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IoT-based Control and Monitoring for DC Motor Fed by Photovoltaic System

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Abstract. Internet of Thing (IoT) makes the monitoring and controlling process become accessible everywhere and every time. In this paper, the IoT is used to control the speed of a DC Motor remotely through smartphone apps. The proposed system uses the 50Wp solar panel and DC-DC Converter to provide 24V dc to the motor. In specific, a PID algorithm is applied to control motor speed from the measured back EMF. There are 3 experiments that have been done. The first is controlling motor speed through a smart phone, the second is the relationship between EMF and DC Motor speed, the third experiment was monitoring motor speed on Thingspeak and Blynk apps.

1. Introduction

Monitoring the real-time situation using IoT has begun to develop. In [1], they develop monitoring of electrical energy in real-time. They use Raspberry Pi to access data via a smartphone. The data monitored is the measurement of voltage, current, and neutral current. The data is used to monitor the electricity used. While the authors [2], have developed IoT-based monitoring systems for the efficiency of solar power plants. They use Raspberry pi and Message Queuing Telemetry Transfer Protocol (MQTT) to be accessed via smartphones.

In addition to the development of IoT-based monitoring, improved DC Motor control performance is also growing. The author [3], has designed a control device with a PID algorithm. The project is applied to DC Motor speed. While in [4] designing motor speed control with fast response and high precision. The two papers already have good results, but motor control has not been specifically applied.

Development of the Solar Panel as a source of energy for DC Motors has been widely developed. As in reference [5], the Solar Panel is an energy source for DC Motor water pumps. Although the results of previous studies have been significant, for applications of solar-powered pumps, PID algorithm is needed to get good results. In this paper describes the development of IoT-based dc-pump motor control, where DC Motors are supplied from the Solar panel. This project contributes to the implementation of PID algorithms and IoT-based controls for DC



Motor speed. This system will be implemented for dc pump regulation systems in remote areas of Indonesia.

The rest of this paper is organized as follow. Material and Method is described in Section 2. Section 3 describes Result and Analysis. Section 4 is conclusion.

2. Material and Method

Figure 1 presents the design of DC Motor Control based on IoT. The system consists of 4 parts. The first part is the DC Converter, this section is to provide 25V to the motor. The next section is about DC Motor control. This project uses the PID algorithm to control DC Motor speed. This DC Motor control is designed based on IoT, so the smartphone becomes the control device. IoT-Nodes need routers to connect to the internet so that nodes can connect with users. The last part is data communication per node. But this paper only discusses one node, which tests the DC Motor control based on IoT. This project uses Thingspeak to monitor the results of DC motor control and Blynk applications to control DC motors.

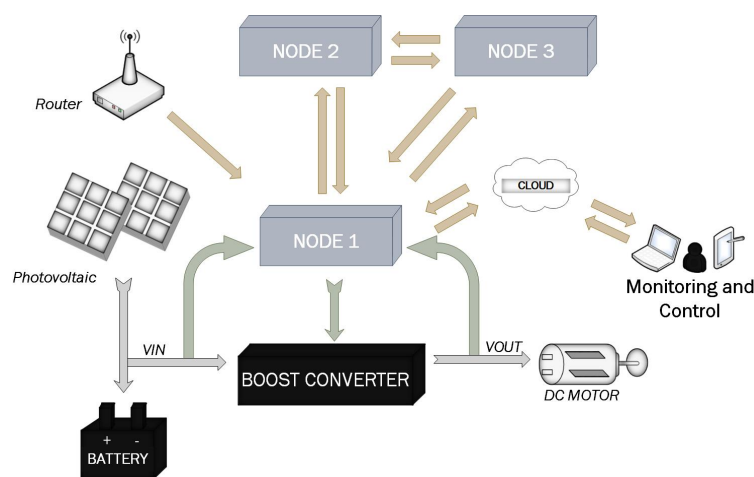


Figure 1. System block diagram

2.1. Solar Panel

This project uses solar modules to supply DC Motor loads. The solar module used for the development of this project is the Solartech SRM-50D Sunrise Solar Module. Here are the parameters of the solar module:

Table 1. Parameter of Sunrise Solartech SRM-50D

Parameter	Value
Standart Power	50 W
Short Circuit Current (Isc)	3.14 A
Open Circuit Voltage (Voc)	21.4 V
Max. Power Current (Imp)	2.88 A
Max. Power Voltage (Vmp)	17.4 V
Max. System Voltage	1000 DC
Number of cell	36

From these parameters, it can be graphed Power to Voltage on Solar Modules. The following is a graph of the PV characteristic:

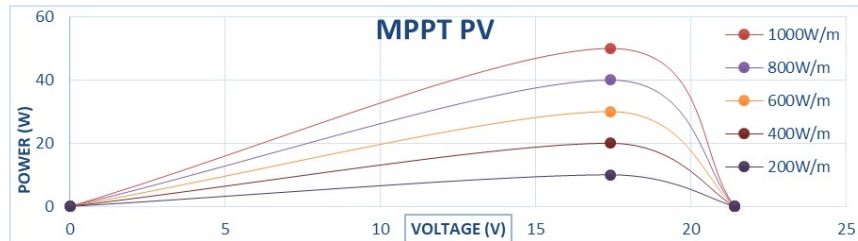


Figure 2. Graph of PV characteristic

From the above graph in Figure 2, it is explained that the lower the Radiation obtained by the Solar Module affects the decrease in power released by the Solar Module. At the same time, the voltage remains at maximum Voltage, so it can be concluded that Radiation will affect the current coming out of a Solar.

In addition to knowing about the parameters of the solar panel, the potential of the location regarding solar conditions is also very influential for the success of this project. This paper refers to the Suncalc.org site to find out the condition of the sun in Hamlet III, Poncokusumo, Malang, East Java, Indonesia. The following are the conditions of the sun at that location:

Table 2. The condition of Solar at the location.

Situation	Hour
Dawn	4:59
Sunrise	5:20
Culmination	11:22
Sunset	17:25
Dusk	17:46

2.2. IoT Based Control System

There are several hardware used in our IoT based control system, namely IoT-Nodes, routers, and DC Motor. Figure 3 shows the proposed system.

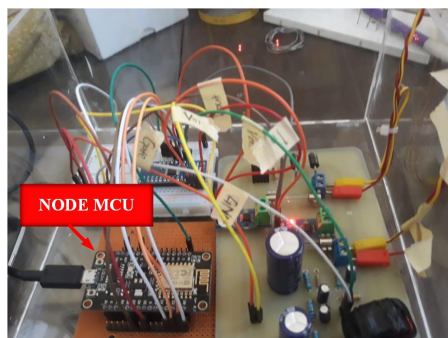


Figure 3. The proposed system

2.2.1. IoT-Nodes The IoT-Node used is the Node-MCU. The Node-MCU is supplied by the solar panel whose output voltage has been set to 5 volt DC. The Node-MCU functions to control and transmit data to the internet. Therefore, this project uses Node-MCU because it already has a wifi module in it.

2.2.2. Router The router functions to connect IoT-Node with the internet. IoT-Node can send and receive data via the internet. Users can control from the phone because the data entered by the user is connected to the IoT-Node via the internet, while the monitoring results are obtained from sensor data.

2.2.3. DC Motor DC Motors in this project can be used for water pumps. The water pump used is a 24 volt DC pump, 10 m³/h with a speed of 4300 rpm [13]. The motor speed at the pump must continue to a stable condition even though the voltage on the solar cell decreases. Therefore, the Node-Mcu will control the speed entering the motor.



Figure 4. DC Motor

2.3. DC-DC Converter

The DC-DC converter used is Boost Converter with the circuit as shown in Figure 5. This converter is used to adjust the voltage to match the value desired by the User. In addition to increasing the voltage, the converter also has a function to stabilize the voltage generated by solar cells. The component we use is an inductor that has a size of 1mh; Capacitors with a capacity of 2200uf / 50V; Diodes 1n5402 with a maximum current of 3A and a maximum voltage of 200volt, and Mosfet with type 1RFZ44n for switching in the circuit. This component we can through the equations that we take from references [6].

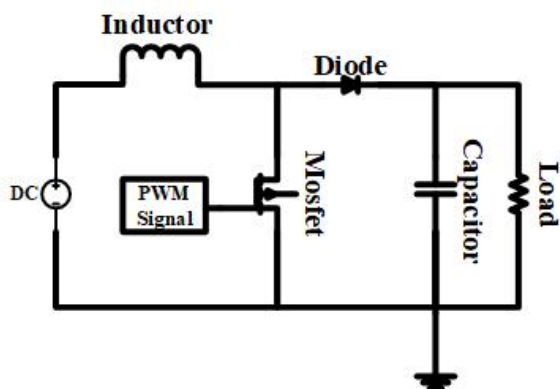


Figure 5. Boost converter circuit

To get the duty cycle value is :

$$D = 1 - \sqrt{\frac{rmp}{Ro}} \quad (1)$$

$$R_{mp} = \frac{V_{mp}}{I_{mp}} \quad (2)$$

$$R_o = \frac{V_o}{I_o} \quad (3)$$

To get the inductor value is :

$$L_{min} = \frac{R_o}{dilfs} \frac{4}{27} \quad (4)$$

$$dil = \frac{V_{mp}D}{Lf} \quad (5)$$

To get the capacitor value is :

$$C_{min} = \frac{D_{min}(1 - D_{(min)})^2}{R_{mp(min)}dV_o f s} \quad (6)$$

$$C_{min} = \frac{D_{max}(1 - D_{(max)})^2}{R_{mp(min)}dV_o f s} \quad (7)$$

$$dV_o = \frac{dQ}{C} \quad (8)$$

2.4. PID

Proportional Integral and Derivative widely used for the control system in the industry according to section 2.3 of the DC-DC Converter, the converter can increase the voltage according to the reference voltage if the PWM signal issued by the Controller matches the desired response. The PID will adjust the PWM signal to get an optimal response. Figure 7 is the code in Arduino about the PID algorithm (use the library on Arudino). Here is a block diagram of a PID [7-8]:

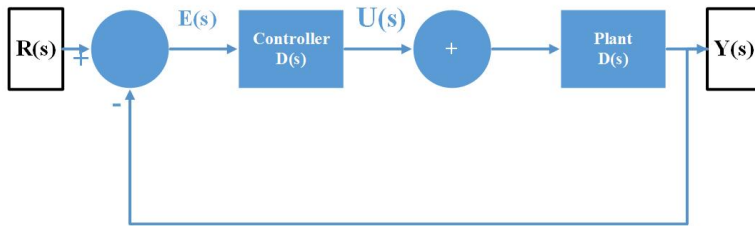


Figure 6. Block diagram of PID

A controller is set using the following formula:

$$D_{(s)} = K_p + \frac{K_i}{s} + K_D. \quad (9)$$

2.5. Data Acquisition

In this project, we do not use motor speed sensors (sensorless) through the Back-EMF method. The Back EMF captured by the voltage sensor and convert to a digital value by ADC which is onboard our IoT-Nodes. If the DC Motor is supplied by a voltage source then the DC Motor will move. When the motor moves, the voltage appears that is opposite to the flow of the permanent magnet coil. This is called the EMF method. EMF is directly related to motor speed, so knowing the emf value can calculate the speed of the motor speed. Figure 8 is the equivalent of DC Motor.

```

#include <PID_v1.h>
#define Sensor A0
#define PWM 3
Double Setpoint, Input, Output; //Define Variables we'll be connecting to
Double Kp=0.07425, Ki=0.012, Kd=0.12; //Initial tuning parameters
PID mypid(&Input, &Output, &Setpoint, Kp, Ki, Kd, DIRECT);
Int Vreff = 25; //define Reff
Void setup()
{
  Serial.begin(9600);
  Pinmode(Sensor, INPUT);
  Mypid.setmode(AUTOMATIC);
}
Void loop()
{
  Setpoint = Vreff;
  Input = Sensor;
  Mypid.Compute();
  Analogwrite(Input, Output);
  Serial.println(String(Output));
  Delay(1000);
}

```

Figure 7. PID algorithm code

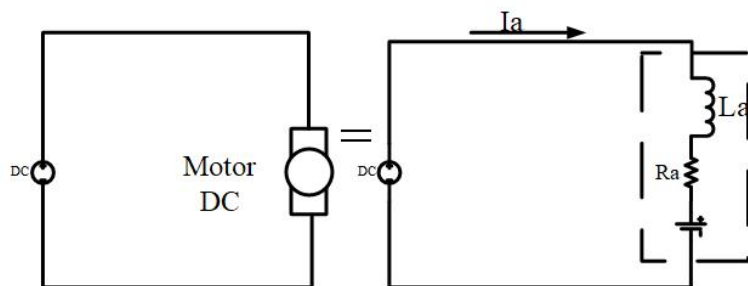


Figure 8. The equivalent circuit of DC Motor

We can represent the motor as a series connection of resistance, inductance, and the back EMF voltage source. It is this voltage source that we want to measure. Here's the equation from EMF [10]:

$$EMF = \frac{n}{k} \quad (10)$$

Speed on the motor can be represented by:

$$n = \frac{V_s - i_a R_a}{k} \quad (11)$$

Which, n is the motor speed. V_s is the input voltage of the motor, I_a is the current from the motor. While R_a is the motor resistance and k is the coefficient.

2.6. Blynk Apps

This project can control DC Motors using smartphones. Blynk is an application that we use to control DC Motors, Blynk can be downloaded for free by users. Its use is very easy, the user only needs to download the blynk application and scan the barcode from the project developer. As an important note, users need to have a connection to connect to a DC Motor. Figure 9 is the Blynk app. In the figure, there is a motor speed controller. Users only need to move the

motor speed cursor (RPM Control) from left to right. In addition to control, the developer also provides facilities to monitor the value of Voltage on the motor and motor speed.

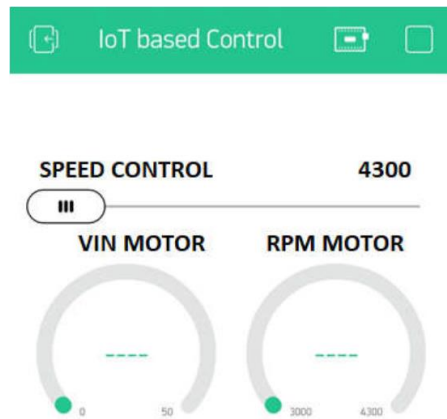


Figure 9. Blynk Apps

2.7. Cloud Systems

The cloud becomes an intermediary for communicating between users and nodes. With cloud systems, users can monitor and control DC Motors remotely. Control is done by inputting the reference speed on the smartphone. The reference speed will be sent to the node through the cloud so that the node will control the motor speed to match the reference speed.

3. Result and discussion

The proposed system experiment was successfully carried out. Table 3 shows the test results from the Boost Converter, where the output of the boost converter is a DC motor. The first experiment (time = 13.42), it shows testing without using a load at all. The next experiment DC motor brakes level 1 and the user enters the motor speed with a value of 4300 rpm (maximum speed). The speed is the same as the reference voltage (24 Volts). During the next test (time = 13.52), using DC Motor braking with level 2, the result of the output voltage and motor speed is still stable. When the output voltage is more than 24 volts, the converter cannot reduce the reference voltage because the Boost Converter only has the function of increasing the voltage value. The results from output voltage have an effect on Motor Speed. This data is a parameter of the PID algorithm. Besides data from the output voltage sensor, another important parameter is the input data from the user. Input data from the user is the value of the desired motor speed. From the motor speed data is converted into voltage data using the EMF method, so that the data becomes a set point to produce PWM signals.

Table 3. Test Results Boost Converter

Time	Vin(Volt)	Vout(Volt)	RPM
13.42	21.09	33.24	0
13.50	21.48	24.39	4300
13.52	21.38	24.49	4300
13.54	21.4	24.33	4300
13.57	21.25	25	4300

The next experiment is to test the relationship between EMF with DC Motor Speed. Figure 10 is the motor speed chart of 10 experiments. From 10 experiments, the average motor speed was 4262 RPM, with a maximum speed of 4297 rpm and a minimum speed of 4207rpm. Figure 11 is a graph of the relationship of EMF with DC Motor speed. The relationship between EMF and DC Motor speed is directly proportional.

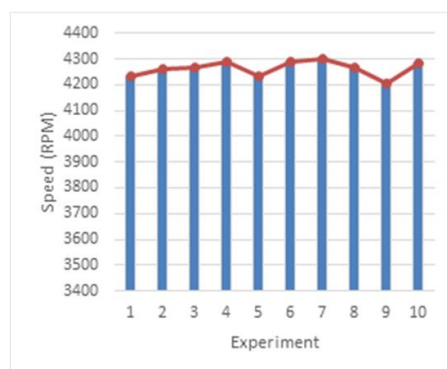


Figure 10. Graph of 10 Experiment

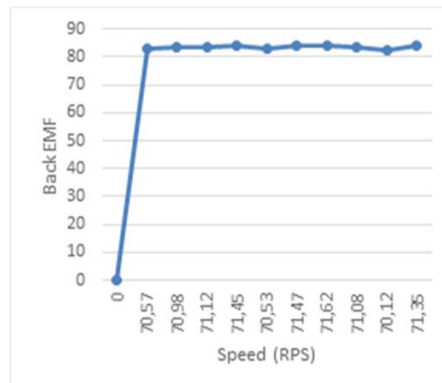


Figure 11. Graph of the relationship between EMF and motor speed

The last experiment is monitoring DC Motor speed on Thingspeak and Blynk app. Figure 12 shows the results of monitoring output voltage in the boost converter. The monitoring results are sent to the Thingspeak web every 15 seconds, while the data to be processed into PWM conducted continuously. The monitoring results from the Blynk application can be seen in Figure 13.

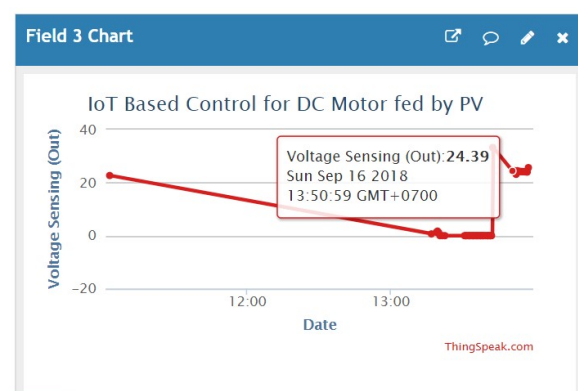


Figure 12. Monitoring using Thingspeak

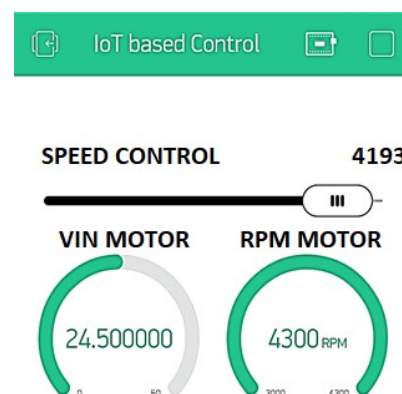


Figure 13. Monitoring using Blynk App

4. Conclusion

The IoT based DC Motor control system which is funded by PV 50Wp was built and tested. This paper describes the development of DC Motor control based on the IoT and the PID uses a Solar Module. The results of the testing tool have reached the motor speed according to the user's wishes. Motor speed is affected by the motor input voltage. When the motor input voltage

is lower than the reference voltage, then the voltage automatically increase until matches the reference voltage. In additional result, the relationship between EMF with Speed dc motor is directly proportional. The results of monitoring also work well.

In the future, this project will be evaluated, and continue to be developed so that the project reaches its maximum. In addition, we will develop the certain protocol for the flat topology of n number nodes which places on the remote area. This system will be used for controlling and monitoring a large number of dc pump fed by Photovoltaic system.

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