PV Inverter Products Manufacturing and Design Improvements For Cost Reduction and Performance Enhancements

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ABSTRACT

This work targets the cost reduction and performance enhancement of utility interactive inverters for photovoltaic applications. The approach is to design a relatively large number of products based on a relatively small number of functional modules to achieve high manufacturing efficiencies and to enhance product reliability. The specific emphasis is on new products designed for high-volume manufacture. To this end, three prototypes have been developed, three-phase 10kW and 25kW inverters and a 2kW single-phase inverter. The key enabling technology involves the application of new Digital Signal Processor (DSP) controllers.

1. Digital Signal Processing

DSP controllers have been recently developed for motor control markets and applications. The requirements for motor control and inverter topologies are very similar. These DSP controllers are highly integrated and task-specific. All of the functions necessary to implement real-time sinewave regulation are included within these embedded controllers. DSP devices can perform repetitive math operations much faster than traditional microcontrollers. Most existing inverter control designs use a microcontroller in conjunction with parts-heavy analog circuitry to perform the high-frequency, Pulse Width Modulated (PWM) regulation tasks. With the advent of DSP technologies for power electronics applications, analog feedback and status sensors are fed directly into the DSP and multiple PWM outputs directly provide the drive logic for the inverter power switches.

This NREL development work is largely based on the development of this DSP technology for use with inverters for renewable and distributed energy applications.

2. Modular Product Architectures

As part of this contract, three DSP based control boards were developed for three different product groups. The control board reference designators and product groups are:

- ***DSP3*** Three-Phase Grid-Tie Inverters
  5kW to 100kW
- ***DSP1*** Single-Phase Grid-Tie Inverters
  1kW to 5kW
- ***DSP2*** Hybrid System Inverter/Chargers
  1kW to 20kW

All control boards use the same DSP controller. More importantly, the firmware being developed for all three controllers is based on functional software modules or blocks of code that are task specific and can be imported from one application to another. As products become more sophisticated, more than half of the engineering development time can be spent on firmware development. One of the NREL contract requirements is to generate a catalogue of "reusable" functional software modules. By so doing, non-recurring engineering charges associated with the product firmware development are substantially reduced as well as the time-to-market for new products.

The 10kW and 25kW three-phase inverters will be the first two products to use the DSP3 control board. The 2kW single-phase inverter will be the first product to use the DSP1 control board. The DSP2 control board is currently being used in the development of new Xantrex mobile inverter products. Development of these mobile products is beyond the scope of this contract but the use of the DSP2 control board serves to illustrate the commercialization potential of this modular design approach.

Other non-control related functional blocks are incorporated in the design of the three "NREL" inverters. The control power supplies, variable speed cooling fan drive and IGBT drive circuits can be used within these product groups and others.

Modularity on a lower tier was also achieved by designing for the fewest number of different component parts to be used on a relatively large number of products. Standardizing on component parts can reduce the costs of purchasing, stocking, kiting, and manufacturing. This approach was successfully used in the development of the NREL inverters.

3. Reduction in Assembly Labor

The three NREL inverter products were designed for high volume manufacture. Testable, modular subassemblies designed with a limited number of component parts are interconnected with the fewest number of hand-wired connections. Using this approach and inverter electrical architectures and mechanical packaging designs targeted for high-volume manufacture, an 80% reduction in assembly costs was achieved.

By way of example, in the 10kW inverter, the number of hand-wired connections was reduced from 115 to 27. Also, the number of mechanical fasteners used was reduced from 64 to 34. These are only two of many significant indicators that illustrate the improvements in product manufacturability.

4. Product Reliability Enhancements

Although product reliability was not a key contract goal and no operational field history for the new inverters is available, the new inverter product architectures should support higher product reliabilities. Internal component operating temperatures have been reduced considerably, the overall number of electrical component parts has been reduced and the number of wired connections has been reduced.

5. Results

The following tables illustrate the success of this development work. The comparison is made between the existing Xantrex Model PV10208 product and the 10kW inverter developed under this contract. The three-phase 25kW inverter exhibits almost identical improvements. The 2kW, single-phase product is more difficult to compare because the existing Xantrex product has a different electrical topology and feature set but the benefits of this design approach are equally supported.

Table 1. Cost Reduction, 10kW Inverter

Area	Cost Reduction
Total Materials	35 %
Subassembly Labor	79 %
Top Assembly Labor	80 %
Total Inverter Cost	**56 %**

Table 2. Component Cost Breakdown, 10kW Inverter

Component	Cost Reduction
Power Bridge	39 %
Heat Removal System	57 %
Enclosure	26 %
Magnetics	8 %
Control	40 %
Hardware	45 %
Shipping Materials	59 %
Total	**35 %**

Table 3. Performance Enhancements, 10kW Inverter

Parameter	Reduction
Weight	47 %
Volume	58 %
Conversion Loss	50 %

6. Conclusions

The contract goals were to achieve and overall cost reduction of 10% to 20% for the three inverters and with no compromise in performance. The cost of the 10kW inverter was reduced by 56% and the cost of the 25kW inverter was reduced by 53%. The 2kW inverter has no basis for comparison but should benefit equally form this design approach.

Not only were the contract cost reduction goals exceeded by a wide margin but the performance and reliability of the products were also enhanced. The conversion efficiency improvement, as reflected in the 50% conversion loss reduction, adds significant value in renewable energy applications. The size and weight reductions also add value by providing less cumbersome product solutions for system designers.