Results of the New Eddy Current Tester for Steam Generator Applications

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Abstract. As a result of the recent developing line of eddy current data acquisition systems a new product comes to the market named Teddy+. With only 4kg of weight constitutes a great advance with regards to the equipments used for this type of inspections available in the market.

This advances, have enabled, among others, to increase considerably the S/N ratio, avoid typical saturation problems in the eddy current signal, increase the inspection speed, eliminate the reference probe, detect the air/tube signal in real time, together with the possibility to integrate the tester inside the pusher thanks to its reduced size and to have integrated the mechanical systems control board as part of the tester.

The software application in charge of data acquisition and analysis has been optimized making it possible a faster and efficient data access, incorporating a new tool to allow a data quality control on-line, which has accelerated the detection process of non-valid registers.

The processes related with the supervision of different analysis have been automated enabling a simultaneous comparison of up to four different analysis types. At the same time the necessary tools to make the successive passes of the resolution process have been included in the analysis software according to EPRI guidelines.

These innovations and improvements place the new SG inspection system from TECNATOM, as one of the most powerful and reliable existing in the market.

1. Introduction

Industrial sectors each time demand more competitive and versatile data acquisition systems able to make automated eddy current inspections. The data acquisition systems must cover a wide range of applications in different markets: energy, manufacturing, aerospace and industry. Tecnatom has developed a new line of eddy current data acquisition systems named TEDDY+ that is able to cover the different markets and applications thanks to its modular architecture allowing building from simple up to high performance data acquisition systems.

This paper presents the new line of data acquisition systems developed by Tecnatom, named TEDDY+, its innovations, technical features and results obtained in a series of applications, highlighting the benefits of this new line.

The new TEDDY+ line of products presented in this paper constitutes one of the most powerful and reliable existing in the market.

2. Equipment Description

First of all lets describe the equipment starting with the innovations of TEDDY+ electronics and architecture.
**Digital Design:** using the most outstanding technology existing nowadays and applying it to all equipment stages, from signal processing to reception stage, enabling to increase the equipments stability with regards to temperature changes, reduce the noise, minimize the size, considerable increasing the acquisition speed and leaving it open to future updating.

**Automatic gain control:** adapting the received signal to obtain an acquisition with the highest possible precision and avoiding saturations in the input stages (see Fig. 1), notifying to the CPU any detected anomaly.

Real time data Acquisition through DSP’s, enabling to increase the received signal quality through the use of programmable filters and configurable, automatic detection of end of tube, channels mixing, and any algorithm that currently or in the future might appear and is applicable to eddy current techniques.

**Array probes and electronic embedded probes support,** prepared to interface with the latest generation of probes and enabling, thanks to its modular concept, the ease of introducing new probe models that might appear in the future.

**Integration with ultrasounds, mechanical controllers, or other commercial modules in the same rack,** thought from its origin to admit connection to other data acquisition systems, integrate it with mechanical control systems and make an all in one system with the incorporation of commercial modules for several purposes in the same equipment.

**Reduced size due to the high technology electronic components used,** the use of the latest components existing in the market has made possible to reduce the size and, at the same time, increase its capabilities to a level difficult to foresee only few years ago.

1.1 **Technical Features**

Amongst the technical features of TEDDY+ we may highlight the following:
- Simultaneous (SI), multiplexed (MUX) or context switching injection modes (MSI).
- Over sampling to dramatically reduce foreign noise sources influence over signal quality (see Fig. 2).

![Figure 1](image1.png)

**Figure 1:** (a) Data acquisition with Freq=100KHz (b) same acquisition with automatic gain option, no saturation of the signals.

![Figure 2](image2.png)

**Figure 2 (a)** Data acquisition with Freq=100KHz (b) same acquisition with oversampling=5

- Number of channels: according to the injection mode we may have
  - SI : From 16 to 256 channels
  - MUX : From 64 to 1024 channels
- MSI: From 128 to 1024 channels
- Acquisition speed of up to 20,000 samples/second (see Fig. 3)

![Image of different acquisition speeds](image1)

Figure 3: 4drill hole 100% at 300KHz with different acquisition speeds, same signal quality.
- Manual & Automatic gain option (32 bits) (see Fig. 4)

![Image of automatic gain option](image2)

Figure 4: 4drill-hole signal at 300KHz and 34dB (in white) same acquisition with automatic gain option and 32 bits (in yellow) giving a signal ≈ 1500 times bigger than without automatic gain option and a slightly better S/N relationship.
- Supports all types of probes, including array probes and embedded electronic probes.
- Inspection frequency from 1Hz to 10MHz
- From 9 to 36 encoders (incremental encoders, TTL or state signals)
- From 16 to 64 digital input/output
- From 4 to 16 analog input/output
- Internal, external, synchronized by encoder and software trigger modes.
- 32 time slots.
- Dynamic filters optimised for each frequency.
- Variable time slot to optimise sampling rate
- Reference probe simulation allows TEDDY+ to eliminate the probe used as a reference in a differential/absolute acquisition. A generator is used to simulate the amplitude and phase of the reference probe
- Autotest option: several parameters of the system are checked in order to control errors or malfunctions like the voltage applied to the probe, saturation in the signal, acquisition speed, power supply and temperature.

1.2 TEDDY+ Product Lines

On June 2005 the first TEDDY+ tester saw the light. It was tested on ASCO power plant on a blank test on a SG, last October and the results were compared to those obtained with TEDDY tester (previous equipment) over a set of tubes with good results (see Fig 5).

Since then, the effort has been put in manufacturing the industrial product lines according to market demands as well as on enhancing the data acquisition software programs related with these lines. Two product lines have been defined the stand alone version, named TEDDY+ allowing different configurations according to the number and type of electronic boards included in the tester, and an integrated version, named TEDDY+SP or suitcase pusher containing in the same package TEDDY+ tester, controller pusher, RPC power driver and pusher mechanics. Both products are being deployed this year.

![Figure 5: In blue acquisition of tube from ASCO plant and in black same tube acquired with TEDDY+ giving equivalent results.](image)

1.3 Software Applications

The TEDDY software applications have been updated to incorporate the control of the new product line. At the same time the data base structure of both the acquisition and analysis applications for tube bundle inspection has been re-designed to support adequately new EPRI requirements and to be able to isolate the eddy current data analysis and acquisition from what may be called operational concepts. The new data management architecture guarantees a robust and fault tolerance system, minimizing operator errors and increasing the communication dynamics between data planning, data acquisition and data analysis.
The structure of the data frame has been completely re-designed to allow all the configuration possibilities available in TEDDY+, like including time-stamp, encoders information, alarms information, analog input information. It also has been included the possibility of independent triggers, this means different data frames per trigger. Also the array sensors and the multi-sensor probes (combination of array elements and a bobbin probe, like X-Probe and I-probe) have changed the classical file data concept. If we add to the above the possibilities of the new equipment of working either in 16 bit mode or 32 bit mode (due to the automatic gain) we can imagine that all the software has been changed in order to couple with all these new possibilities in a efficient and reliable way, and always guaranteeing total compatibility with previous data formats and equipments.

New data representation views have been defined taking into account time stamp information (stripchart, lissajous, 3D, etc)

![Figure 6 Diagnostic window showing temperature, power and sampling speed control.](image)

Some of the enhancements of the new system include a diagnostics window to check the electronic boards temperature, power voltage, and sampling speed (see figure 6).

2. Applications

In order to cover the different markets and applications is necessary to count with an architecture highly modular that enables the composition from simple to high capabilities equipment. The solution included in TEDDY+ is based on PC104 architecture that has arised as an standard in the PC based control systems of high capabilities and reduced size. Under this architecture there exists a great amount of commercial modules available (DSP’s, ambient control, axis control, video, sound, etc) that together with the modular concept design enable an easy expansion of the data acquisition system.

Thanks to this architecture it is possible to reach different markets and adapt easily the particular needs that a certain inspection problem might arise.

In the following lines it is described the main features of TEDDY+ in a series of applications.
2.1 Steam Generator Inspection

The key product developed for this type of inspection is the suitcase pusher TEDDY+SP. This new suitcase concept has reduced tremendously the number of cables and components used in previous systems generation. Some of the main features are air detection in real time, reference probe simulation avoiding the use of a second probe for absolute channels, synchronization with mechanical controllers (pushers and robots) and total automatization of the signal acquisition and analysis process. On figure 7 the suitcase pusher is shown and on figure 8 a first row tube acquired with TEDDY+ is shown.

![Figure 7: TEDDY+SP, Suitcase Pusher on the left of the image and TEDDY+ on the right.](image)

![Figure 8 First row tube from a mock-up acquired with TEDDY+SP, on right lissajous absolute channel with reference probe simulation.](image)

To the outside world, there are only an Ethernet connector, a 110-220 Votls plug and air intake, all the rest of connexions are internal and do not need to be reconnected each time, simplifying considerably the installation of this equipment.

The new system is helping to reduce cost, time duration and dose of the steam generator tube inspections. Also, for the plant, there is a reduction in the amount of waste, due the reduced number of probes and cables used, and a reduction of the platform contamination, spread by the pusher, thanks for the sealed design of this equipment.
2.2 *Heat Exchanger Inspection*

Any of the two products can be used for this type of inspections TEDDY+ or TEDDY+SP, with four sensors and capabilities of one array probe. The system can be complemented with RFET and/or UT. It counts with air detection in real time and reference probe simulation and synchronization with mechanical controllers (pushers).

**Figure 10** a) TEDDY+ stand-alone version b) Acquisition set: PC control & TEDDY+

2.3 *Large components Inspection*

In the case of large components, the use of array probes implies a clear competitive advantage with regards to punctual probes since it enables much faster inspections as well as the inspection of complex geometry surfaces. An example of these type of inspections is J-Weld inspection as shown on figure 10, where a multicoil element is used with external multiplexers.

**Figure 10** a) Multi-coil element J-Weld Inspection and b) C-Scan Representacion data output
3. Conclusions

The new line of digital eddy current systems enable faster inspections, are easier to calibrate, avoid signal saturation, give a better signal/noise relationship, and are prepared to be expanded to reach special applications.

The two lines of products TEDDY+ standalone and TEDDY+SP suitcase pusher cover constitute a compact, robust and versatile new generation of EC testers for Nuclear Pressurized components.

This new equipment will help to give an important step forward to improve the quality and reliability of the steam generator tube inspections, while reducing cost and dose. This was possible thanks to the extensive use of state of the art digital electronics and software, together with a design fully oriented to get these goals.