

Quality Control in Smart Motor Manufacturing Factory Using SDN Framework

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Abstract

Dynamometer is a device that is used for measuring important characteristics of a motor before it is released to the market. Recently, manufacturer applied the idea of dynamometer into medical business and created a new product, which was called hand-held dynamometers. This device can be used to evaluate the strength of human parts: arm, back, leg, etc... In this paper, we will focus on the most common dynamometer type, which is applied in motor manufacturing. By measuring and drawing the main features of the motor, we can provide users with information about the working region to deliver the best performance and longest life-time. In large manufacturing companies with thousands of motors and dynamometers, we leverage the SDN design with edge controllers to provide a flexible decentralized management system to deal with the low latency and reliability requirements and huge data transmissions from thousands of motors and sensors.

1. Introduction

Recently, *smart factory* aims to automate the factory on multiple levels to increase the flexibility of the production process and reduce the downtime to achieve maximum utilization of all the resources in large heterogeneous systems with IoT devices, sensors, production lines and other machines. It comprises many components ranging from tiny devices (i.e. sensor) to autonomous machines like programmable logic control (PLC) driven robotic arms and even automated guided vehicles (AGV) [1]. Quality control in manufacturing becomes more and more strict in recent years, motor manufacturers aim to reduce the malfunction and low-quality product, by using the dynamometer. A dynamometer is an instrument, which is used to measure the speed, torque, or power of an engine. It calculates the power by measuring the rotational speed and torque from an engine at the same time and then multiple these two values with a constant. The rotational speed is found by measuring the number of moving times of the shaft.

There are various kinds of dynamometers used for different purposes. The dynamometers are mainly classified such as absorption type, motoring type, and transmission type. The transmission is one in which power is measured, without being absorbed or used up, during transmission [2]. While the absorption type produces torque. In doing so, they aim to measure by creating a constant restraint to the turning of a shaft by mechanical friction, fluid friction, or electromagnetic induction. Acting as a load, the dynamometer is driven by the motor (the prime mover in general) and it is necessary to have the ability to handle any speed or load at any levels of torque in the motor for testing. Thus, we need to equip the dynamometer with some special sensors to measure the torque and speed.

In this paper, we design a power absorption dynamometer and regenerate the power from the motor to run a generator. Depending on the required objective, we need to design a suitable type of control systems. For instance, dynamometers,

which are equipped with a “braking” torque regulator, are able to provide a set of braking force loads and the under testing device can be configured to work at any frequencies (electric motor) or any fuel flows (internal combustion engine). But in this paper, we build a dynamometer with a speed controller (i.e. Delta inverter) and a power absorption unit offers a range of torque that is necessary to adjust the motor to run at the desired speed. Because the power absorption unit (PAU) in our system is a generator, we will use an adjustable resistor for our load. Hence, we can easily change the load, which the motor has to drive and as a consequence, the motor speed can be modified. The value of the resistor should be big enough for the motor work in any conditions. By continuously increasing the value of the load, we can draw the graph to show the relationship between the torque and speed of a motor and also find the ideal working range to maximize the proficiency and life-time. Power of motor could be calculated by multiplying the torque and the speed and the constant, which can be varied depending on the units of two above parameters.

Software-Defined Networking (SDN) is a new networking paradigm that decouples network control from the data forwarding hardware. Using SDN technology, the smart factory can better manage networks, which enables dynamic, programmatically efficient network configuration. The network intelligence is logically located in software-based controllers (control plane) and the network devices become mere packet forwarding entities (data plane) [1]. Also, integrating SDN design with edge computing technology can provide a flexible decentralized management system to deal with the low latency and reliability requirements and huge data transmissions from thousands of motors and sensors.

Therefore, we can summarize our contributions in this paper as follows:

- We build a device to detect defective or low quality motors by measuring the characteristic and provide the operation range for customer.
- We provide a design for smart motor manufacturing by integrating SDN and edge computing technology.
- User interface of the system provide for engineers to remotely monitor and interfere to the status of devices if there are any emergencies. For example, the current is too high, the motor speed overshoot the limitation etc...

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2. System Model.

The proposed model is shown in Fig. 1. The main programming code is written in ladder, which is the best visual programming language and easier to learn [3], combining with function block to process the raw data coming from sensors. The communication between devices are set up in different industrial protocol: PLC S7-1200 connect with Motor Driver (Delta Inverter) by using a MODBUS module - RS485 2 wires type [4]. Because the program cycle of the main Operation Block in PLC is very large compare to the speed of the motor, so we could not measure it within a basic program. However, the high-speed counters (HSC) of the S7-1200 help us to process those fast events, measuring the speed in case of only one pulse or a few pulses per rotation [5]. We also add one additional module to read the current from the dynamometer. This module will interrupt the consequence and turn off the motor if it detects any values over the capacity of the dynamometer.

As shown in Fig.1, characteristics of motor 1 and 2 will be measured by edge controllers. These measured data will be processed at edge controllers and analyzed to find the ideal working range of the motors for each production line. Also, edge controllers can update available tracks and choose the best one for our AGVs according to thousands sensor signals in the smart factory. Then the processed data will be transferred over data plane and stored in central databases system in the main server at the control plane. We leverage the design in [1], which shows one of the benefits from the SDN design is the ability to re-configure the network in real-time and avoid the complexity of static configuration for network devices. Moreover, it allows to detect and to react to conditions quickly such as avoiding outages of machines by re-configuring and re-planning a production line. In doing so, the vital data from several sources needs to be gathered and processed in real-time in order to compute an up-to-date environmental model of the factory. This scenario supports the important requirements ranging from network aspects such as bandwidth and latency, computational resources in order to process a huge amount of data generated within a factory as well as safety and security aspects [1]. Based on the production line characterization, the appropriate amount of computing resources (e.g., CPU, RAM, and storage) and the network resources must be allocated for edge controllers and network elements by control plane. Also, multiple edge controllers increase the availability of services and decreases the risk of single-point of failure. Another edge controller can take over tasks or assist an edge controller in resolving a task cooperatively, if there is any overload or problem on a certain one.

2. Measuring and drawing characteristics of motors to discover the working range

3.1. The basement theory:

The induction motor has two main parts: the *stator* and the *rotor*. The *stator* is the stationary part and the rotor is the rotating part. The former is a three coil winding, given AC currents to it and this will create a rotating magnetic field, which forces the rotor to run [6]. The speed of the *rotor* also refers to the speed of the motor, and it depends on the motor load. Increasing the load on the motor causes the motor speed decreases, thus increasing the slip and torque. We will take advantage of the above characteristics to find

the ideal working range.

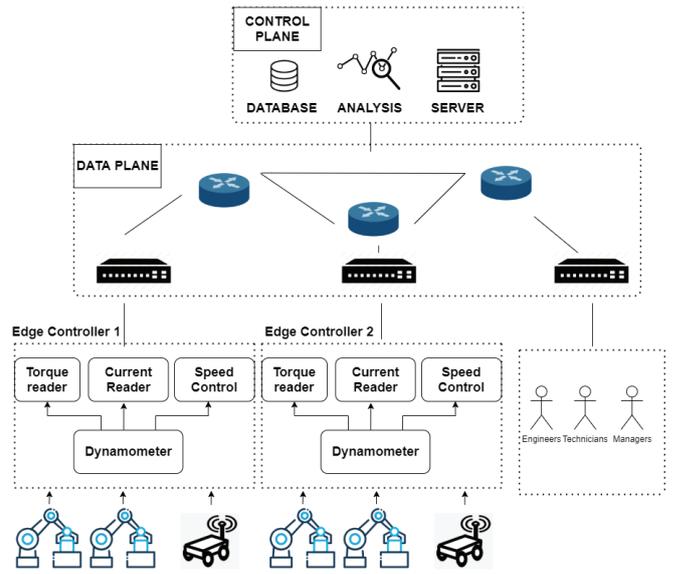


Fig. 1: System model of motor manufacturing factory using SDN design.

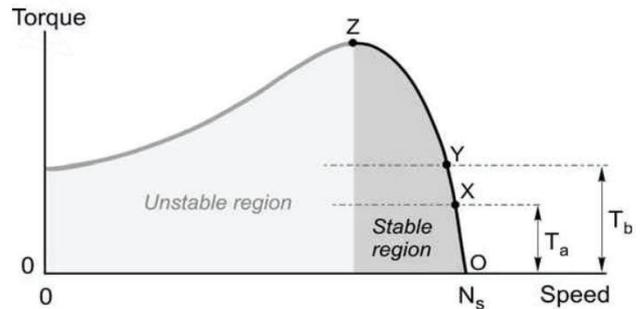


Fig. 2: Induction motor torque-speed characteristic [7]

3.2. Power calculation:

As you can see in Fig. 2, the motor starts to run with a specific torque and this number has an important role for engineers to select motors. Motor with high torque being used to pull heavy loads, while the low torque one is used as a fan. Motor torque fluctuates a while before it reaches the stable region, therefore we should not calculate the power at the first stage and wait for the stability of the motor. We equipped dynamometer with sensors to detect the motor speed and the torque while running

Definition:

$$Force = Torque \div Radius \tag{1}$$

$$Distance = Radius \times 2 \times \pi \times RPM \tag{2}$$

$$Power = Force \times Distance \tag{3}$$

$$HP = \frac{2\pi NT}{4500}$$

Where $N = rpm$ and $T = torque \text{ kgm}$ [2]

We replace the Force and Distance in equations (1) and (2) into the (3) equation. We can get the formulation to calculate power as follows: $Power = f(N, T)$.

3.3. Experiments:

The power absorption unit here is the generator, it takes the power in form of mechanical energy from the motor, regenerates it into electric energy, and passes it through a variable resistor. The resistor works as a load and converts electric energy to heat.

As shown in Fig.3, since we decrease the load of the motor, the

speed goes up and the torque decreases, and multiply these two parameters we get the actual power. After we get the right feedback signal from our sensors, we will draw a graph to show the relationship between speed and torque just like Fig. 2. Firstly, we need to run the motor with the minimum load and then increase it until the shaft of the motor is locked. The result of our model will be shown in Fig. 4.

3. Performance Evaluations

The system performance indicates the relationship between torque and speed in Fig. 4. They have a similar shape to Fig.2, however, the model graph is not as smooth as the ideal one, due to following reasons:

- We increase the value of the resistor manually, so the input load increase not uniformly
- The noise of the proximity sensors, which are caused by the vibration of the device

As shown in Fig.4, the best operating region for the under-testing motor is from 1100 rpm to 1300 rpm, before it reached the break-down region. Note that, the torque shown in the graph is not the maximum value of the under-testing motor can produce (it depends on the distance from the shaft axis to the sensor position). In our model, the value of the starting motor is low, which indicates the motor can easily drive the generator.

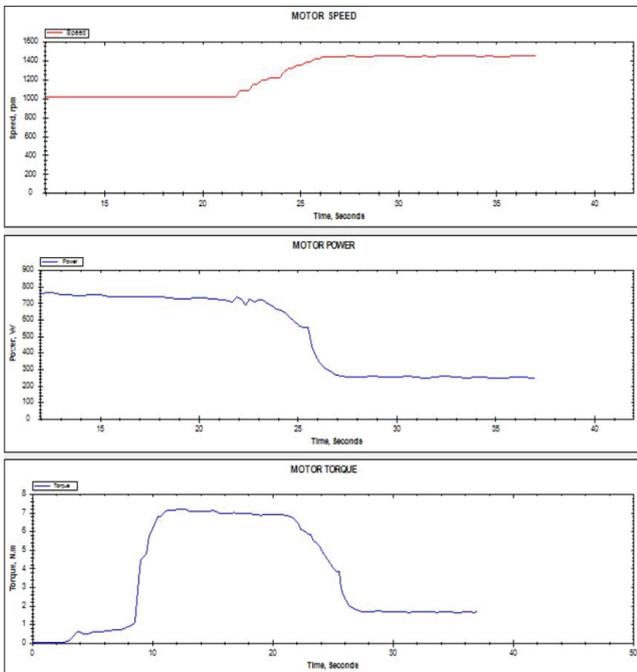


Fig. 3: Speed, Power and Torque vs time

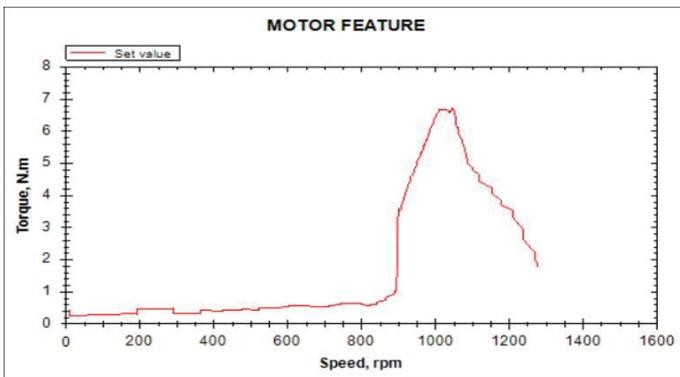


Fig. 4: Induction motor torque-speed characteristic (Model)

4. Conclusion

In this paper, we implemented an approach to find out the ideal working region for new motors based on the graph of torque and speed. The results are imperfect because of noises and limitation of the structural mechanics, which cause the vibration of the systems at some frequencies. In future smart factories, SDN technology and edge controllers can help to provide flexible and scalable management systems to improve network performance, monitoring and control process.

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