Secure voltage supply

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Latest modular UPS technology
Availability is everything in a UPS, making ABB’s Conceptpower decentralized parallel architecture (DPA) design the preferred choice, ensuring power is always on when you need it. Each highly reliable standardized module is self-contained and can be online-swapped at any time, ensuring 99.9999 percent availability, making routine maintenance safe and easy. With class-leading efficiency of up to 96 percent, your power consumption and cooling effort are minimized. And, by adding expansion modules only when required, you only pay for the power you need. www.abb.com/datacenters
As we head into the last quarter of the year, ABB’s power protection business continues to strengthen, with developments underway across the globe.

The major news of the day is ABB’s entry into the North American UPS markets with two UL listed modular UPS products – the Conceptpower DPA 500 480 V UL and Conceptpower DPA 120 208 V UL. The launch of these two new products will benefit our existing global operating customers who are seeking to leverage ABB’s premium services across continents. The new products will provide power protection solutions for power ranges from 20 kW up to 3MW, and make the successful and reliable DPA platform available for North American customers who, in the past, have had to settle for conventional UPS solutions with limited modularity and scalability.

There is more on the product side. In addition to the 480 V UL-compliant versions of the modular UPSs mentioned above, ABB is delighted to announce the launch of a new, parallelable version of the DPA UPScale ST UPS aimed at applications up to 400 kW. This series 2 follows on from the success of the DPA UPScale ST series 1 – one of ABB’s biggest selling UPSs ever. Another product highlight is the introduction of the PCS100 AVC-20, an active voltage conditioner for voltage regulation, designed for use by industrial and large commercial operations in environments where an unstable network or utility voltage affects productivity. The system’s leading-edge technology ensures a continual supply of utility power where the electric infrastructure is stressed, unstable or unreliable.

From November 2015, ABB will begin assembling two modular UPS product lines DPA UPScale ST and the rack-independent DPA UPScale RI, at our plant in Nelamangala on the outskirts of Bangalore, India. Up to four frames per day can be produced here on two assembly lines. Producing locally will allow us to reduce delivery time to the customer, help us to decrease costs and the ability to introduce products faster into the market.

Moving eastwards, the Nantong Cel-lulose Fibers Company chose ABB’s PCS100 AVC-40 active voltage conditioner to deliver the advanced power protection the company required, by securing the plant’s voltage supply during very deep sag events. The plant frequently sees drops of up to 50 percent in the nominal utility voltage supply, which the PCS100 AVC-40 can correct in less than 5 milliseconds to within the tolerance range of the factory equipment, ensuring no impact upon productivity.

You can find out even more regarding power conditioning in the article about the Royal Danish Navy warships. Power protection now ensures a steady voltage to the shore power station at the Naval Base Korsoer in Denmark, where the inrush current from three large frigates previously caused the network to drop out.

The naval station has now installed ABBs PCS100 reactive power conditioner (RPC) which is able to respond instantly to power quality events, while providing continuous reactive power correction. As a result, the problem has now been solved.

In central Europe, our products have been responsible for maintaining energy flow. HELL energy drinks – sold in many countries around the world - called in ABB to help with power grid problems that were causing expensive production disruptions. In a very successful collaboration, four ABB PowerWave 33 500 kW (2 x 2 x 500 kW) uninterruptible power supplies (UPSs) – plus a bank of batteries providing an autonomy time of 5 minutes - were installed as a solution to Hell’s power woes. Energy flow and energy drink flow are now guaranteed.

Recently, we have produced several tools that explain the benefits of ABB power protection products. For example, a promotional video and white paper on the AVC-20 (http://new.abb.com/ups/power-and-voltage-conditioners/voltage-conditioners/pcs100-avc-20/highlights), as well as an article on how the latest modular UPS technology boosts data center efficiency and flexibility. Data centers are a particularly important market for our products and this article describes how a modular infrastructure allows for rapid deployment of power equipment, lean construction, containerization, prefabication of standard devices, easy retrofitting and the ability to expand as required.

In conclusion, it just remains for me to thank you all once again for reading this update.

Enjoy this issue of power!

Elina Hermunen
Head of Marketing and Product Management
Power Protection
Discrete Automation and Motion division
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Supplying energy to the energy drink

Providing uninterruptible power supply to the production facility of HELL Energy Drink
HELL energy drinks - a market leader in Hungary, Romania, Bulgaria, Cyprus, and Azerbaijan, and available in a further 40 countries - are canned in the company’s world-class plant in Szikszó, Hungary. It is there, that the huge automated production line produces around 300 million cans of energy drink annually.

The complex automation systems used in the beverage production process need to have an uninterrupted and stable source of electrical power. Unfortunately, supply voltage disturbances happen all too often, so ABB in Hungary was called in to help find a suitable solution. Attila Balogh, ABB’s project manager explains, “ÉMÁSZ, the electrical utility company responsible for this region, is trying to combat the disturbances (including outages) in the voltage supplied to their clients, such as HELL Energy Drink. However, the manufacturers of Hell Energy Drink need to ensure that they have a clean and reliable power supply.”

ABB, with the support of the local partner MNT Kft, carried out a detailed analysis of the local power supply voltage conditions as well as the type of load connected. Based on the measurements, all actors involved proposed the supply of four ABB PowerWave 33 500 kW (2 x 2 x 500 kW) uninterruptible power supplies (UPSs) - with a bank of batteries providing an autonomy time of 5 minutes. The customer agreed on the scope of supply and the solution proposed by ABB in cooperation with the local expert partner MNT Kft, who acted as the consultant/designer and battery supplier. “Only nine weeks was allowed for the period from signing the contract to the system switch on – including battery installation, cabling, distribution boards, production and delivery of the UPSs, and connection to the main distribution board. However, thanks to the collaboration between the parties involved the job was completed before the deadline. Having worked closely with HELL for some time, we knew each other well and this helped the project a lot,” commented Attila Balogh.

"Our brand has been characterised by quality and reliability since the outset, and these high standards must be maintained and promoted by our production background as well."

ABB’s UPS protects the entire production hall and is connected to the main distribution board, after the two input supply transformers. This configuration allows production to be operated from either transformer and provides continuous operation for every load in the production hall.
"This project in the food and beverage industry provides an excellent demonstration of the flexibility of ABB's UPS solutions."

It was not only the product benefits that ÉMÁSZ took into consideration when it selected ABB to be its supply partner. In close cooperation with the experts of ÉMÁSZ, HELL and MNT Kft, ABB were constructively seeking the feasible solutions for the project right from the outset. The proposed solution to be applied is very unique and only ABB was able to undertake to implement it.

“Relying on the professional contribution of benchmark quality from ÉMÁSZ, we opted for the technical solution proposed by ABB, since we needed a quick and effective solution to eliminate our issues arising from current fluctuations and outages. To this end, in 2011, HELL, the only one amongst the energy drink producers, had its own production facility built and equipped with the most modern technology available in order to ensure seamless and predictable supply for its customers and markets. Since, besides the domestic market, our production facility in Szikszó also supplies energy drinks to our dynamically developing export market, covering more than 40 countries, it is essential for us to fully utilise the production capacity of the production line, which is a key requirement when you have export of this magnitude.

Our brand has been characterised by quality and reliability since the outset, and these high standards must be maintained and promoted by our production background as well. We owe special thanks to both ÉMÁSZ and ABB for their quick assistance in addressing our needs. We are entirely satisfied with the great job they have done,” said Szabolcs Béres, Director of HELL production facility.

Renzo Salmina, Regional Sales Manager located in the head office and factory in Switzerland, noted, “Often ABB carries out UPS projects with data center clients but this project in the food and beverage industry provides an excellent demonstration of the flexibility of ABB’s UPS solutions and is a perfect example of synergy between the local ABB business unit, our local channel partners MNT and the ABB factory in Switzerland. You could say that this project for Hell was heavenly.”
New UPS production facility in India

Power Protection is strengthening its local presence in India with the first manufacturing location for the assembly of uninterruptible power supplies (UPS).

From November, the two modular UPS product lines DPA UPScale ST and the rack-independent DPA UPScale RI will be assembled at the plant in Nelamangala on the outskirts of Bangalore. Up to four frames per day can be locally produced on two assembly lines.

For several years, ABB’s Power Protection product group has been present in India with regional sales offices. This additional local assembly unit will increase the cost-effectiveness and improve efficiencies. The Indian market, at this stage, is one of the most price sensitive markets. With the local sourcing of components, ABB’s Power Protection product group improves price competitiveness while maintaining the highest quality standards. Additionally, local production is an important factor for acceptability within the Indian market.

“The future belongs to India. If you want to benefit from the dynamics of the Indian market, we need to localize the production program in India. Producing locally will give us a chance to reduce the delivery time to the customer, help us to cut costs due to reduced transportation costs and direct purchases and it will help us to introduce new products faster and cheaper. The new facilities will strengthen our position in this important growth market in line with our strategy,” underlined Amina Hamidi, Product Group Manager, Power Protection.
Steady voltage to shore power station

ABB’s PCS100 reactive power conditioner (RPC) provides the ideal power solution to the Royal Danish Naval base in Korsoer, Denmark.
Power protection now ensures a steady voltage to the shore power station at the Naval Base Korsoer in Denmark, where the inrush current from three large frigates previously caused the network to drop out.

From the time a new warship leaves the yard, right up until it is taken out of service after many years of dedicated work, the power is, in principle, never switched off. The components of the large radars and other high-tech equipment require constant power supply and cooling. Therefore, all electrical shutdowns of the equipment are only conducted according to prescribed procedures.

The Danish Navy has made use of the shore power station for many years, but the three new frigates with their huge cooling compressors caused power failures to the shore power station at the naval base. “When a frigate like Iver Huitfeldt is restarted it can take two men two to three hours and after a number of interruptions to the power supply, components can become damaged” says Dennis Singh, Electrical officer of the frigate Iver Huitfeldt.

The naval station has now installed ABB’s PCS100 reactive power conditioner (RPC) which is able to respond instantly to power quality events, while providing continuous reactive power correction. As a result, the problem has now been solved. “We now have a constant voltage of 450 volts, and it does not change, regardless of consumption” emphasizes Dennis Singh.

"We now have a constant voltage of 450 volts, and it does not change, regardless of consumption."

Interruptions to the power supply, components can become damaged” says Dennis Singh, Electrical officer of the frigate Iver Huitfeldt.

Keeping peace with the neighbors
The frigates have an average of 120 to 150 sailing days with the rest of the time being spent in port. If they were to operate their own generator, the fuel cost would be extremely expensive and require far more maintenance, therefore for financial reasons this has been avoided. In addition, such large diesel engines are exceedingly noisy resulting in a number of complaints from residents of a new apartment block situated in the harbor. However, the neighbors can now enjoy beautiful sea views without experiencing noise pollution and the Naval Base Korsoer has a shore power station that works consistently and is future-proof, a win for all involved!

“The other day there was a power failure throughout the town of Korsoer, but we were able to start up again without problems” says Bent Jørgensen, who is the electrician at the Naval Base Korsoer.

General problem
Production plants, warships and many other facilities are confronted with a number of disturbances, from distortion of supply voltage, to harmonics and high inrush currents. An unstable supply can result in downtime, and either reduces the life of expensive electronic equipment or causes damage to it.

For that reason, ABB sees a great demand for the PCS100 RPC which is available from 100 to 2000 kVA and responds instantly to power quality events, while providing continuous reactive power correction.
Powering plant operations

Secure voltage supply powering operations at Nantong Cellulose Fibers Company
The global tobacco market is in steady decline as smoking becomes less fashionable in the developed economies of the USA and Europe. However, in emerging markets such as India and China, the industry is booming thanks to the cultural changes buoyed by the flourishing economy. In fact, China is the world’s largest tobacco market with over a quarter of the enormous population partaking. In 2013, the country’s largest manufacturer sold 2.5 trillion cigarettes – that’s 43 out of every 100 cigarettes made worldwide¹.

A key component of a cigarette is the filter, which is intended to reduce the amount of smoke inhaled and absorb some of the chemical by-products produced by the lit tobacco. Filters are made from cellulose fiber extracted from wood pulp (the fiber product is known as the ‘tow’), which is then processed into vinegar cellulose diacetate tablets and eventually formed into small cylinders following filtration, spinning and drying procedures.

"We chose ABB’s PCS100 AVC-40 specifically because of the efficient way it works, drawing the additional voltage required to restore the power supply, directly from the utility rather than relying on expensive energy storage in the form of batteries"
A reliable low maintenance solution

Yi Lu, the engineer who is in charge of this project at NCFC explains the issues that the plant faced with their existing battery-powered solution, “Each power quality event which causes production to shut down, costs us around $500,000 USD. We urgently needed a reliable method of protecting the plant which reduced our costs and ensured we were able to remain productive throughout voltage sags and outages.”

Nantong Cellulose Fibers Company chose ABB’s PCS100 AVC-40 active voltage conditioner to deliver the advanced power protection the company required, by securing the plant’s voltage supply during even very deep sag events. The plant frequently sees drops of up to 50 percent in the nominal utility voltage supply, which the PCS100 AVC-40 can correct in less than 5 milliseconds, to within the tolerance range of the factory equipment ensuring no impact upon productivity.

Lu continues, “We chose ABB’s PCS100 AVC-40 specifically because of the efficient way it works, drawing the additional voltage required to restore the power supply, directly from the utility rather than relying on expensive energy storage in the form of batteries. ABB also provided full installation and commissioning support to make sure we take full advantage of the system’s features. The training and service provided by ABB was a key factor in our choice of supplier.”

PCS100 AVC-40 is an innovative solution to industrial voltage supply problems. Providing uninterrupted power without relying on energy storage systems means that the system has a small foot print and is free from the cooling requirements of battery units. This will allow it to be installed in existing equipment rooms or confined spaces which eliminates the need to design and build added floor space.

Looking to the future

Since the installation of the first ABB PCS100 active voltage conditioner three years ago, Nantong Cellulose Fibers Company has saved over $1.5 million in lost production and maintenance costs, which has enabled the company to expand its operations and become China’s leading supplier of cellulose fiber to the tobacco industry.

With China’s economy growing ever-larger, the market for tobacco products is likely to follow suit. NCFC, with its advanced power protection, is well placed to meet the increased demands of its cigarette manufacturing clients who, in turn, will continue to supply China’s expanding population.

References

The PCS100 AVC-20 video highlights the benefits of installing a PCS100 AVC-20 for your business in commercial or industrial applications.

Watch ABB’s PCS100 AVC-20 video.

The PCS100 AVC-20 is a power protection system designed for use in industrial and large commercial operations in environments where an unstable network or utility voltage affects productivity. The system ensures a continual, regulated supply of utility voltage where the electric infrastructure is stressed, unstable or unreliable.

Watch the PCS100 AVC-20 video here on the ABB website.

To find out more about ABB’s PCS100 AVC-20 marketing material, please click here.
ABB enters North American UPS market
ABB has expanded its modular UPS technology for use in large and mid-sized data centers, server rooms and other IT infrastructure applications with a 480V UL version of the Conceptpower DPA 500. With over 15 years of experience in designing and manufacturing UPS systems in Europe and Asia, ABB now brings this expertise to the UL market in North America.

Initially launched as a 400V IEC version in 2013, the Conceptpower DPA 500 is the only modular UPS on the market that is easily scaled to provide up to 3 MW of clean, reliable power. The fundamental component of the UPS is a 100 kW slide-in module. Five of these modules can be installed in a single frame, and six frames can be configured in parallel. UPS modules can be added to the system as power requirements grow, thus avoiding the need to over specify the original configuration.

The Conceptpower DPA 500's “online-swap” capability, in which modules can be inserted and removed with the UPS running securely in double conversion, simplify routine maintenance and eliminate service-related downtime. Not only does this feature improve availability, but it also reduces cost, since service engineers spend less time on-site and any risk of data or production loss are minimized. Modularity ensures reduced inventory levels of specialized spare parts. Additionally, this online-swap technology helps data centers achieve “six nines” availability (99.9999 percent), highly desirable for data centers in pursuit of zero downtime.

Reliability and availability are ensured by the Conceptpower DPA 500’s proven Decentralized Parallel Architecture (DPA). Each module contains all the hardware and software required for full system operation. The modules share no common components; each of them has its own independent rectifier, battery charger, batteries, inverter, static bypass, logic control and control panel. With all the critical components duplicated and distributed among individual units, potential single points of failure are eliminated.

"ABB is making a concerted effort to expand our overall portfolio for our customers and partners in North America," said Hans Pfitzer, Vice President of Engineering and Product Management in ABB’s Power Protection Product Group. “Expanding the Conceptpower DPA 500 platform to support UL standards and voltages strategically positions ABB to provide our data center customers with a complete portfolio of power quality products.”

The Conceptpower DPA 500 boasts the lowest cost of ownership compared to other UPS systems by offering high energy efficiency, scalability and an optimized modular design to enable easy front access serviceability. A class-leading energy efficiency surpassing 96 percent significantly reduces system running costs and cooling expenses. More importantly, the efficiency is optimized and significant savings are achievable under every working condition. The straightforward nature of the Conceptpower DPA simplifies every step of the deployment process, from planning through installation and commissioning to full use. Flexible setup and fast maintenance mean lower operating and maintenance costs.

The Conceptpower DPA 500 is part of ABB’s broad range of products and integrated solutions that ensure data centers operate with optimum reliability and efficiency. From power distribution systems to enterprise management and grid connections, ABB provides savings in installation, energy, space and maintenance.
Power protection – UPS
Data center boost

Latest modular UPS technology boosts data center efficiency and flexibility
With the intensifying demand for space, power and cost containment in their facilities, today’s data center owners and operators have turned to modular designs to gain the flexibility and cost efficiencies they need.

Modular infrastructure allows for rapid deployment of power equipment, lean construction, containerization, prefabrication of standard devices, easy retrofitting and the ability to expand only as needed. Large centralized infrastructure often has resulted in overprovisioning for future growth, leading to wasted real estate and equipment. It has required maintenance employees to shut down systems while they locate faults in the centralized infrastructure that is critical to all the center’s operations. These days, however, data centers are built in modular blocks that help isolate problems while keeping the data flowing. Modular infrastructure has now evolved to even higher levels of availability and efficiency with the latest technology for uninterruptible power supply (UPS) systems.

A new type of modular UPS eases maintenance

UPS capabilities are among the most critical for data centers; yet, they have been among the most vulnerable and troublesome when a failure occurs.

Traditional UPS systems are housed in large frames that are very complex to install and service. Since redundancy is required in most instances, data centers typically have two of these large, hundred-kilowatt frames, with a third cabinet to house all the cabling of the output isolation switches. If a failure were to occur in the primary UPS, the system would need to be taken down to repair it while switching to the backup UPS.

Likewise, expanding capacity with such a centralized system becomes difficult. Engineers must touch the entire infrastructure, upstream and downstream, a time-consuming and expensive process that in most cases requires the scheduling of downtime.

Consequently, modular UPS units have become popular as a way to limit interruption of operations for maintenance or replacement. Modular UPS recently has taken a big leap forward with the development of decentralized parallel architecture (DPA) that eliminates single points of failure and downtime during maintenance while significantly easing installation. The most advanced designs of these DPA UPS modules—well-proven in Europe and Asia for the past two years, and now being introduced in North America—make protecting the power in modern data centers nearly as simple as pulling a suitcase from a shelf.

While one fault can bring down an entire centralized UPS system, DPA allows full operations to continue during UPS maintenance or in the unlikely instance when a module may fail. With an advanced system of this type, a typical configuration may include up to five 100 KW modules installed in a single frame. Each standardized module houses all the hardware and software required for it to operate independently of the other modules. These self-contained components include rectifier, inverter, battery converter, static bypass switch, back-feed protection, control logic, display, and Mimic diagram for monitoring and control.

Typically, a modular UPS system will contain at least one extra module for redundancy beyond the critical-load capacity needed. If any individual module fails or otherwise requires maintenance, it can be swapped out of the frame while the system remains online in double conversion without interfering with any operations and without transferring the load to bypass. The remaining modules continue to supply a full level of protection. Maintenance on the pulled module can be conducted offline and offsite while the spare module takes over its duties.

As the data center grows, operators can simply add more modules to provide the required power backup, with no need for over-specifying when the facility is initially enlarged. One way to set up DPA modules is to use multiple frames holding up to five 100 KW modules each. As many as six frames can easily be combined to furnish up to 3 MW of protection. This standard has been configured by ABB, which is one of the first suppliers to introduce modules that can scale to megawatt proportions.

Furthermore, with a footprint about half the size of conventional UPS technology, a modular system can be particularly effective for data centers in crowded urban areas with little or no physical space for expansion.

“The modular UPS streamlines and simplifies installation, maximizing reliability and availability while minimizing total cost of ownership,” says Elina Hermunen, global head of marketing for ABB’s UPS business. “It makes the system easier to manage and also allows for different architectures inside one data center with various levels of security, as you may find with colocation centers.”
The future of UPS
What may be the next evolutionary steps for UPS capabilities? Hermunen forecasts that UPS modules will become increasingly important and flexible technology for use in conjunction with data center microgrids powered by renewable resources. Easily maintained UPS modules will filter the highly variable power quality these sources generate to provide a clean and steady sinus wave for data center power.

She also anticipates that, before long, increasingly smart UPS systems will be able to predict power supply issues. “Data centers are becoming more automated,” she observes, “so UPS has to integrate into monitoring and managing systems. In a few years we will be focusing not just on reliability and availability but also predictability. UPS devices will collect and analyze data to predict what is likely to happen.”

As for now, modularity is rapidly becoming the standard for UPS, largely because of its ability to dramatically slash the cost of one of the data center’s greatest financial burdens—maintenance and service. A variety of DC and AC concepts are likely to be tested, with placement of UPS devices at different stages of power distribution. “We’ll end up not with just one standard model of how data centers will be built and protected,” Hermunen advises, “but the options will be narrowed to just a few, with decentralized parallel architecture currently among the hottest prospects for success.”
Unbalanced voltage supply

The damaging effects on three phase induction motors and rectifiers

Electronic control systems are the cornerstone of efficient, modern industrial processes. The performance and reliability of instruments, sensors, relays, actuators and electric motors can all be affected by the quality of power supplied to them.

Variable Speed Drives (VSD) that trip, Programmable Logic Controllers (PLC) that suddenly experience faults, motors that overheat and erroneous sensor signals can all cause interruption and shutdown of industrial processes. This can result in major restart delays, product scrapping, customer dissatisfaction, consequential losses and significant costs to business.

Unbalanced voltage causes

All electrical networks suffer from power quality issues in varying degrees and frequencies. Brief sags and surges are common but networks can exhibit voltage supply irregularities that may be present for prolonged periods of time, or are constantly present on the network. Where a voltage imbalance exists on a supply network, it is usually due to generation faults, unmatched impedance on transformer banks, or large single phase loads on the three phase network.

Customer installation produced voltage imbalances are most commonly the result of single phase loads not connected evenly across the 3 phase system. Single phase motors, heating and cooling loads are very commonly connected in such a manner that one phase conductor carries significantly more current than the other two. The Line to Neutral Voltage of one phase is lower that the other two. Similarly, where the majority of the load is connected over only two phases, one Line to Neutral voltage is higher than the other two. In either case, Line to Line voltages are affected.

Figure 1 demonstrates an over voltage on one line, and an under voltage on another at the Medium Voltage (MV) or High Voltage (HV) transformer, while the third is at specified voltage. On the Low Voltage (LV) secondary, not only are the Line to Neutral voltages on two phases clearly over and under by 10% respectively, measuring the Line to Line vectors (dashed lines) shows voltage varying from specification.

This white paper deals only with the simple over and under voltage and the influence on motors and electronic rectifiers and the consequential effects of those devices. Further reading is available in other papers referencing phase angle shift that occurs with unbalanced voltage in three phase installations.

Unbalanced voltage and induction motors

The effect of unbalanced voltage on induction motors is widely known by most technicians and plant engineers. Motor torque and speed are negatively affected and the motor may produce excessive noise. The voltage imbalance can also cause an increase in current imbalance and a temperature rise far greater than the voltage imbalance percentage. We can calculate the increased temperature in an induction motor winding as a result of voltage imbalance.

Voltage imbalance in a three phase system is expressed as a single percentage. As in Figure 1, there may exist an under voltage and an over voltage.

Figure 1
To calculate the system imbalance and the resulting temperature rise in the winding, the following formulae are used:

\[
\text{Voltage imbalance} \% = \left(\frac{\text{Maximum imbalance}}{\text{Average voltage}}\right) \times 100
\]

**Example:**

- Measured line to line voltages
  - L1 - L2 = 392V (-2%)  
  - L2 - L3 = 400V (0%)  
  - L3 - L1 = 412V (+3%)  

\[
\text{Average voltage} = \frac{392 + 400 + 412}{3} = 401.33V
\]

\[
\text{Voltage imbalance} \% = \left(\frac{12}{401.33}\right) \times 100 = 2.99\%
\]

\[
\text{Temperature rise} \% = \left(\text{Voltage imbalance} \%\right)^2 \times 100 = 17.88\%
\]

The table in Figure 2 demonstrates the formula above outlining the exponential winding temperature increase, compared with the increase in voltage imbalance. An imbalance greater than 2% is unacceptable as it results in a temperature rise in the winding that will be beyond the motors specification at or near full load; the life of the motor may be decreased. NEMA limits require no more than 5% unbalanced voltage. Studies show that the average life expectancy of insulation halves with every 10° of temperature increase.

<table>
<thead>
<tr>
<th>Effect of unbalanced voltage on winding temperature for 3 phase induction motors</th>
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<tbody>
<tr>
<td>% Voltage imbalance</td>
</tr>
<tr>
<td>2%</td>
</tr>
<tr>
<td>3%</td>
</tr>
<tr>
<td>4%</td>
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<tr>
<td>5%</td>
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Not only does the increased operating heat induce premature expiration of the motor, excess current is also drawn with no additional power output, therefore over-stressing the supply cables and potentially reaching levels where the current overloads and the Variable Speed Drives (VSD) over current protection will trip.

VSD diodes, DC link capacitors and rectifier power supplies will experience additional thermal stress as a result of the increased AC line currents-to compensate for the voltage imbalance. Triplen harmonics can also be produced as a result of the increased stress to the rectifier diodes.

### Unbalanced voltage and rectifiers

Any electronic equipment that converts AC to DC will have a rectifier; computers, PLC’s, Uninterruptible Power Supplies (UPS), and VSD’s. Rectifiers are a non-linear load where the current output waveform is not linear to the voltage input waveform.

The diodes in a typical rectifier switch when the switching threshold voltage is exceeded in the positive direction. During each half cycle, two phases will exceed the switching threshold voltage, as one is decaying another is rising and vice versa—thus producing two peaks in the line current draw.

When operating correctly and the voltage is balanced, the AC supply current waveform has a double pulse per half cycle shape, as shown in Figure 4. The area under the graph is effectively power in watts, required to operate the connected DC load.

Current flow cannot transfer or commutate immediately from one diode to another in a rectifier due to supply inductance. The rectifier begins to exhibit differing conducting modes where varying numbers of diodes are simultaneously conducting. Further supply imbalance results in overlap of these modes, where more varying quantities of diodes are conducting. The angle of overlap is determined by the time taken to complete commutation.
The AC input line current waveform in Figure 5 represents an AC voltage supply imbalance of 5%. The line current waveform starts to look like a single pulse indicating an increased switching of the diodes and an increase in current through the diodes. The same amount of power still needs to be supplied, therefore the area under the graph must remain the same as in Figure 4, hence the AC line current peak is larger.

The larger the voltage supply imbalance, the more single pulse shape the AC line current waveform becomes. Again, the same amount of watts is required so the amplitude of the waveform needs to increase as the duration decreases to maintain the area. Line current significantly increases with larger voltage imbalance as shown in Figure 6.

Increased line current flows through the diodes and associated capacitors of the rectifier, increasing the stress on these components and the heat generated as a result of the increased switching load. Ripple on the supply line appears due to the high switching frequency, which leads to the existence of uncharacteristic triplen harmonics.\(^1\)

Most modern VSD's found in today's industrial plants have a Pulse Width Modulator (PWM) rectifier, where unbalanced voltage supplies will produce increased line current-a 100Hz ripple on the DC bus of the VSD and a reactive power (kVAR) increase. These phenomena can cause the VSD to trip on over current or under voltage on the DC bus. Technicians may have difficulty tracing a fault, as the connected load may not show any immediate or obvious faults.

**Correcting unbalanced voltage supply**

It is near impossible to supply industrial plants with a perfectly balanced voltage. As single phase loads are distributed unevenly or switched unpredictably, the power supply system will always contain a degree of asymmetry and there is little to no control of events on the transmission or distribution network.

The PCS100 AVC-20 designed and manufactured by ABB, is purpose built to provide continuous balanced voltage at the utility supply level. Whether the unbalanced voltage is a result of an unstable network supply or unbalanced single phase loading within the plant, the PCS100 AVC-20 will correct up to a 20% unbalanced voltage continuously, even if the voltage imbalance is permanently present on the supply.

Where the unbalanced voltage continually and randomly fluctuates due to either network issues, or loads and faults within the customers’ installation, the PCS100 AVC-20 will correct the unbalanced voltage within 20 milliseconds, or less than one cycle, and continue to correct and adjust the level of correction as necessary to ±1% of the set nominal voltage.

The presence of an appropriately sized PCS100 AVC-20 on the low voltage supply to your industrial plant can help to eliminate all the issues, process interruptions, premature aging and costs that unbalanced voltage supply to 3 phase induction motors and 3 phase rectifiers found in industrial plants can cause.

To find out more about ABB’s PCS100 AVC-20 solutions:

www.abb.com/ups

**References**


Eliminating voltage sags

06. An underground data center
Uninterruptible power for Ficolo’s 8,500 square meter underground data center

09. Cyberex UPS FAQs
The most frequently asked questions about Cyberex UPS, now answered

16. Center of attention
The rise of the cloud is radically changing the data center industry

23. Voltage conditioning for sag correction
The PCS100 Active Voltage Conditioner 40 delivers rock-solid voltage

Continuous voltage regulation

06. Automotive excellence
Voltage regulation for one of the world’s largest vehicle manufacturers

10. Power protection sewn up
Continuous power for one of Vietnam’s leading polyester fiber manufacturers

14. The new PCS100 AVC-20
Active voltage conditioner designed for voltage regulation

18. Powering aerospace development in China
Protecting China’s large passenger aircraft program

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A continual, regulated supply of utility voltage?

Absolutely.

The PCS100 AVC-20 is a power protection system designed for use in industrial and large commercial operations in environments where an unstable network or utility voltage affects productivity. The system ensures a continual, regulated supply of utility voltage where the electric infrastructure is stressed, unstable or unreliable. Visit www.abb.com/ups/pcs100