LANL Proposal to ILC GDE
for the period
October 1, 2006 to September 30, 2007

Optimized Converter-Modulator Development for ILC Application

WBS 3.8.4

1. Abstract—The first generation 10 Megawatt pulsed converter-modulators, implemented at Los Alamos National Laboratory (LANL) are now utilized for the Oak Ridge National Laboratory (ORNL) Spallation Neutron Source (SNS) accelerator klystron RF amplifier power systems. The various systems operate up to 140 kV, or 11 MW peak power, or up to 1.1 MW average power with a maximum pulse duration of 1.5 ms. This is similar to the ILC single tube requirement of 1.5 ms, 10 Hz, 120 kV, and 15 MW peak power. The component improvements realized with the SNS effort coupled with new applied engineering techniques have resulted in dramatic changes in overall power conditioning topology. As an example, the 20 kHz high-voltage transformers are less than 1% the size and weight of equivalent 60 Hz versions. With resonant conversion techniques, load protective networks are not required. A shorted load de-tunes the resonance which results in limited power transfer. This provides for power conditioning systems that are inherently self-protective, with automatic fault "ride-through" capabilities. By altering and iterating the Los Alamos design, higher power and more efficient systems can be realized for the ILC application. An optimized converter-modulator would be capable of operating two (2) parallel multi-beam klystrons (MBK) with long cable lengths (> 1 km) with high electrical efficiency (~95%). As a point of comparison, the baseline Fermi-Tesla modulator is 89% efficient, operates 1 tube, and requires a large access tunnel next to the accelerator tunnel. With a converter-modulator, the number of modulators required for the ILC would decrease by ½ the anticipated (~540) modulators and provide for smaller beam and access tunnels. This could save the ILC project over $100 million, in addition to lowering energy costs.

2. *Statement of Work*

This Section contains the Statement of Work to be performed at LANL. Semi-annual technical progress report for this work package will be submitted at the mid-point and close of the fiscal year to the GDE-Americas Regional Office. These reports will contain descriptions of technical progress, statements of goals for the next reporting period, and indications of long-range plans. Within two months following the end of the fiscal year, a final technical report for this work package will be submitted, in which the actual work accomplished will be compared with the scope defined in the work package in this document.

2.1 Scope of Work

WBS 3.8: Main Linacs: RF Systems

WBS 3.8.4: Optimized Converter-Modulator Development for ILC Application

Summary:

This R&D effort will provide improvements to the LANL/SNS modulator presently being used at SLAC for their ILC accelerator test stand. This was the first production modulator for the SNS project that Los Alamos sent to SLAC in 2005. One of the limiting factors for the peak power performance of this current (SNS) converter-modulator design is the IGBT switching current. The proposed effort addresses this limitation by adopting a parallel IGBT configuration thereby distributing the switching current. This is the first of two steps to enable the operation of 2 MBK's from a single converter modulator. Following the successful demonstration of the parallel IGBT H-bridge switching network, a follow on program will be proposed to modify the design from three present 3 phase converter to one of 5 phases. This would allow reliable operations of two MBK's from a single converter modulator, with lower component loading as compared to the SNS application.

The FY07 R&D effort would be related to hardware and software modifications to the LANL/SNS converter modulator currently at SLAC. The design and fabrication of the required circuit components will be performed at Los Alamos and then installed and high power tested at SLAC.

Motivation:

To accomplish the ILC demonstration at SLAC, a different "tuning" of the modulator is required along with new parallel, higher power H-bridge IGBT switching networks. To provide a different tune for the modulator, changes to the transformers and resonating capacitors are required, with an example of the SNS system as shown in Figure 1. The anticipated ILC designs will provide for lower e-field stresses, a 50% reduction as compared to SNS, and other mechanical design improvements.

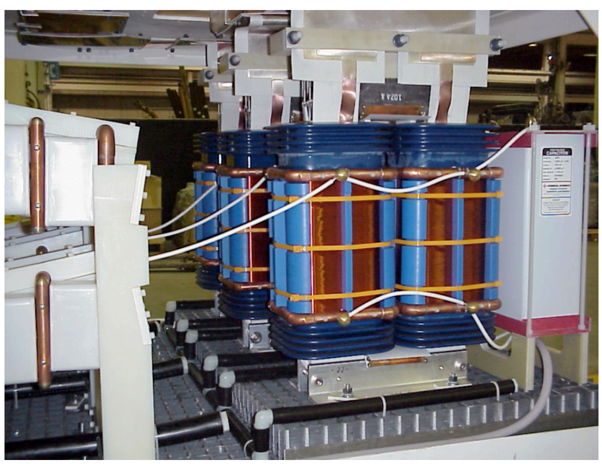

Figure 1. Nanocrystalline Transformers and Resonating Capacitors

Work to be performed:

To validate that the parallel IGBT configuration will support the 30 megawatt drive pulses for 2 parallel MBK klystrons, parallel H-bridge IGBT switching networks will be utilized as a direct plug-in replacement to the existing SLAC converter-modulator assemblies.

Measurement of the system performance under load at SLAC will then be used to evaluate the pentaphase converter-modulator design will provide suitable margin for operating 2 parallel MBK's with long output cables. This design would then be pursued in FY 08.

A view of the existing H-bridge switching network is shown in Figure 2, as used at LANL, ORNL, and SLAC. The direct plug-in replacement with 2 parallel IGBT's, in each position of the H-bridge, optimized for the ILC 30 MW pulse application, is shown in figure 3.

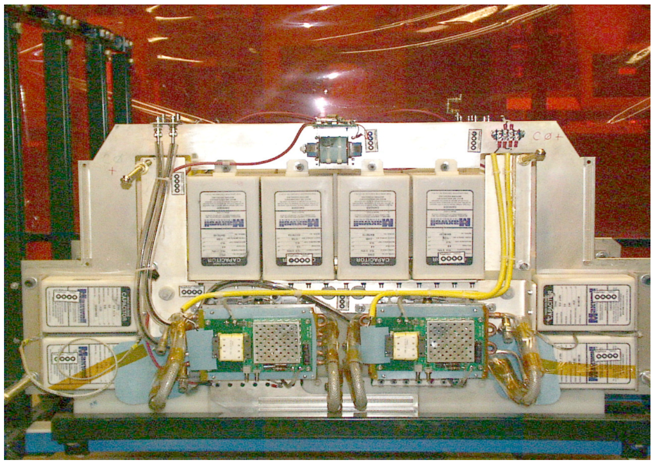

Figure 2. SNS H-Bridge Switching Assembly

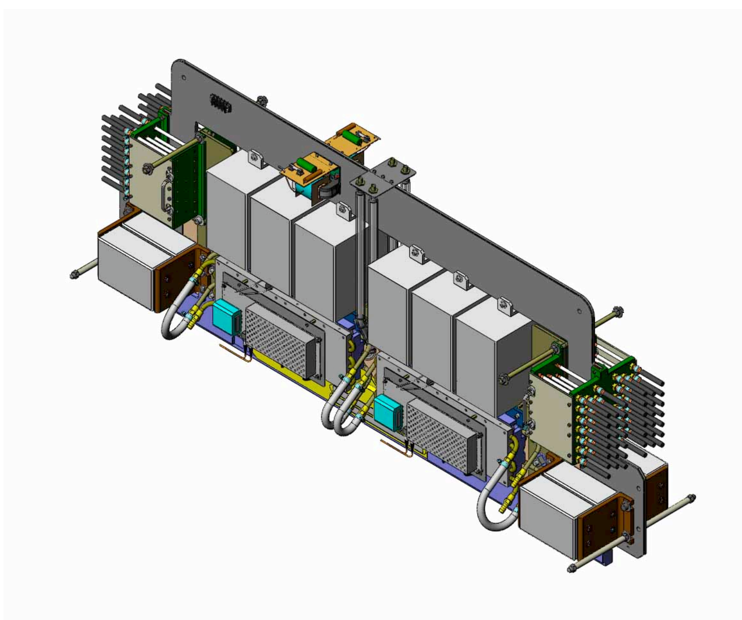

Figure 3. Proposed ILC 30 MW H-Bridge Switching Assembly

In addition to fabricating, installing, and testing the hardware as indicated above, for FY07, we will demonstrate adaptive flat-top control at full power. This will require subtle circuit changes to the converter-modulator. Figure 4 shows successful adaptive control techniques, as demonstrated for SNS at low duty cycle, but unfortunately, at full average and peak power, the IGBT's energetically fail. We believe we have solved this problem and will successfully demonstrate adaptive control capability at full power.

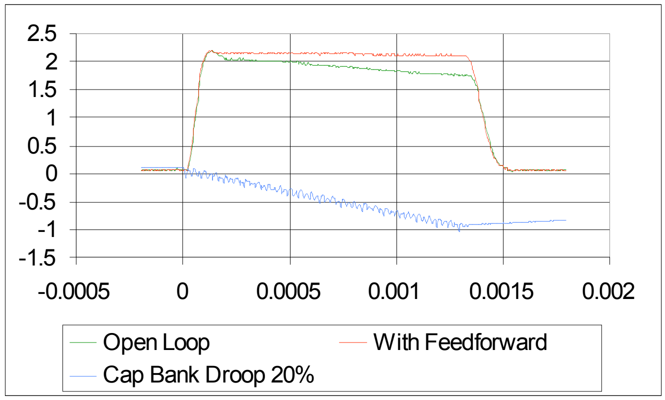

Figure 4 Successful Adaptive Flat-Top Control at Reduced Duty

Collaboration with other institutions:
The high power components will be evaluated at SLAC.

Milestones and deliverables:
The evaluation of the high power components successfully evaluated at SLAC will provide insight into the ability to save the ILC project ~100 million dollars. These tasks can be performed in one year as the schedule indicates in Figure 5. These tasks will can be completed with .5 FTE Engineering, .5 FTE design, and .75 FTE technician.

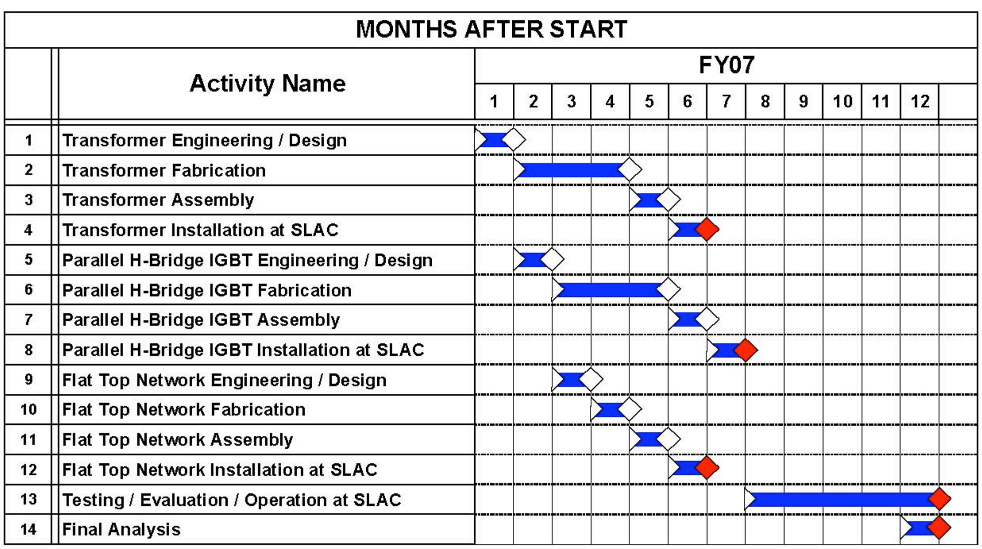

Figure 5. Converter-Modulator Upgrade Schedule for High Power Demonstration

Cost summary:

Cost Element	Direct	Indirect
Staff	$94 k	$102 k
Designer	$70 k	$76 k
Tec-6	$70 k	$76 k
M&S	$200 k	$76 k
Total	$434 k	$330 k

Table 1. Required Budget for Dual MBK Viability Power Demonstration

The budget required to demonstrate converter-modulator operation, that can save the ILC project ~100 million dollars, is given in Table 1. This includes the manpower, travel, and all component development costs necessary to achieve this project. The component developments are iterations and improvements to the SNS designs that were successfully completed in that program. A modest 764k$ investment will have a significant return to the ILC project.