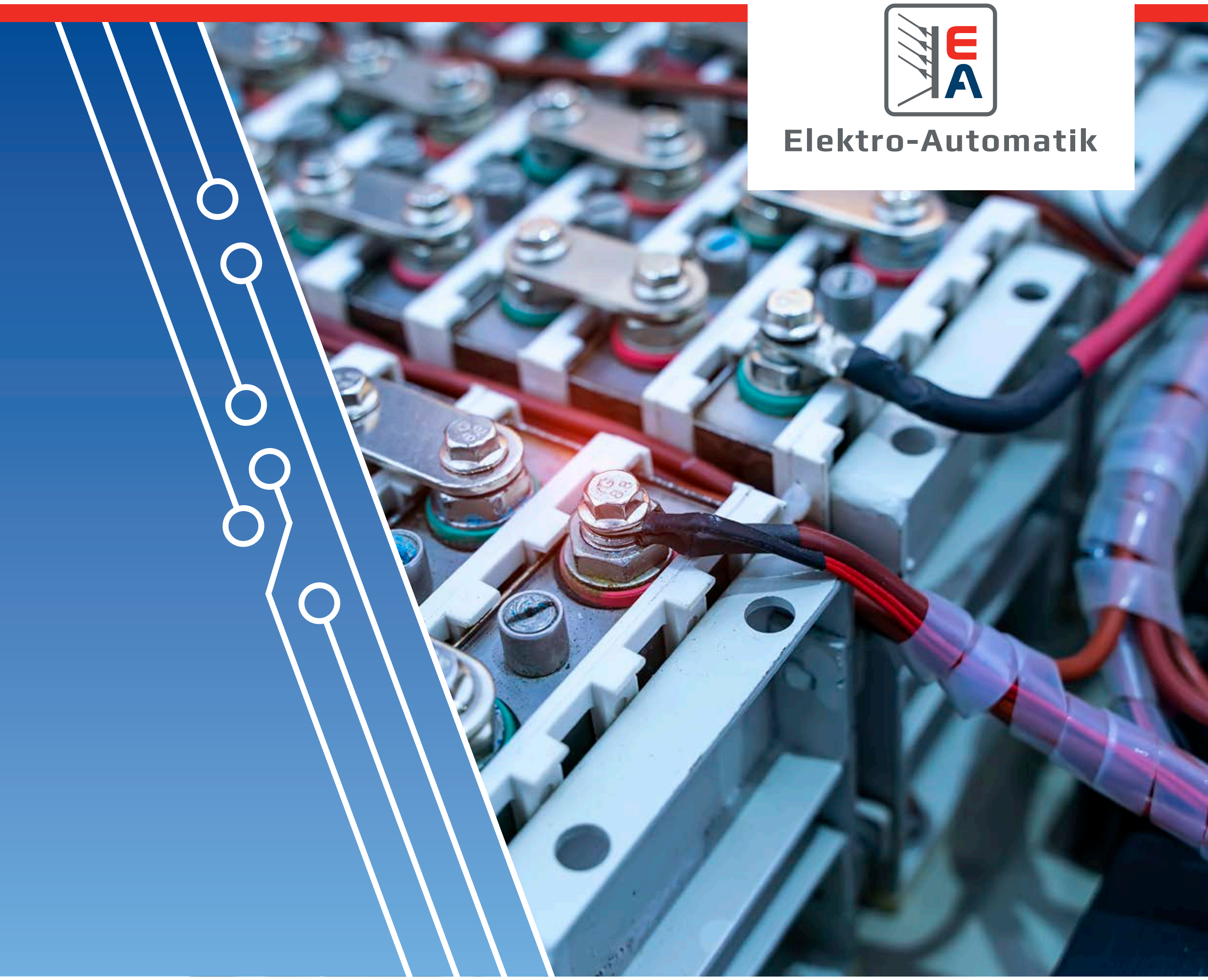


Elektro-Automatik

WHITE PAPER:
REGENERATIVE LOADS: JUST HOW MUCH POWER CAN YOU REALLY SAVE?

Programmable DC power supplies have long been leveraged in power electronics and battery testing. In the array of performance testing and product characterizations that need to be performed, test engineers often run into the issue of where to burn off the excess energy from, for example, burn-in, battery cycling tests, and an energy storage system's (e.g., battery, fuel cell stack, etc.) discharged energy for shipment. Typical solutions generally use either a resistive load bank or an electronic load to release the excess in the form of heat rapidly. Naturally, this comes with thermal management considerations that can make this solution a lot less straightforward than it first appears to be.

However, this process does beg the question, can all this power be recycled and reused within the facility? Just within the United States, federal reforms have been made to accomplish "100 percent carbon pollution-free electricity (CFE) by 2030" [1], from solar tax credits to subsidies for "pollution control," such as grants for recycling industrial products [2]. For quite some time now, there has been a drive for large industrial facilities to "go green" and run more efficiently. Regenerative electronic loads offer an energy-saving alternative to resistive load banks by redirecting the load power back to the utility.

The amount of power a plant can save annually is considerable, and this only increases the larger the plant and the testing operations within the facility. Elektro-Automatik's (EA's) regenerative electronic loads offer 96% efficiency allowing businesses to recycle the vast majority of the power that would have otherwise been dumped. This is the next evolution in DC programmable power supplies—recycling all the energy and returning it to the local power grid. This article aims to discuss the amount of energy savings an industrial facility will see when switching to a regenerative load.

DISSIPATING UNWANTED ENERGY AS HEAT WITH RESISTIVE LOAD BANKS AND ELECTRONIC LOADS

DC load banks simulate electrical loads to test the power source and ensure it meets its specification design criteria or manufacturer's ratings. These loads are meant to accurately portray the behavior of an actual load without connecting to its normal operating load to verify the source and to ensure the source can meet the demands in the field; the excess energy is generally dissipated in the form of heat. Load banks can be resistive, reactive (including inductive and capacitive loads), or capacitive.

The most common, the resistive load bank, mimics the load by converting electrical energy into heat via power resistors. During testing, adjustment, calibration, or verification procedures, a load bank is connected to the output of a power source, such as a generator, battery, amplifier, or photovoltaic (PV) system, in place of its usual load. The load bank presents the source with electrical characteristics like its standard operating load while dissipating the power output normally consumed by it. The power is converted to heat by a heavy-duty resistor or bank of resistive heating elements in the device. The device usually also includes instruments for metering, load control, and overload protection. They must replicate, prove, and verify the real-life demands on critical power systems. Load banks are also used during the operation of intermittent renewable power sources such as windmills to shed excess power that the electric power grid cannot absorb. Load banks offer an initial inexpensive solution if noise, workspace, and efficiency are not factors for your application.

More recently, programmable electronic load banks that use active circuitry to dynamically simulate changing load profiles such as constant voltage (CV), constant current (CC), constant power (CP), and constant resistance (CR). An electronic load is an instrument that sinks power, using transistors to simulate ohmic resistance. This is an advantage to a load bank; an electronic load can perform a long-term burn in and step changes in power and other characteristics that enhance testing quality. This yields even better results when testing DC voltage and current sources, such as batteries, power supplies, capacitors, or turbines. This addresses the limitations of a fixed value (a.k.a. passive) load bank that may not be sufficient to meet complex testing requirements.

FEEL THE BURN: APPLICATIONS THAT ARE PARTICULARLY WASTEFUL

Regardless of the load's programmability, it must still dissipate excess energy in the form of heat. This is not always a straightforward task. It must be accomplished with convective cooling using either forced air (i.e., fans) or liquid (i.e., immersed in a water tank). The most common dissipative load is typically the resistive load bank, where a series of convection-cooled power resistors burn energy in the form of heat, wasting 100% of the energy. A resistive load bank similar to the one shown in Figure 1 will have the downside of being loud, adding significant ambient noise to the factory environment. Moreover, any active cooling system comes with an added energy burden—it is not free to turn up the air conditioning, run fans, or keep a cooling tank.

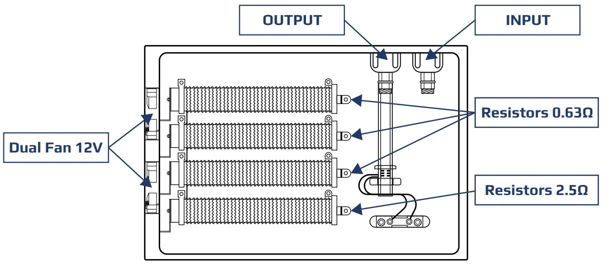


Figure 1. Image of a resistive load bank with DC fans.

There are quite a few tests that will sink massive amounts of power. The industrial testing of batteries and fuel cells requires the cell to be discharged prior to shipment to ensure these components can be safely integrated into a stack or larger system. This burning of potentially useable energy is not limited to the discharging of energy storage devices, burn-in testing of many devices under test (DUTs) (e.g., DC power supplies, motors, inverters, micro-inverters, batteries, fuel cells, etc.) requires fan-cooled resistive load banks to run many-day-long continuous burn-in cycles and ensure the operating lifetimes of the UUT (e.g., 5,000 hours for automotive, 10,000 hours for backup power systems). These burn-in cycles are done by testing products/components under normal, accelerated, or even extreme environmental conditions before performance testing.

These labs are quite costly, and many facilities run testing round-the-clock. Figure 2 is a basic example of a typical lab setup for performing battery validation. From a test and measurement perspective, taking advantage of every last amp-hour the battery offers over its entire lifetime is important. This requires the DUT, the environmental chamber to perform stress tests and thermal analysis, the automated test equipment (ATE) (e.g., programmable power supply, electronic load, and measurement rack), and all its test software/analytics.

Figure 2. Typical lab setup for battery validation.

USING REGENERATIVE LOADS TO POWER A GREENER FACTORY

During testing, technologies such as batteries, traction controllers, bidirectional EV chargers, and fuel cells require both a source and a sink. A battery, for instance, must be charged and discharged to test the bidirectional energy transfer to and from the EV battery for regenerative braking. Typically, these tests are performed with two assets: the programmable DC supply and either an electronic load or a passive load (resistive banks). Instead, regenerative electronic loads can convert discharge power (P = V*I) into usable electricity for the facility (Figure 3).

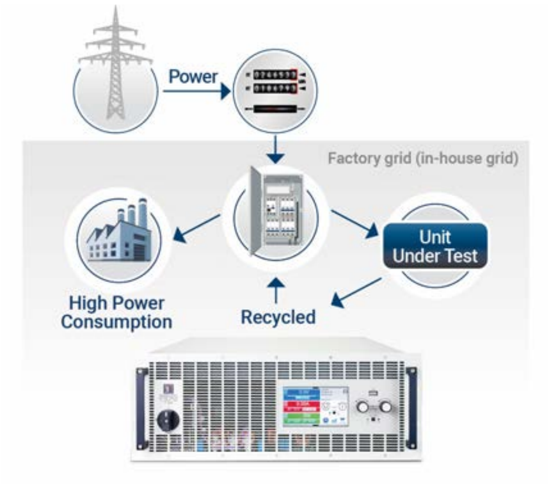


Figure 3. Energy flow with the regenerative power supply.

This is cost-effective in two different ways:

1. **The total power demand and associated electrical costs are reduced.**
2. **Regeneration keeps the devices significantly cooler, which in turn reduces the energy and equipment required for facility cooling.**

This allows maximum flexibility when planning, upgrading, or rearranging laboratory or manufacturing workspaces.

THE BENEFITS OF EA'S BIDIRECTIONAL POWER SUPPLIES

EA's bidirectional power supplies (PUB) combine both regenerative electronic loads and programmable power supplies in one asset, so instead of burning the power, a regenerative load is implemented to feed the wasted energy back into the local grid. Energy is sent through the DC-DC converter into the DC-AC inverter (current source) that, in turn, synchronizes with the distribution grid to recycle power (Figure 4).

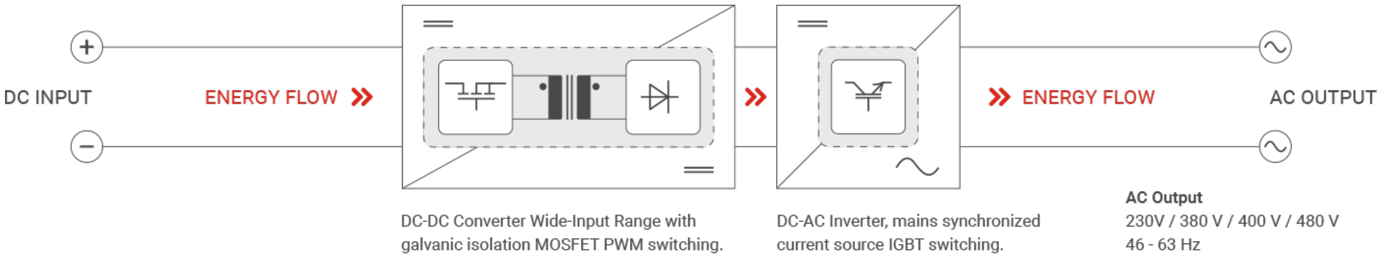


Figure 4. The programmable DC power supply is directly connected to the grid-tied inverter stage.

The PUB series offers 60 kW in a power-dense 6U package. Different models within the EA PUB series offer varying current and voltage ranges (see Figure 5). With wide-ranging inputs, these devices can be used anywhere in the world. Since these products are commercial-off-the-shelf (COTS), it is relatively easy to get the required customer support, and these devices are proven without the need for complex customizations to meet customer needs. EA offers easily accessible localized support—a quality that cannot be said for many existing power supply manufacturers. This support extends beyond North America to include Europe, China, and the Asia Pacific.

Power Unit	**EA-PU 10000 6U**
Power Unit	**EA-PUB 10000 6U**
Power Unit	**EA-PUL 10000 6U**

Model	Voltage	Current	Power
10360-480	0 – 360 V	0 – 480 A	0 – 60000 W
10500-360	0 – 500 V	0 – 360 A	0 – 60000 W
10750-240	0 – 750 V	0 – 240 A	0 – 60000 W
10920-250	0 – 920 V	0 – 250 A	0 – 60000 W
11000-160	0 – 1000 V	0 – 160 A	0 – 60000 W
11500-120	0 – 1500 V	0 – 120 A	0 – 60000 W
12000-80	0 – 2000 V	0 – 80 A	0 – 60000 W

Figure 5. EA's PUB bidirectional power supplies integrate regenerative capabilities.

Outside of the regenerative load feature, these power supplies incorporate a true autoranging capability, which allows these solutions to mimic and load a wide range of voltages and currents from a single solution. A built-in arbitrary waveform function generator, which significantly simplifies test setups (e.g., easily modulating DC load frequencies for AC perturbation measurements on fuel cells). This lowers barriers for a range of dynamic testing applications allowing for a quicker time-to-test. Anybus communication ensures that the power supplies can easily swap between common digital industrial interfaces, including RS232, Profibus, CAN/CANOpen, DeviceNet, Modbus, Ethernet, Profinet, and EtherCAT. Modules are easily installed via an interface card slot on the power supply, making it easy to switch between popular industrial communication protocols (Figure 6).

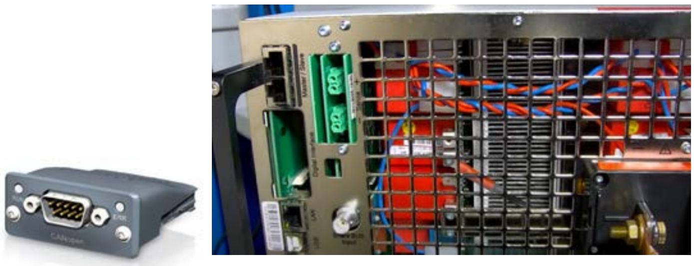


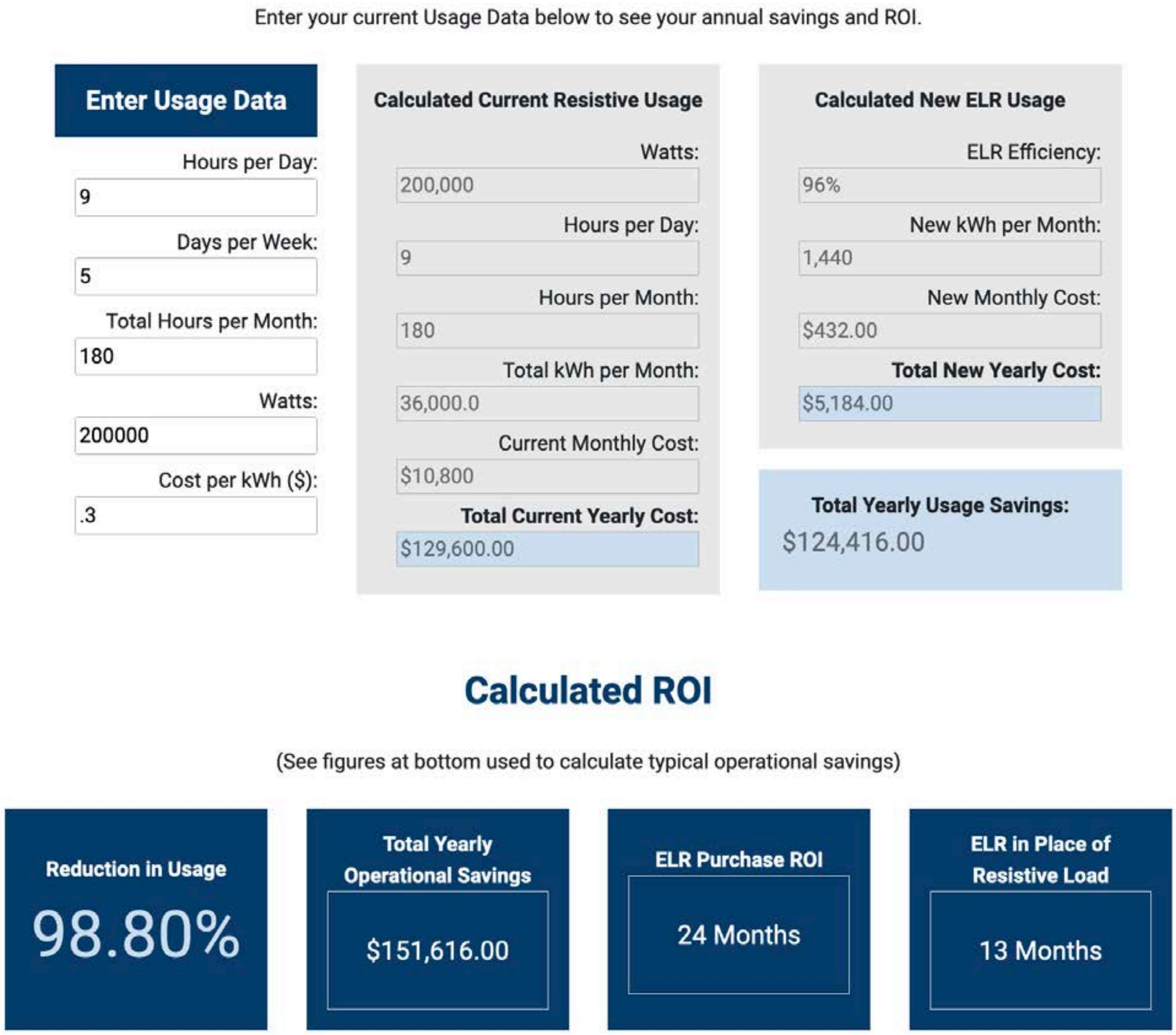
Figure 6. Anybus communication interface modules (on the left) are easily installed into an EA power supply's digital interface slot (on the right) and can be swapped based on changing test needs with a simple screwdriver.

These features future-proof this equipment as it can keep up with changing test needs. Automated test setups are complex, and as the testing operations scale up, so does the level of complexity that comes with it. Some of the benefits of implementing the EA's bidirectional power supplies are as follows:

- Lower energy costs and reduced electrical infrastructure
- Smaller/less footprint/ higher device density
- Smaller cooling fans dramatically reduced audible noise
- Lower environmental cooling costs
- Internal components do not get as hot, allowing the power supply to last longer

THE REGENERATIVE ROI

This feature comes with a considerable return on investment (ROI). Figure 7 illustrates the potential power savings with industrial testing facilities sinking 20 kW of power with tests such as the ones described above using a 40-hour work week and the average rate of $0.3 dollar per kilowatt hour (kWh) in the United States.



Enter your current Usage Data below to see your annual savings and ROI.

Enter Usage Data

Hours per Day: 9
Days per Week: 5
Total Hours per Month: 180
Watts: 200000
Cost per kWh ($): .3

Calculated Current Resistive Usage

Watts: 200,000
Hours per Day: 9
Hours per Month: 180
Total kWh per Month: 36,000.0
Current Monthly Cost: $10,800
Total Current Yearly Cost: $129,600.00

Calculated New ELR Usage

ELR Efficiency: 96%
New kWh per Month: 1,440
New Monthly Cost: $432.00
Total New Yearly Cost: $5,184.00

Total Yearly Usage Savings:
$124,416.00

Calculated ROI

(See figures at bottom used to calculate typical operational savings)

Reduction in Usage
98.80%

Total Yearly Operational Savings
$151,616.00

ELR Purchase ROI
24 Months

ELR in Place of Resistive Load
13 Months

Figure 7. The annual ROI for an EA bidirectional power supply for a 20 kW load with a 40-hour work week.

As shown at the bottom of Figure 4, the cost of EA's ELR bidirectional power supply, for instance, is offset within two years, this figure is reduced to 13 months if the ELR is used in place of a resistive load. All of the upfront capital invested in the ELR directly contributes to a decrease in operational expenditures (OPEX) in terms of energy used (e.g., recycled power, HVAC load reduction, etc.) for years to come. The additional benefits are freeing up factory floor space and allowing for a healthier, less noisy work environment.

It is important to note that this number of 20 kW of power that would otherwise be sunk into an electronic load is, in some cases, quite a conservative estimate. A customizable calculation can be made with the EA's ROI calculator; the only parameters that need to be entered are the usage data for the application itself. The rest will auto-populate.

Many test facilities try to maximize floor space by testing as many devices in parallel as possible. This could mean paralleling hundreds of DUTs for a multi-day long burn-in and accelerated stress tests. This operation can also be scaled up on the facility-level, where multiple labs might reside within one facility to maximize testing and better centralize data on all testing operations for advanced facility management (e.g., analytics, predictive maintenance, etc.). In these cases, the amount of savings intensifies. With traditional loads, burning heat can impact the test itself. Changing the ambient temperature and airflow required will impact the accuracy of the test itself [4]. Redirecting this energy also means that the components within the ELR do not run as hot, allowing the power supply to have a longer field life.

CONCLUSION

Programmable DC power supplies are a cornerstone test equipment for massive applications from EVs to renewable energy systems. The power burden of testing devices within these systems is often seen as a "necessary evil" for most facilities. However, that does not have to be the case. Regenerative electronic loads rethink the conventional approach of sinking all the power used during a test that is no longer in use anymore. Instead, these power supplies can massively reduce the OPEX of testing facilities with a bit of smart planning and infrastructure support.

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At the headquarter in Germany in the industrial centre of North Rhine Westphalia more than 300 qualified associates, in a facility of 21000 m², research, develop and manufacture high-tech equipment for laboratory power supply, high power mains adaptors and electronic loads with or without power feedback. The sales network includes branches in China and USA, sales office in Spain and an extensive partner network.

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