# A Novel Thermal Network Model for Double Stator Brushless Doubly-Fed Generator With Cage-barrier Rotor Based on Improved Mechanical Structure

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***Induction***—In order to enhance the torque density and efficiency of existing wind driven generator further, a novel double stator brushless doubly-fed generator with back-to-back cage-barrier rotor(DSBDFG) has been proposed. However, the mechanical failure of inner stator striking rotor has been occurred in the process of prototype machine experiment. In order to solve this problem, an improved mechanical structure is presented instead of the original mechanical structure. In addition, in view of the rich harmonic magnetic fields existing in this generator which generates lots of losses, and also because of its compact structure which makes the heat dissipation difficultly, it brings in the risk of high temperature easily. Therefore it is a challenge to receive the temperature rise distribution of DSBDFG quickly and accurately. For this purpose, a novel thermal network model for the entire structure is proposed for temperature rise calculation based on the improved structure. Finally, the correctness of the thermal network model are verified comparing with finite element simulation results and the rationality of improved structure of DSBDFG is verified by experimental study.

## Mechanical structure of DSBDFG

### *A. Operation System*

The inner and outer stator of DSBDFG both contain two sets of windings named power winding (PW) and control winding (CW). The operation system of DSBDFG is shown in Fig.1.

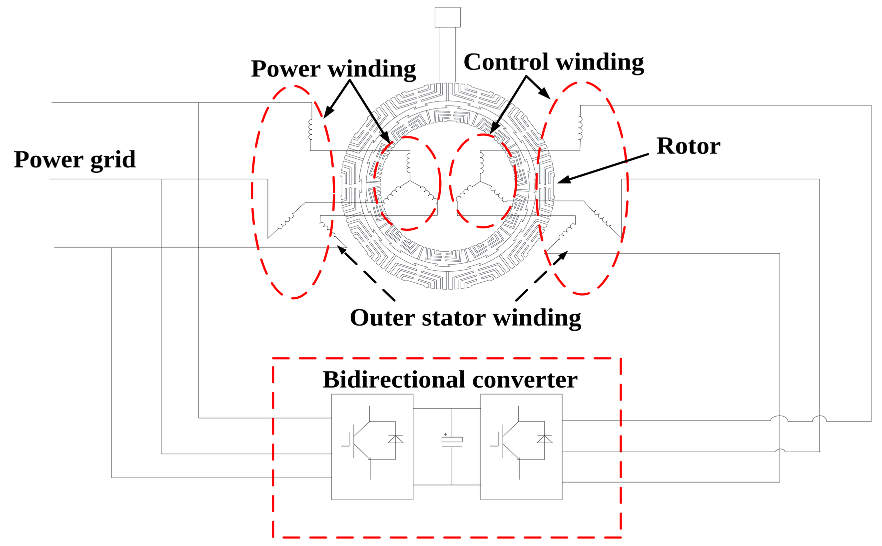
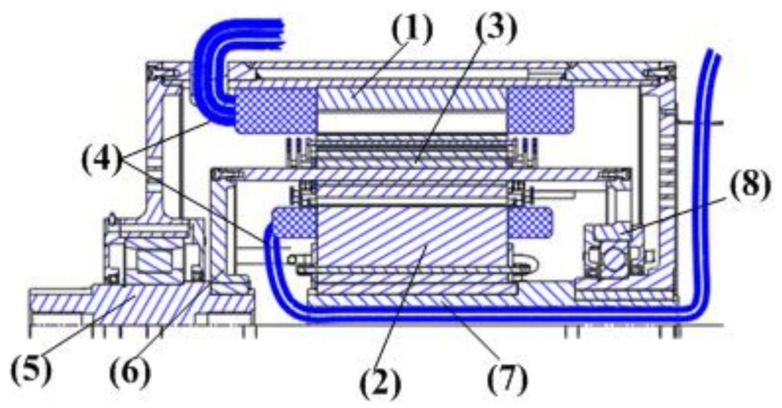



Fig.1 Operation system of DSBDFG

### *B. Original Mechanical Structure*

The original mechanical structure of the DSBDFG is shown in Fig.2.




1-Outer stator 2-Inner stator 3-Rotor 4-Winding
5-Drive shaft 6-Rotor front end cover 7-Stationary shaft 8-Rotor rear end cover
Fig.2 Original mechanical structure of DSBDFG

The cage-barrier structures are adopted for DSBDFG rotor which respectively consists of cage bars and magnetic-barrier structures shown in Fig.3.

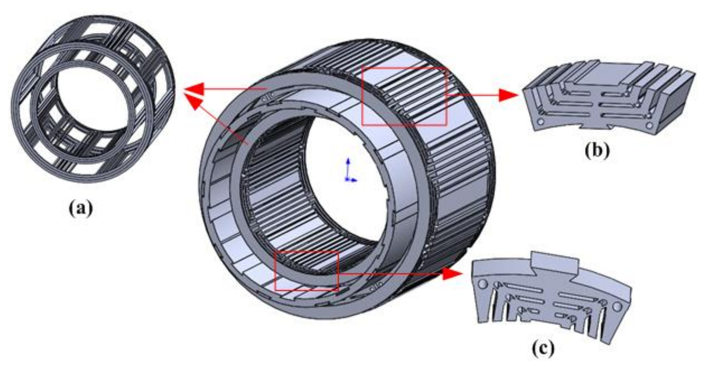
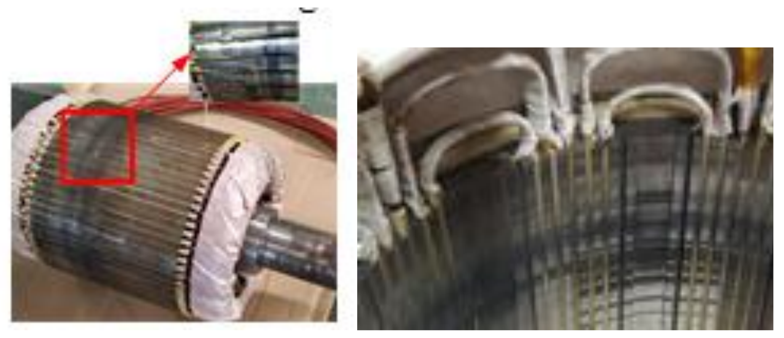



Fig.3 Rotor structure (a) Cage bars (b) Outer magnetic-barrier module (c) Inner magnetic-barrier module

### *C. Improved Mechanical Structure*

When the prototype machine is running at the rated speed, the inner stator collides with the rotor inner surface periodically. The accident consequences are shown in Fig.4. The improved structure is shown in Fig.5.



(a) (b)
Fig.4 Accident consequences (a) Inner stator (b) Rotor inner magnetic-barrier structure

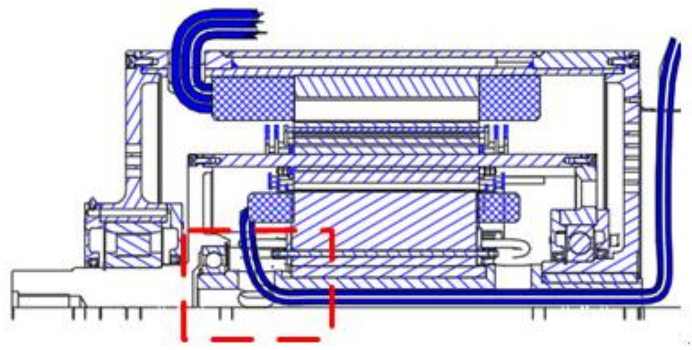


Fig.5 Improved structure of DSBDFG

## Temperature field calculation and analysis

### *A. Thermal Network Model*

A novel equivalent thermal network model based on the improved mechanical structure at natural cooling condition is presented which is shown in Fig.6

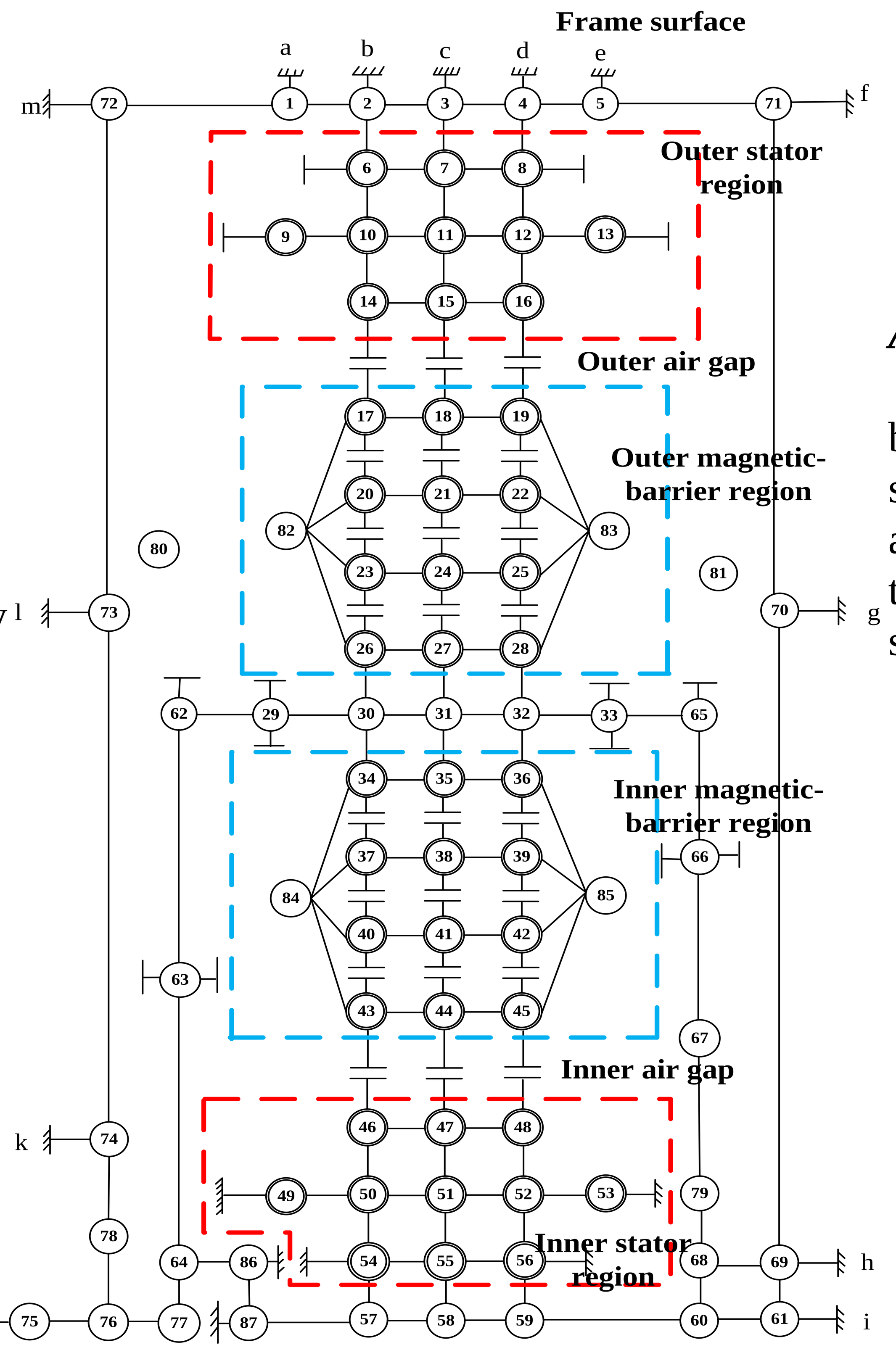



Fig.6 Thermal network model for improved structure DSBDFG

### *B. FEM Model*

The results obtained from FEM are shown in Fig.7. The temperature comparison results between FEM and TNM are shown in Table.1.

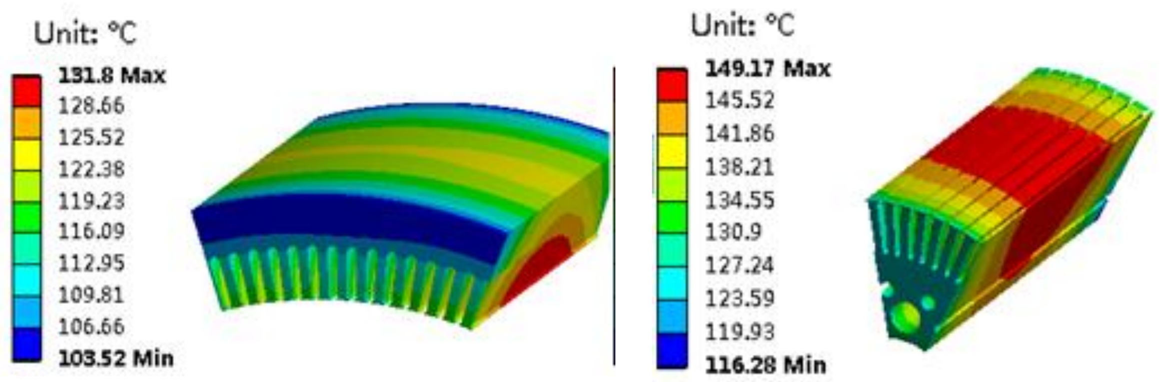



Fig.7 FEM results (a) Outer stator (b) Inner stator

TABLE I
THE COMPARISON RESULTS BETWEEN TWO METHODS(°C)

| Items | FEM | ETN |
|---|---|---|
| Outer stator | 103.5~131.8 | 110.1~119.7 |
| Inner stator | 116.3~149.2 | 139.8~157.3 |

## Prototype machine development and experiment

### *A. Parameter test*

The resistances of inner and outer windings are measured by digital DC bridge. The results are shown in Table.II. The self-inductance and mutual inductance of power winding and control winding are tested by static measurement and the test platform is shown in Fig.8, and the test results are shown in Fig.9.

TABLE II
RESISTANCE MEASUREMENT RESULTS

| Items | Value (mΩ) | | |
|---|---|---|---|
| | Phase A | Phase B | Phase C |
| Total PW | 165.4 | 165.3 | 165.3 |
| Total CW | 261.85 | 261.6 | 261.7 |


Fig.8 Inductance test platform

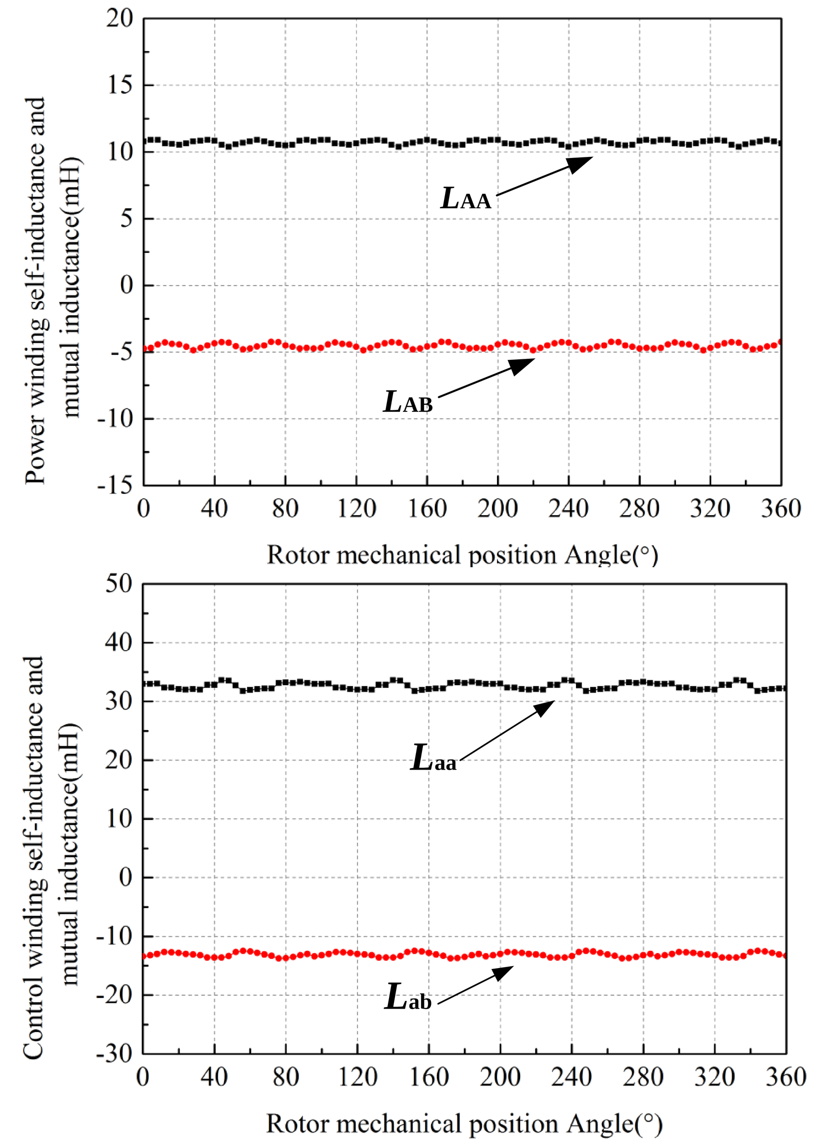



Fig.9 Inductance test results

### *B. No load test*

Fig.10 shows the power winding no-load back EMF waveform at the rated speed.

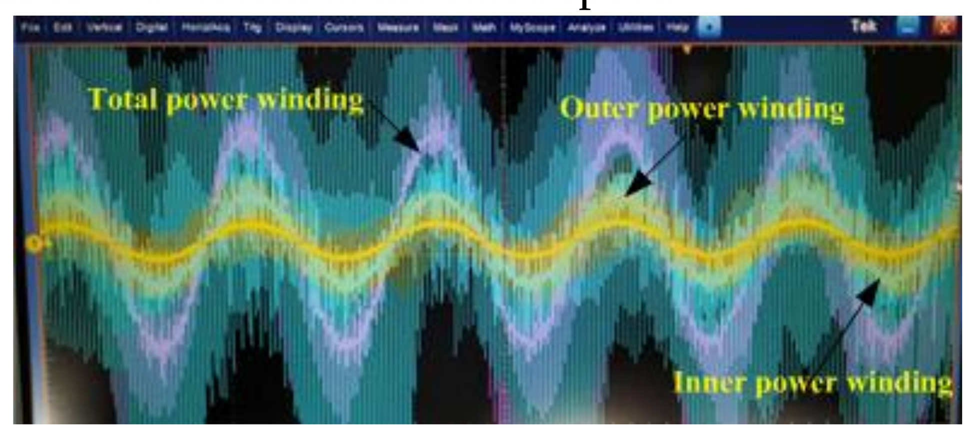



Fig.10 Power winding no-load back EMF

## Conclusion

This paper proposes an improved mechanical structure for DSBDFG to solve the mechanical failure found in the prototype machine experiment. A novel equivalent thermal network model is presented for temperature rise accurate calculation of DSBDFG based on improved structure. The rationality of the improved structure is verified by prototype machine experiment and the correctness of equivalent thermal network model is verified by comparing the ETN results with the FEM results.