data acquisition which will extend the lifespan of the machine.To perform electric current analysis, sensors are installed to measure the current. These sensors feeds the data to a monitoring system, which is a part of the CNC machine's monitoring device.

Many modern CNC machines are nowadays made with the capability of combining machine tool monitoring with the CNC machine’s control system, making it easier to implement real-time data based on the current analysis.

It's important to maintain a historical record of the current data. This historical data can be valuable for trend analysis, maintenance scheduling, and process optimization over time.

CHAPTER 2
LITERATURE SURVEY



2.1 LITERATURE SURVEY

1. Title:- A Comparative Study of Using Spindle Motor Power and Eddy Current for the Detection of Tool Conditions in Milling Processes.

   Author:- Abbass, J. K. , & Al-Habaibeh, A. (2015)

   Summary:- In this paper, we are going to look at the difference between the spindle motor power and the eddy current sensor power for tool wear. We are going to compare the spindle power with the power of eddy current sensor using real time parameters. The parameters used in this paper are: 1. Cutting forces 2. Vibration 3. Current 4. Power 5. Temperature These parameters are used in a wide variety of current analysis & simplification techniques.

2. Title:- Viability of motor current sensors for tool condition monitoring during peck drilling operations with coolant and inverterfed ac motors.

   Author:- Nicholas E. Carder (May 2021)

   Summary:- In this paper, we apply two condition indicators for tool condition monitoring (TCM) to a new set of data measured with hall-effect current sensors that attempts to simulate conditions inside a modern industrial manufacturing plant. CNC machines are highly complex systems. Motor current is not directly associated with tool wear in the same way as vibration, force or sound pressure. Implementing current sensors necessitates more domain knowledge for sensor placement and post processing.

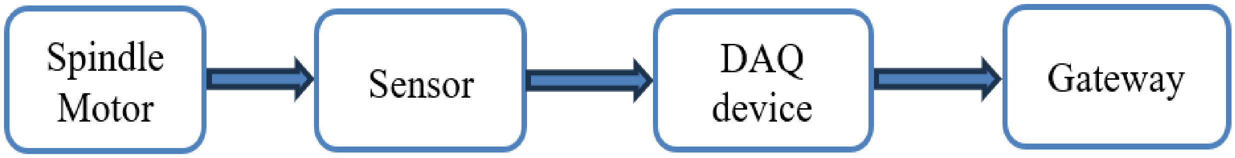
3. Title:- Diagnosis of Cutting Stability of Portable Automatic Beveling Machine Using Spindle Motor Current.

   Author:- Kim, Tae Young, An, Byeong Hun, Kim, Hwa Young (Jan 2022)

Summary:- This study describes a real-time tool and cutting state monitoring system for automatic machine operation. As a cutting state monitoring signal, a motor current is detected from the automatic machine's spindle drive system to monitor an abnormal state. The automatic analysis of machine process is processed using the face milling cutter. The cutting force mechanism is identical to the milling process.

CHAPTER 3
SYSTEM SCHEMATIC AND SPECIFICATION

3.1 BLOCK DIAGRAM



1. Spindle Motor:-The spindle motor is the important component in the CNC machines. It is used to drive the rotation of the tools which are used in particular CNC machine.
The spindle motor is used to generate mechanical motion which are used in machines.

2. Sensor:-The sensor, which will be used in this current analysing system will be Hall Effect Sensor. Which will specifically monitor the parameter on which the system is based i.e, current.This sensor will provide the real time data on the performance of spindle motor.

3. Data Acquisition (DAQ) Device:-The DAQ device will be responsible for collecting data from the sensor and converting and transmitting analog or digital data received from sensor. This device will most importantly convert analog signal to digital. Thus this collected and converted data will be sent to a gateway wich will be a cloud server.

4. Gateway:-The gateway is the cloud platform where the data will be stored which is collected from the DAQ device. The received digital data will be stored on cloud platform of the Gateway.

3.2 METHODOLOGY

1. Spindle motor

The spindle motor in a CNC (Computer Numerical Control) machine is a critical component responsible for rotating the cutting tool or workpiece during machining operations. The methodology of the spindle motor in a CNC machine involves selecting and appropriate motor type, ensuring sufficient power and torque, implementing precise speed control, incorporating cooling and lubrication systems, utilizing high-precision bearings, designing an efficient drive mechanism, integrating with the control system, and conducting regular maintenance and monitoring.

The methodology of the spindle motor involves several key aspects:

Here's an overview of the Spindle motor information for the research paper:

1. Motor Type:

   Spindle motors used in CNC machines can vary in type, including AC motors, DC motors, or more advanced options like servo motors or stepper motors. The choice depends on factors such as torque requirements, speed range, precision, and cost.

2. Speed Control:

   Power and Torque: The spindle motor must provide sufficient power and torque to drive the cutting tool or workpiece effectively through various materials and machining operations. The power and torque requirements depend on factors such as the material being machined, cutting tool size, cutting parameters, and desired cutting speeds. The spindle motor should be capable of precise speed control to accommodate different machining requirements. CNC machines often require variable speed capabilities to optimize cutting performance for different materials and cutting operations.

3. Cooling and Lubrication:

   Spindle motors generate heat during operation, particularly at high speeds or heavy Loads. Adequate cooling mechanisms, such as air or liquid cooling systems, are employed to maintain optimal operating temperatures and prevent overheating. Additionally, lubrication systems ensure smooth operation and longevity of the spindle motor bearings and other moving parts.

High-precision bearings are essential components of spindle motors to minimize friction, support axial and radial loads, and maintain accurate concentricity during high-speed rotation.Common bearing types used in spindle motors include angular contact ball bearings, cylindrical roller bearings, and tapered roller bearings.

The spindle motor is typically coupled with a drive mechanism that transmits power from the motor to the spindle shaft. This mechanism may include components such as belts, gears, or direct-drive systems, depending on the specific design requirements and performance characteristics desired.

Regular maintenance and monitoring of the spindle motor are essential to ensure optimal performance and longevity. This includes periodic inspection, lubrication, bearing replacement, and monitoring of operating parameters such as temperature, vibration, and power consumption.

2.DHAB S/24 Transducer:

The DHAB family is best suited for DC, AC, or pulsed currents measurement in high power and low voltage automotive applications. It features galvanic isolation between the primary circuit (high power) and the secondary circuit (electronic circuit). The DHAB family gives you a choice of having different current measuring ranges in the same housing (from ± 20 up to ± 600 A).

Features:-

- Open Loop transducer using the Hall effect sensor
- Low voltage application
- Unipolar + 5 V DC power supply
- Primary current measuring range up to ± 75 A for channel 1 and ± 500 A for channel 2
- Maximum RMS primary admissible limited by the busbar, the magnetic core or the ASIC temperature T° < + 150 °C
- Operating temperature range: - 40 °C < T° < + 125 °C
- Output voltage: fully ratiometric (in sensitivity and offset) 2 measuring ranges to have a better accuracy.

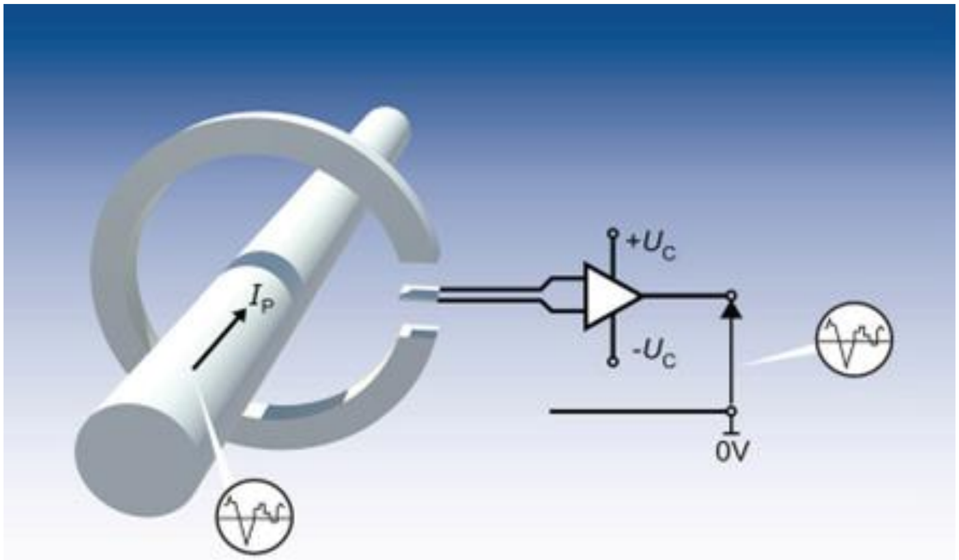


Fig. 1: Principle of the open loop transducer

Principle of DHAB Family:-

The open loop transducers uses a Hall effect integrated circuit. The magnetic flux density B, contributing to the rise of the Hall voltage, is generated by the primary current I_P to be measured. The current to be measured I_P is supplied by a current source i.e. battery or generator (Figure 1).

Within the linear region of the hysteresis cycle, B is proportional to:

$B\ (I_P)$ = constant (a) x I_P

The Hall voltage is thus expressed by:

$V_H = (R_H/d)$ x I x constant (a) x I_P

Except for I_P, all terms of this equation are constant. Therefore:

V_H = constant (b) x I_P

The measurement signal V_H amplified to supply the user output voltage or current.

Mechanical Characteristics:-

- Plastic case >PA66-GF25<
- Magnetic core Channel1:FeNi alloy Channel 2: FeSi alloy
- Mass 69.5 g
- Pins Brass tin plated

3. Dimensions

4.1 MODELING AND ANALYSIS

DHAB S/24 sensor is the hall effect sensor which gives us the choice of having different current measuring ranges in the same housing (from ± 20 up to ± 600 A). This hall effect sensor is connected to Raspberry Pi. Sensor has 4 terminals including 2 current measuring channel 1 range upto ± 75 A and ± 500 A for channel 2. Other 2 is 5V input and GND terminal. DC input is applied to the sensor for measuring the current. DHT11 sensor is used to measure the temperature of the DC motor. Capacitors of 0.1 microfarad are used one is used between the output terminal of hall effect sensor and Arduino. And another capacitor is used between the input terminal of hall effect sensor and Arduino.

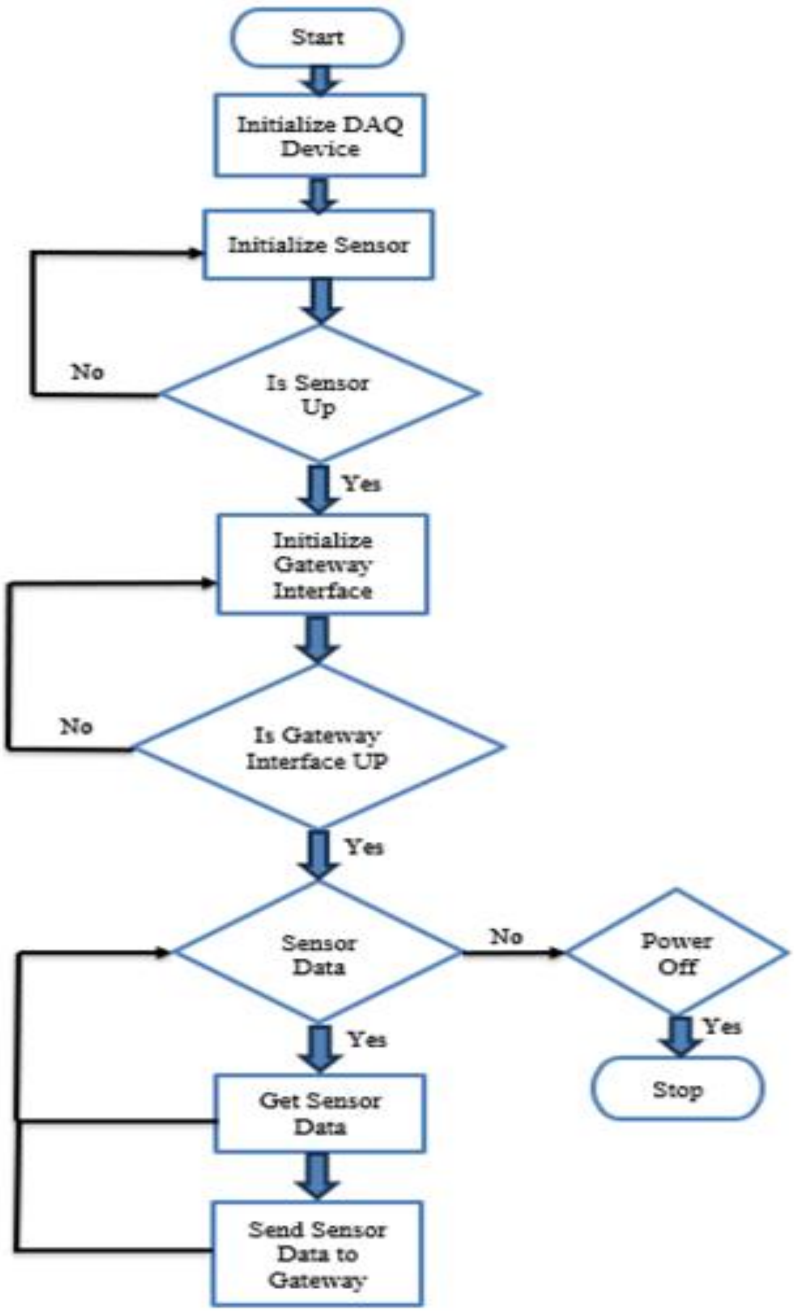


Figure 1: System Architecture

1. Initialize DAQ Device: This step involves initializing the Data Acquisition (DAQ) device, which is the hardware component responsible for interfacing with sensors and converting analog signals into digital data that can be processed by a computer.

2. Initialize Sensor: After initializing the DAQ device, the next step is to initialize the sensor itself. This typically involves establishing communication with the sensor, configuring settings such as sampling rate or signal range, and checking for any errors during initialization.

3. Is Sensor Up?: This decision point checks whether the sensor is operational after initialization. If there are any issues with the sensor, such as communication errors or hardware faults, the process will stop, indicating that further troubleshooting or maintenance is required.

4. Initialize Gateway Interface: Assuming the sensor is operational, the system proceeds to initialize the gateway interface. The gateway interface serves as the communication link between the sensor and the DAQ system, facilitating the transfer of data between the two components.

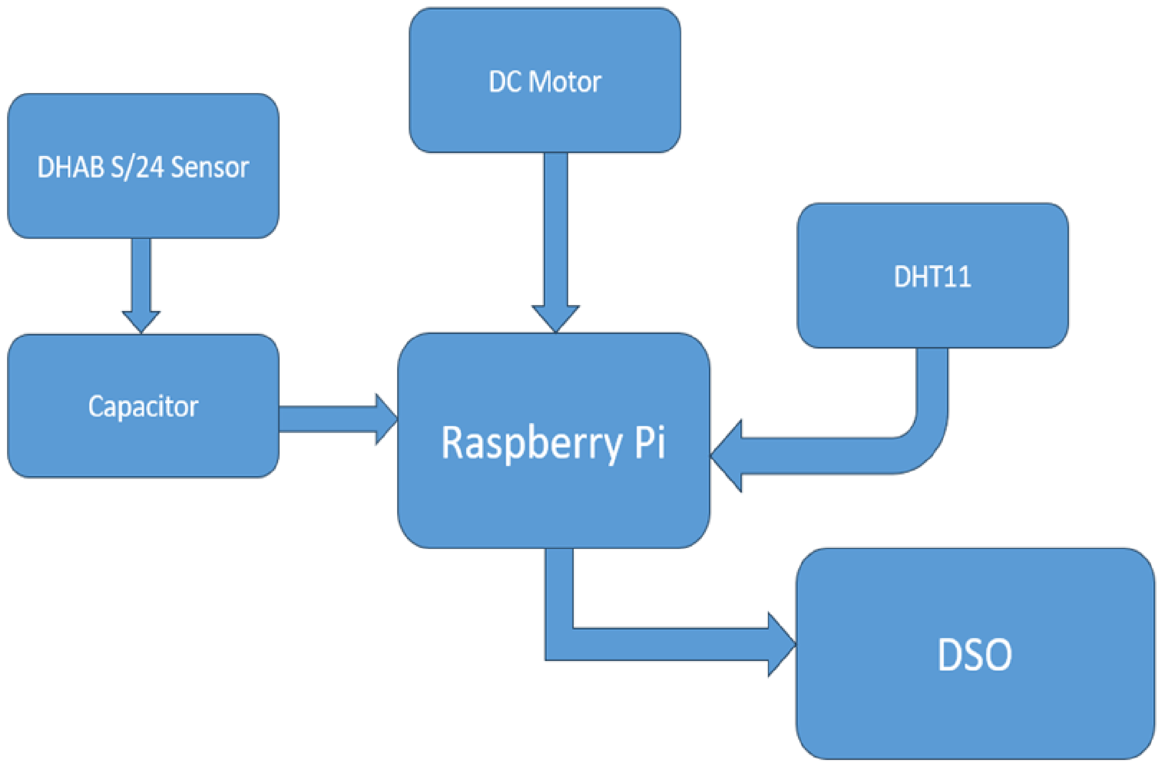
5. Is Gateway Interface Up?: Similar to the previous decision point, this step checks whether the gateway interface is functioning correctly. If there are any issues with the interface, such as connectivity problems or configuration errors, the process will terminate to prevent data loss or corruption.

6. Sensor Power Check: Once the gateway interface is confirmed to be operational, the system performs a check to ensure that the sensor has sufficient power. This step is essential for ensuring reliable data acquisition, as sensors may fail to provide accurate readings if they are not adequately powered.

7. Get Sensor Data: Assuming the sensor has power and is communicating successfully with the DAQ system, the next step is to retrieve data from the sensor. This may involve sending commands to the sensor to initiate data acquisition and reading the resulting sensor measurements.

8. Send Sensor Data to Gateway: Finally, the retrieved sensor data is sent to the gateway interface for further processing or transmission to the computer for analysis. This step completes the data acquisition process, allowing the DAQ system to collect and record sensor measurements for various applications.

4.2 HARDWARE IMPLEMENTATION AND WORKING



Components used :-

1. Dc motor
2. Raspberry Pi
3. DHAB S/24 Hall effect sensor
4. DHT11 sensor
5. Capacitor
6. Connecting wire

Working :-

1. Raspberry Pi:

Raspberry Pi can be used to collect data from sensors measuring current or any other electrical parameter. It can interface with sensors using GPIO pins or through analog-to-digital converters (ADCs). Raspberry Pi's processing power can be utilized to perform real-time data processing and analysis on the acquired current data. Algorithms can be implemented to analyze trends, detect anomalies, or perform calculations.

2. DC Motor:

The DC motor here will convert the electrical energy to mechanical energy.To control the motor, you would connect the positive terminal to a digital output pin on the Arduino and the negative terminal to the GND pin.

3. DHT 11 Sensor:

The DHT 11 sensor operates by sensing temperature and humidity using dedicated sensing elements, transmitting the data to a microcontroller through a digital interface, and then decoding and calculating the temperature and humidity values for further processing or display.

4. Automotive current transducer DHAB S/24:

The DHAB family is best suited for DC, AC, or pulsed currents measurement in high power and low voltage automotive applications. It features galvanic isolation between the primary circuit (high power) and the secondary circuit (electronic circuit). The DHAB family gives you a choice of having different current measuring ranges in the same housing (from ± 20 up to ± 600 A).

5. Connecting Wires:

Wires are used to establish electrical connections between the components. Make sure to connect the positive and negative terminals of each component to the accurate power source and ground, respectively.

DHAB S/24 sensor is the hall effect sensor which gives us the choice of having different current measuring ranges in the same housing (from ± 20 up to ± 600 A). This hall effect sensor is connected to Raspberry Pi. Hall effect Sensor has 4 terminals including 2 current measuring channel 1 range upto ± 75 mA and ± 500 A for channel 2. Other 2 is 5V input and GND terminal. DC input is applied to the sensor for measuring the current. DHT11 sensor is used to measure the temperature of the DC motor. Capacitors of 0.1 microfarad are used one is used between the output terminal of hall effect sensor and Arduino. And another capacitor is used between the input terminal of hall effect sensor and Arduino.

CHAPTER 5

PROJECT PLANNING AND METHODOLOGY

5.1 CONCLUSION

Implementing machine tool monitoring systems is an effective way to prevent damage to machine tools, cutters and workpieces during production processes. If the cost of the monitoring system is too high, it may not be acceptable for industrial use. For electric current analysis, sensors are usually installed to measure the current. These sensors transmit data to the monitoring system, which can be part of the CNC machine control system or a stand-alone monitoring device, we can design the monitoring system cost-effectively. Regular monitoring and analysis of flow causes detection problems, which reduces the performance and life of spindle motors. This monitoring system provides an early warning of detected problems, allowing the operator to take all protective measures to ensure the safety of the spindle motor.

Faults in machining processes can lead, not only to high repair expenses, but also to extraordinary financial losses due to unexpected downtime.Therefore, it is important to develop a reliable and inexpensive Intelligent monitoring system. To provide reliable condition monitoring systems, research studies have used a wide range of the sensitivity measuring methods and sensors with different experimental work to create a successful monitoring system to detect tool wear and faults [1]. Unfortunately, the performance of monitoring systems is still far behind the expectations due to its high cost/performance ratio.

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