PRELIMINARY 5 MW DUAL-MODULE DUAL-PORT DESIGN

USN ONR CONCLUSION

A preliminary design for a 5 MW, 4,160 V dual-module, dual-port Resonant Link inverter was designed and all critical key aspects of the hardware design were addressed. A list of design validation tests were identified and briefly described.

Circuit modelling was performed to demonstrate the potential inverter performance as well as support the power electronics components specification. Information received included component weight, volume, efficiency, and cost estimates for all major components. Improvements and refinements of these component requirements will be performed during the detailed design and component procurement phases.

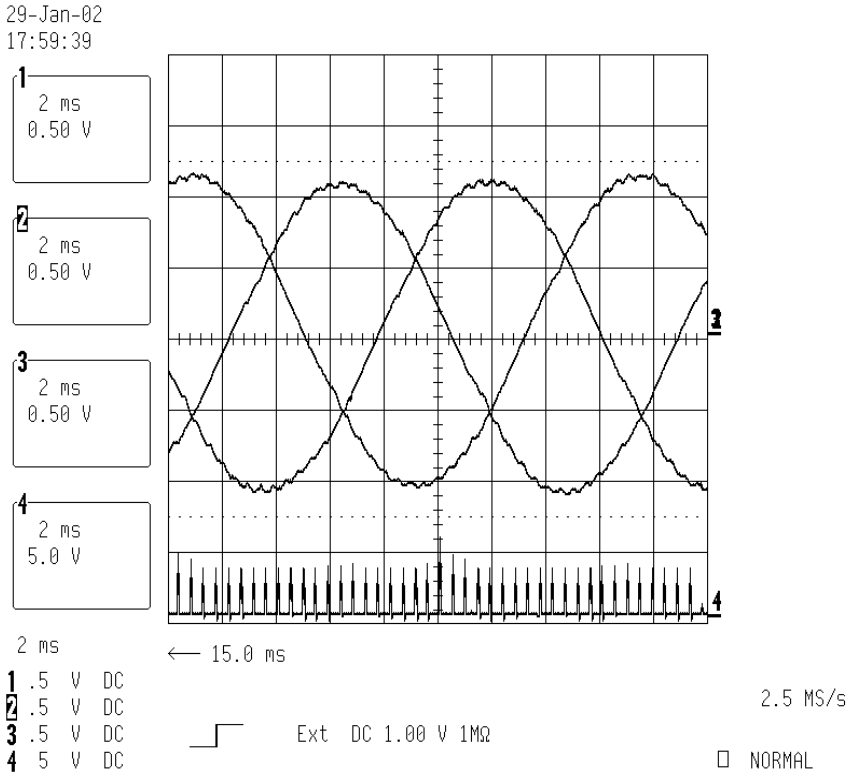
With preliminary power electronic weight, volume, and form factor a system layout was generated. The layout yields a high-power density of 3.1 MW/m^3 for the single port output module and supports the power density of 5.5 MW/m^3 for a 20 MW inverter or higher, originally projected for the 1999 Royal Navy study. Comparing the projected power density with data provided by Electric Boat indicated that the Resonant Link power density is a factor of ten higher than what can be presently fielded for 4,160 V PWM inverters. However, assuming that the present Resonant Link size may double to comply with various Navy requirements, the Resonant Link system will still have five times higher power density than that of a mature PWM system.

The preliminary modelling also shows that the dual-module Resonant Link inverter has voltage on both the input and the output with a dV/dt of 13.3 V/usec in comparison to 7,500 V/usec for a four level PWM inverter. In addition, the projected efficiency is higher than 98% over most of the power range, using the spaced-out manufacturer components.

The layout of the 5 MW was performed to permit the installation of the system in a configuration that can be transported for testing with motors in various locations. Recently, SAIC was made aware, through communication with Electric Boat and ONR, that the selected form factor is most likely not the preferred form factor for shipboard installation. For the detail design we will take the recommended form factor and other Navy guidelines into consideration. It is the belief of the SAIC team that there will be no problem increasing the inverter height and reducing the depth, since the Resonant Link is not limited to ultra-low inductance interconnections, such as for the PWM inverter.

In conclusion, the team has not run into any showstoppers. No technical breakthrough or component development is required for the Resonant Link 5 MW drive and system scaled-up to 20, 36 or 50 MW for any required number of modules, in the module power range of 5 to 10 MW. Unlike for the PWM system, the Resonant Link modules can be effectively time interleaved, producing a high-frequency output ripple where the THD of the input and output current can be readily reduced to less than 0.3% with a small low-pass filter input and output filter.

PFM


29-Jan-02
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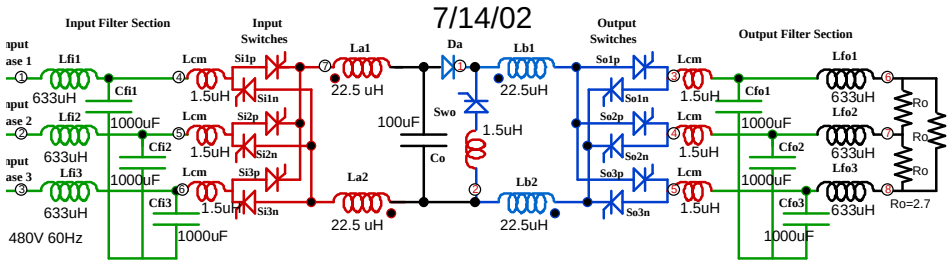
1
2 ms
0.50 V
2
2 ms
0.50 V
3
2 ms
0.50 V
4
2 ms
5.0 V
2 ms
15.0 ms
1 .5 V DC
2 .5 V DC
3 .5 V DC
4 5 V DC
Ext DC 1.00 V 1MΩ
2.5 MS/s
NORMAL


7/14/02
Input Filter Section
Input Switches
Output Switches
Output Filter Section
Lfi1
633uH
Cfi1
1000uF
Lfi2
633uH
Cfi2
1000uF
Lfi3
633uH
Cfi3
1000uF
480V 60Hz
Lcm
1.5uH
Si1p
Si1n
Si2p
Si2n
Si3p
Si3n
La1
22.5 uH
La2
22.5 uH
Da
Swo
100uF
Co
1.5uH
Lb1
22.5uH
Lb2
22.5uH
So1p
So1n
So2p
So2n
So3p
So3n
Cfo1
1000uF
Cfo2
1000uF
Cfo3
1000uF
Lfo1
633uH
Lfo2
633uH
Lfo3
633uH
Ro
Ro=2.7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PFM ACCOMPLISHMENTS

ONR funded $1M effort FY00-FY02

- **Actual operational hardware at the 250 kW power level**
- **System was tested in the AC-AC synchronous, AC-DC, and AC-AC asynchronous mode up to full power level.**
- **Theoretical performance was validated with experimental results.**
- **A total harmonic input and output harmonic current distortion of less than 1 %**
- **Results indicate that with a five time-interleaving module, a total harmonic distortion of less than 0.1 % can be achievable for a potential quiet propulsion drive application.**
- **Measured output voltage dV/dt of less than 1 V per microsecond is over a 1000 times smaller than for a comparable PWM drive, thus eliminating the motor insulation degradation problem of PWM power systems.**
- **PFM inverter topology is very scaleable in voltage and power to the 30-60 MW level required for ship propulsion drive application**
- **Projected power density for a 20 MW ship propulsion drive is of the order 5.5 MW/m3.**
- **PFM is extremely fault tolerant as evidenced by the fact that not a single thyristor or other component was damaged during the development and testing of this 250 kW inverter topology**

PFM FY03 – FY04

SAIC FY03: **Follow-on effort shall utilize the 250 KW, 480 V AC to AC PFM test results and know-how to perform a preliminary design for a 5 MW, 4,160 V, three-phase PFM motor drive.**

The three-phase 5 MW PFM will be designed:

- **5 MW/6.25 MVA operation with full phase current testing of three of the 15 phases for the 20 MW 4,160 IPS ship propulsion motor.**
- **This PFM will deliver a phase current up to 870 A that will exceed the phase current required for the 20 MW IPS propulsion motor drive.**
- **Using five such interleaving PFM modules, a 15-phase motor can be driven at 25 MW or 31.25 MVA.**
- **The 5 MW PFM variable speed motor drive can also be used to control the 5 MW three-phase 4,160 V AC super conducting motor.**
- **The 5 MW PFM variable speed motor drive can also be adopted to run any 4,160 V three-phase induction or permanent magnet motor (PM).**