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Integration of Wind Energy System in Shipboard using Frequency converter

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Abstract

In recent years, shipping industries are directed towards energy-efficient ships with less pollution. The conventional ship uses diesel generators to drive the propulsion motors. Implementation of hybrid microgrids to the shipboard power systems (SPSs) reduces the cost of propulsion and increases the efficiency of ship system. In this regard, research works focus on integrating renewable energy sources such as solar PV and wind with conventional diesel generators, batteries, fuel cells, etc. The various energy sources in shipboard power systems have to be managed technically as well as eco-friendly. Hence an energy management system is mandatory in the ships to control and observe the overall performance of the SPSs. This paper proposes the integration of wind energy systems with high-frequency power electronic converter in SPSs.

Keywords : *Energy Management System, shipboard power system, hybrid microgrid, high-frequency converter, and wind energy system.*

I. INTRODUCTION

Nowadays, the shipping industries focus on the research of fuel economy and reducing the emission of carbon. The shipping regulators impose several regulations on energy storage systems, carbon emissions, and efficiency. The modern All-electrified ships (AESs) consist of integrated power systems such as renewable energy sources like solar, wind, fuel cells, and battery energy storage system with the high-voltage AC with the help of solid-state electronic Devices [1]-[3]. The electric propulsion system uses variable speed drives to drive the propulsion motors. Hybrid microgrid and power electronic converters in shipboard power systems (SPSs) replaces the IC engine, which mechanically drives the propulsion unit, and hence reduces the cost of propulsion and size of the ship.

Through various ship energy efficiency management programs (SEEMPs), the main shipping regulatory body, the International Maritime Organization (IMO), and other regulatory authorities structured several measures to preserve the energy efficiency in all recent vessels. Several indices have also been introduced to observe carbon dioxide and other greenhouse gas emissions from the ships. In accord with this, numerous modern technologies are introduced in SPSs to have green and aerify propulsion systems with the integration of hybrid microgrid, energy storage, and waste energy recovery systems.

The promising opportunity is the implementation of the integrated power system (IPS) in the next generation of automated ships, which is rapidly increasing in marine propulsion systems. This paper introduces new concepts and technologies and explores new methods to simplify marine electrical propulsion system development. A new control scheme for the DC-DC boost converter to boost the rectified DC voltage, and the PWM inverter to generate the required AC voltage at the desired frequency is discussed in [4]. Different operating conditions are summarized to investigate the performance of the proposed system compared with the conventional schemes. Also, the total harmonic distortion (THD) analysis is also carried out for different scenarios. The

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design implementation and operating performance of the matrix converter in a marine electric propulsion system is discussed in [5]. A comparative analysis is also presented for

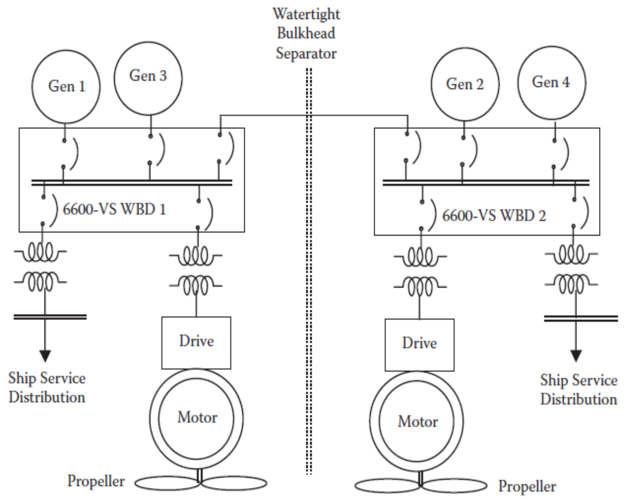

Fig 1.Shipboard power system architecture

various power converter topologies by evaluating the potential performances of the matrix converter.

II. HYBRID MICROGRIDS IN SHIPBOARD

In the last few decades, much attention is focused on renewable energy resources along with conventional sources. The conventional AC generators supply most of the shiploads. The renewable sources such as solar, wind, fuel cells can share some of the ship service loads subject to the availability of resources, and battery storage systems can supply some of the DC loads in ship power systems. Hence, the hybrid microgrid in ship systems has diesel generators and non-conventional energy sources. The electric propulsion system replaces the mechanical way of propelling the motor and thereby reduces the long shaft connected to the motor. The electric propulsion system also reduces maintenance costs. In integrated ship power systems, the main diesel generators are connected to the AC bus, and other renewable energy sources and energy storage batteries are connected to the DC bus. In DC system, AC is converted to DC employing power electronic converters and fed to the DC distribution systems. DC system has more advantages than AC systems owing to the absence of heavy transformers as in AC systems and thereby reduces the weight of the systems. Additionally, the DC system eradicates reactive power compensation and harmonic problems. The structure of a shipboard power system architecture is depicted in Fig. 1. The generator supplies power to the propulsion motor via propulsion

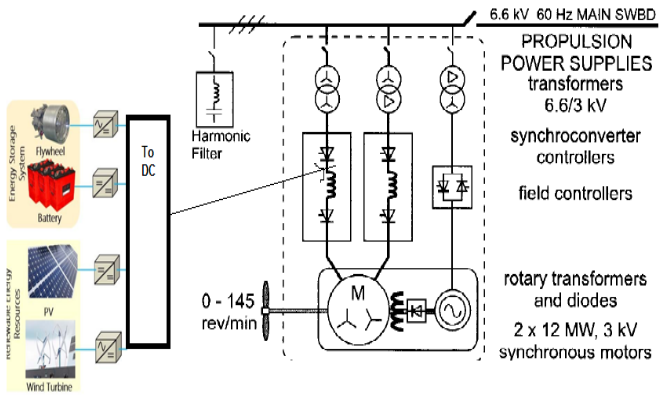

Fig 2.Hybrid microgrid in Shipboard

transformer and power electronic converters. The generators supply 6.6 kV to main switchboard, which is further given to thyristor/diode rectifier via a step-down transformer. The renewable energy sources are connected to the output side of AC / DC converter. The overall design of hybrid microgrid in shipboard is shown in Fig. 2.

III. GENERATORS IN SHIP SYSTEMS

The prime movers and generators play vital role in shipboard power systems. Usually, gas turbines and diesel engines are used as prime movers in ships. Prime movers convert different source energy into mechanical energy and by employing the generator, mechanical energy is converted into electrical energy. The prime mover is connected to the generator through the coupling shaft.

The SPS consists of either wound rotor synchronous generator (WRSG) or permanent magnet synchronous generator (PMSG). The automatic voltage regulator (AVR) performs the operation of voltage regulation in the generator and exchanges the reactive power in the generator. It is inferred that power generation using AC generator is cost effective than DC generators.

IV. ELECTRIC PROPULSION SYSTEMS

The operating costs and marine pollution are challenging issues in the shipping industry. Hence, researches are focused on reducing operating costs without increasing pollution. The electric propulsion system is one of the best alternatives to solve these issues. The propulsion motor is driven by the prime movers or a ship generator.

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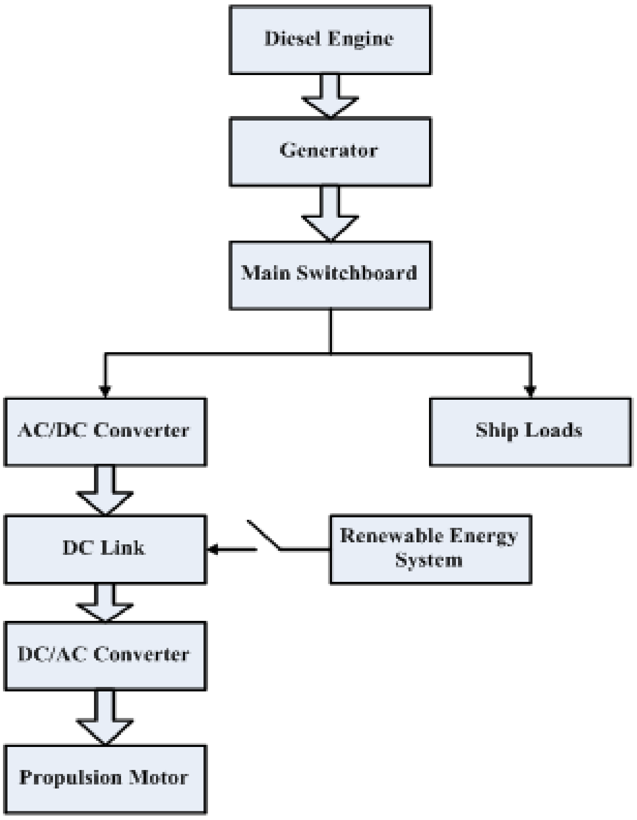

Fig.3. Schematic diagram of All-electrified ship

The propeller shaft is connected to the large propulsion motors and the generator is driven by wind turbine prime mover. In electric propulsion system, the direction of rotation of the propeller is controlled and governed by variable frequency drives based electric motor. The overall schematic of All-electrified ship is shown in Fig. 3.

1. DC MOTORS

In the past seagoing vessels, DC motors are used because of their simplicity of operation, and simple power converters requirements. However, its power rating is limited, and proper maintenance is required otherwise there is a risk of flashover in it.

2. AC MOTORS

Induction motors and synchronous motors are mostly used in propulsion systems. Induction motors on board ship is mainly used in Fans, pumps, and other applications. In such applications, the induction motors need to be started under no-load conditions. If the induction motor is not started under no-load, the starting current would be very high. Cycloconverter based Induction motor in a podded propulsion system provides good speed control and eliminates the disadvantage of high starting current in an induction motor.

Synchronous motors are used in podded propulsion systems due to higher power ratings, which are generally excited and started by power electronic converters. However, the high power ratings result in huge size, and these motors are generally heavy.

V. POWER CONVERTERS

The Power Electronic converters in shipboard power systems along with hybrid microgrid enhance the speed control operation of propulsion motor, voltage/Frequency regulation, and reactive power compensation. With the help of a marine high-frequency converter, an AC motor provides rotational speeds in a wide range and maintains torque control. The voltage/Frequency regulation properties of high-frequency converter exhibit good speed control of

propulsion motor on the shipboard. Proper selection of frequency converters in the ship power system reduces the distortion in shipboard equipment. Incorporating renewable energy sources into the ship system is a challenging task and installation of wind energy may lead to vibrations in ship vessels. Ship vibrations absorption techniques could be used for such kind of disturbances. Fig.4 shows the wind energy systems

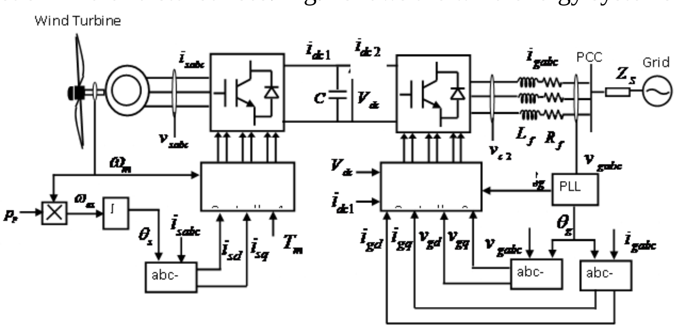

Fig.4. Wind energy system

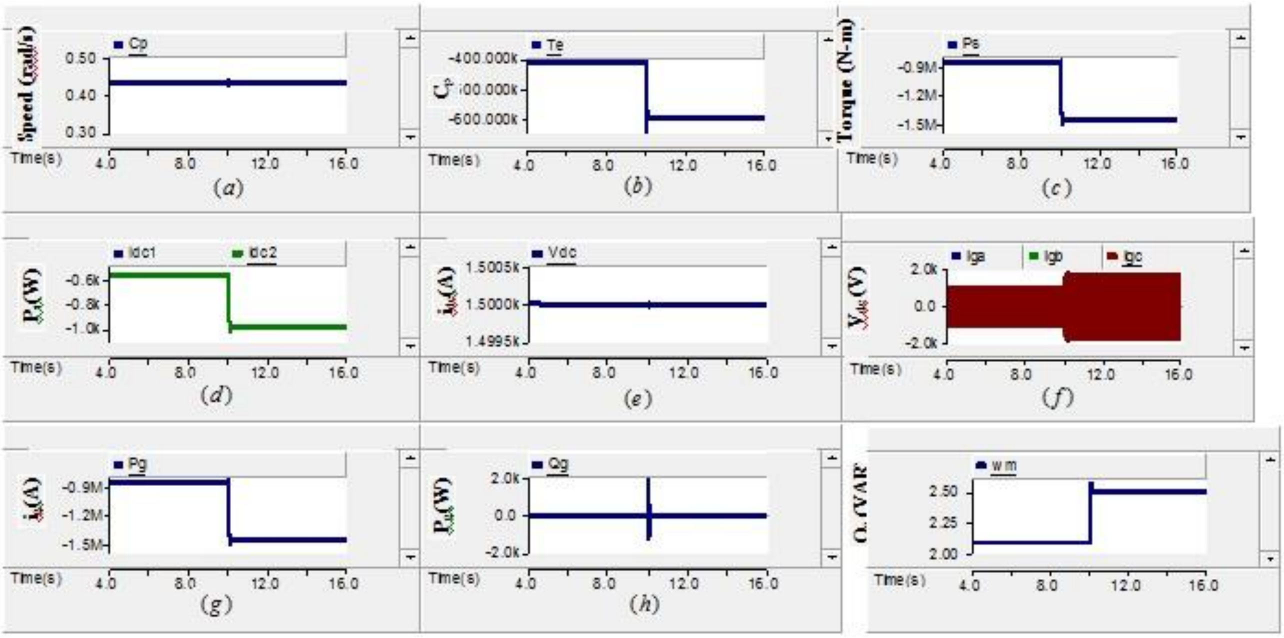

Fig.5 Performance of wind energy system during wind speed change from 12m/s to 8 m/s (a) wind turbine speed, rad/sec; (b) wind power co-efficient; (c) electromagnetic torque, N-m; (d) Stator active power, W (e) dc-link currents, A (f) dc-link voltage, V; (g) PCC currents, A; (h) PCC active power, W; (i) PCC reactive power, VAR.

VI. CONCLUSION AND RESULTS

In this paper wind energy systems which are to be integrated with ship power systems and power generation from wind energy system is analyzed. Converters are used for AC/DC and DC/AC conversions. The performance of wind energy system during wind speed change from 12m/s to 8 m/s was analyzed with the help of PSCAD and the following parameters were obtained (a) wind turbine speed, rad/sec; (b) wind power coefficient; (c) electromagnetic torque, N-m; (d) Stator active power, W (e) dc-link currents, A (f) dc-link voltage, V; (g) PCC currents, A; (h) PCC active power, W; (i) PCC reactive power, VAR.

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