CAT 2 – An Improved Version of Cryogenic Analysis Tools for Online and Offline Monitoring and Analysis of Large Size Cryostats

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Abstract. CAT, Cryogenic Analysis Tools is a software package developed using LabVIEW and ROOT environments to analyze the performances of large size cryostats, where many parameters, input and control variables need to be acquired and studied at the same time. The present paper describes how CAT works and which are the main improvements achieved in the new version: CAT 2. New Graphical User Interfaces have been developed in order to make the use of the full package more user friendly as well as a process of resource optimization has been carried out. The offline analysis of the full cryostat performances is available both trough ROOT line command interface both using the new graphical interfaces.

INTRODUCTION

In order to perform specific and very challenging fundamental physics measurements [1,2,3,4], large mass detectors need to be cool down to very low temperature (few mK temperatures) by means of Large Size Cryostats (LSC). LSC are very complex and delicate systems that need to be operated in real time. In fact, their monitor and control system is quite a challenging task based on the abundant number of sensors, very different from each other. Thus a punctual and precise understanding of the cryostat behavior, in both cooling down and stable mode conditions, is a critical issue in order to avoid the damage of expensive instrumentation as well as to reach base temperature. For this reason, both on-line and off-line analysis are relevant. The former allows monitoring and controlling the cryostat with a dead time that makes possible to operate continuously and in parallel all the several critical parameters and instrumentations. The latter gives information about the whole system, describing the entire process with a more accurate analysis. In both cases, a smart software package able to perform dedicated classes of analysis on the cryostat performances is definitely required. The improved version of Cryogenic Analysis Tool (CAT 2), based on the previous version CAT [5], is a LabVIEW and Root-based software [6,7] package which architecture has been developed in order to fulfill several requirements as the necessity of managing and treating a very large quantity of data coming from different types of sensors. These aspects are directly linked to the most important task of the on-line/off-line analysis of a LSC: understand the behavior of the whole system with an accurate analysis. CAT 2 permits to operate a very precise data analysis of the whole cryostat and also to tailor and customize it in order to fit user analysis needs.

CAT ARCHITECTURE AND FUNCTIONALITIES

DATA ACQUISITION SYSTEM

All the variables and parameters used to monitor and control LSC are acquired with several different DAQ systems; thus, they have different type and standard. Moreover, taking into account the complexity of the cryogenic system, the same variable could be taken from multiple apparatus, resulting in a huge amount of information to analyze. For

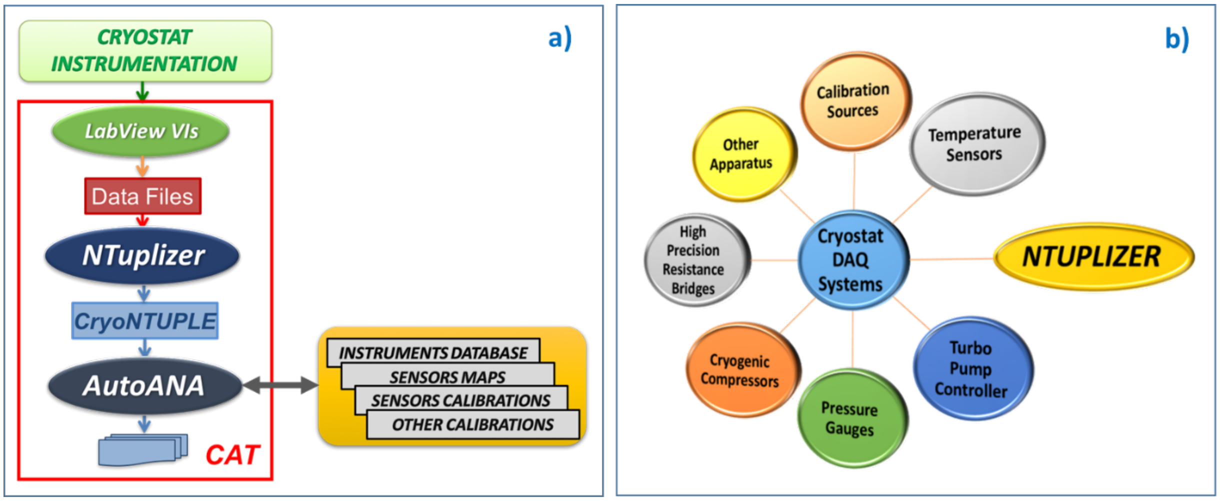

FIGURE 1. (a) Flow Chart of the different signals coming from the real instrumentation going to CAT; (b) The NTuplizer collects, elaborates and stores all the information coming from each single instrument.

example, parameters as temperature and pressure are related to several systems like gas-compressors, vacuum pumps, flow meters and so on; it means that for the same parameter, different standards are used and it requires a dedicated different analysis. All those information needs to be acquired, converted and stored in real time into Data Files, see Fig. 1, in order to perform Online and Offline Analysis. Concerning the former analysis, CAT has the Online Data Acquisition System based on NI LabVIEW software [5] and it is capable of data exchange among a central workstation and numerous distributed sensors. Virtual Instruments (VIs) have been developed in order to monitor and control all the instrumentation. The raw data are acquired, processed online, displayed and finally stored. In this way, a Full Cryogenic System Monitor Interface has been implemented which can be run not only on Personal Computer but even on several industrial platforms. Alarms are extra features that could be calibrated with the Online Analysis to improve safety of both equipment and people.

DATA CONDITIONING: NTUPLIZER AND CRYONTUPLES

CAT architecture is based on several modules. The first one is the so-called *NTuplizer,* which matches together all the information and rearrange them in a proper way to be analyzed. The *NTuplizer* collects, select, elaborates, converts and finally stores all the raw data in a single *CryoNTUPLE* (*.root* files) as schematically represented in Fig. 1. Every *CryoNTUPLE* contains a list of several Root-Trees, one for each instrument acquired by the whole system. In every single section, the absolute time (as a difference between the current TimeStamp and the initial TimeStamp) is calculated. Each *Root-Tree* has several *Root-Trees-Branches* containing all the physical variables acquired class by class, such as time, temperatures, pressures, frequencies, currents, voltages, resistances, etc. The *Root-Leafs*, instead, contains all the relative information coming from each single instrument.

THE ANALYSIS MODULE

The core of CAT is represented by the Automatic Analysis Module (*AutoANA*) and its schematics is represented in Fig. 2. It is a package that performs a sophisticated and dedicated analysis for each single instrument, consisting of C++ codes that calls, iteratively, a list of functions, generically called *CryoPlotter.* Starting from an integer, that defines the Instrument ID Number, these macros can perform analysis either of the whole system or simply of a part of it. Each *CryoPlotter* opens and reads the CryoNTUPLE; then it collects all the necessary information to perform the dedicated analysis required by the operator, see Fig. 3.a, 3.b.

FEATURES, INPUT PARAMETERS AND SINGLE ANALYSIS

Other dedicated modules provide high level of customization. *CryoSettings* module, which takes input variables from *CryoCard,* is an external file where several parameters can be defined by the user for automatic or manual analysis

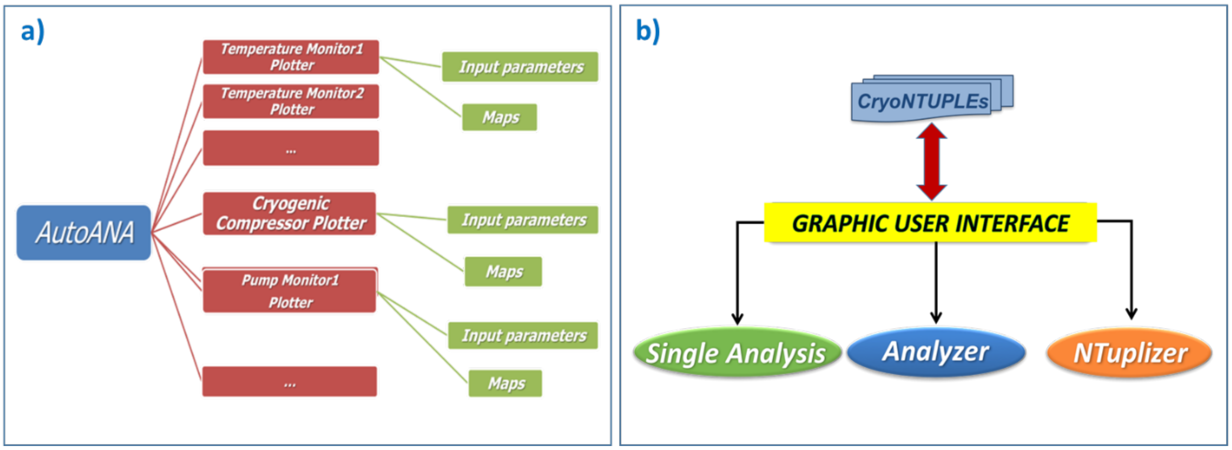

FIGURE 2. (a) The AutoANA consists of a routine that calls iteratively a list of functions, generically called CryoPlotter; (b) CAT 2 Graphical User Interface main structure.

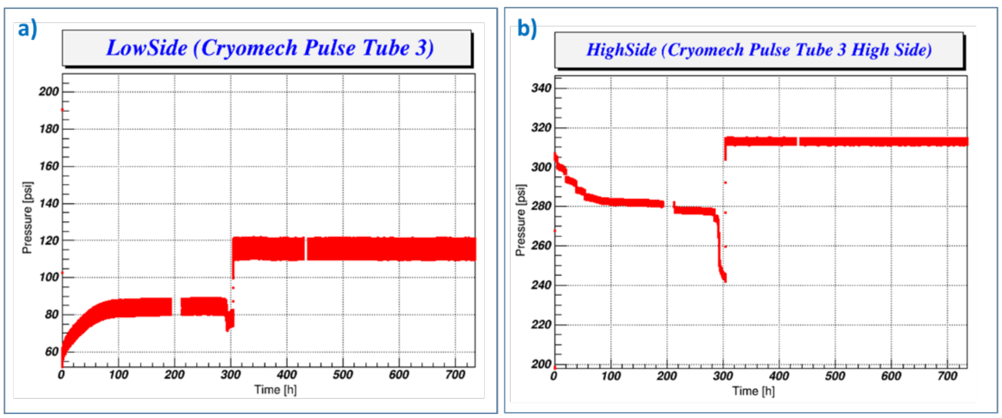

FIGURE 3. GM Cold head ^{4}He compressor LowSide (a) and HighSide (b) pressure distributions.

studies. Furthermore, *CryoMap* modules (see Fig. 2.a and Fig. 2.b) defines variables like sensor names, geometries, calibration tables, offset values and status of each instrument involved in the LSC monitoring system. Dedicated Data Analysis can also be performed by means of single macros, independent from *AutoANA*. The *PerformanceAnalyzer,* for example, analyzes one single sensor, characterizing the performances in terms of efficiency, degradation and so on as a function of the time as well as a function of several other cross parameters, chosen by the user. More sophisticated and customized analysis and modelization of the instrumentation and of the whole cryostat have been also implemented.

THE CAT2 GRAPHICAL USER INTERFACE

The CAT 2 package is an improved version of the previous Cryogenic Analysis Tool. In this version, a new Graphic User Interface (GUI) has been successfully introduced. In this way, all the basic operation of CAT is totally under control and can be achieved with a direct and immediate interaction between software and user. The GUI can be customized depending on the number and type of sensors that are placed on the cryostat. A simply mockup of the interface is shown in figure Fig. 4. In this sketch is shown a simplified version of the real software interface, that is actually in use in some large experiments and R&D. Starting from the raw data, the user has two possibilities: either generate a new *Ntuple* or use a pre-existing one. The new generation and loading processes follow a more structural and robust approach, having as input parameter the folder where all the data files are placed; this is done by means of the Browse button. After the loading/generating phase, the user can perform different kind of offline analysis: the complete one, a single sensor analysis or define his personal and customized analysis macro. A single sensor analysis can be performed by clicking on the chosen sensors, represented on the GUI as triangles or dots of different colors,

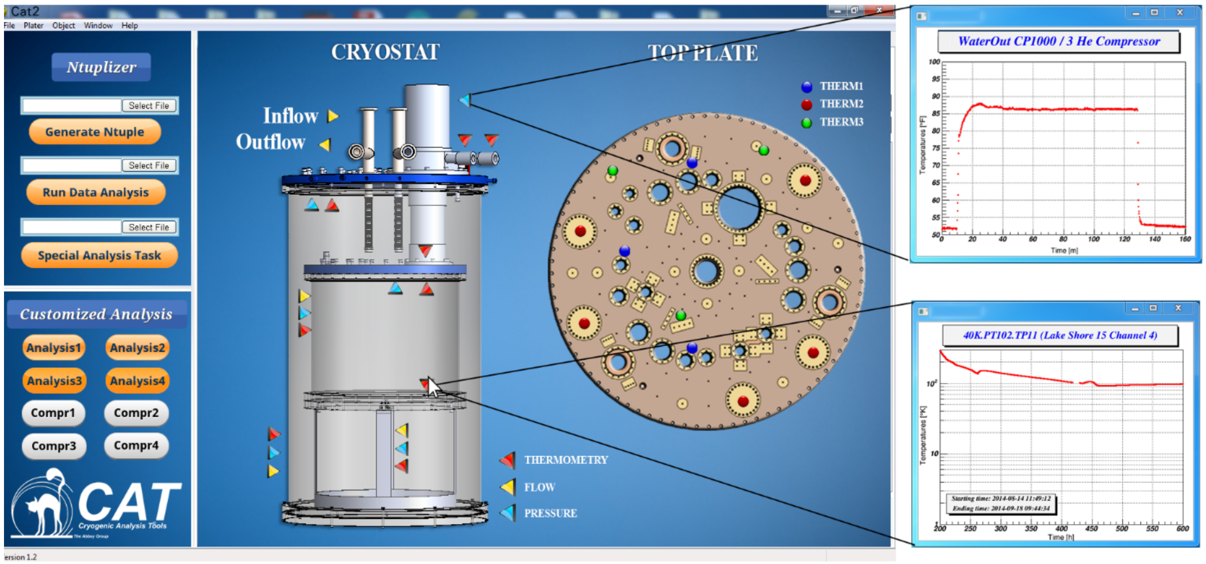

FIGURE 4: An example of one of the many CAT 2 Graphical User Interfaces.

depending on the kind of sensor you are looking at. The resulting plot will appear on a new popup window, directly on screen. In this way, the analysis is focused on a limited number of sensors, saving memory and CPU resources. The complete analysis can be performed using the "Run Dedicated Analysis" button. Finally, a customized analysis code, based on the *Cryontuples*, can be loaded from the dedicated section.

CONCLUSIONS

An improved version of Cryogenic Analysis Tool software package called CAT, Cryogenic Analysis Tools, has been developed in order to perform analysis of Large Cryogenic Systems where the number of acquired sensor can be large. The version 2.0 of the CAT (CAT 2) Package have been released, it is properly working and has been used to monitor and control the cool down of a very large size cryostat presently under test. A Graphical User Interface has been added. It can be customized to match the precise configuration of sensors (i.e. location, type, number) and make the analysis easier for the user. With this new approach, memory usage and CPU resource can be saved.

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