A High Quality Power Supply at the ESRF

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Abstract

The loss of beam caused by electric storms is by far the main source of interruption to user service in spring and summer. The disturbances occur in the form of drops on the mains causing variations of the RMS value of the 50 Hz waves on at least one phase line. These drops frequently result from arcing to the earth from lightning on the 225 kV or 400 kV lines. The average case of a voltage drop can be described as being in the 20% drop range and lasting 200 ms. It was necessary to find a solution in order to provide the users with the service they are entitled to. It was therefore decided to install a High Quality Power Supply. The system, which will come into service in 1995 on the ESRF site, is based on 10 alternators in parallel to the mains, working as reactive power compensators. In addition, 10 mechanical accumulators store 5 seconds of energy to power the process in case of mains drops. As soon as the drop is detected, the input circuit-breaker is opened and the accumulator delivers the energy to the alternator. When the quality of the input network is correct again, the input circuit-breaker is closed to restore normal conditions. At the ESRF a solution incorporating the use of diesel engines which will be able to power the machine during peak-rate electricity periods has been chosen.

1. INTRODUCTION

The ESRF has achieved a high level of performance, surpassing its target specifications. The lifetime has increased by a factor of 4. This is an instantaneous measurement of the decay of the stored current over a few minutes. This extremely good performance is due to a very high vacuum level, a perfect orbit correction and the overall regulation quality of the equipment. This includes not only the main magnetic field parameters but also environmental conditions such as ground settlement, air temperature of the tunnel and the water cooling system (flow and temperature) of all power devices.

This extremely good instantaneous lifetime is considerably altered when looking at long-term figures, particularly over the spring and summer period each year. The loss of beam caused by electric storms is by far the main source of interruption to user service, 90% of cases in May and June 1992, 67 events in June 1993 (more than 2 per day on average).

2. PHENOMENON CHARACTERISTICS

Grenoble is in the mountainous region of the Alps. The Alps are traditionally an electricity producing area, with a very dense network of high aerial lines which are extremely sensitive to lightning hits. Analysis of the cause of these perturbations, carried out by ESRF and the energy supplier, revealed that perturbations are transmitted over more than 100kms of lines. They are the result of voltage drops on the mains in the form of variations of the RMS value of the 50Hz waves, on at least one phase line. These voltage drops frequently result from arcing to the earth from lightning on the 225kV or 400kV lines. During the time it takes for the circuit-breakers to isolate the faulty line and extinguish the arc and before the line is available again, drops occur lasting from less than 100 ms to one second, with a loss of voltage from 5% to 80%. The average is a 20% voltage drop lasting 200 ms

The chart below shows the distribution of voltage drops over the period of one year.

date : from	7-Aug-92	to 18-Juil-93	
delta U/U	Number of cases	proportion	sigma
.-5% to -7%	86	31%	31%
.-7% to -12%	97	35%	66%
.-12% to -20%	46	16%	82%
.-20% to -40%	32	11%	94%
.-40% to -60%	11	4%	97%
.-60% to -80%	7	3%	100%
.-80% to -100%	0	0%	100%
total =	279		

with the repartition on the number of conductors.

triphase events	12
biphase events	57
single phase	129
total	198

and the distribution in time length.

time	Number of cases		
0.1sec	97	35%	35%
0.2 sec	108	39%	73%
0.3 sec	8	3%	76%
0.4 and 0.5 sec	21	8%	84%
0.6 and 0.7 sec.	17	6%	90%
0.8 to 1 sec.	24	9%	99%
1sec to 2 sec.	4	1%	100%
total	279		

From the table below it is clear that stormy weather is the main cause of the drops.

The following table is a distribution of the events by months in the year.

	events
Aug-92	29
Sep-92	12
Oct-92	2
Nov-92	1
Dec-92	2
Jan-93	0
Feb-93	1
Mar-93	0
Apr-93	11
May-93	37
Jun-93	67
Jul-93	36
total =	198

This excludes three complete cuts lasting 3 min, 1 hour 12 min and 1 hour 29 min.

It was necessary to find an acceptable solution to provide the users with the service to which they are entitled. Other laboratories are also confronted with such storm-related problems, however, it must be emphasised that at the ESRF, when such events occur, the quality of the beam provided to the users is destroyed. It was only recently that EDF, the French electricity producer, recognised that the transport of electricity by aerial line is sensitive to lightning effects right up to the user. It also affirms that transport by cable is simply not economical over long distances.

Other service institutions such as hospitals, airports, radar stations or even silicon manufacturers, all have systems to protect their electricity supply from cuts. They often start-up their systems once they have been warned of an imminent storm, by a special weather forecast station, in order to avoid micro-cuts.

3. FINDING SOLUTIONS

Given the character of the drops, the main concern was to reduce sensitivity to the phenomena for all ESRF equipment. After a desensitisation campaign that lasted one year it was shown that the electron beam was at last no longer lost at a 5% drop level but more likely between a 10% and 12% drop level. 2/3 of events can be avoided, however, the character of the beam changes during such drops, even when the system doesn't trip. The magnetic hysterisis on the electro-magnet induces a modification of the machine tuning and this happens without notice. In all cases, 1/3 of the events cannot be prevented.

To guarantee the 6,000 hours per year of high quality beam time for user service, another solution has to be applied. The solution to counter such effects is to install a High Quality Power Supply (HQPS). The main idea is to disconnect the ESRF from the French grid so as to avoid perturbations, induced by storms, which kill the electron beam.

- The obvious solution could have been to use one of the dam turbines (22MW), situated close to the site, to work as an isolated network. A link with cables (4kms) would have to be installed to avoid lightning effects. The management of a series of dams is unfortunately unsuitable for a single user service and EDF was not in favour of this solution. The stability of the mains and the over-voltage protection was another important obstacle to this solution.

- The traditional solution with static invertors fed by lead-acid batteries, connected to individual equipment would require the installation of a great number of batteries. The cost and lifetime of energy stored was prohibitive and therefore such a solution could not be envisaged.

- The mechanical fly wheel system rotating on the mains frequency, coupled to an alternator could not fulfil the vibration specifications when considering the 10 μmeter range.

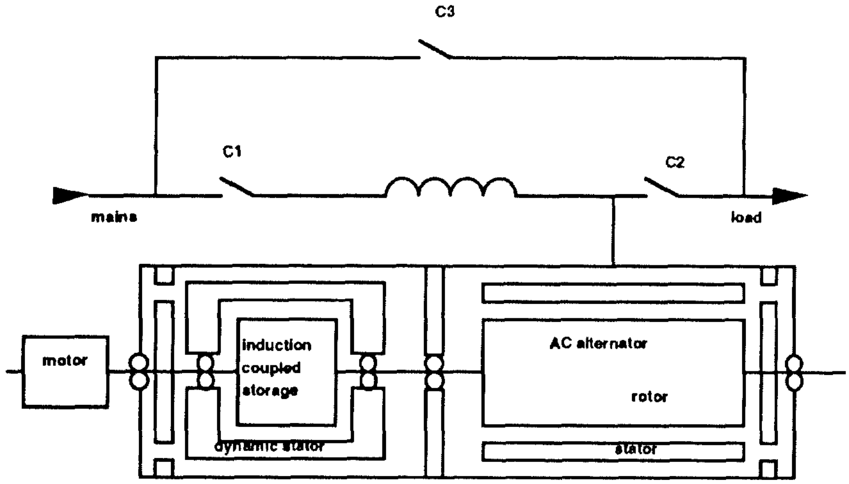
- New and very promising technology using super-conducting energy storage was also looked into. Reliable equipment is unavailable at present, however, work is being carried out in the US on a first prototype storing several MJ. An industrial model of the equipment will not be available for some years yet.

- It was decided that a system using dynamic mechanical storage composed of two electrical machines, one synchronous machine and one asynchronous inverted machine would be the best choice considering the size of the power plant. It is a modular concept which can be implemented in a redundant arrangement.

4. DESCRIPTION OF THE CHOSEN SOLUTION

The system, which will be implemented in 1995 on the ESRF site, is based on 10 alternators in parallel to the mains working as reactive power compensators. In addition, 10 mechanical accumulators store 5 seconds of energy to power the process in case of mains drops. As soon as the drop is detected the input circuit-breaker is opened and the accumulator delivers energy to the alternator. In order to decouple the short-circuit power of the mains from the alternators, a large choke is connected to avoid dissipation of the energy from the accumulators in the short-circuit. When the quality of the input network is regular again, the input circuit-breaker is closed to restore normal conditions. In order to increase reliability a redundant unit is able to take over a failing one.

The figure below describes the system's different elements:



Dynamic Mass storage and voltage regulator

At the ESRF a solution to power the machine during peak days has been adopted using diesel engines. In this version the recharging of the accumulator will be carried out by the diesel engines while the circuit-breaker is still open. This enables the system to be ready for a second voltage drop before the accumulator is recharged. This system will screen the perturbations to keep the voltage within +/- 5% and frequency +/- 1%. As the alternators are running in parallel with the mains, efficiency of the entire system at full power is around 96%. The Diesel engines will run about 400 hours per year, mostly during peak days in winter. No more than 50 additional hours will be taken to recharge the accumulators when the mains is out of specification. The anticipated long-term beam life-time will thereby be restored during spring and summer.

5. TIMETABLE

The first factory tests are scheduled for autumn 1994 and the entire Power Plan will be commissioned under storm conditions in spring 1995. The two-storey building to house the equipment will be ready in December 94. The large switchgear on 20 kV level is a centralised version which optimises the power needed but more time is required to implement and to supervise such a system. The remote-control system to drive and monitor the efficiency of the plan will be commissionned at the same time as the site acceptance tests.

6. CONCLUSION

This new method to obtain a clear power network is ambitious. It is the most efficient way to achieve the required production of 6000 hours per year of beam for user service. By adding the diesel engines to the basic principle, the institute will lower its electricity bill and provide a much better service for the users. The effects will also be appreciated by everyone in charge of equipment and in particular by those in charge of highly sensitive devices.