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# Conceptual Design of Electrical Propulsion System for Nuclear Operated Vessel Adventurer

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## 1. Introduction

A design concept of the electric propulsion system for the Nuclear Operated Vessel Adventure (NOVA) is presented. NOVA employs Battery Omnibus Reactor Integral System (BORIS), a liquid metal cooled small fast integral reactor, and Modular Optimized Brayton Integral System (MOBIS), a supercritical $CO_2$ ($SCO_2$) Brayton cycle as power converter to Naval Application Vessel Integral System (NAVIS).

## 2. Concept of NOVA

NOVA is designed to satisfy the requirement of a compact, simple, safe and innovative integral fast reactor system [1-2]. NOVA is mainly powered by BORIS. BORIS is designed to generate 22.2 $MW_{th}$ for at least twenty consecutive years without refueling and also to meet the Generation IV Nuclear Energy System goals of sustainability, safety, reliability, and economics. The general scheme of NOVA is shown in Fig. 1.

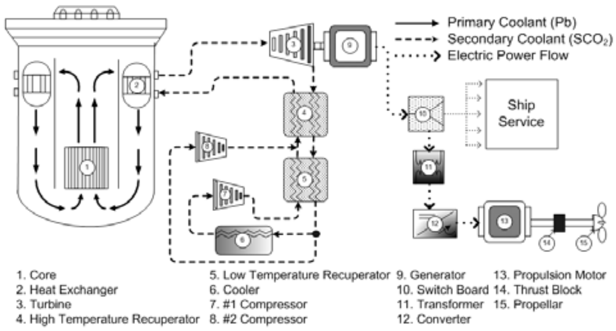


Fig. 1. General scheme of NOVA

## 3. Design of NAVIS

NAVIS has three foremost parts, generating and distributing system, power electronic converter, and the High Temperature Superconductor (HTS) motor as shown in Fig. 2. The power electronic converter consists of two converters, i.e. a rectifier and an inverter. The rectifier functions to convert the alternating current of the output transformer to the direct current. The inverter has the opposite function of the rectifier. It converts the direct current to the alternating current. The inverter feeding the motor operates with natural commutation, made possible by the electromotive force (EMF) of the machine. By this method, the inverter does not require complex and costly force commutating circuits which form an integral part of solid-state variable speed motor drives [3-4].

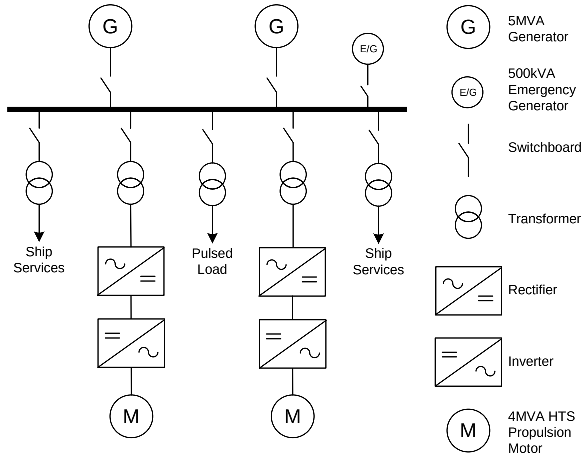


Fig. 2. Single line diagram of NAVIS

### *3.1 Motor*

The HTS motor is chosen as the propulsion motor of NAVIS because it allows a significant size reduction and efficiency improvement, so that a great deal of costs can be recouped. The high magnetic field produced by the superconducting field windings enables an air core construction without core losses, replacing the conventional iron core and cooper field winding [5].

The motor speed is controlled by changing the inverter output current frequency. The correlation of frequency and speed of the motor can be written as

$$\text{revolution per minute (rpm)} = \frac{120 f}{p} \quad (1)$$

where $f$ is frequency and $p$ is number of motor poles. For purpose of control system, a four-pole, three-phase wye connected HTS motor was considered.

### *3.2 Converter*

The scheme of the converter and its control is shown in Fig. 3. The line converter (rectifier), together with the inductor DC filter, acts as the DC current source. The output $I_{dc}$ is impressed at the DC input of the motor converter operating as an inverter**.** Natural commutation of the inverter is made possible by the fact that its AC terminals are connected to the synchronous machine, which is seen by the inverter as a three-phase AC source. The relationship between the fundamental component (RMS value) of the rectangular wave AC line current and $I_{dc}$ can be written as

$$I = \frac{\sqrt{6}}{\pi} I_{dc} \qquad (2)$$

Figures 4 and 5 show the simulation results by using the Matlab software.

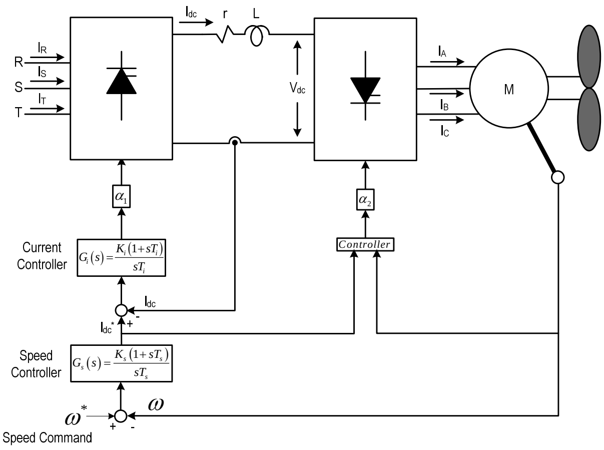

Fig. 3. Motor drive control system

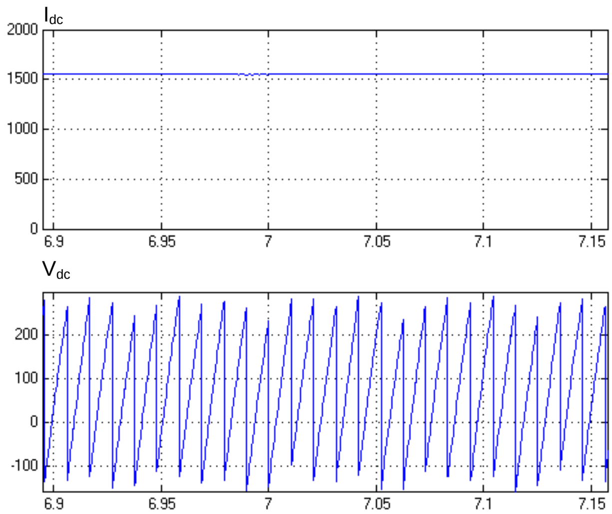

Fig. 4. Inverter input

### 4. Conclusions

A design concept of the electric propulsion system for NOVA has been presented. NOVA employs a machine commutated inverter-synchronous motor drive system. In this drive system, the thyristor inverter operates with natural commutation. Consequently, the inverter does not require the complex and costly force commutating control circuits.

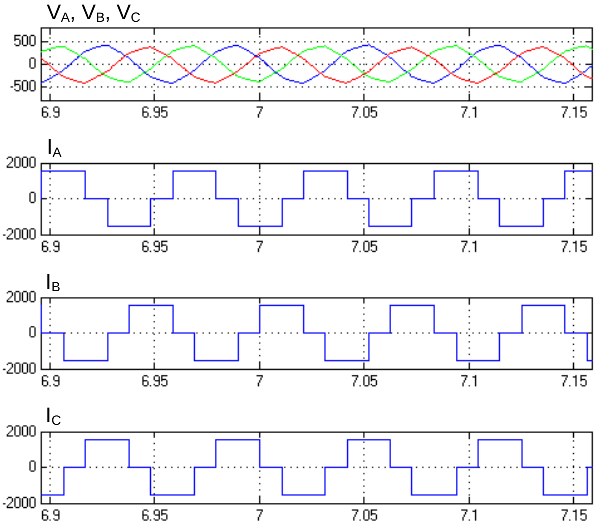

Fig. 5. Inverter output

### ACKNOWLEDGMENTS

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### REFERENCES

[1] B. Halimi, T.W. Kim, H.M. Son, K.Y. Suh, Design Concept of Propulsion System for Nuclear Operated Vessel Adventure, KNS Spring Meeting, Gyeongju, Korea, 2008

[2] N.H. Kim, T.W. Kim, H.M. Son, B. Halimi, K.Y. Suh, Naval Application of Battery Omnibus Reactor Integral System, Proc. 19th International Conference on Structural Mechanics in Reactor Technology, 2007.

[3] J. Rosa, Utilization and Rating of Machine Commutated Inverter-Synchronous Motor Drives, IEEE Transaction on Industry Application, Vol. IA-15, No. 2, pp. 155-164, 1979.

[4] S.D. Sudhoff, E.L. Zivi, T.D. Collins, Startup Performance of Load-Commutated Inverter Fed Synchronous Machine Drives, IEEE Transaction on Energy Conversion, Vol. 10, No. 2, pp. 268-274, 1995.

[5] M. Joo, Dynamic Control of Large-Scale High-$T_2$ Superconducting Synchronous Motor, IEEE Transaction on Applied Superconductivity, Vol. 14, No. 2, pp. 908-911,2004.