High Quality Power Supply (HQPS) at the ESRF

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ABSTRACT

After three trimesters of operation the system has proved to be very efficient in recovering from mains drops. These frequent drops are mainly caused by thunder storms, which the Grenoble region is very well known for, and the problem is further intensified due to the numerous very high voltage aerial lines (225 and 400 kV) in the area. Despite some teething problems, during this last winter the diesel engines were also used during peak electricity days to reduce the energy bill. The solution of redundancy, adapted directly onto the 20 kV line of this 10 MVA power source, is a new way of supplying electricity to all the sensitive equipment of the ESRF Storage Ring. The reliability and availability of the equipment connected downstream has greatly improved due to the reduced stress induced on the equipment.

1 RECALL OF THE QUALITY PROBLEM

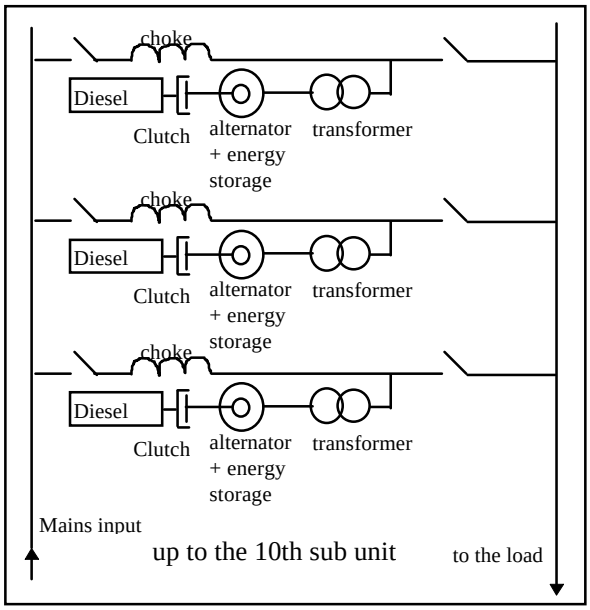
The mains quality in a montaneous region is a problem not to be underestimated. The mean time between failure of the accelerator complex and more precisely the Storage Ring equipment was greatly reduced during spring and summer each year. Some 250 drops (deeper than 5%) are currently recorded on the 20kV input feeders of the site. Even the fact that a large part (30%) of them are compensated by the numerous power supplies when the drops are between -5% and -7% the remaining ones were very often sufficient to go beyond the regulation range of the rectifiers provoking a beam loss. The energy supplier specifications are such that they have no other solution than to recommend a decrease in sensitivity to this kind of perturbation.

The time lost and the destruction induced from time to time to the machine has been counted during several years and could be estimated at 200 hours per years.

A first report described the reasons for the technical choices made [1],[2]. The system implemented on the ESRF site has been able to compensate all drops except for three, but a solution to get 100% satisfaction is already implemented and is awaiting the thunderstorms.

2 POWER PLANT DESCRIPTION

The system is composed of 10 sub units of 1MVA each connected in parallel in a N+1 redundant way. The parallelism is performed at the 20kV level. This means that the system is composed of two 20kV busbars one for the input and one for the output. 31 High Voltage 20kV cells are used to manage the different switching possibilities. The general line diagram below describes the arrangement of the HQPS system:



Single line diagram of HQPS power plant.

The rotating machines are located on the first floor while the electrotechnical elements (transformers, chokes, 20kV circuit breakers, electronic devices, master controller) are located on the ground floor. This type of arrangement was dictated by the high voltage cable trays and trenches necessary for the large curving radius of the cables. The general view of the building can be seen below.

the floor area is 480 m2 and the height of the chimneys has been calculated to respect the French law on gas exhaust, 10.6 meters from the bottom .

3 PERFORMANCES

The system is designed to compensate all kinds of drops. The reaction of the system to perturbations is such that three typical behaviors could be described.

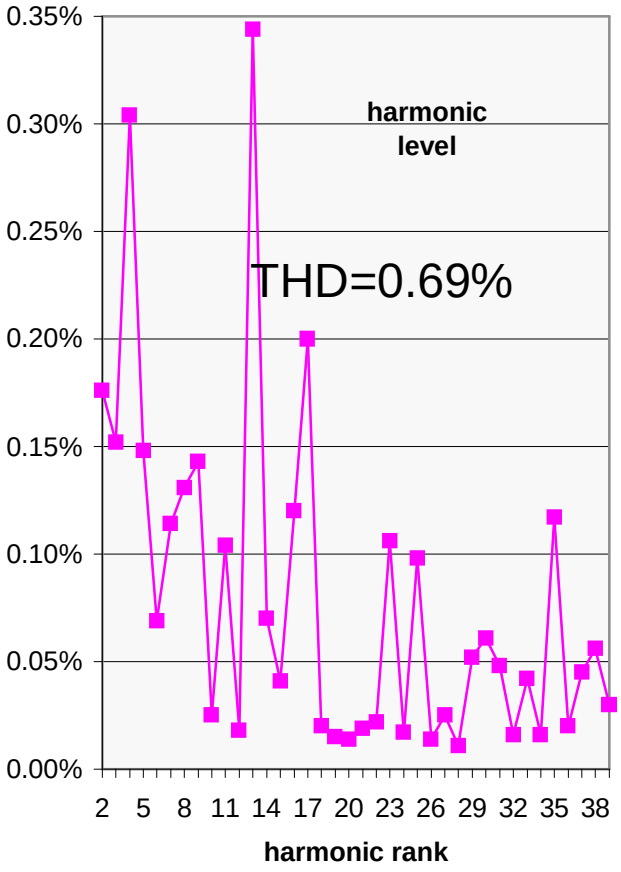
1)The simple compensation where only the alternators are used. This case is characterized by less than a 20% drop single phase, or less than a 10% drop three phases. In this case no diesel engine is started, the accumulator is not used and there is no disconnection from the supplier. This case covers 90% of the events.

2) Greater compensation is observed when the drop is deeper than 20% 160ms, or than 50% 60ms. In this case the diesel engines are started and the accumulators used during the acceleration of the motors. The system disconnects the perturbation from the grid to avoid back powering the outside users. This has represented 20 starts of the diesel engines over the last 11 months.

3) The third case is where the system does not respond properly to a perturbation. three cases has been observed for external causes and three for internal faults. The main default is characterized by the very large drops when the lightening affects the site directly resulting in a 55 to 80% drop. The homopolar wave created by this “direct hit” has not so far correctly been handled. The impedant neutral was not guaranteed during one second and all the references used to drive the thyristor drives were lost. The constructor has now reduced this time to some 10ms and the system is waiting to test this out. The three internal faults are human mistakes. One was an over consumption by more than 10%, the two others are linked with the harmonic filter reactive compensation.

4 HARMONIC FILTER AND POWER FACTOR

On the ESRF site all loads are power semiconductor driven. The direct consequence is a large harmonic current which creates some voltage distortion. In order to limit this effect, four harmonic filters have been installed. Rank 5 , 7, 11 and 18 are tuned. The capacitive power at 50Hz of these filters is about 6MVAr and can overdrive the alternators when the load is not connected. The software to drive the different harmonic ranks has been changed and is now working but it tooks a while to correctly analyze the problem. The harmonic pollution coming from outside the ESRF is now stopped by the input chokes and the Total Harmonic Distortion is currently around 0.7% for the Storage Ring and less than 1.1% at full power during injection. The 4th and 13th harmonic rank are dominating, but have no consequences on the mains quality.



5 REDUNDANCY

The real power needed to inject beam into the Storage ring is not far from 90% of the nominal power of the HQPS system. The redundancy concept was adopted to allow smooth operation and to allow for the unavoidable failures of a new design. In addition, the special contract with the electricity supplier imposes to use the diesel engines during peek off days (“EJP” days in the French grid). The redundancy is designed to isolate one faulty unit without any consequence on the load. After some software troubleshooting this is now working correctly. Furthermore, after several months of experience during last winter a new software has been implemented which allows to run less diesel engines than the number of alternators. This versatile active power sizing enables us to achieve a high conversion efficiency. This is particularly important for gas emission regulations. The global reliability is therefore at its maximum with this type of redundancy arrangement. The only parts which are not redundant are the two 20kV busbars and the master Programmable Logic Controller. Up to now there is no sign of weakness in these devices.

6 ”EJP” POWER PRODUCTION

Last winter the power plant was used to reduce the electricity bill of the ESRF. On 22 days we received a signal from the electricity supplier requesting us to consume less than 2MW on site. This applies to working days only and from 7:00 am to 1:00 am the next day. The two redundant tanks procure an autonomy of four of those days. The total volume of fuel used during winter is 538 000 litre for 1854 MWh produced. An automatic filling procedure of lubricating oil is installed. After each day the control unit automatically checks the level and readjusts to be operational for the next start-up.

7 ENVIRONMENTAL CONSIDERATIONS

The main environmental considerations are the gas exhaust content, the acoustic noise generation and the vibration transmitted to the structure and the ground.

7.1 Gas exhaust control

The system is control by local authorities in order to assess the low emission level. The diesel engines have been modified to respect the level given in the supplier’s specifications. All parts of the injection and turbocompression devices were adapted and upgraded to comply with a low level of particle and gas rejection in the atmosphere. During steady state operation the following levels are measured :

gas	**CO**	**CO2**	**NO**	**NO2**	**HC**	**PM**
mg/NM3	**180**	**12%**	**1300**	**30**	**14**	**10**
max val	**220**	**14%**	**1500**	**50**	**18**	**12**
autorized	**450**	*****	**1800**	**100**	**20**	**50**

PM stands for Particle Matters, HC for unburned Hydrocarbon. The authorized limit for NO and NO2 is counted globally in NOx and there is no legal limit in concentration for CO2. A large effort has been devoted to CO and Particle Matters emission reduction. The building is ready to accept catalyst exhausts to improve the emission of gas. A special device has been implemented to reduce the amount of black smoke created during startup. This device avoid overfuelling whilst keeping the speed start rapid (1 second). The alternative liquid gas solution has been rejected just because of the slow start of this type of fueling.

7.2 Acoustic Noise generation

On the first floor level the rotating units are separated in pairs with acoustic panels. The exhaust system is equipped with four silencers and two pressure release exhausts per diesel engine. In each cell housing two motors the noise level is around 95dBA, with the diesel engine stopped and 106dBA with the diesel engine at full power. Outside the building at 5meters from the walls not more than 65dBa is recorded where at the site border the motorway produces 70dBA with the HQPS completely inactive.

7.3 Mechanical vibration effects

During commissioning the ESRF team recorded the vibration induced by the whole setup. Each supporting frame is equipped with 16 vibration dampers. Under the frame the concrete basement is separated from the floor by 3 cm of cork to avoid acoustic transmissions. The global result is that not more than 1 micrometer can be recorded 30m away from the building. The level recorded on the ground floor is around 2 micrometers vertically and 3.6 horizontally during the startup of the diesel engines. The vibration induced on the concrete was taken into consideration during the design phase. Building reinforcement also participate to the acoustic noise damping.

8 CONCLUSION

This large power plant enables the Storage Ring to enhance the Mean Time Between Failure. The day to day average value is now around 50 hours during stormy weather. Less and less unexplained faults of equipment are now recorded. The 6000 hours of permanent operation of the facility is now achievable.

REFERENCES

[1] A High Quality Power Supply at the ESRF, J-Francois Bouteille on behalf of the ESRF project Team , EPAC 94, London 1994.

[2] Les electrons du synchrotron chassent les creux de tension. J3E n 642 5th April 1994 Jacques Darmon.