HOW DIRECT COUPLING IMPROVES THE RETURN ON INVESTMENT OF PV

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ABSTRACT

Nextek has substantially improved the commercial efficiency of solar Photovoltaic (PV) systems by the invention of a Multi-Source Power Module. One path in the module allows for the Direct Coupling of PV to a DC load, eliminating the inversion to AC that is required in standard solar PV systems. Where the load requires more power, other sources such as the grid or stored electricity, are combined with the DC to service the load. In this way, the threshold losses of inversion are avoided, and more power is delivered. Consumers realize a dramatic acceleration of the payback of PV-powered building applications.

The Power Module outputs highly regulated DC by prioritizing its three inputs, 1) DC from a distributed generation source such as PV, 2) AC from the utility grid, and 3) optional battery storage. Precise metering, monitoring and control can also be performed at the module.

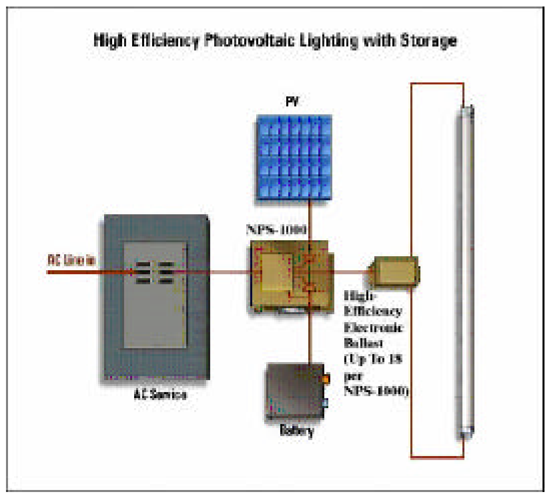

Fig. 1: A Direct-Coupled Power Module forms the basis of a highly efficient modular system.

1. THE TEST

As shown in Fig. 1, this new interface for power acts like a router in a computer network by efficiently delivering system resources where they are needed. While PV direct-coupled to fluorescent lighting was used in this demonstration, the direct Coupled system is highly versatile and modular. Storage is easily integrated for uninterruptibility and demand-shaping; and other DC sources such as wind turbines or fuel cells are suitable candidates for inputs.

Two identical sets of solar arrays and electric loads were installed side-by-side. One array was connected with a high quality inverter and the other was connected with Nextek's Direct Coupling technology. Both solar PV systems were carefully monitored by making measurements using accurately calibrated true-power meters to read both instantaneous and integrated (accumulated) watt-hours. The object was to measure the amount of effective solar PV array energy reaching the loads through the two systems under the same solar irradiation conditions. A series of tests over nine days were performed so that a variety of weather conditions could be taken into consideration, shown in Fig. 2.

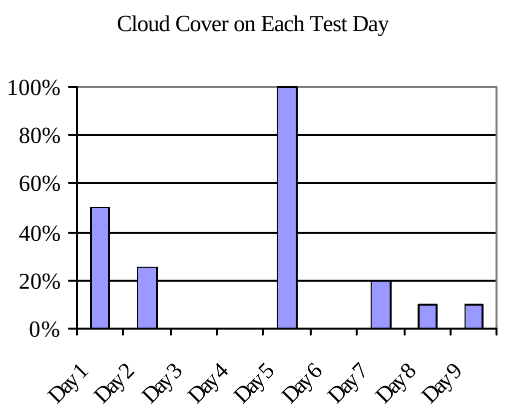

Fig. 2: Cloud Cover During Test Period.

Solar PV systems using Direct Coupling technology deliver several benefits visible in the results. For the inverter-based system, the threshold loss is the largest factor, and will dominate other variables - especially in smaller systems. In the 900w arrays tested, the power electronics that burden the inverter are a phantom load of 50 to 70 watts. Integrated over time, these losses are devastating to production, as the data show. This shortfall, however, isn't the only loss in certain systems. Where a peak power-tracking device is used, it also consumes power – perhaps less than it contributes in an AC delivery paradigm - but it adds in any event a greater level of complexity that increases the initial capital expenditure and therefore postpones the return. The Direct Coupling system and method is quasi-peak tracking as it passively collects at near the peak power point of 54 volt arrays, as it is designed to take the electricity at a point very near or at the optimal operating voltage of the load. These features allow for superior collection of the sun's energy. As shown in Fig. 3, the Direct Coupled system delivered on average 93% more kilowatt-hours to the load than did the inverter-based system.

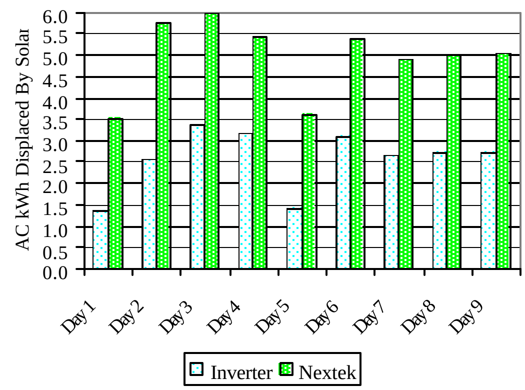

Fig. 3: Daily Total AC kWh Displaced.

Looking at one day in detail can further illuminate these results and give graphic clarity to the source of the disparity. Fig. 4 shows the constant load on top, and how the competing systems vie to displace the AC kilowatt-hours needed to supplement the solar power.

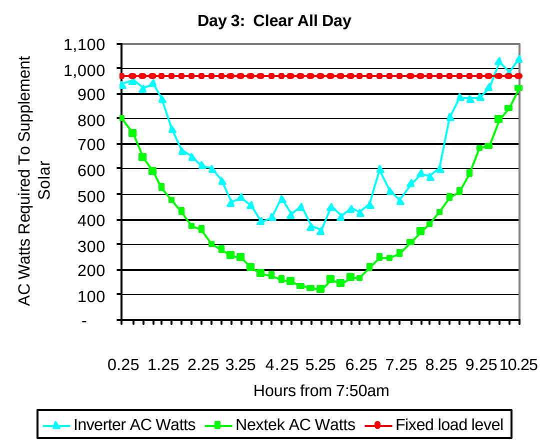

Fig. 4: Comparison of AC Watts Required To Supplement Solar On Clear Day.

The jagged path of the inverter system never intersects the smoother profile of the Direct Coupled system. The difference in contour reflects the different paradigm of the algorithm. The inverter employs a peak power-tracking device that actively looks to "find" the peak power point of the available energy so as to optimize its collection. The Direct Coupling module, on the other hand, achieves this goal by design, not through an external fix. By feeding the solar power collected at the panel voltage to an interface using that operating voltage as its own, the system handles the electricity less, thereby lowering the loss. This average difference between these two lines is the difference in total system losses. The area below the lines is the integrated representation of the AC power needed to supplement the DC to service the load. Here the DC paradigm again shows its inherent economy. In such a system the incentive is to undersize the solar, closely matching the peak load requirement with the actual peak output. This lowers the largest driver in the economic equation for most buyers: the up-front cost of the PV itself. It also provides a highly geared incentive to begin to consider what on the customer's side of the power equation has always been the least popular exercise: analyzing the power requirements of the appliances we buy.

The Direct Coupling paradigm has a greater impact over conventional practice that must be explored further. Because the drain of the inverter is relatively constant, its effect on the total system output is greater as a percentage when the harvest is low, i.e. when the sun is most obscured by the cloud deck or nearest dawn or dusk. It is telling that on the worst day for solar collection — when the sun was least available — the Direct Coupling system delivered 155% more kWh than the competing inverter-based system (see Fig. 5 below). The conclusion, therefore, is that the poorer the solar availability, the more critical the decision to employ Direct Coupling, for economic reasons.

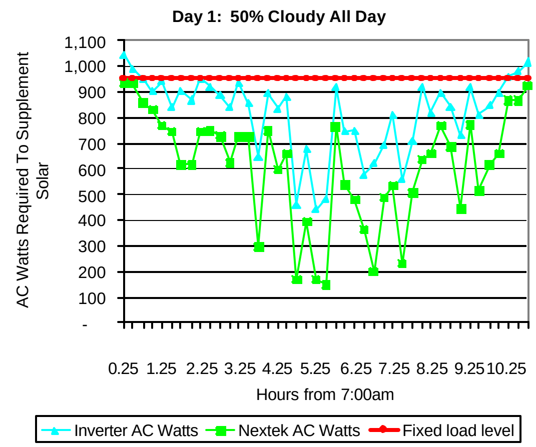

Fig. 5: Comparison of AC Watts Required to Supplement Solar On Cloudy Day.

2. <u>THE LOAD</u>

In this test, electronically ballasted florescent lights (T-8s) were the load. Most commercial and industrial building lighting loads are intrinsically DC by virtue of the use of electronic ballast. These ballast operate in three stages where the first is rectification, which delivers the DC it makes from the AC delivered to it; the second is a high-frequency oscillator which provides its product to the third stage: the lamp driver itself. Conventional ballast were replaced in this test by DC-ready ballast, which are ballast manufactured without the rectification section. In small quantities these are price competitive with standard ballast, but in large volume they should be consistently cheaper because they have fewer parts. The inverter-based system produces AC that blends with the grid-delivered AC to service the loads in the building, many of which are electronic, and therefore are DC by nature. Energy is always lost due to the inherent inefficiency of inverters at the generating source and again by the rectifiers at the load. In conditions of lower solar irradiation such as very cloudy days, the early morning and late afternoon there is not enough solar electricity produced to operate an inverter and the solar power is totally wasted.

This is the advantage of Direct Coupling: directly connecting the photovoltaic DC source to the building lighting load. With the Nextek system, available PV power is delivered directly to the load with unprecedented efficiency (~98%), with any remaining power requirement supplemented by the Nextek power module's high efficiency AC to DC converter. Solar energy and building AC are continuously blended to provide a highly regulated power source to the load. By eliminating the need for an inverter the Nextek approach dramatically reduces intervening losses when the sun is shining and in conditions of lower solar irradiation the solar power is still fully utilized.

3. THE CALCULATION

There are several important variables that affected the outcome of this demonstration, as described in Table 1. First, the test was conducted in Long Island, NY, where the electricity rates are high compared to most of the country. This relatively high avoided cost supports the premise that solar is economical because more money is saved when the alternative is more expensive. Also, it is assumed that the load is operating seven days a week, during peak hours. This is also important because the panels are an expensive asset and they need to be working as much as possible to increase the capacity throughput. Economics will favor assets that are producing value all or most of the time versus those infrequently working. Also important is the size of the systems. One can expect certain economies of scale that would improve the inverter-based system's performance in large installations.

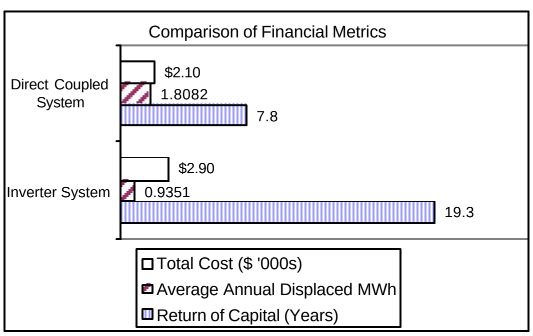

Fig. 6: Financial Metrics To Illustrate Direct-Coupling Advantage.

These calculations do not include the subjective, but real effects of tax benefits such as accelerated depreciation and special treatment that may vary by state. Also, the time value of money isn't considered in the return calculation. The very real benefit of having a cap, or limit, on the price of peak power consumed over the life of the system is also not quantified, but it is real. These embedded realities, like the environmental impact that using solar has, mean different things to different people, and so have been separated from this technical exposition.

TABLE 1: ASSUMPTIONS USED IN 900W PEAK SYSTEM

KEY ASSUMPTIONS	Inverter System	Direct Coupled System
Cost of Solar @ $6.50 installed	$5,850	$5,850
Retail Cost of Interface of 1kw	$1,100	$500
3hrs labor @ $85	$255	$255
System Rebate of $5	-$4,500	-$4,500
Avoided Cost per kWh	$0.15	$0.15
Days per year operating	365	365

4. THE IMPLICATION FOR DEVELOPING ECONOMIES

Many people in developing countries have encountered the rural use of solar, which is invariably a crude form of Direct Coupling, usually involving batteries, a light bulb and a radio. "Crude" because these systems are not tuned to take advantage of what the DC world has to offer: the battery is usually a car-type designed for high-power, not deep cycles; the light-bulb is low wattage, and the radio is necessarily near-by because the 12v DC can't get very far due to excessive losses in the wire. The essence is there, but the elegance is absent. A very small investment can upgrade this arrangement through better engineering.

The power module has three ports for input: DC, AC and storage (also DC). These three commingle to produce one very tightly regulated DC output. Inherent in the power module's design is battery management, which is very much needed to optimize the storage medium's life. Also regulation is very important, because if there is a common AC source available, or generated, it will be subject to great spikes and frequent brownout conditions.

This arrangement can deliver a far higher quality system to the world's communities that need it the most, and the range of loads is not paltry: lights, radios, computers, fans and phones.

5. CONCLUSION

While the cost of Solar PV continues to decline, it remains dependent upon government incentives to be cost effective. In time, as materials get cheaper in volume and systems become more modularized, the cost benefit analysis will become more attractive. By providing a more pre-engineered solution, this multi-source power module will cut the cost of design and installation dramatically. By reducing the number of parts, reliability will also increase. We believe that Direct-coupling will always deliver significantly more energy to predictable loads than traditional methods can, not counting the benefit of a having a port that automatically and seamlessly manages the storage of electricity. Therefore, Direct-coupling is the logical choice of topology for this source of electricity and DC loads that can be married to it.

ACKNOWLEDGEMENTS

Bill Wilhelm, a former Division Head Scientist at the Brookhaven National Laboratory, and EVP of Nextek Power Systems, Inc. is the inventor of this system and method. He is a pioneer in the DC domain, and recognized the twin trends of distributed generation and the increasing density of electronic loads in buildings as an important field of research over ten years ago.