Rethinking Power Generation with a Virtual Power Plant Alternative

For decades, diesel generation has been the traditional back-up power sources for facilities to keep critical processes running during outages. Given increasing emissions restrictions and state and federal regulations shifting requirements for on-site generation, natural gas generation is gaining favor.

To maximize the total cost of ownership, while reducing emissions, improving utility power quality, providing an uninterruptible power supply (UPS) to all connected loads, generating revenue in marketbased programs, all with the cleanest and lowest operating cost turnkey technology available, there are not many options in today's market.

e2Companies patented R3D® Virtual Utility® introduces a bridge technology which utilizes a fast-discharge battery energy storage system (BESS) with a traditional, rich burn Natural Gas generator that alleviates resiliency and reliability concerns with the cleanest and lowest operating cost technology available, monitored 24/7/365 in our Network Operations Center, the Grove (Grid Response Optimization of Virtual Energy).

Table 1 highlights the comparisons of the system, emissions, and cost between the R3Di® System, a Tier 4 Diesel, and a Diesel paired with BatteryUPS.

ADDRESSING VARIOUS POWER CONCERNS

Should a facility experience utility voltage and power issues, or experience constant utility loss, the R3Di® System is the preferred choice to solve a multitude of problems, including:

- Complete loss of utility
- Transient voltage
- Low/high voltage sags/spikes
- Low/high frequency
- 1 & 2-Phase losses
- Harmonics
- Overcurrent from utility

	Company	R3Di®	Diesel and Battery UPS	Tier 4 Diesel
System	No Interruption to Full Site Operations	✓	✗ *limited*	✗
	Instantaneous Reliability & Resiliency without Interconnection	✓	✗	✗
	Conditioned Power	✓	✓	✗
Emissions	Cleanliness			
	Compliance & Indemnification	✓	✗	✗
Costs	Initial Cost	$ $	$ $ $	$ $
	Total Cost of Ownership	$	$ $ $	$ $
Utility	Continuous Sync	✓	✗	✗

Table 1: Solution Comparison Table

Alone, a diesel generator provides power. To enable the solutions for the above concerns, the diesel generator must be paired with a UPS. The R3Di® System provides the benefit of a UPS, already incorporated into the power generation system, in one turnkey solution. Components are summarized in Figure 1.

The patented R3Di® also allows for participation in ISO/utility demand response (where applicable) and can be used to avoid high priced hours in addition to integrating with onsite renewables and electric vehicle (EV) charging stations.

RETHINKING DIESEL GENERATION COUPLED WITH AN UNINTERRUPTIBLE POWER SOURCE (UPS)

By itself, a diesel generator will not provide a "no-blip" experience at a facility when there is a loss of utility power. Traditionally, pairing a diesel generator with a UPS provides instantaneous, un-interruptible power to only the facility's sensitive electronic loads. The purpose of the UPS is to bridge the time between loss of utility and the transfer to the generator. All other loads (HVAC, lighting, etc.) lose power while the generator comes up to rated voltage and frequency and connects to the bus. With the R3Di®, all facility loads, not just the sensitive electronic loads, can be connected to the R3Di®'s instantaneous, uninterruptible power system.

This is possible due to the R3Di®'s High C-rate, fast discharging battery system. Most traditional UPS systems utilize battery systems that are designed for an instantaneous slow discharge maximizing their availability. This limits those batteries' ability to deliver power to loads that require high inrush currents such as pump motors, elevators, and large transformers. Due to the LiFePO4 chemistry and cathode design of the R3Di®'s battery system, the high discharge (or C-rate) capability allows highly inductive loads to connect to the battery instantly without voltage or frequency sags. Traditional UPS composition consists of lead acid batteries, needing replacement after a fiveyear lifecycle due to power constantly flowing through the batteries, which leads to quicker degradation. The R3Di® BESS System is designed to a twentyyear life, with an extended battery life due to the composition of lithium iron phosphate (LiFePO4) and High-C discharging capabilities.

Electricity does not continuously flow through the batteries in the R3Di®, extending their life to twenty years or 10,000 cycles. The generator is paired to pick up load as the batteries begin to deplete, then recharges the batteries once they have dropped to a selectable depth of discharge.

Power Conditioning

Like a traditional UPS system, the R3Di®'s Double Conversion System helps smooth transient loading, providing power conditioning and quality, with a seamless (sub-cycle) transfer of power with no interruption to facility's load. Unlike conventional UPS systems, the R3Di® utilizes bi-directional, full fourquadrant insulated-gate bipolar transistors (IGBT) inverters in both the AC-DC rectification and DC-AC conversion stages.

A stand-alone diesel would not be able to protect a company's sensitive equipment form any transient voltage sags or surges.

> **High-energy voltage transients, sags and swells, frequency deviations and harmonics are all mitigated through the double conversion process.**

Beyond on-site power generation for reliability, the R3Di® System can play the role of grid assurance, by firming renewables without intermittent power loss with its power conditioning abilities.

A Safer Battery System

The R3Di®'s lithium iron phosphate (LiFePO4) battery chemistry is safer than other systems that utilize lithium ion (Li+), VRLA or lead acid. All batteries store and release electrical energy through electrochemical reactions. When a battery purposely discharges electrical energy, ions move from one electrode to the other through a liquid medium called, electrolyte. If during this process the battery undergoes some stress, e.g., an internal short, abnormal heat, etc., the cobalt present in the cathode can release firesustaining oxygen.

This can result in "thermal runaway", which is a heat generating reaction that is greater than the ability of a battery cell to release. In lithium cobalt oxide batteries, thermal runaway can result from the omission of the cobalt with its negative temperature coefficient. The LiFePO4 battery, as found in the R3Di® System does not use cobalt, greatly reducing the risk of fire ignition or propagation. LiFePO4 is thermally and chemically stable, making it less prone to explosions or fires due to misuse or structural damage.

Doube Conversion Inverter System
- Continuous power conditioning
- Uninterruptible power transfer

Lithium Iron Phosphate Battery Plant
- Safer than Lithium Ion
- High energy density

Other Components in Upper Enclosure
- System controls
- Redundant HVAC system
- Fire alarm & fire suppression systems

Rich Burn Natural Gas Generator
- Prime power rated for 8760

Figure 1: Stacked R3Di® System Design

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SYSTEM DETAILS

The R3Di®'s BESS takes up considerably less space than that of a Half-C or 1-C battery system. Where space is restricted, the R3Di® System can be configured in a smaller footprint by moving the UPS outdoors and stacking it above the generator, as shown in Figure 2, meaning no interior building space is required.

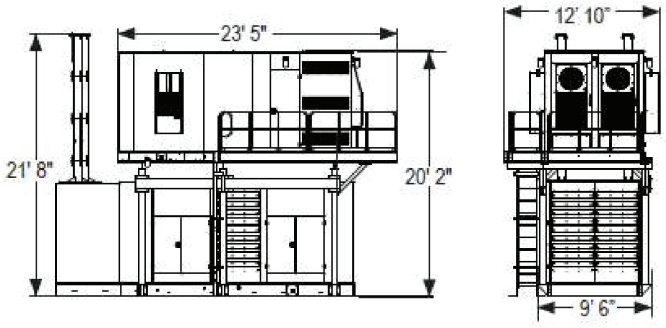

Fig. 2: Side and Front View of the R3Di® System Generator and BESS

The R3Di® System can be paralleled with additional units, in 1MW increments. It is intended to be modular and eliminates, or greatly reduces, balance of plant versus diesel or other systems. Facilities that have experienced a prolonged outage are impacted by the loss of production, stored product, machinery, and sensitive equipment, as well as the manhours to reset processes and restore the facility.

Even so much as a voltage sag/surge can affect equipment. The seamless conditioning the R3Di® provides protects sensitive equipment and sustains operations during longterm outages. A diesel generator can support the facility, but due to the emissions profile of the diesel engine, it cannot run in prime applications.

> **With the R3Di®, your facility can be online 8,760 hours per year without utility, running 24/7, powering you through storms or other long-duration outages.**

Emissions

The R3Di® System operates as an on-site utility and can do so with drastically reduced emissions and lower operating costs as compared to a similar sized emergency backup diesel generator. Emissions[1] reductions as compared to diesel include the following for a 1MW solution[2]:

- 99% reduction in NOx
- 99% reduction in PM
- 88% reduction in CO
- 61% reduction in VOC

This is a prime-rated application with no additional aftertreatment system, such as a catalytic reduction (SCR) needed. Should there be concerns about future and stricter emissions restrictions, today the R3Di® System is Hydrogen ready up to 20% and can run on multiple fuel sources like liquid natural gas (LNG) and renewable natural gas (RNG). The System is designed to be future proofed as alternate sources of power develop, such as fuel cells.

Comparison of Fuel Sources

Diesel fuel has been a standard for back-up systems; however, there are many risks associated with this fuel source, including concerns surrounding fuel storage, storing thousands of gallons of fuel on-site and its condition. Diesel fuel must be polished or replaced after its short shelf life, creating higher operating costs and more frequent maintenance. Diesel generation systems may require onsite fuel storage which can create additional safety and environmental concerns. Although certain industries and the Authority Having Jurisdiction (AHJ) may require specific amounts of on-site fuel, the fuel source's reliability may be impacted by supply constraints in long-duration outages

Conversely, natural gas is available in abundance and delivered underground, directly to the system. During extreme weather events, flooding itself is unlikely to stop the flow of natural gas, especially with upgraded pipelines made of polyethylene, natural gas lines can withstand the pressure of water and flooding.[3]

1. Nitrogen Oxide (NOx); Particulate Matter (PM); Carbon Monoxide (CO); Volatile Organic Compounds (VOC)

2 Power Solutions International. (2020). Steady State Emissions Rates.

3 Gas Technology Institute. Reliability Assessment of Diesel vs. Natural Gas for Standby Generation, 2016.

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Natural gas pipelines are "generally recognized as the safest and most reliable means of transporting..."[4] with a 91% efficiency rating[5].

Typically, generation of one kilowatt (kW) at a facility would cost $0.06 using natural gas generation vs $0.30 using a diesel generator. Fuel costs between pipeline natural gas and diesel vary greatly, as well as the volume of fuel used. For days after Hurricane Ian, which hit Southwest Florida in 2022, fuel was scarce[6]; however, the natural gas lines remained operational. It was close to eight days for power to be restored to all customers, except where infrastructure was destroyed. The R3Di® System kept running, despite catastrophic damage[7] to the power grid with over 2.6 million power outages across Florida.

With piped or tanked fuel supply, the R3Di® System can also be used in a mobile application, providing power to remote or damaged areas.

ON-SITE POWER AND REVENUE GENERATION

If a facility is located in a deregulated energy market, economic and other incentive programs may be available in which to participate. Emergency only diesel is exactly that, for emergencies, only. Without proper permitting and aftertreatment system upgrades, there could be no participation in revenue generating programs. The R3Di® System helps customers realize economic benefit in those deregulated markets, participating in demand response, capacity and transmission management, price avoidance, and more[8].

ENVIRONMENTAL SOCIAL GOVERNANCE (ESG), SOCIETAL RETURN ON INVESTMENT (SROI) & TAX BENEFITS

New initiatives to reduce carbon emissions include tax benefits for those companies that proactively plan to reduce their footprint. SROI considers the present value of project costs, project revenues, and socioeconomic benefits and costs. This financial benefit is used to measure a company's value creation and positive impact for its community.

Reductions in emissions from cradle to grave increase companies' SROI; benefitting the greater good and health of our society. The R3Di® System, as compared to diesel, has significantly higher SROI as calculated by a 3rd party.

> **Total NPV of SROI is approximately a $7MM benefit as compared to a diesel generator.**

New initiatives to reduce carbon emissions include tax benefits for those companies that proactively plan to reduce their footprint. As the United States prepares for electrification, the Inflation Reduction Act (IRA) of 2022 was passed, which includes energy investment tax credits for microgrid controllers constructed before January 1, 2025., for which the R3Di® System may qualify.

	R3Di®	Diesel	Difference
Tons of C02e released during gen. runtime[9]	6,641	19,702	(13,061)
PV of C02e released by gen. runtime[5]	$0.23M	$0.80M	($0.53M)
Total PV of Societal Cost	$0.12M	$0.84M	($0.72M)

Table 2: SROI R3Di® vs. Diesel

ADDITIONAL VALUE WITH ELECTRIC VEHICLE ADOPTION

As electrification of vehicles becomes standard, there will be a need for 1.2 million public chargers[10]. With thousands of gigawatts of demand from those chargers, there will be a need for additional power capacity to support the grid.

4 Van Ness Feldman, LLP. Natural Gas Pipeline Safety and Reliability: An Assessment of Progress. American Gas Association. 2015.

5 Cantrell. Direct Use of Natural Gas Versus Electrification. 2022. SGA

6 Florida Power & Light. FPL restores power to 92% of customers affected by Hurricane Ian. October 5, 2022.

7 Baker, Malik, Chediak. Ian Leaves Florida's Grid in Tatiers. Bloomberg News. September 29, 2022.

8 DISCLAIMER: In applicable markets where such programs are available. Results are not guaranteed.

9 Based on 200 hours run time

10 Kampshoff, Kumar, Peloquin, Sahdec.Building the electric-vehicle charging infrastructure America needs. McKinsey & Company, April 18, 2022. P.1.

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The R3Di® allows for on-site DC Fast Charging (DCFC) for EV cars, trucks, fleets, etc. which is something that diesel generation cannot do.

DCFC provides a quick recharge for EVs but has substantial power requirements as shown in the below table. The R3Di® provides excess generation to power EV chargers directly or support the facility and the EV chargers during power outages or when experiencing power quality issues.

	Power Output	Time for Full Charge[11]
Level I	1kW	40-50 hrs.
Level II	7-19kW	4-10 hrs.
Level III DCFC	50-350kW	20 min-1 hr

Table 3: EV Charging Levels

ALL THE BENEFITS IN A TURNKEY PACKAGE

The R3Di® and the 24/7/365 Network Communications Center, the Grove; together, the Virtual Utility® all make one comprehensive solution brought to you by a vertically integrated firm. The full turnkey system is presented from contracting, to construction, commissioning, and beyond with our services agreements.

The services agreement can include planned and unplanned maintenance, 24/7/365 monitoring in the Grove, and on-going energy management through Palm Energy, unlocking the full capabilities of the Virtual Utility®.

This package means there is no need to hire a general contractor (or sub-contractors); e2Companies handles all engineering, procurement, and construction activities which are included in the purchase cost:

- Insurance and Indemnification
- Engineering
  - Electrical
  - Civil
  - Mechanical
  - Environmental
- Permitting (construction, emissions/environmental)
- Electrical – wiring
- Commissioning

Diesel solutions are typically equipment-only quotes: no engineering, no construction, no electrical work, and no ongoing services are included. A customer would be responsible for hiring a general contractor or procuring all pieces on their own, meaning separate projects become separate costs. For example, a 1MW R3Di® System's total cost to install comparison shows that the R3Di®, unlocking the value of a Virtual Utility® in a turnkey solution is on average30% less than the cost of a traditional diesel + UPS system installed.

11 US Department of Transportation: Charger Types and Speeds. May 4, 2023.

The below graph is an estimate, final costs subject to engineering review and project planning. The graph does not include any market revenue that may be available.

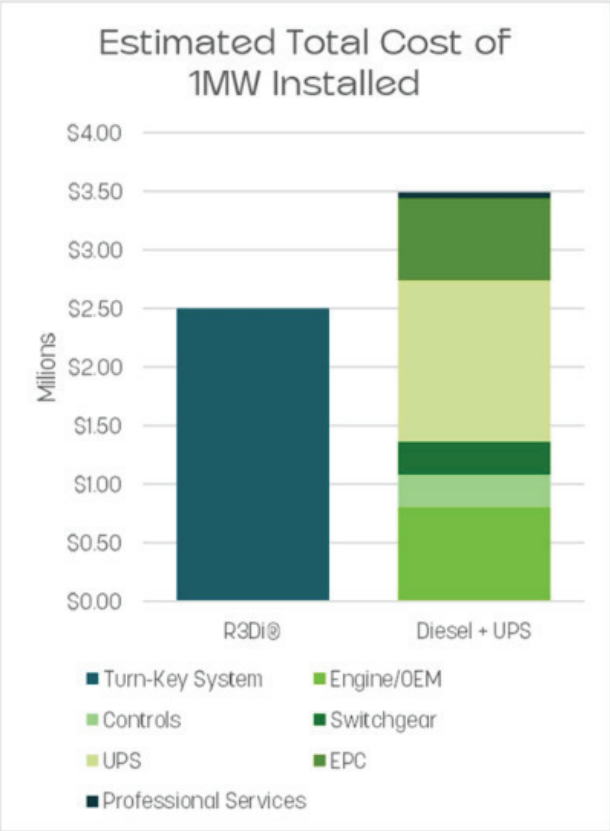

Chart 1: Total Cost of Install

Conclusion

In summary, the R3Di®, with its BESS and Natural Gas generator technology, lowers emissions, and provides continuous, conditioned power from a reliable fuel source and is a reliable transition on the "Path to Zero Emissions".

The R3Di® Virtual Utility® creates an on-site source of power, complete with 24/7/365 monitoring and optimization, delivering more than just back-up power for your business.

For further information, please visit e2companies.com or scan the QR code to schedule a consultation with us.

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