TECHNICAL INFRASTRUCUTURE RECOVERY AFTER A MAJOR FAILURE

L. Randot, CERN, Geneva, Switzerland

ABSTRACT

Faults on the Technical Infrastructure (TI) are often the cause of CERN accelerators stops. This document shows how CERN TI operators deal with this kind of problems in order to restore the working conditions for the accelerators as quickly as possible. Based on the importance and the nature of a failure, the whole of the accelerators complex can be affected, thus involving several users and technical systems. This document treats major problems concerning all CERN activities and domains such as main failures in electrical network, in cooling systems, in data-processing networks etc. It describes the causes of these incidents and the consequences. It explains how CERN has organized the recovery process according to priorities and dependencies, in particular concerning the staffing, the diagnostic tools, the priority lists, the stand-by services as well as the way in which this kind of major failures are coordinated.

INTRODUCTION

LHC (Large Hadron Collider) will use the most advanced superconducting magnet and accelerator technologies ever employed. It will consist of two colliding beam storage rings, installed in the 27 km tunnel used in the past for the LEP machine. The two superconducting magnet channels will accelerate the protons to 7 TeV before they are made to collide. To bend the 7 TeV protons around the ring, the LHC superconducting dipoles must be able to produce fields of 8.33 Tesla which require a current of 11850 A, possible only under the cryogenic regime of super-fluid helium at 1.9 °K. To be able to reach such values, the LHC relies on a reliable and highly available Technical Infrastructure. Power and water consumption at CERN are comparable with those of a small town; CERN will consume an estimated 1000 GWh per year and will see passing 6 million cubic meters of water per year (water will be recycled).

Working together in the CCC (CERN Control Center) with the machine operators for LHC, SPS (Super Proton Synchrotron) and PS (Proton Synchrotron), Technical Infrastructure operators are present throughout the year.

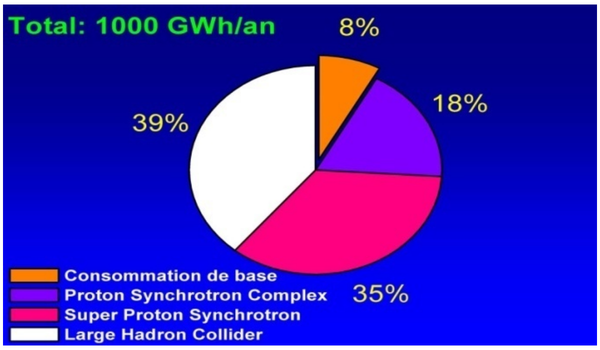
They monitor and operate the complete Technical Infrastructure (TI) of CERN 24 hours a day, 365 days a year via a fully computerised remote control system . The systems monitored include:

- The electrical and fluid distribution networks
- Heating, cooling, ventilation and air conditioning equipment
- Safety and communication installations
- High vacuum and cryogenic systems for PS, SPS and LHC
- Control and monitoring infrastructure equipment

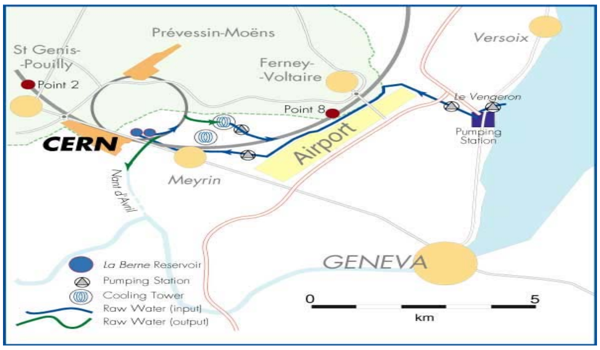
The TI operators monitor and analyse the states of these systems and take corrective measures, such as remote actions, calling of stand-by services and first-line on-site interventions outside normal working hours. The TI operators co-ordinate troubleshooting activities of different intervening teams to ensure the proper functioning of CERN's Technical Infrastructure.

Major technical and co-ordination problems are analysed and reported to the responsible equipment groups and the TI operators participate, where possible, in the implementation of improvements. In particular they collaborate closely with the accelerator and physics experiments control rooms to optimise the restart after major failure.

The following pages will describe how major failures are treated at CERN, starting with a definition of a major failure, describing the most common causes and consequences of major failures and finally explaining how faults are treated in terms of priorities and what tools are used.



CERN yearly nominal electricity consumption



Schematic view of CERN’s water supply

MAJOR FAILURES

In the present discussion, we define a “MAJOR FAILURE” as a technical fault which has a large impact on one or several CERN accelerators and other important installations such as the LHC cryogenic installations or the CERN computer centre. Major failures can have various causes, but often give similar consequences.

CAUSES

Although accelerator stops can be caused by a failure in the water cooling, the ventilation, the vacuum system or by computer or computer network failures, such failures are most often localised to one accelerator and interventions can generally be concentrated around the point of failure. Major failures are generally electricity failures at a central point in the distribution network. The reasons for major electrical problems can be for example a fault on the incoming 400kV line, thunderstorms, equipment faults in ageing equipment or even wild animals getting inside an electrical substation and causing short circuits. On September 16, 2007 a weasel tripped a 66kV breaker feeding LHC point 6 (that particular weasel will not do it again). If the electricity distribution fails, this has an immediate effect not only on the accelerators, but also on all other service systems.

CONSEQUENCES

A major power outage has immediate consequences on almost all installations. Magnets, RF cavities and other accelerator equipment lose power and trip, cooling circuits stop, ventilation and air-conditioning units come to a halt, cryogenic equipment and helium compressors are brought to a standstill and a number of other systems all fail at the same time.
Only equipment on unbreakable power supplies (UPS) resist the power failure. The control system is powered by UPS and will receive and transmit thousands of alerts to the CCC in a few seconds.
The control room operators are faced with an avalanche of alarms and incessant phone calls from people on site having noticed the breakdown explaining that their installation is top priority and must be tended to immediately.
It is the job of the TI operator on shift to understand what has happened, make a first diagnostic of the state of the installations and launch the recovery process.

OPERATIONAL METHOD & TOOLS

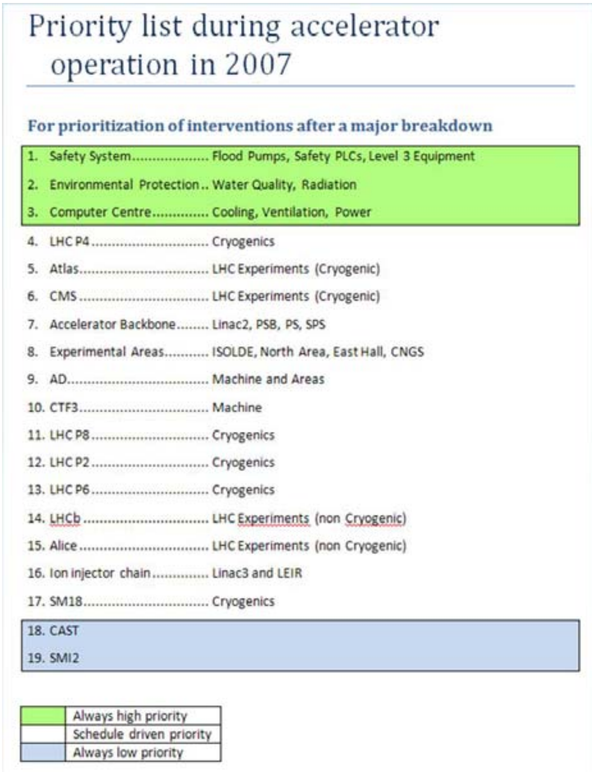
Major failures are difficult to handle for several reasons:

- They occur rarely (luckily), giving very little experience with such situations for each operator.
- Although the cause of the problem often is similar, it never seems to be quite the same (lightning never strikes twice in the same place).
- The activities of the lab evolve over time, changing the importance of interventions; LHC dipole testing was important in past years, LHC sector cooling is important now and other systems will be important in the future

To help him face a major failure, the TI operator on shift has a recovery procedure based on a list of predefined priorities and a set of tools developed to ease the diagnostics and co-ordination work that will follow the failure.

RECOVERY PROCESS

As mentioned above, the CERN's operational priorities change over time; experiments come and go, new accelerators are built and new infrastructure is commissioned all the time. Priorities also change within the year; the priorities during the shutdown period are not the same as during a physics run, work on the LHC commissioning is taking place in different sectors at different times. A current list of priorities is necessary if the TI operator is supposed to be able to make the right decisions in the recovery work. The list must be dynamic and should be updated as often as needed. Figure 3 below shows the current priority list approved by CERN management.


Priority list during accelerator operation in 2007

For prioritization of interventions after a major breakdown

1.	Safety System	Flood Pumps, Safety PLCs, Level 3 Equipment
2.	Environmental Protection	Water Quality, Radiation
3.	Computer Centre	Cooling, Ventilation, Power
4.	LHC P4	Cryogenics
5.	Atlas	LHC Experiments (Cryogenic)
6.	CMS	LHC Experiments (Cryogenic)
7.	Accelerator Backbone	Linac2, PSB, PS, SPS
8.	Experimental Areas	ISOLDE, North Area, East Hall, CNGS
9.	AD	Machine and Areas
10.	CTF3	Machine
11.	LHC P8	Cryogenics
12.	LHC P2	Cryogenics
13.	LHC P6	Cryogenics
14.	LHCb	LHC Experiments (non Cryogenic)
15.	Alice	LHC Experiments (non Cryogenic)
16.	Ion injector chain	Linac3 and LEIR
17.	SM18	Cryogenics
18.	CAST	
19.	SMI2	

Always high priority
Schedule driven priority
Always low priority

Priority list during accelarator operation 2007

The priority list describes which the most important systems to recover are. So, in case of main electricity blackout, the TI operator knows exactly that the first system to re-establish is the safety one including fire/gas/evacuation equipments, safety PLCs and flood

pumps. The environmental protection is the second priority with the water quality and the radiation emission, and the third one is the Computer Centre (power and cooling system) which is THE critical system for data-processing and communications. After that, the TI operators will be able to deal with the technical installations affecting directly the accelerators. For example, the different cryogenic systems for the LHC magnets or experiments. The accelerator backbone (sources, injectors and accelerators) is the next step in the recovery process, as well as the experimental areas.
Obviously, there are technical constrains. The first is that you cannot restart an installation without checking that all supplies this installation needs to run are back. For example, the air conditioning for the Computer Centre can't run if the chilled water system is not operational, which depends itself on the water cooling system and the power supply.
The second constraint is staff availability. TI operator disposes only of two technicians on call 24/7 per system. This means for example that in case of a main power outage, the delay to re-establish an operational electrical network will able to be very long. To avoid this kind of situation and minimize the technical downtime, TI operator can rely on several tools specially designed for recovering operation.

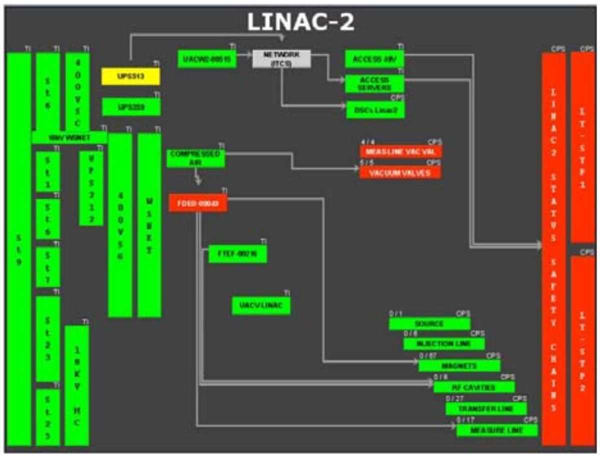
SPECIAL TOOLS

The very first tool is a technical check list. This describes in accordance to the priority list, which are the technical systems we need to restart first in case of electricity blackout.
The checklist, based on the priority list, describes for each item on the list how to verify the current state, how to diagnose a problem and what actions are needed. The checklist also includes a first section describing how to find the cause of the problem and a list of people to contact immediately

CHECK-LIST							
COUPURES D'ALIMENTATION MAJEURES							
		OK	Heure	NOK	Heure	Commentaires	Instruction
POINT DIAGNOSTIC	CCC et CCR alimentés?	☐		☐			A
	Téléphones en service?	☐		☐			B
	ENS opérationnel?	☐		☐			C
	Réseaux électriques	☐		☐			D
	Identifier la panne avec ENS	☐		☐			E
	Auto-transfert?	☐		☐			F
	État Diesels	☐		☐			G
	État 5?12	☐		☐			H
	Demander de l'aide	☐		☐			I
	Superviseur TI	☐		☐			J
	Collègues en journée	☐		☐			K
INFORMER	Piquets électriques	☐		☐			L
	Piquet 1er niveau	☐		☐			M
	Piquet 2ème niveau	☐		☐			N
	Utilisateurs	☐		☐			O
	Cryogénie	☐		☐			P
	Cooling ventilation	☐		☐			Q
	Détection incendie – gaz	☐		☐			R
	Diffuser l'information	☐		☐			S
ACTION	Système de sécurité	☐		☐			T
	Protection environnement	☐		☐			U
	Centre de calcul	☐		☐			V
	Installations cryogéniques	☐		☐			W
	Expériences LHC	☐		☐			X
	Accélérateurs	☐		☐			Y
	–	☐		☐			
		☐		☐			

Technical Infrastructure check list

From the CCC we can't operate without power and computer networks, so the check list shows us which the most important diagnostics to do first are. Moreover, the check list includes with each action to do a special instruction with pictures and diagrams. The aim is to rapidly find all essential information to act.
The second thing to do is to inform the right people. Obviously, during a power outage the two on-call specialists will be called. But TI operator has to inform the different users like for the cryogenic or cooling systems. For that, TI operator uses special tools to send automatic SMS or message on computer to inform users of a technical problem.
Finally, the TI operator manages the situation by coordinating the breakdown requests and sending technicians to the right places. In that way, all the technical systems are checked and restarted as fast as possible.
From that point on, all the main technical installations are running. The electrical network and the water supply are operational as well as the data communication.
The next step is to recover the accelerators and so minimize the downtime. That's why a special application was developed: the GTPM views (Technical Major Failure Management).



GTPM view for LINAC2

It consists of several dynamics pictures containing boxes. Animated with 3 colours (green = ok, yellow = warning, red = not operational), each box represents a main equipment essential for accelerator operation. Thus, with GTPM application, TI operator gets always general views of all necessary technical systems to ensure the best accelerators exploitation. Electrical sub stations, water cooling circuits, air conditioning systems, vacuum string, access control equipment and magnets alarms are all represented. For each machine there is a general view and several detailed sub views. A part from the colour of each boxe, a link connects some of them to show the dependencies between systems.

Finally, it becomes easy by reading GTPM views to know which system TI operator has to restart first to make available all technical systems and so, recover the accelerators complex. After having "recovered" all GTPM boxes in green and checking that all technical systems are operational, TI operator informs machines operators that they can restart the different accelerators.

CONCLUSION

Major failures are most often due to electrical outages. Its impact on the accelerators operation are very large and most of time, the consequence is the machines stop. These breakdowns induce a large number of faults on various equipments from different sites. The analysis is not easy and the situation can be very complex to understand. For recovering the technical infrastructure, TI operators must react according to operational priorities approved by management. A checklist and a set of tools to help them are also available in the aim to finalize the recovery process as efficiently as possible.

For the future, we can imagine few tools to provide better information to users with a lot of help communication on line. Extend the GTPM application to LHC operation and other important facilities (e.g. LHC experiments and computer centre) is a good way to minimize the impacts of a major failure.