Production power on a budget: How to generate clean reliable power, Part 4

BY **GUY HOLT**

IN THE PRECEDING PARTS OF THIS SERIES, we discovered the new math of low line noise. We found that the substantial reduction in line noise that results from using power-factor corrected HMIs, Kinos, and LEDs on the nearly pure power waveform of an inverter generator creates a new math when it comes to calculating the load you can put on a small portable gas generator. In the past, we had to de-rate portable AVR generators of less than 10 kVA because of their inherent shortcomings when dealing with non-PFC power supplies. The harmonic distortion created by the non-sinusoidal current drawn by non-PFC power supplies reacting poorly with the high impedance of conventional generators limited the number of non-linear loads you could power on a portable generator to 60% of the rated capacity (4200 W on a 6500 VA generator). Now, since inverter generators have virtually no inherent harmonic distortion or sub-transient impedance and light manufacturers are making power-factor correction available in smaller HMI, Kino, and some LED ballasts, this conventional wisdom regarding portable gas generators no longer holds true. According to the new math of low line noise, you can load an inverter generator with power-factor corrected loads to 100% capacity.

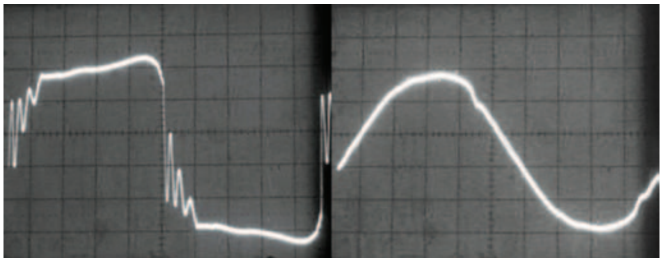

Figure 1 – (Left) Power waveform distorted by non-PFC 1200 W HMI ballasts on conventional generator. (Right) Near perfect power waveform of the same lights with PFC ballasts on inverter generator.

Now that low line noise enables the operation of more lights on portable generators, there are three remaining impediments to their use in motion picture production. Their limited power distribution panel, un-reliable ground-fault protection, and the mechanical noise they make. Let's first look at how the power distribution panel on the North American models of the Honda EU6500i and EU7000i generators (generators popular in motion picture production lighting) does not give the user full access to the generator's potential power. With that understanding, we will engineer a means of providing power in a single 120 V circuit to power larger lights (e.g., 5 kW tungsten or 4 kW HMIs), or more numerous small lights, than could be powered on these generators otherwise. Finally, we will explore how to provide reliable ground-fault protection with the Honda EU6500i and EU7000i generators.

To understand how it is possible to get 7500 VA from generators that are set up by the manufacturer to provide no more than 6500 VA, you must first understand that Honda has engineered a single base model of the EU6500i/EU7000i for the world market which they customize for the different national markets. The difference between the various national models of the Honda EU6500i/EU7000i is primarily in the power output panel, which is configured according to the electrical system and electrical codes of the country in which the generator will be sold. For the US market, Honda distributes the generator with a 120 V power output panel that does not provide access to the full power of the generator, which is in excess of 7500 VA. To see that this is the case, all we have to do is compare the wiring schematic of the UK model (the EU65i) to the North American model (EU6500i.)

With just a glance at the wiring schematics of the US and UK models in **Figures 2** and **3**, you will notice that the back end of the UK model is the same as the North American model. Both machines use inverter modules (IU) to convert 3-phase AC power to DC, and then a microprocessor to switch the DC back to AC according to a pulse width modulation logic (PWM) to create a 120 V circuit (see Part 3 of this series in the Summer 2017 issue of *Protocol* for details.) Both generators array two 120 V circuits in series, and 180 degrees out of phase, to generate 240 V power, while the North American model offers the option to configure the circuits in parallel to provide more 120 V power.

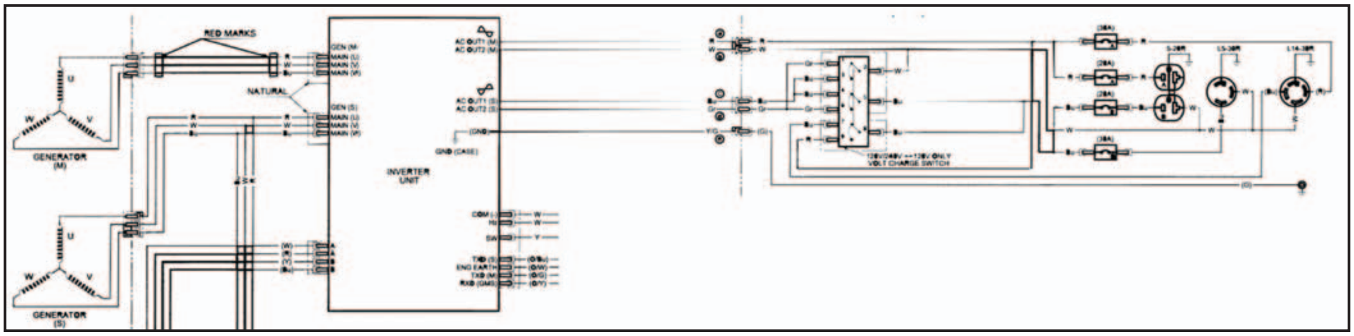

Figure 2 – Wiring Schematic of the North American EU6500i

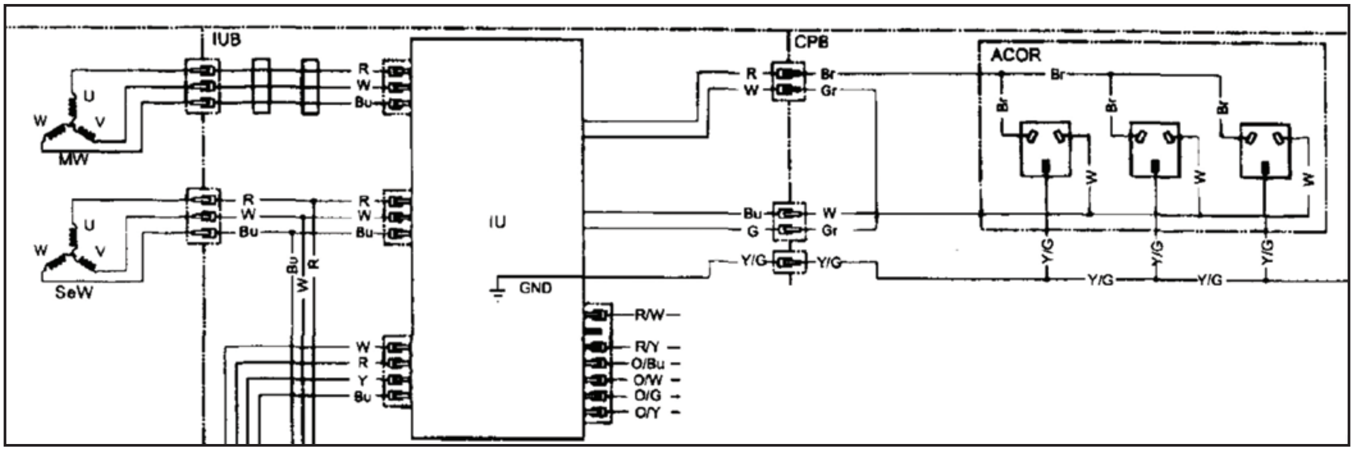

Figure 3 – Wiring Schematic of the United Kingdom EU65i

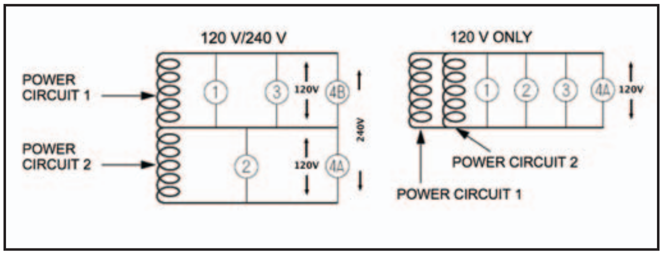

Figure 4 – Series configuration (left) and Parallel configuration (right) of the 120 V circuits generated by the Honda EU6500/EU7000 generators

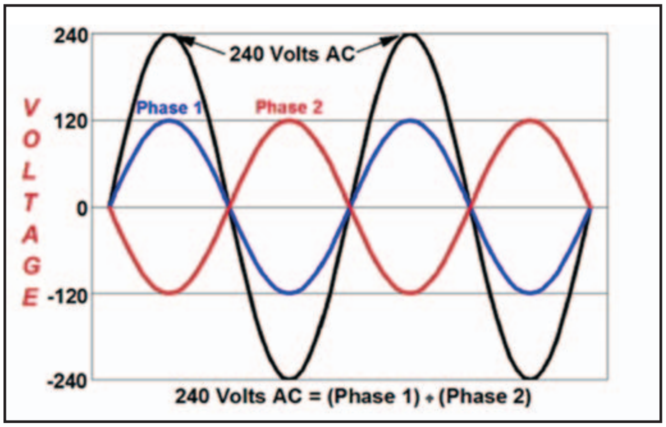

Figure 5 – The voltage of opposing legs of a single phase circuit add while the current carried on the legs subtract.

An inspired design, the one base model enables Honda to optimize the generator's power output for the national markets in which the generators will be sold. For countries that use 230 V/240 V power, they wire the circuits in series. For North American countries, which operate on 120 V, they wire them in parallel. That voltage is additive in a series configuration (see **Figure 5**), while current carrying capacity is additive in a parallel configuration, enables Honda to optimize the generator's output. For example, when the 120 V circuits are arrayed in series, and 180 degrees out of phase (as illustrated in **Figure 4**), the generator generates true single-phase 240 V power and provides access to the full output of the inverter module. The downside to this configuration (standard for the UK model, optional for the North American model) is that it limits the amount of power that can be drawn at 120 V.

For 120 V markets like the US and Canada, Honda provides more 120 V power by arraying the 120 V circuits in parallel. To synchronize the voltage output and phase angle of the two 120 V circuits, the generator's microprocessor sets up a master/slave relationship between the circuits. The voltage and phase angle of the slave 120 V circuit conforms to that of the master 120 V circuit by adjusting the pulse width modulation logic creating its voltage waveform. Once the voltage output and phase angle of the two 120 V circuits are synchronized in this fashion, a single circuit is created that is capable of supporting twice the amount of 120 V load (in a similar fashion two EU6500i/EU7000i generators can be paralleled). However, Honda limits our access to 50 A by distributing it through circuits with 20 A and 30 A breakers. The end result is that more power is available through the 240 V series configuration. A close examination of the front-end of the UK model, the EU65i, makes this clear.

The 240 V UK model, the EU65i, is a better indicator of the true generating capacity that Honda has engineered into the base model of the EU6500i/EU7000i generators. Where the North American EU6500i generator has 20 A/ and 30 A/120 V circuits with over-current protection, the EU65i has 16 A/240 V circuits without over-current protection. According to UK electrical codes, that can only be the case if Honda has engineered an electronic circuit breaker into the generator's microprocessor so that current is shut off to the 240 V receptacles when the generator becomes overloaded. Sure enough, the manual for the UK model states that it has an electronic circuit breaker rated for a continuous load of 7650 VA, which is the equivalent of two 16 A/240 V circuits (16 A x 240 V = 3840 VA/ circuit x 2 = 7650 VA).

Tapping the North American models in a similar fashion, I found that the EU6500i and EU7000i generators have the same electronic circuit breaker and same generating capacity as the UK version: 7650 VA. This is significant because it means that, with a slight modification, a small single-phase step-down transformer, powered by the 4-pin 240 V Twist-Lock receptacle on the generator, can provide more power in a single large 120 V circuit. For instance, a 7.5 kVA transformer/distro will step-down the 7650 VA at 240 V to a single 60 A/120 V circuit that is capable of powering larger lights, or more small lights, than could be operated otherwise on the North American models of these generators. How does a transformer do it?

A transformer typically consists of two sets of coils or windings (a basic step-down transformer is shown in **Figure 6**.) Each set of windings is simply an inductor. AC voltage is applied to one of the windings, called the primary. The other winding, called the secondary, is positioned in close proximity to the primary winding, but is physically isolated from it.

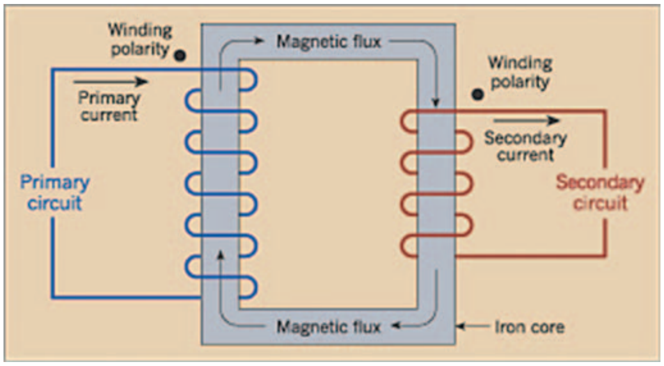

Figure 6 – Windings of a 2:1 step-down transformer

The alternating current that flows through the primary winding establishes a magnetic flux, some of which induces a voltage across the secondary winding. The magnitude of this voltage is proportional to the ratio of the number of turns on the primary winding to the number of turns on the secondary winding. This is known as the "turns-ratio." A 240 V-to-120 V step-down transformer has a turns-ratio of 2-to-1. To maximize the flux linkage between the primary and secondary circuits, the coils of both circuits are wrapped around an iron core, which creates a low-reluctance path for the magnetic flux.

In this fashion, step-down transformers can give us access to more power from the Honda EU6500i and EU7000i generators than is otherwise available to North American users of these generators. If we supply the 240 V output of a modified EU6500i or EU7000i generator to the primary side of a transformer with a 2-to-1 turns-ratio, it creates a 120 V circuit on the secondary, the load side of the transformer. Used in this fashion, a step-down transformer will provide the near full capacity of Honda EU6500i and EU7000i generators (7650 VA), in a single 120 V circuit to power larger lights or more small lights, than could be operated otherwise on these generators.

Another benefit to using a step-down transformer with a Honda EU6500i or EU7000i generator is that it greatly simplifies set electrics. By evenly splitting the load of whatever is plugged into it between the two sides of the generator's output, a transformer automatically balances the load on the generator so that you don't have to. Which means you don't have to be an experienced electric and know what power your individual lights draw to balance your load, as you would with a large diesel generator. The *i*Monitor display on the Honda generators makes it especially easy. Simply plug lights into the transformer. When the load displayed on the *i*Monitor reaches 7650 VA you have balanced the generator to its full power capacity (a blinking LED overload indicator on the *i*Monitor display will tell you when you begin to approach overloading the generator).

A new paradigm for using portable generators in motion picture production has finally taken shape. One that makes it possible to power larger lights or more small lights than has ever been possible before on small portable gas generators. First, when your lighting package includes HMI, fluorescent, or LED lights, it is essential to have PFC circuitry in their power supplies. Second, operate them on an inverter generator. The combination of greater efficiency and nearly pure power waveform drawn by the lights and the low impedance of inverter generators makes it possible to load them to full capacity. Third, use a step-down transformer to load the generator to capacity by accessing the full power of the Honda EU6500i and EU7000i generators.

As we saw in the preceding parts of this series, the primary factors limiting the number of HMI and fluorescent lights (non-linear loads) that could be powered on a portable generator, were their inefficient use of power and the harmonic noise these lights created (the left voltage waveform of **Figure 1**.) Quartz lights (probably the most inefficient means of generating light these days) were, in turn, limited by the constraints imposed by the generator's power distribution panel (there was simply no place to plug in a tungsten or HMI light larger than 2 kW.) However, with the recent incorporation of PFC circuitry in HMI, Kino, and LED power supplies and the introduction of inverter generators, it is now possible to generate clean stable set power (the right voltage waveform of **Figure 1**.) And, now that it is possible, by means of a step-down transformer, to gain access to more power in a single circuit, larger lights (HMIs up to 4 kW or Quartz lights up to 5 kW), or more small lights, can be operated on portable gas generators than has ever been possible before. For example, where the new power factor corrected universal ballast for the Kino 4' 4Bank fixture draws only 2.8 A (compared to the 4.6 A drawn by the old ballast), the 14 A difference between using a PFC 4 kW HMI ballast and non-PFC 4 kW HMI ballast can mean the difference between running eight additional Kino 4' 4Bank fixtures on a portable generator or not. That is an appreciable increase in production capability given the light sensitivity of digital video cameras these days.

Given this new math, when you add up the incremental savings in power to be gained by using only PFC HMI ballasts, add to it energy efficient sources like power factor corrected Kino Flos and LEDs, and combine it with the pure waveform of inverter generators, you have, I would argue, what amounts to a new paradigm in lighting with small portable generators. Where before, you could not operate more than a couple non-PFC 1200 W HMIs on a conventional AVR generator, now you can run a lighting package consisting of a PFC ARRIMAX 4000 W HMI, an ARRI Skypanel 60 LED, four ARRI L7 LED Fresnels, and a couple of PFC Kino 4' 4Banks on a Honda EU7000i generator with the aid of a 60 A full power transformer/distro. Given the extreme light sensitivity of digital video cameras these days, it is possible to get very decent production values with such a lighting package.

Figure 7 – Martin Landau and Paul Sorvino in *The Last Poker Game*

In fact, a milestone of sorts was recently set when the film *The Last Poker Game* was shot using nothing more than a Honda EU6500i. What makes this a milestone is that *The Last Poker Game* is no micro-budget indie. Starring Martin Landau (*Mission Impossible*) and Paul Sorvino (*Goodfellas*), the film was produced by seasoned producers Peter Pastorelli, Marshall Johnson, and Eddie Rubin. Pastorelli's credits include the Netflix film *Beasts of No Nation* (which he produced alongside Johnson) and *The Disappearance Of Eleanor Rigby* (starring James McAvoy and Jessica Chastain). Johnson's other credits include *Blue Valentine* and *The Place Beyond the Pines* with Ryan Gosling; Rubin's credits include *Love and Honor*.

Given the light sensitivity of the ARRI Alexa camera they used, the production was able to get away with nothing more than what could be plugged into wall outlets or powered by one of our modified 7500 W Honda EU6500i generators.

In the next installment of this series we will explore how a transformer can eliminate the two remaining impediments to using

Figure 8 – Covered for rain, a modified Honda EU6500 powers a 4 kW ARRI M40 ARRIMAX fixture through a 60 A transformer/distro.

portable generators in motion picture production and event staging: un-reliable ground fault protection and the mechanical noise the generators make. ■

Guy Holt has served as a gaffer, set electrician, and generator operator on numerous features and television productions. He is recognized for his writing on the use of portable generators in motion picture production (available soon in book form from the APT Press). Guy has developed curriculums on power quality and electrical hazard protection that he has taught through the IATSE Local 481 Electrical Department's "TECs" Program. He is the owner of ScreenLight & Grip, a motion picture lighting rental and sales company that specializes in innovative approaches to set power using Honda portable generators.