AUTOMATIC MULTIPACTORING CONDITIONING OF THE SUPER-CONDUCTING RESONATORS IN THE ALPI LINAC

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Abstract

In the multipactoring conditioning process of super-conducting resonators the RF power is absorbed by resonant electrons which keep the accelerating field limited at very low levels.

In the ALPI linac 57 super-conducting cavities are now installed and multipactoring is eliminated feeding the resonators with RF power by the same 100 W amplifiers used for normal operation, before cooldown while the cryostat shields are kept at liquid nitrogen temperature (60 K). This procedure is efficient and lasts only some hours (2-8) if the resonators are kept in each multipactoring level, no matter if in a continuous or pulsed mode.

Some computer-driven automatic procedures have been recently added to ALPI RF control system, in order to reduce the man-power necessary to perform this highly time consuming operation. The first results of this automation effort have been encouraging and the system is here described.

1 INTRODUCTION

At present the super-conducting linac ALPI includes 48 lead-plated copper, 4 niobium sputtered copper and 5 niobium bulk quarter wave resonators (QWR) operating at 160, 160 and 80 MHz respectively[1]. The ALPI cryogenic system uses liquid helium to keep the QWRs in the super-conducting state and He gas at about 60 K and 7 bar for the refrigeration of the cryostat thermal shields.

Since 1993, when the first lead-plated copper resonators were installed, there have been several failures in the technological plants or in the electrical power distribution which caused warmup of the shields. On these occasions gases and impurities cryopumped by the shields were released and partially absorbed by the superconducting surfaces of the cavities. After each of these events most of the cavities had to be conditioned again.

In spring 1995 an emergency cold box was installed, to keep the shields cold even in case of long failures of the main refrigerator or electrical blackouts.

2 THE MULTIPACTORING PROCESS

Multipactoring[2] is a resonant process where free electrons in a cavity (whose presence is due to ionized gas or field emission) are accelerated by the RF field towards the resonator surface. For a given range of kinetic energy (some keV) the hit of each electron on the surface extracts one or more electrons from it (secondary emission coefficient greater than 1). This may cause an avalanche process that starts at certain energy levels of the electromagnetic field and at certain geometrical positions inside the cavity and is resonant with the radiofrequency. For a given range of input RF power this electronic loading does not allow any increase of the energy stored in the cavity as any additional RF power is adsorbed by the oscillating electrons. When present, this phenomenon is associated with typical levels of RF fields and may be overcome by increasing the input RF power beyond certain threshold values as the resonant condition vanishes at a higher level of electromagnetic field.

The process of multipactoring conditioning consists in supplying RF power to the cavity to start the resonant process and to maintain it until the electrons hitting the surface have expelled the impurities from the critical positions and the secondary emission coefficient becomes less than 1. RF cavities suffer from multipactoring in function of their geometrical shape, while the intensity of the process depends on the emission coefficient of the surface, i.e. on the kind and quality of the surface and on the presence of impurities.

Generally a preliminary heating of the cavities in vacuum (baking) helps to outgas their surfaces and reduces the intensity and the endurance of the phenomenon. ALPI resonators were immediately installed in the working cryostats, without preliminary tests and treatments. Baking was mostly run once and was characterized by the following values: resonators heated at 350 K for 12-24 hours with the shields at 60 K and an internal pressure in the cryostats of about 10e-7 mbar.

The process of multipactoring conditioning is performed on the ALPI resonators kept at room temperature: an inductive variable coupler allows to reach the critical coupling condition even in this situation. For the normal-conducting state there is no practical limit on the power that may be dissipated in the resonators (while there is a limit of 7 W average power per cavity at 4.2 K) and the wider resonance band makes it easier to maintain the multipactoring effect.

The RF amplifiers allow to send up to 100 W of direct power in the cavities and this is sufficient to condition the multipactoring process up to 20 kV/m of accelerating field. As the resonators are switched on in self-excited loop through the RF controllers used for normal accelerating operations, several cavities may be run at the same time. When the loop phase is set correctly, the oscillating state is stable also in case of frequency drifts (while normal-

conducting, the cavities have floating temperatures). The periods of multipactoring conditioning are in the range of 2-8 hours; 8 hours are necessary for the first conditioning after installation, 2 hours or less for the following ones.

A resonator is considered to be "multipactoring-conditioned" when, set in critical coupling condition, an increasing RF power to the cavity is associated to an increasing level of signal from the pick-up and the reflected power remains zero in the whole range of RF power.

Until June '95 every resonator had been conditioned completely in manual mode, setting and varying the coupling conditions, RF power level, loop phase parameter and checking the pick-up signal on a scope from time to time. The conditioning periods were not so long to need special techniques, such as the use of freon[3]; however, because of the number of resonators to be treated, the multipactoring conditioning of the whole linac needed long periods of surveillance and adjustments by operators. An automation of this conditioning process was expected to reduce the global time and the man-power necessary to perform it.

3 THE PROCEDURES

In summer '95 the whole superconducting linac ALPI was warmed up to 300 K for maintenance. For several weeks the cryostats containing the resonators were kept at room temperature and filled with a slight overpressure of nitrogen gas. In September the vacuum and cryogenic systems were in operation again and soon after the RF conditioning of the cavities started, since the linac had to be ready to accelerate the beam at the beginning of November.

Two new semi-automatic procedures available on the RF control system[4] made the multipactoring conditioning easier. These procedures are included in the RF control system and may be used only if the man-machine interface is activated by the operator with an enabling option ("warm"), so that a special window is made available to start the activities with high levels of RF power for long periods.

Some manual checks are necessary before using these procedures: the vacuum in the cryostat must be good enough to tolerate the outgassing due to multipactoring (the initial pressure in each cryostat has not to exceed the value of 10e-7 mbar), the temperature of the cryostat shields must be sufficiently low (less than 70 K) and the resonators have to be warmer than the cryostat shields (to avoid cryo-pumping on the cavities surface). After these initial checks the amplifiers are switched on and the resonator parameters adjusted for free self-excited[5] oscillation at a low level of RF power (less then 20% of the maximum, which is 100 W) with the position of the coupler such that the reflected power is minimum. Once the vacuum in the cryostat has got back to the initial range one of the two semi-automatic procedures may be started.

The procedure "run1" was prepared to increase the RF power level in the cavities of each cryostat slowly, with steps that may be customized in amplitude (in the range 1-20%) and in period (in the range 1-40 min). After the last period of "run1" at the highest level of RF power the value is set back to a standard level of 20% of the maximum (about 20 W). If this RF power sweep has to be repeated the procedure must be re-started manually. This procedure was especially thought for a smooth but steady outgassing of the cavities at increasing levels of RF power: typical good working parameters for "run1" were an amplitude step of 10% (about 10 W) and a step duration of 5 minutes.

Differently from "run1", the second procedure "run2" was prepared to ramp periodically the RF power in the cavities in a saw-tooth mode (from 0 to about 100 W) without time limits. The only parameter that may be changed in this no-end procedure is the increasing step or RF power within each ramp (in the range 0.1-2.0%). The kind of treatment performed by "run2" proved to remove most multipactoring levels without further adjustments.

At the moment all the cavities inside a cryostat must be treated by the same procedure (either "run1" or "run2").

During the last multipactoring conditioning of ALPI both procedures were used to prepare the medium beta cavities. In the past years all these resonators were treated several times manually after their installation; these methods have not yet been tested on new resonators.

4 RESULTS

About 90% of the multipactoring conditioning of the ALPI medium β cavities was performed by 10 executions of "run1" (increasing the selected period at each new start-up) followed by a set of 10 executions of "run2" with decreasing RF power slope.

The operation on the whole linac was completed in 3 working days (8 hours per day) since more than one cryostat (3 or 4) could be treated at the same time. From time to time the coupling condition had to be adjusted, to find a new position for the coupler and to change the loop phase. At the end of the first three days two more days were necessary to check all pickup signals of the resonators on the scope. Only 5 cavities showed to need further conditioning which was then performed in manual mode.

5 FUTURE DEVELOPMENTS

At the moment the new facility is still too slow, since the procedures may not be run on more than 4 cryostats together. This limitation is due to the fact that the first version was implemented in a very simple way, using the central supervisory workstation.

In the future version the management of the RF controllers[6] and amplifiers to generate the power ramps will be moved from the supervisory graphic workstation to the network VME computer allowing to start both "run1" and "run2" independently on each cavity of the linac and without limits on the number of cryostats to be activated at the same time. In this way it will be possible also to start different procedures on different cavities in the same cryostat, a feature which may be useful when these show

very different behavior.

Moreover a new data acquisition board is now under development which will allow the detection of the multipactoring levels even at very low RF fields by monitoring the pickup signal and measuring the response to a power step in the resonator probe. This enhancement is expected to improve the effectiveness and reduce the time of the conditioning procedures of the ALPI linac.

6 REFERENCES

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