SJIF Impact Factor (2023): 8.574| ISI I.F. Value: 1.241| Journal DOI: 10.36713/epra2016 ISSN: 2455-7838(Online)
EPRA International Journal of Research and Development (IJRD)
Volume: 8 | Issue: 12 | December 2023 - Peer Reviewed Journal

BRAKE RESISTOR TEMPERATURE ESTIMATION IN POWERED-OFF RAILWAY CONTROLLER

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ABSTRACT

There are many different parts that make up the railway electrical propulsion system, including the pantograph, transformer, rectification, DC link, inverter, auxiliary supply, induction motor and other sections. To dissipate braking energy into the railway, a brake resistor is attached to the DC Link. When energy is being lost in the brake resistor, its temperature rises. We need to continuously estimate the temperature on board using the internal clock, especially when the control system is out for some reason and the temperature sensor is not providing us with actual data. This projected temperature at system startup enables us to immediately act to manage the system. In this Paper, I've covered an algorithm for precise temperature estimation that takes into account thermal resistance, thermal capacitance, ambient temperature, initial temperature and the real amount of time it takes for a system to turn down.

Estimating the temperature of the brake resistor is an important aspect for ensuring correct operation and safety in the event of control system malfunctions and power outages. By using cutting-edge sensors and algorithms, it is possible to estimate the brake resistor's temperature correctly and take the necessary steps to avoid overheating, fire dangers and system failure in general.

KEYWORDS- *Brake Resistor, Temperature Estimation, Control System, Railway, DC Link*

I. INTRODUCTION

- Estimating the temperature of the brake resistors is important for maintaining the secure operation of railway systems in the case of a power outage. The brake resistor is important in the process of releasing extra electrical energy produced during braking. However, in the absence of a power source, the control system malfunctions, which can result in uncontrolled braking and a possibly hazardous rise in the brake resistor's temperature.
- To avoid overheating and potential harm to the resistor itself, it is crucial to estimate the temperature of the brake resistor. High temperatures might cause electrical problems or fire risks, endangering the overall safety and dependability of the railway system.
- A reliable temperature estimation system is added to railway control systems to overcome this issue. When the power supply is off, this system continuously measures and estimates the temperature of the brake resistor using a variety of sensors and algorithms. These sensors, which collect information on the brake resistor's operational circumstances and electrical energy dissipation, may be heat sensors, current sensors, or a combination of the two.
- The advanced algorithms used by the temperature estimation system take into account real-time data such the resistor's thermal conductivity, ambient temperature and the rate of energy dissipation. These algorithms are made to precisely forecast temperature increases, issue prompt alerts, or start the necessary countermeasures to reduce the risk of overheating.
- Corrective actions are promptly initiated when the temperature estimate system identifies a probable increase in temperature above predefined criteria. To disperse excess heat, these methods may entail turning on a cooling system, such as a fan or liquid cooling system. In order to stop additional temperature rise, the system may also lower the electrical energy input to the brake resistor or even start emergency braking procedures.
- A dependable safety feature, the brake resistor temperature estimate system ensures the protection of railway systems in the event of control system failures and power outages. By measuring and tracking the brake resistor's temperature, it is possible to reduce the dangers of overheating, averting emergencies and preserving the general functionality and integrity of the railway system.

II. RAILWAY PROPULSION SYSTEM

The electrical traction system in railways plays an Important role in powering and controlling induction motors, which are commonly used for train propulsion. Several key components make up this system, each serving a specific function in supplying power to the motors and ensuring efficient operation.

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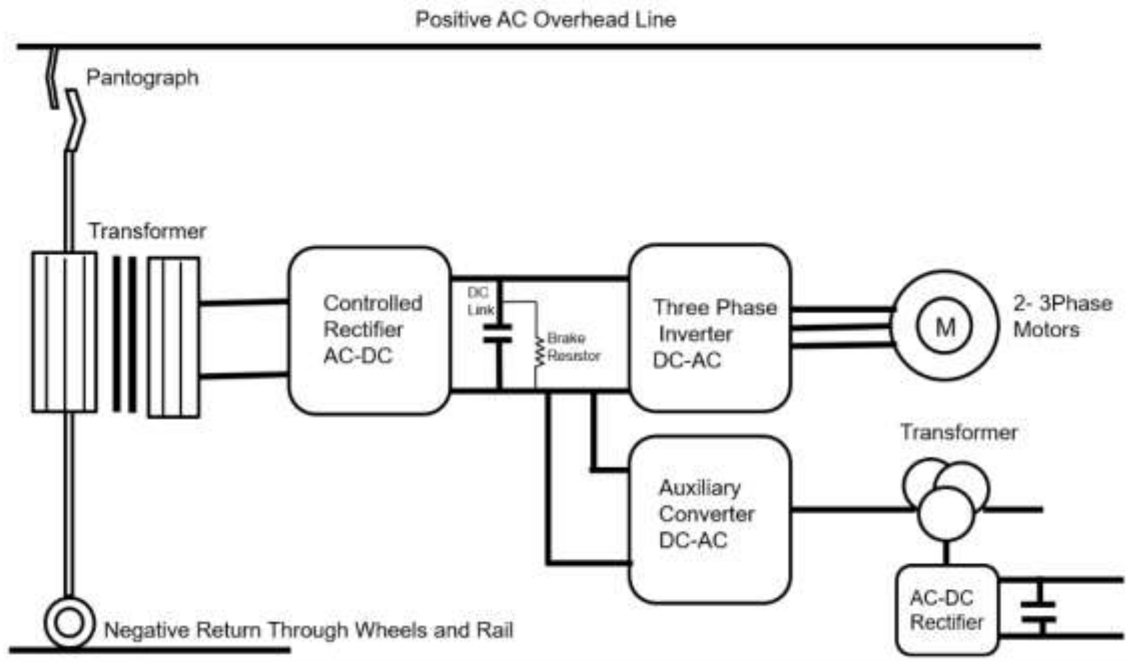

Below are the main components of a railway electrical traction system for powering induction motors:

Overhead Lines or Third Rail The power supply for the traction system typically comes from overhead lines or a third rail. Overhead lines consist of a network of wires suspended above the tracks, while a third rail is an additional rail installed alongside the running rails at ground level. These power supply methods deliver the necessary electrical energy to the trains to power the induction motors.
Pantograph/Catenary System In the case of an overhead line configuration, the pantograph is the device mounted on top of the train that collects electrical power from the overhead lines. It uses a sliding contact to establish a connection and transmit power to the train's traction system. The catenary system consists of the continuous overhead wires supported by masts or other structures.
Transformer The power received from the overhead lines or third rail is typically at a very high voltage. A transformer is used to step down this high voltage to a lower, more manageable voltage suitable for the train's traction system. It converts the electrical energy from the power supply to a level that can be efficiently utilized by the induction motors.
Rectifier As induction motors require alternating current (AC) to function, the electrical traction system incorporates rectifiers that convert the incoming AC power to direct current (DC). These rectifiers typically utilize diodes to establish a one-way flow of electrical energy, feeding the following components with DC power.
Inverter Induction motors require AC power to operate and the inverter is responsible for converting the DC power from the rectifier back into a controlled AC waveform. Inverters use power electronic devices, such as Insulated Gate Bipolar Transistors (IGBTs), to generate the desired AC frequency and voltage for the induction motors.
Induction Motors The most common type of motor used in railway traction systems is the three-phase squirrel cage induction motor. Induction motors are rugged, reliable and capable of handling the high power demands of traction applications. These motors convert electrical power into mechanical power, propelling the train.
Motor Control Unit The motor control unit manages the operation of the induction motors, regulating their speed, torque and direction. It consists of various control algorithms and sensing devices that monitor motor performance and adjust the power supplied to achieve the desired operation.
Protection and Safety Systems The electrical traction system incorporates a range of protection and safety systems to prevent damage to the components and ensure safe operation. These include overload protection, short-circuit protection, ground fault detection and emergency stop mechanisms.

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a. Mathematical Equations for Brake Resistor Temperature Estimation

- ✓ In a railway system, the brake resistor is utilized to release extra electrical energy produced during regenerative braking. Uncontrolled braking might result from a malfunctioning control system, releasing too much energy into the brake resistor. The resistor's temperature may significantly rise as a result of this.
- ✓ To ensure the brake resistor operates safely, temperature estimation is necessary. If the temperature rises over the maximum permitted level, the resistor may overheat and suffer possible damage. Additionally, the overheating of the resistor may cause electrical problems, fire risks, or even brake system failure.
- ✓ It is possible to prevent the brake resistor from overheating by calculating its temperature. These procedures can involve starting a cooling system, lowering the amount of electrical energy used, or applying emergency braking techniques. This helps to maintain the railway system's dependability and safety, particularly when the control system malfunctions.
- ✓ The temperature coefficient of resistance (TCR) for the resistor material can be used to derive the mathematical equation for resistance estimation depending on temperature. The TCR gauges how much resistance changes with each degree of temperature change.

The general equation for resistance estimation from temperature is as follows:

$$R2 = R1 * (1 + \alpha * (T2 - T1))$$

Where:
R1 is the initial resistance at temperature T1
R2 is the estimated resistance at temperature T2
α is the temperature coefficient of resistance for the material of the resistor

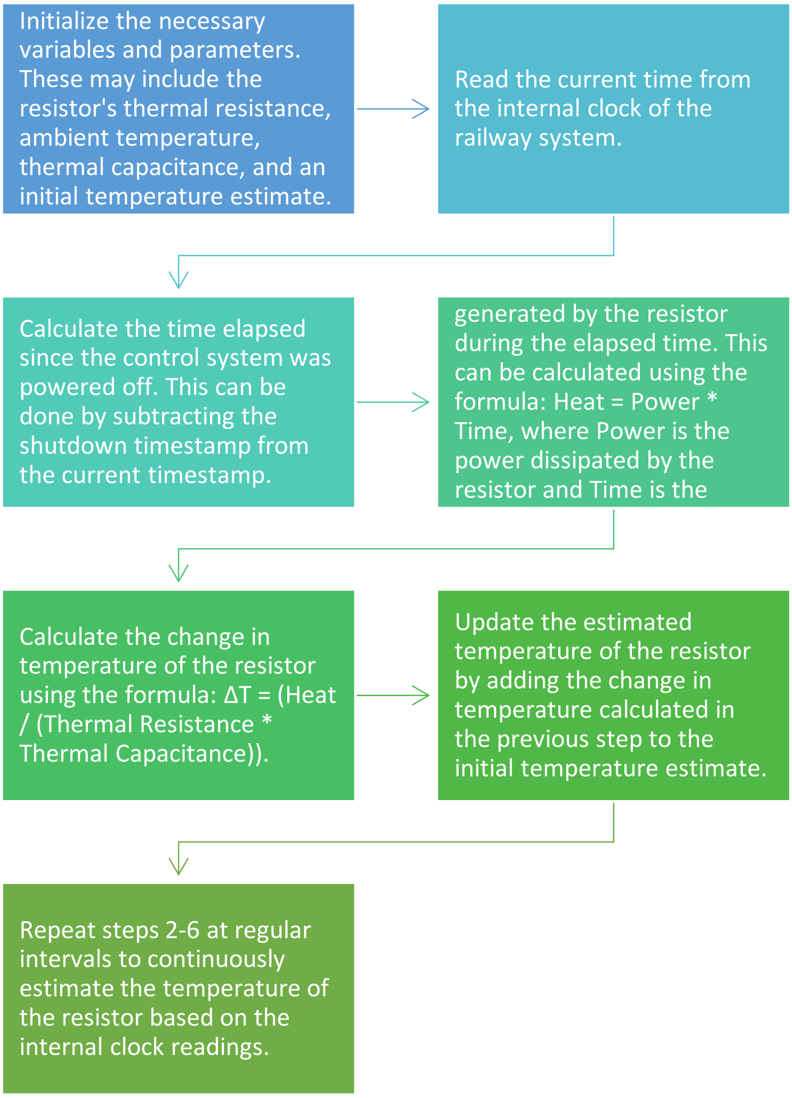
- ✓ This equation makes the assumption that temperature and resistance have a linear relationship over a narrow temperature range. Since some materials might have nonlinear connections, it's vital to keep in mind that this equation only delivers an approximate result within the bounds of its applicability.
- ✓ Additionally, the resistor manufacturer normally provides the resistance at the reference temperature (R1) and the temperature coefficient of resistance (). These figures rely on the particular substance that was utilized to make the resistor.
- ✓ The equation provides an estimate of the resistance (R2) at the desired temperature by taking into account the reference resistance (R1), the related temperature (T1) and the target temperature (T2). The resistor's temperature can then be monitored using this estimation to avoid overheating or damage in a variety of applications, such as in train braking systems.

b. Brake resistor Value Selection Criteria

While selecting a brake resistor for efficiently dissipating heat generated during regenerative braking in railways, below factors Can be considered

III. CONTROL ALGORITHM FOR BRAKE RESISTOR TEMPERATURE ESTIMATION

Below general steps we can follow to estimate the temperature of a brake resistor using the internal clock in a railway system when the control system is powered off.



The accuracy of the temperature estimate will depend on the accuracy of the parameters used, such as the thermal resistance and thermal capacitance. Additionally, depending on the specific characteristics of the resistor and the environment, additional factors may need to be considered in the temperature estimation algorithm, such as convection and radiation effects.

a. Software Solution

MATLAB Code for Power Dissipation into Brake Resistor Based on IGBT ON Time

```
R_dc = 3.3; % DC Link Resistance (in Ohms)
V_dc = 1800; % DC Link Voltage (in Volts)
P_dc_excessive = 130; % Excessive Power on DC Link (in Watts)

% Calculate the current on the DC link
I_dc = sqrt(P_dc_excessive / R_dc); % DC Link Current (in Amperes)

% Calculate the power dissipation on the brake resistor
P_brake_resistor = I_dc^2 * R_dc; % Power dissipation on the brake resistor (in Watts)

% Calculate the IGBT ON time for brake resistor
T_IGBT_on = P_brake_resistor / (V_dc * I_dc); % IGBT ON time for brake resistor (in seconds)

% Display the results
```

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```
disp(['DC Link Current: ' num2str(I_dc) ' A']);
disp(['Power Dissipation on the Brake Resistor: ' num2str(P_brake_resistor) ' W']);
disp(['IGBT ON Time for Brake Resistor: ' num2str(T_IGBT_on) ' s']);
```

Output:
DC Link Current: 6.2765 A
Power Dissipation on the Brake Resistor: 130 W
IGBT ON Time for Brake Resistor: 0.011507 s

MATLAB Code for Brake Resistor Temperature Estimation in case of Powered-Off Controller

```
% Constants
  ambientTemperature = 25; % Ambient temperature in degrees Celsius
  timeStep = 0.1; % Time step in seconds
  offDuration = 20; % Duration of ECU power off in seconds
  powerOnTemperature = 100; % Brake resistor temperature when ECU is powered on in degrees
         Celsius
initialTemperature = 200; % Temperature before power off in degrees Celsius

% Initialize variables
  time = 0;
  temperature = initialTemperature;

% Power off duration
  while time < offDuration
   % Calculate temperature change during power off
    temperatureChange = (ambientTemperature - temperature) / 10;

   % Update temperature
    temperature = temperature + temperatureChange*timeStep;

   % Update time
    time = time + timeStep;
  end

% Power on duration
  time = 0;

  while time < 5
   % Calculate temperature change during power on
    temperatureChange = (powerOnTemperature - temperature) / 5;

   % Update temperature
    temperature = temperature + temperatureChange*timeStep;

   % Update time
    time = time + timeStep;
  end

% Output the estimated brake resistor temperature
  disp(['Estimated brake resistor temperature after power on: ', num2str(temperature), ' degrees
         Celsius']);
```

Output:
Estimated brake resistor temperature after power on: 73.3837 degrees Celsius

Above code consider constant power dissipation by the brake resistor and ignores convection and radiation effects.

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IV. CONCLUSION

- ✓ In conclusion, this study has looked at the value of estimating brake resistor temperature in applications, with a focus on how it relates to railway systems. It is possible to apply the same principle to different electric vehicles. When the control system fails or the power supply is cut off, the temperature estimation approach outlined in this work offers a vital tool for guaranteeing the safe and dependable operation of brake resistors.
- ✓ The likelihood of an overheated brake resistor can be reduced by precisely measuring its temperature. Overheating can result in electrical problems, fire risks, resistor degradation and even braking system failure. The safety and integrity of railway systems must therefore be maintained through constant assessment of the brake resistor temperature.
- ✓ The suggested approach for estimating temperature takes into account variables including thermal capacitance, thermal resistance, ambient temperature and the resistor's thermal conductivity. Through the use of sensors and algorithms, these factors are recorded, allowing for the real-time assessment of temperature rise and prompt alerts or the beginning of required actions.
- ✓ The use of a trustworthy temperature estimation technique has various advantages. When necessary, it permits the activation of cooling systems, including fans and liquid cooling methods. It also enables the brake resistor's electrical energy input to be reduced or, if necessary, emergency braking actions to be initiated.
- ✓ Estimating the temperature of the brake resistor has significance outside of the rail systems. It can be used in many different fields and situations where the release of extra electrical energy while braking is necessary. The risk of accidents or system failures can be reduced, equipment damage can be avoided, operational reliability is ensured and safety issues can be addressed by monitoring and predicting the temperature.
- ✓ The technique for estimating brake resistor temperature described in this research study advances techniques and technologies for assuring the secure and effective operation of braking systems. The overall performance, dependability and safety of numerous systems in the railway and other industries are improved as a result, which emphasizes the significance of ongoing monitoring and preventative steps to avoid overheating.
- ✓ Further research and development in this area will continue to refine and optimize temperature estimation methods, contributing to even more effective solutions in the future.

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