Financial Benefits of Protecting Power Networks with Software-Defined Electricity

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ABSTRACT - Software-Defined Electricity™ is a power electronics technology now available from 3DFS that radically improves the stability, productivity and efficiency of power networks, the backbone of all commercial and industrial operations.

With clean electricity, assets operate as designed reducing errors and improving their individual consistency of work output. The importance of this is clear when motors, batteries, power supplies, and electronic devices all physically reduce their operating temperature when the VectorQ Series power controller is turned on.

Software-Defined Electricity maintains optimal power flow and sustainable surge protection in Real-Time, for the entire power network at all times. This consistently high quality power dramatically improves stability for operations that have spotty or poor quality power and <u>*absolutely minimizes*</u> *the energy consumption through intelligent distribution of power.*

VectorQ Series power controllers leverage the powerful Task Oriented Optimal Computing to analyze electricity with such fine detail that every single device that consumes electricity in a power network can be identified and tracked with complete accuracy all the time.

The ability of precision, non-intrusive load monitoring from the panel opens up new capabilities in asset monitoring and forecasting. Tracking devices over time also reveals their lifetime digital operating signature because every mechanical action has a corresponding electrical signature.

As the VectorQ Series power controller is operating in the power network, it builds models of power consumption for every single connected load. During the normal course of operations, the model updates, resulting in an error free baseline of each load working in its live environment.

This is the most accurate operational baseline possible, and the cornerstone of a completely predictive power network, where every device signals when there is any error in operation.

There are critical benefits unique to Software-Defined Electricity, that can be achieved no other way and multiple layers of cost savings and offsets that immediately impact operations upon installation and will remain.

Payback is most accurately determined when the entire operation is reexamined through the context of clean electricity and its impacts.

I. What is Software-Defined Electricity™?

Software-Defined Electricity™ is a power electronics system installed into any electrical network that actively protects infrastructure and loads, maximizes asset productivity and minimizes energy consumption and carbon footprint at all times by dynamically cleaning and balancing the electricity in Real-Time.

Installation occurs at the panel level with a VectorQ Series power controller, a hardware device that includes 3DFS' proprietary Task Oriented Optimal Computing™ which is a powerful data processing system. Each power controller leverages edge computing, processing up terabytes of data a minute in an active power network during the function of analyzing and correcting the electricity in Real-Time.

Software-Defined Electricity™ is guaranteed to deliver the absolute highest quality power to every asset in an electrical network at all times. Optimal power delivery guarantees the least possible energy consumption and the highest work output, directly reducing costs and increasing revenue potential.

This level of Real-Time power analysis provides the functionality to completely digitally map a power network, identifying every asset by the way it consumes electricity.

Tracking electricity consumption of assets is the most accurate way to diagnose operational and mechanical problems, opening access to a robust new predictive analytics platform which can be customized to any power network, for any device connected.

II. Electrical Losses and Anomalies in Power Networks

Electrical Losses Exist in Power Networks

Modern power networks experience electrical energy losses during the normal course of operation and incremental losses over time. The losses are identifiable with the use of sensors.

Retrofit Energy Savings Devices and industry standard methods are available in the market that partially mitigate the negative impact on power delivery.[1] It is important to recognize that partial mitigation of these losses is not a solution to their existence, rather it is only compensation that temporarily improves energy efficiency.

Power Factor

Power factor is the ratio of the real power that is used to do work and the apparent power that is supplied to the circuit and it is well documented for wasting energy, harming assets and increasing utility penalties.

Having poor power factor also increases capital expenses by requiring oversized infrastructure in anticipation of poor power factor. The chart below shows how these variables affect the infrastructure size [11].

kW	100	100	100	100	100
Power Factor	100%	90%	80%	70%	60%
kVAr	0	48	75	100	133
kVA	100	111	125	142	167
Load amperes	120	133.7	150.5	170	201
Transformer	100 kVA	125 kVA	125 kVA	150 kVA	200 kVA
NEC wire size	1/0	1/0	2/0	2/0	4/0
Wire diameter	0.375	0.375	0.419	0.419	0.528

The present methodology for mitigating power factor, VAR support and related problems is the unintelligent, analog solution of placing capacitor(s) in series with the power network to statically shift the phase between current and voltage.

Capacitors must fully charge and discharge to be effective, their ceiling efficiency as a solution is about 50%. They also wear out relatively quickly and must be replaced every few years to maintain effectiveness and they increase their energy consumption and raise the voltage of circuits with age reducing their economic feasibility.

Harmonics

Harmonics are the result of non-linear power production/consumption which cause a rippling effect in the power network exhibited as distortions in the sinusoidal curves during power delivery.

There are many harmonics, each having different effects on the power network, but in general induce a temperature rise in the power network infrastructure, cabling and loads which significantly shorten their lives. This can add up to 15% on Capital Expenditure and 10% on Operational Expenditure. [9]

The present methodology for mitigating harmonic distortion is the unintelligent, analog solution of placing a transformer(s) or inductor(s) as a shunt to the power network to absorb and inject power.

These systems absorb most of the energy from the harmonic mitigation, significantly impacting their efficiency and often requiring additional forced air cooling to remove the increased BTUs emitted during operation of the device.

Imbalanced Phases

In multiphase environments, the balance of power draw across phases is an important consideration when determining the efficiency and capacity of a power network.

When there is an imbalance across the phases, at the panel level, there is direct energy loss both upstream in the transformer and on the load side. Upstream transformers suffer from eddy currents and demagnetization and the load side suffers from overdraw on phases and dangerous neutral currents.

The present methodologies for balancing load side phases are unintelligent and typically fall into either physically shifting loads across phases or some sort of resistive solution that absorbs power on an overloaded phase.

Physically shifting loads is not always practical or possible and any resistive solution is simple energy waste.

Voltage fluctuation

The inability to maintain a consistently stable voltage is one of the most significant contributors to wasted energy and harm to assets. Voltage sags often occur because of the inrush current required to charge capacitors, start motors and other devices

Overvoltage provides too much power pushing loads and internal circuitry to extreme temperatures and energy absorption, negatively impacting their operation and undervoltage starves the loads pulling them to the opposite extreme preventing the devices from operating fully and frequently shutting down.

The dollar waste is significant, with the average costs of a single voltage sag varying greatly from one sector to another, but always financially punishing: [3]

- Fine chemicals $250,000
- Microprocessors $130,000
- Metal processing $45,000
- Textiles $25,000
- Foodstuffs $25,000

Ground and Neutral Currents

Ground and neutral currents are direct electrical energy losses that create unwanted noise in the power network and waste energy throughout the infrastructure or into the earth through the ground connection.

The neutral line is subjected to overloading of current by as a factor of three when harmonics are present in the power network resulting in a clear increase in heat in cables and conductors. [2]

The present methodology for reducing ground and neutral currents are to add expensive isolation transformers or to oversize the gauge ground and neutral wires to assist in absorbing/carrying more of the loss.

Surges, Transients and Lightning Strikes

Surges and transients entering a power network can be the result of large machinery shifting huge amounts of power, abrupt power outages from falling tree branches, lightning strikes in the secondary distribution, or anything in between.

These sudden jolts of energy are extremely harmful and dangerous to power network infrastructure, loads and the people operating within those environments. Depending on the facility and number of digital devices that are relied on for operation, the vulnerability to surges can have considerable cost potential that can exceed $100,000.[4]

The present methodology for surge protection is the use of in line TVSS technology, which prevents the majority of excess energy from continuing on the circuit by absorbing it and causing permanent damage within the surge protection device.

The protection capacity of these devices is halved with each transient event necessitating their replacement every 1-3 years depending on how active the power network is with transients and surges.

<u>Effects of Losses on Load and Power Network Performance</u>

All machines powered by electricity are mechanically designed to operate in a specific way. The component use and circuit layouts are designed to receive consistent power during operation in exchange for consistent work. Deviation in power supply negatively affects work output.

The electrical losses and power anomalies that exist in live, networks alter the power quality in Real-Time. These instant and perpetual fluctuations in power quality have an associated liability cost as they strain the loads ability to perform optimally.

It is obvious that a sag or surge in power does not simply make a machine work slower or faster, it pushes the circuits powering the machine outside their designed operating limits which has direct, negative and unknowable consequences on the work that the machine performs.

Stable, consistent, high quality power increases the performance and reliability of machines which means the work being performed will be more consistent no matter what the machine is designed to do.

Effects of Losses on Generator Capacity

The generation of electricity, no matter the source is limited by electrical energy losses. When a generator operates, the losses (power factor, harmonics and phase imbalance) are all at their worst, resulting in energy being created and immediately dissipated as heat throughout the generator, turbine shaft, exhaust and engine instead of usable electricity in the power network.

These losses severely limit generator capacity, rendering it unable to endure 100% load, usually restricting the capacity to around 55-65% of the rated load. This loss in capacity is typically baked into business plans by procuring oversized generators which is a direct waste of fuel.

Electrical losses reduce the stability of the power that is produced as well which typically results in much wider fluctuation in voltage than when the power network is receiving grid supplied power, further reducing efficiency and increasing wear and tear.

Mitigating these losses on generation will improve the output of the generator and stability of the power network.

Effects of Losses on UPS and Battery Performance

UPS and battery capacity is limited by the efficiency and losses during dis/charging of the batteries. The balance across the phases of a UPS is also an important consideration for the performance, cost and operating capacity.

When considerable heat is present during dis/charging, it is a sign of direct degradation of the batteries as well as additional stresses on the UPS system that result in less run time, decreased efficiency and more maintenance.

An important point on high end UPS systems like in data centers and hospitals is that maintenance is expensive and almost certainly requires the UPS to be in bypass mode (which means no power protection) while working on them.

Electrical Losses Constantly Wear and Tear Assets

The perpetual fluctuation in electricity, even at the tiniest level has an erosive quality on the machine circuits and components. This is an inescapable fact of machine electricity consumption. The more the power deviates from perfect, the more of an impact it will have on machine circuitry.

All electrical energy distortions affect how the machine receives power, so every load in the power network is always being over and underpowered in Real-Time. This effect wears the internal circuitry of every load, affecting their operation in a variety of negative ways all of which erode performance and efficiency over time.

Other Problems Resulting in Energy Waste

The design, makeup, layout, age and quality of the power network infrastructure and loads will also have an effect on the waste that is created during the normal course of operation.

Power quality problems will always affect load performance, wear and tear and lifespan as well as increase the energy consumption of the network. The common methodology in addressing power quality related problems in power networks is to individually address them with “specific corrective equipment” with each device serving as an additional parasitic load consuming energy in search of energy efficiency. [5]

III. Technology Behind Software-Defined Electricity™

Software-Defined Electricity™ is a power electronics system installed into any electrical network that actively protects infrastructure and loads, maximizes asset productivity and minimizes energy consumption and carbon footprint at all times by dynamically cleaning and balancing the electricity in Real-Time.

It is a model based computing/power electronics system that synchronizes (brings to unity) the electricity in Real-Time. Synchronization of electricity means that at the panel level, the power factor remains at unity for all loads, harmonics are maintained under 2%, phases are perfectly balanced, neutral and ground current are zeroed, voltage is maintained digitally stable and there is always sustainable surge protection.

This quality of electricity is sustained at all times no matter the upstream fluctuation or downstream consumption pattern.

<u>Digital Measurement of Electricity</u>

3DFS Technology leverages Task Oriented Optimal Computing™ to sample and process electricity data in extremely high fidelity. The technology is sampling/deriving 26 parameters using current and voltage samples in 24 bit resolution at MHz sampling rates on each phase, neutral and ground, through a precision, software controlled oversampling methodology.

This proprietary data acquisition process, acquires and distills to a perfect, near error free digital mimic of the analog signal nanoseconds after it is sensed opening up true Real-Time visibility of electricity flow.

VectorQ2 Power Controller OFF

Figure 1: VectorQ2 screenshot of uncorrected electricity measured in Real-Time. Captured from live video demonstration. [6] See full videos at vimeo.com/3dfs

Having this data at this moment in time is the foundational data stream that feeds the model and allows for Real-Time Synchronization.

<u>Real-Time Synchronization of Electricity</u>

Electrical energy losses all have an independent and simultaneous negative effects on the power network. The 3DFS synchronization process uses advanced modeling, fed by the Real-Time digital data stream to analyze all of the losses together and build a Real-Time, accurate and precise understanding of power flow.

Knowing exactly what the true “in the moment” demand of electricity is and that the desired result is synchronized electricity, the function of the technology is to provide the delta, which is provided by the Flash Energy Storage system.

VectorQ2 Power Controller ON

Figure 2: VectorQ2 screenshot of electricity corrected in Real-Time. Captured from live video demonstration. [6] See full videos at vimeo.com/3dfs

<u>Flash Energy Storage</u>
The power electronics portion of Software-Defined Electricity™ is what provides the synchronization in Real-Time.

It is a proprietary transistor based injection/consumption energy storage system made up of a capacitance source and an inductance source. It is able to precisely deliver whichever is required for synchronization every microsecond in response to the Real-Time demand of the power network based on the nanosecond level analysis.

This method of electricity correction adjusts the power in Real-Time to maintain perfectly matched demand for every load, in any situation. This creates a self-healing power network that responds instantly to any electrical event providing flexibility and resiliency to any operation.

<u>Autonomous Power Flow</u>
Electricity demand is simply machines requesting power from other machines. ***If the capacity is available and the power network is designed and wired properly, installing Software-Defined Electricity™ will ensure self-contained optimal power flow at all times, in any situation without the need for data to be transmitted from the power network.***

A reliable power network that does not need to be connected to the data network for control and operation is a more secure and stable power network.

Connected devices within power networks have opened up a vulnerability. Some of these devices can be hacked and their power consumption can be altered to negatively impact a power network, potentially leading to destabilization or worse. Autonomous, self-healing power networks is a natural defense against any form of this power network manipulation through the process of Real-Time synchronization.

This assurance will result in much more consistent operations, better production and budget forecasting, and improve the physical and cybersecurity of the facility power network.

IV. VectorQ Series Power Controllers
<u>VectorQ Series Power Controllers</u>
The VectorQ Series power controllers are the hardware 3DFS products that provide Software-Defined Electricity™. All VectorQ Series power controllers have two major components: Real-Time Sensing/Computing and Power Electronics

Real Time Sensing/Computing
The proprietary computing methodology, Task Oriented Optimal Computing™ operates at the convergence of the analog and digital worlds. It is constantly acquiring and processing data.

Power Electronics
That data is fed through an advanced model and the Flash Energy Storage System performs the synchronization of electricity in Real-Time.

Installation of VectorQ Series Power Controllers

VectorQ Series power controllers have a very small footprint. With the low voltage products, if first mounted next to an electrical panel, they can be fully installed within 20 minutes, in many cases without disrupting power.

The installation is in parallel with the power network, similar to installing an additional load in the panel.

Parallel Installation of VectorQ Series

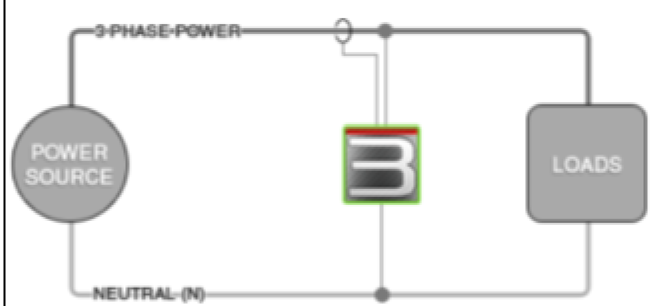

Figure 3: 3DFS Technology is installed in parallel with the power network. It is represented as a dipole in Kirchoff's Law.

The full installation requires the temporary removal of the front panel. Three Flex-coil current transformers (1 for each phase) are installed around the incoming phases. A three block fuse (1 for each phase) is installed into the panel for a voltage connection. If neutral and/or ground wires are available, they are also wired to the power controller. The panel can then be returned and the installation is complete.

Simple Install, Easy Commissioning

Figure 4: The VectorQ2 is installed within 20 minutes and commissioned with the flip of the switch. The only operating cost is the electricity consumption (~$100 per year)

Flip Switch Commissioning of VectorQ

The commissioning of a VectorQ Series power controller only requires the flipping of the fuse at the panel. The device will immediately turn on and begin analyzing the power network.

Once there is an understanding of the electricity flow, it will begin the process of synchronization with the utmost safety and efficiency. No further maintenance or attention is required unless indicated by a red light on the front of the VectorQ2 power controller.

Safety and Security of VectorQ Series

Fault Detection/Event

The VectorQ Series power controller will detect a fault the instant it occurs. The correction process ceases during the fault event but the non-invasive measurement continues at high fidelity and a record of details is created for review after the event.

An alert will be sent and the data and analytics will be stored for review in the user interface.

Failure of VectorQ Series

The VectorQ Series power controller is presently installed in parallel with power networks that are overbuilt to absorb the losses which exist in an uncontrolled power network.

If the VectorQ ceases to work for any reason (internal or external) the power in the network will simply return to its natural, uncorrected, unbalanced flow. There will be no sudden or significant harm to the power network, although all of the inefficiencies and inconveniences that presently exist will eventually return.

Cybersecurity

VectorQ Series power controllers leverage edge computing processes, using and erasing 99% of acquired data on site within microseconds of acquisition. All data transferred is encrypted at the 256 AES industry standard and tunneled through a private Virtual Private Network (VPN) to a cloud hosted web application.

VectorQ Series power controllers are not controllable from the outside of the device. It is designed to automatically synchronize electricity based on the Real-Time data acquisition and nothing else.

Any disruption to the VectorQ Series power controller is instantly flagged and the system will immediately shut off and cease all operation.

<u>Scalability of VectorQ Series</u>

The software that runs VectorQ Series power controllers is universal for electricity synchronization. The hardware must be scaled according to power and voltage requirements.

Presently available off the shelf components are readily available to develop a wide range of 3DFS products and services that scale up to the secondary distribution voltage (26 kV).

Higher than 26kV products are possible but require additional research and development.

<u>VectorQ2 Power Controller</u>

The VectorQ2 Power Controller is a 3DFS product that provides Software-Defined Electricity™ for 208/240V power networks.

Small Physical & Energy Footprint

Figure 5: The VectorQ2 has a small physical footprint and a small energy consumption footprint, with a maximum power consumption of 120W at any point.

See Attachment A for VectorQ2 Technical Specifications

Efficiency of VectorQ2 Power Controller

The maximum amount of power that can be processed by a VectorQ2 is 60kW. Most applications do not ever achieve the maximum coverage, or only temporarily hit the 60kW power draw. The average load factor of a VectorQ2 is about 75%, translating to about 45kW. [7] At this load, annual power processed is 0.34 MWh per year

Hourly power processed **x** *Hours per year = Annual power processed*

45kW/h x 24hr x 365 days = 0.34MW/h per year

The VectorQ2 power controller is 99% efficient at perfectly cleaning 0.34MWh of power for the nominal cost of $109.23 per year.

Cost of Ownership of VectorQ2 Power Controller
There is no operating cost of ownership for a VectorQ2 power controller. The cost is limited to the energy consumption.

While idling, the VectorQ2 consumes about 70W of power, and when fully loaded, about 120W of power consumption.

Assuming full year of absolute maximum power consumed, *the annual power consumption of a VectorQ2 is 1048.32 kWh per year*.

Hourly power consumed **x** *Hours per year* **=** *Annual power consumed*
120W **x** *24hr* **x** *365 days* **=** *1048.32 kW/h per year*

With an average US electricity price of 10.42 cents per kWh, *the annual cost of ownership of a single VectorQ2 power controller is $109.23.* [8]

Annual power consumed **x** *hourly cost of electricity* **=** *Annual cost of operation*
1048.32 kW/h per year **x** *10.42 cents per kWh* **=** *$109.23*

Plug and Play, Zero Maintenance Operation
Once installed and commissioned, there are no maintenance costs or software upgrades required for the power controller. It will work continuously 24/7 until replaced.

Projected Life Expectancy of VectorQ Series
The unique design and operation of the VectorQ2 introduces very little stress to the internal medical grade components and increases their functional lifespan.

Under normal power network conditions, the projected life span of VectorQ Series power controllers is greater than 15 years.

V. Power Quality Rating
Traditional power quality metrics are calculated by considering harmonics and power factor, however there is a third, equally important power quality consideration, balance across phases. An imbalance across phases at the electrical panel level is known to induce neutral currents on the load side and cause eddy currents and demagnetization in the upstream transformer on the utility side. These are all direct losses and should always be considered in electricity flow efficiency calculations.

Power Quality Rating™ ("PQR") is a metric created by 3DFS to show the true efficiency of electrical energy flow in power networks. It is based on an equation that includes harmonics, power factor and balance across phases.

Calculating Power Quality Rating

$$\frac{\left(\frac{\cos\varphi}{\sqrt{1+(THD_V)^2}\times\sqrt{1+(THD_I)^2}}\right)_{L1}+\left(\frac{\cos\varphi}{\sqrt{1+(THD_V)^2}\times\sqrt{1+(THD_I)^2}}\right)_{L2}+\left(\frac{\cos\varphi}{\sqrt{1+(THD_V)^2}\times\sqrt{1+(THD_I)^2}}\right)_{L3}}{3}$$

Figure 6: Power Quality Rating is a metric that reveals the true electrical efficiency of the power network. In other words, how much energy purchased in Joules is used as electrical power vs. how much is wasted as heat or vibration somewhere in the power network.

In joules of energy purchased, a PQR of 100 represents 100% of the joules of energy consumed as electricity for the work intended. A PQR of 33% represents that 33% of the energy was consumed as electricity and the rest was absorbed by the power network and loads as energy other than electricity (i.e. heat, vibrations, etc.)

Whether during generation, transmission, distribution, storage, conversion or consumption of electricity, the PQR reveals how much electrical energy waste is occurring in the moment.

<u>Average Uncorrected Power Quality Rating</u>

A typical power network environment experiences an average Power Quality Rating (PQR) of between 9% and 45% with the median lying at approximately 33%.[7] In unusually poor circumstances, the PQR can hover be lower, <5% and in very static power networks with mainly resistive loads, the PQR will naturally hover much higher at around 99%.

Just like all electrical parameters, it is a live metric that changes and fluctuates as the electricity is consumed in the power network.

<u>Improving Power Quality Rating with Software-Defined Electricity™</u>

In a typical power network environment, the VectorQ Series power controller will maintain the Power Quality Rating at approximately 98%, with the minimum being 72% and the maximum being 99%.

PQR represents between 91-95% of all electrical energy losses. It does not account for losses due to inefficient design of the power network, poor quality materials used within the infrastructure, and other uncontrollable factors. In general, PQR can be used as a definitive metric for efficiency of incoming electrical power usage.

If a power network has an uncorrected PQR of 32% and a corrected PQR of 96%, the difference, 64% is the improvement (2x) in the usage of power in that network.

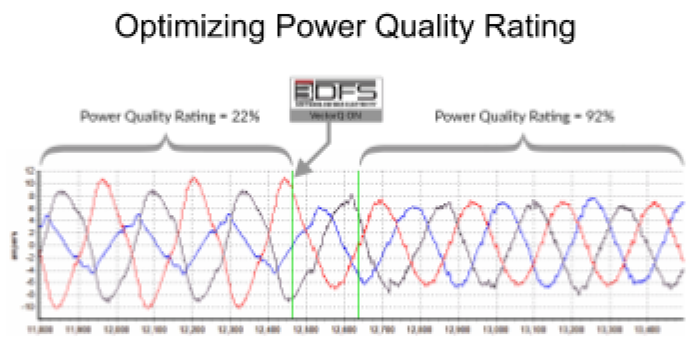

Figure 7: The Power Quality Rating can be corrected in Real-Time, improving the electrical efficiency of the network and increasing the amount of energy consumed as desirable work intended and reducing the waste heat throughout the network.

So if this power network were the same as the above example of 0.34 MWh per year of electrical power consumed, the difference would be stark.

If correction were not activated, there would be 64% losses during the conversion of electrical power to the work being done (i.e. producing light, rotating fans or pumping refrigerant inside HVAC, etc.)

With corrected power in this case, the losses (~4%) are controlled for during the conversion of electrical power to the work being done. The result is desired work being done in the same time with less energy consumed to do it. It is automated maximization of electrical efficiency which has a significant impact on year over year energy consumption.

The total annual energy savings in the above example, based on the observed typical conditions seen in previous installations of Software-Defined Electricity™, will fall within a range of 17-44% with $6,162 being the expected minimum annual cost savings and $15,405 being the maximum.

Annual Energy/Cost Savings w/ a VectorQ2 Unit			
	MW/h	$$	Savings %%
Minimum calculations	0.06	$ 6,162	17.65%
Median calculations	0.10	$ 10,270	29.41%
Maximum calculations	0.15	$ 15,405	44.12%

While electricity universally acts the same, every power network is different meaning that the savings experienced with Software-Defined Electricity™ installed in the power network may be very similar to this example or different.

Powering loads with clean electricity will absolutely reduce electrical energy waste and improve power network stability and load performance. The resulting annual energy and cost savings will be dependent on the power network design, makeup, age and how power is used within it.

VI. Expected Results from Software-Defined Electricity™

Load Performance and Work Output Improvement

Every machine that consumes electricity has been mechanically designed to perform work in a very specific way, however their performance is limited when the quality of electricity provided to them is dirty. The quality and consistency of the power provided to a load determines the quality and consistency of the work it performs.

It is obvious that a surge or sag in the power does not make a device work faster or slower, rather it strains the circuitry by carrying either too much or not enough power in the moment. This is constantly occurring; a never ending back and forth fluctuation of power to every device in the network. As a direct result of this, modern day power networks are unable to achieve maximum work productivity.

When 3DFS Technology is embedded into the power network, every load receives perfect power in the moment, at all times. When every load receives perfect power in the moment, their individual performance increases and becomes more consistent. This naturally leads to an improvement in the coordinated operation of systems and processes by reducing errors and waste while maximizing stability and efficiency.

Some examples of load productivity improvement in power networks that are protected by Software-Defined Electricity™ include:

Example 1: Reduced Data Packet Loss in Transmission

A data center server rack is mechanically designed to store and transmit data over a network upon request. They are not 100% accurate at performing these tasks, and there are errors that occur which corrupt and lose packets.

Packet loss increases the energy consumption and slows the amount of time required to respond to a data request which ultimately results in lower profitability.

With Software-Defined Electricity™ protecting this server rack, all of the IT equipment simultaneously improves in its operation:

- Servers transmit data with less packet loss
- PDU distributes power emitting less heat
- Switches and routers have fewer errors in operation
- UPS charges and discharges faster, deeper and emits less heat

Example 2: Reduction of Power Supply Temperature

Electronics operate on DC power, but our grid delivers AC power to homes and businesses. In order to bridge this divide, power supplies are used as an adapter and convert AC to DC. Each electronic device requires a power supply, so the process of AC/DC conversion never stops. It is a constant.

Losses are unavoidable as evidenced by power supplies operating hot to the touch. These losses add unnecessary energy consumption to the operation and also constantly emit heat into the facility environment, which increases the cost of heat evacuation.

With Software-Defined Electricity™ protecting the power network, all of these power supplies will operate at their designed efficiency. There will be a sustained drop in the operating temperature of the power supplies of approximately ***20 degrees Fahrenheit***. This exhibits the relief experienced by the power supply which is finally able to perform its function without interference.

Example 3: Asynchronous Motors Operate Synchronously

Asynchronous motors are a fraction of the cost of synchronous motors, and therefore are widely used for the majority of work that requires motors in our everyday lives.

Asynchronous motors drive our HVAC, air compressors, generators, pumps, and numerous other functions and processes from residential all the way up through heavy industrial scale. They are a significant workhorse of modern society.

A common occurrence with asynchronous motors is speed droop. A four pole motor operating at 60Hz is is supposed to operate at 1375 RPM (Rotations per Minute). However, this RPM shifts depending on the load factor of the motor. When it is fully loaded, there is a drop in the RPM because it requires more energy to rotate the shaft and that power is not readily available.

This droop in power delivery by the motor is an example of inconsistency in work production. It results in less work being accomplished over a given period of time.

Using HVAC as an example, this translates into a longer operating time to cool an environment to a particular temperature. Over the lifetime of the HVAC, this additional operating time adds unnecessarily to the energy consumption and wear and tear of the unit.

In addition to work performance, these inductive motors

With Software-Defined Electricity™ protecting the power network, motors receive the exact, in the moment power they demand based on their design. This results in the motor always operating at its designed RPM and delivering the full power to the task at hand.

In the case of the HVAC, this would result in cooling an environment to a particular temperature faster, with less energy consumed.

Example 4: Improving Audio Recordings/Live Performances

Recording studios and live performance venues are very sensitive to electrical noise. Audio engineers can spend up to 60% of their time removing, filtering and cleaning up noise in post-production from a recording and live performance experiences can be ruined if noise is not kept in check.

Ground and neutral currents are the primary source of this audio noise and are typically coupled with fluctuating harmonics because of the non-linear usage of power during recording and particularly for live performances because of the joint reliance on lighting and video.

The common industry practice is to add isolation transformers or increase the size of power wires to absorb the losses in an effort to mute the effects of the power as much as possible during the recording/performance.

With Software-Defined Electricity™ protecting the power networks, ground and neutral currents are zeroed and all harmonics up to the 23rd are corrected in Real-Time during the natural process of synchronization. Clean electricity eliminates a majority of the noise that exists in these power networks.

This results in a better overall product with less labor hours spent on achieving that result.

Example 5: *RF Signal Propagation Improvement*
Radio is one of the most common forms of communication in modern society. Radio waves are electromagnetic waves that are propagated by an antenna at a specific frequency allowing anybody who can tune into that frequency to pick up that signal.

The distance that the radio waves are propagated and able to be received is a function of the power used in creating the signal. Fluctuation in the power directly results in fluctuation in RF signal. As the signal travels further from the antenna, this fluctuation becomes more noticeable distortion in the signal.

The natural process of RF signal propagation also causes a significant amount of power quality problems in the antenna power networks. The presence of high harmonics and ground and neutral currents further erode the capacity of RF signal propagation and introduce more distortion.

With Software-Defined Electricity™ protecting the antenna power networks, the power provided to propagate the RF signal is always perfect, resulting in the strongest and most stable RF signal possible.

In addition, the zeroing of ground and neutral currents and harmonic correction nearly eliminate the noise in the network during RF signal propagation, significantly increasing the quality of the signal and the distance that it can be received.

Example 6: *Increase the Detectable Distance of RADAR*
RADAR provides some of the most important functions in our daily awareness and safety including in astronomy, air defense, ocean surveillance, and meteorological precipitation monitoring.

RADAR works by an antenna transmitting electromagnetic waves with a receiver and a processor disaggregating the echoes to determine an object's location and speed.

In this sensitive environment, impedance, harmonics, phase angles and other specific parameters are inextricably linked to the distance covered and accuracy of signal processing.

With Software-Defined Electricity™ protecting the antenna power networks, the power provided to propagate the electromagnetic signal is always perfect resulting in an improved signal transmission. This occurs because the noise in the network is nearly eliminated and the Standing Wave Reflection experienced during signal transmission is significantly reduced.

Software-Defined Electricity™ also improves the reception of the RADAR by approximately -6dB improvements by significantly increasing the effective aperture of the antenna. This improvement in distance covered and accuracy of detection will improve every existing use of RADAR and open up new applications and discoveries.

Generator Performance and Output Improvements
Electricity is not generated already synchronized. The losses that are present in power networks are also present at the generation of electricity, no matter the method.

With Software-Defined Electricity™ activated, the performance of the onsite backup generators will immediately experience a dramatic improvement in the power production capacity and quality. Each generator will always be able to operate at its rated output value and maintain optimal efficiency and power stability at any load factor.

There will be an increase in fuel efficiency through loss reduction as described above in the Effects of Losses on Generator Performance of around 25% depending on the age and type of generator.

For facilities with more than one backup generator, the capacity improvement experienced by each one quickly adds up allowing a significant reduction in overall operating time.

In conjunction with the fuel savings, the operational expenses of owning and managing generator sets can decrease by up to 50%.

UPS, Battery Performance and Output Improvements

With the phases maintaining perfect balance, the UPS capacity is maximized and the battery cell wear and tear is reduced and evenly spread across the phases.

With Software-Defined Electricity™ installed, every battery in the power network is constantly delivered balanced, perfect power during the charging cycle which maximizes the capacity and rate of charge. During the discharge cycles, each battery experiences the maximum depth and rate of discharge with optimal efficiency.

This improvement in the quality and balance of power that coursing through the UPS will reduce the heat emitted during the dis/charge cycles and increase its useful life.

Every battery design is different, but in general, the expectation is that an ideal dis/charging environment increases the number of useful charge cycles, depth of discharge and charge rates by approximately 10%

Power Network Stability

At a high level, the correction of electricity is a Real-Time response to any live electrical event to return the electricity to synchronized. In other words, Real-Time synchronization creates self-correcting, autonomous power flow, which is the ultimate in both the flexibility and stability of the power network.

Automatic Impedance Matching

Within the process of Real-Time synchronization is automatic impedance matching for every load. The impedance will be maintained under 1 milliohm at all time on the supply and load sides simultaneously.

This creates perfect power flow no matter how many times there is a transition in the power source or a shift in the load profile.

In other words, when a facility goes off grid and on to backup generator supplied power, the voltage will not fluctuate and the current will remain undistorted and balanced during the transition and/or while islanded.

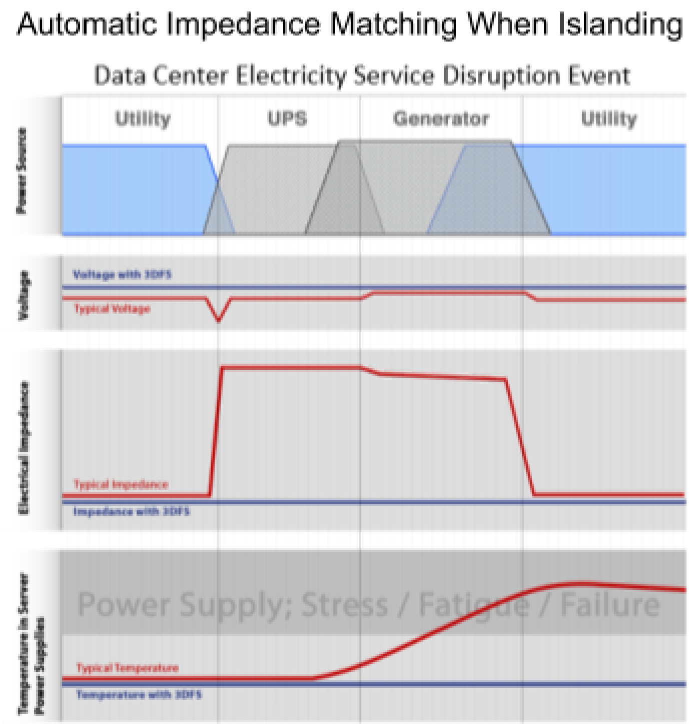

Figure 8: When a data center goes off grid, the transition from utility power, to UPS (or flywheel), generator, and then back to utility is traditionally a very unstable time because the electrical impedance is much higher while off grid, which rapidly affects electronic internal components. With Software-Defined Electricity installed, the impedance is maintained at less than a milliohm at all times, no matter the power source.

If capacity is available, from the load perspective, there will be no noticeable difference in the power quality supplied to the facility during the entire islanding transition. This will significantly improve uptime, efficiency and operational effectiveness during islanding.

Maintaining Separation of Power Network from Data Network

The VectorQ Series power controller is an edge computing system. In an active power network, the device processes terabytes of data every minute in order to perform Real-Time Synchronization, however only 1-5MB of data is transmitted from the device daily for reporting and power network diagnostics.

By maintaining all of the data processing on site within each VectorQ Series power controller, it opens access to a new software controlled layer of streaming data and analytics that is already processed, therefore is exact and error free.

This allows the power network to operate autonomously without any external data transfer to occur for either monitoring or control. The separation of the dependency on power networks and data networks is an improvement in the security of the power network.

Sustainable Surge Protection

Software-Defined Electricity™ provides Real-Time, sustainable lightning protection at the "Class C" DIN VDE classifications ("Class II / Type 2" IEC Classification) level. Strikes are prevented from entering any panel protected by a VectorQ Series power controller and affecting the loads and always provides full protection.

This is accomplished with the proprietary Flash Energy Storage System and is completely sustainable and non-degrading without requiring any upgrades or replacement of parts.

Sustainable surge protection also includes transients that are not weather related, but are nonetheless harmful. As an additional benefit, data and analytics will be recorded on every event for review.

Stacked Layers of Energy Savings

1st Layer - Direct Savings from Loss Prevention

The direct result of electrical losses is energy waste. Perfect power quality at all times eliminates those losses which results in less energy being consumed to perform the work demanded for every single load individually and direct energy savings.

Depending on the type, age, design and condition of the load, the expected energy savings varies. In general, inductive loads like motors and compressors experience a sustained 20-25% energy consumption reduction and the remaining non-resistive loads like lighting, electronics, computers, etc. will experience a sustained 10-15% energy consumption reduction.

2nd - Reduced Environmental Conditioning

A substantial portion of environmental conditioning like air conditioning is used to evacuate heat from indoor environments that was created by electrical energy waste to begin with.

Upon installation of Software-Defined Electricity™, it can be expected that there will be a ~20^{o}F temperature drop in the power supplies, motors, wires, electrical panels, fuses, etc. This reduction in waste heat emitted in the facility environment will decrease the need for environmental conditioning.

3rd - Optimized Work Output per Period of Time

The improvement of load performance will result in additional energy savings aside from loss reduction in certain loads. Asynchronous motors will not experience droop and always operate at the designed RPM whether they are loaded or not. This constant supply of perfect power applied will allow work to be optimally performed.

In HVAC motors, this translates into shorter cooling cycles. In fan motors it translates into less turbulent air flow. In servers it translates to better data transmission and fewer errors. Whenever mechanical operations are streamlined with less friction applied outside of the purpose, it results in less energy consumed to accomplish the task.

4th - Expert System in the Power Network
Each load has a unique pattern of electricity consumption. All of the internal components and circuits that make up the machine electronics are static and therefore the electricity is predictable when it enters a circuit.

Software-Defined Electricity™ is an artificial intelligence driven system with the goal of improving power delivery efficiency. The technology constantly builds models of each load as it operates in the power network, all the way down to the circuit level.

On a simple load like a computer, every process that runs relies on different sets of circuits, but they are all characteristics of that the load power consumption. The improved model over time is able to anticipate the upcoming power needs of the circuits and deliver the power with better efficiency.

This process will improve the power network efficiency by a few percentage points over time adding an additional 2-5% of energy savings over time.

<u>Utility Penalty Reduction/Elimination</u>
Demand Charges
Utility measurements occur every few minutes and are designed for a one month reporting system, meaning that individual data points are collected every few minutes and analysis occurs at the end of the month. This sparse measurement creates uncertainty in the accuracy of the fees assessed with limited data verification possibilities.

Peak startup current can be particularly punishing with respect to demand charges. In an uncontrolled network, startup current is drawn disproportionately on the phase directly powering the load resulting in the temporary overloading of that phase and contributing to excessive demand charges.

Utility demand charges are assessed based on time of use. The basic solution is to consume less grid power in a balanced way during the time when the charges are applied.

3DFS Technology maintains synchronization and balance in electricity flow at the microsecond level. This ensures that from both a time of use and balanced phase perspective, the facility power consumption always maintains the lowest possible demand charge assessment potential.

Power Quality Related Utility Charges
Utility penalties related to power quality differ by utility and change over time. While some industries are not presently assessed certain penalties, a simple regulatory adjustment can change that. Power consumers are historically vulnerable to these penalties, but with Software-Defined Electricity™, the effect of these penalties becomes minimized and/or eliminated.

No matter the reason for power quality penalties to be assessed, whether for power factor, harmonics, imbalance, voltage deviation, etc., Software-Defined Electricity™ maintains perfect power quality and therefore precludes the facility from any penalty assessment.

Depending on electricity usage, the industry and processes performed and utility supplying power, fees, penalties and tariffs assessed can eclipse 25% of the total power bill, nearly all of which can all be prevented.[10]

<u>New Layer of Data</u>
The fast and efficient data processing capabilities of Task Oriented Optimal Computing™ provide access to new types of software controlled data streams. Nearly everything about these data streams are customizable to the desired application.

Error Free Digital Data
Task Oriented Optimal Computing™ operates at the nanosecond level by oversampling the input electricity data while incorporating all of the noise and error removal. All

of the necessary data processing for Real-Time synchronization is completed and waiting to perform a precision action at the stroke of each microsecond.

This is the highest possible quality of noise and error free electricity data possible. It is the true and exact, digitized data and analytics for electricity flow in power networks.

Non-Intrusive Load Monitoring
Every machine that consumes electricity is comprised at least is some part, of individual components and circuits. Even if these machines were manufactured and assembled on the same assembly line, each of the individual components has differences in tolerance, wire thickness, solder thickness, etc. that collectively make up a unique electrical consumption signature.

This pattern over time is the baseline performance signature of that load. The VectorQ Series power controller builds and maintains models of this baseline performance for every single load in the power network. As each load operates, the corresponding model continuously updates and improves to always maintain the most up to date working model of the power network.

Automatic mapping of the loads allows owners to individually identify and track any load in the power network by the way it consumes power. This functionality is a powerful new tool for asset monitoring, energy budget forecasting and capacity planning.

Seamless Platform Integration via API
Access to this streaming error free non-intrusive load monitoring data can be created through an API and designed to fit any standard. This makes for an easy integration for virtually any conceivable platform that would involve energy data and services or asset management.

<u>Predictive Analytics</u>
By building the baseline model of each load in the power network, the VectorQ Series power controller tracks any deviation from original baseline which reveals valuable information about the operation of the load. Any significant deviation of power consumption in the Real-Time model can be instantly identified and flagged.

Deviations from the normal operation model can mean a variety of things including

- Load wear and tear
- Failure of an internal load component or the load itself
- Maintenance or repair requirements
- Undesired tampering with the load
- Inappropriate use of the load

As the owner interacts with the database of events and categorizes the devices and events that are important, the predictive analytics will become a reliable tool in the management of the facility and the output efficiency of the operation.

The digital mapping of facility power networks can be extended to multiple facilities and all be accessible from a single web based software application.

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Attachment A: VectorQ2 Technical Specifications

		VectorQ2
Electrical Specifications	Operating Voltages	208/240 VAC; Automatic detection and Configuration
	Admissible Voltage Tolerance	±10 %
	System frequency	60 Hz , USA Mainland operation only
	Reactive Correction Range	3 kVAR per phase / 9 kVAR total over 3phases
	PF Correction Degrees	+/- 90 deg
	Power Rating	Up to 30kW total load power (9kVAR per phase)
	Harmonic Measurement/Correction	Up to 53rd Harmonic; Up to 23rd Harmonic
	Nominal Operating Current per phase	30A
	Maximum Operating Current per phase	50A
	Connection Type, Voltage	In Parallel via 3L+1N+1G cable
	Connection Type, Current	FlexoCoil™ Current Transformers
	Typical internal standby power consumption	90W
	Maximum internal power consumption	120W
	Round Trip Efficiency	> 96% at full power
Electrical Parameters	Input phases	One Phase, Two Phase, Three Phase.
	Voltage Tolerance	± 10% on indicated supply voltages
	Frequency Range, Tolerance	60 Hz ± 1%
	Reactive Component Compensation, nominal	9 kVAR total / 3 kVAR per phase
	Correction Limits - % THD	Under 1.2% typical - Up to the 23rdHarmonic of the input frequency
	Correction Limits - Power Factor	1.0 (± 1%) for Inductive and Capacitive load
	Correction Limits - Non Harmonic Distortions, Dynamic Range	Amplitude up to +300% of input voltage Current up to 200% of maximum level
	PF & THD Sensing and Measurement	Flexible, Dynamic, Fuzzy Logic, 1,000 times per sine wave or better
	Response Time	Microseconds regime
Mechanical Parameters	Enclosure	Aluminum, powder paint enclosure, Non-flammable
	Ambient Operating Temperature	-5 C°, +42 C°
	Ambient Humidity	95% (no condensation allowed)
	Connection Voltage	3L+1N+1G cable, 6ft standard length
	Connection Current	3 x FlexoCoil™ current sensors
	Grounding	Via cable and either of two screw on side of bottom chassis
	Dimensions	405mm (H) x 413mm (W) x 244mm (D) 16in; (H) x 16.3in; (W) x 9.6in; (D),
	Weight	45 lbs
	Installation	Wall / DIN rail optional

