STATE OF SHORE POWER STANDARDS FOR SHIPS

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Abstract - Ship service electrical power consumption at the shore side has rapidly grown for commercial ships. The environmental impact of the pollution created while at berth has many ports restricting the operation of on-board generators. Shutting off these on-board generators and supplying ship’s power from the shore power system can reduce the air pollution emissions. With the development of medium voltage power plugs and receptacle assemblies, cold ironing projects for larger ships are more prevalent. Various organizations are working on developing standards for implementing shore power. The paper will highlight the efforts of IEEE, ISO and IEC to develop standards for medium voltage on-shore power supply connections for.

Index Terms — Cold ironing, shore-side power, ABS, *IEEE P1713,* IEEE-45, *ISO/TC8/SC3*, IEC 60092-201.

I. INTRODUCTION

California has a reputation for tackling environmental issues and a target of the latest round of initiatives is pollution from ports, including emissions from ships while at berth. The California Air Resources Board [1] estimates that emissions can be reduced by 18 tons per day if every vessel calling three or more times per year to California’s ports was able to connect to shore-side power. Two major ports in Southern California have implemented plans to supply power to vessels making frequent calls and are putting serious efforts into developing standards for these connections. These ports are located adjacent to each other on San Pedro Bay, about 20 miles south of downtown Los Angeles. Together, they form the third-largest port complex in the world.

Why are they serious about proving shore power? Hoteling emissions from ocean-going vessels account for about 20 percent of the total diesel PM emissions from the Ports in the Los Angeles area. These emissions are responsible for about 34 percent of the port emissions related risk in the modeling receptor domain based on the population-weighted average risk. These emissions resulted in the largest area (2,036 acres) where the potential cancer risk levels were greater than 200 in a million in the nearby communities. The second highest category contributing to cancer risk levels above 200 in a million was cargo handling equipment, which impacted a residential area of 410 acres and is responsible for about 20 percent of the total risk in the modeling receptor domain based on the population-weighted average risk. Reducing emissions from these two categories will have the most dramatic effect on reducing the port emissions related risks in nearby communities [2].

New standards development has been initiated to ensure systems are compatible at ports around the world. Coordinated development of analytical techniques, port infrastructure and shipboard electrical plants will facilitate the implementation of an “any ship, any port” concept.

Plugging into shore-side power, known as “cold ironing,” should make use of near-zero or zero emissions technology to provide cleaner power to docked ships. Shore-side power measures call for:

1. Ports to require shore-side power as a condition of new terminal leases or renewals;
2. Ports to invest in infrastructure for electrical power;
3. Ports to redevelop shore-side power for providing power to ships;
4. Negotiate opportunities to subsidize development of shore-side power for harbor craft;
5. Ship owners to fund the costs of retrofitting ships to accommodate shore-side power.

To provide shore power to the vessel, appropriate provisions and modifications are required on the shore and on the vessel. On the shore side, an appropriate special power system is required to hook up the power delivery cabling system via power receptacles and power plugs. Power may be delivered at 11 kV, 6.6 kV or 440 V, depending upon the rating of the vessel’s on-board normal power supply equipment. However, the 6.6 kV system appears to be the voltage that will apply in the majority of installations. Many ship operators and port authorities are struggling with the absence of appropriate standards and specifications for interconnecting the ship service loads to on-shore power distribution systems.

This paper will review the current state of providing shore power for large commercial ships and describe the main features of a shore power system with emphasis on personnel and equipment protection and recommendations on the standardization of methods of analysis of interconnected shore power and vessel power systems with emphasis on fault current analysis (protection), power system stability, loading and unloading of vessel power systems to shore utility systems, methods of communication and protective relaying and dual frequency operation.

II. CURRENT STATE OF SHORE POWER

Shore-side power for large ocean-going vessels has been a hot subject for the past few years in the port authority, environmental protection and engineering circles. Many known implementations of shore-side power systems are presented in references [3] and [4]. The viability of shore-side power applications and their ability to power ships at berth depends greatly on the infrastructure outlay. For this measure to be successful, sufficient power must be available for use at the wharves and on land for substation development, and cable-laying right-of-ways must be available close to the terminals. In addition, all ships must be modified to enable connection to shore power.

One port in Southern California has fitted 2 terminals with shore power and plans are being developed for 7 other terminals. Figure 1 illustrates an installation in Los Angeles. Another port in Southern California has two shore power projects under construction and three others in the design stage. Both ports have committed to provide shore power to vessels while at berth. These ports have planned and selected a 6.6 kV supply voltage infrastructure with power delivery up to 7.5 MVA per berth. Figures 2 and 3 illustrate a method for accommodating the ship-to-shore cables. Specific shore side power supply system grounding requirements are still under discussion with various ship authorities. Initial discussions with a few ship authorities indicated shore side power supply system grounding to be high resistance grounding to ungrounded system.

Fig. 1 6.6 kV connection box on wharf

Fig. 2 Cable reel on ship for shore-side connection

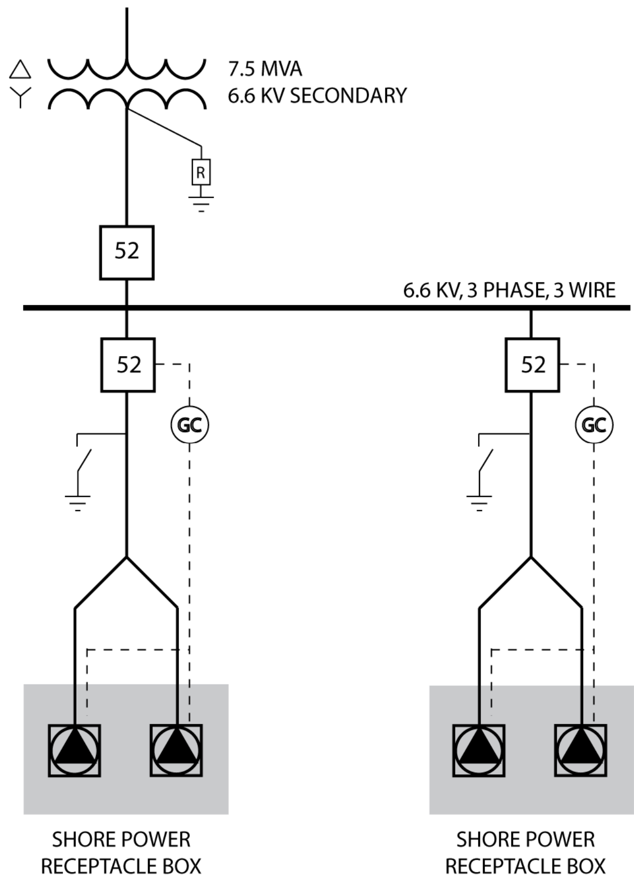
Fig. 3 Cable extended from ship for shore-side connection

Other US Ports investigating the possibility of cold ironing projects are Houston (Texas), Richmond and Norfolk (Virginia), Seattle and Tacoma (Washington), and Oakland and San Francisco (California). International activity includes the Hanseatic Ports (Baltic Sea) which have shore-side power as part of their environmental program, and Lubeck Port which implemented a trial shore connection in August 2005.

The existing installations of shore power are specific to the vessel class. These installations can be grouped into the following categories: container ships, tanker vessels, ferries / barges, bulk carrier ships, and passenger ships. Each category has requirements specific to its vessel type.

III. SHORE POWER SYSTEM FEATURES

Shore power connections for commercial ships typically range from 2 MVA to over 10 MVA in capacity. Figure 3 shows the shore-side system for connecting container vessels.



Note: Although more than one shore power receptacle box may be installed on the secondary side of the transformer, only one shore power receptacle box will supply power to a ship at any one time.

Fig. 4 Typical shore-side power system

A. Shore Power Supply

The shore power supply typically requires interface with the serving utility. Container and bulk carrier ships are typically fed with 6.6 kV while passenger ships connect at 6.6 and 11 kV. All recent installations have been at 60 Hz. ISO and IEC standardization efforts thus far is supporting 60 Hz only as the standard for future installations. High resistance grounding is typically specified for safety reasons [5].

An earth grounding switch is provided to discharge the induced voltage of the shore power feeder before being disconnected from the shore power outlets. The grounding switch has a mechanical interlocking scheme between the shore power circuit breakers and shore power outlets to prevent the mating or un-mating of a plug and receptacle while the shore power feeder is energized [6].

B. Shore Power Receptacle Boxes – Pier Side

The shore connection enclosure houses power and control receptacles for connecting the ship to shore. The shore power receptacle box shown in Figure 4 contains two 7.2 kV, 3-phase, 350 A receptacles.

Shore side connections need to be located away from cranes at the edge of the wharf at locations flexible enough to accommodate different ships at berth.

C. Shore Connection Boxes – Ship Side

Most container ships are wired to accept either 6.6 kV or 480 Volt services from shore. To a much lesser degree other voltage systems and even different frequencies do also exist. However, regardless of this fact, the owners of new container ships are informed by the Ports in the Los Angeles area that 6.6 kV, 60HZ will be the only voltage provided on shore. Conversions to other voltages if needed by a particular ship, will be the responsibility of the ship owner to provide on the ship itself. Ship builders, ship owners, ports and terminal operators are presently pursuing this thought as a standard that is forthcoming. If a particular installation is different than described here, it is due to the fact that the Port, the terminal operators and ship owners have special circumstances and have agreed to cooperate with each other, to encourage the implementation of cold ironing sooner than later. This is true for container ships only and to some degree this requirement will apply to other ships also, such as: Cruise ships, tanker vessels and LNG carriers.

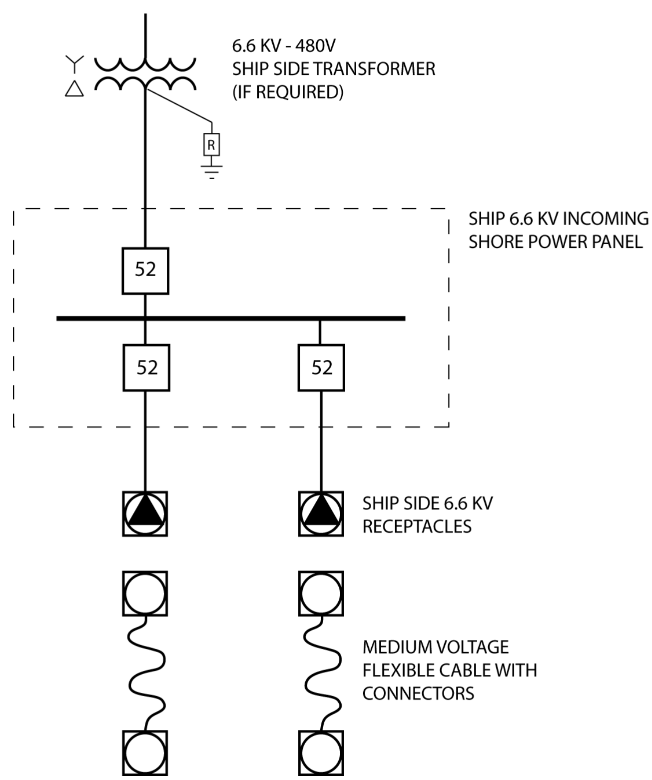


Fig. 5 Typical shipboard 6.6 kV shore power system

D. Cable Connections (Ship to Shore)

For container ships, cables used for connecting the ship to the shore connection box are fed from cable reels on the ship. Cables for connecting other vessel types may be from the shore or ship.

Cable handling must accommodate tide changes and vessel movement. Cables need to be flexible and be suitable for the marine environment. Cables are also subject to tension at times. Commercial ships can be fitted with cable managers to reel down cable to wharf connection points. The cable managers can be fitted with tension sensors to trip the circuit when allowable tensions are exceeded.

E. Ship Incoming Panel

Existing ships require retrofits to accept medium voltage shore power connections. Many new ships are being built with the equipment necessary to make shore power connections.

F. Power Transfer

Vessels with critical loads may require parallel operation prior to de-energizing onboard generation. Both ship and shore electrical distribution systems including shore-to-ship power outlets will need to be rated for the increased fault levels. Most existing vessels are not equipped for parallel operation and will require modifications to permit paralleling the two sources.

IV. STANDARDS ACTIVITIES

The IEEE, the International Standards Organization (ISO) and the International Electrotechnical Commission (IEC) have taken steps to develop standards for connecting large commercial ships.

A. IEEE P1713 Electrical Shore-to-Ship Connections

The Marine subcommittee under the Petroleum and Chemical Industry Committee of the IEEE Industry Applications Society formed a working group in September 2006 to work on development of cold-ironing standards. The working group's Project Authorization Request IEEE-P1713 was approved by IEEE-SA in December 2006. The scope of the project covers system components necessary for connecting large commercial ships including the shore power supply, shore connection boxes, cable connections, ship incoming shore power panel and control system. The standard also addresses safety considerations, maintenance and inspection.

The standard will address three categories of ships for shore power connections: container ships, tanker vessels, ferries / barges, bulk carrier ships, and passenger ships. The areas to be covered include:

Shore Power Supply
- Frequency / voltage tolerances
- Interlocks
- Grounding

Shore Connection Boxes
- Enclosure
- Receptacle assembly
- Earthing switch

Cable Connection
- Ship-to-shore
- Plug connection

Ship Incoming Panel
- Overcurrent protection
- Interlocks

Control System
Utility Interface
Safety Considerations
Maintenance
Inspection

The Marine Industry Subcommittee is responsible for the development of shipboard electrical standards, IEEE STD 45 - Recommended Practice for Electrical Installations on Shipboard [7], IEEE STD 1580 [8], IEEE STD 1662 [9], IEEE-P1709 [10] and IEEE-P1713. The IEEE-1713 will make appropriate reference to these standards for maintaining shipboard electrical system integrity and safety.

B. ISO/TC8/SC3 N428 – Standards for Electrical Shore Connections

The first meeting of the working group was held in September 2006 in Washington DC [11]. Recognizing the obligation of port states and port authorities to ensure clean air for port communities and the reality that "cold ironing" is one of the options they are using to meet this requirement, the working group agreed to develop an ISO standard for on-shore power supply. This standard will also consider the operational needs of ship owners, operators, facilities, and other affected parties in the marine industry. The working group agreed that drafting of the standard would be best accomplished if it were divided among 5 drafting groups according to vessel type: tankers/LNG, bulkers, containerships and ro/ro, cruise ships, ferries, with issues important to vessel types being discussed wholly within that drafting group and sub issues important all groups being discussed by all groups, but concentration of ownership being assigned to one group, to ensure commonality is achieved where practically possible. The scope to be discussed by all groups was to cover at a minimum the following issues:

Power Demand (for 20 years to come)
Voltage (440 V, 6.6 kV, 11 kV)
Frequency (50 or 60 Hz)
Power Quality
Reliability and Fault Tolerance
Power Transfer
- Phase rotation
- Voltage matching
- Synchronization
- Time to transfer
- LTC transformer

Grounding
Code and Standards Coordination
Equipment Location
- Transformer
- Frequency converter
- Shore connection point
- Wharf outlets (position & number)

- Cable management system (position & number of cables)

Communication, Control & Protocol
Testing & Responsibilities
Procedures

C. IEC 60092-201 Clause 14: Shore Connections

IEC TC 18 circulated a draft copy for comment in October 2006 and intends to include the standard in a revision to the consolidated edition of the IEC 60092 series, Part 1: Design, equipment, installation, verification and testing. The draft is an overview of requirements for shore connections and does not address the specific requirements of different vessel types. The scope covers the following:

Onshore Requirements
- Power grid
- Installation

Interface Ship Shore
- Plug and socket outlet
- Shore connection cable
- Communication
- Contact sequence

Onboard Requirements
- Installation
- Shore connection transformer
- Interlocking concept
- Protection concept
- System control
- Power grids and earthing concept
- Current supply systems
- Tests
- Documentation

V. CONCLUSIONS

New standards development has been initiated to ensure shore power systems for connecting ships are compatible at ports around the world. Coordinated development of analytical techniques, port infrastructure and shipboard electrical plants will facilitate the implementation of an “any ship, any port” concept.

When these standards are published, more ports will embrace shore power to reduce the environmental impact of pollution created while vessels are at berth.

VI. ACKNOWLEDGEMENTS

The authors would like to acknowledge the staff at the Port of Long Beach and the Port of Los Angeles for sharing on-going project information related to shore-side power systems. . We also applaud the efforts of IEEE, ISO and IEC for their standards activities in the area of shore-to-ship connections.

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VIII. VITA

Mr. Kevin Peterson (M’87, SM’97) started his career in consulting engineering with SPARVAN Inc. in 1983 while studying for his bachelor’s degree. He was promoted to Chief Electrical Engineer in 1989. In 1991 he started P2S Engineering Inc, a consulting electrical, mechanical, and telecommunication engineering firm. The Long Beach, California based firm currently has a staff of seventy-five personnel. Mr. Peterson serves as the firm’s President / CEO. His experience in the electrical engineering field has encompassed a variety of projects involving industrial and commercial power and lighting systems. Mr. Peterson is Past President of the IEEE Industry Applications Society and has been actively involved with the society since 1988. Mr. Peterson received his B.S. degree in Electrical Engineering from California State University, Long Beach in 1986. Mr. Peterson is a Registered Professional Engineer in California, Arizona, Nevada, Washington, Oregon, and Puerto Rico.

Mr. Peniamin “Ben” R. Chavdarian (M’65 – SM’03) is the Chief electrical engineer for the design of electrical facilities for the Port of Long Beach in Long Beach, California. Duties include the preparation of electrical specification, design, and of drawings related to all electrical projects. Provide expert advice of electrical systems for container terminals; cold ironing system design and operation for ships; cruise ship terminals; marinas; bulk handling facilities; container crane busbar systems; crane automatic transition system between two independent busbar systems; container crane cable reel system; container crane power estimation; container crane system analysis; power distribution and control monitoring systems for refrigerated containers; power for dredging machines; high mast lighting system for container terminals; high and low voltage power distribution system; other system infrastructures required such as communication, telephone, security, data network, public address, intercom, closed circuit television, fiber optics, fire alarm, antenna, remote monitoring of high voltage, remote controls for low voltage, addressable signs. Mr. Chavdarian has been a member of IAS since 1967 and has served through all the offices of the Los Angeles Chapter. He has been a member of the City of Los Angeles Technical Advisory Code Committee since 1979 and a member of National Council on Qualifications for the Lighting Professions (LC) since 1999.

Mr. Moni Islam is the Project Manager at Northrop Grumman Ship Systems. Mr. Islam has thirty-four years diversified electrical engineering experience in planning, designing, developing, and implementing new shipbuilding and ship modernization programs. Mr. Islam is the Chair Elect of IAS-PCIC- Marine Industry Sub-Committee (2005-2007), IEEE Standard 45 central committee Vice-Chair and working group member of IEEE-1580 and working group member of IEEE Standard-P1662. Mr. Islam has been involved in “All Electric Ship” R&D programs for many years. Mr. Islam has authored many technical papers on shipboard electrical power and made technical presentations. Mr. Islam was the principal investigator of Ship Smart-System Design (S3D) feasibility study and principal investigator (NGSS) for ISSB (Integrated Structural Building Block), ONR funded research projects. Mr. Islam has authored “Handbook to IEEE Standard 45, A Guide to Electrical Installation on Shipboard (August 2004 Release)”. Mr. Islam received his Bachelor of Marine Engineering Technology with distinction from the Merchant Marine Academy, Bangladesh in 1969, and Bachelor of Electrical Engineering Degree with Honors from Fort Schuyler, Maritime College, State University of New York in 1975.

Mr. Chris Cayanan (M’03) is an electrical engineer with P2S Engineering in Long Beach, California. He has over five years of electrical engineering experience. His experience in electrical engineering has encompassed a variety of design and construction projects involving low and medium voltage power distribution systems, specialty systems, and area lighting. Mr. Cayanan’s project experience has included industrial facilities, port facilities, manufacturing plants, and power plants. He has been a field engineer, project coordinator, start-up engineer and quality inspector for different projects. His professional activities include serving as an active member of ISO Standards for Electrical Shore Connections and Secretary of the IEEE IAS I&CPS Power Systems Engineering Committee. Mr Cayanan received his B.S. degree in Electrical Engineering from University of Wyoming in 2001 and currently finishing his Master of Electrical Engineering Degree from California State University, Long Beach. Mr. Cayanan is a Registered Professional Engineer in California.