BY **RICHARD CADENA**

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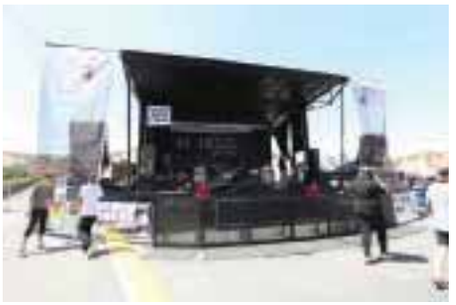

The Helios 250 solar-powered stage at the Warped Tour (produced by Kevin Lyman) on the Insidious Kevin Says stage.

The Helios 250 from Kleege Industries is a portable stage with solar collectors on the roof. Batteries in the forward compartment store the electricity generated by the solar panels for later use.

The Helios 250 solar powered stage in action during Willie Nelson's Country Throwdown in 2011.

Solar power in live event production

THE LIVE EVENT PRODUCTION INDUSTRY is the remora of the technology world. We like to glom on to the sharks of technology, hitching a free ride and feeding off of the leftovers and fragments of their every meal.

When you're not the biggest fish in the ocean and you have limited resources, it's smart to rely on a larger host to help supply your technology meals. We've been living off of the research and developments of the computer industry for years, and now we may be hitching a ride with the auto industry. With the success of the electric vehicle (EV) hinging on breakthroughs in battery technology, the auto industry has the biggest need to improve the technology, and that industry also is most interested in hydrogen fuel cell technology. When auto manufacturers move the technologies along, we'll be right there to snatch up their technological crumbs. There are several entities who are working on improving battery technology, and the live event production industry will likely benefit.

Perfect power pending

Battery technology already plays a significant role in video and film production, powering cameras and lights, and solar powered stages currently enjoy a minor role in live event production. Solar power and battery technology go hand-in-hand because photovoltaic (PV) cells convert energy from the sun to electrical energy, but they can't store it. Therefore, it has to be consumed as it is generated or stored using batteries.

Solar power has several advantages. It's much cleaner than grid power or portable generator power, it's totally silent, and once the hardware is paid for, it generates free electricity. So why, then, is it not used more often in live event production?

Kevin Lyman, producer of the Warped Tour, is one of a handful of festival producers who currently uses solar energy to power a stage on tour.

"I think [solar] technology is getting better," he said in a telephone interview. "The second generation of stages definitely are [better]. We are able to run a full day of sound on them, whereas before we would always have to run a backup generator. We would have some problems, and we would have to go to backup power at certain times. But the latest generation, especially the one that Kleege built for us, is fantastic."

The stage Lyman is referring to is a product of Kleege Industries, the San Diego, CA-based staging company who has been offering solar powered stages for several years. The stage was built in collaboration with Mark McLarry of Alternative Power Productions, who provided the expertise in the use of solar power. The model used for the Warped tour is a 32' x 24' (9.75 meters x 7.3 meters) solar hybrid called the Helios 250. It has a 4.8 kW solar array, which harvests sunlight and stores the energy in a bank of lead-acid batteries with a total capacity of 2,800 amp-hours. When they are fully charged, they can supply up to 120 A at 120 V for almost a full day or for a few days in a row for partial days. But the package isn't perfect.

"We still carry a backup just in case," Lyman added. "You can't have a problem where you can't run the stage."

The potential "problem" with 100% solar is that you can't always rely on a bright, sunny day to get the full power from the solar panels and recharge the batteries. In a perfect world, the sun shines all day, every day, year-round, the air temperature is cool, and the sunlight falls at just the correct angle to maximize solar panel output. But in the real world, there are days when the skies are overcast, and the

power generated by photovoltaic cells drops significantly. Solar cells can provide some energy on overcast days due to the ultraviolet radiation that is not affected by cloud cover, but production can range from around 50% to as low as 5% in some cases.

For that reason, the Warped Tour mobile stage travels with a 10 kVA biodiesel generator equipped with an automatic transfer switch so that the show can go on, uninterrupted, rain or shine, day or night. However, Nevin Kleege, CEO of Kleege Industries, says that the solar power system on the Helios 250 works very well.

"The Warped Tour plays in pissing down rain, and we've never even come close to not having enough power to run a show," Kleege said.

The backup generator just provides the peace of mind for the show organizers.

Another limitation of solar power is the amount of energy a system can generate and store and thus the size of the stage it can supply. Today, the efficiency of solar panels is around 15% (although some manufacturers claim efficiency of as high as 21.5%), which means that if there is 1,000 W/sq-m of sunshine, which is the standard test condition for solar panels, then you should be able to get around 150 W/sq-m of electrical power. That's fine for a small to medium-sized stage like the Helios 250, which is about a 71-sq-m stage. If its roof was completely covered with solar panels, it would yield almost 11 kW. For a larger stage with audio and lighting, that's anemic. A 60' x 40' (223-sq-m) stage with a roof that is completely covered in solar panels, for example, would yield about 33.5 kW, which would supply a total of about 150 A.

Typically, a solar powered stage has a bank of batteries to store large amounts of energy when the stage is not in use and to prepare for any conditions when it is in use. The economics work for a small or medium-sized stage, especially when low power-consuming LEDs are used for the lighting, but larger stages would require a massive amount of batteries with a hefty price tag. For a show that lasts three hours, plus another hour or so for set up, sound check, and standby (probably a very conservative estimate!), a larger stage with a 1,200 A supply (equivalent to 400 A three-phase, which is typically found in venues) would require a total of 4,800 A-hours or 576 kW-hours of battery capacity, which is roughly the equivalent of 10 or 11 Tesla model S 53 kW-h batteries. At the current prices, that's roughly $100,000 for lead-acid batteries (at $0.17 per kW-h), they would weigh a total of about 31,000 lb (14,000 kg) and take up about 200 cu ft (5,760 L).

The same battery power in lithium-ion technology would cost about $271,000 (at $0.47 per kW-h), and they would weigh 9,900 lb (4,500 kg) with a total volume of 88 cu ft (2,500 L). To put those volumes in perspective, a 53' tractor trailer typically has a volume of about 4,000 cu ft and a 17' box truck has about 865 cu ft of volume.

Even if the power requirements for the

big stage were more modest, say 100 A for lighting, 50 A for audio, and 100 A for video, that would still require about $21,000 worth of lead-acid batteries or about $56,000 worth of lithium-ion batteries, and it's unlikely that any staging company will invest that much in a solar powered stage. As Kleege says, "to make it work, you have to have the right sized lighting and PA."

If solar power is going to make it to the big stage, then it's going to need a big boost from better battery technology. That's exactly what the auto industry has in mind.

Building better batteries

Conventional wisdom says that when you want to store large amounts of electrical energy, use lead-acid batteries because the alternatives are expensive, although the equation is rapidly changing. Lead-acid battery technology is 150-years old and has advanced little in terms of the energy storage-to-weight ratio and cost. Currently, the best battery technology is lithium-based. Lithium-ion batteries have about three times the energy storage-to-weight ratio and about twice the energy density compared to lead-acid batteries, which is why they're used in electric vehicles, but they also cost roughly three times as much.

Even using lithium-ion batteries, the maximum range of the typical EV on a single charge is about 100 miles or about 200 miles in the more expensive Tesla sedan. The EV industry is targeting much longer range, and, as a result, the need for better lithium-ion battery is driving intense research on behalf of the EV industry.

If IBM researchers have their way, then better batteries are on the way. According to their website, "The world is poised to enter a new era of energy" because of "high density energy storage technologies." In 2009, IBM launched the Battery 500 project to develop lithium battery technology with ten times the energy density of current lithium-ion battery technology. They claim to have demonstrated the chemistry for what is called "lithium-air" battery technology. The project was born out of the Almaden Institute, a think tank made up of academics, government, industry, researchers, and the media.

Another such think tank is the Joint Center for Energy Storage Research (JCESR at www.jcesr.org), a consortium of government, academic, and industry researchers whose mission is to reach five times the energy density at one-fifth the cost within five years—the so-called 5-5-5 goal. They have been working on a solution since they were funded in December 2012.

According to the JCER Director George Crabtree, lithium-ion has been improving in energy density at a rate of about 5% per year, and it has been getting cheaper by about 8% per year. If they are going to meet their goal, he says, that's not enough. So they're working on a more disruptive technology, and although they're only in the early stages of their research, they

have already found that lithium-sulphur, for example, works better than lithium-ion. They are also experimenting with magnesium, aluminum, and other battery chemistries. They have developed model systems, although "not at commercial scale."

When an interviewer asked Crabtree whether or not they can realistically reach their goal within the four remaining years, Crabtree flipped the question. "There's no reason that it can't be much *more* than five times as efficient," he said.

"If you take the back of an envelope, which scientists like to do, and a pencil, and you ask yourself, 'What is the best that the battery can ever do?' Everyone agrees that it's a factor of 10. So that's well beyond the factor of five that we're shooting for."

"We're shooting for half of that," Crabtree added. "That is typically what mature energy technologies do; they give you half the theoretical potential. So, although a factor of five is aspirational, it's aggressive, it's a stretch goal, it's well within reason that we can do that."

Money talks

As much as we in the live event production industry would like to see more solar powered stages, it boils down to economics. The reality of the situation is that, at current prices, it costs about twice as much to build a solar power stage as it does to build a non-powered mobile stage, so it's challenging for a staging company to make it work. Kleege points to the fact that few, if any, of his competitors offer solar stages.

"There's a reason that no one else is (building solar powered stages)," Kleege said. "Would I like to see more of them? Yes. If I had not partnered with a solar company, we couldn't have done it because we couldn't afford to do it. It's phenomenal technology. I would love to put more of them out there. I'm not the most clever person in the world, but there's unquestionably a business reason why (there aren't more solar powered stages)."

"If I get $500 a show and it cost me $100 grand, and then I have to put maintenance on top of that—the batteries are going to have to be replaced after X years—before it pays back, I've already thrown new batteries into it. It's not there *yet*," he says with an emphasis on the word "yet."

In that three-letter word is the key to the future of powering the live event production industry, not only for festivals and outdoor shows but for venues and transportation alike. The cost of solar panels and batteries is coming down, and the price of diesel fuel is going up.

According to a study conducted by SEIA/GTM Research called "US Solar Market Insight," the average installed price in the US for residential solar systems dropped 16.4% from the third quarter of 2012 to the third quarter of 2013 reaching an all-time low of about $3 per watt. As would be expected, the result is that the number of solar installations is growing.

At the same time, the cost of diesel has risen significantly over the last several years. From 1997 to 2013, diesel rose from £0.62

per liter to £1.39 in the UK and from $1.29 per gallon to $3.88 in the US. Not only are prices generally rising, but they're also very volatile, making it challenging to predict long-term costs of a touring show.

The inflection point

The biggest impact of the dropping price of solar power will be in areas where the cost of fuel is highest. As of December 2013, the cost of diesel fuel in the UK is about £1.39 per liter (about $8.60 per gallon) versus about $3.88 per gallon (about £0.63 per liter) in the US. So, the incentive for using solar power is much higher in the UK and in Europe in general than in the US.

That may explain why advocates of solar power have organized in the UK. The Green Festival Alliance (http://www.juliesbicycle.com/about-jb/green-festival-alliance) is a group of festival promoters and vendors who have studied solar power under the guidance of Julie's Bicycle. According to their findings, fuel costs are one of the five biggest expenses associated with festivals, and power consumption accounts for up to 70% of the carbon footprint of an event, excluding audience travel and transportation. [These figures are based on a limited number of festivals (11) in the UK. To read the full report, visit http://bit.ly/greenstages.]

The higher cost of fuel in Europe probably also explains the presence of FireFly Solar in the UK (www.fireflysolar.net), a supplier of a full range of portable solar powered and hybrid generators. Their products range from 3.5 kVA up to 45 kVA, and they have supplied bespoke (or "custom," as we say in North America) containerized hybrid power systems of up to 100 kVA.

As the cost of solar panels and large energy storage comes down, and the price of fuel goes up, at some point they will intersect and solar power will reach an inflection point where the demand will skyrocket. That time is drawing nearer. But even though economics is an important factor, it's not the only factor. As Kleege points out, there is also a faction who values altruism over economics.

"It works very well for Kevin (Lyman). It's worth it to him to say, 'I've got this solar powered thing here,'" Kleege added.

"It's a conscientious decision by people," Lyman concluded. "A lot of people are using it when it's available. When there's an option, I think that people would be willing to pay a little bit more to do it."

At some point within the next few years, people won't have to pay more for solar and will probably be able to pay less. ■

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