DOI 10.5162/SMSI2025/P04

UHF RFID Based Strain Sensor for Hydropower Generators

M. Lenzhofer[1], A. Horn[1], S. Culetto[2]
[1] Silicon Austria Labs GmbH, Europastrasse 12, 9524 Villach, Austria,
[2] KELAG-Kärntner Elektrizitäts-Aktiengesellschaft
Außerfragant 72, 9831 Flattach, Austria
Martin.Lenzhofer@silicon-austria.com

Summary:
The presented work focuses on developing an RFID sensor capable of being implemented on the rotor of a power generator of a hydro storage plant to enable condition monitoring of dedicated positions suffering under stress in terms of start-stop operation scenarios. The strain sensor value is read out wirelessly via a UHF RFID system, which either supplies the sensor or transmits its measurement result. The analyzed measurements done in a post-processing step prove the possibility of using such technology within the generator use case.

Keywords: RFID sensor system, RFID technology, strain sensor, wireless measurement, sensor tag

Introduction

The generators in hydro storage plants are not operated continuously but are started and stopped as required. Due to this operation mode and also in case of load shedding resulting in overspeed conditions, high repetitive mechanical stress occurs at certain positions in the rotor, contributing significantly to the generator's aging. Available systems mainly just monitor the torque by flanged transducers, but there are no measuring systems monitoring stress, for example at the pole plates. Also, reliable transmission of measured values in such a harsh environment, which is characterized by the metallic housing, the high rotor speed of nominally 500 rpm, the high excitation voltage of 10.5 kV, and the generated power of up to 32 MVA, leading to high electromagnetic field strengths, remains challenging. The goal of this project was to develop a system that monitors the operating status of the rotor. On the one hand, it was necessary to find a suitable technology for transmitting measured values and, on the other hand, to realize a sensor that does not require an additional power supply. Additionally, the system should be as light as possible to avoid imbalance. Also, the fixture must be properly designed to avoid any damage to the generator in case of failure.

Description of the System

The proposed measurement system is based on ultra-high frequency (UHF) radio frequency identification (RFID) technology and consists of a commercially available reader unit and a developed passive sensor tag, [1,2]. Several vendors on the market currently provide RFID ICs combined with the ability to connect to external sensor circuits directly or via a digital bus interface. The main players are ASYGN, Farsens, Impinj and NXP. A chip of the type AS3212 from ASYGN was used for the implemented solution. The AS3212 is the first UHF RFID product that embeds a full analog sensor interface including a switched capacitor amplifier (SCA) and analog-to-digital converter (ADC) unit for monitoring external resistive sensors.

As all main modules are integrated within this chip, just a few components to match the antenna impedance, and the external sensor must be attached, refer to Figure 1.

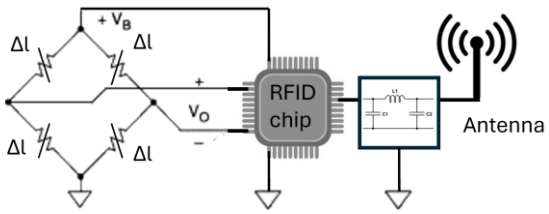

Fig. 1. Block diagram of the RFID sensor tag.

One main challenge is the implementation of the system in the generator. The developed solution is based on integrating a commercially available ceramic patch antenna of the type ISPC.86A.09.0092E from Taoglas, working as a director element. The reflector is realized through a conductive plane, which is proposed to be in the shape of the blade of the fan wheel of the generator. The blade profile in front of the antenna is realized with PEEK material and both parts are screwed together and secured by Nord-lock washers with additional adhesive,

refer to Figure 2. The profile is important to avoid disturbances in the cooling airflow. Also, the blade weight with the integrated antenna is matched to the blade weight of the original one to stay balanced.

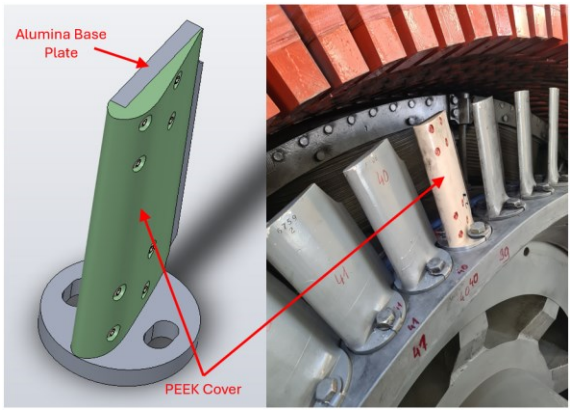

Fig. 2. The developed fan blade is built up by two parts with an integrated antenna.

As the connection to the sensing element must be as short as possible, the chip is integrated into a package with the matching network, and a long wire connects the antenna to the chip, refer to Figure 3. As this cable is a coaxial version it is shielded from disturbances. This wire is accordingly bandaged around the rotor and additionally fixed by adhesive. To read out the sensor two antennas are mounted on the stator side within the generator's housing that are connected to an RRU 4500 reader unit of Kathrein, refer to Figure 4.

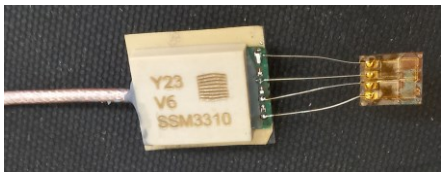

Fig. 3. Packaged RFID sensor with the connected strain sensor element SGT-2/1000-FB11 of OMEGA.

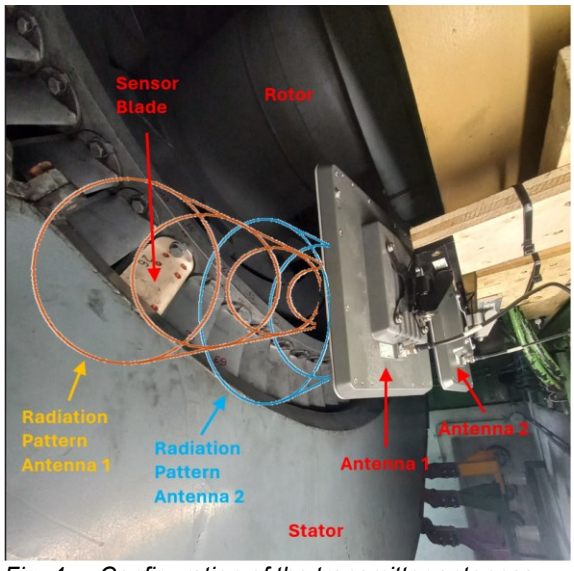

Fig. 4. Configuration of the transmitter antennas.

Measurement Results

The system is tested within a predefined procedure, where the turbine is first started up to start up the generator at a nominal speed of 500 rpm. After 5 minutes, the excitation voltage is switched on. After a further 5 minutes, the load of 20 MVA is activated, and another 5 minutes later, the generator is switched off again, refer to Figure 5. This step-by-step activation is necessary to examine the external influences on the measurement result.

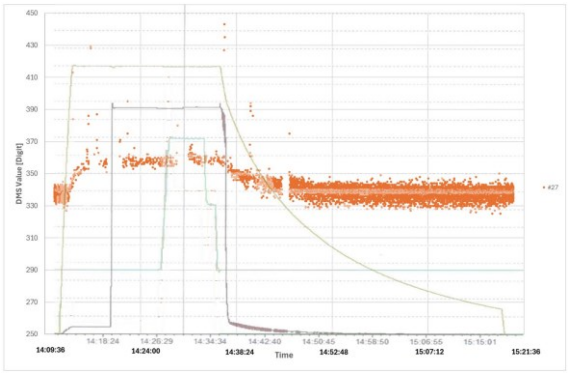

Fig. 5. Correlation of the measured ADC values (orange dots) with the generator characteristics, where the ochre curve represents the rpm value, the grey one the excitation voltage, and the green one the load cycle.

Conclusion and Outlook

Several test runs proved that strain on the defined position of the rotor in a hydropower plant generator can be measured. However, some issues regarding disturbances in the measurement result were identified, which need to be addressed in further optimization steps by providing a more stable power supply during the AD conversion.

Acknowledgment

This work has been jointly supported by the industry partner KELAG-Kärntner Elektrizitäts-Aktiengesellschaft and by Silicon Austria Labs (SAL), owned by the Republic of Austria, the Styrian Business Promotion Agency (SFG), the federal state of Carinthia, the Upper Austrian Research (UAR), and the Austrian Association for the Electric and Electronics Industry (FEEI).

References

[1] Senadeera, Praharshin & Wickramasinghe, Shyama & Jayasinghe, J.M.J.W.. (2024). Impedance Measurement of a Chip-Based Passive UHF RFID Sensor Transponder. 782-787. 10.1109/SoutheastCon52093.2024.10500136.

[2] Liu G, Wang Q-A, Jiao G, Dang P, Nie G, Liu Z, Sun J. Review of Wireless RFID Strain Sensing Technology in Structural Health Monitoring. *Sensors*. (2023); https://doi.org/10.3390/s23156925