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Review of electric propulsion for small boats/drones

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Abstract. Nowadays, electric propulsion is one of the main fields of research (whether we are talking about the automotive field or the naval field). This paper presents the electric propulsion used on small boats (drones): the advantages of using electric propulsion, storage mode and possible methods of obtaining electricity (renewable sources of electricity).

Keywords - electrical propulsion, renewable energy, electricity storage, power systems, small boats, drones, USV.

1. Introduction

This paper proposes to be important using electric propulsions for small boats (drones).

This paper aims to present various studies and observations on the advantages of using the electric propulsion system, different possibilities or methods of storing / storing electricity, but also methods for producing electricity using renewable resources.

Thus, this paper is divided into 4 sections that present the problems mentioned above.

2. Electrical propulsion

All electric ship (AES) is regarded as the future trend for modern navy ships due to the ever-increasing electric power demand of high-energy weapons. In order to improve the fuel efficiency, power density and dynamic response, integrated electric propulsion system has become an essential part of AES. Due to the large power demands, low voltage alternating current (LVAC) distribution system is not suitable anymore. Medium-voltage direct current (MVDC) system has many advantages over medium-voltage alternating current (MVAC) system and is regarded as the next generation ship integrated power system (IPS). Medium-voltage high-power electric propulsion drives are key components in the electric propulsion system. Traditional two-level inverters are not suitable for medium-voltage applications. Instead, multilevel inverter is a good choice due to the merits of low voltage stresses, low dv/dt , high working voltage and high harmonic performance. Among all the multilevel topologies, neutral-point clamped (NPC), flying-capacitor (FC) and cascaded H-bridge (CHB) multilevel converters are the earliest and most classic topologies in industry. [1]

Growing conveyance effectiveness provides the preeminent habitation for reducing carbon dioxide (CO₂) emanation, which is a crucial delinquent in global warming. Thus, detrimental air pollution from squander emanations can be abbreviate by choosing to drive an electric vehicle (EV)EV provides a superior emanation contour as compared to interior incineration vehicles. EVs has lower inclusive emanations complacent and it provides superior emanation locality and technique. During charging and operating an EV, renewable energy corresponding solar or wind provide almost emanation free. Therefore, EVs charged comprehensively with renewable energy [2]

Conventional petrol/diesel vehicles have a huge movable portion as compared to battery electric vehicles (BEVs). In EV it is not necessary to change liquid fuels or oil. EV requires comparatively diminutive overhauling, no exclusive squander structures, starter motors, gasoline inoculation structures, radiators, and numerous further parts. EV runs on electrically powered engines and hence there is no need to lubricate the engines.[2] Mostly, in electric vehicles DC and AC motors are used for electric propulsion because of their significant performance. In control methods, DC motors can easily control with less efficient but are preferred for electric vehicle topology. Apart from that, Hybrid vehicles use AC motors with major control schemes. For permanent magnet synchronous motor, the DC-DC converter provides

the constant DC voltage in which the converter operates in boost mode for increasing the voltage level of battery. [3]

The permanent magnet synchronous motor for hybrid vehicles in recent applications have high power density, high efficiency. The speed of permanent magnet motor is controlled by handling field-oriented control (FOC). In this paper, the input for the integrated DC-DC converter is given from the output of the battery where increase in the level of voltage occurs and the converted voltage is supplied to the inverter and this inverter controls the high power PMSM.[3]

To take advantage of electric propulsion, several large vessel kinds, namely, cruise vessels, icebreakers, drill ships, and warships, have been generally designed with Integrated Electric Propulsion (IEP) system in recent decades.[4]

The power systems of the mechanical and electric propulsion vessels are shown in Fig. 1 (a) and (b)[4], respectively. With the IEP system, the prime mover installed in the ship is reduced as shown in Figure 1, so the overall weight and volume of the installed equipment can be reduced. Also, fuel consumption would be reduced because the engine can be operated at more efficient operating points. [4]

An ANPC/H-Bridge hybrid inverter for high power medium voltage ship electric propulsion drives by hybrid utilization of Si devices and SiC devices. The modulation method is introduced, which can make the Si devices operate at the fundamental frequency and the SiC devices operate at the carrier frequency. A closed-loop NP voltage balancing method is proposed based on the NP current model. The validity of this method is demonstrated by simulation results.[1]

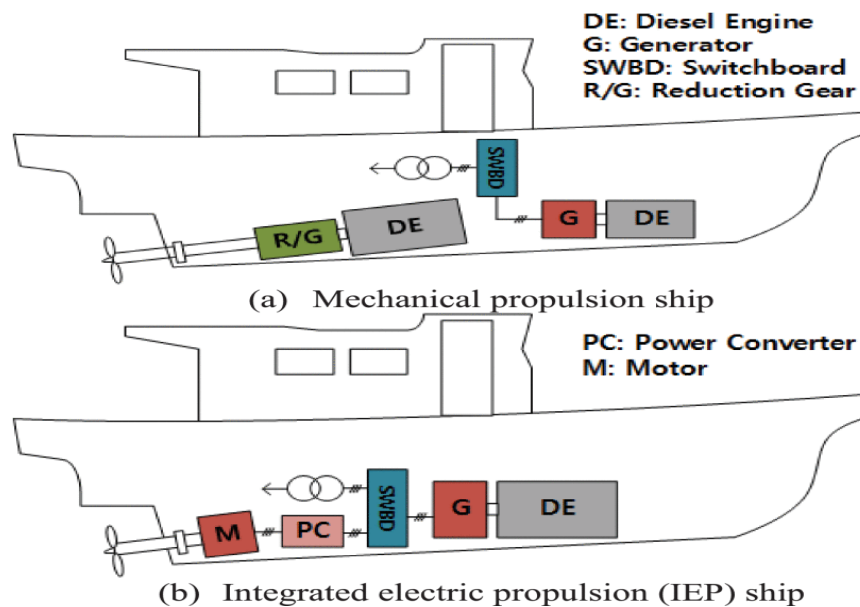


Figure 1- (a) (b)- Power system diagrams of vessels.[4]

3. Electricity storage

Renewable Energy Sources (RES) have shown remarkable growth worldwide thanks to various support policies put in place in several countries in the last two decades. This increasing spread poses significant challenges related to the safety and the reliability of the electrical system. Moreover, the variability and non-dispatchable nature of these sources exacerbates these problems even more. In this regard, Energy Storage Systems (ESS) may be proposed as a possible solution and are poised to become a fundamental element of the electricity infrastructure of the future.[5]

Energy storage technology has become an important support for large-scale distributed and centralized new energy generation.[6] Storage technologies that are designed to operate on a daily or multi-day

storage cycles. Most of PSH facilities today were built to assist base-load power plants to operate more efficiently by consuming excess energy during off-peak periods to be injected back into the system during on-peak hours, as illustrated in Figure 2. A typical PSH facility will use lower cost, off-peak electricity to pump water into an upper reservoir, and then reverse the process during the on-peak periods. The net energy generated by pumped storage hydro is net negative due to the losses incurred in pumping.[7]

Distributed energy storage can effectively solve the problem of resource waste caused by the randomness of renewable energy output, help to reduce peak-to-valley difference, and improve the utilization rate of renewable energy such as wind and light.[6]

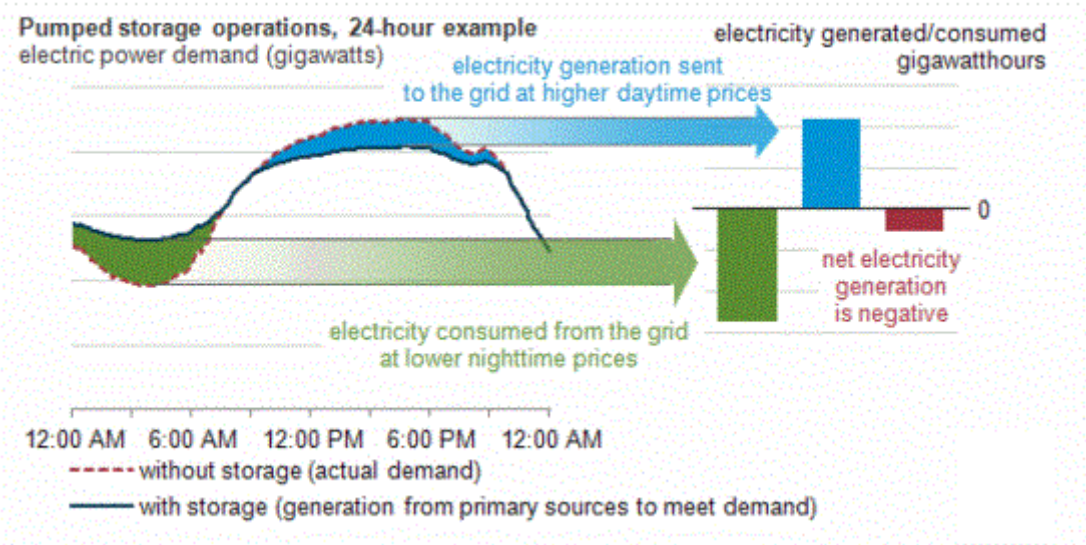


Figure 2 - PSH provides grid reliability even with net generation loss[7].

Short-run profits are realized when the power can be sold at prices higher than the cost of pumping, which includes but is not limited to the cost of electricity to operate the pump (pumping losses), and other operational costs. In order to operate with a positive net financial margin (short-run profit) for energy sales the difference between on- and off-peak prices must be sufficient to cover any pumping losses. In order to maximize profit, it is necessary to minimize lost-opportunity costs, which generally occur when storage is not utilized during periods of highest value. The fast-response capabilities of PSH are also valuable for providing energy reserves if the water is not used to generate electricity. Operating reserves can be provided while either in generating or pumping mode. PSH facilities generally have a lost-opportunity cost for providing these operating reserves and may also have water-management costs if the upper or lower reservoir has other uses or limitations. A PSH facility is constrained by the limits of upper reservoir storage capacity, by the rapidity of how fast it can empty and refill the upper reservoir, and by the time-out period needed to revert between pumping and generating modes.[7]

Electric energy storage (EES) technologies have been used in different forms to serve in different applications, including peak shaving, load leveling, renewable capacity firming, frequency regulation, reserve capacity, and power quality services. EES is deemed as one of the strategic energy technologies in the European Commission’s SET-Plan in achieving EU energy targets and decarbonization of the power sector. In liberalized electricity markets, where momentary power supply and demand drives the spot electricity prices, the variation of supply/demand can be directly reflected in the final prices. Electricity storage is one of the solutions that can smooth this imbalance by providing buffer storage to decouple the instantaneous supply and demand, resulting in more economical and reliable operation of

the power system.[8] Economic benefit of the storages consists of decreasing of customer outage costs (COC) due to customer experienced interruptions. Thus, the storage is economically feasible investment if the savings of COC are bigger than investment costs of the storage.[9]

4. Renewable Electricity (Production)

The basic idea of the future zero carbon energy system is assumed to be that by the year of 2100, all electrification in residential and commercial sectors, electrical vehicle and bio-diesel truck in transportation sector, hydrogen steel making, recycle cement production, bio-refinery for material production, etc. in industry sector will be realized. The final energy demand is obtained through a bottom-up simulation method based on the framework comprised of residential, commercial, industry and transportation sectors and their several sub-sectors. It is expected that many distributed power sources such as solar and wind will be installed in the power system because of their advantages in the reduction of environmental loads, maintaining power system reliability, cost reduction.[10]

Lean Production (Lean Production, LP) is also known as the sophisticated production, which means no waste, high efficiency and effectiveness. LP is a set of ideas and principles of the operations management system. Its goals are to satisfy the demands of customers, pursue the sustainable improvement, and at last achieve the required value of customers[11].

Owing to pertinent environmental conservation objectives and promoting laws, and guidelines by various cities administrators. Electricity plants and production schemes has continuously advanced in the direction of carbon-free technologies. To this end, many countries electricity grids managers are employing a high percentage of renewable plants to sustain the steady functioning of their national electricity load requirement. This will assist in achieving a hundred percent renewable electricity grid structure in the future. A hundred percent renewable grid architecture will be dependent on national electricity system planning, operation and control. Market methodologies to promote purely renewable electricity grid installations will equally have to be addressed. The future purely renewable electricity grid architecture will be intelligently controlled utilizing the Internet of Renewable Energy (IoRE) as posited by Famous O.[12]

To analyze the penetration of renewable generation sources into the energy, production and trade balance of the electricity market system, it is necessary to consider first of all the specifics of electricity generation by renewable sources. Therefore, three statistical indicators should be used as indicators, reflecting both technological and commercial results of using various, primarily renewable, sources of generation:

- a) in the technical system: installed capacity of the generation sources connected to the electric power system (availability of physical assets of diversified generation);
- b) in the production system: the amount of electricity generated by the generation sources specified in paragraph (a) (owners of physical assets, willing and opportunity to produce taking into account weather conditions);
- c) in the commercial system: revenue from the sale of electricity generated by the generation sources specified in paragraph (b) (spot and contract prices, diversification of price and quantity risks caused by weather conditions).

The numerical values of all three statistical indicators (a), (b), (c), ranged in chronological order and distributed by generation sources, are the levels of a multidimensional time series. Each of the indicators (a), (b), (c) of a multidimensional time series reflects its own stochastic process that occurs in time and space. The numerical values of indicators (a), (b), (c) have their own units of measurement and their own orders of number.[13] [14]

The intermittency of renewables brings about both technical and economic issues for the functioning and usage of purely renewable grid structure. A way to address intermittency of renewable electricity

generation is electricity storage. An electricity storage facility will allow surplus electricity generated from renewable electricity sources to be put into storage and dispatched later when required. Electricity storage facilities will be used in an islanded solely renewable electricity grid architecture.[12]

Theoretically, in the process of diversification of generation sources due to the penetration of renewable energy, the principle of equivalence can be realized. According to the principle, all sources of generation tend to have equal values of their individual indices, and integral indices tend to their minimum values. Practically, this is more desirable than real.[13]

A zero-carbon electricity system is proposed as shown in Figure 3, in which both the nuclear power and hydro power are connected to the large grid. It is expected that many distributed power sources such as solar and wind will be installed in the power system because of their advantages in the reduction of environmental loads, maintaining power system reliability, cost reduction, etc. Especially, a large amount of Electrical Vehicle (EV) batteries can absorb the fluctuations of electric load and renewable energy power output.[10] [15]

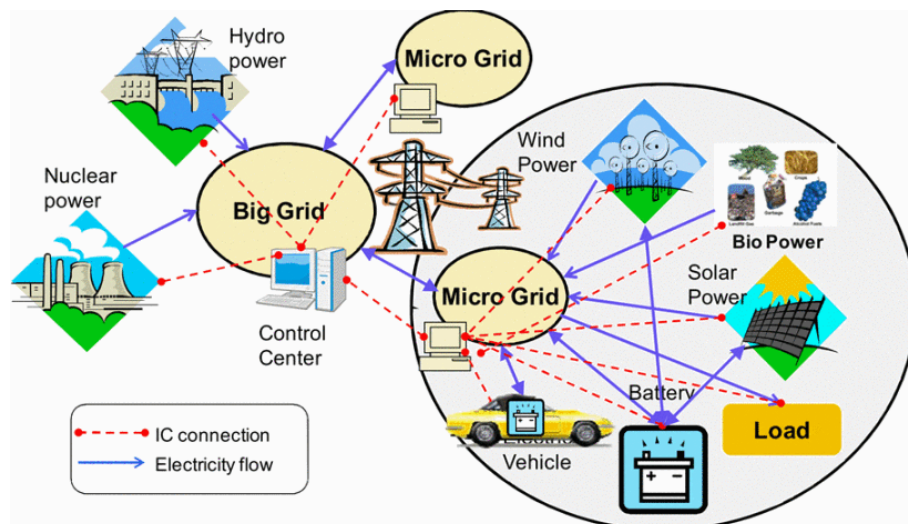


Figure 3 - Proposed zero-carbon electricity system for the future Japan.

Many optimization models for analyzing energy and environment systems have been proposed and developed in Japan, all of which aim to find the least cost solution subject to various technology and environment constrains for meeting energy/electricity demand. [16] [17]

However, the authors argue that, if humanity is serious about the climate change issue, the least total amount of CO₂ accumulation in the atmosphere goal should be pursued. Furthermore, the costs that will arise from the negative environmental impacts of fossil fuel burning and climate change are not considered in the existing least cost analysis models, meaning that these results cannot be accepted as realistic. The physical constrains include area availability, technology maturity, and material resource availability. Natural constrains include solar radiation intensity, wind speed, biomass potential and wave strength. The system constrains include back-up power sources, fluctuation absorption and reserve power flow issue.[10] [18] [19]

5. Small boats/drones(USV) and propulsion system

Unmanned Surface Vehicles (USVs) can serve the roles of providing Intelligence, Surveillance and Reconnaissance (ISR) to a fleet as well as performing Mine Countermeasure (MCM) missions. Many of these missions require some period of low observable/stealth mode operation of the USV. power

systems for Unmanned Surface Vehicles (USVs) must provide power for vehicle propulsion and for sensors, computers, communications links, and actuators. These power systems must work autonomously and intelligently to provide the right mix of energy/power for particular missions to ensure successful mission completion and must be flexible enough to operate in stealth mode.[16]

Hybrid power systems for vehicle propulsion consist of a combination of power sources such as diesel generator, batteries, fuel cells, etc. The battery pack is used to provide power for the USV during the stealth mode of operation. The battery pack is used to provide power for the USV during the stealth mode of operation. This Hybrid electric propulsion combines the heat engine and fuel tank of a conventional vehicle with the battery and electric motor of an electric vehicle. Hybrid electric vehicles turn energy into electricity while the vehicle is coasting and braking or when the diesel generator is generating more power than is required to propel the vehicle. Electricity is then stored in a battery until it is needed.[16][3]

The realized prototypal of SI-DRONE is a vessel of 2.10 meters long, 1.60 meters wide and 140 kg of weight with a draft of only 0.17 meters and a payload of 80 kg of scientific equipment dove la communication with the remote operators, one drone pilot and one drone navigator/instrumental, is guaranteed from two separated radio data link systems for a high safety navigation operation.[17] The principal propeller power is generated by a group of batteries which ensure 48V 42Ah for the controller of the DC motor. The second instrumental power is generated by a group of batteries that will provide 24 V - 42 Ah coupled to a DC / DC 24V / 12V. The autonomy of the battery groups is increased by a series of parallel solar cells applied on the surface and side of the Drone for a total of 250 Wh. Autonomy Day (in the presence of sunlight to recharge the solar cells) was tested in 4/6 hours sailing continues to 1/2 power and over 8 hours of operations instrumental made with on-board instruments. In the block diagram, figure 8, it is possible to observe power system and the PWM control of the electric motor that is coupled to a propeller-jet units with steering electro actuated. The variables of the motor and rudder position of the jet are transmitted remotely via telemetry in a LAN operating on RadioLINK terrestrial or satellite and received by STADAM centre.[17][16]

The electric system consists of two part. One is power system and the other is control system. Power system contains an wireless emergency stop system and two 24V batteries. One battery is used for two thrusters and the other battery is used for control system. By using remote controller, thruster power can be turned off when an emergency situation is happened.[18]

Accurate mathematical models of USVs are necessary for high-performance controller design, and much related work has been conducted and published. Originally, linear models were often used owing to their simple structure, and a typical example is the first-order Nomoto model, which was proposed by Nomoto in 1957.[19] It has since been extensively used and become one of the mainstream modeling methods for USV systems. The Nomoto model is usually effective under the following assumptions:

- a) the forward speed is time-invariant or changes very slowly (the loss of speed is negligible);
- b) the inertia is large enough to ensure that the USV is in displacement mode;

However, the deficiencies of the Nomoto model are also clear in the following ways: first, it presents poor performance when describing the details of the ship dynamics and improperly accommodates slipping motion.[19]

6. Conclusion

This paper presents a first study on surface drones (USV), electric and hybrid propulsion system. Also in this work a summary was made of how to store energy and obtain renewable energy. It is important that surface drones (USV) use renewable energy, so the study of obtaining renewable energy and storing this energy is important. The best propulsion system for these surface drones is the electric propulsion

system. It is important to remember that not only the propulsion system consumes energy, but also the other electrical subsystems of the platform (drone control system, drone sensors, etc.)

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