Iryna MAZURENKO, Andriy PAVLYUK, Yuriy VASETSKY

Institute of Electrodynamics, National Academy of Sciences of Ukraine

Parameters of superconducting magnets with racetrack-shaped coils and support structure placed inside torus

Abstract *– Toroidal SMES composed of racetrack-shaped coils with spokes inside torus are considered. The volume of superconducting winding in comparison with usual O-shaped coils is considerably lesser. The volume of structural mechanical materials does not exceed the corresponding values for D-shaped toroidal system. For these reasons proposed configuration of SMES may be alternatives to conventional coil systems.*

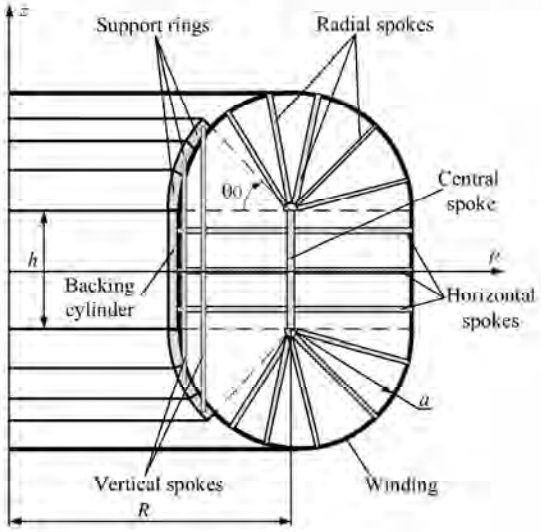
Key words – superconducting magnetic energy storage, toroidal solenoid, racetrack-shape coils, support structure, parametrical analysis

Introduction and SMES configuration

Superconducting magnetic energy storage (SMES) with elements of mechanical support system placed inside torus is considered. As it shown in [1] the toroidal systems with spokes placed inside each O-shaped coil solve two mechanical problems: eliminating bending moments in the support system and ensuring uniform mechanical stress in all the spokes and supporting structure. As a result, the volume of the support system is significantly below compare with traditional O-shaped coils with belts around coils, and this volume is about the same for more complicated D-shaped toroidal system. On the other hand O-shaped torus has larger volume of superconducting winding than D-shaped toroidal system.

The main purpose of this paper is to investigate the volumes of superconducting and structural materials for "racetrack"-shaped toroidal system.

Each coil has upper and lower semicircular parts with radius a and central straight part with length h (Fig. 1). The set of spokes are in tension. The sum of forces in the radial spokes must be equal to zero. Therefore the radial spokes are absent in a sector with the angular size $2\theta_0$. Here as well as at straight part the electromagnetic forces balanced by reaction compression forces in support rings and backing cylinder.



Main results

Usually for SMES initial parameters are the following: energy of magnetic field W, permissible maximum values of induction of magnetic field B_m and density current j_m of superconducting winding, properties of construction material of the support system (permissible values of mechanical stresses of tension σ_t and compression σ_c). Among the SMES required parameters are: volume of superconducting winding V_{sc}, volume of the mechanical support system material counteractive to forces of tension V_t and compression V_c. Dependences between initial and required parameters are given by [2]

$$V_{sc} = \frac{W^{2/3}}{j_m B_m^{1/3} \mu_0^{1/3}} k_{VSC}(\varepsilon, \lambda), \; V_t + V_c = \frac{W}{\sigma} Q(\varepsilon, \lambda), \qquad (1)$$

where $k_{VSC}(\varepsilon, \lambda)$ and $Q(\varepsilon, \lambda)$ are dimensionless parameters that are determined by geometrical characteristics $\varepsilon = a/R$ and $\lambda = (2a + h)/2a$.

It is established that the volume of superconducting winding has minimum value at $\varepsilon_{min} = 0{,}63$, $\lambda_{min} = 1{,}89$. The value $k_{VSC}(\varepsilon_{min}, \lambda_{min}) = 11{,}99$ is approached to minimum analogous parameters of D-torus that equal to $k_{VSC\,D}(\varepsilon_{min\,D}, \lambda_{min\,D}) = 11{,}70$ at $\varepsilon_{min\,D} = 0{,}68$, $\lambda_{min\,D} = 1{,}75$.

The calculation results show, that the parameter Q practically does not depend on λ and it does not exceed at the same ε values for D-shaped toroidal system.

Conclusions

The toroidal magnetic system composed of "racetrack"-shaped coils with spokes inside torus has considerably lesser volume of superconducting winding in comparison with usual O-shaped coils. The volume of structural mechanical materials does not exceed the corresponding values for D-shaped toroidal system. So, the toroidal SMES with spokes and racetrack-shaped coils could provide attractive alternatives to conventional coil systems in the development of SMES devices.

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Authors*: PhD Iryna Mazurenko, Institute of Electrodynamics, aspirant Andriy Pavlyuk, Institute of Electrodynamics; Prof., Dr.Sc. Yuriy Vasetsky, Institute of Electrodynamics, 56, Peremogy Avenue, 03680, Kiev-57, Ukraine, E-mail: yuriy.vasetsky@gmail.com;*