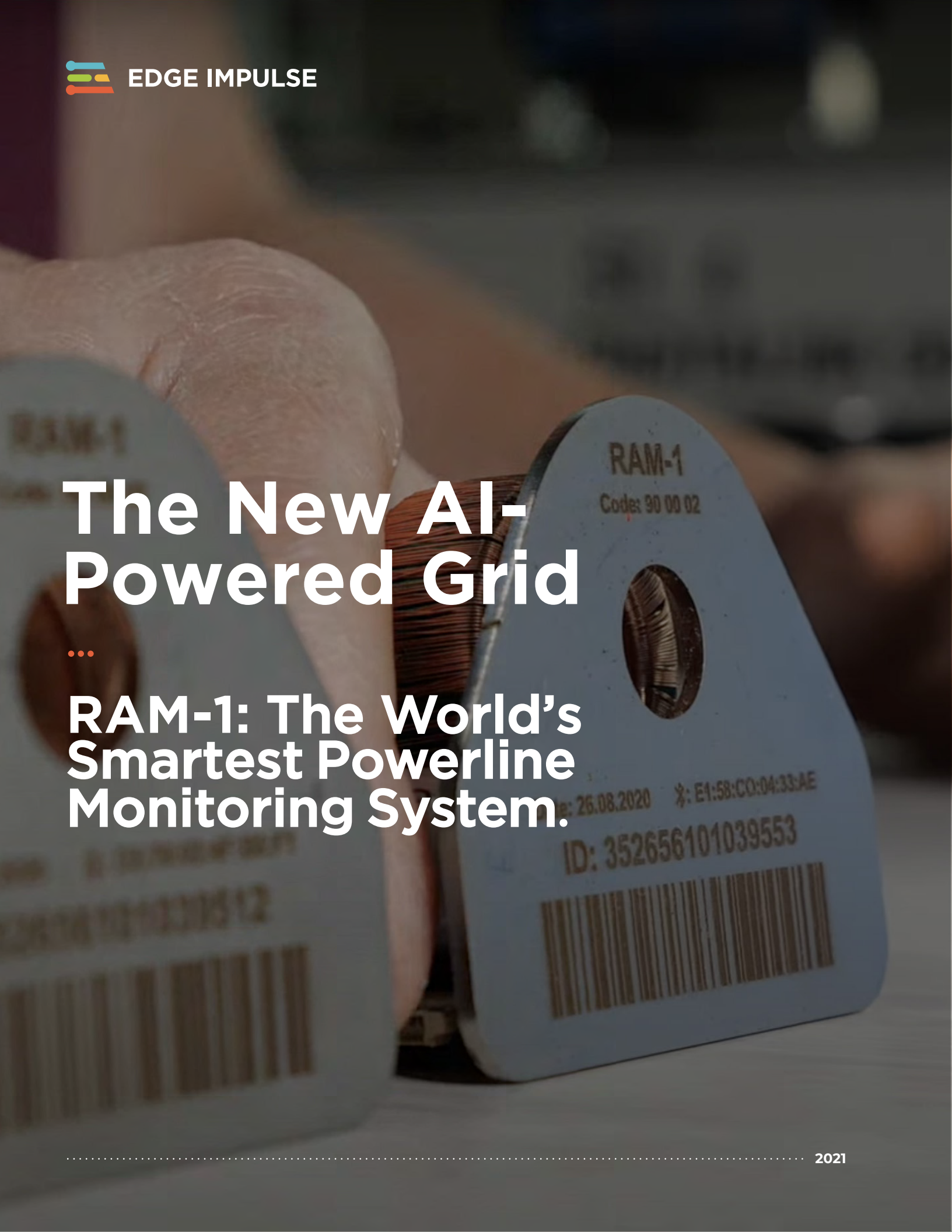
EDGE IMPULSE



The New AI-Powered Grid

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RAM-1: The World's Smartest Powerline Monitoring System.

2021

The electric power grids which supply energy to the machines that run our modern way of life are some of the largest interconnected systems in the world. With an increase in energy demand, changing environmental conditions and the need to accommodate diverse energy sources such as gas-fired plants and renewables, it is more important than ever to preemptively predict and prevent potential outages and failovers.

In recent years, environmental conditions in places like California have resulted in infrastructure failures that resulted in major environmental destruction, property loss, and numerous human casualties. When it comes to high-power electricity distribution, even a simple infrastructure failure can quickly escalate into catastrophic consequences.

A Smart Grid Monitoring Solution, Powered by Edge Impulse

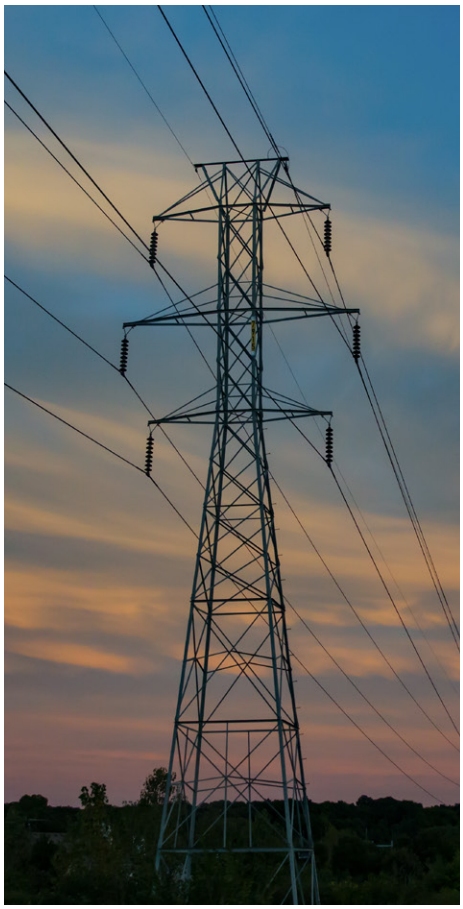
In 2019, Izoelektro, Irnas, Arm and Edge Impulse collaborated to develop and deploy a next-generation power grid monitoring device, running embedded machine learning models. This allowed Izoelektro to build one of the most advanced power grid monitoring systems in the world. Called RAM-1, it is designed to alleviate problems resulting from powerline failures. Taking advantage of Nordic Semiconductor's nRF9160 SiP with its Arm® Cortex®-M33 core, the team created machine learning models that can run inferencing on the pole-mounted devices so efficiently that they are capable of lasting 20 years on a single battery charge. This enables power grid operators to detect a range of potential faults remotely and take immediate corrective action in the event of failures without sacrificing power consumption. In addition, the RAM-1 is equipped with the nRF52811 SoC and utilizes BLE functionality to provide easy commissioning as well as an alternate data channel when cellular network is unavailable.

A Modern, Rugged, Predictive Maintenance Device

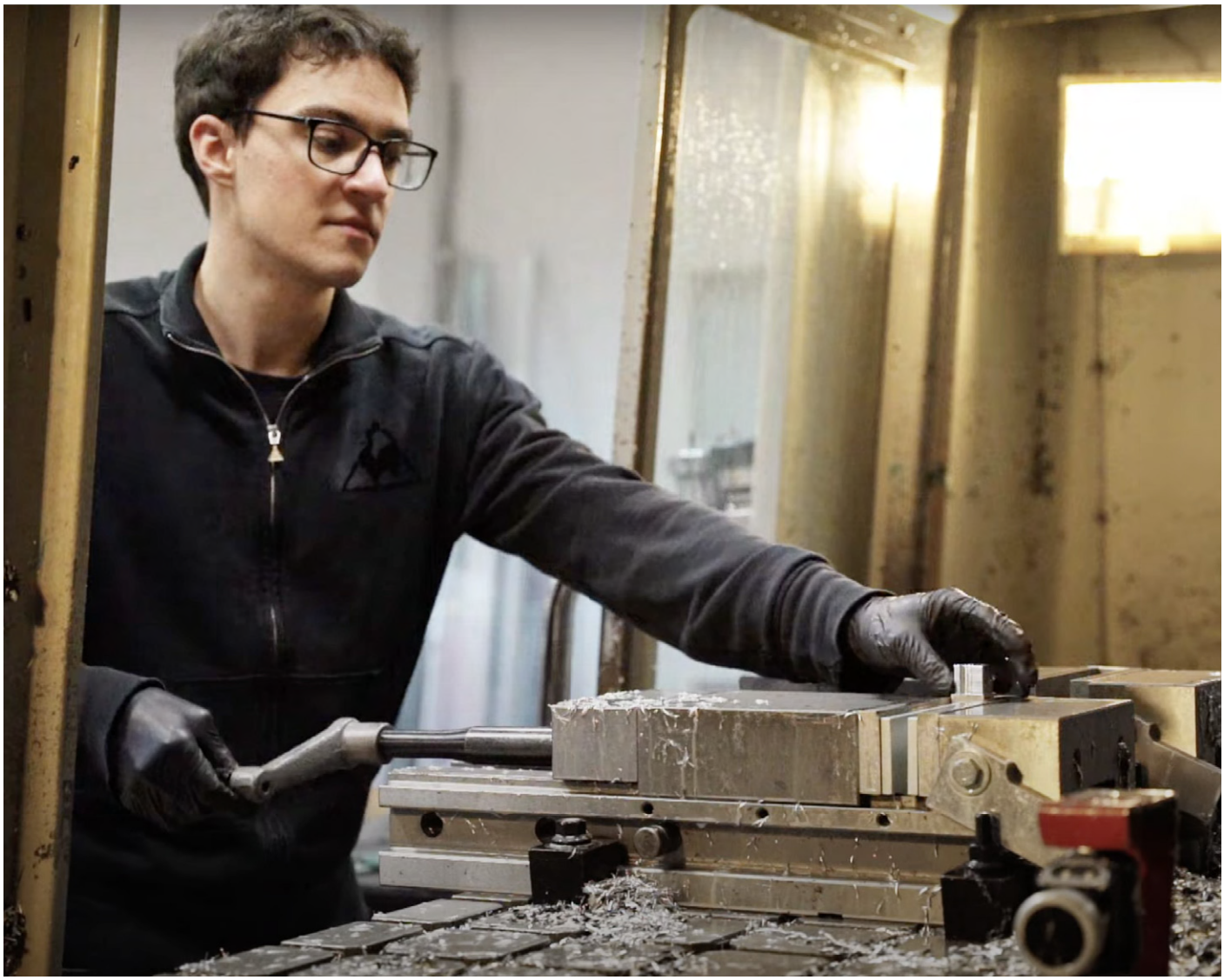
The RAM-1 is the first device sporting a wide range of features to be deployed on electrical grid towers directly, with a robust design optimized to withstand harsh weather conditions and temperatures from -49° to 185°F. By leveraging Irnas, an expert IoT design house, the team was able to solve complex engineering challenges related to embedded software and modeling, mechanical design, connectivity configuration, energy consumption optimization, and low-power remote device management to enable continuous performance monitoring, remote upgradability, testability, and robust reporting.

Anytime, Everywhere Communication for Remote Locations

RAM-1 is an NB-IoT and LoRaWAN-connected device for monitoring electrical power grid systems. The device processes electromagnetic field data on-device and utilizes embedded machine learning for event recognition, classification and prediction with the following attributes:



- Distributed generation – RAM-1 can be integrated into an electric grid powered by wind turbines, solar farms, independent power facilities, and microgrids.
- RAM-1 has built-in predictive maintenance features, such as detection and outage management, outage localization, and to get customers back on line faster.
- Load control and demand response – Controls load fluctuations from increased demand, aging infrastructure, renewables, and distributed generation.
- Substation monitoring – Improves reliability and decreases the risk of blackouts and brownouts caused by aging infrastructure.
- Load monitoring – Understand when circuits may be overloaded and quickly respond with corrections.
- Conservation voltage reduction – Manage voltage levels on feeders to reduce loads and conserve energy.
- Continuous customer engagement – Empower active consumer engagement and energy conservation programs.



Building a Smart System That Delivers ROI, Longevity and Customer Satisfaction First

Building a device that can last for 20 years requires a real vision for continuous upgradeability. The use of Nordic Semiconductor's nRF9160 Cortex-M33 SiP and nRF52811 Cortex-M4 SoC enables rapid development with plenty of computing capabilities at low power, leaving enough headroom for future improvements with over-the-air update support. The development of new Edge Impulse machine learning models provides assurance that the system will continue to work towards maximizing the "added value per mWh," with new and improved "apps" that change and evolve with time. In this application, approximately 25% of energy is allocated for standby operation – 50% for communication and 25% for data acquisition, thus creating room for added value.

This is where machine learning at the edge excels. Acquired data is no longer thrown away by simply using it in averages or numerical algorithms, but instead is used to detect fine details and events from data that would traditionally be ignored. The power consumption to run the machine learning models is orders of magnitude lower than the energy used for RF communication. Leveraging embedded machine learning via Edge Impulse offers the following benefits:

• Increasing grid reliability – By continuously monitoring its surroundings and relaying this information to the user, the RAM-1 device gives real-time insight into the state of the grid. With this information the operator can then adjust the maintenance plan accordingly, ensuring greater reliability throughout the lifetime of the grid.

• Reducing financial losses – The low-cost device can monitor the grid for an array of weak spots that can be fixed before they present an actual problem in the grid, thereby reducing unplanned outages, additional manual labor, purchase of new equipment, etc.

• Critical event detection, classification and prediction – Infrastructure failures in remote areas with limited access can cause catastrophic natural and human disasters. With smart monitoring and machine learning integrated in the RAM-1, the risk for such incidents can be minimized by event prediction, advanced classification, and utilization of this data for making the right decisions to prevent critical outcomes.

• Reducing carbon emissions – On average, 65% of electricity is still produced in thermal power plants. This means that the carbon footprint of the average kWh is still very high. One way to combat the CO2 emissions is to optimize the distribution of electrical energy and reduce its losses. The RAM-1 device can do just that and secure a greener tomorrow.

Future-Proof Anomaly Detection with Proactive Maintenance Solutions

Using Edge Impulse, the team created several solution tiers that deliver some of the critical capabilities necessary for RAM-1 to deliver on its promise. The first tier is anomaly detection, upon which a low-power trigger event of RAM-1 analyzes the waveform and determines if an anomaly has been detected. The solution is based on a large dataset collected from RAM-1 devices deployed in the field monitoring steady state, combined with laboratory measurements of these steady state situations.

"From a device that originally reported the state of surge arresters, RAM-1 has rapidly become an IoT device for remote monitoring, machine learning, and advanced analytics of power grids," says Jure Pungerčar, Deputy CEO, Izoelektro. "We are excited about the possibilities of a truly smart power grid and the ability to improve the operation, stability, and reliability of electricity distribution."

Think of this implementation on-device as the gatekeeper of data transmission. Non-anomaly waveforms are of no particular interest to be sent to the cloud for further analysis as there is not much new knowledge about the system available from that information. Upon detecting the anomaly however, that waveform is of significant importance and carries information about the system state.

The second tier of the solution is the anomaly recognition and classification stage, starting on the cloud side and over the lifetime of devices propagating to devices themselves, further reducing the need for RF data transmissions. This ongoing development process merges the anomaly events sent by the devices in the field with the laboratory replications of known events and creates an expanding set of classes related to various new observations learned in the field.

"On-device machine learning will be facing numerous opportunities in the very near future. With exciting co-development of microcontroller technology, connectivity infrastructure and software tools, the number of use cases is expected to grow exponentially. Our challenge is to create the most optimal development environment so we can stay on top of every coming new advancement."

– Luka Mustafa, IRNAS CEO

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