7st International Seminar of Research Month 2022
Volume 2023
http://dx.doi.org/10.11594/nstp.2023.3332

NST Proceedings
OPEN ACCESS

Conference Paper

Temperature Monitoring via the Internet of Things Using PID-iTCLab

Basuki Rahmat *, Minto Waluyo, Tuhu Agung Rachmanto

Universitas Pembangunan Nasional "Veteran" Jawa Timur, Surabaya 60294, Indonesia

*Corresponding author:
E-mail:
basukirahmat.if@upnjatim.ac.id

ABSTRACT

iTCLab or Internet-Based Temperature Control Lab is a temperature control kit for feedback control applications with an ESP32 Microcontroller, LED, two heaters, and two temperature sensors. The heater power output is adjusted to maintain the desired temperature setpoint. Thermal energy from the heater is transferred by conduction, convection, and radiation to the temperature sensor. Heat is also transferred from the device to the environment. In this paper, it is shown how to program temperature monitoring on the iTCLab Kit via the Internet of Things (IoT) using the Arduino programming language. The controller used is Proportional Integral and Derivative (PID). From the experimental results, the temperature monitoring system works well, and the results of temperature control via a cellphone using the IoT MQTT Panel are shown by the real situation.

Keywords: Temperature, monitoring, PID, IoT, iTCLab, Kit

Introduction

Temperature measurement is one of the most commonly used techniques as many operations and tasks need to be performed in any industry. Usually used heaters, including temperature sensors. In the case of temperature sensing, a temperature sensor is used which is installed in the place where the temperature is to be sensed. The temperature in that place can be monitored via the internet using the Internet of Things.

Temperature monitoring can be done through Proportional, Integral, and Derivative control systems. One of the most widely used types of control systems in the industry. Monitoring and controlling temperature through the PID control system, some of which can be read in the following research results. Application of a temperature control system using a modified Smith fuzzy PID in an oil filling device for a deep sea hydraulic system (Huang et al., 2018). Benchmarks from the use of microcontrollers for temperature monitoring and control to process dynamics and control (Park et al., 2020). Utilization of a new optimization algorithm based on the epsilon constraint-RBF neural network for PID controller tuning in a decoupled HVAC system (Attaran et al., 2016). Research on PID control system experiments using the APMonitor Temperature Lab for Undergraduate Students (Oliveira & Hedengren, 2019). Research on introducing digital controllers to undergraduate students using the Arduino TCLab Kit (de Moura Oliveira et al., 2020).

Currently monitoring and controlling PID is also carried out remotely using Internet of Things (IoT) technology. Some research on monitoring and or controlling PID using IoT can be read in the following research results. The use of the Neural Network model as an Internet of Things congestion control uses a PID controller and an immune-hill-climbing algorithm (Quwaider & Shatnawi, 2020). Research on how to control and simulate PID-based motors and Internet of Things systems (Zhang & Gao, 2021). How to integrate IoT with LQR-PID controller for online monitoring and control of flow and pressure in fluid transport systems (Priyanka et al., 2020). How to perform an IoT fusion-based model predictive PID control approach technique for oil

How to cite:
Rahmat, B., Waluyo, M., & Rachmanto, T. A. (2023). Temperature monitoring via the internet of things using PID-iTCLab. *7st International Seminar of Research Month 2022*. NST Proceedings. pages 197-203. doi: 10.11594/ nstp.2023.3332

pipeline infrastructure (Priyanka et al., 2021). Research on how to implement PID controller for the liquid level system using mGWO and IoT application integration (Bhookya et al., 2022).

In this research, remote monitoring of the temperature as a result of PID control will be carried out, using IoT. The control system is implemented in an internet-Based Temperature Control Lab (iTCLab) Kit. iTCLab is a product of one of the state universities in Indonesia, namely Universitas Pembangunan Nasional "Veteran" Jawa Timur. This kit is inspired by Brigham Young University's TCLab Kit (BYU, 2018).

Material and Methods

The basic Internet of Things (IoT)-based application system with the Message Queuing Telemetry Transport (MQTT) protocol consists of at least 4 main components, namely Hardware/physical (Things) in this case iTCLab devices, internet connections, Cloud data center as a place to connect, save or run applications as MQTT Broker, and IoT MQTT Panels to monitor and control remotely via mobile. Where the iTCLab system is controlled using PID control. The proposed system architecture is shown in Figure 1.

The MQTT broker, which is at the core of the MQTT Publish/Subscribe protocol, is a server that receives all messages from the MQTT client and then routes the messages to the appropriate subscription client. The MQTT broker used in this research is a free online public MQTT broker from HiveMQ. Meanwhile, IoT MQTT Panel is an application that allows the management and visualization of IoT projects, based on the MQTT protocol. With this application, an IoT-based iTCLab PID monitoring system project can be created. In this research, the IoT MQTT Panel is used to monitor the temperature state that has been controlled by the PID controller remotely using a cellphone.

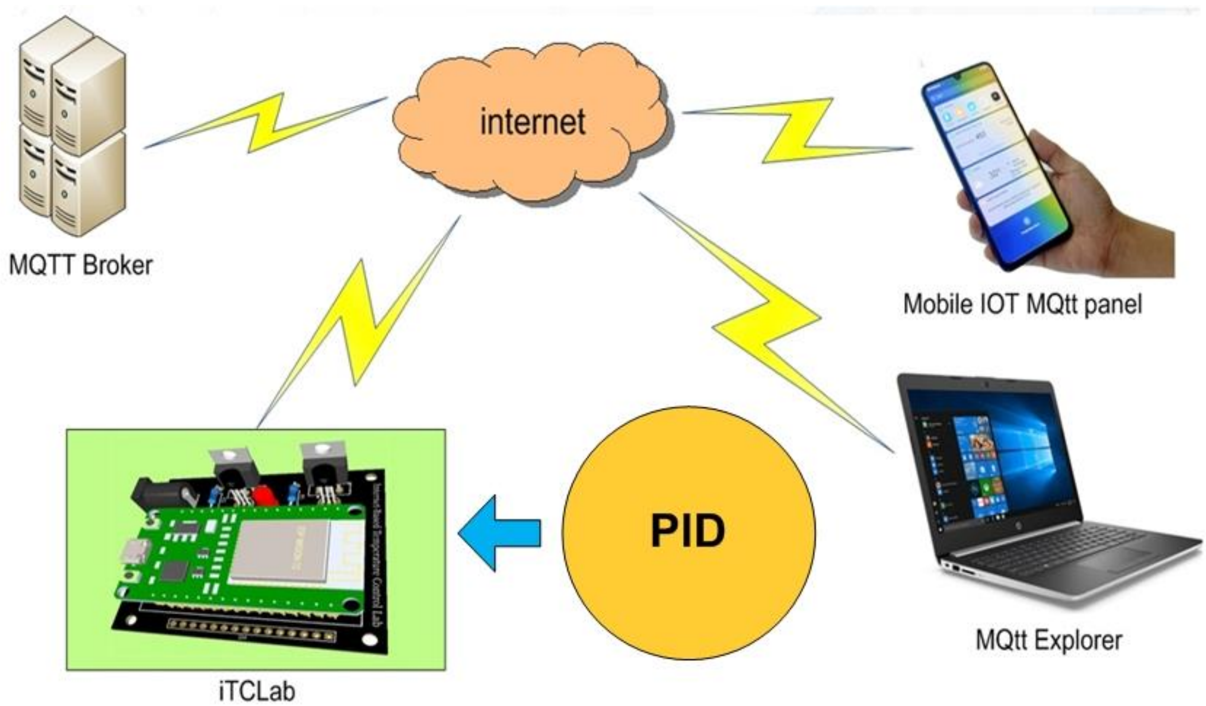

Figure 1. The architecture of temperature monitoring via the Internet of Things using PID-iTCLab

From the system architecture in Figure 1, to run as desired, a program was first created using the Arduino programming language. This program contains controlling the iTCLab Kit using PID. PID control temperature data retrieval. Equipped with a way to connect to IoT. This program is embedded in the iTCLab Kit. When run, if the settings are correct, it will successfully connect to the MQTT Broker. Next, the settings are made according to the created topic, on the MQTT IoT Panel. If appropriate, then monitoring the temperature of the PID control via mobile phone can be carried out.

Results and Discussion

Testing the PID programming and settings on the iTCLab Kit is shown in Figure 2. Through the serial monitor on the PC, we can see the temperature readings of the PID control results from the iTCLab Kit. Some important program snippets are shown on the following command line:

```
float pid(float sp, float pv, float pv_last, float& ierr, float dt)
{
  float Kc = 10.0; // K / %Heater
  float tauI = 50.0; // sec
  float tauD = 1.0;  // sec
  // PID coefficients
  float KP = Kc;
  float KI = Kc / tauI;
  float KD = Kc*tauD;
  // upper and lower bounds on heater level
  float ophi = 100;
  float oplo = 0;
  // calculate the error
  float error = sp - pv;
  // calculate the integral error
  ierr = ierr + KI * error * dt;
  // calculate the measurement derivative
  float dpv = (pv - pv_last) / dt;
  // calculate the PID output
  float P = KP * error; //proportional contribution
  float I = ierr; //integral contribution
  float D = -KD * dpv; //derivative contribution
  float op = P + I + D;
  // implement anti-reset windup
  if ((op < oplo) || (op > ophi)) {
    I = I - KI * error * dt;
    // clip output
    op = max(oplo, min(ophi, op));
  }
  ierr = I;
  Serial.println("sp="+String(sp) + " pv=" + String(pv) + " dt=" + 
String(dt) + " op=" + String(op) + " P=" + String(P) + " I=" + 
String(I) + " D=" + String(D));
  return op;
}
```

```
void loop() {
  new_ts = millis();
  if (new_ts - ts > 1000) {
  char suhu1[4];
  char suhu2[4];
  char SetPoint[4];
  char Nilai_op[4];
  client.loop();
  cektemp();
  pv = cel;   // Temperature T1
  dt = (new_ts - ts) / 1000.0;
  ts = new_ts;
  op = pid(sp,pv,pv_last,ierr,dt);
  ledcWrite(Q1Channel,op);
  pv_last = pv;
  dtostrf(cel, 1, 0, suhu1);
  client.publish("Suhu1",suhu1);
  dtostrf(sp, 1, 0, SetPoint);
  client.publish("SetPoint",SetPoint);
  dtostrf(op, 1, 0, Nilai_op);
  client.publish("Nilai_op",Nilai_op);
  delay (200);
  dtostrf(cel1, 1, 0, suhu2);
  client.publish("Suhu2",suhu2);
  delay (200);
  }
}
```

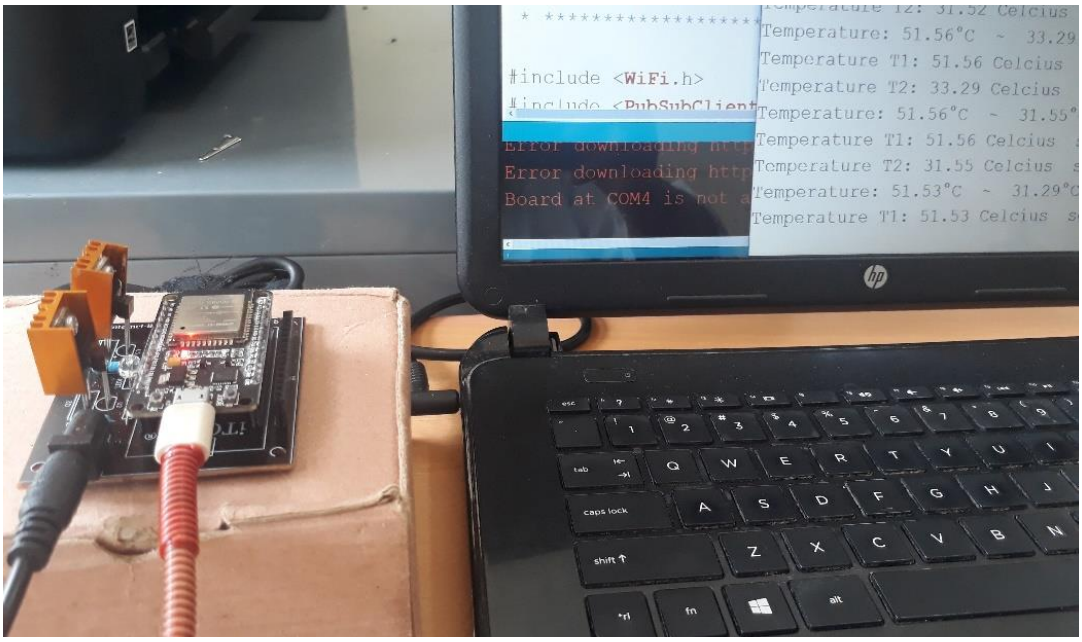

Figure 2. System testing using the PID-iTCLab

Next, the settings are made according to the created topic, on the MQTT IoT Panel. The selection of the panel used, and the settings that must be made on the MQTT IoT Panel, are shown in Figures 3 and Figure 4. If the settings are appropriate, monitoring the temperature control results using PID via cellphone can be done. In this experiment, an example of the results of temperature monitoring using PID-iTCLab is shown in Figure 5 and Figure 6.

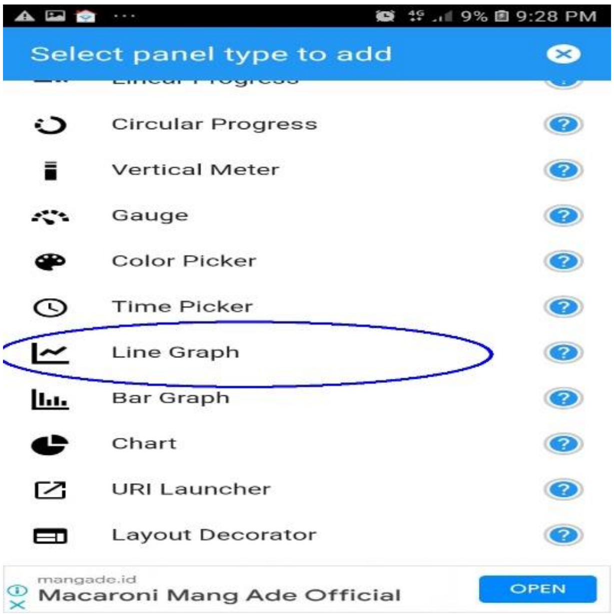

Figure 3. Panels used in IoT MQTT Panel

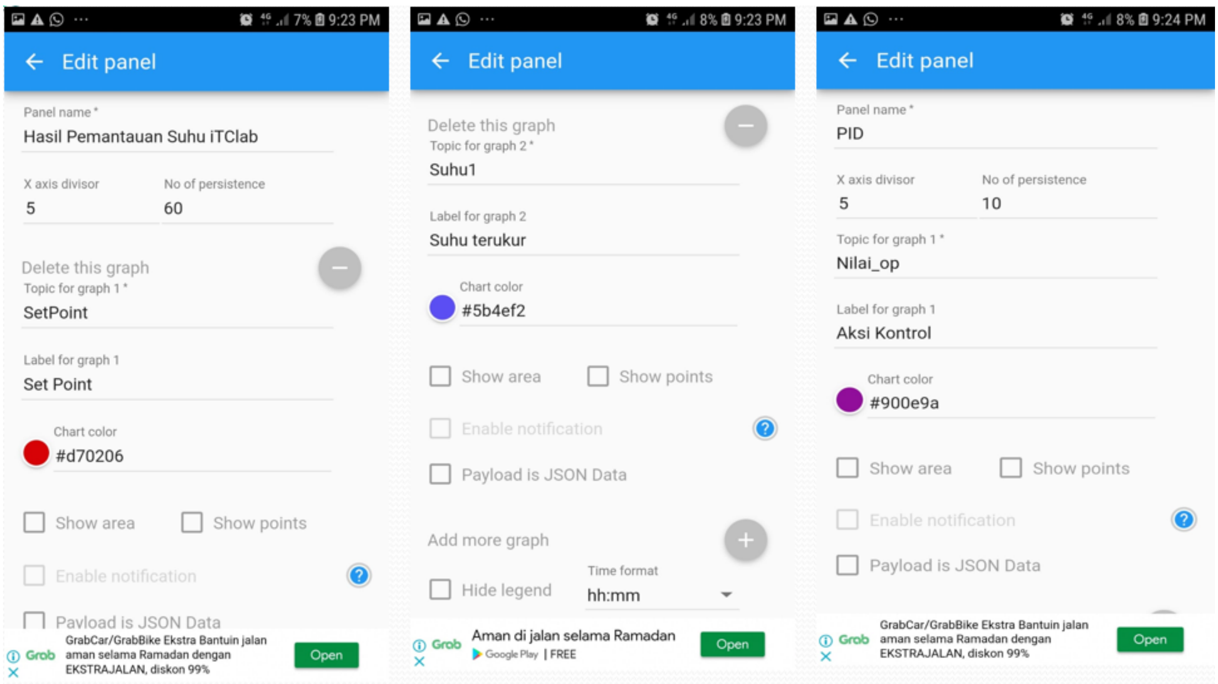

Figure 4. Setting Topics in IoT MQTT Panel

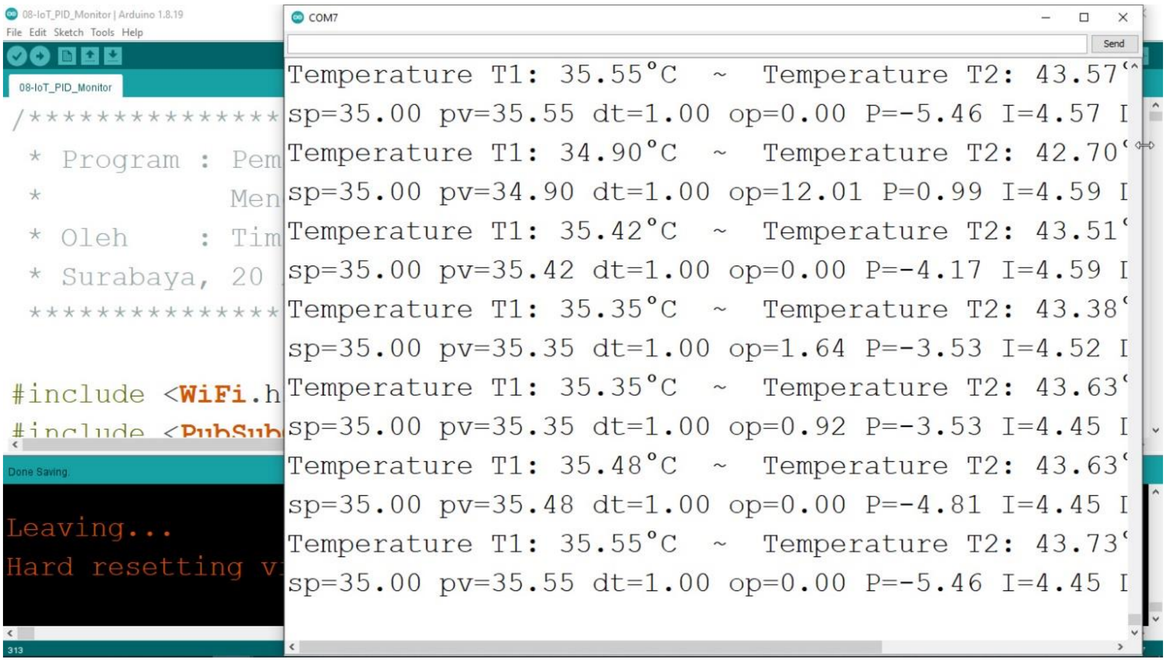

Figure 5. Experimental results on the Serial Monitor

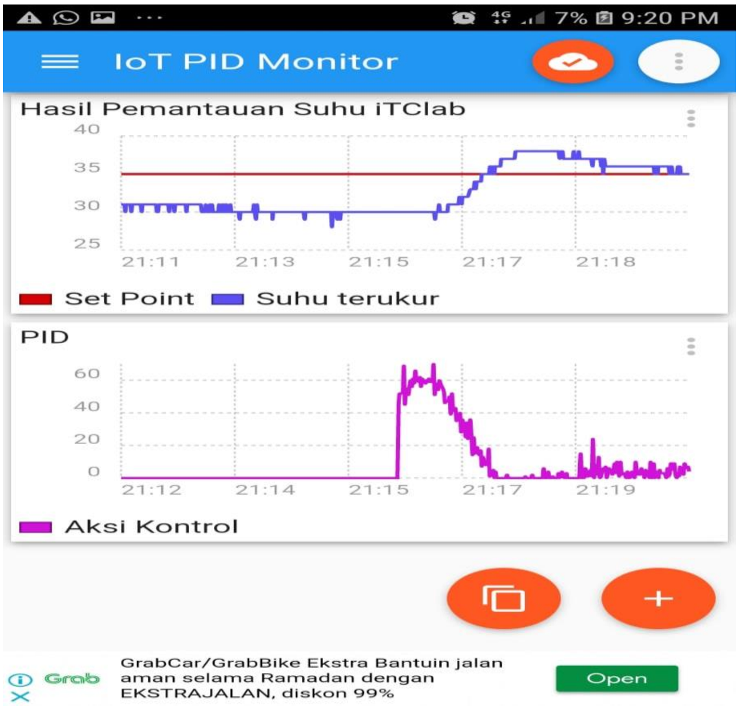

Figure 6. Experimental Results on the IoT MQTT Panel

From the experimental results in Figure 6, it can be seen that the MQTT IoT Panel has successfully connected to the MQTT Broker. This means that the temperature monitoring program uses the PID Controller and the settings on the iTCLab Kit are correct. The temperature sensor readings from sensor 1 and sensor 2 have also been successful. Seen from the readings a few degrees Celsius. Then the temperature observation of the PID control results through the IoT MQTT Panel, was carried out for some time. This test was also successful. Seen results of temperature monitoring, results of PID control. It can be seen that the output temperature of the iTCLab Kit follows the set point value.

Conclusion

From the experimental results, it can be shown that the iTCLab Kit can be used as a device for monitoring the temperature of the control process using a PID controller via the Internet of Things (IoT). Control results monitoring program with PID is created and embedded in the iTCLab Kit. Furthermore, management and settings for mobile monitoring and control are carried out using the MQTT IoT Panel. The experimental results show that the monitoring system has worked well. This is indicated by the results of temperature monitoring from the iTCLab Kit that can be carried out on a mobile basis as expected.

Acknowledgment

This work was financially supported by the Directorate of Resources of the Directorate General of Higher Education of the Ministry of Education, Culture, Research, and Technology by the Multi-Year Research Contract for the Leading Higher Education Applied Research Program Number: 09/UN63.8/LT-Kontrak/III/2022, March 16, 2022.

References

Attaran, S. M., Yusof, R., & Selamat, H. (2016). A novel optimization algorithm based on epsilon constraint-RBF neural network for tuning PID controller in decoupled HVAC system. *Applied Thermal Engineering*, *99*, 613–624. https://doi.org/https://doi.org/10.1016/j.applthermaleng.2016.01.025

Bhookya, J., Vijaya Kumar, M., Ravi Kumar, J., & Seshagiri Rao, A. (2022). Implementation of PID controller for liquid level system using mGWO and integration of IoT application. *Journal of Industrial Information Integration*, *28*, 100368. https://doi.org/https://doi.org/10.1016/j.jii.2022.100368

BYU. (2018). Apmonitor.com. *Temperature Control Lab*. Retrieved from http://apmonitor.com/pdc/index.php/Main/ArduinoTemperatureControl

de Moura Oliveira, P. B., Hedengren, J. D., & Rossiter, J. A. (2020). Introducing Digital Controllers to Undergraduate Students using the TCLab Arduino Kit. *IFAC-PapersOnLine*, *53*(2), 17524–17529. https://doi.org/https://doi.org/10.1016/j.ifacol.2020.12.2662

Huang, H., Zhang, S., Yang, Z., Tian, Y., Zhao, X., Yuan, Z., … Wei, Y. (2018). Modified Smith fuzzy PID temperature control in an oil-replenishing device for deep-sea hydraulic system. *Ocean Engineering*, *149*, 14–22. https://doi.org/https://doi.org/10.1016/j.oceaneng.2017.11.052

Oliveira, P. M., & Hedengren, J. D. (2019). An APMonitor temperature Lab PID Control experiment for undergraduate students. In *2019 24th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA)* (pp. 790–797). https://doi.org/10.1109/ETFA.2019.8869247

Park, J., Martin, R. A., Kelly, J. D., & Hedengren, J. D. (2020). Benchmark temperature microcontroller for process dynamics and control. *Computers & Chemical Engineering*, *135*, 106736. https://doi.org/https://doi.org/10.1016/j.compchemeng.2020.106736

Priyanka, E. B., Maheswari, C., Thangavel, S., & Bala, M. P. (2020). Integrating IoT with LQR-PID controller for online surveillance and control of flow and pressure in fluid transportation system. *Journal of Industrial Information Integration*, *17*, 100127. https://doi.org/https://doi.org/10.1016/j.jii.2020.100127

Priyanka, E. B., Thangavel, S., Prasad, P. H., & Mohanasundaram, R. (2021). IoT fusion based model predictive pid control approach for oil pipeline infrastructure. *International Journal of Critical Infrastructure Protection*, *35*, 100485. https://doi.org/https://doi.org/10.1016/j.ijcip.2021.100485

Quwaider, M., & Shatnawi, Y. (2020). Neural network model as Internet of Things congestion control using PID controller and immune-hill-climbing algorithm. *Simulation Modelling Practice and Theory*, *101*, 102022. https://doi.org/https://doi.org/10.1016/j.simpat.2019.102022

Zhang, R., & Gao, L. (2021). Research on motor control and simulation based on PID and Internet of things system. *Microprocessors and Microsystems*, *80*, 103602. https://doi.org/https://doi.org/10.1016/j.micpro.2020.103602