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REMOTELY OPERATED EQUIPMENT FOR INSPECTION, MEASUREMENT AND HANDLING

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Abstract

As part of the application of ALARA radiation dose reduction principles at CERN, inspection, measurement and handling interventions in controlled areas are being studied in detail. A number of activities which could be carried out as remote operations have already been identified and equipment is being developed. Example applications include visual inspection to check for ice formation on LHC components or water leaks, measurement of radiation levels before allowing personnel access, measurement of collimator or magnet alignment, visual inspection or measurements before fire service access in the event of fire, gas leak or oxygen deficiency. For these applications, a modular monorail train, TIM, has been developed with inspection and measurement wagons. In addition TIM provides traction, power and data communication for lifting and handling units such as the remote collimator exchange module and vision for other remotely operated units such as the TAN detector exchange mini-cranes.
This paper describes the equipment built to-date, the on-going studies and explains the services a remote handling system can offer.

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1 INTRODUCTION

As the LHC project moves from installation and commissioning activities to the operation phase, equipment groups have become more and more aware of their need to access the tunnel to inspect, measure and handle equipment whilst minimising the dose to their personnel. A safer way to approach their equipment is remotely by using a ‘machine’ that can remotely look, take measurements and be operated from a control room.

A remote-controlled machine access will minimise the personnel dose and allow evaluation of human intervention needs before sending in personnel. This will allow unnecessary interventions to be avoided. Any remote systems must be very reliable to avoid repair interventions as otherwise the goal of minimising doses will be lost.

A general review of all remote operation needs has come up with quite a long list.

1.1 Vision and sound

It is requested to inspect equipment to check displays or general equipment condition. An example is to check the icing of cryogenic components. It will be useful to inspect the tunnel conditions (e.g. water leaks) and to identify a gas leak or smoke position.

To avoid bring our body into the tunnel as a support for the eyes and so to go into radioactive zones just to ‘have a look’; it is possible for a remotely controlled machine to go in with cameras to allow preparation and optimisation of human interventions. In order to reduce the number of persons during an intervention, all supervising persons could follow the operation remotely, giving feedback and instructing personnel in the tunnel. This machine can be used by operators to guide the maintenance personnel during their repairs and check the quality of the work and the status of the equipment after intervention and before powering.

1.2 Measure

After a reasonable period of beam stop time, RP technicians are the first to enter the tunnel to measure the residual doses to grant access and determine the access time for the personnel intervening into the LHC. From the first stages, it became evident that to reduce the dose to those technicians, this kind of measure should be done by a remote system travelling around the whole tunnel.

RP also wants to carry out repeated surveys of dose rates around the whole LHC.

Further requests for measuring are to measure temperatures (tunnel or components) and collimator alignment during shut down. This ‘remote’ measurement will avoid geometers spending long times in highly radioactive areas to take this time-consuming measurement. They could access then only for realignment if needed.

1.3 Handling

Another request was to remotely handle the more highly radioactive elements in the LHC machine. Up to now, we have received requests for collimators replacement and TAN detectors regular exchange.

2 TIM AS SERVICE PROVIDER

The TIM (Train Inspection Monorail) has been developed as multipurpose service provider to perform, assist and respond to the identified needs:

- Carrying out visual inspection when the LHC access is open or closed;
- Providing traction/vision and power to ‘ad-hoc’ wagons;
- Providing vision and signal transmission to separate units such as TAN and CAT eye.

To ensure high reliability of the TIM, only industrial electronic component and ‘off-the-shelf’ components (motors, transmission, wheels…) have been used, thereby avoiding special development.

2.1 Why the TIM?

A small train travelling on the monorail very rapidly seemed the best solution because it benefits from existing large scale infrastructure such as:

- Continuous Monorail with 380 V power feed rail all along the LHC tunnel;
- GSM Network through leaky feeder cable anywhere in LHC underground sites.

This gives the advantage of having a device which can travel in the whole LHC tunnel without expensive installation of a special infrastructure (Communication, support, guiding system…).

2.2 What you can expect from TIM

TIM can reach all positions in LHC where the monorail is installed and has autonomy of 20 km. It can transport several client wagons (up to 1tonne at a speed of 3 km/h). It is equipped with brushless DC motor and Siemens Safety PLCs (with high safety standards).

Key dimensions are 480 mm wide, 530 mm high, 1m long per wagon. The basic configuration is two wagons: one motor /control wagon and one energy wagon (24 V, 145 Ah).

Figure 1 –Head TIM energy wagon

Batteries can be charged from the mains (380 V plug), and by monorail power feed rail in any position in the tunnel (when stopped) via an automatic power connector.

The position of the TIM is calculated by counting the turns of the drive wheel corrected by the reading of code bars positioned into the tunnel every ~110 m: the position of the code bars is known and memorized. Using this system, the operators send the TIM to a certain Dcum.

The TIM standard train is equipped with 2 pan-tilt cameras on the 2 ends with integrated web-based control.

Due to the limited bandwidth of EDGE (240 Kbps), one picture every 5s is obtained at the control station. In addition to images, measured data, and sound can be obtained continuously in real-time at the control station.

It is possible to record data taken with the corresponding Dcum or to transmit on-line to the control station on the surface.

2.3 Safety related aspects

Several safety aspects have been investigated and solved for the TIM train. In particular, TIM should work in the tunnel without people BUT in case people are present:

- ‘Human’ obstacle presence is checked by 2 laser scanners at each extremity which automatically stop the train when an obstacle is detected. Braking distance is compatible with detection distance;
- Buzzer and flashing light to warn personnel of TIM arrival;
- Emergency stop switches are fitted on the TIM to allow personnel in the tunnel to stop TIM if necessary;

- Memorization of fixed obstacles is foreseen to identify what is a temporary, i.e. not ‘human’ obstacle.

2.4 And small TIM…

To travel around the LHC machine when all the doors are closed (before persons can go in, but with no beam) a small TIM has been developed. Its section dimension is 30 x 30 cm and LHC management has approved that sector and ventilation doors have a free passage compatible with this TIM.

This TIM can travel faster than the standard TIM (up to 12 km/h) since it will probably be used to urgently reach zones in which a machine failure has happened and give an image/radiation feedback to guide the maintenance. It will be able to travel to the destination automatically once the operator enters the Dcum number.

The principle of the small TIM is the same as the first TIM: components have just been squeezed into the reduced volume.

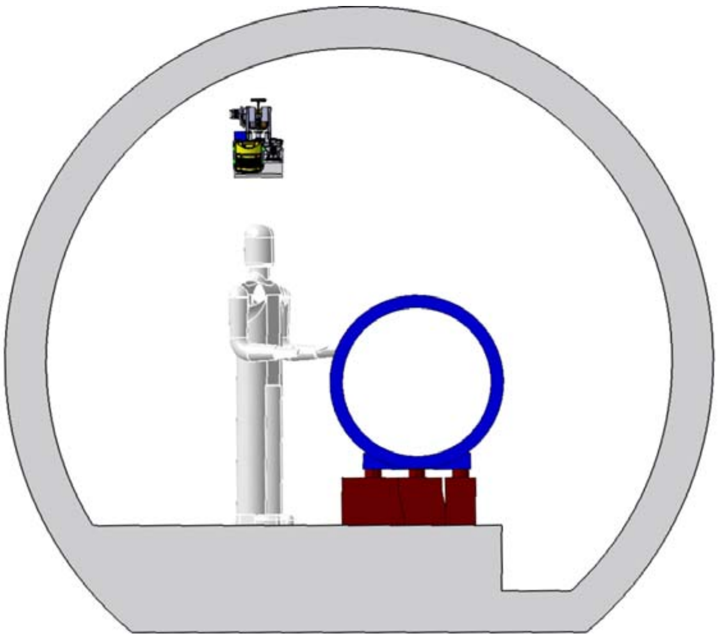

Figure 2 –Tunnel section with small TIM

3 CLIENT WAGONS UNDER DEVELOPMENT/CONSTRUCTION

3.1 General requirements/geometry for client wagons

Clients are requested either to build their own wagon or to procure the measuring system and specify their needs in order to allow TS/HE to develop a dedicated wagon for them.

As general requirement, the proposed wagon or equipment shall be compatible with the TIM or small TIM dimensions and permissible weight depending on which train they want to use (access restrictions). Moreover, their interface shall be compatible with the TIM system concerning power feed and signal and image transmission.

3.2 Radiation measurement wagon

This wagon will be used for repeatable ‘benchmark’ radiation surveys.

TIM can enter the tunnel before human access is granted to measure LHC residual dose along the tunnel and this measure can be used to determine (and optimise) the correct waiting time before intervention. Its dimensions are compatible with the small TIM.

3.3 Inspection wagon

TIM is equipped with 2 pan-tilt cameras on the 2 ends, but to give the operator a complete 3D understanding of a specific zone, a dedicated camera wagon has been built. This wagon is equipped with an extensible arm and a pan-tilt camera at the end. This camera can be orientated / zoomed as needed to look at anything at several angles/height. It will be used as ‘proximity camera’ for handling operations or fine alignment of the TIM.

A campaign of tunnel position memorisation in sector 3-4 has been completed with Civil Engineering group for surveillance of actual and potential future water leaks. A certain number of manometers are installed in the tunnel vault in this zone to check the water pressure on the vault. All positions (TIM Dcum and camera tilt/pan zoom) have been memorised to allow recording of all manometer as an automated operation during technical stops.

3.4 Collimator handling wagon

As collimators are one of the most activated LHC components during runs, a dedicated handling system called MACARENA is under development to remove and replace failed collimators during LHC lifetime. The most highly activated collimators will be those installed in point 3 and 7 straight sections in proximity of the monorail. An ad-hoc TIM wagon will be able to transport and install/remove those items. This wagon includes 2 pivoting arms equipped with wire rope hoists fitted to a rigid structure.

The TIM positions itself automatically in front of the collimator, orients cameras and extends stabilisers (as a mobile crane). The 2 lifting arms then unfold one after the other and lift the collimator following a special path (to disconnect it from water and power plugs) and place it on the wagon itself. The stabilisers can then be retracted and the complete wagon leaves.

3.5 Collimator alignment measurement wagon

Due to the high collimator residual dose rates, the Survey group has proposed the development of a TIM wagon able to remotely measure the collimator alignment. This operation will avoid the need for SU personnel to spend long periods near collimators to measure the alignment of each one individually. By using this wagon, the survey personnel intervention will be needed only when collimators needing to be realigned, if any.

4 FURTHER REMOTE UNITS UNDER DEVELOPMENT

4.1 TAN detectors handling

Several detectors belonging to different collaborations (ATLAS, CMS, CERN, LHCf) are installed into the vertical slot of the TAN and need to be regularly inserted and removed during the yearly LHC run depending of the beam characteristics (low or high luminosity, particles source). The exchange of these detectors needs to be done rapidly during technical stops giving no time for radiation cool down. Their residual doses can reach 20 mSv/h for which a remote exchange system is needed.

After studies, it emerged that a dedicated mini-crane system can do the work correctly. A preliminary study has been presented and approved by collaborations and has now received finance from ATLAS.

It will be an ad-hoc system permanently installed above each TAN able to remove detectors and copper bars from TAN to nearby shielded containers and back. The load capacity will be 100 kg and it will be remotely controlled with 3 cameras. All electronics and control systems will be installed in a removable control box to avoid radiation during LHC runs.

For this project, TIM can be a valuable help for lighting, vision and control transmission.

4.2 CAT eye

In order to access and allow vision of areas that are not equipped with monorail, a small robot on tracks was developed. This robot has small dimension (800 mm wide 1 m long) and weight (80 kg) and it is equipped with a motorized column camera to view at different levels and angles. It is equipped with WIFI communication system and can transport a load up to 50 kg.

It is remotely controlled and it can be complementary to the TIM to look ‘from underneath’. The CAT eye is available for all users.

5 CONCLUSION

In order to respond to remote operated machine request, a number of machines have been developed and are currently under construction. By exploiting the LHC existing infrastructure, TIM can offer several services while reaching all parts of the tunnel with sector and ventilation doors opened or closed. It can offer more services depending on CERN partner’s requests in future.

Our team is available to answer to all requests for remote operations in LHC and elsewhere at CERN, with the aim of minimising the radiation dose to personnel.

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