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Multi-objective Optimization Design of Repetitive Pulsed High Magnetic Field System

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Introduction

- The development of frontier science technology makes new requirements to repetitive pulsed high magnetic field(RPHMF).

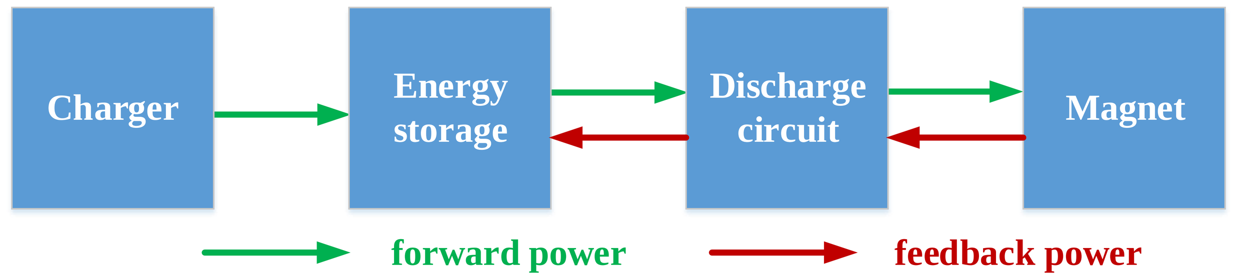

Fig.1. Comparison of traditional methods and proposed methods

- However, the parameters of the magnet and power can't match optimally in traditional design method, and could not meet the requirements of magnetic field, frequency and so on at the same time.
- This paper proposes an optimal design method of RPHMF system based on a novel multi-objective algorithm, and analyzes the relationship between magnetic field, temperature field, structure force field and design object.

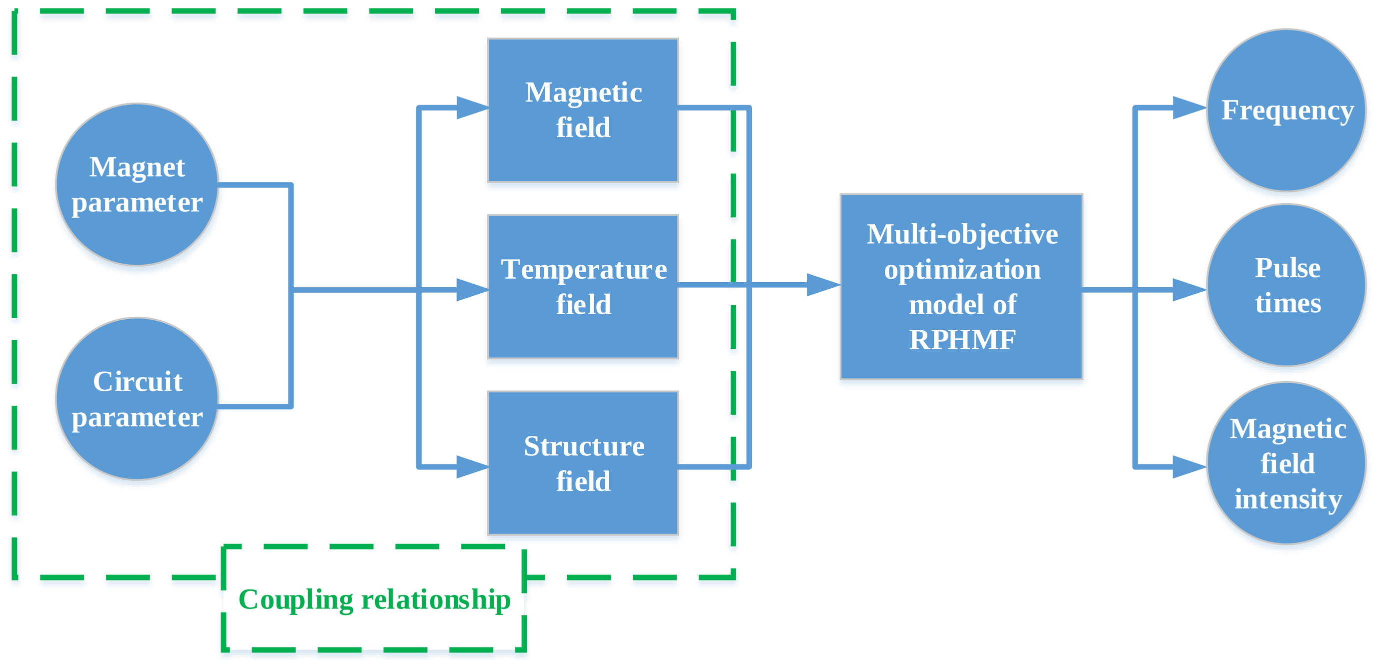

Fig.2. Abstract of the multi-objective optimal design

- This design method helps to solve the mismatch between magnet and power parameters in traditional design method

Analysis of RPHMF System

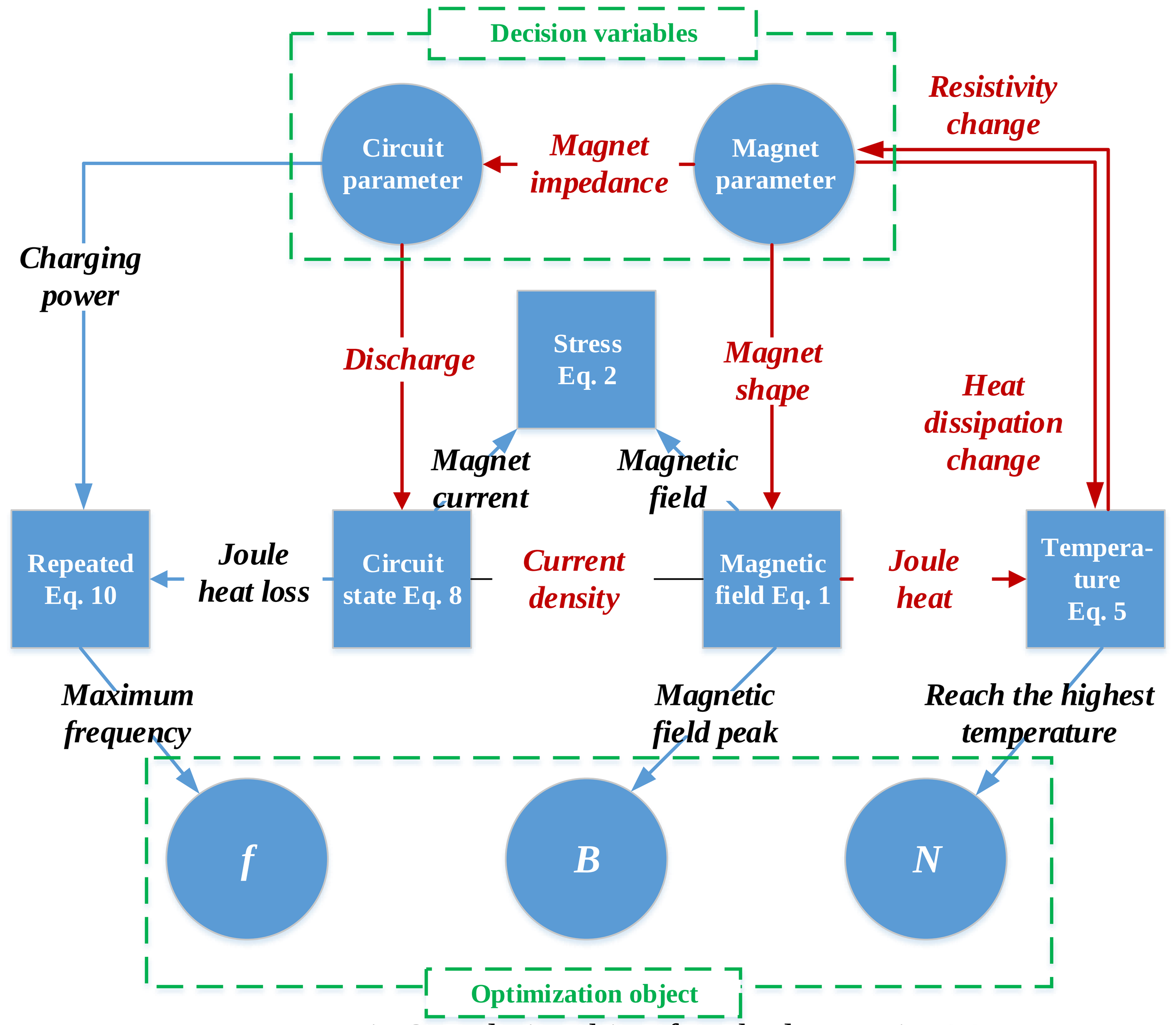

Fig.3. Relationship of each element in RPHMF

- RPHMF system have several design aims at the same time such as *f*, *B*, *N*.
- The design objects of the circuit and magnet aren't independent.
- The designs are also limited by three physics fields as magnetic field, thermal field, structural mechanics together.
- There are complicated couplings in the circuit and magnet designs by the energy, temperature and stress.

Multi-objective Algorithm of RPHMF

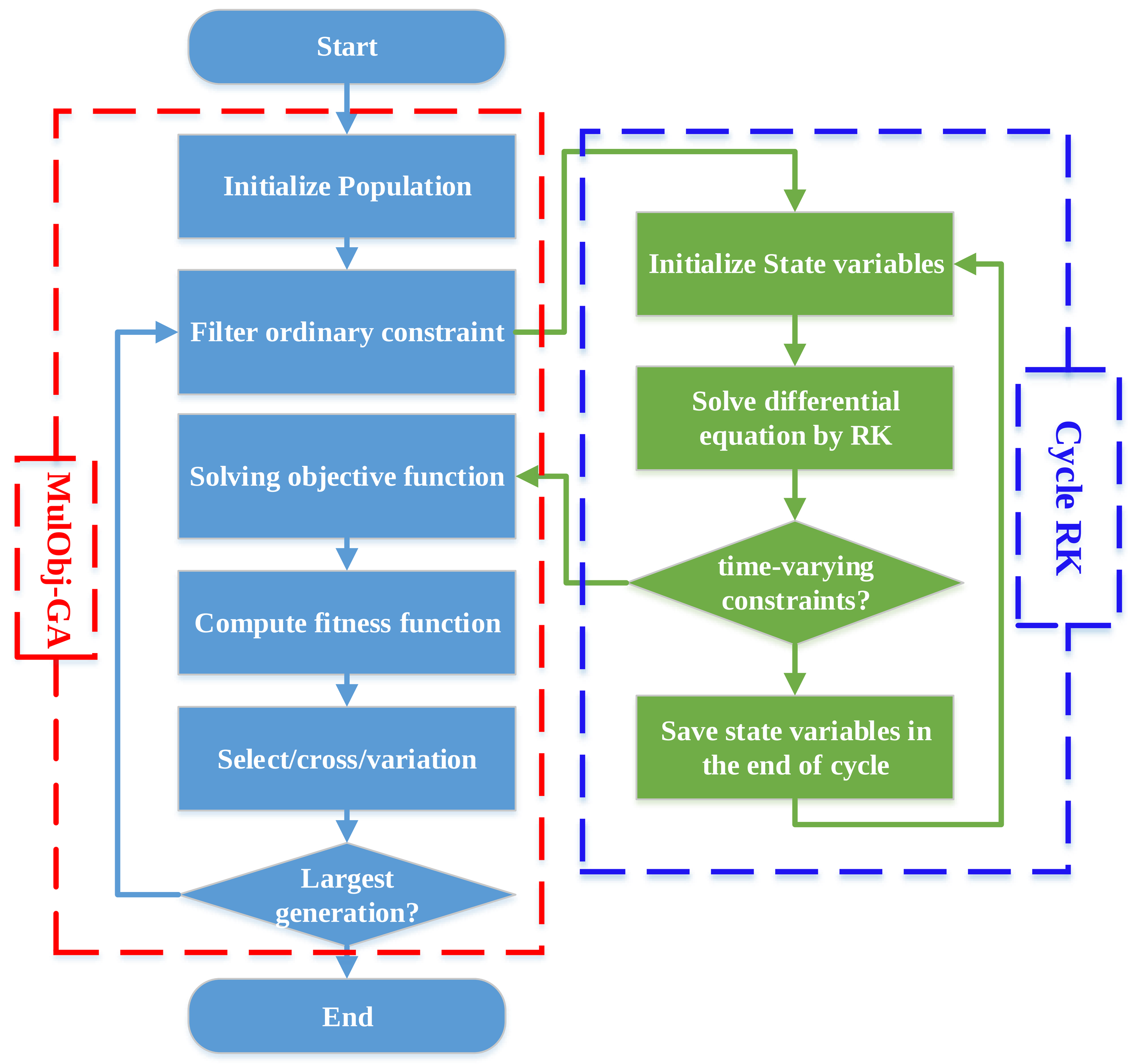

Fig.4. Algorithm flowchart of RK-GA

- Design the cycle RK method to solve the problem of topology time-varying.
- Design genetic algorithm to quickly find global optimal solution
- Avoid the disadvantage of the traditional common fundamental approximation calculation method

Optimization Results

- As a design example, based on the requirements of RBWO, the multi-objective optimization model is built for its RPHMF system:

$$\max \ [f_m(\vec{X}), N_m(\vec{X})]$$

$$\text{s.t.} \begin{cases} B_{\max}(r_1,r_2,h,S_c,U_s,C_p,t)=3\text{T} \\ A(r_1)\geq 380\,\text{mm}^2 \\ \varphi(r_1,h)\geq 90\% \ (\text{h}<60\,\text{mm}) \\ pw(r_1,r_2,h,S_c,U_s,C_p)\geq 1\text{ms} \\ T(r_1,r_2,h,S_c,U_s,C_p,t)\leq 400K \\ \sigma(r_1,r_2,h,S_c,U_s,C_p,t)\leq 200\text{MPa} \\ \text{P}_s=10\text{kW} \end{cases}$$

$$\vec{X}=(r_1,r_2,h,S_c,U_s,C_p,t)$$

- Then solve the multi-objective model by the RK-GA, optimization results are represented in the Pareto frontier figure.
- Select the optimal individual of the Pareto set by inflection-point method.
- Design method proposed has 30% in frequency or 40% in the pulse times rise compared to the traditional.

Tab.1. RBWO design requirements

Parameter	Range
Object of Design	
Storage capacitor (uF)	[200,1000]
Charging voltage (V)	[1000,2000]
Magnet bore (mm)	[20,40]
Magnet diameter (mm)	[50,100]
Magnet length (mm)	[100,200]
Coil cross-sectional area (mm^2)	[4,16]
Restrictions	
Magnetic flux density (T)	>3
Magnetic field area (mm^2)	>350
Magnetic field uniformity	>90%
Pulse width (ms)	>3
Magnet temperature (K)	<450
Magnet stress (MPa)	<200

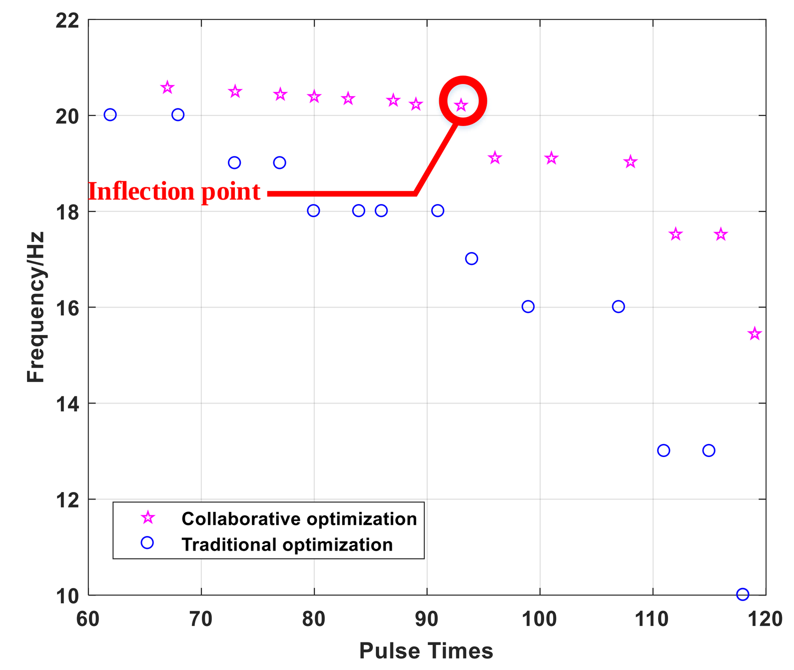

Fig.5. Solution result of Pareto frontier

Experiment and Conclusion

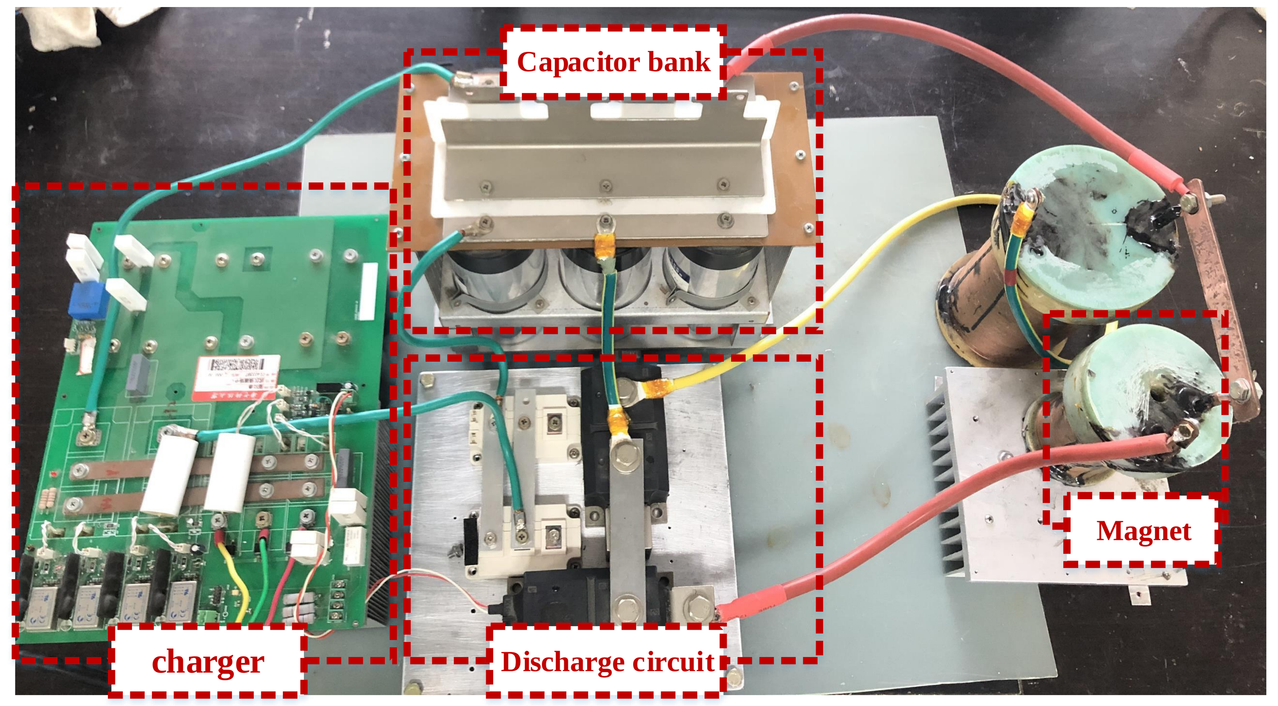

Fig.6. Prototype of RPHMF system

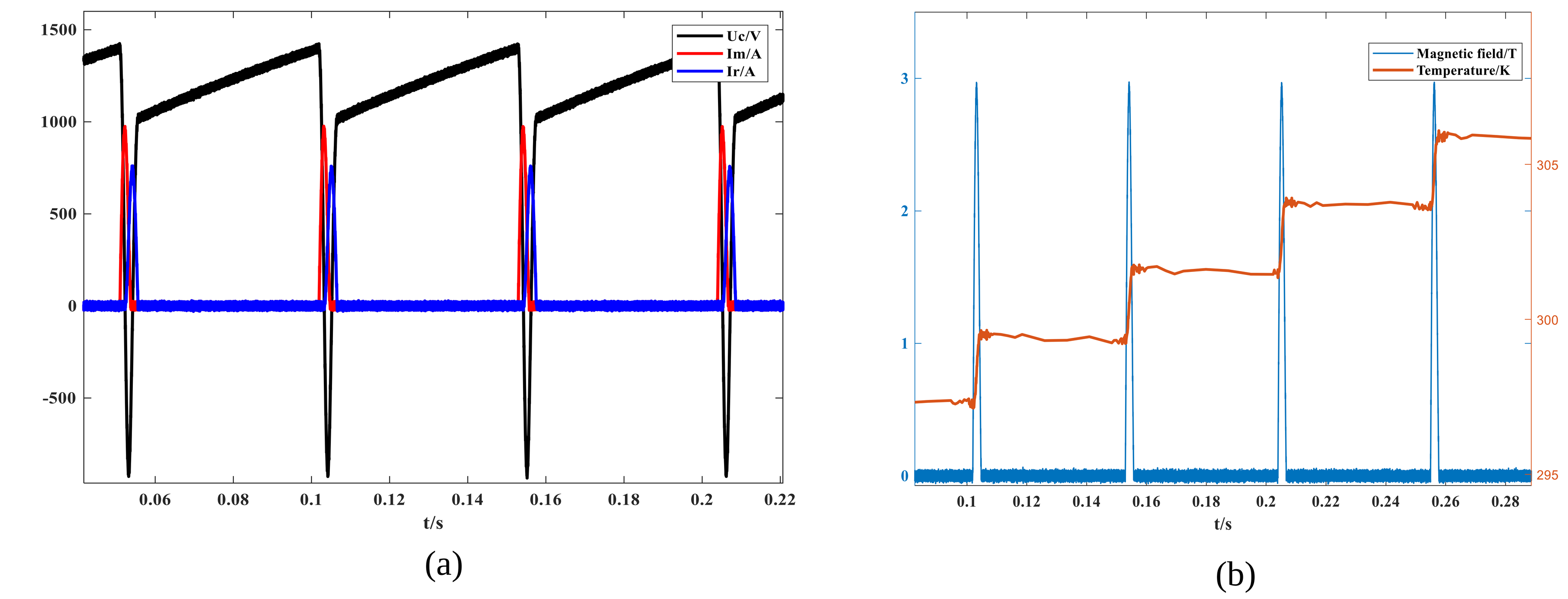

Fig.7. waveform Results (a) Discharge circuit waveform (b) Magnetic field waveform

- The experiments achieved 3T/20Hz RPHMF, verified the feasibility of the multi-objective optimization design method.
- This optimization algorithm can be applied to various power supplies, magnets and work condition. Therefore it has important application value for the design and optimization of RPHMF.