

Smart and green cargo handling equipment for port sustainable energy management

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1. Introduction

Sustainability performance of a port affects the city where the port is located. While the competitiveness of a port is important, its commitment to corporate social responsibility is expected from stakeholders such as local residents. In recent years, there is an increasing demand for new and effective solutions to achieve green port operations and enhance the productivity simultaneously. The port industry has attracted scholars' and industry's attention about its environmental performance and energy cost (Sislian et al., 2016). To establish ports with sustainability and green operation has become a popular topic.

Ports' primary function is cargo handling and cargo handling operation consumes majority of energy in terminals (Acciaro et al., 2014). Therefore, energy consumption of cargo handling equipment significantly affects a port's sustainability performance and energy cost. Deploying smart and green cargo handling equipment contributes to environmental protection, energy preservation and cost efficiency. This would be especially helpful for next generation ports which strive for a quantum leap in all aspects of sustainability, namely economic, social, and environmental performances (Lee et al. 2018). The overall benefits include reducing power consumption, energy cost, and environmental pollution while achieving growth in ports and terminals.

2. Features of smart and green cargo handling equipment

A key question is: what is the design of smart and green cargo handling equipment? Its features should lead to efficient energy storage and management, thus benefiting both the environment and economics. This paper describes the design of a smart energy storage and management system in electric cargo handling equipment. The specific features are:

1. A full featured and generic **battery management system** (BMS) that can be used with a variety of battery packs. This generic BMS is able to perform predictive health monitoring and management of installed energy storage system which is independent of energy storage suppliers.
2. An **energy management system** (EMS) that controls the power supply between the batteries and the motor drive unit. The battery system supplies energy to the load via an EMS that mainly consists of a super capacitor and a current regulator. The system fully

utilizes the advantages of the super capacitor (with fast charging/ discharging profile) and lithium ion batteries (with high energy density) allowing for efficient cargo operations.

The energy storage and management system can be used in cargo handling equipment in ports such as prime mover, forklift and automated guided vehicle (AGV). Battery pack is a main energy source to the electric cargo handling equipment under study. In a battery pack, a BMS is smart when it is able to control and supervise the battery operation. The battery's inner status should be given to perform supervision and determine the energy source operation. In addition, thermal management and cell balancing in the battery pack should also be performed by the BMS. In the vehicle propulsion system including the motor with electric setups and the energy sources, energy management strategies are taken to achieve system green operation and sustainability.

For cargo handling equipment to be smart and green, an efficient and effective energy storage system is necessary. Such a high-performing energy storage system is designed to achieve sustainable energy management and efficient operations. In the energy system, the energy sources of battery pack and supercapacitor modules are used considering the system demand and their characteristics (Du et al., 2016). Energy management strategies should be designed to determine the energy sources' operation (Lam et al., 2017). Since battery packs will be used as the energy source for green cargo handling equipment, battery management is an essential module in the system. By applying battery management and energy management strategies, smart and green cargo operation will be achieved.

The concept of the energy storage system is shown in Figure 1. The designed system will meet the system energy demand and supervise the energy sources operation status intelligently, which establishes smart and green cargo handling equipment. To charge the energy sources, a network of charging stations has to be established in the cargo terminals. Fast charging will be performed in the charging stations to super capacitors. Then, a sustainable port which is energy-efficient and environment-friendly will be realized by designing smart and green cargo handling operations. Both economic and environmental benefits will be achieved.

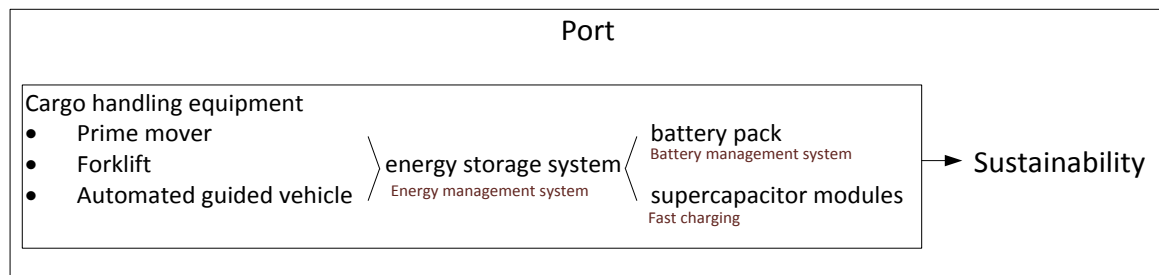


Figure 1 Energy storage and management system in cargo handling equipment

3. Conclusion

When the developed EMS is turned on, the dynamic portion of the total load current is mainly addressed by the super capacitor while the battery just needs to bear the remaining small part of load. Moreover, the current regulator developed can stabilize the battery current within a narrow range. These features allow for protection of the battery and thus extension of its life span.

Cargo operations will be continuous as the super capacitors are being charged at strategically selected locations, e.g. at container unloading/ loading points of a terminal. This hybrid system results in fast charging, regeneration and extended operation profile. The system self-commissions itself to an energy storage designed for a given set of requirements irrespective of suppliers. Therefore, the system is flexible and energy efficient.

For future research, battery charging by renewable energy sources such as solar energy can be developed. Sustainability performance of cargo operations can then be further enhanced.

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