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Development of a Remote Monitoring and Control System for a Medium-Voltage Substation Using IoT Infrastructure and Node-RED

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INTRODUCTION & AIM

The main goal of this work is to develop and implement a remote monitoring and control system for a medium-voltage substation using Internet of Things (IoT) technology and the Node-Red platform. The system aims to enable real-time supervision and reduce the need for on-site interventions. Modernizing substations is essential to enhance efficiency, safety, and reduce operational costs. The use of IoT and Node-Red allows the creation of integrated, accessible, and easily maintainable solutions, contributing to the modernization of the electrical sector.

METHOD

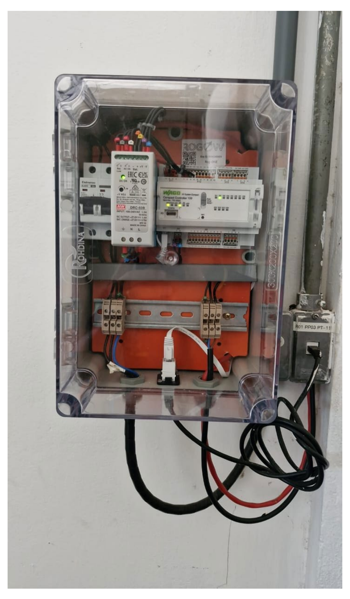
The “IoT-Box” was installed in a medium-voltage substation located outside the main building. The substation is separate from the facility and includes two 100 kVA transformers and two 800 kW generators.

The physical components of the IoT-Box are:

- Acrylic enclosure;
- CC100 controller;
- 6A two-phase AC circuit breaker;
- AC/DC converter;
- 12V battery;
- Terminal blocks.

For the installation of the “IoT-Box,” it was necessary to set up an internet connection point in the substation. The multifunction meters have RS485 communication capability, which, as discussed, allows the integration of one or more components into a single “master.” A unique ID was assigned to each meter, and all were synchronized at a baud rate of 19200.

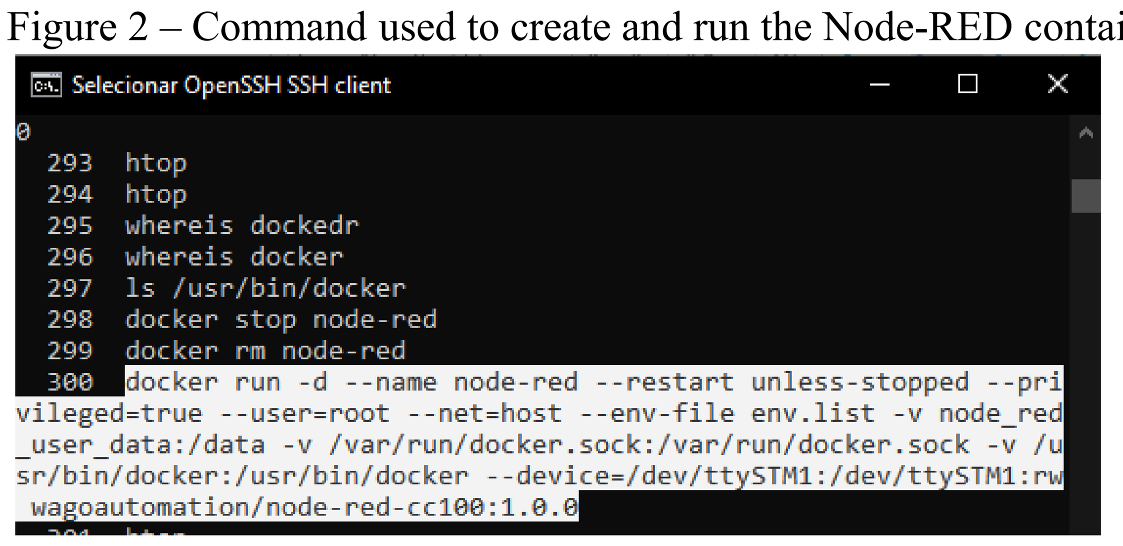
Figure 1 – “IoT-Box”



The controller includes the Docker Engine and an embedded Node-Red. Docker allows us to create and run applications in containers. To open the Node-Red workspace, we initially need to edit the Node-Red image settings in a Dockerfile.

Docker allows access to different contexts; in our case, the “node-red” context is a ready-made image, so there was no need to edit its definitions in a Dockerfile. Once the image is created, we need to run a container.

Figure 2 – Command used to create and run the Node-RED container.



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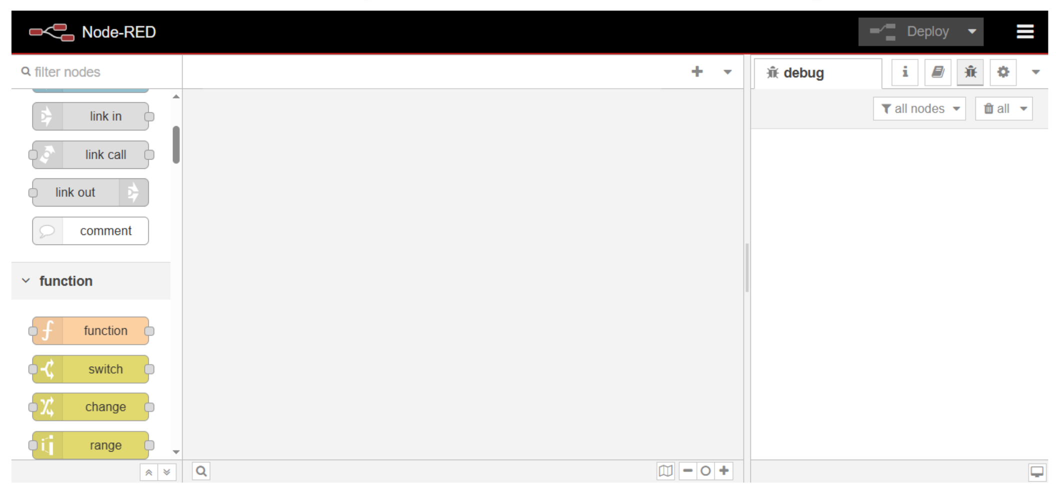
Selecionar OpenSSH SSH client
0
 293  htop
 294  htop
 295  whereis dockedr
 296  whereis docker
 297  ls /usr/bin/docker
 298  docker stop node-red
 299  docker rm node-red
 300  docker run -d --name node-red --restart unless-stopped --privileged=true --user=root --net=host --env-file env.list -v node_red_user_data:/data -v /var/run/docker.sock:/var/run/docker.sock -v /usr/bin/docker:/usr/bin/docker --device=/dev/ttySTM1:/dev/ttySTM1:rw wagoautomation/node-red-cc100:1.0.0
```

After setting up the Node-Red environment, it is possible to access a specific IP address that provides direct access to the platform. The development environment is low-code, allowing logic to be built mainly through interconnected nodes, with the option to enhance functionality using function nodes that employ JavaScript as the programming language. From the Node-RED environment, through the “Dashboard 2.0” palette, it is possible to quickly display on the dashboard the information collected from the substation meters connected to the embedded system.

Figure 3 – Node-RED workspace

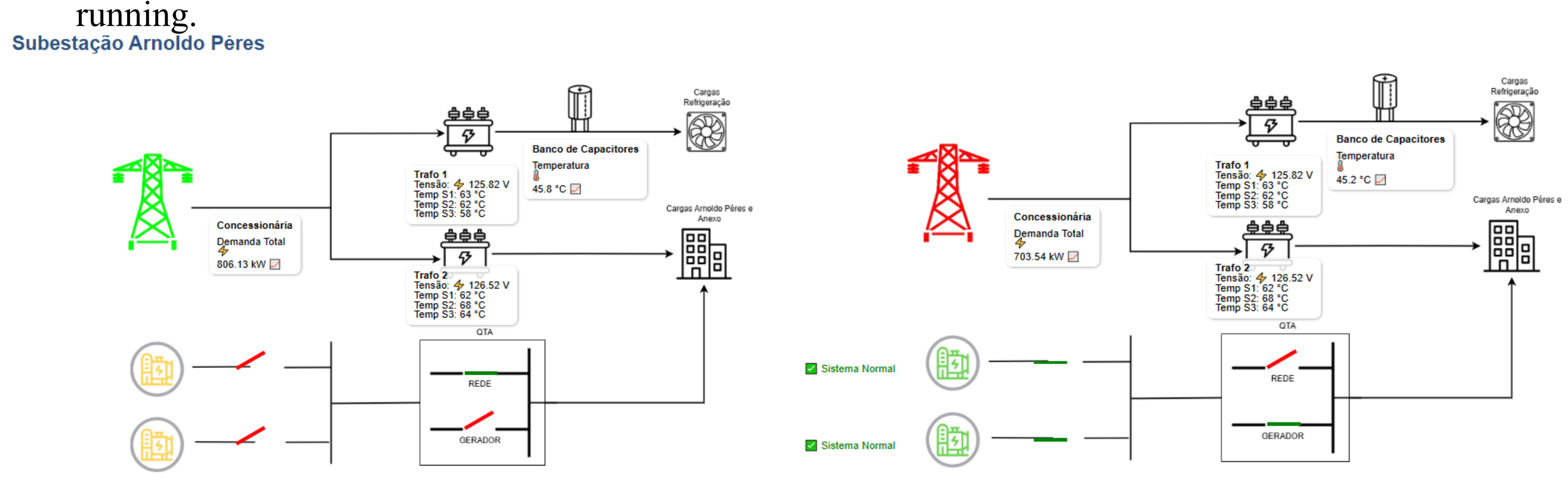


RESULTS & DISCUSSION

In the mimic diagram, we have the status of the two generators and their availability on the generation bus. We also have the Automatic Transfer Switch (ATS) panel, which shows whether the building loads are being supplied by the utility or by the generators. When the circuit breaker is connected, it is displayed in a horizontal position and colored green; when it is disconnected, it is slightly raised and turns red.

The mimic is a static PNG image used as the background. The green and red circuit breakers are responsive to the data received from the Node-RED flows. Information such as temperature, demand, and transformer voltage are also dynamic. The yellow generator icon turns green when the generator is running, and the grid icon turns red to indicate a power outage.

Figure 4 – A mime representing a power outage caused by the utility company, but with the generators running.



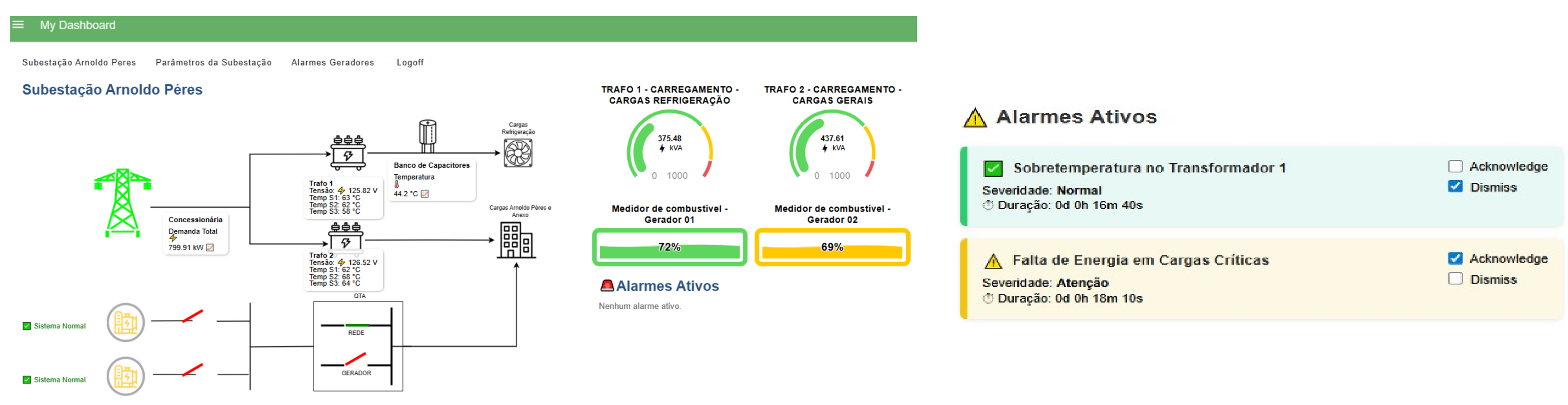
The substation also includes two 1000 kVA transformers. In the mimic, just below each transformer illustration, we display the temperatures of the three phases and the average three-phase voltage. Next to the utility symbol, we can see the total demand value, and below the capacitor bank, we can see its temperature. When either the demand or temperature reaches a high level, yellow and red warning indicators appear.

On the gauges beside the diagram, we can observe the apparent power of both transformers. It is noticeable that the gauge labeled “General Loads,” which corresponds to the lighting and outlets panel, shows a higher value, reflecting the increased temperature in the three phases as shown in the mimic.

We can also see the fuel level of both generators displayed on the Dashboard with responsive colors: green indicates a good level (above 70%), yellow signals attention (below 70% but not critical), and red indicates a severe condition (below 60%), requiring immediate action.

We can observe the first version of the alarm status display, which shows the description, duration, and severity of each registered event. The colors are responsive to the severity level. The active alarm status panel was built using the Dashboard 2.0 template, which is based on the Vue.js framework.

Figure 5 – Overview of the dashboard and active alarm system.



CONCLUSION

For the current purpose, the system proved to be efficient. The operators connected to the local internet network are able to access the dashboard and obtain all measurable information from the substation without the need to travel to the site in person.

FUTURE WORK / REFERENCES

Figueira, Micaela Machado. Remote Monitoring and Control System of a Medium Voltage Substation Using IoT Infrastructure with Node-Red. 2025. Undergraduate Thesis (Electrical Engineering). Advisor: Israel Gondres Torne. Manaus, Brazil.