Performance Investigation of PLC Hardware for Portable Two-Wheeler Dynamometer Test rig

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Abstract. The dynamometer is an instrument used for torque, force and velocity measurements. In a two-wheeler dynamometer frame, that is the easiest thing to use. So, until now, the testing has been held in the same place, but doing something new is making the whole system portable and being able to carry it anywhere. Therefore, PLC should be used to measure the parameters for input purposes, as many types of PLC are available. The machine is then connected to SCADA for an additional point. In order to monitor the working of the two-wheeler chassis dynamometer, the sensor is also used in the device and can change the parameters. The entire dynamometer will be controlled using PLC and HMI (human-machine interface). Like the Sensor Actuators, it can integrate the device with the hardware. I decided to go with Mitsubishi PLC for this research because it has all the specifications I need and the cost that makes this a cost-effective system is lower. The effects of all the parameters are displayed on the HMI panel. For the sensors of the test rig, the simulation was developed and 3 percent of errors were identified compared to the results of the simulation with the data sheet.

Keywords: Dynamometer, Portable Chassis Dynamometer, PLC, SCADA.

1. Introduction

The quantity of two-wheeler is much greater in our country as we live in a developing country. In India, the number of two-wheeler is around 70 per cent of India's total vehicle. Of this 70 percent, about 55 percent of two vehicles come under the 100cc to 350cc range. These two-wheelers are mainly used daily for the purposes of daily commuting. The condition of Indian roads is not as decent as we all realize, so these two-wheelers have a lot of wear and tear. And there is a fair decrease in output to these vehicles over a period of time.

In the chassis dynamometer system, the dynamometer functions as an energy-absorption unit. This chassis dynamometer was designed to measure the condition of the vehicle in order to carry out various basic tests, such as performance tests between the standard air filter and the K&N air filter, acceleration tests between two speed points, maximum speed tests, tests of different gear speeds, load tests, and tests of fuel consumption [2]. Measurement unit for dynamometer, mechanical force or electricity, transmitted by rotary shaft. As power is the combination of torque (turning force) and angular velocity, torque measurement devices are basically all dynamometer power measurement
devices. The shaft's velocity is measured singly. A flexible metal ring that bends when a force is applied in such a way that the amount of bending tends to collapse as a measure of the force applied is used in the instruments for force measurement, and a hydraulic 'load cell' that calculates compressive loads in terms of fluid pressure. PLC is a system that monitors input devices constantly to make decisions based on personalized PLC programming to manage the state of a machinery's output devices. Mitsubishi FX series PLC programming port contact protocol. Presentation of a portion of the LabVIEW-based communication software. The serial communication is introduced between the PLC and the Industrial PC [3]. In order to increase productivity in everyday life, temperature measurement and control are very important in the industrial and agricultural sectors. Traditional temperature control techniques, which not only waste a lot of workforce and financial resources, but also cause faults and accidents due to incorrect temperature measurements, are needed for manual practice. Therefore, real-time wireless temperature monitoring is useful for timely inspection and security of control products, as well as saving the labor force [1].

2. Field Survey

| Parameter                     | Value  | Two-Wheeler                             |
|-------------------------------|--------|-----------------------------------------|
| Max Torque                    | 28.00 Nm | Royal Enfield model classic 350          |
| Max Power                     | 29.91 Kw | KTM model 250                           |
| Maximum Wheelbase ratio       | 1412 mm | Hero X-Pulse                            |
| Maximum weight                | 195 kg  | Royal Enfield thunderbird 350           |
| Maximum speed                 | 9000 rpm | KTM model 250                           |

3. Methodology
**Pre requirement of Mitsubishi PLC**

- Mitsubishi Provides its Programming Language with its PLC Hardware
- Use of any Other Programming Language can be Work with Mitsubishi PLC
- It has Low Cost Compared to Other PLC

**Using of Mitsubishi PLC (fx5u-32mr)**

Compatible with the I O programmable logic controller (PLC), the platform (Mitsubishi FX5U series) has 32 digital inputs (type 24VDC sink / source) and 32 relay / transistor outputs. Link MELSEC (3C/4C Frames) and the communication protocol to MELSOFT. It has program capacity of 64k steps, and 32 built-in inputs. By offering a wide variety of new and existing add-on options, the FX5U continues the FX tradition of complete flexibility. Integrated standard Ethernet functions, I / O analogue, data logging, position control, security, communication, and networking are further enhanced. This will allow users to recognize more powerful systems, but overall fewer components, saving time and money [4].

![Mitsubishi fx5u-32mr PLC](image)

**Figure 1. Mitsubishi fx5u-32mr PLC [4]**

**Parker Drive 514C**

The 514C industrial environment controller is designed and should be mounted in a closed box that provides controller and user protection. At the terminals cited, the controller should be permanently grounded. The 514C controller is built to track permanent magnet or DC Shunt cutter speeds. All 4 operating quadrants will have control of the motor speed. The controllers are equipped to work within the range of 110 Vac to 415 Vac at 50 or 60 Hz from a single-phase AC power supply. For internal power generation and principal supply contactor sequencing, auxiliary supply is required. A linear, closed loop system with feedback from either a tach generator or armature voltage, with a selectable feedback source to turn, regulates the DC engine rpm. A current loop within the speed loop also guarantees the addition of regulated current levels to the engine, with programmable switches being able to scale the actual levels for motor protection, a stall detection circuit is given and the current will be streamed within the engine range of 55 to 60 seconds. At the event of a short circuit, the safety of the controller is provided by an instant overcurrent trip circuit that overrides the power. [5].
Types of sensor used in dynamometer

Load cell
A load cell is a device that transforms a force or charge into a measurable output. Load cells can come in various types, including hydraulic, pneumatic, strain gauge, piezoelectric, and capacitance, but the subject of this handbook will be strain gauge load cells. The most popular strain gauge load cells are classified as a device which transforms a force or load into an electrical equivalent signal or a digitized load value. General load cells are ideal for periodic static force measurement applications consisting of measuring devices, structural testing devices, and material testing. [6]

| Specification of Load cell |
|---------------------------|
| Supply Voltage            | 110-500V +10% user selectable |
| Auxiliary supply          | 110/120 or 220/240V +10% user selectable. |
|                           | Single phase 50-60Hz +10% |
| Ambient                   | 0-40°C - Altitude: up to 1000m without derating |
| Overload                  | 150% for 60 seconds |

Pre requirements of RTD PT 100 Sensor

- As per the standard bearing No. 6209 SKF selection the temperature required maximum 120° C
where the RTD PT 100 measure temperature range between 0- 200° C
- It gives an accurate reading compare to others sensors.
- The Important key point of the sensor is it contains a probe type sensor so it doesn’t require special mounting.

**RTD PT-100 Temperature sensor**

A conductor is a substance in which the electrons are less bound to the outer orbit of the atom. If the energy of the material is increased, the atoms will move (vibrate) more and more by heating up, for example, and at some point, these electrons can leave their orbit and float freely inside the space between the atoms. The higher the temperature, the quicker the atoms move, and the harder it is for the electrons to move through the space between the atoms, so there is less space between them. [8].

| Temperature range | ±0.3 °C |
|-------------------|---------|
| Accuracy          |         |

Table 3. Specification of RTD-PT100

**Pre requirement of Strain Gauge**

As per the Field Survey it has been concluded that the maximum torque is 28Nm.

**Strain Gauge**

A strain gauge is made of very fine wire, or foil, placed and fixed to a flexible backrest in a grid pattern. If there is a change in the shape of the strain gauge, its electrical resistance can change. The wire or foil in the strain gauge is designed in such a way that a linear change in the resistance occurs when force is applied in one direction. The tension force is extended by a strain gauge, allowing it to become thinner and wider, leading to resistance increases. The same is true for compression power. The pressure gauge compresses, becomes thicker and shorter, and resistance decreases. The strain gauge is mounted on a flexible backrest that allows a load cell to be easily added, representing the minute change to be measured.[7]

| Measurable Strain | 2 to 4% maximum |
|-------------------|-----------------|
| Temperature Range | −30°C to +80°C   |

Table 4. Specification of Strain Gauge
Fig 5. Strain Gauge

**Pre requirement of Magnetic Pulse Pickup**

The rotor of the dynamometer has a gear of 24dp which makes easy to use pulse pickup of measuring the RPM. It can also withstand higher temperature up to 113°C.

**Pulse Pickup**

A pulse pick sensor mounted on the case defines the velocity, which detects a 60-tooth wheel located on the coupling core. All electrical signals are routed to a terminal box mounted on the bedside table which provides the dynamometer control system with the interface.

| Table 5. Specification of Pulse Pickup |
|---------------------------------------|
| Gear Pitch      | 24dp                    |
| DC Resistance  | 1200 ohms               |
| Operating Temperature | 73°C to 113°C          |

Fig 6. Pulse Pickup

4. Result & Validation

**Simulation with the sensor**

For the Simulation with the sensors I have used the Arduino Board for input purpose because PLC is not available in the proteus software.

RTD PT-100 or Temperature resistance detectors, are instruments used for temperature measurement. These sensors are among the most accurate sensors available which cover wide temperature ranges.
Fig 7. Simulation of RTD-PT100 Sensor

- Grove-UART- Grove UART is a model of Grove Software Module which is customizable. Pin 1 is the RX line (used by the base unit to receive data, so it's an input) where the TX line is Pin 2 (used by the base unit to send the Grove module data).
- Connector- An electrical connector is a system used to connect electrical conductors and build an electrical circuit.
- Arduino Uno- Inputs-light on a sensor, finger on a button-and transform to output-can be read by Arduino boards-activate a motor, switch on an LED, and publish something online.
- Capacitor- Capacitor is a simple storage system for holding and releasing electrical charges, as the circuit requires.
- DRDY Pin- This pin is used for advanced uses where you are asking the sensor to start reading and then wait until this pin is high.
- SDO- For the input sent from Max31865 to the processor, this is Serial Data Out.
- SDI- This is a serial data input for the data sent to Max31865 from the processor.

Fig 8. Graph of Temperature with resistance

Load Cell- Load cell, are the instruments used for measurement of weight carried out by the system.
HX711 is a 24bit ADC which amplifies and digitally converts the output of the load cell. The Arduino is then fed with this amplified value. The load cell senses the weight and gives an analogue electrical voltage to the HX711 Load Amplifier Module.

2N4403- It is a type of general-purpose PNP Bipolar junction transistor used in low-power switching and amplifier applications where holes and electrons are transferred.

Capacitor-It is an electronic passive component, with two terminals. A condenser is an instrument that stores electrical energy in an electrical field.

Resistor-A resistor is a passive two-terminal electrical component which as an element of a circuit implements electrical resistance. In electronic circuits, resistors are used to reduce current flow, modify signal levels, separate voltages, bias active elements and terminate transmission lines, among other applications.

Arduino Uno- Inputs-light on a sensor, finger on a button-and transform to output-can be read by Arduino boards-activate a motor, switch on an LED, and publish something online.

Strain Gauge- The strain gauge is mounted on a flexible backrest that makes it simple to apply to a load cell, representing the minute changes that need to be measured.
Fig 11. Simulation with Strain Gauge

- O-PAMP: The Operational Amplifier is a DC-coupled high-gain electronic voltage amplifier with a distinct input and typically a single-end output.
- POT-HG: It is an instrument called as potentiometer used for measuring the voltage. Potentiometers are typically used on audio equipment to control electrical devices such as volume controls. Potentiometers operated by a mechanism can be used as transducer of position.
- Relay: It is used when a circuit can be operated by a low-power signal. The signal coming from one source to another also works to move.
- Resistor: A resistor is a passive two-terminal electrical component which as an element of a circuit implements electrical resistance. In electronic circuits, resistors are used to reduce current flow, modify signal levels, separate voltages, bias active elements and terminate transmission lines, among other applications.

5. Conclusion

The two-wheeler chassis dynamometer is a test rig which is used to test the two-wheeler's performances. In previously used dynamometer was equipped with the Microcontroller for collecting performance data. But due to high costs of microcontroller it's not affordable to use in Portable Two-Wheeler chassis dynamometer. Hence in the present study the PLC & SCADA system is implemented for a better output and more precious outcome. PLC allows us to expand the setup by having a greater number of I/O Ports. The system will work under any conditions, such as extreme heat, extreme mechanical vibrations, electrical noise when in cooperated with a two-wheeler dynamometer test setup. The sensors will allow us to read all the parameters of the vehicle and enable us to solve this problem. The processing speed increasing by 20%.

The simulation was built for the sensors of the test rig and 3% of errors were found compared to the outcome of the simulation with the data sheet.

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