Beam Instrumentation Department

DC Current Transformer (DCCT)

Calibration Talk

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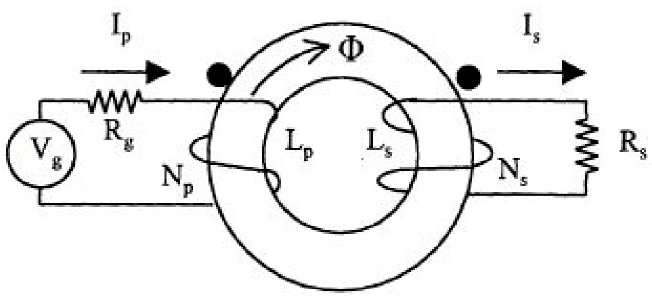
Introduction

- Beam monitors are designed to sense the electric field, magnetic field, or some combination.
- Beam current monitors are generally devices that interact with the beam's magnetic field to measure beam current, charge, and/or pulse shape.
- Beam current monitors are based on transformer circuit theory.

Basics of Classical Transformer



$$\Phi_k = \frac{L_k \cdot i_k}{N_k}$$

$$\Phi_T = \frac{L_p \cdot i_p}{N_p} - \frac{L_s \cdot i_s}{N_s}$$

$$i_s = \frac{s \cdot \Phi_T \cdot N_s}{R_s}$$

$$V_g = i_p \cdot R_g + s \cdot \Phi_T \cdot N_p$$

- Current in any *N* turn winding *k* produces a magnetic flux in the core.
- The voltage appearing across each winding is proportional to the time rate change of the total flux.
- In the beam current model, the voltage generator is replaced by a current generator.
- For $R_{beam} >> R_s$, the secondary current is very close to $1/N_s$ times the beam current.

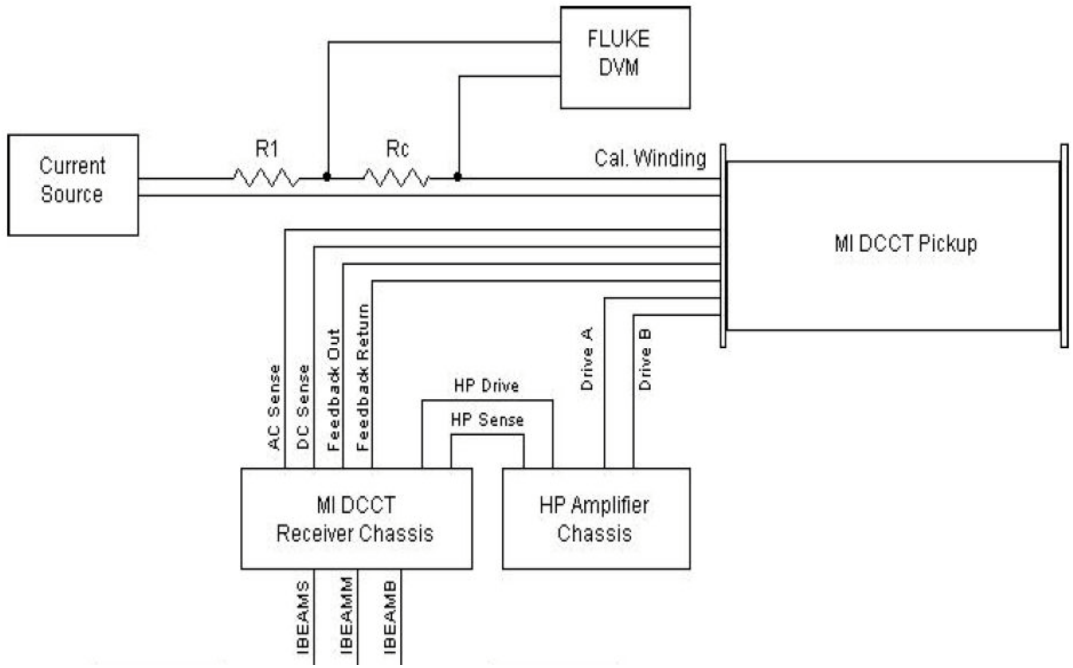
DCCT Intensity Monitor System

- The pickup consists of 2 sets of cores, which are excited in opposite senses with the beam signal acting as the primary turn.
- Placing these toroidal transformers in the feedback loop creates an active current transformer, extending the system's useful bandwidth.
- Any magnetic flux change in the active beam transformer core is handled with the addition of a magnetic modulator and control loop.
  - A particle beam in the aperture of the toroids will introduce asymmetry and give an output of even harmonics at the modulation frequency. The 2nd harmonic component of the output signal is proportional to the primary current and its phase is determined by the direction of the beam.
  - A synchronous demodulator detects this 2nd harmonic signal synchronous with input.
  - Using that signal in a closed feedback loop, a feedback current is produced to null out the magnetic imbalance – maintaining 0-average flux.
  - A stable, precision resistor in the feedback path yields a voltage output.

DCCT Output Signals

- DCCT Receiver has 3 different buffered outputs to provide more useful scaling: The "S" is for small intensities, "M" for medium, and "B" for big.
- The "B" output is simply a buffered output of the signal received.
- "M" output has amplification and a low-pass filter. (e.g. 500 Hz anti-aliasing LP Filter for MI DCCT).
- "S" output has additional notch filtering to remove parasitic resonant 1^{st} and 3^{rd} harmonic frequency components (e.g. 200 Hz & 600Hz Filter for MI DCCT). It also has gain.
- "B" is used to provide inputs to digitizing front-end. As a result, a intermediate filter module is used to mimic filtering schemes in "M" and "S". This allows the digitizing front-end to keep similar responses the old MADC readings over the full range of beam intensities.

MI DCCT Calibration Test Setup



- Current source is typically a precision voltage supply.
- Known DC currents are sent through calibration winding of detector.
- Test currents are determined by measuring voltage drop across calibration resistor as current source is stepped from 0 to full-scale.
- ACNET readings are compared to calculated intensities for a given current range under test.
- Calibration setups for other DCCTs (e.g. RR, TEV, PBAR) are similar.

Example of DCCT Calibration Calculations

Electron Charge =	1.60E-19
RFFrequency (8Gev/150Gev) =	52958000
Burden Resistor (Ohms) =	10.12

			I:BEAM				
			35.531716	<<--max	Calculated from I:BEAM readings		
VIN	Amps	Watts	Calculated	ACNET Measured	Voltage Reading	LSF CORRECTED (E12)	Errors With Correction
0.000	0.000	0.000	0.000	0.142	0.036	-0.047	0.047
0.832	0.082	0.068	5.694	5.180	1.383	5.656	0.038
1.537	0.152	0.233	10.522	9.490	2.536	10.534	-0.012
2.167	0.214	0.464	14.841	13.360	3.571	14.914	-0.073
2.873	0.284	0.816	19.675	17.610	4.707	19.724	-0.049
3.547	0.350	1.243	24.289	21.670	5.793	24.320	-0.031
4.275	0.422	1.806	29.275	26.040	6.961	29.266	0.009
5.003	0.494	2.473	34.261	30.390	8.124	34.189	0.071

	GAIN	OFFSET
lsf	0.883525448	0.183094923
Old	3.74	0.006
New	4.233041629	-0.200441224

Σ Errors	0.000
χ2 (E12)	0.018
RMS / σ (E12)	0.054

I:BEAM

%Δ in Gain	*13%*
Δ in Offset	*-0.21*