SHIP TO SHORE POWER:

US NAVY HUMANITARIAN RELIEF?

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Background

While the author was training to become a US Navy Enlisted Reactor Operator, qualified operators repeatedly stated, “This sub could power a small city.” In a similar vein, it was proposed that US Navy ships should provide electrical power during the response to Hurricane Katrina in New Orleans. These off the cuff assessments prompted a more realistic assessment: is it feasible to power facilities ashore from a ship?

History

During World War II, there were seven destroyer escorts converted into Turbo-Electric Generators (TEG) specifically for the purpose of providing electrical power to shore facilities. They were the Donnell (DE-56), Foss (DE-59), Whitehurst (DE-634), Wiseman (DE-667), Marsh (DE-699), and two British lend-lease ships; Spragge (K-572, ex-DE-563) and Hotham (K-583 ex-DE-574)[1]. Data for these ships are sparse in general.

Consider the Wiseman, for which more data is available. This ship had oil fired boilers producing steam to turn turbine generators which in turn powered electric propulsion motors. This electric ship configuration is optimal for providing electric power ashore since all the power in the ship is already being converted to electric. The Wiseman had transformers and cable reels topside to deliver power at high voltages over relatively long distances. Wiseman powered the city of Manila during WWII and the port of Mason during the Korean War. Wiseman delivered 5,806,000 kWh to Manila over five and a half months[2], giving an average generation capability greater than 1.4 MW.

The US Army also used ship to shore power to power remote stations. One notable case is that of the Sturgis/MH-1A, A WWII era Liberty ship equipped with a nuclear power plant used to provide power to the Panama Canal Zone from 1968 to 1975[3]. The MH-1A power plant on the Sturgis generated 10MW electrical power which allowed the canal locks to be operated more frequently.

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[1] http://www.de220.com/Conversions/TEG.htm

[2] http://www.desausa.org/de_photo_library/uss_wiseman_1.htm

[3] http://www.atomicinsights.com/aug96/MH-1A.html

Thus history shows that ships can provide power to the shore, if only in limited amounts, and using specialized ships.

Present

There are currently no US Navy ships designed specifically to provide power to the shore. They are however designed to be powered from the shore and this capability could be used to act as a power source. For example, the author's ship, USS Key West (SSN-722), a Los Angeles class nuclear powered fast attack submarine, once received 'shore power' from a destroyer while moored alongside the destroyer anchored off Monaco. This allowed the labor intensive nuclear reactor plant on the submarine to be shutdown. The gas turbine generators on the destroyer require fewer watchstanders and had to run to power the destroyer's own loads. This anecdotal evidence shows that power can be made to flow from at least one US Navy ship and conceivably could flow from most.

The capability to provide power can be evaluated by considering the ship as a load and assuming that whatever power it can draw, it can deliver. For USN ships smaller than carriers and amphibious ships, the unit of measure is the single shore power cable. These cables are rated to 400A at 450V 3 phase or 0.312MW assuming a unity power factor[4]. Submarines and surface combatant ships typically can connect up to eight cables, yielding a total of 2.5MW. For a carrier, the shore power supply must deliver 21MVA at 4160V[5]. Amphibious ships are presumably between these values. Without significant changes, current Navy ships could theoretically supply 2.5 to 21MW of electrical power to the shore. This again assumes generation capacity to match the ship as a load and also assumes this capacity is above that required to power the ship and its power plant.

What if more power is needed? More ships could be used, but there is also more power onboard each ship. This other power is the power for propulsion. Remembering the Wiseman, it was an ideal ship for supplying power because all the power of the boilers

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[4] http://neds.daps.dla.mil/Directives/11310a3.pdf

[5] http://www.wbdg.org/ccb/NAVFAC/INTCRIT/fy99_01.pdf

was first converted to electricity by turbine generators. Today's Navy ships are not 'all electric' and so a significant portion of the power onboard is dedicated to propulsion and is often coupled directly to the propeller shafts. Steam plants fired by oil or nuclear reactors offer a sort of middle ground. While the propulsion turbines are coupled to the shafts, the steam can be diverted upstream. In this scheme, high pressure steam would be piped out of the ship and used to drive a larger turbine generator. The spent low energy steam and condensate would then be piped back into the ship and into the condensate system, closing the loop. Piping is not as forgiving or flexible as cabling, this would not be a trivial set up and is probably impossible for a submarine..

Considering the publicly available shaft horsepower ratings for the ship as the electrical power available, it is clear that much more power is in the hulls than is available through the shore power connections.

Ship type	**Total Shaft Power (HP)**	**Electrical Power (MW)**
Fast Attack Submarine	35000	26
Large Deck Amphib	70000	52
Carrier	260000	194

Table 1 Power Available From Steam Plant Ships

Note that most surface combatants are driven by gas turbine or diesel engines and their propulsion power cannot feasibly be extracted from the ship.

Future

The Navy is driving toward all electric ships in a case of history repeating. This is driven by the desire to access propulsion power to supply combat systems. As stated previously, all electric ships are ideal for providing power to shore since all their power is first converted to electricity. The future destroyer DD(X) is being designed as an all electric ship with two Rolls-Royce MT-30 gas turbine generators producing a total of 78MW of electrical power[6].

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[6] http://en.wikipedia.org/wiki/DD(X)

The future carrier CVN(X) will be nuclear powered and have a steam plant but will also have increased electrical generation (104MVA)[7] to support launching planes using electrical power.

Neither DD(X) nor CVN(X) is designed to deliver power outside the hull, but it would be easier to export it as electrical current than as steam.

Loads

To investigate the claim of powering a small city, a 'rough order of magnitude' (ROM) calculation was performed. The author's most recent electrical utility bill was used to determine the average power of a house, and then this number was used to determine how many houses could be powered. The bill was for 1203kWh over a 29 day period giving an average load of 1.7kW. Again, this is a ROM calculation and does not incorporate seasonal variations in power use nor the likelihood of reduced use in an emergency situation.

Using the existing shore to ship power capability, the submarine can power 1500 nominal homes: more of a town than a small city. The carrier can power 12000 houses and that is a small city.

Ship type	**Shore Power (MW)**	**Houses**
Submarine	2.5	1500
Carrier	21	12000

Table 2 Powering Houses with Existing Ships Equipment

If the steam plant of an amphib or a carrier were modified to increase electrical generation to match propulsion power, many more houses could be powered, equivalent to a medium city based on population only.

Ship type	**Steam Power (MW)**	**Houses**
Amphib	52	31000
Carrier	190	110000

Table 3 Powering Houses with Steam Plants

[7] www.empf.org/empfasis/sept04/carrier.htm

Lastly, if all the generation capability of future ship classes could be made available external to the hull, a large population could be supplied.

Ship type	Generation Power (MW)	Houses
DD(X)	78	46000
CVN(X)	104	61000

Table 4 Powering Houses with Future Ships

The US Navy is not chartered to act as a power utility, they are not likely to power the shore except at forward military or disaster locations. In these cases, residential housing is not likely to be the first load supplied. Instead, hospitals and other vital infrastructure are likely to receive priority. This prioritization is important since a single hospital can be a significant load. Based on one report discussing emergency generation installation, a value of 2MW per hospital was determined[8].

Using shore power, a submarine or surface combatant can power one hospital with a small surplus. This undermines the claim for a small city since few loads will be powered after the hospital. A carrier can power ten and a half hospitals, likely allowing some residential power after the vital infrastructure is supplied.

[8] www.ecmweb.com/mag/electric_dual_kw_gensets/index.html

Interconnection

Grounded vs Ungrounded

transformers

also addresses voltages

Grid damage

Load selection

Regulation

Generators in parallel

‘Small City’

My electrical bill:

1203 kWh / 29 days = 1.7 kW avg

seasonal variations

less in emergency conditions

SSN shore power (1.4 MW)

810 homes – A very small town

CVN shore power (21MVA~21MW)

12,000 homes – Significant town

All Electric DD(X) (78 MW)

45,000 homes – Small City

Hospitals

2 MW emergency generation needed

www.ecmweb.com/mag/electric_dual_kw_gensets/index.html

HVAC cannot be shutdown

SSN shore power (1.4 MW)

insufficient

CVN shore power (21MVA~21MW)

10 hospitals

All Electric DD(X) (78 MW)

39 hospitals