A Large Scale Double-Stator Direct Driving HTS Wind Generator

Yi Cheng[1], Dawei Li[1], Ronghai Qu[1], Feng Lin[1]

1. College of Electrical and Electronic Engineering, Huazhong University of Science and Technology

Introduction

Abstract : This paper proposes a double-stator topology for HTS wind generator with rotating HTS field winding and the electromagnetic design of this generator is made. In addition, the feasibility and practical value of this machine are evaluated by comparison with the same scale one regular HTS wind generator and one double-stator permanent magnet wind generator in term of the weight, volume and cost of active materials. The results reveals double-stator HTS wind generator has great advantage in volume and mass reduction.

TABLE I
BASIC SPECIFICATION OF 15 MW WIND GENERATOR

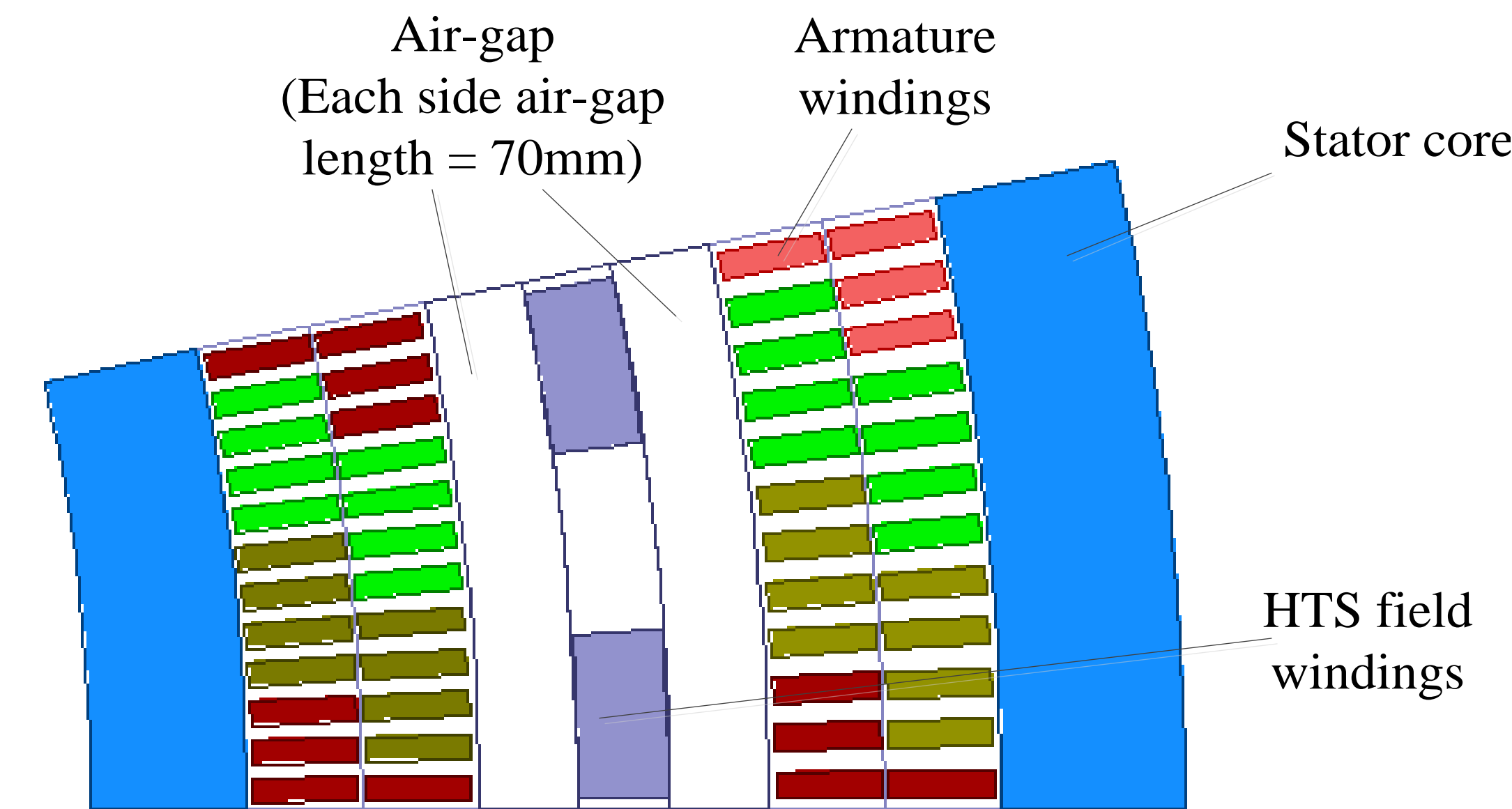| Parameter	Value
Number of phases	3
Output power	15MW
Number of poles	30
Rated revolution	9rpm
Rated phase voltage	2.73kV
Rated phase current	1.83kA
Approx. diameter	4.5m
Effective axial length	0.98m

Fig. 1. 2D model for double-stator HTS wind generator

➢ Double stator---two group armature windings adopted to increase electrical loading
➢ Nonmagnetic teeth---eliminating teeth harmonics and reducing the active material mass

Comparison

TABLE II
SPECIFICATIONS OF THE REGULAR HTS WIND GENERATOR AND DOUBLE-STATOR PERMANENT MAGNET WIND GENERATOR

Parameter	Single-stator HTS machine	Double-stator PM machine
Stator outer diameter(m)	6.10	8.76
Axial effective length(m)	1.00	1.05
Magnetic loading(T)	2.5	0.8
Armature winding current density(A/mm²)	3	3

Comparison between proposed topology and the same scale regular HTS wind generator and double-stator permanent magnet wind generator in term of the weight, volume and cost of active materials is made. Table II shows the specifications of the other two topologies.
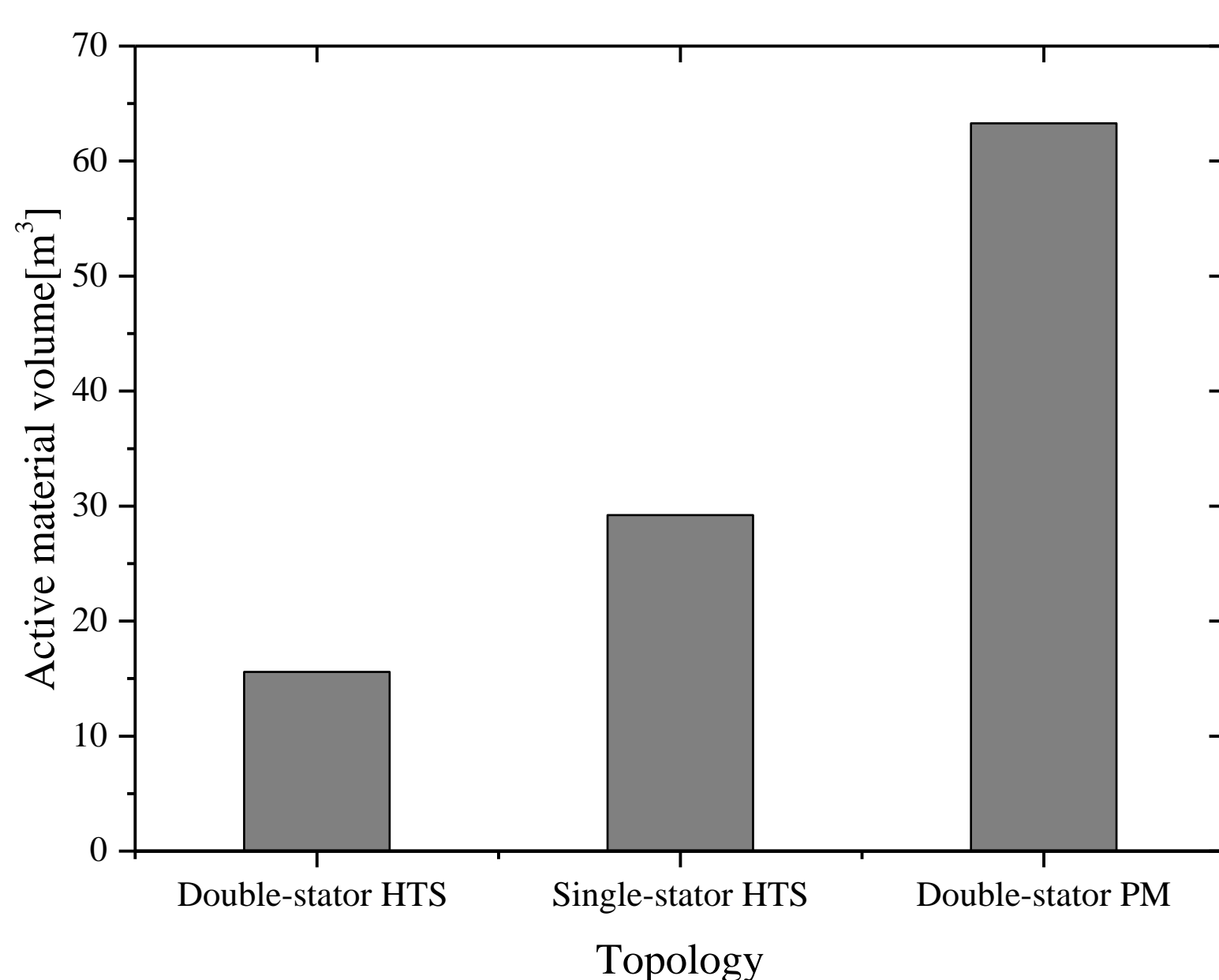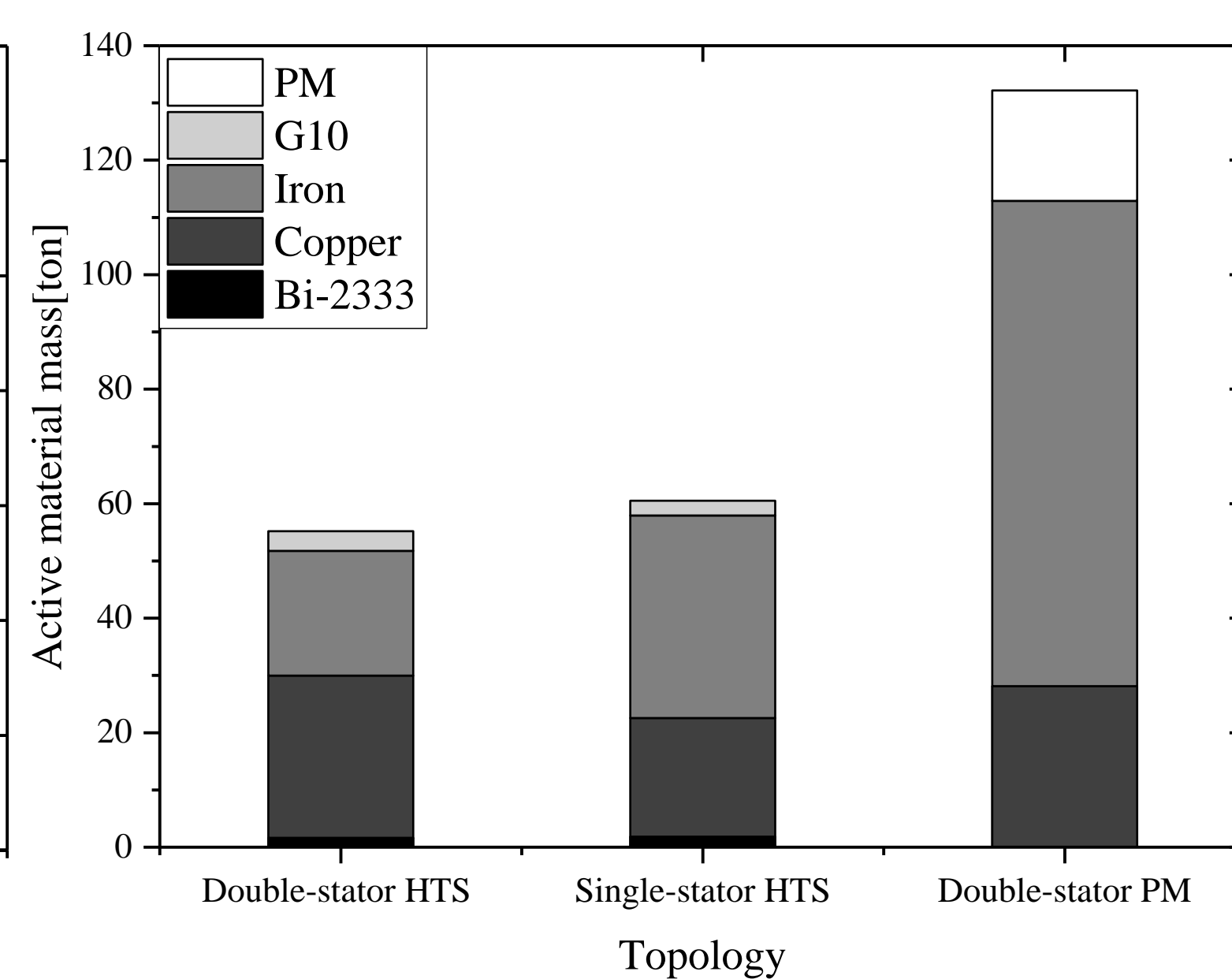

Fig. 5. Active material volume comparison

Fig. 6. Active material mass comparison

TABLE III
ACTIVE MATERIAL COST FOR DIFFERENT TOPOLOGIES

	Double-Stator HTS	Single-Stator HTS	Double-Stator PM
HTS	12844.32	13796.52	0
Copper	262.37	192.02	260.753
Iron	28.04	45.53	109.063
G10	51.68	38.34	0
PM	0	0	375.861
Total(kEuro)	13186.41	14072.41	745.677

This result shows that double-stator HTS wind generator has great advantage in volume and mass reduction while the active material cost is much higher.
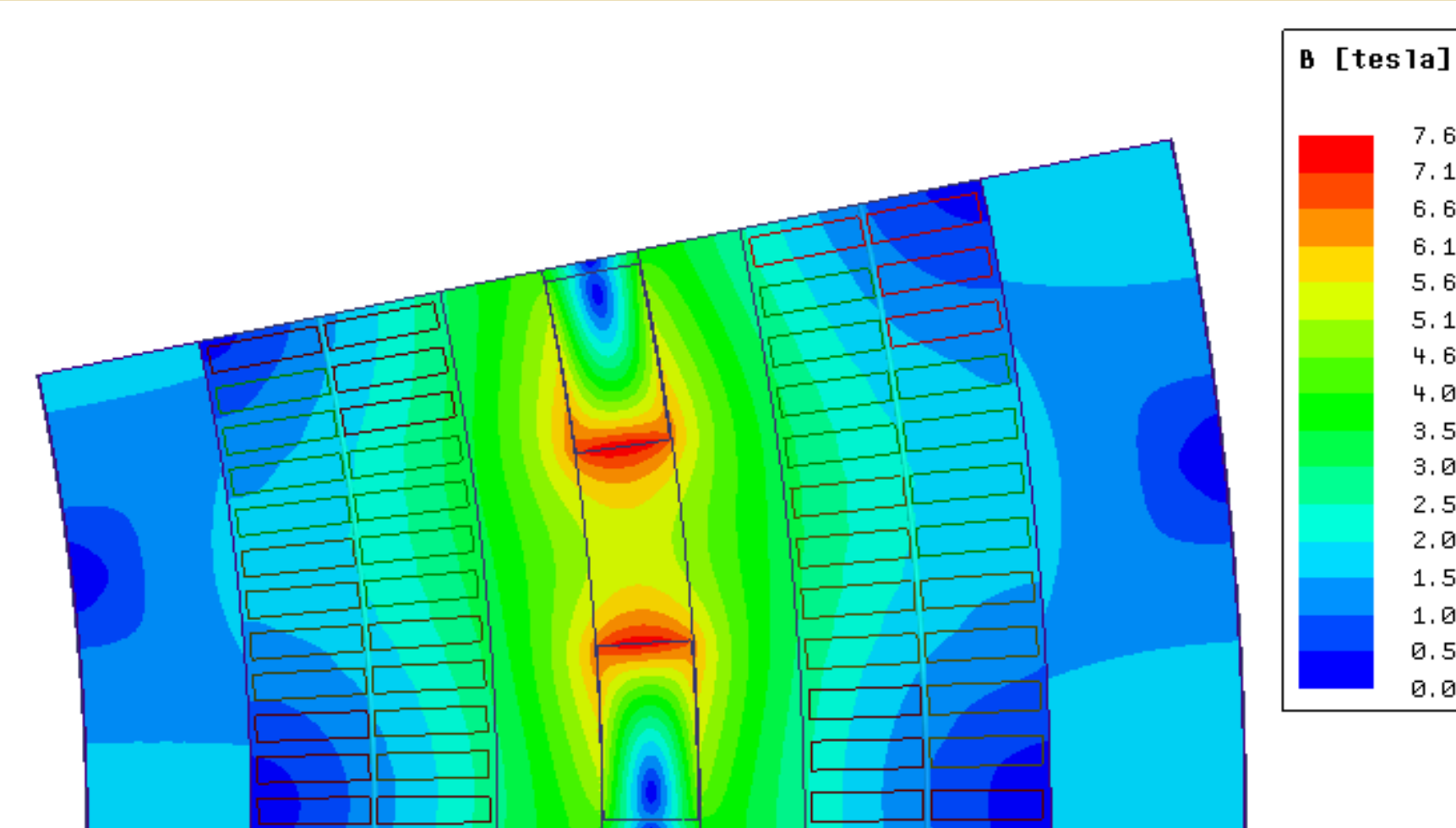
Electromagnetic Analysis

Fig. 2. No load magnetic flux density distribution

The maximum flux density around the field coils is 7.6T, And the maximum flux density in the middle line of the armature is around 2T.
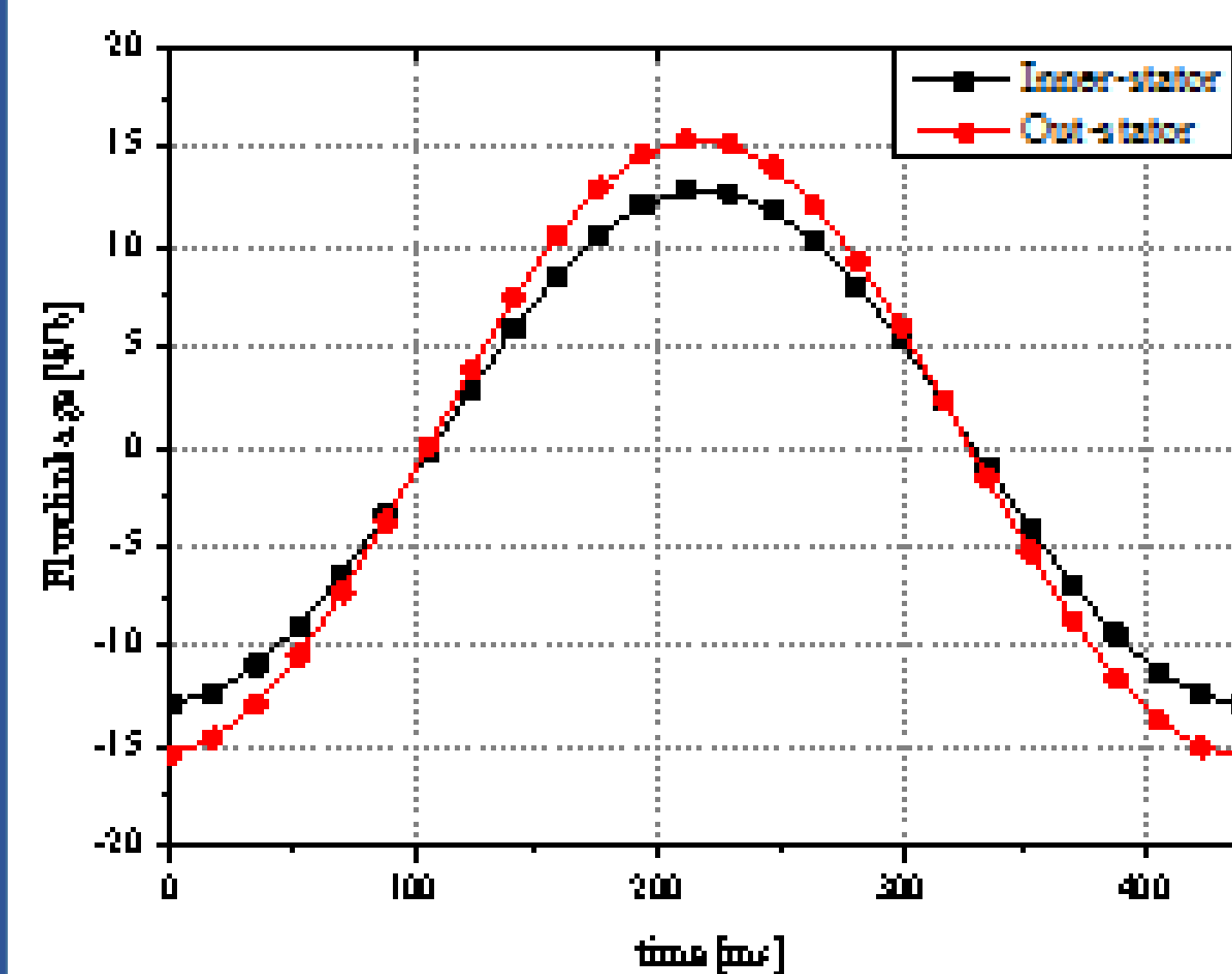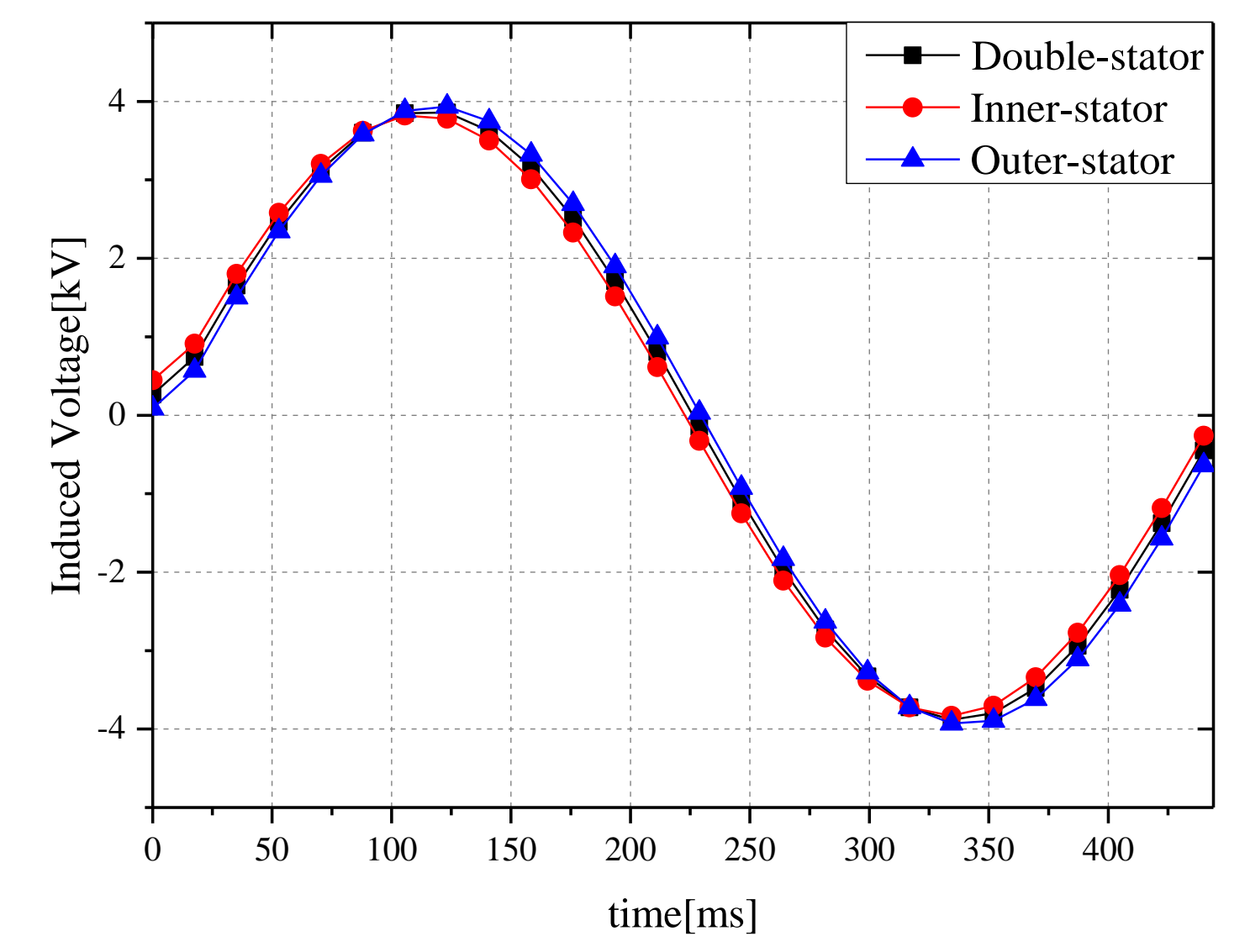

Fig. 3. Fluxlinkage waveform of A phase

Fig. 4. A phase induced voltage waveform of each windings

These two armature group windings adopt parallel structure. The voltages of two group armature windings is carefully analyzed to avoid loop current. The fluxlinkage waveform of A phase for each winding with one turn is shown as Fig. 3. The ratio of magnet flux of outer-stator armature windings to inner-stator armature windings is $\Phi_{out}/\Phi_{in}=1.198$. Keeping the same voltage, the relation $N_{in}/N_{out}=\Phi_{out}/\Phi_{in}$ can be deduced according to the formula

$$E = \sqrt{2}\pi K_w N f \Phi$$

Where E—induced voltage, K_w--winding factor, N--the number of series connected turns per phase, f--frequency, and Φ--magnet flux per pole.

Conclusion : In this study, 15 MW double-stator HTS wind generator is designed. The voltages of two group armature windings is carefully analyzed to avoid loop current. Furthermore, two other topologies, one regular HTS wind generator and one double-stator permanent magnet wind generator are put forward to make comparisons with this double-stator HTS machine. This result shows that double-stator HTS wind generator has great advantage in volume and mass reduction. The disadvantage is that the active material cost is much higher due to exorbitant price of HTS tapes.