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Design of the High-Current DCCT Applied to the FTPMF System

Shaozhe Zhang, Zhenglei Wang, Jianfeng Xie, Sabrina Li, Xiaotao Han, Member, IEEE, and Liang Li

Wuhan National High Magnetic Field Center， Huazhong University of Science and Technology, Wuhan, China， 430074

I. Introduction

- The measurement accuracy of current directly, which determines the stability of high flat-top pulsed magnetic field (FTPMF), is a key aspect in some scientific studies, such as nuclear magnetic resonance (NMR) . The Direct-Current Current Transformers (DCCT) is the best choose to improve the stability. However, upping to tens of kiloamperes in the FTPMF system, the magnitude of current makes it a challenge for DCCT to achieve fast tracking when the current rises and precise measurement during the flat top simultaneously.
- In Wuhan National High Magnetic Field Center(WHMFC), a prototype of 30kA DCCT applied to the FTPMF is designed. This poster will show the calculating formulation of the linear region of the magnetic modulator, the key component to detect magnetic flux in the cores, the result of simulation and the pretest.

II. Design and Simulation

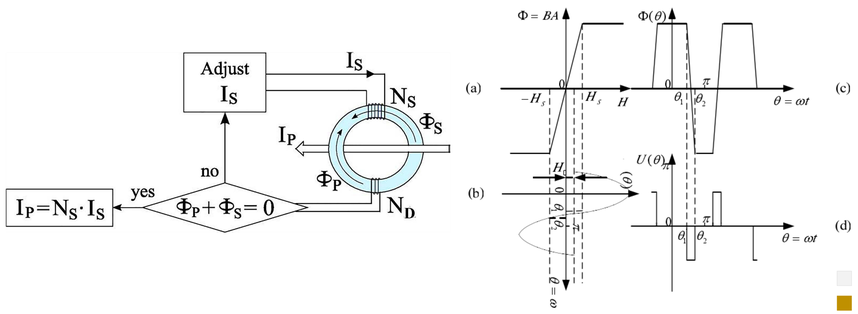

Fig. 1 Basic principle of zero-flux current transducers

- Excitation windings are formed by 1000-turns coils on the two cores, respectively. The internal and external diameters of each core are 350 mm and 366 mm, and their square sections are 80 mm2.
- The cores are made of the nanocrystalline material with high permeability, and the inductance of these two windings is about 1.5 H.
- The current-limiting resistors(R1, R2) are used to set the peak of the excitation current.
- The excitation windings are driven by a centre-tapped transformer, by this way they can be used as detection windings with differential output at the same time, see Fig. 3. The excitation voltage of the transformer is 50 Hz sine wave.
- The second harmonic is extracted by band pass filters and a DC signal is obtained by the PSD and low pass filter, and the relationship between the DC signal and the offset current is linear when the modulation cores are not saturation.
- In order to guarantee the high accuracy, a linear power amplifier of class AB is used. Its maximum output voltage is 140 V and magnification is 14.
- The performance of DCCT is studied by the root locus method. The gain and integral time of PI controller are finally set as 1 and 0.22, respectively
- The burden resistor Rm is AZ-H1-1R00 (Power rating: 10 W, temperature coefficient: < 3 ppm/K) manufactured by ISA.

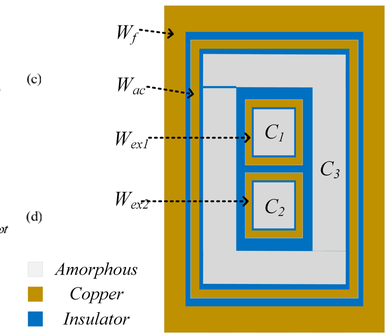

Fig. 2 Configuration of the magnetic head

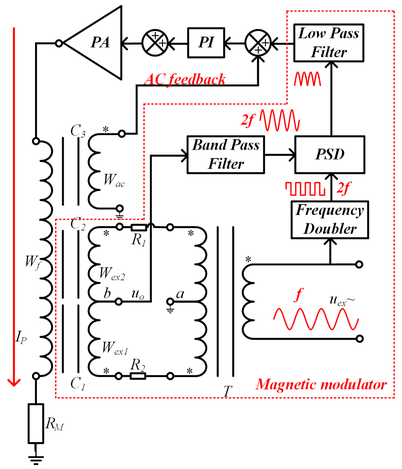

Fig. 3 Schematic of DCCT measurement system

III. Result and Discussion

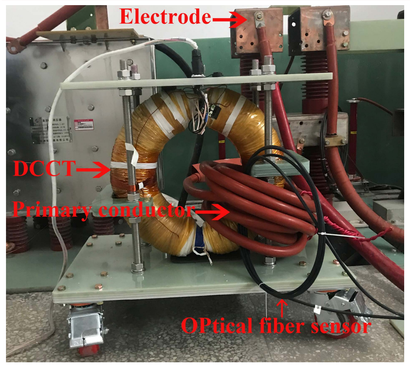

Fig. 4 Photo of pretest

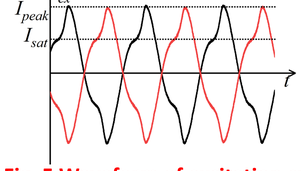

Fig. 5 Waveform of excitation current

Table I EXPERIMENTAL RESULTS OF LINEAR RANGE OF MAGNETIC MODULATOR

Test	I_{peak} (mA)	I_{sat} (mA)	k	I_{ex} (A) Calculated	I_{ex} (A) Tested
1	101	1.24	0.5	[-49.9 49.9]	[-49 49]
2	151			[-74.9 74.9]	[-75 75]
3	2.83		0.7	[-1.11 1.11]	[-1.1 1.1]
4	4.24			[-2.1 2.1]	[-2.1 2.1]

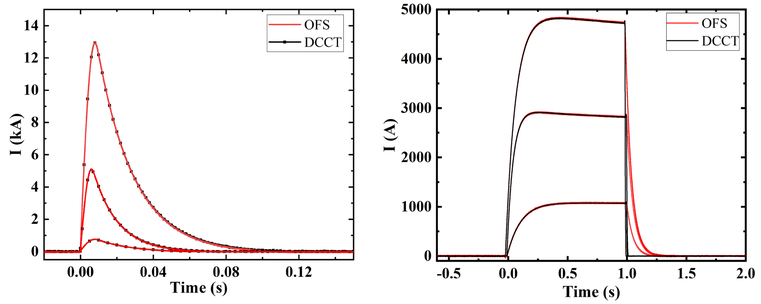

Fig. 6 Test of pulsed current and pulsed flat-top current

- Based on the existing experimental conditions in WHMFC, the pretests of DCCT were conducted in the FTPMF system. Fig. 4 shows the photo of pretest and a commercial optical fiber current sensor (OFS) with accuracy of0.1% (manufactured by Beijing SWT Optical Communication Technology Co., Ltd.) is used as a comparison.
- The power source is capacitor bank or battery bank for Dynamic performance and steady state performance(Fig. 6), respectively.
- The difference between OFS and DCCT in falling edge(Fig.6) is caused by different crowbar brunch topology.
- Based on the simulation analysis, the estimating formula of linear range of magnetic modulator is obtained:

$$-kN_{ex}(I_{peak}-I_{sat}) < I_{LR} < kN_{ex}(I_{peak}-I_{sat})$$

- The experimental results suggest that the linear range of magnetic modulator can be estimated by above.

IV. Conclusion

- Experimental results show that the dynamic performance of prototype can meet the measurement requirement.
- The linear range of magnetic modulation depends on peak of the excitation current and the saturation current of excitation core, and its calculating formula is given.
- However, the accuracy of optical fiber current sensor is lower than DCCT, thus the accuracy of DCCT cannot be calibrated. We are actively seeking help from the national measurement stations

References

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