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DC Electrical Power Distribution

Introduction

At the inception of electrical power distribution, distribution systems based on direct current (DC), where electric charges do not change direction, dominated the electricity distribution market. Unavailability of efficient low-cost voltage transformation technology, a requisite for increasing the distance between the power generation source and power consuming load, constrained then dominating DC distribution systems. Alternatively, power distribution systems based on alternating current (AC), where electric charges periodically reverse direction, did not suffer from the distance constraint due to availability of low cost transformers, which can raise the system voltage to allow delivery of power with smaller size copper wire. This facilitated AC distribution systems to leverage the economy of scale to install large centralized generators and cover wide geographic areas, allowing the eventual emergence of AC distribution as the current leading force in electricity distribution market. This ascendance of AC also led to the proliferation of electrical loads that operate efficiently in AC distribution systems such as induction motors.

Current and Future Electrical Loads

In recent years, digital devices such as personal computers, telephonic equipment, televisions, etc. comprise significant part of electrical consumption. These devices need stable DC power supplies for their operation. As a result, these devices include converter boxes to change the alternating current from wall sockets into direct current. This conversion of power from AC to DC can raise system inefficiency as much as ten percent and also affect power quality such as harmonic distortions.

Currently, digital devices represent as much as twenty percent of the total electricity consumption and their share in the future will expand even higher with widespread adoption of fluorescent and LED (light emitting diode) lamps. The upsurge in consumers' embracing of electric vehicles (EV) can make DC even more significant as electric vehicles charge on direct current and consume substantial amounts of power. In coming years, we may witness as much as fifty percent of total electrical loads need DC power supply. Therefore, opportunity for energy savings will intensify as the growing number of electrical loads demands DC power supply.

DC Distribution

DC power distribution is already common in large data centers and telecommunication networks. Instead of having power converters serve each computer, data centers employ large centralized converters and distribute 380-volt DC power throughout the data centers. DC power distribution affords immunity from harmonic distortions to sensitive electronic equipment. In addition, replacing the AC-to-DC converters attached to individual servers with more efficient centralized inverters can decrease power consumption by 15 percent compared with conventional AC configurations. Intel estimates annual power savings of $1.2 million for a medium-sized data center served by a DC distribution system in the U.S.

DC power distributions in commercial facilities are also evolving as cost competitive option due to the availability of low cost, highly efficient LED lamps and compact fluorescent lamps (CFLs). Energy saving analysis conducted by the Berkeley National Laboratories estimates that DC power driven CFL is almost 10% more efficient than that of AC counterparts. DC powered LED lamps offer even higher efficacies. The study cited above depicts that DC powered air-conditioning units yield greater efficiency compared to their AC counterparts. Modern AC powered efficient air-conditioning units include brushless DC permanent magnet motors driven by variable frequency drives (VFD). VFD initially rectifies the AC input (i.e. converts it to DC), then applies pulse width modulation to create the desired output frequency. Therefore, DC powered VFDs can bypass the losses associated with power rectification. Similar to air conditioners, variable-speed compressors with brushless DC motors present utmost energy savings for refrigeration equipment. Thus, DC powered refrigeration equipment enjoys inherent efficiency advantage.

In addition, the same study calculates energy saving of 33% for a typical residential building when efficient DC power driven loads substitute conventional AC loads. DC power distribution is especially economical when a facility incorporates distributed renewable energy resources such as solar photovoltaic panels as they can supply power to the DC loads directly without double conversions involved in AC distribution systems (DC-AC-DC).

Emerge Alliance, a consortium based in San Ramon, California, established a standard for 24-volt DC ceiling circuits. Emerge is now commencing on bringing DC power to the desktops to power computers, phones and other digital equipment without the need for inefficient converter boxes.

DC Transmission

Increasingly, long distance transmission lines utilize high voltage DC (HVDC) due to ease of control and lower losses than high voltage AC transmission lines. These long distance HVDC transmission lines are the key to delivering power from large scale renewable energy sources such as wind and solar farms. Surging demand of DC loads at the consumer levels and integration of HVDC transmission lines can spawn an opportunity to bridge the divide, enabling medium-voltage DC distribution between them. Delivery of DC power from high-voltage line to end user is especially appealing in rapidly developing economies and communities that are constructing new power infrastructure and large scale renewable energy resources.

Conclusion

With growth of DC-based end-use applications and renewable energy source such as solar, the question obviously arises whether it makes sense to convert DC power from solar electrical systems into AC for distribution within the building, just to revert it back to DC at the load? Energy savings of DC-based appliances coupled with the avoided AC-to-DC conversion losses within those appliances can sum as much as thirty percent. The energy advantages of DC distribution will soar if these trends continue as anticipated, including the compulsion to reduce carbon emissions and lower harmonic distortions.

References:

http://www.nrel.gov/esi/pdfs/wkshp_1012_power_change_world.pdf
http://hightech.lbl.gov/documents/data_centers/DCDemoFinalReport.pdf
http://efficiency.lbl.gov/drupal.files/ees/Catalog_of_DC_appliances_and Power Systems_LBNL-5364E.pdf
http://www.emergealliance.org
Arrillaga, Jos; High Voltage Direct Current Transmission, second edition, Institution of Electrical Engineers, 1998.