NEXTEK Power Systems

DC POWER DISTRIBUTION, LIGHTING AND CONTROLS SYSTEM

DC TECHNOLOGY OVERVIEW

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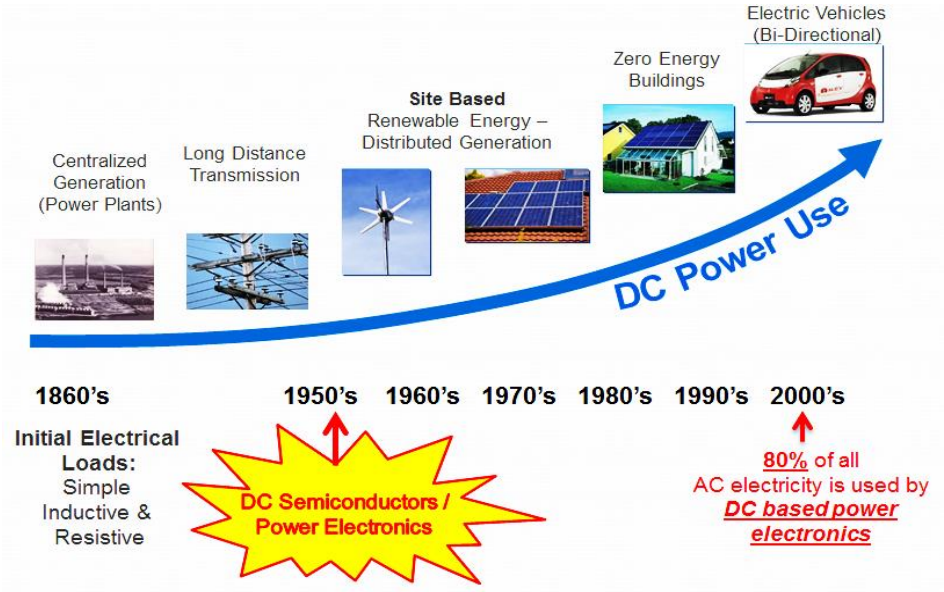
EMerge® ALLIANCE GOVERNING MEMBER

DC TECHNOLOGY OVERVIEW

A. INTRODUCTION

For over a century, the conventional design of lighting and power systems within buildings has been based on using Alternating Current (AC), electricity provided by utility companies collectively called 'The Grid'. Power and lighting systems that use Direct Current (DC), electricity are now available for the buildings of today and tomorrow. The following graphic depicts the evolution of electricity and the clear trend ***toward*** increased DC power use.



The purpose of this document is to provide information regarding the features and benefits of a DC-based system and how these differ from conventional AC technology. The balance of this document should provide you with additional detailed information and resources needed to arrive at a fundamental understanding of how DC technology can be designed and installed.

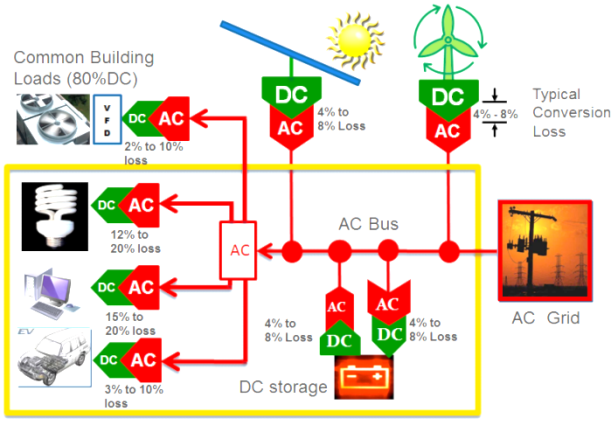
B. DC SYSTEM TECHNOLOGY OVERVIEW

The essence of DC Technology consists of using DC electricity to power DC devices in and around a building or campus.

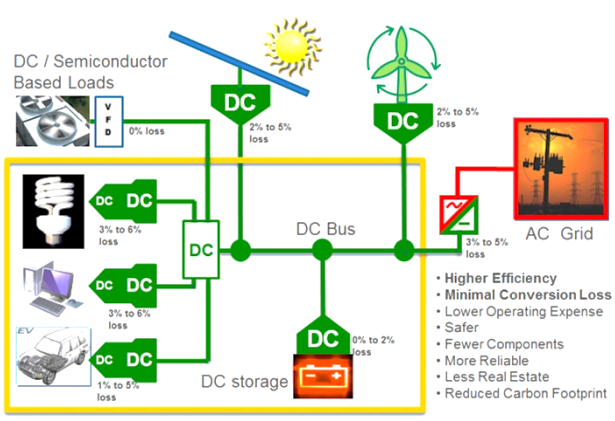
In our modern world, over 80% of building loads are actually DC loads that require AC to DC 'power supplies' to operate.

Using DC electricity to power DC devices is more efficient, eliminates additional hardware and is easier to maintain and manage. The following diagrams highlight the fundamental difference between AC and DC power technologies:

Traditional AC Power Architecture



DC Microgrid Power Architecture



DC TECHNOLOGY OVERVIEW

The DC approach has many similarities to AC power, but there are some fundamental and game changing differences between the two approaches.

- It is possible to create and store power at the building site in a much more efficient way than with AC power.
- With the 24 VDC Class 2 power and lighting approach, it is possible to install a fully functional system in a faster and easier way than the conventional AC method.
- With DC power, the need to 'synchronize' operating frequencies (50 Hz / 60 Hz), between components within a system or across systems becomes *eliminated*. Much easier to scale and manage power platforms.

DC lighting, distribution and control systems all include the following primary elements:

1. A power source or sources (AC, DC or BOTH)
2. A DC power distribution network
3. DC lighting fixtures and other DC powered devices
4. Lighting controls

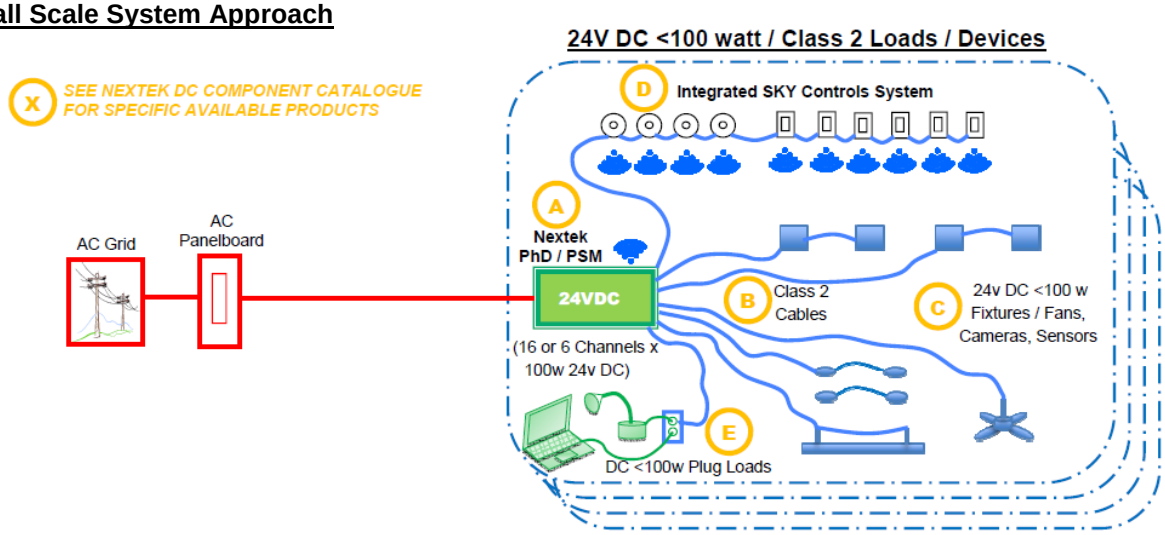
DC system designs as described herein conform with standards as established by the EMerge Alliance® (EMerge). For more information regarding EMerge, please visit www.emergealliance.org.

While EMerge does not manufacture any products, many of their members do produce DC products that operate on either the EMerge 24VDC or 380VDC standards. More companies are adding new DC products to the system on a weekly basis. Some of the companies participating in this technology revolution represent the premier lighting and power technology companies in the world and include Acuity Brands, Philips, Osram-Sylvania, Emerson, Bosch and many more. Other contributing EMerge member companies that provide support services and system development input include; Underwriters Laboratory, NEMA, EPRI, Lawrence Berkley Labs and many others. For a complete list of companies, see: http://www.emergealliance.org/About/OurMembers.aspx

DC SYSTEM – CORE DESIGN CRITERIA

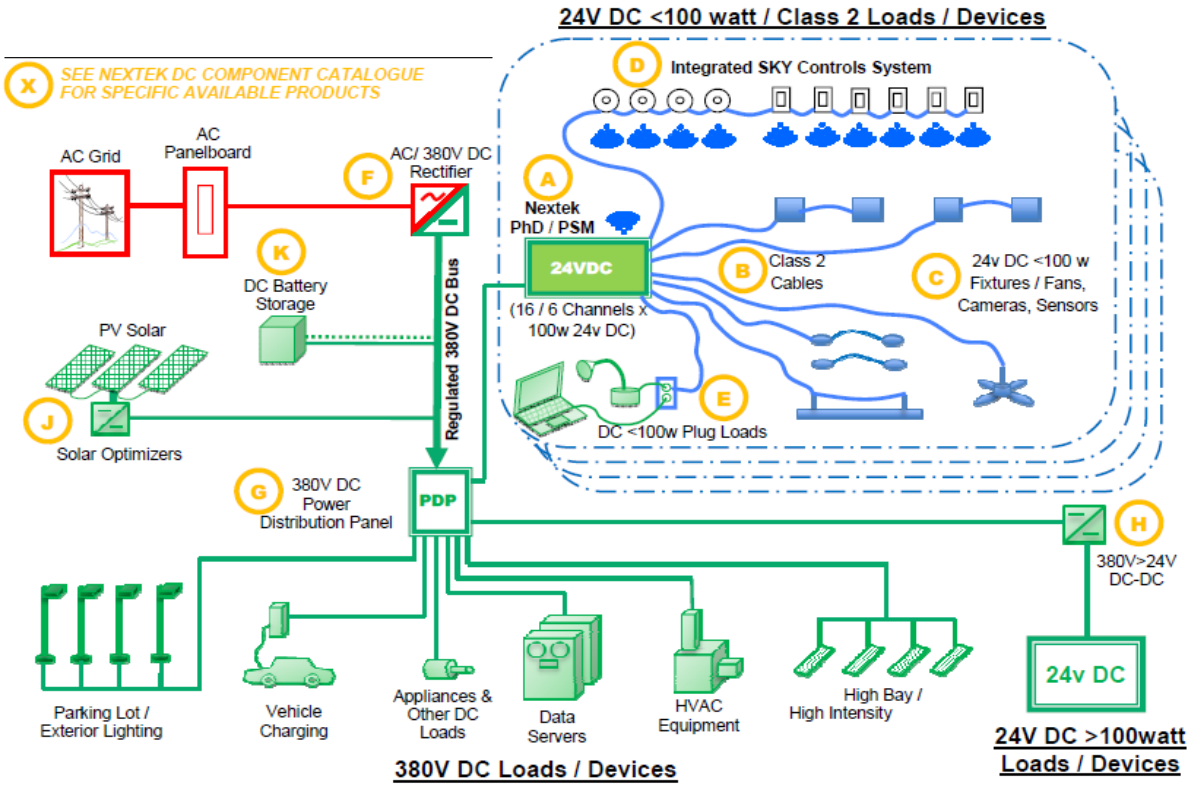
The DC systems defined in this overview are based on either 380 VDC for large scale projects (typically over 10,000sf) or 24VDC for smaller scale projects or smaller areas within a larger scale design. Within the 380 VDC system there is often a portion of the system that incorporates the 24 VDC lighting and power distribution technology. The following graphic representations offer a summary view of the different scale designs.

Small Scale System Approach



DC TECHNOLOGY OVERVIEW

Large Scale / Campus System Approach



If you prefer to have a more specific introduction to this technology, a web based presentation course titled **'DC Microgrid Technolgy – Introduction / Design / Examples'** is available from Nextek Power Systems. This AIA / CES approved course offers 1 LU of HSW + SD credit to AIA members and qualifies for self reporting for other professionals. If interested, please contact Nextek to schedule an online or in-person presentation.

For additional information regarding DC component and system information and design clarifications, please refer to the following resources:

https://www.dropbox.com/sh/b2824hsxbo4bfih/AACF7f8WOM6WN_rzv3ILkmBga?dl=0
www.emergealliance.org
www.nextekpower.com

Or, for more specific personalized design assistance and product guidance, please contact:

info@nextekpower.com

BENEFITS OF DC TECHNOLOGY

The principal advantages of utilizing DC system technology include:

- Safe-to-the-touch low volt Class II wiring (24 VDC system)
- Significant Reduction in installation labor costs (both time and labor rates)
- Increased operating efficiency = reduced energy costs
- Robust, cost saving wireless control system
- Elimination of most traditional conduit, j-box and MC cable distribution
- Ability for building owner to apply accelerated depreciation of system purchase
- Enhanced ability for Direct Coupling® of DC system to PV Solar or other renewable energy
- Improved system resilience
- Reduced system maintenance costs
- Inexpensive re-configurability – maximum flexibility
- Enhanced ability to incorporate future battery storage

Some of the system benefit highlights that warrant additional detail include:

- With the advent of LED lighting, computers and all things 'electronic', every single one of these devices requires an AC to DC power supply. These power supplies are typically very energy inefficient. The DC microgrid architecture calls for a centralized source of *highly efficient* DC power that is then simply distributed to the appropriate DC building loads. By incorporating DC Microgrid technology, the use of expensive energy becomes significantly improved while simultaneously eliminating the multiple assorted smaller power supplies that ultimately end up in landfills.
- Since the bulk of the installation of a DC lighting system consists of distributing safe-to-the-touch Class II wiring and devices, this work can be performed by less expensive field personnel. For years, Electrical contractors have had 'low volt' or 'structured cabling' divisions that have installed computer and communication systems in buildings. These skilled trades can fully install the 24 VDC system but are typically less costly than their full journeyman of master electrician peers. With the increased ease and speed of a DC installation, combined with use of less expensive labor, *the savings associated with installation of these DC lighting systems is significant.*
- A DC microgrid based lighting system will typically operate at an improved efficiency when compared to the same fixtures being powered from AC sources. The savings are typically between 5% and 15%, but may be much higher when replacing older legacy fluorescent or similar AC systems.
- The base wireless lighting system available with the DC lighting system can provide extremely robust and granular function and control of the lighting components for a fraction of what a typical AC based system that provides similar function. This is because this fully integrated system is able to control each channel of the DC power supply. This eliminates the traditional use of the power pack / relay devices present in most AC based systems. Combine this saving with the additional savings of not having to run wiring between devices, and you have a very powerful, and flexible system at a significantly reduced cost. One final powerful feature is that virtually any web enabled device (smart phone, tablet, computer), can become a fully functioning lighting and scene controller, making the SKY Controls a complete and robust lighting control system.

Regarding cost advantages, a condensed overview of reasons why a DC system cost is less than an AC system is as follows:

- The vast majority of the conduit, j-boxes and mc cable associated with the typical installation of an AC system are eliminated with the DC system.
- The labor to install the simple plug-and-play, Class II distribution wiring system of the DC system that replaces traditional conduit and wire is significantly less than the labor of installing conduit, j-boxes and mc cable of an AC system. Savings are generated by both reduced installation hours combined with use of less costly low-volt trade personnel.
- The quantity of AC circuits can typically be reduced.
- The purchase and installation of DC power supplies and distribution equipment will be required.

- All lighting fixtures and system devices will need to be configured to operate on either 24VDC or 380VDC power. There may be a price difference between the AC and DC versions of a given fixture or device. In general, the cost difference between DC and AC fixtures should be minimal. In large quantities, the DC fixtures will most likely be less expensive.
- The DC based wireless lighting controls system is typically much less expensive than a comporable AC lighting controls system that offers the same degree of performance and operation.

These benefits and advantages combine to deliver a higher value power, lighting and control system.

DC SYSTEM COMPONENT REVIEW

Every DC system has a DC power source, DC distribution, DC loads and some form of control system. The components described in this section provide an introduction to some of the primary components that form a DC system. This section is not intended to limit the availability of DC components, but to offer a basic introduction to some key components available in the market, which is growing on a weekly basis.

POWER hUB DRIVERS (PhD)

(For spec sheet, see
https://static1.squarespace.com/static/53769ce0e4b08ebb6e297ef8/t/5a70819524a6940ca881aa93/1517322648430/phd-cutsheet-012918.pdf

Every PhD provides 16 channels (similar to circuits) of Class 2 - **24VDC** output power, each rated at **96watts** (total of 1,600 watt, nominal). It is available in the following varieties of input power:

- **Wide Range AC -OR- DC input**
- **AC 90 to 305 VAC**
- **127 to 431 VDC**

Each PhD is mounted in the ceiling space and can rest on the ceiling grid or be attached with suspension cable or framing to building structure. Each PhD can typically cover between 2,000 and 4,000 square feet of building area, depending on loads or application.

PhD units are equipped with a wired or wireless interface that allow them to become a web connected device. This ability to communicate through the internet or the building LAN provides a wide variety of highly desirable options for control and energy monitoring interface to multiple other web enabled devices and data bases. All at dramatically reduced costs compared with traditional comparable technology found in AC systems.

CLASS II DC WIRING SYSTEMS

Class 2, DC wiring can be accomplished with very simple **2 conductor** wiring and does **NOT** need to be in protective conduit or MC cable. This allows for very fast and simple 'plug-and-play' installation. PhD channel connectors and luminaire disconnects are commercially available.

For cable lengths less than 40ft., 12 AWG conductor wire is used. For cable lengths between 40ft and 70 ft, 10 AWG conductor wire is recommended.

All cables may be pre-manufactured by Nextek with plug-and-play connectors on each end, -OR- field terminated to suit certain design requirements. .

DC LIGHTING FIXTURES AND 'DRIVERLESS' LED FIXTURES

The lighting revolution of the past several years has made LED lighting the dominant technology for lighting fixtures. This trend favors the DC power platform since all LED fixtures are fundamentally 'DC' powered devices. To operate with the Nextek PhD 24 VDC power architecture, LED fixtures can be provided either with or without LED Drivers. For the unique 'driverless' fixtures, the Nextek PhD units 'are' the LED driver and can provide steady state –OR- PWM (dimming) power directly to LED chipsets within LED fixtures.

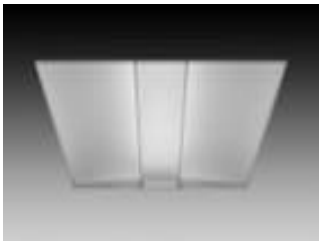
THIS UNIQUE 'DRIVERLESS' ARCHITECTURE PROVIDES IMPROVED RELIABILITY, INDUSTRY LEADING ENERGY PERFORMANCE AND VIRTUALLY ELIMINATES SERVICE MAINTENANCE NORMALLY NEEDED WITH AC POWERED LED FIXTURES. (No need to replace AC/DC LED drivers…EVER!).

Nextek does not manufacture light fixtures, but has developed collaborative relationships with a significant number of fixture manufactures who can provide LED 'driverless' fixtures in a wide variety of types, shapes, sizes and performance characteristics. In some cases, converting an 'AC' powered LED fixture to a 'DC' powered may involve simply removing (or not including) the AC/DC drivers. Nextek can assist with determining if this option is viable.

Some 24 VDC fixtures also use DC/DC drivers. Those fixtures may offer certain control or operational options. The Nextek PhD power architecture can serve all of these fixture types.

Regarding fixture style, there are a wide variety of fixtures available from a significant number of manufacturers. A more detailed sampling of fixture types is available on our growing catalogue: https://www.dropbox.com/sh/b2824hsxbo4bfih/AACF7f8WOM6WN_rzv3ILkmBga?dl=0 Following are the 'basic' summary of most common styles, BUT, there are **many** additional fixture types available:

Troffer



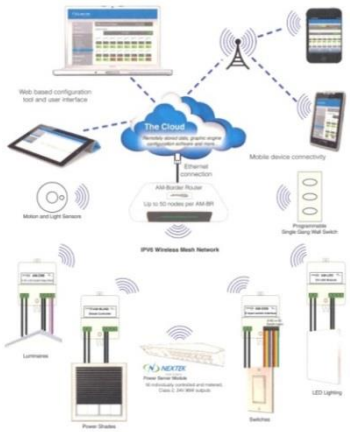
Downlight

Linear Pendant

Decorative

Specialty

SKY Controls' - LIGHTING CONTROL SYSTEM



AC based lighting control systems have become very sophisticated and typically rely on use of CAT5 Ethernet communication wiring, power pack relay units and remote control panelboard contactors to facilitate control needs as mandated by ASHRAE 90.1, California Title 24, energy codes and energy sensitive building owners. An alternate, highly robust and cost effective integrated wireless control system option is uniquely available for the Nextek PhD based DC system architecture. Use of motion and light sensors to facilitate automatic zone control along with programmable switching is available The **Nextek SKY Controls** wireless system also allows any web enabled device (smart phone, tablet, computer), to become a lighting system controller. system utilizes wireless mesh network technology to that allows programed control devices to communicate between and with one another. This architecture offers extreme flexibility and an unmatched level of granular control of a lighting system at typically around half of the installed cost of a comparable AC system. Please Review 'SKY Control Overview ' at https://www.dropbox.com/sh/b2824hsxbo4bfih/AACF7f8WOM6WN_rzv3ILkmBga?dl=0

DIRECT COUPLING® CONNECTION TO SOLAR PV SYSTEMS (Optional)

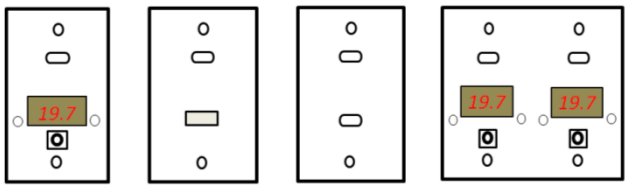
One of the most compelling and attractive features of the DC Microgrid architecture is the ability to connect DC powered building and lighting loads directly to the DC output of PV solar systems. This unique option *eliminates* the need for expensive, unreliable DC to AC inverters and allows the building owner to enjoy significantly more of the valuable energy being generated by these solar powered systems. This is accomplished through use of designing the primary DC bus and all power sources to operate at 380 VDC. In addition to the improved performance and reliability of the PV system, additional cost savings are realized from the elimination of licensing, regulation and fees associated with the traditional grid-tied AC connected systems. With no connection or interface with the AC grid, every PV system becomes more efficient to use and simpler to permit, configure and operate. Since scale and configuration is unique to every building site, please contact Nextek to review best practice options and get recommendations for primary components. A growing percentage of DC lighting customers are utilizing PV Solar as a power source.

DC DIRECT DESKTOP POWER

For the past 70 +/- years, EVERY 'electronic' device made has required an AC to DC power supply. Some devices have power supplies built inside the unit, like televisions or desktop computers. Some devices, like laptops, phone chargers, radios, have external power supplies (wall warts or 'bricks'). These power supplies are typically quite inefficient and when the life of the electronic device is over, the power supply ends up in the landfill. A much better solution is to power common DC devices DIRECTLY with only a power cable and use the 24 VDC power from the Nextek PhD unit as the core or source power. Since DC electronic devices operate at different DC voltages and connector types, Nextek has developed a multi-function 'DC Hub Plate' that provides up to 100 watts of any of the following DC outputs:

- USB – C (DC voltage becomes 'negotiated' between device and USB-C jack)
- USB – A 5 VDC
- Conventional 2.5 mm Barrel connector with +/- adjustment between 12 VDC and 20 VDC

The Nextek DC Hub Plate is modular based on connectors desired and configured in either standard single or double gang rough-in boxes. Below are images for example versions that are being developed:



ADDITIONAL DC SYSTEM COMPONENTS

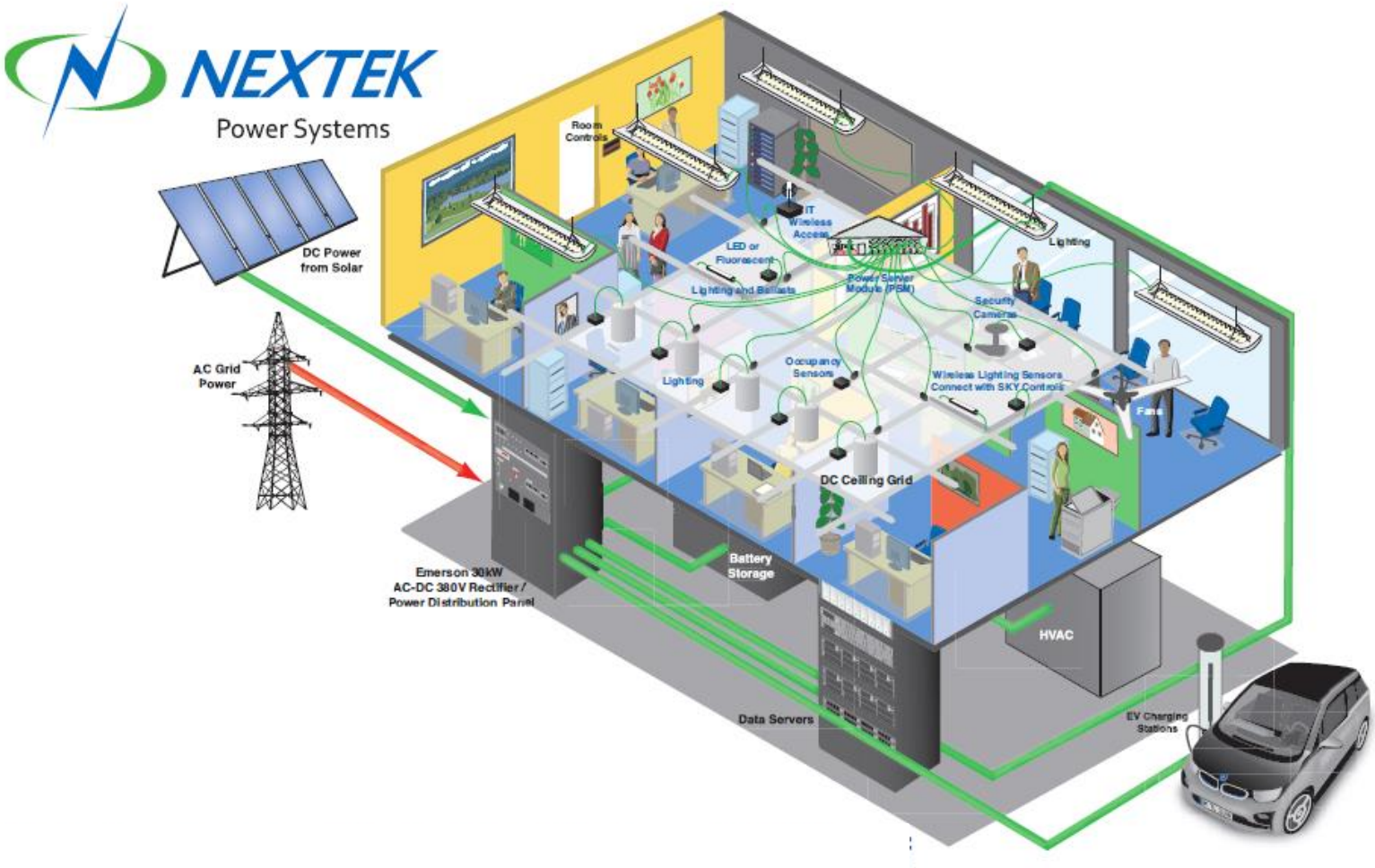
In addition to the core components as described, certain DC system designs may have additional components including, but no limited to:

- An AC to DC large scale rectifier (DC power supply) that delivers 380VDC power
- Other non-lighting DC loads such as; Data Equipment, fans, car chargers, HVAC motors, etc.
- Assorted disconnects or distribution components

For these additional devices, please contact Nextek to learn of the latest in DC devices that are compatible with the Nextek and EMerge Alliance DC standards.

SYSTEM DESIGN OVERVIEW SUMMARY

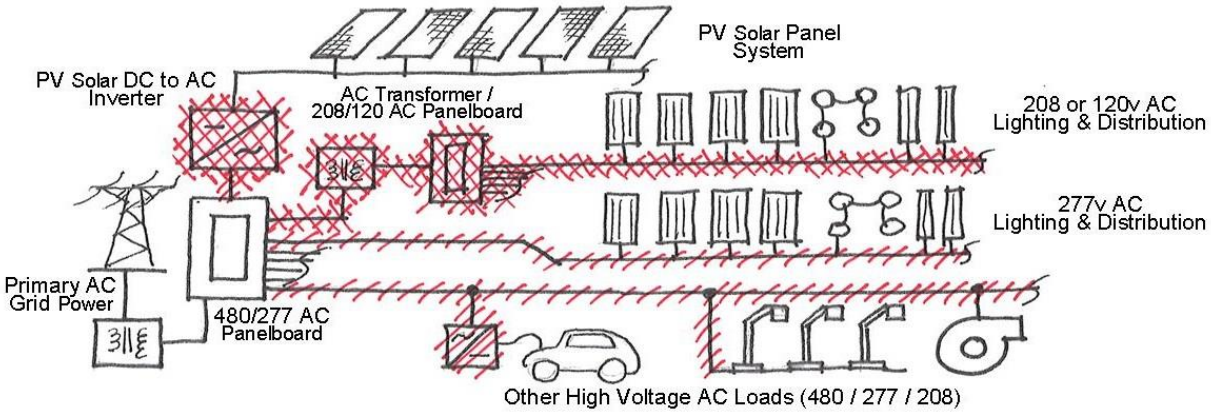
A visual graphic of how an entire typical DC system may be configured is as follows:



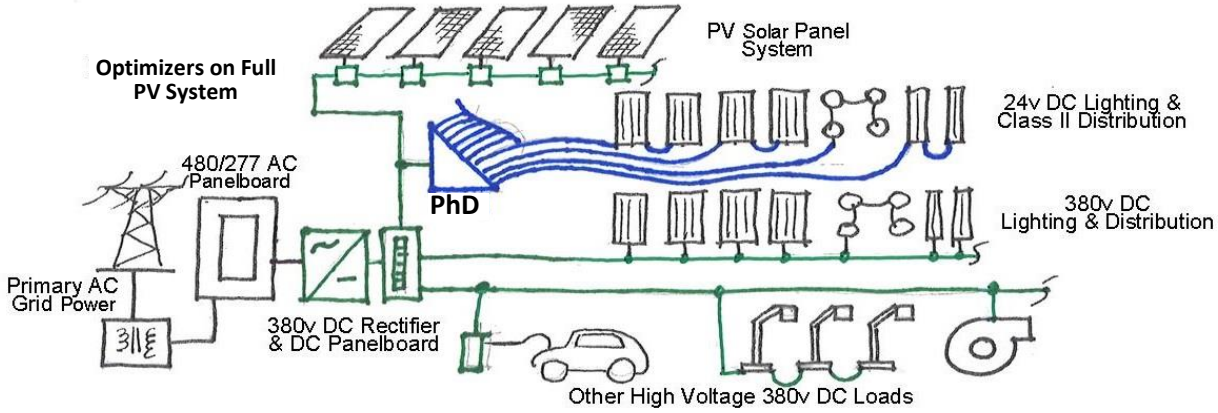
C. DC COST / BID CLARIFICATIONS

The following provides a general graphic illustration of what system components may be eliminated in a traditional AC system and added in either the large scale 380VDC system or small scale 24VDC system.

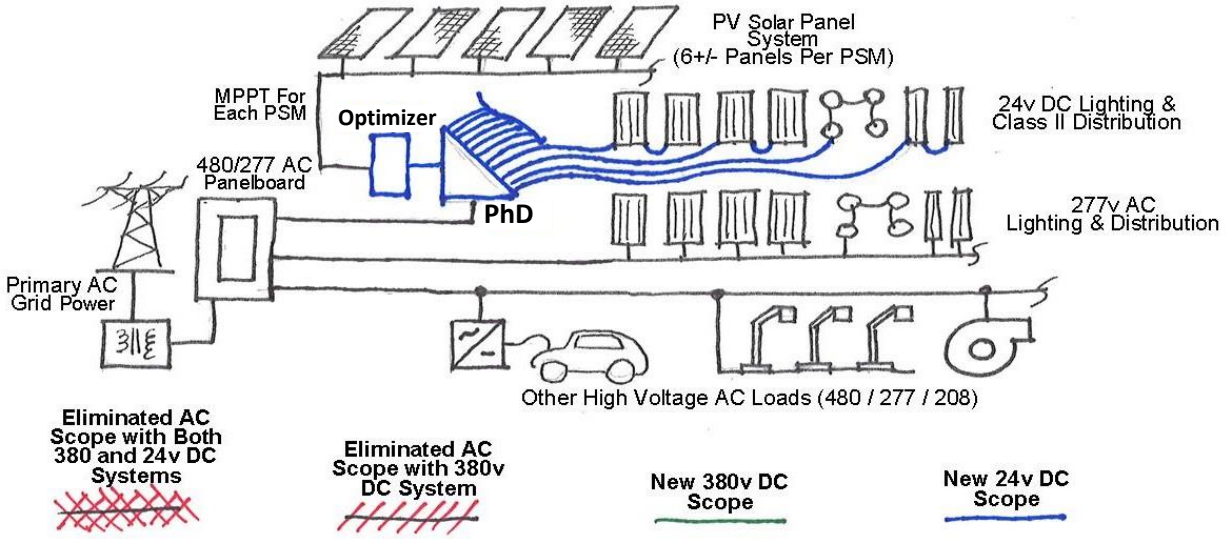
TRADITIONAL AC SCOPE GRAPHIC



380v DC SCOPE GRAPHIC —(Large Scale)



24v DC SCOPE GRAPHIC —(Small Scale)



DC TECHNOLOGY OVERVIEW

AC / DC SCOPE COMPARISON

AC Systems	DC Systems

BUILDING POWER SOURCES / EQUIPMENT

Connection To Grid Power

Buildings powered exclusively by AC power are typically connected to the local AC power utility company. AC power is typically provided in either 480 / 277v or 208 / 110v. Some dated AC systems utilize 240v AC. Residential voltages are typically 220 / 110. Power coming to the building is typically at a much higher AC voltage and is delivered in either 3 phase or single phase fashion. AC transformers are used to change from one voltage to another.	For DC systems that are fed from AC Grid utility power, they are connected via use of an AC / DC power supply that deliver either 380 VDC or 24 VDC power. The size of the power supplies are dependant on how much DC power is utilized within the building. Larger buildings will have large scale units that typically deliver 380 VDC power. Smaller buildings or areas of a building that have smaller DC loads will have 24 VDC power supply units.
NET COST DIFFERENCE: The DC system will require an AC/DC power supply to convert and distribute DC power. This will add marginal cost to any project, but should be partially offset by reduced AC circuits, panelboards and step-down transformers.	

Use of on-site Renewable Power (Solar PV / Fuel Cell Generator / Wind Generator)

Most 'building scale', on-site renewable power generates power in a native DC form. To use this power in an AC system, you need to utilize a DC to AC 'Inverter'. With the DC Direct Coupled® system, an Inverter is not needed. Inverters typically have a history of reliability and efficency negative characteristics.	Integrating 'building scale' renewable power into a DC Microgrid system does not require any inverters and it typically easy to design for. The most common approach is to be sure that the Renewable source includes 'optimizers' that will regulate the otherwise fluctuating power to a 380 VDC +/- 5% output.
NET COST DIFFERENCE: The optimizers used in a DC application are typically less expensive and easier to integrate into a system than the DC to AC inverters required with an AC system. A DC system with this feature should be less expensive, more reliable and more efficient producing an improved Total Cost of Ownership (TCO).	

POWER DISTRIBUTION

High Voltage Circuits / Panelboards

AC lighting or power panelboards provide varying quantities of different size ciruit breakers that control power to lighting and power devices throughout a building. Typical commercial breaker sizes are 15 to 20 amps @ 120, 208 or 277 volts.	380 VDC power distribution is very similar to HV AC distribution except that the panelboards and breakers are 'DC rated'. There are a number of companies that make DC rated breakers and disconnects. NOTE: Many jobs do NOT have 380 VDC distribution, so this topic is Not Applicable in those circumstances.
NET COST DIFFERENCE: The DC panelboards and breakers are less common than their AC versions, so there is a premium in cost for them. However, there are generally fewer DC circuits required to cover a similar building area. The net result is that the project cost would be comparable between AC and DC circuits.	

High Voltage Power Distribution Wiring

High Voltage AC power distribution is accomplished via a network of conduit, wire, junction box and MC cable. This method is similar for 120v, 208v or 277v AC systems. Wire size increases with lower voltage.	The 380v DC wiring typically utilizes the same conduit, wire and j-box materials and labor as a traditional 277v or 480v AC distribution system. Wire gage may be different from AC.
NET COST DIFFERENCE: Cost difference High Voltage AC and DC wiring distribution is comparable and in some cases identical.	

Low Voltage Circuits Vs 'Channels'

N/A	24 VDC Power hub Drivers (Phd's), provide 16 channels of 24v DC power, each rated at 96 connected watts of power. Each channel becomes utilized like a mini 'circuit' to power up to 96 watts of 24 VDC load. This method of power management replaces the traditional AC approach.
NET COST DIFFERENCE: Cost difference for this method of Low Volt power distribution is accounted for elsewhere in this document, but generally represents a significant net cost savings to a project.	

DC TECHNOLOGY OVERVIEW
AC / DC SCOPE COMPARISON

24 VDC Low Voltage, Class 2 Branch Wiring

AC Systems	DC Systems
AC Branch wiring is only done with traditional conduit, MC cable, j-boxes and insulated wire. AC branch wiring always requires use of a ground wire.	Wiring used to serve 24 VDC fixtures and loads consists of 2 conductor (no ground required), wire. Plenum rating is optional. Wire gage is typically 12 AWG up to 40 ft length and 10 ga from 41 ft to 70 ft. Quick connectors are typically used. VERY QUICK / VERY SIMPLE - SAVES LABOR COMPARED TO TRADITIONAL AC INSTALL
NET COST DIFFERENCE: Installation of the Class 2 wiring solution provides a SIGNIFICANT COST SAVINGS as compared to typical AC branch wiring. Labor costs should be around HALF of the AC method, and costs for conduit, MC cable, j-boxes and conductors is ELIMINATED.	

LIGHTING FIXTURES

24 VDC Low Volt LED Fixtures (Materials)

AC powered LED fixtures EACH have an AC to DC 'driver' (power supply), that convert AC to DC for powering the LED chips. These drivers typically also provide a dimming option.	Nextek has co-developed and tested a wide family of LED 'driverless' fixtures that operate (on/off and dim), DIRECTLY from our PhD power module. In addition to these core fixtures, there are a number of additional 24 VDC LED fixtures that utilize a DC to DC driver in them. Souces for some of these fixtures are refenced in the sharred catalogue provided in this document.
NET COST DIFFERENCE: With the removal of the AC to DC drivers, the 'driverless' fixtures are typically less expensive than comparable AC fixtures that each require a driver to operate. The net cost to any project should be a reduction in fixture cost.	

24 VDC Low Volt LED Fixtures (Installation)

Installation of AC powered light fixtures typically involves removal of a cover plate to expose internal wiring, then installation of a strain relief fitting at the end of some MC cable, wire nut connection of the 3 conductors to the internal fixture wiring, then replacement of the cover plate.	The 24 VDC fixtures typically have a 2 conductor whip that can simply connect to the 24 VDC branch feed wire outside the fixture via a simple push-in wire connector or wire nuts. Some fixtures ship with simple disconnects on these whips.
NET COST DIFFERENCE: DC fixtures install faster and easier than AC fixtures. There are fewer wires, fewer steps and fewer fittings. In cases where disconnect fittings are provided, the connection simply involves pushing the 2 bare wires into the fitting. The net result is that installation of a 24 VDC fixture can typically be done in around 1/2 of the time of a typical AC fixture.	

LIGHTING CONTROLS

Lighting Control Systems

Typical AC lighting control systems consist of a very wide array of devices and systems. Most of these systems require an extensive network of CAT 5 wiring to connect assorted programmable switches with power packs, dimmer modules or relay controled panelboard breakers to turn fixtures on / off / dim. While these systems are very powerful, they are also very complicated and installation is quite labor intensive.	The recommended integrated SKY Controls system provided by Nextek is a robust wireless system that can produce performance comparable to any similar scope AC system. This is accomplished due to the ability of the SKY system to control the root 24 VDC power at the PhD unit. On/Off/Dim on a per channel basis is possible. Or multiple channels or PhD units can be programmed to operate in scenes. All devices communicate wirelessly via a mesh network protocol that is also connected to the internet. Installtion of devices is extremely fast because they do not have to get wired to fixtures or each other. The only wiring is to provide low power 24 VDC from the PhD via 16 ga 2 conductor wire. There are multiple devices available including switches, motion and light sensors, tablets, relays and other devices. Refer to the full SKY cataloge for additonal information.
NET COST DIFFERENCE: Installtion of the wireless SKY Controls is typically around 1/2 the cost of a comparable AC based system with similar device and performance criteria.	