RF Voltage at Injection

By E. Ciapala

Control of the RF voltage produced by an RF unit is achieved by varying the DC voltage applied to the modulating anode of the klystron via a tetrode, the klystron RF drive level remaining fixed. In voltage loop mode, used during normal operation, the tetrode is driven by a feedback loop such that the summed detected RF voltage of all the cavities follows the reference input.

The voltage which can be produced is limited in range and there is a minimum RF output level which can be obtained. This depends on the klystron power supply voltage and input drive level, which are chosen to provide most efficient klystron operation at maximum power.

For the copper cavity RF units this minimum is around 15% of the maximum voltage, i.e. 7 MV. For the presently installed superconducting (SC) cavity unit, 233, with four cavities the minimum RF voltage is 8 MV. With all these 9 units in use the minimum voltage which can be obtained is 64 MV, which is close to the 70 MV used at injection for \( Q_s = 0.087 \).

On the basis of the same minimum klystron power an SC cavity unit with 16 cavities will have a minimum total voltage of 16 MV. The minimum circumferential voltage which will be obtainable with 12 SC cavity units and 8 copper cavity units is therefore around 250 MV. If two klystrons are used per SC cavity unit the minimum will be around 325 MV. For reasonable quantum lifetime at 90 GeV a \( Q_s \) of 0.12 is required, this means just over 2000 MV RF voltage. If the acceleration from 20 GeV is to be done with constant \( Q_s \), the required injection voltage is 150 MV. There are two possible methods of obtaining the required injection energy circumferential voltage.

One method would be to vary the klystron drive level during the ramp, starting at a low value at the beginning of the ramp and gradually rising to the optimum value at top energy. The main disadvantage of this approach is the resulting variation in the response characteristic of the voltage loop with changing drive level. It would be difficult to maintain the required performance and stability throughout the range. In addition the drive level ramp function would require careful setting up and would be different for each klystron.

Another method would be the relative dephasing of RF units at injection in some symmetrical manner (e.g. in pairs) with gradual programmed rephasing during the ramp. If a unit is dephased by \( \phi \) radians the effective voltage is reduced to a factor \( \cos \phi \). Dephasing by values approaching \( \pi/2 \) should be avoided since the relative change in voltage due to phase variations (or noise) is proportional to \( \tan \phi \). This should not be a problem in this case since the voltage is only to be reduced to around half its value i.e. with a dephasing angle around 60 degrees.

The SC cavity RF units will be equipped with function generators to allow dephasing and programmed rephasing. The hardware will be similar to the present voltage function generators and controlled by the general machine timing system. For overall or global voltage control the phase offsets will be taken into account by the central controller. In addition the central controller will be capable of direct control of the de-phasing.