Voltage Distribution Research on Flux-Coupling-Type SFCL

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Abstract——The level of short circuit current in power system is increasing rapidly, and flux-coupling superconducting fault current limiter based on paralleled superconducting windings can effectively limit short-circuit current by the increased impedance after decoupling of the windings. The superconducting windings with high coupling factor is the core component of this SFCL, and the voltage distribution of windings may be uneven depending on the winding type and operating condition. This could affect the quenching of superconducting windings, and even endanger the insulation. In this paper, the voltage distribution of pancake-winding and layer-winding is theoretically analyzed, then simulations considering different operating conditions were carried out, and two prototypes were processed and the experiment results are in accordance with simulation to some degree.

1. Structure of FC-SFCL

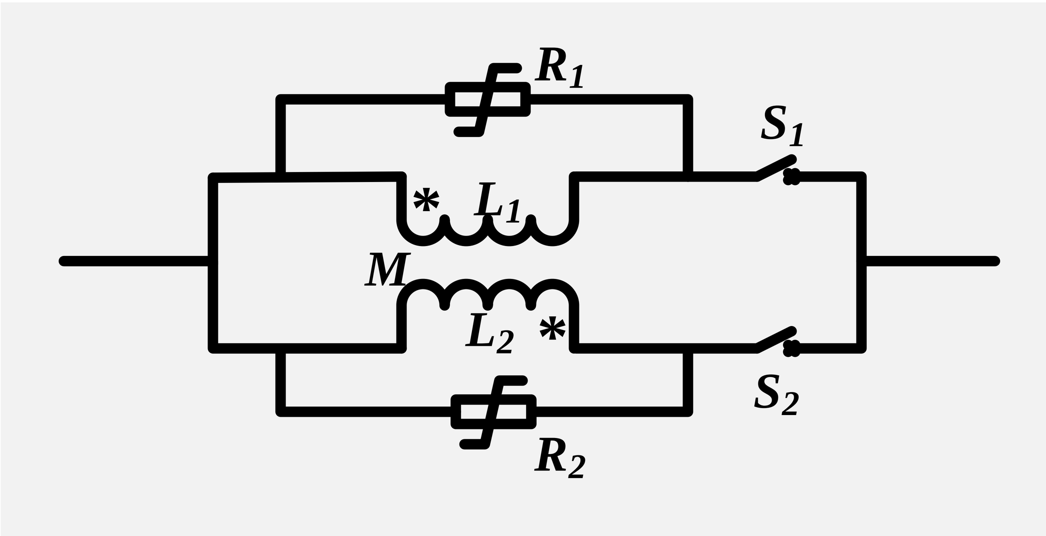


Fig.1. Basic structure of the FC-SFCL.

2. Two structure types of HTS winding

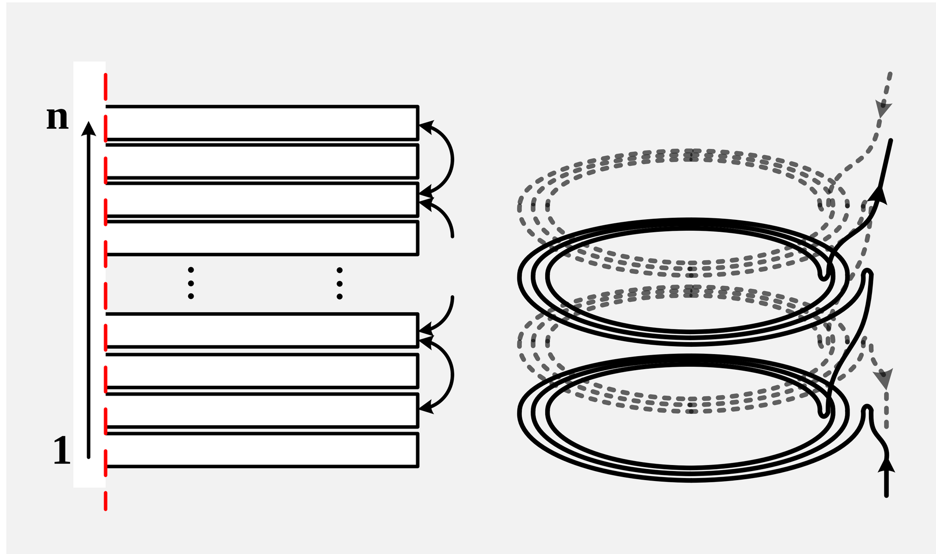


Fig.2. Pancake-winding.

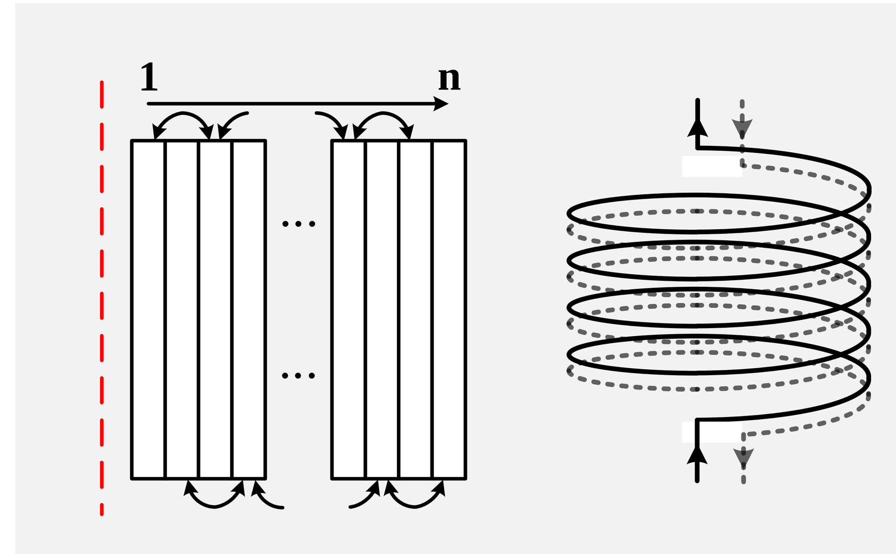


Fig.3. Layer-winding.

3.Simulation

Table I PARAMETERS OF TAPE.

Item	Value
Width (PI insulation contained)	5 mm
Thickness (PI insulation contained)	0.44 m
Critical current (77 K, self-field)	> 200 A

Table II PARAMETERS OF PANCAKE–WINDING.

Item	Value
Turns of each coil	16
Number of coils	16
Gap between adjacent coils	2 mm
Inner diameter	165 mm
Outer diameter	172 mm
Height of winding	110 mm

Table III PARAMETERS OF LAYER–WINDING.

Item	Value
Turns of each coil	18
Number of coils	14
Inner diameter	165 mm
Outer diameter	171 mm
Height of winding	92 mm

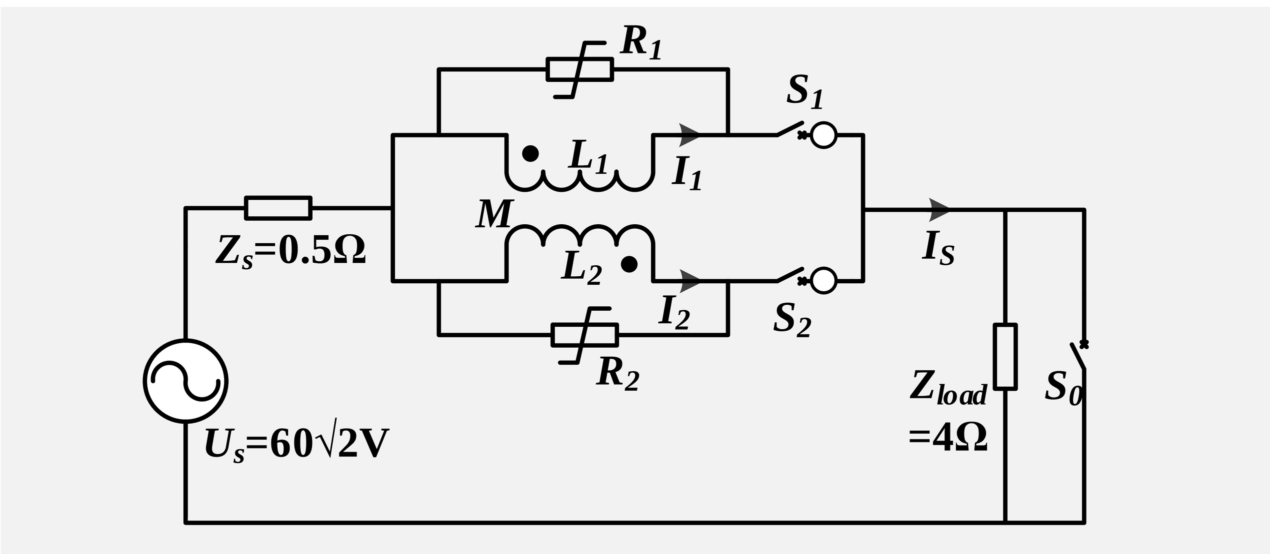
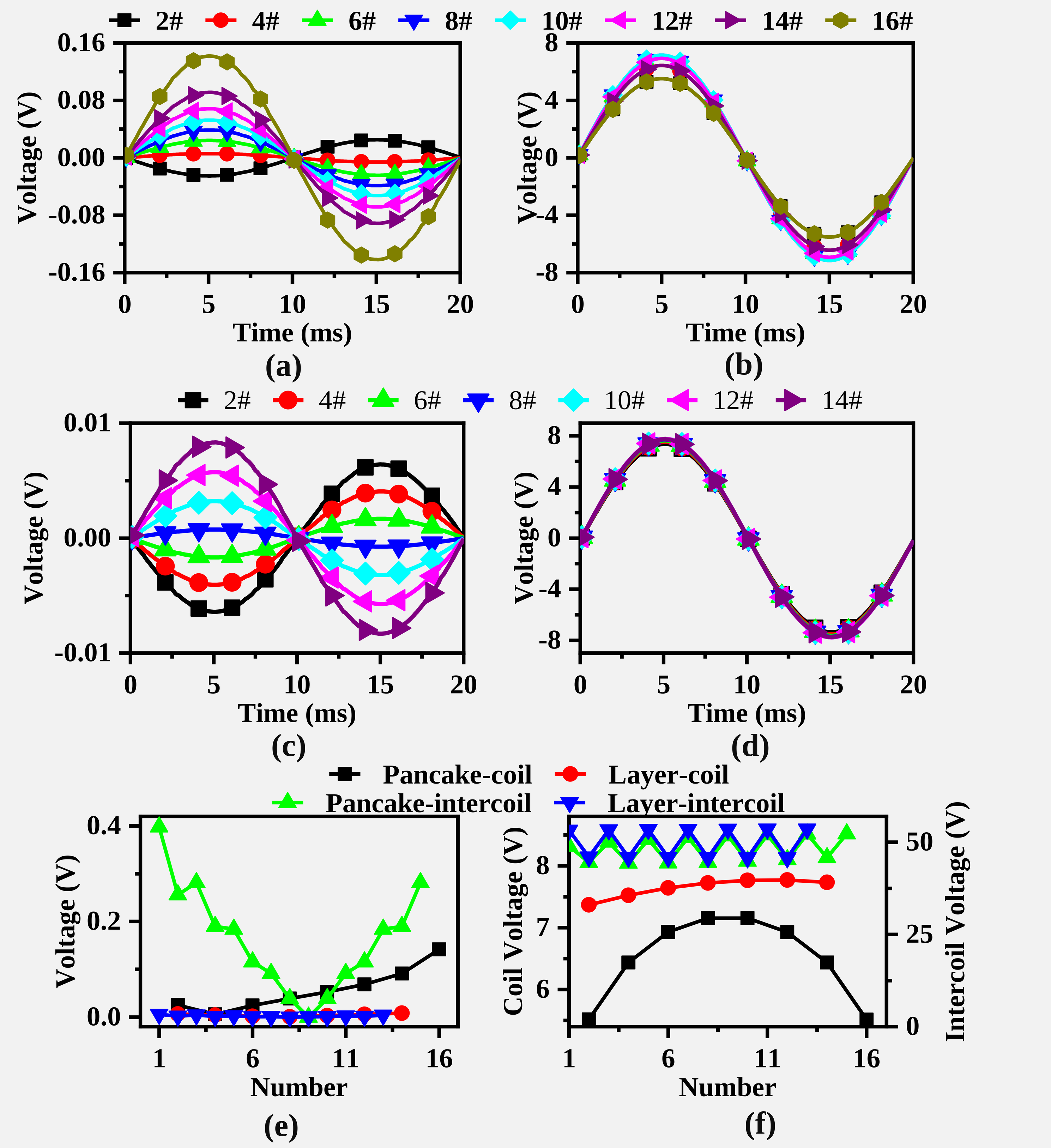


Fig. 4. Circuit of simulation



(a) Voltage waveforms of coupled pancake-coils. (b) Voltage waveforms of decoupled pancake-coils. (c) Voltage waveforms of coupled layer-coils. (d) Voltage waveforms of decoupled layer-coils. (e) Amplitudes of coil voltages and intercoil voltages under coupled state. (f) Amplitudes of coil voltages and intercoil voltages under decoupled state.

Fig. 5. Voltage distribution of simulation

4. Experiments

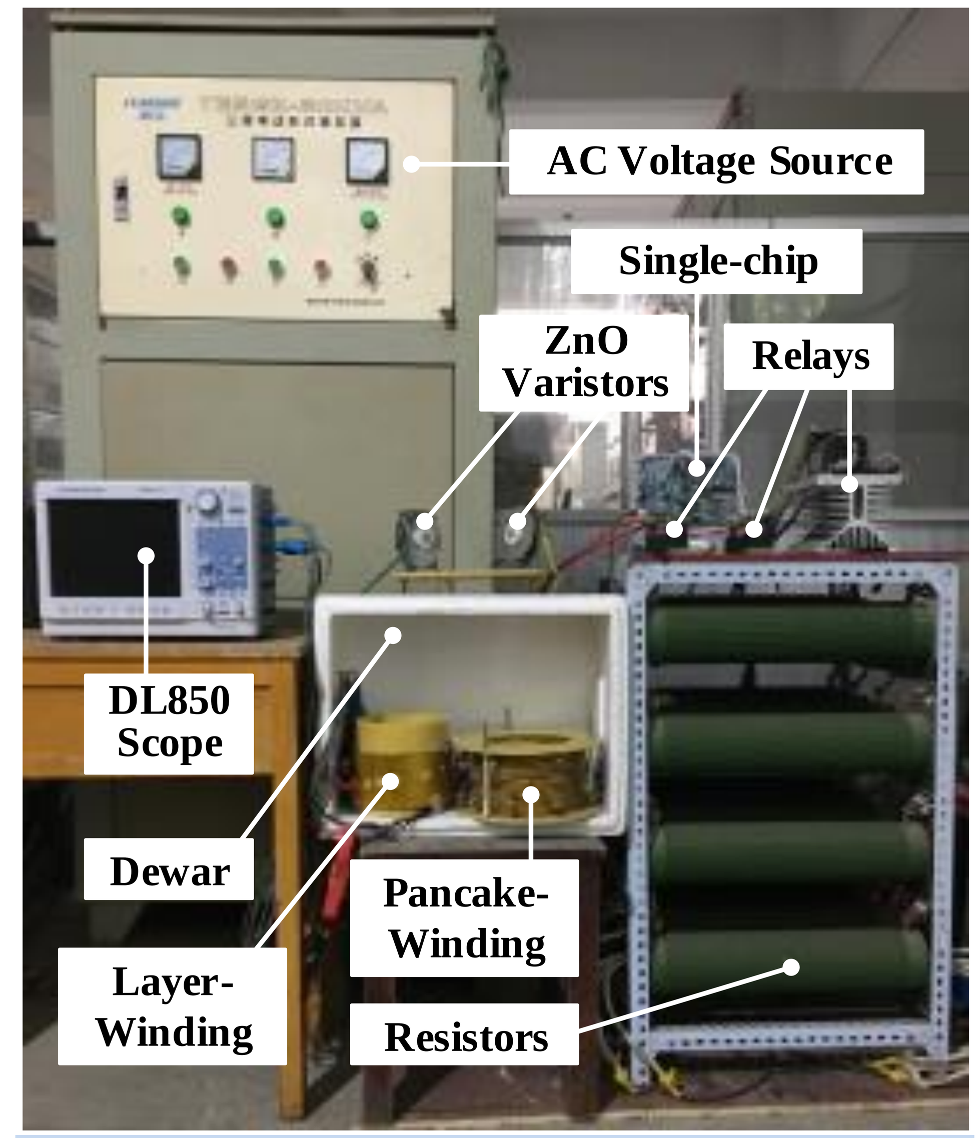
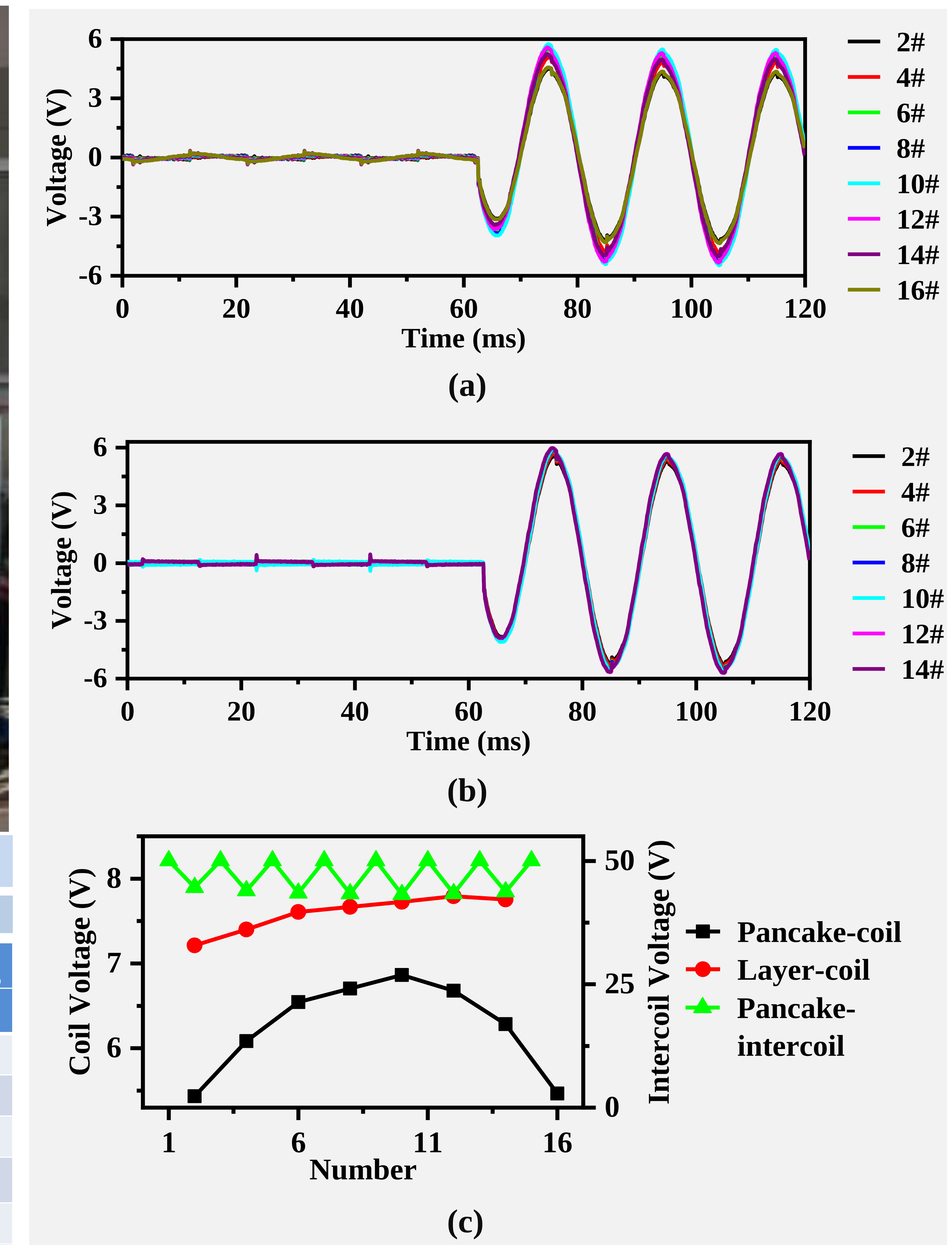


Fig. 6. Experimental platform

Table IV PARAMETERS OF PANCAKE–WINDING.

Coil Number	Pancake-winding			Layer-winding		
	L_{eq1}	L_{eq2}	L_{eq3}	L_{eq1}	L_{eq2}	L_{eq3}
2#	255	262	263	360	356	349
4#	299	306	294	368	364	358
6#	322	329	317	374	370	368
8#	333	340	324	378	373	371
10#	333	340	332	380	376	374
12#	322	329	323	378	376	377
14#	299	306	304	376	374	375
16#	255	262	264			

The unit of Table II is μH. And L_{eq1}, L_{eq2} and L_{eq3} represent the equivalent inductance obtained by theory, simulation and experiment, respectively.



(a) Voltage waveforms of pancake-coils. (b) Voltage waveforms of layer-coils. (c) Amplitudes of coil voltages and intercoil voltages under decoupled state..

Fig. 6. Voltage distribution of experiments

5. CONCLUSION

1) When coupled, the two windings have a similar voltage distribution that voltages of end coils are larger and the middle ones are lower, and there is a phenomenon of phase reversal.
2) When the windings are decoupled, the middle coils have higher voltages. Pancake-winding has a symmetrical voltage distribution whereas layer-winding has an asymmetrical and more even one.
3) The intercoil voltage distribution of two windings is at a rather low level under coupling state but at a high level of sawtooth under decoupling state.

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