Instrumentation & Control Architecture Applied for safe operation of a Hydrogen Isotopes Storage System

Eusebiu Ilarian Ionete, Bogdan Monea*, and Marian Vacaru

Abstract— A critical issue, in direct connection with the tritiated heavy water processing in a detritiation plant, is the safe storage of the obtained Tritium, both for environment and operating personnel. The properties of Hydrogen storage used materials refers to their ability to high "connect" Hydrogen, to have a large storage capacity, to be easily achievable and, if necessary, to allow its easy recovery. The metals and intermetallic compounds are the most used materials. To build a safe storage container for Tritium resulted from a heavy water detritiation facility, we investigate titanium powder and titanium sponge as a storage material for Hydrogen isotopes, Protium and Deuterium. Since the reaction of metal hydride formation is, in most cases, sever exothermic and for many materials almost spontaneous, new control system architecture applicable to Hydrogen isotopes storage media, taking into account all those properties, is presented. This architecture uses the resources of a DCS (Distributed Control System), based on i-processor technology (able to integrate all typical control functions, friendly display options, an alarm management system, historical data bases and advanced control tools). These resources usage allows us to operate a Deuterium and Tritium storage system under automatic control and to use an advanced Operator Interface too. The DCS closed loop algorithm is used for manual and automatic closed loop control for monitoring the corresponding operating conditions.

Keywords—architecture, control system, hydrogen, isotopes, storage, safe operation

I. Introduction

HYDROGEN isotopes storage systems design rely on smooth interaction and integration between schemes, components and volumes processed. Do not refer only to the design of a classical system of Hydrogen storage but to a complex control system dedicated to storing and handling Hydrogen isotopes, tracking distribution routes, terminal equipment and return, relief and exhaust systems. In the design stage is extremely important to establish the instrumentation and control system - based perspective. The handling of radioactivity in a nuclear power plant or any other nuclear installation as well as in nuclear medicine is subject to many restrictions and relevant legislation, concerning the compliance of safety measures. One important safety task is the securing of a contamination-free working environment, typically needed for the personnel, working inside the controlled areas [1].

Although there are opinions sccording to which in a time with already tight budget, providing detailed specifications will be added to the project cost, to meet the design intent, a deficient control system design will certainly lead to additional human and financial effort outside the project budget. The costs can be controlled by standardizing the proposed methods and by directing the task to those in the best position to accomplish it.

The main purpose of this paper is to achieve insight to a control system architecture and design process successfully used to provide a really smooth operation of a control system for particular storage medium of Hydrogen isotopes. Even if the outlined process is not the only one viable method for successful control design, it provides a model to emphasis key elements of design. These elements tackling must be made directly and proactively to ensure that design intent is fulfilled.

II. Hydrogen Isotopes And Storage Media

Hydrogen, one of the key energy medium for the „Hydrogen-based economy" of the future has three naturally occurring isotopes, the common or light Hydrogen called protium (^{1}H), found in abundance in the universe, the heavy Hydrogen called Deuterium (^{2}H) representing up to 0.015% of the overall Hydrogen found in nature, and the super-heavy Hydrogen, the radioactive one, called Tritium (^{3}H). The heavy Hydrogen isotopes are of great importance in the nuclear energy technology, both ^{2}H and ^{3}H being promising fuel components for the thermonuclear fusion reactors in the future. A reliable, economical and safe storage medium is a critically needed component of Hydrogen isotopes applications.

Used in many experimental research studies focused on the field of substances produced by deuterated microorganisms, synthesis of deuterated drugs and polymers, synthetic deuterated fibers, gas to coat metal oxide semiconductor transistors and other components for laser and optical technologies, Deuterium is also very useful during the cleaning

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processes or prior to maintenance of Tritium production facilities. It can be produced from heavy water, by the means of several technological processes, electrolysis for example and stored for use when appropriate.

In contrast with Deuterium, Tritium, a radioactive isotope generated by nuclear reactors, is currently in researchers' focus due to the implications of its impact on the environment, and the prospects of containment of that impact. At Tritium decay ^3He stable isotope is produced and β-radiation with relatively low energy is released (E_{max} = 18.6 keV, E_{ave} = 5.71 keV). It takes about 12.3 years for half of any given quantity of Tritium to decay into helium-3. This corresponds to an annual decay rate of about 5.5%. Helium-3 is a rare isotope of Helium-4, an inert, nontoxic, nonradioactive gas. Helium-3 absorbs neutrons; this property has resulted in its widespread use for neutron detection. Neutron detection is a key component of applications in security, medicine, industry and science. Another property is the ability to polarize its nucleus with application in Magnetic Resonance Imaging (MRI). Finally, helium-3 has unique cryogenic properties. Low-temperature physicists use a mixture of helium-3 and helium-4 to achieve temperatures just a few thousandths of a degree above absolute zero (millikelvins). At temperatures below 2.5 millikelvin, helium-3 becomes a super fluid [2].

The presence of Tritium in heavy water (primary coolant and moderator) used in CANDU nuclear reactors is a major source of radiation for operations personnel and radioactive contamination of plants. During the life time of a reactor, as a result of neutron capture, Deuterium in heavy water is partially converted to Tritium. The quantity of Tritium in the reactor systems tends to increase to an equilibrium value.

To eliminate the negative effects due to presence of Tritium in heavy water used in CANDU type nuclear reactors worldwide, the possibility to achieve equipment for Tritium extraction from tritiated heavy water has been researched. At ICIT Ramnicu Valcea, Romania an experimental pilot plant for Tritium and Deuterium separation was build, the research desideratum conducted on this facility being the development and implementation of heavy water detritiation technology at industrial scale to Cernavoda NPP.

Existing Hydrogen storage methods include compressed Hydrogen, liquid Hydrogen, metal hydrides and chemical hydrides [3]. An important issue to solve after Hydrogen isotopes or isotope mixture have been obtained is related with their safe storage, especially for obtained Tritium, which is radioactive. Storage in solid form is preferred (metal tritide or deuteride) at the expense of a gaseous or liquid storage [4]. The storage used materials have to be able to strong "bond" Hydrogen (Deuterium or Tritium), at normal temperature and pressure, to have a large storage capacity, and the obtained tritide/ deuteride to be easily obtained and to allow, if necessary, Tritium/Deuterium recovery. Metal tritide/deuteride reaction is exothermic and usually spontaneous at room temperature, especially when the metal is finely divided. Since the reaction is reversible, Tritium/Deuterium immobilized in the solid form can be recovered by heating the storage vessel at a specific temperature characteristic of each material.

Tritides can store large quantities of Tritium without taking-up a large volume. Materials that may be used are titanium, uranium, intermetallic compounds (ZrCo, ZrNi). Since the partial pressure of Tritium in the absorbent bed is very low, the bed absorber works as a vacuum pump that stores all Hydrogen isotopes. Depending on the chosen metal storage tritide are both advantages and disadvantages:

- *Titan* is an inexpensive metal that can absorb and store Tritium in a compact solid form at a pressure of approx. 1.33 E-07 mbar. It is used as a storage medium for long periods and retains decomposed Helium to a concentration of 0.3 to 1 atom of He at each Ti atom. Titanium tritide is very stable, even when exposed to air. Instead, it is difficult to recover stored Tritium on titanium bed than on other metals, being necessary to provide a large amount of heat [5]. The thermodynamic parameters of Tritium absorption of titanium between 500 and 550 ºC can be calculated with the equation of Van't Hoff for engineering purposes:

$$\ln P_{H_2} = \frac{\Delta H^0}{RT} - \frac{\Delta S^0}{R}$$

where P_{H2} is the equilibrium pressure of plateau, H^0 the standard enthalpy of reaction and S^0 the standard entropy of reaction.

As shown in scientific literature [6] the thermodynamic parameters for Hydrogen adsorption on titanium sponge ΔH^0 ($kJ.mol^{-1}$) and ΔS^0 ($J.K^{-1}.mol^{-1}$) have the following values: 101.5 and 165.3, for the first plateau and respectively 179.6 and 290.3 for the second plateau.

- *Uranium* is the most used material in Tritium storage beddings, due to fact that Tritium can be easily and quickly recovered, and because it removes impurities (gases) that can be accumulated during the process (^3He, N_2, O_2, and Ar). In the presence of uranium, at room temperature, Tritium forms uranium tritide. Inert gases, for example Ar, can be removed by pumping with a vacuum pump after the pressure has stabilized. ^3He is pumped after initially absorber bed was warmed. Instead, N_2 and O_2 form stable compound of uranium in absorbent bed that can not be removed at all. [6]
- *Intermetallic compounds* (ZrCo, ZrNi) are used for Tritium temporary storage. For intermetallic compound ZrCo increasing the number of absorption/ desorption cycles the storage capacity decreases due to zirconium hydride formation. ZrNi presents properties of a good Tritium storage material due to a not very high temperature necessary for recovery, but, because of high balance pressure at ambient temperature it is possible leakages to occur and operating personnel and the environment can be affected. [6]

III. Experimental

To comply with European safety norms regarding Tritium storage a well elaborated design of Tritium storage tank must be realized. A first step in our study was related to Hydrogen isotopes adsorption. For this purpose an experimental stand (Fig. 1), consisting of a reactor vessel, Hydrogen and Deuterium pressure cylinders, buffer tank, manual, control and pressure reducing valves, valves with an open/close characteristics and related measurement instrumentation (pressure, temperature and vacuum), has been designed and built.

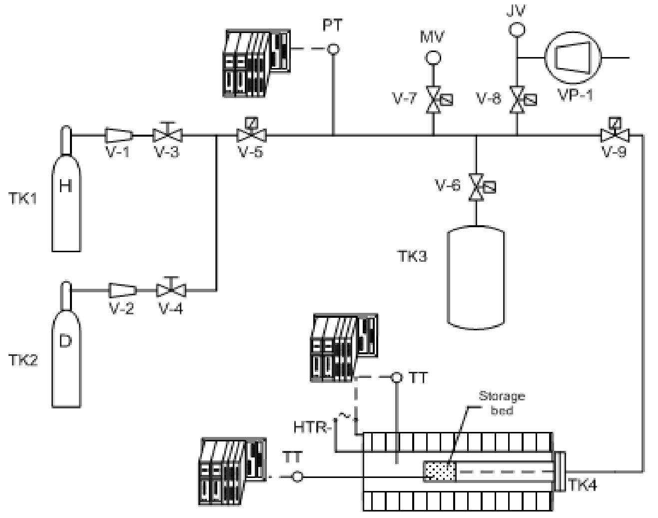

Fig. 1 Hydrogen isotopes storage experimental device

(V-1, V-2 - Pressure reducing valves; V-3, V-4 - Manual isolating valves; V-5 ÷ V-9 - automatically operated valves; TK1 - Hydrogen tank; TK2 - Deuterium tank; TK3 - Metering vessel; TK4 - Storage vessel; MV - Vacuumeter; JV - Vacuum gauge; PT - Pressure transducer; TT - Temperature transducer; VP-1 - High Vacuum Pump)

Pressurized gas cylinders (TK1 and TK2) filled with Hydrogen/Deuterium were used as source for isotopes. The bottled gas purity, for both Hydrogen (Protium) and Deuterium, was 5.0. To measure the correct amount of gas that was meant to be stored, a metering tank (TK3) has been provided, with well-defined volume of 0.5 liters and whose filling pressure was well controlled and measured.

Two different storage media have been tested: titanium powder, for the first set of experiments, and titanium sponge for the second set of experiments. After an activation process [7, 8], followed by cooling to ambient temperature, a highly controlled amount of protium/Deuterium gas was introduced into the reactor, at a pressure conveniently set.

Activation of metal samples under vacuum, by insufficiently using high activation temperature will cause future incomplete samples hydriding. Compounds adsorbed on metal surface are not completely eliminated, preventing the dissociation of Tritium molecule and the beginning of the absorption process. The required time for activation process is different depending on the material used for absorption. If the samples are heated for insufficient time, similar to activation temperature, adsorbed impurities can't be removed from metal surface, preventing Tritium adsorption. Thus, to obtain maximum Tritium concentration in metal samples, in both powder and sponge titanium form, it is enough to heat the sample under vacuum for 5 hours since reaching the temperature of 600^oC.[6]

The temperature in the absorbent bed and on the reactor walls was measured by means of thermocouples. Measurement results are shown in Fig. 2, 3.

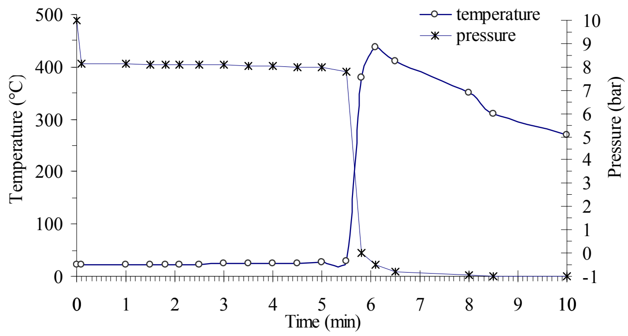

Fig. 2 Protium absorption curve on titanium powder

It can be seen that the increase in temperature is fast and significant, these being the major issue to be considered in the designing process of a large and long term storage tank, if one with appropriate design is not available on the market. The same factors must be considered for the correct election of the gas admission control valves characteristics with adequate flow coefficients.

Hydrogen isotopes may be transferred out of manifolds, containers, tanks etc., by heating and pumping out all the gas retained on the bed surface.

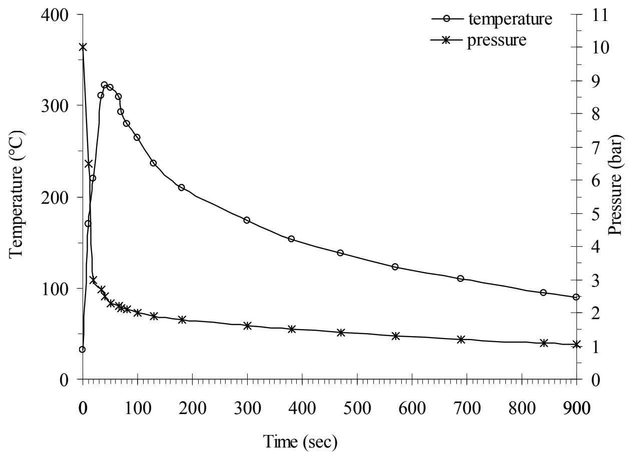

Fig. 3 Deuterium absorption curve on titanium sponge

The proposed solution for Hydrogen isotopes storage tank (Fig. 4) is in the shape of double cylinder, with the inner cylinder accommodating the storage alloy.

The inner storage tank is provided with means for heating and cooling, on the outside walls, and with a tube for Hydrogen passage during adsorption and desorption process. The inside design is in such a way that it provides a large area for gas adsorption and desorption per unit volume and thereby increases the amount of Hydrogen adsorption per unit volume.

Because Helium-3 is produced during storage by Tritium decay, from Titanium bed, and it is present in gas form inside of the vessel, the pressure will build-up and the vessel must be designed to sustain the whole amount of decayed Tritium.

The design permits efficient cooling of each inside storage unit having a large area for heat transfer [9].

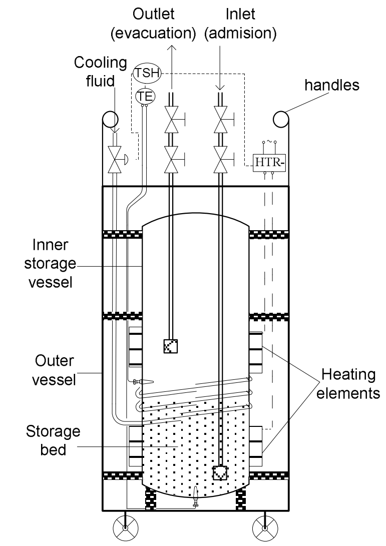

Fig. 4 Hydrogen isotopes storage tank

According to the isotherm data, titanium can absorb Hydrogen up to about 2 atoms of H per atom of Ti. The capacity for protium and that for Tritium are expected to be about the same. According to materials research, titanium films can be charged with pure Tritium to 1.9 T/Ti, and with Tritium and Deuterium mixtures to 1.62 (T+D)/Ti [8, 10]. The capacity data for protium should apply to Tritium for all practical purposes.

IV. Layout Of The Hydrogen Isotopes Storage System

Starting from the adopted constructive solution for Hydrogen isotopes storage tank (Fig. 4), architecture of a Hydrogen isotopes storage system, operable in a safe and easy manner, which includes several getters and all related support systems, it is proposed.

A layout diagram of the proposed hardware architecture, in which some of the components have been deliberately omitted in order to present a most simple facility, is given (Fig. 5). The scheme is limited to showing the routes taken by the various media used, the most important devices/equipments and the various analysis take-off points necessary for the description of the analytical problems involved [11].

Process systems and equipment that carries Tritium is contained in a dry-nitrogen-purged secondary enclosure in the form of a glove box.

The storage system is equipped with specific analytical tools for processed Tritium inventory analysis (gas chromatograph) and for measuring the radiological Tritium in atmosphere concentration in the glove box (Tritium monitor). These resides in a air purged compartment inside the glove box which is kept at the same pressure level as the room by a pressure balance pipe equipped with a non return valve.

The nitrogen-purged glove box has access, through gloves, to equipment for normal operation and maintenance activities. The nitrogen-purged glove-box atmosphere is at a slightly negative pressure with respect to the room atmosphere and contains <10 ppm oxygen. The nitrogen-purged glove-box atmosphere is monitored for Tritium, oxygen, water vapour, pressure and temperature. The nitrogen-purged glove box has adequate provision for moving equipment in and out.

The box layout should be able to perform a range of issues: both Deuterium and Tritium storage process functions, with proper handling; to provide and assure adequate protection to limit radioactive materials releases; another clean-up system, located in another enclosure, for the clean-up purposes in case of any leaks; and to have low level of oxygen to prevent explosion mixtures formation. Depending of the isotopes source, the system can be operated as batch process and limited to previously approved Tritium quantity, according with regulatory body, to limit the heat generated during the Tritium immobilization process and to limit the consequences of the malfunction leading to a Tritium release [12, 13].

The major objective of the proposed system, referring to Tritium - low radioactive material, is to assure a very low dose to facility staff and to the general public according with the principle ALARA (As Low As Reasonable Achievable). The architecture includes safety systems and control systems, consisting of area Tritium monitors, able to maximize safety and to minimize the reliance on managerial control [14].

Start-up procedure **-** before Hydrogen, or Hydrogen isotopes, can be allowed to enter the system all the various sections must be flushed out with nitrogen, N_2, or helium, He, in order to remove the air. The operation is completed by using a vacuum pump and the corresponding control instrumentation to evacuate the remaining gases.

After its activation process [7, 13] outside of this facility, the getter tank is manually entered through transfer ports inside of the glove box and manually connected to dedicated records. The glove box is then sealed by closing the transfer ports. During all the operations the concentrations of impurities inside the glove box is continuously monitored. If the level of impurities is in normal/acceptable limits, the process of adsorption can be triggered by opening the tube connection to the Tritium metering tank (TMK) by means of a dedicated pneumatic valve. If the TMK vessel was filled previously all the gas will go straight into the getter or, in the situation when the TMK vessel was empty a delivery of a batch from another system that is interconnected with is expected. This may be a cryogenic distillation system, an electrolyzer or another source of Hydrogen isotopes.

To keep the pressure of the glove box atmosphere below the room pressure during the transfer process, the port doors are never simultaneously open. The transfer port doors are equipped with position indicator switches for open/close control.

With the exception of getter introduction to the glove box all other maneuvers are DCS controlled.

Safety - A very important aspect is installation safe operation. Most problems are located at storage tanks, measuring tank and technological routes, where the possibility of any leaks inside glove box can occur. The system is equipped with the following safety installations:

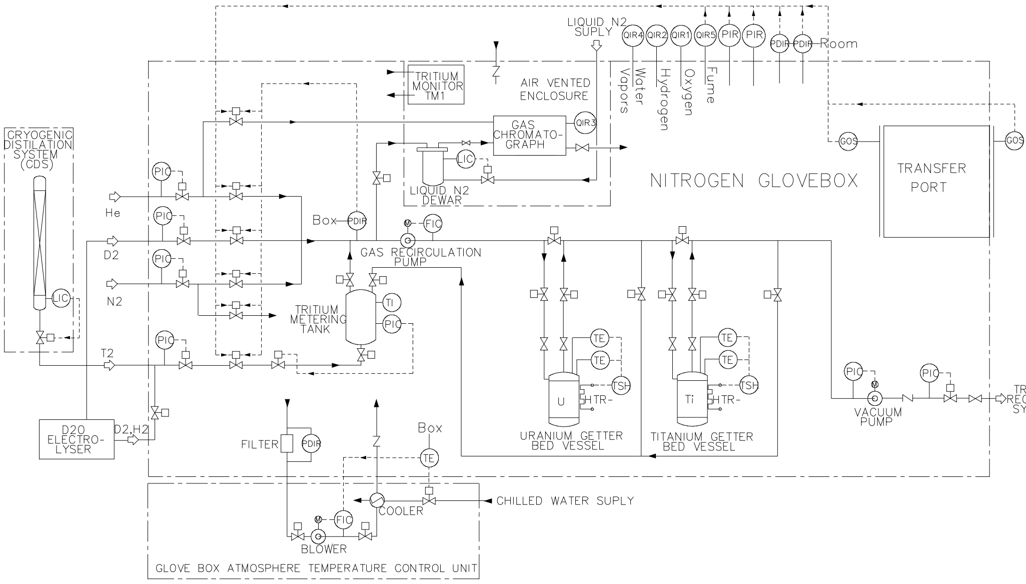

Fig. 5 Hydrogen isotope storage box

- Redundant pressure difference measurements between glove box atmosphere and room atmosphere;
- Redundant pressure difference measurements between primary system and glove box atmosphere;
- Redundant temperature controllers for the storage tanks;
- Temperature control of the glove box atmosphere;
- The whole equipment, which is located in the glove box, has to be certified Anti-ex.

Analysis instruments **-** Several analysis instruments and equipments are used to survey the glove box facility critical parameters. The particular analysis take-off points (Figure 5) and a short indication of component measurement is provided:

- QIR-1, instrument for determining low O_2 content in glove box atmosphere, coming from in-leakage from the air purged compartment or from the room atmosphere;
- QIR-2, instrument for determining low H_2 content in glove box atmosphere, coming from in-leakage from the room atmosphere or from the primary system in form of HT;
- TM-1, Tritium in glove box atmosphere measurement;
- QIR-3, gas chromatograph, for quantitative evaluation. This type of measurement instrument is widely used in chemical applications for determining chemical composition of a mixture of gases both quantitative and qualitative. Separation is based on the composition of the mixture of gases according to their chemical attributes. The sample is injected into a gas carrier along a chromatography column. In this the separation of mixture components takes place, the species being adsorbed on the surface of column packing. The adsorbed gas will be stopped in the column, resulting an less average speed of it. Finally, at the end of the column, the components will go out at intervals of time can thus be measured by special detectors (detectors with thermal conductivity, with flame ionization, mass spectrometers, or ionization chamber with very low volume); [15]
- QIR-4, water vapors determination, coming from in-leakage from the room atmosphere;
- QIR-5, fume detector in case of fire event.

By measuring of critical values, the DCS sets an alarm to the local monitor and to the centralized computer and hardware control system.

V. Measurement, Control And Monitoring Architecture

Industrial process control systems have often two levels: the low level of equipment and simple control logic and the upper level of complex control of production [16]. In this paper, the entire measurement, control and monitoring architecture, based on the hardware facility presented in Fig. 5, was designed to work on three levels of control (Fig. 6). First level is the field level, where all the transducers, analyzers,

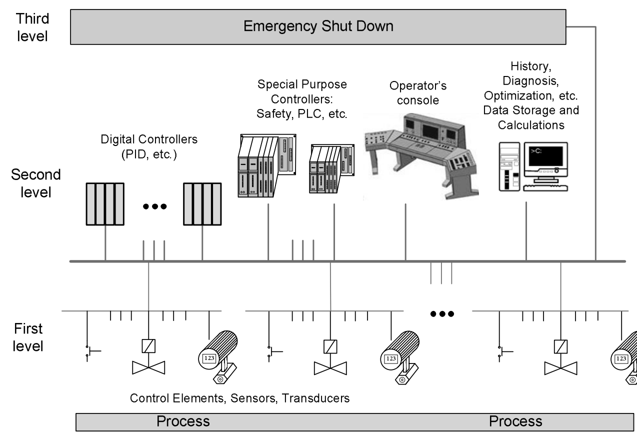

Fig. 6 Instrumentation & Control Architecture

switches and actuators reside. Second level is the DCS level, where the measured parameters and field information, with the help of interfaces hardware and software, are transferred to the human operator in intelligible way. The parameters history evolution, the hardware memorization of them and the level limits resides on this level. The third level is for system emergency shut down and override.

The use of Distributed Control Systems (DCS) useful to control complex process in the industry that involves multiple variables and control loops. The continued development of these DCS systems by manufacturers result in great advantages for the users of this kind of technology [17]:

- flexible hardware architecture and software tools [18] which come with advanced algorithms of optimization, modelling and control;
- robust communication systems between hardware components such as workstations, smart devices, sensors;
- capabilities which manage alarms and abnormal events;
- integrated diagnostic features in hardware, communications and control;
- capacity to have redundancy in the design of the systems in both hardware and software levels;
- ability to create historical data bases and efficient manipulation;
- security by having limits on the access to the parts of the control system;
- user-friendly graphic tools that are useful in manipulating the system.

This architecture uses the resources of a DCS (Distributed Control System) which is based on i-processor technology (able to integrate all typical control functions, friendly display options, an alarm management system, historical data bases and advanced control tools). These resources usage allows us to operate a Deuterium and Tritium storage system under automatic control and to use an advanced Operator Interface too. The DCS closed loop algorithm is used for manual and automatic closed loop control for monitoring the corresponding operating conditions.

The use of the DCS graphics interface results in easier operation of the storage system for operators. The HMI has three main functions [17]:

- to provide visualization of process parameters;
- to enable interaction with the process;
- to provide alarms and event notification to the operator about any abnormal situations in the plant.

The following general design criteria must be considered:

- simplicity;
- easy and fast verification of a failure, clearly recognizable by the human operators, without intrusive testing;
- "fail-safe status" definition, in consequence of any possible failure (loss of power, of communications, bad quality of some peculiar process inputs);
- single failure tolerance;
- separation (no propagation of any fault to other DCS units)
- easy maintenance also while the system continues its normal operativity (applications changes, or different configurations setting can be done "on-line" for processor redundancy, the module insertion/removal is possible with the cabinets powered)
- use of standardized components, thus limiting the qualification needs of equipment employed.

A. First Level

Sensors, switches and actuators - the control system performance is related with the quality of the sensors that provide information to it and the actuators that allow it to interface the equipment. This devices should be reliable and with a very good accuracy. Thus, the elaboration of specifications for these components, and the selection of them based on the specifications, is critical. The interface between the DCS processors (Level 2) and the sensing and actuating system (Level 1) is provided by the controller Input/Output (I/O) circuit boards. While it is not necessary to understand or specify the details of how this interface works, in the process of elaboration it may be desirable to include language in the specifications that covers some features in this area [19]. Topics to consider include I/O modularity, processor modularity, and override capability.

In our system sensor specifications should address every type of input that is required on the project from the analog temperature and pressure sensors to the digital current sensors, flow and atmosphere content. Due of the specificity of the system some sensor types may involve multiple specifications paragraphs to define the accuracy or sensing element requirements for different applications within the system. Actuator specifications also need to be tailored to this particularly case, the Hydrogen isotopes storage, where all the actuators are powered with nitrogen in order to keep the oxygen level inside of the glove box at a low level.

In many instances the actuator specifications will be included with the specifications for final control elements like control valves. Regardless of where they occur, the specifications should address power source (pneumatic, ac or dc electric) actuating force, actuating speed, precision, position feedback requirements and auxiliary equipments such as positioning relays, a gauge for pressure indication and limit switches. Where DCS controllers will drive pneumatic actuators specifications regarding the electronic to pneumatic interface devices should also be included. Important items to address might include the required output span, requirements for a gauge to indicate input pressure, the ability to manually override the output and the micro switches to indicate the valve current status.

*Final control elements - t*he most common final control elements in the current technology, used for the above system presented in Figure 6 are control valves and variable speed drives. Each of these components requires special attention in the specification language. The control work of these components must coordinate with the work of other components with different specifications [19]. The multi-disciplinary aspects of these elements may also require special attention to coordination during design since the design work can be done under different sections or divisions of technical specifications.

The technical specification for the chosen control valves for the project must include important parameters and must be addressed in specific terms in order to achieve a successful design. These parameters include, but are not limited to: materials of construction, type of interconnection to the upstream and downstream system, temperature and pressure ratings, actuating gas for specific situations, actuator power source, failure mode upon loss of power, operating speed and sizing, presence of miniature switches to confirm the current status of the valve.

For the enumeration and identification of measurement and drive points a specific name was given to each measurement and actuating location involved in the process automation management. This was done according to standard international symbols used in automation (ANSI/ISA-S5.1-1984). In order to ease the implementation of software program and to facilitate technology process systematization to each measurement or process actuating point has been allocated a number of individualization containing:

- Point short name – provide a consistent way to reference the point in the layout documents;
- Point symbol – provide an indicative way to reference the point in the layout documents and design schemes;
- System and service – consists in the full name of the point and the system that it corresponds to. For multiple installations the first number can indicate the memberships of that particularly installation;
- Sensor type – only a minimum level of information about sensor type is presented at this level, the rest of them are part of the technical specifications [19].

B. Second Level

Control and monitoring points - system control and measurement points reside on this level. The human operator working on this level is necessary to have not only a good knowledge of the system design intent but also a very good understanding of how the system will be commissioned and operated for life. Taking into account how the system will work when selecting control and monitoring points will achieve a more easily operated facility. On the glove box layout diagram presented on the console screen all the measurement points will show the current measured value respectively:

- Temperature - temperature measurement points helps diagnose operational problems, critical for the well working of the installation;
- Pressure, differential pressure - to achieve the pressure differential concept between rooms and for the measurement of gas quality stored in system tubes and metering tank (MTK) the pressure measurement is essential;
- Oxygen content – is continuously measured and monitored to maintain hazardous protection of the glove box atmosphere;
- Hydrogen content – is the first step in tightness diagnosis of the inside of the glove box elements and for preventive maintenance.

Monitoring and Diagnostic Points - serve three main purposes: to understand system performance, to add flexibility to the system and as a tool for tracking maintenance needs. Monitoring points are often utilized for manual automated system diagnostic methods to detect problems. Smart alarms can notify the operator of these problems. Examples of monitoring and diagnostic points will include the switches installed on open/close valves, to confirm the current status, and on the transfer ports doors, to validate next steps in tools the transfer procedure. It will be less expensive to install monitoring points during the initial construction phase than later. If the point must be added during the start-up phase in response to a commissioning need, an alternative solution has to be find with a lot of procedures involved witch is not always an easy task.

Monitoring points also provide valuable information for maintenance. For example points that notify the operator of high filter pressure drop are especially important in detecting dirty filters, since the filter pressure drop varied with flow, points that measure and records maximum temperature are important for system components life evaluation.

Physical points and Virtual points: The value of virtual points - computer based control systems, DCS or PLC, employ two classes of points: physical points and virtual points. Physical points exist as hardware devices, typically sensors and actuators. They are hardwired to the controller I/O to allow the control program to execute the intended functions and provide information for diagnostics and troubleshooting. In contrast, virtual points exist in the controller's memory and are used to store set points, counter and timer values, perform mathematic calculations and act as logic flags in case of over fulfillment of preset values. They may also represent physical quantities such as incrementing number based on opening and closed of valve, flow rate calculated based on a differential pressure signal or consumption calculated from flow rate and a temperature difference. Not all virtual points are important for automatic control. However, the information provided by virtual points can be very useful to human operators. It is important that the designer ensures that the details associated with the virtual points are a part of the turn-over package provided to the Owner once the system is commissioned and tested for properly functioning.

Network Card to Obtain Monitoring Points – a piece of equipment with many output parameters that interfaces with the control system in an economical way to obtain operational information. While the input and output from a single loop should be hardwired to the controller where the loop resides other points such as the start/stop command and proof of status feedback can sent across the network since they are generally not continuously varying processes and are not part of the control loop. For example, the following points should be available through the network card:

- proof of operation
- selector switch status contact (hand/auto/off). This point is absolutely mandatory and in the same time very desirable. Allows an alarm when the piece of equipment has been into a mode where the drive is not functioning. One point with a general alarm can be used to monitor both switches.

For the cost of a network card and twisted shielded pair, the numerous parameters that go along with the drive are available, including start/stop, feedback proof of speed, status contact, current, kW, faults (programmable), and diagnostic points. Since these points can be obtained by the network card instead of hardwiring, more controller I/O capacity is available for other points. A network card can access many points and drive parameters for less money than would be spent hardwiring.

C. *Third Level*

The third level is reserved for proper isolation and emergency shut down of the system if, in the upstream Hydrogen supplying plant somewhere, an abnormality is detected. It acts as master for the first two levels and lead to total isolation of the installation. It is available to plant engineers with the use of a password. At this level resides the design procedure that compute the PID parameters and the control options for them, like auto tuning and adaptive control. DCS must provide available self-diagnostic procedures to check incoming failure of components and must be possible to force the equipment in "fail-safe" conditions, if those are not available, for example by personalization of functional blocks used in application programs.

V. Conclusion

Hydrogen storage systems designs hinge on the smooth, integrated interaction between the systems components and the processed volumes. The solution presented above it is not just a Hydrogen storage system, it is a system design and made for handling Hydrogen isotopes, especially Tritium, a distribution system, terminal equipment, return system, relief and exhaust system. It is critical for the instrumentation and control to reflect this system-based perspective.

The system configuration with the proper diagram allows the user to see the entire process and visualize the potential interactions without having to flip between multiple documents. A detailed system sequence of operation provides a good overview of how system is intended to perform, where are the critical measurement points, in some situations with the representation of maximum admissible values, and a useful reference for the commissioning and operation personnel.

Taking advantage of computer based DCS the system integrates all typical control functions.

The technical specifications associated with the instrumentation and control system are an important part of the overall control design because they contain many of the technical details that are critical issues to success. The function and content of the technical specifications are just as important as other mechanical section. The lack of detailed control system technical specification can lead to difficulty in operation.

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