

Multiharmonic beam loading compensation in the J-PARC synchrotrons

Thursday, 3 October 2013 11:25 (25 minutes)

Beam loading compensation is a key for acceleration of high intensity proton beams in the J-PARC synchrotrons, the rapid cycling synchrotron (RCS) and the main ring (MR). In both rings, magnetic alloy (MA) loaded rf cavities are employed to achieve very high accelerating voltages. The Q values of the MA cavities of the RCS and the MR are set to 2 and 22, respectively, so that the frequency responses cover the frequency sweep of the accelerating rf to follow the velocity changes of the proton beams without tuning bias loops. Furthermore, the wide-band (Q=2) cavities of the RCS are driven by dual-harmonic rf signals for bunch shaping to mitigate the space charge effects. On the other hand, the wake voltage in the RCS cavity consists of not only the accelerating harmonic, but also the higher harmonics. The higher harmonic components of the wake are source of the bucket distortion. In case of the MR, the cavities are driven by the single harmonic rf, however, the neighbor harmonics are within the cavity frequency response. The neighbor harmonics are source of the periodic transient effects and they are a possible source of coupled bunch instabilities. Therefore, multiharmonic beam loading compensation is necessary for both of the RCS and the MR. We employ the rf feedforward method. We developed multiharmonic feedforward systems for the RCS and the MR. We present the configuration of the feedforward system. The system uses the I/Q demodulation and modulation technique and it works essentially as a tracking bandpass filter. Although the system is rather simple, the commissioning of the feedforward is not trivial. We developed the commissioning methodology of the feedforward. We present the commissioning methodology, the commissioning results, and the beneficial effects of the feedforward compensation in the beam operation. The feedforward compensation is now indispensable for high beam power operation of the RCS and the MR, at several hundred kilowatts.

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Session Classification: Session 2: Operations