Network and Software Architecture Improvements for a Highly Automated, Robust and Efficient Realization of the Italian National Time Scale

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***Abstract*— Recently, the informatics infrastructure of INRiM Time and Frequency Laboratory has been completely renewed with particular attention to network security and software architecture aspects, with the aims to improve the reliability, robustness and automation of the overall set-up. This upgraded infrastructure has allowed, since January 2020, a fully automated generation and monitoring of the Italian time scale UTC(IT), based on dedicated software developed in-house [1]. We focus in this work on the network and software aspects of our set-up, which enable a robust and reliable automatic time scale generation with continuous monitoring and minimal human intervention.**

Keywords— informatics architecture; cybersecurity; redundancy; robustness; virtual machine; monitoring; maintenance; timing; time scale generation, time and frequency laboratory

I. INTRODUCTION

Time is the only measurement unit continuously available, therefore the generation of a real-time time reference is strictly connected with robustness and redundancy concepts.
UTC(IT), the Italian reference time scale, is based on a robust and redundant hardware architecture [2], put in place at INRiM premises to allow a continuous and efficient timing service. This is achieved by steering independently two Active Hydrogen Masers (AHM) towards Rapid UTC (available from the Bureau International des Poids et Mesures – BIPM) in an automatic way, generating a "master" time scale and a "backup" time scale (Fig. 1). The backup time scale is aligned to the master time scale at sub-nanosecond level in order to allow a seamless switch in case of anomalies. Such possibility is automatically ensured by a prototype unit for switching signal developed by SKK Electronics [3]. At the same time two additional test time scales are generated (highlighted in blue in Fig. 1, based on the same atomic clocks of the official ones. The test chain relies on totally independent hardware and it is used as validation platform for alternative algorithms performance and robustness tests.

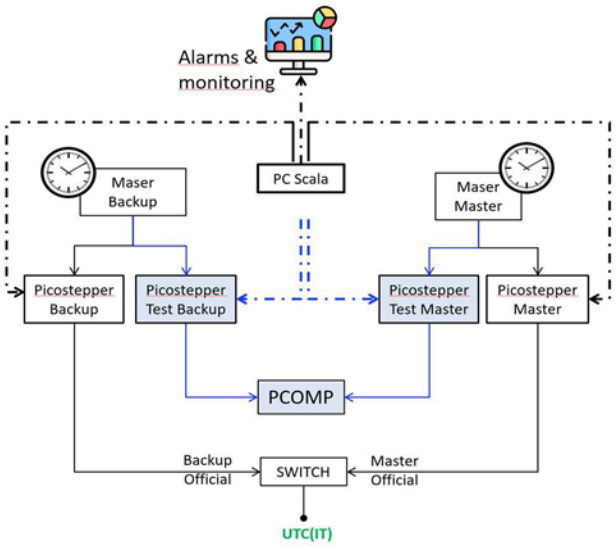


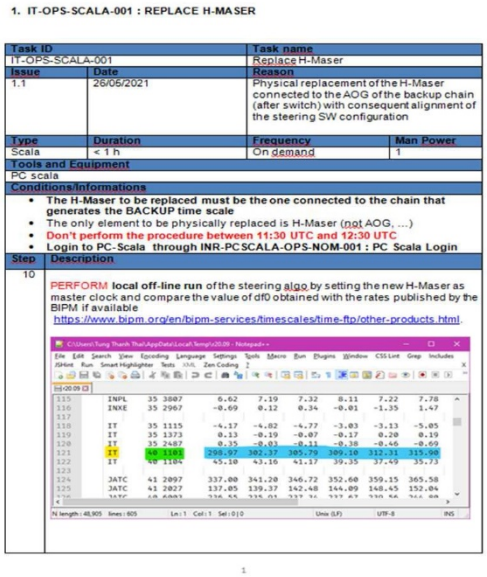
Fig. 1. The generation of UTC(IT)

In order to facilitate the management of all the equipment involved in the generation of the national time scale UTC(IT), the laboratory's informatics infrastructure, in both terms of hardware and software, and the underlying network architecture are redesigned. Particular interests include the need to better access and control these devices remotely without compromising cybersecurity aspects, and to reduce the effort needed for monitoring and maintenance activities.

V. AUTOMATIC MONITORING - MAINTENANCE

The new overall architecture has led to greatly reduced managing and maintenance complexity with respected to the previous configuration.

On the generation of UTC(IT), a daily monitoring report is automatically generated and sent to staff via email. This includes internal parameters of the steering algorithms that are currently both in use as principal steering option and also algorithms under testing; for example, Fig. 5 shows the estimation of the AHM frequencies versus Rapid UTC and INRiM's Cesium Fountain and also the expected steering corrections. These debug quantities are useful for preliminary investigations from remote, in the case of unexpected events. In addition, the email also contains near real-time time transfer results so our staff can easily check the behaviour of the generated time scales at INRiM with respect to UTC, UTCrapid, and the best local realizations of UTC, namely UTC(k)s.



1. IT-OPS-SCALA-001 : REPLACE H-MASER

Task ID		Task name	
IT-OPS-SCALA-001		Replace H-Maser	
Issue	Date	Reason	
1.1	26/06/2021	Physical replacement of the H-Maser connected to the AOG of the backup chain (after switch) with consequent alignment of the steering SW configuration	
Type	Duration	Frequency	Man Power
Scala	< 1 h	On demand	1
Tools and Equipment			
PC scala			
Conditions/Informations			

- The H-Maser to be replaced must be the one connected to the chain that generates the BACKUP time scale
- The only element to be physically replaced is H-Maser (not AOG, ...)
- Don't perform the procedure between 11:30 UTC and 12:30 UTC
- Login to PC-Scala through INR-PCSCALA-OPS-NOM-001 : PC Scala Login

Step	Description
10	PERFORM **local off-line run** of the steering algo by setting the new H-Maser as master clock and compare the value of df0 obtained with the rates published by the BIPM if available https://www.bipm.org/en/bipm-services/timescales/time-ftp/other-products.html

Fig. 5. Example of written procedure for replacing an AHM involved in the time scale generation chain

Such monitoring described above is an example of a specific service that was recently implemented. In a more generic term, a new monitoring web page (https://www.tfmonitoring.inrim.it) is available for all staff to check easily, and in every moment, the behaviour of the UTC(IT) time scale and all the other parameters of interest, including, but not limited to, internal atomic clocks parameters, environmental parameters, computer status, NTP status and overall system health. Relevant information about our time dissemination services are also made available to public access (Fig. 6).

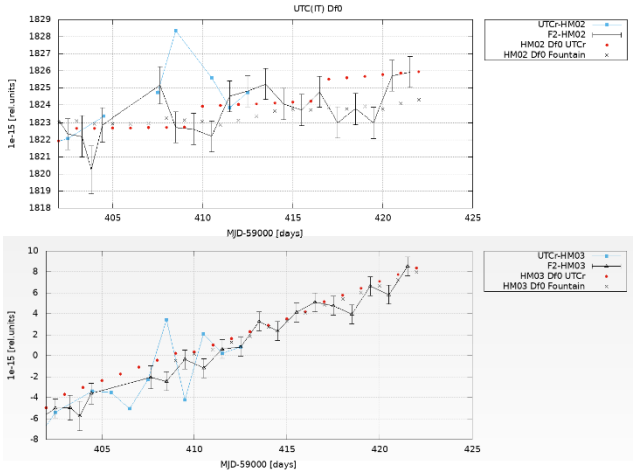


Fig. 6. UTC(IT) monitoring email: Steering corrections

Last but not least maintenance and troubleshooting procedures are defined and made available for staff; for example, see Fig. 7. Such procedures can be triggered by specific automatic alarms, maintenance needs or anomalies detected by skilled operators' observation of monitored parameters. All the maintenance, both preventive and corrective, and contingency procedures are detailed in different steps, in order to allow the proper and easily execution even in the cases in which a quickly and immediately intervention is needed.

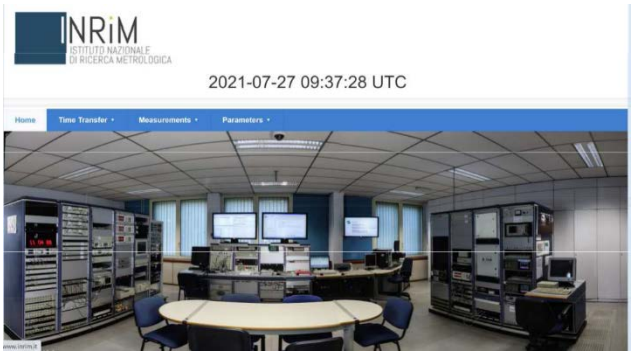


Fig. 7. INRiM Time and Frequency laboratory web page

An efficient monitoring platform is an important value since INRiM has been involving, for many years, in various projects aimed to the control of timing services provided by GNSS systems and augmentation systems, such as Galileo and EGNOS, with European Union Agency for the Space Programme (EUSPA) and the European Space Agency (ESA), alongside many other scientific and industrial partners.

VI. CONCLUSIONS

This approach to automation has proven to be efficient, shown by the state-of-the-art performance of UTC(IT) [5]. The continuous automatic monitoring allows to promptly recognize any possible issue. The modular software architecture guarantees the possibility to continuously improve the algorithms with limited coding workload. Last but not least, the informatics architecture allows a complete remote control of software as well as measuring instruments, which results to be essential during the current pandemic period.

ACKNOWLEDGMENT

Icons were taken from https://www.flaticon.com and https://webtai.bipm.org/database

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