

# Power System Stability of an Electric War Ship Can Be Improved with Hybrid Energy Storage

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**Abstract** - Electricity is one of the most promising factors that can influence the life style of human beings in the day to day physically growing world, and it does not have any limitations in either sector when it is applicable to a ship technology. However the past, but the future is totally depends upon electricity. With increasing requirements and features of ship leads to increasing the necessity of electricity more. Hear the concept of introduced is All-Electric ship (AES) because it is completely depends on electricity. However the loads on ship are dynamic in nature. Sudden load changes on system leads to face dangerous problem like voltage fluctuation of the ship power grid. Environmental emission and increased fuel consumption. In order to reduce sudden changes on system efficiency, and to operate system in a stable manner, we proposed hybrid energy storage system (HESS) in association with the fuel cell energy generation for use in AES. The Hybrid Energy Storage System (HESS) designed with battery and superconducting magnetic energy storage system (SMES). To encounter all the conflicts are raised in the ship power system can be stabilized by using HESS.

**Key Words:** All-Electric Ship (AES), Superconducting Magnetic Energy Storage System (SMES), Hybrid Energy Storage System (HESS), Dynamic Loads, Coil Gun.

## 1. INTRODUCTION

Now a day everyone knows how the electricity influencing the human life style, including ship technology. In previous decades electricity does not have that much scope to use it in everywhere, that's why the ships are, depends upon the mechanical propulsion. In the mechanically propelled ships the propeller was directly connected to the steam engine or turbine. However after the decades the electricity has enhanced its capacity and growth in generation. To utilize the electricity, mechanically propelled ships are shifted to electric propulsion, and here the concept of All-Electric Ship was proposed by U.S navy and it is towards the implementation too. The design of All-Electric Ship is subjected to reach thousands of Mega Watts (MW) for upcoming generations. To meet that much of power requirements, the power system must be associated with the multiple power sources. The AES is designed such a way to fulfil all the requirements and are treated hear as the loads. Those are ship service loads, lighting loads, fire assistance loads, propulsion loads and pulse loads such as electric weapons like coil gun, they can put pay loads into an orbit.

The coil guns stores the energy prior to attack the target and it is require vast amount of power within a short duration while it get triggered.

The Hybrid Energy Storage System (HESS) proposed at so many areas out of that some noticed here, those are used at railway sub-stations by using fuzzy logic control. The SMES can be used in hybrid vehicles, in which the cryogenic fuel tank has been placed for the purpose of cooling, because the Superconducting Magnetic Energy Storage System (SMES) has been constructed with superconductor which is having a zero resistance. While SMES feeding the high loads there is a chance to get over heating with this, there may be chance to lose his superconducting capacity. To avoid this condition it needs cooling and that can be provided with the help of cryogenic fuel. So the SMES is always operated under the 0°C temperature or 472<sup>0</sup> K temperature. The SMES is mainly used for high power density storage. The HESS is introduced in micro grids in order to suppress the power quality issues were raised by the renewable energy sources. Coming to the ship power technology the concept of HESS (SMES) is used to feed the demand of the ship, not only for the peak loads but also for the pulse loads. However several studies have been carry out to suppress effects of pulse loads on ship power system with assistance of HESS. The combination of supercapacitor and batteries are also used to supply the pulse loads and to maintain the grid stability with different control mechanisms. A flywheel energy storage system is used in association with the ship propulsion motor system, by regulating the speed. To improve the ships power system and operate it in healthy manner by adjusting the speed of a generator braving the pulse as well as in peak load period.

This paper proposes the use of the Superconducting Magnetic Energy Storage (SMES)/Battery and fuel cell generation as an auxiliary power generating source in AES. The SMES is used here out of the super capacitor and flywheel energy storage. Only because of it is capable of high power density storage, faster time response and it does not have a limitation over the charging and discharging life cycles. Everyone knows the batteries are not capable of storing high power density. Because battery is a high energy storage devices and it cannot respond at the time of feeding pulse loads as per the requirement. SMES can be treated as a high power density storage device and battery is high energy density storage device. The charging and discharging controlling mechanism of the SMES and the battery are

taking separately. The battery was charged and discharged with separated inverter module with PI controller and the SMES can be charged separately without sharing the control mechanism of battery. To feed the both pulse loads and peak loads, and integrating the fuel cell generation also to meet the demand of the ship and finally to meet the power demand. The ship need to integrate all the power sources as an integrated power system and to maintain the ship power system with in the permissible levels.

## 2. MODEL ANALYSES

The power flow on ship from generation to the utilization has been given in the block diagram representation of AES is shown in Fig, A

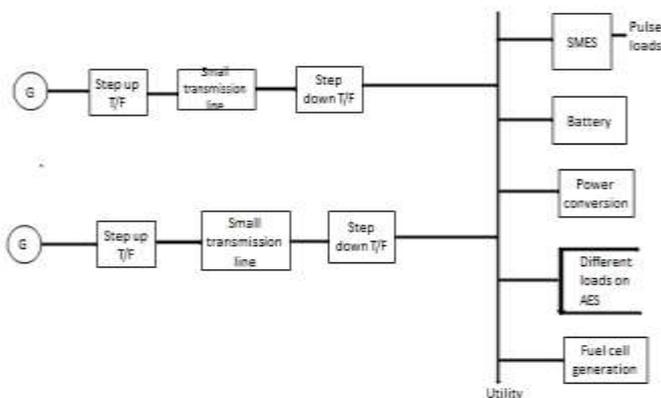


Fig -A: Block Diagram of AES

Power generation on the ship can be done with the help of two generators and one fuel cell stack to meet the considered power demands on ship. The two generators are connected to the transformer via small transmission line, and power provided by the two generators to the load uniformly. Bur the fuel cells are considered here as the auxiliary power generation, this stack cannot compete with that two generators. The loads installed the AES are service loads, propulsion loads including pulse loads etc. Here pulse loads are taken as the electric weapon i.e. electric coil gun. These coil guns required a huge amount of power when it is triggering. So it is not possible to feed that much of power with the help of generation. Because ramp rate of ship’s generators are very small, when it is compared with ramp rate requirement of electric weapon. The ramp rate of the generators that was installed in the design of All-Electric ship in the range of approximately 40-55 MW/Minute, but the requirement of the pulse load ramp rate nearly 100MW/Second ramp rate. So to meet that requirement HESS is cumulated to the ship power system.

### 2.1 Power Generation in an Electric Ship

To generate a power on ships are have to consider some constraints at the time of power generation. Those are generation active power limit and power equilibrium limit,

ramp rate limits etc. The simple mathematical equation are given for that is as follows

$$\sum_j^N P_{ij} = P_{Ai} + P_{Bj} \tag{1}$$

$$P_j^{\min} \leq P_{ij} \leq P_j^{\max} \tag{2}$$

Whereas  $i=1,2,3, \dots, M$   
 $j=1,2,3, \dots, N$

$$\frac{P_i(m) - P_i(m-1)}{\Delta t} \leq T \tag{3}$$

Where  $P_i$  and  $P_j$  are the limits of the active power delivered by the generator  $j$ ,  $p_i(m)-p_i(m-1)$  are the power generated by the generator at two conditions  $\Delta t$  and  $T$ . These limits states that the ramp rate of the generator from the above condition, we cannot meet the required ramp rate at the time of application of pulse load, so the HESS can meet the required ramp rate.

### 2.2 Hybrid Energy Storage System

The hybrid energy storage system consists with the two elements. One is super conducting magnetic energy storage system and second one is battery, SMES is used to the high power density device. Which can support the system under the transient period, majorly SMES is used to deal with the short term energy deficiency. The energy stored in SMES, given in the mathematical from

$$L = \frac{\phi}{I} \tag{4}$$

$$E = - \frac{d\phi}{dt} \tag{5}$$

From eq. (4)

$$\phi = LI$$

The work done per unit charge is

$$\frac{dw}{dt} = EI \tag{6}$$

According to lenz law

$$\frac{dw}{dt} = LI \frac{dI}{dt}$$

$$dw = LI * dI \tag{7}$$

The energy stored in an inductor

$$dw = \int_0^\alpha L(I)dt$$

$$W = \frac{1}{2} LI^2 \tag{8}$$

The SMES is designed as per the requirement of the ship load as well as battery too. The battery capacity is calculated to support the pulse load is given as

$$\text{Battery capacity} = \text{Pulse loads} \times \text{time (hr)} / \text{SOC} - (\text{upper limit} + \text{lower limit})$$

While comparing both the battery and SMES, the SMES is more expansive than a battery. The main aim is to reduce the size of the SMES and to maintain the voltage level at 25KV. The design parameter of an AES is given in table I.

**Table -1:** The design parameter of AES

S.No	Equipment	Quantity	Value
1	Generator	2	100MVA,25KV, 50Hz
2	Transformers	2 2	11MVA,315kV/440V,50Hz 250MVA,33/315kV,50Hz
3	Drives	2	500hp,327.87kW
4	Battery	Bank	15kWhr
5	Fuel Cell	Stack	50kW,625V (DC)
6	SMES	1	$7H \ m^2 \ s^{-2} \ A^{-2}$

### 2.2 Electric Propulsion

In this model the DC drive is used the propulsion system. In this model the podded propulsion is used, in this the propeller is directly connected to the DC drive the mechanical power developed by the motor is given as

$$P_{mc} = 2\pi nq$$

Where

- q → Torque of the propeller
- n → speed of motor

The speed of the motor is given as

$$n = \frac{120f}{P}$$

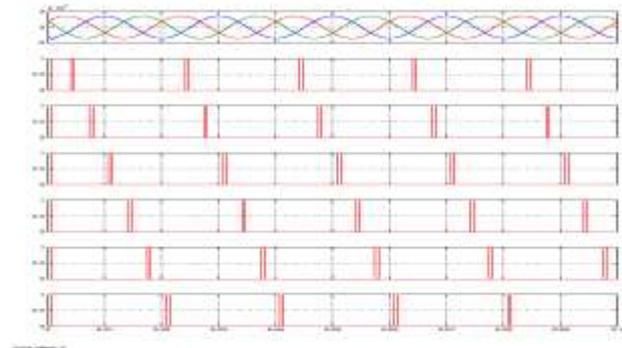
Where

- n → speed in rpm
- f → frequency
- p → number of poles

### 2.3 Energy Storage System

In the energy management system the several studies demonstrated that the dynamic droop control used to manage the different power sources. In this paper very simple methodology is used to control the energy management system. One and only problem in the design of electric ship due to the conflicts raised by the pulse loads, so in order to meet the requirements in this model the charging

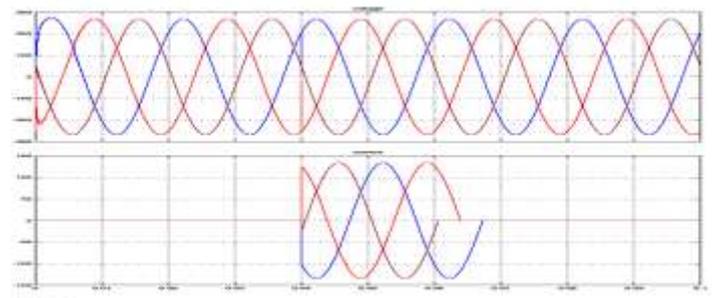
and discharging of SMES and the separate controller is used to charge and discharge the battery. The SMES has controlled by the pulse with modulation technique and it is depicted in Fig. B.



**Fig -B:** Control of SMES

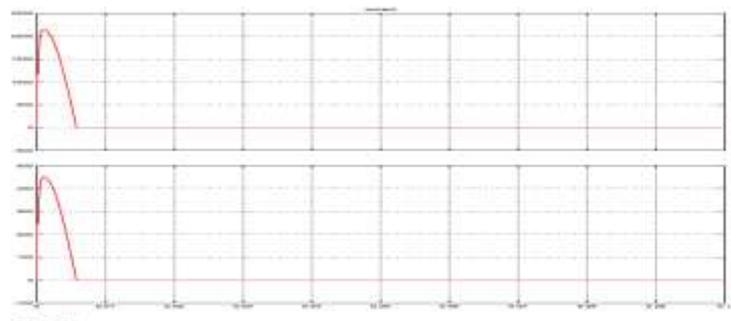
### 3. SIMULATION RESULTS

The simulation results of the constructed simplified model of AES depicted in the Fig.A, and it is modelled in the MATLAB/Simpower system software and the results obtained after the simulation process are given. If the A.C supply is in a position to feed the pulse load, due to continue supply, it cannot feed the load and there may be a chance to get the system block out and it is depicted in the Fig. C.



**Fig -C:** Pulse Load Feed by the AC Supply

So with the help of SMES to feed the pulse load, it can deliver the required amount of load with in the short duration that is depicted in Fig. D.

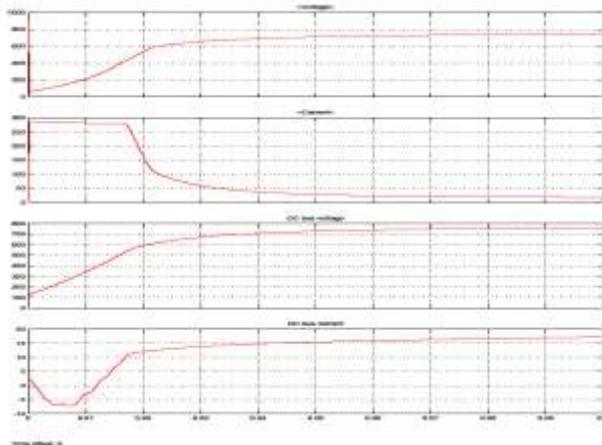


**Fig -D:** Pulse Load Feed by the SMES

The contribution of fuel cell generation to feed the load can be given in Fig. E. Here the powers generated by the fuel cell taken the proton exchange membrane fuel cell type, out of

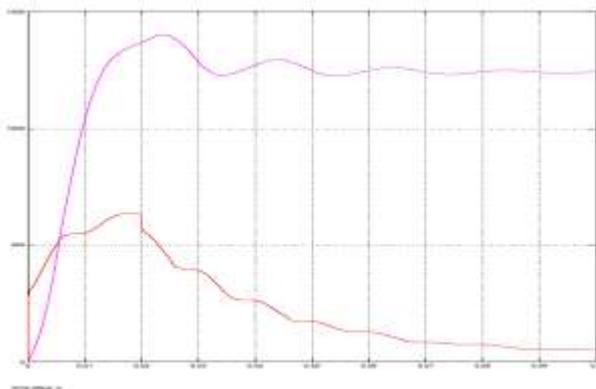
various fuel cells only because of, these are developed exclusively for the transport applications.

One of the considerable loads on ship is the propulsion load, the podded type of propulsion has been used in this method, and power consumed by propulsion system is given in Fig. G, Fig. H



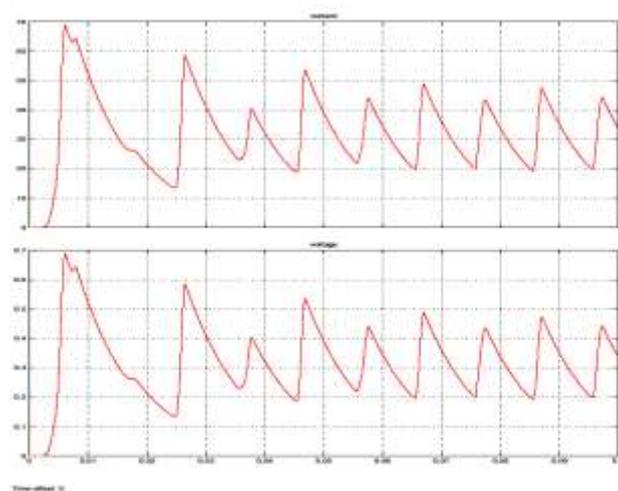
**Fig -E:** Fuel cell Contribution to Load

The reserved energy is used when the deficient of energy from the battery that is shown in Fig.F

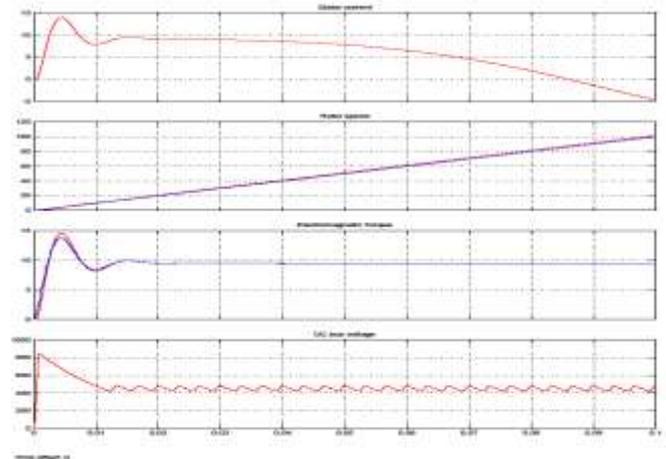


**Fig -F:** Power Stored in Battery

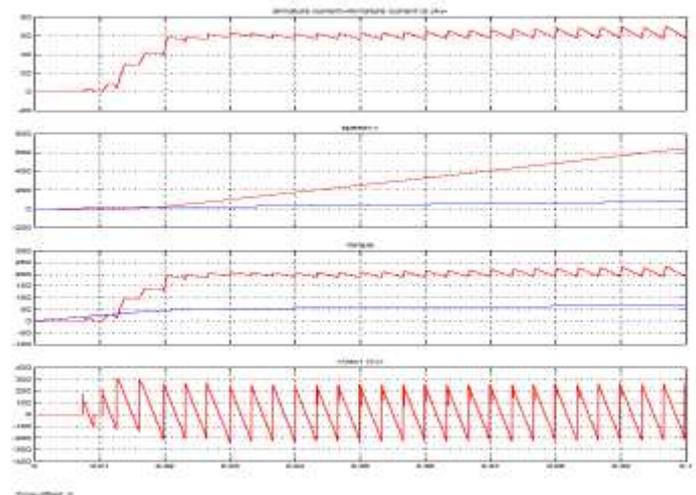
Load supplied by the battery was depicted in Fig, F.



**Fig -G:** Load Supplied from the Battery



**Fig -G:** Propulsion Load feed by AC drive



**Fig -G:** Propulsion Load feed by DC drive

### 3. CONCLUSION

This paper proposes that the use of SMES/Battery HESS in association with the fuel cell power generation, based on the separate control mechanism of both SMES/battery. Because there is a need to feed of pulse loads are regular on the design of AES. So in order to meet that requirement, SMES has given the highest priority than battery storage, so the battery was controlled separately using PI controller in order to operate the system under the permissible levels and SMES was controlled with pulse width modulation method. Maintenance is also plays a prominent role to make the system stable, by operating the generator at constant output, irrespective with on and off pulse loads furtherly to investigate this approach need an experimental setup with a healthy laboratory condition.

## ACKNOWLEDGEMENT

Thank you. Mr. M Manohara sir for your excellence, your motivation and inspiration of you, helps me to complete this project.

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## BIOGRAPHIES



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