Reliable performance

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Power correction that you can rely on?

Absolutely.

By choosing from ABB’s PCS100 Industrial UPS solutions, you are selecting from a unique line up of advanced technologies and expertise. This low voltage power protection product provides a lifetime energy storage, high efficiency and availability and a small footprint. With ratings from 150 kVA to 3000 kVA, the PCS100 UPS-I gives superior value to operations in the industrial, utility and commercial sectors. Visit www.abb.com/ups
For this edition of our magazine, I have been invited to say a few words about how our UPS, power conditioning and power solutions business looks heading into the end-of-year holiday season.

Without a doubt, one of the big stories this year is the product launch of our Conceptpower DPA 500. The UL version, which was launched at the 7 x 24 conference in San Antonio, received a very enthusiastic reception indeed. This modular UPS covers the power range from 100 kW to 3 MW and is ideal for those looking for a compact UPS solution with zero downtime and maximum availability. DPA 500 has definitely struck a chord with customers. For instance, we have just sold two systems to the Tokslordmart nylon and plastic factory in Nigeria, where high power density was definitely a fundamental requirement, given the lack of available space for the installation.

While winning a new customer is a great achievement, what is even better is to win back a former customer. This is what has happened with China Star Optoelectronics Technology (CSOT), a major Chinese flat panel display (FPD) manufacturer. After losing out to competition in a previous bid, ABB has again taken control and won the contract to provide sixteen PCS100 AVC-40 active voltage conditioners to CSOT. With China’s FPD industry booming, CSOT is increasing operations and investing 16 billion yuan into a new facility in Wuhan City. ABB’s active voltage conditioner has already protected CSOT’s Shenzhen factory from several voltage sags that caused other unprotected loads to shut down, and this fact stood us in good stead in the current pursuit.

In Asia, ABB’s UPS products were showcased at three Asian events in 2015. Thanks to the sterling efforts of ABB’s UPS representative in Korea, Mr. Shin Deok-Young, and our local partner there, IEC, we have been able to make a big splash with our UPSs at the two major 2015 industry trade fairs in Korea - the Global Electric Power Tech and the Seoul International Electric Fair, SIEF. Meanwhile, in Yangon, Myanmar, Mr. Zaw Lin, executive director of ABB’s partner in Myanmar, the Asia Pacific Quality Electric Co., launched ABB’s UPS products to an expert user audience. Around 80 participants from resellers and end-users attended this event, which created good follow-up leads. The event attracted a lot of interest, including Myanmar TV who turned up to interview the team.

As well as Asia, ABB’s UPS has been in the news in Germany. Under the motto “ITC Products of the Year 2015,” Germany’s leading trade magazine for the IT sector, “Funkschau”, prompted its readers to select the best and most innovative products in ten different categories.

This annual reader poll has become one of the largest surveys in the information and telecommunications business-to-business industry. This year, our Power Protection team put the Conceptpower DPA 500 into contention, with resounding success. The UPS took a proud third place in the “Uninterruptible Power Supplies” category and may now carry the “ITC Products of the Year” winners’ emblem.

Just across the border in Poland, ABB has established a new distribution partner for the UPS product range. An agreement was signed with Siltec Sp. z o.o. whereby the company will become the new distributor of ABB’s complete UPS product range: single-phase, three-phase, standalone and modular. By focusing on the development of a sales network based on cooperation with a reputable partner such as Siltec, we not only ensure an increase in market share of ABB’s UPS systems in Poland, but will also be able to provide high-quality service and technical support for end customers.

2015 has undoubtedly been a year of product highlights and a glance into 2016 reveals that the new year will be no different! Among others, we will increase the number of products we have for the UL market and we will also extend our industrial UPS offering.

I am looking forward to a very successful 2016, as I am sure you are too. It only remains for me to take the opportunity to wish you and your families a very happy Christmas and a joyful New Year.
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Scan our QR Codes with your smart phone to find web links, videos or event pages, providing further details about ABB’s products or services.
New UPS distribution partner in Poland

ABB has signed a distribution agreement with a company in Poland within the field of uninterruptible power supply systems (UPSs)

Siltec Sp. z o.o. of Poland will become the new distributor of ABB’s UPS systems on Polish territory, which will include both the delivery of sales and service. The agreement, signed during the Bielsko Energetab fair in September 2015, covers the complete UPS product range: single-phase and three-phase, stand-alone and modular type.

ABB is a global supplier of commercial UPS systems with power ratings up to 5 MW. ABB was searching for an additional distribution partner in Poland who would offer end customers a full range of services, from design consulting, through to the selection of technology and equipment sales and after-sales service and maintenance.

“We wanted to work with a company that has expertise and extensive experience in providing complete power supply systems, not just individual products,” says Renzo Salmina, Regional Sales Manager of ABB in Switzerland.

“By focusing on the development of a sales network based on cooperation with a reputable partner, such as Siltec, we not only ensure an increase in market share of ABB’s UPS systems in Poland, but also provide high-quality service and technical support to the end customers,” comments Wojciech Dziwisz, ABB’s UPS systems in Poland, and adds “we have very good products, but customers expect complete systems consisting of not only the UPS, but also batteries, security systems, or generators. To ensure that we build a good solution for the customer, everything has to be carefully chosen and many factors are taken into account. This is the reason why we need a good partner.”

Siltec Sp. z o.o., with headquarters in Warsaw, has been operating in the UPS industry since 1982. “Our company’s focus has always been on the quality of services and products offered. The partnership agreement that was signed with ABB for the sale and service of UPS fits very well with our approach and with the way in which we work with the customer,” says Radoslaw Sekura, project manager at Siltec.

First-rate ABB products, combined with experienced and qualified staff, will offer customers a comprehensive range of the highest quality.

UPS systems function as a backup uninterruptible power source, using a range of solutions for energy storage. Analysis by Frost & Sullivan shows that the market for UPS systems in Poland is expected to grow by more than 6 percent per year and in 2017 achieve a value of over $75 million. Clients for UPS solutions are largely owners of data centers and public sector infrastructure, where continuity of supply is of critical importance.
Winning ways

ABB’s Conceptpower DPA 500 scoops third place in ITC Products of the Year 2015

Under the motto “ITC Products of the Year 2015,” Germany’s leading trade magazine for the IT sector, “Funkschau,” prompted its readers to select the best and most innovative products in ten different categories.

This annual reader poll has become one of the largest surveys in the information and telecommunications business-to-business industry. In this, the seventh year of the poll, 6,300 readers participated, returning nearly 44,400 votes.

This year, ABB put the Conceptpower DPA 500 into contention with resounding success. The Conceptpower DPA 500 took a proud third place in the “Uninterruptible Power Supplies” category and may now carry the “ITC Products of the Year” winners’ emblem. Our thanks go to the Funkschau readership who participated in the poll.

Mike Umiker, Local Product Group Manager Power Protection, accepted the award in Sasbach on behalf of ABB. He commented, "thank you to the Funkschau readers who voted ABB’s DPA 500 UPS solution as being one of the best ICT products in the UPS category. This is a clear confirmation that our highly efficient and modular plug-DPA 500 UPS meets the high availability and flexibility expectations of modern data centers and other users with critical electrical loads."
ABB wins back major Chinese manufacturer

Power protection for CSOT's new flat panel display factory in Wuhan City
After losing out to competition in China Star Optoelectronics Technology's (CSOT) phase two project, ABB has again taken control and won the contract to provide sixteen PCS100 AVC-40 Active Voltage Conditioners to China's major flat panel display (FPD) manufacturer.

With China’s FBD industry booming in recent years and consumer demand expected to remain strong in China, local makers are expanding their production capacity. By 2018, China is forecast to become the largest FPD-producing region in the world, accounting for 35 percent of the global market. Thus, to further enhance the competitiveness of the company, CSOT are increasing operations and investing 16 billion yuan into a new 6G facility in Wuhan City. The flat panel display (FPD) fabrication environment is among the world’s most competitive and technologically complex, making reliable power protection a paramount addition to operations.

ABB’s Active Voltage Conditioner (AVC) has already protected CSOT’s Shenzhen factory from many voltage sags over the years, which caused other unprotected loads to shut down. Therefore the investment in ABB’s technology for the new Wuhan factory made complete sense, to ensure they receive the advanced power protection required to protect their sensitive process tools.

Mr Dai, Junsong, power manager for the CSOT Wuhan project says “ABB’s Active Voltage Conditioners in our Shenzhen factory have performed very well. We experience a number of thunderstorms in summer here in Shenzhen and the AVC has always successfully protected the loads from voltage sags.”

A reliable low-maintenance solution
The PCS100 AVC-40 is an innovative solution to industrial voltage supply problems. Providing conditioned power without relying on energy storage systems means that the system has a small foot print and is free from the cooling (air conditioning) requirements of battery units. “We chose ABB’s PCS100 AVC-40 for three important reasons. Its performance in our current factory in Shenzhen where it has never dropped a load in four years, it doesn’t require batteries and it is extremely reliable," continued Mr. Dai.

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The PCS100 AVC-40 is frequently implemented in businesses using sensitive or high-precision equipment where the loss of voltage for even a few milliseconds results in the failure of the machinery and damage to its yield. The PCS100 AVC-40 corrects under or over-voltage events in less than five milliseconds, allowing sensitive equipment to remain operational throughout the disturbance.
DPA 500 bound for Nigeria

ABB’s Conceptpower DPA 500 modular UPS fits the bill in Nigeria
ABB’s Conceptpower DPA 500 modular uninterruptible power supply (UPS) fulfills power requirements from 100 kW to 3 MW and provides maximum availability for those who aim for zero downtime as well as a low cost of ownership.

The modular, parallel architecture underpinning the Conceptpower DPA 500 delivers a highly reliable product that is easy to maintain. Modularity lends itself well to keeping UPS footprints small, which is ideal where real estate is limited and expensive - as a modular UPS rack has a small footprint and when extra modules are added, no extra floor space is required. It is exactly this ease of expansion, without consuming further real estate, that has attracted the Tokslordmart nylon and plastic factory in Nigeria.

“The Tokslordmart factory presently has a 250 kVA Riello UPS and the management wants to add more machines to the production line,” explains Ahmad Awad, ABB’s Regional Sales Manager, MEA. “However, the power room is a bit short of space, so it would become very congested if he were to add any more standalone systems.”

The customer first became aware of the Conceptpower DPA 500 at a seminar organized by ABB’s channel partner Powercell at the Sheraton Lagos Hotel in May 2015. Mr. Ahmad Awad gave an inspiring product presentation of this modular solution and highlighted its advantages – especially the ease of future expansion and the simplicity of service. Expanding the DPA 500 at a later date does not consume any more floor space within the power room.

The customer has now ordered two DPA 500 units, including two modules in each, which are soon to be installed and commissioned in collaboration with ABB’s local partner, Powercell.

Overall, the Conceptpower DPA 500 has been a great success, with an impressive installation base spread around the world and no quality issues.
Unbalanced voltage supply; the damaging effects on three phase induction motors and rectifiers

An interview with Holger Hannemann - Global Sales Manager, ABB Power Conditioning

Could you provide our readers with an overview of the history of ABB’s Power Conditioning business and a summary of your most recent projects?

It started in 1995 with the idea of power electronics based products to protect industrial applications from power quality problems. Voltage sags or dips were identified as the problem with the highest financial impact on operations. In 1997, we successfully commissioned our first Active Voltage Conditioner in a facility producing PET drinking bottles. Together with our customers, we developed a range of products and solutions to protect sensitive equipment from external supply problems and problems created by their own operations. Depending on the customer’s protection philosophy and technical infrastructure, we offer industrial UPS systems at low and medium voltage levels, static frequency converters, reactive power conditioners and voltage conditioners.

In 2014, we launched a Medium Voltage UPS and one year on, we have delivered units to a number of sites. This year we gave our voltage conditioner a facelift. The PCS100 AVC-40 and most recently the PCS100 AVC-20, a new voltage regulator product targeting markets with generation issues, where the voltage is out of the tolerance band for long durations. Since 1997, we have installed thousands of units with over 1000 MVA worldwide.

What are the main causes of an unbalanced voltage supply?

In most cases, an unbalanced loading of the three phases causes voltage imbalance. These could be single or two phase loads that are not equally split over all phases, for example boilers, heaters, air conditioning, welding and single phase power supplies for computers or servers etc.
What issues can an unbalanced voltage supply cause for commercial and industrial companies?
The problems typically arise on connected three phase loads like motors, drives and rectifiers. The loads will draw the same amount of power, but due to unbalanced voltage this will affect current wave forms causing increased stress on all of the components. With motors you can hear it by an increase in noise and see it as torque and speed issues plus an extreme temperature rise. Voltage imbalance has a negative impact on the life expectancy of motors and power electronics. Let’s take an example; a 5% voltage imbalance results in a motor temperature increase of 50%. But every 10 degree temperature rise halves the life expectancy of the motor insulation. So operating a motor with 5% voltage imbalance means this machine will reach less than 5% -10% of its typical age.

You have just released a new voltage-regulating product, the AVC-20, where do you see this being used? Are there any specific markets that you are targeting?
The AVC-20 is targeting long duration voltage regulation problems, which are called brown outs. The voltage deviates on one or more phases from nominal values, for minutes or even hours. Often, it is a result of local generation capacity issues and can be seen in developing countries where the power supply can’t cope with the increased demand. Typical areas are the Middle East, Africa or India where the supply voltage may be lowered by 10-20 % for many hours.

How does the AVC-20 correct an unbalanced voltage supply?
The AVC-20 uses the same topology as our AVC-40. We measure the supply voltage and correct voltage magnitude and phase angle problems on the load side of the device. While the AVC-40 deals with very deep voltage dips for a short period of time (seconds), the AVC-20 can correct +/-20 % of voltage deviation without any time limit.

Conventionally how have businesses had to resolve the complications of fluctuating voltages? What advantages does the AVC-20 have over these methods?
In most cases it has been up to the business to deal with the problem. Typical solutions are a tap change transformer (usually 1-2% voltage steps) or a servo regulated transformer to adapt or correct the voltage. They are physically big, introduce losses of another 3-5% and have a slow response time. The AVC-20 is typically half the size, lower losses and is much faster in resolving the problem. After 20 milliseconds the voltage and phase angle problems are corrected and this is fast enough to protect assets and operations from tripping.

As the world becomes more developed and industrialised do you believe unreliable electricity sources will become a more prominent issue?
Utilities, especially in developed countries, do a very good job offering a stable and uninterrupted power supply, but unfortunately they cannot protect from every scenario. Overhead lines are exposed to weather events, therefore exposed to lightning or trees touching a line. Other customers connected to the same distribution can also introduce problems that are caused at their end. While we barely see power outages, we have voltage events everywhere in the world, so there is a growing demand in power protection.

Does ABB have plans to develop similar equipment in the future? What are the difficult problems in power regulation that you would like to solve?
We are always working on new solutions and currently have many ideas and desires to implement these. A tendency that we often see is “bigger is better”, system sizes are growing and there is a demand for a complete power protection solution at higher voltage levels. These solutions are expected to offer a smaller footprint and higher efficiencies to lower operational expenses. We are working on our next generation of power electronics which will be the base for new products to address our customers’ needs.

To read the white paper about unbalanced voltage supply and the damaging effects on three phase induction motors and rectifiers, please click here.
ABB's UPS systems on show at the Global Electric Power Tech exhibition in Korea

ABB's UPS showedcased in Asia

The advantages of ABB’s uninterruptible power supplies (UPSs) have been introduced to several large audiences of industry professionals in a series of events in Korea and Myanmar.

Thanks to the sterling efforts of ABB’s UPS representative in Korea, Mr. Shin Deok-Young, and local partner International Electric Company (IEC), ABB was able to make a big splash at the two major industry trade fairs in Korea.

In May, at the COEX exhibition center in Seoul, ABB’s UPS products were well presented at the Global Electric Power Tech - a top exhibition for electric and energy industries in Korea attended by over 30,000 professional decision makers from the construction, inspection, safety supervision, general industry and maintenance sectors. These visitors, from 360 companies in 29 countries see the exhibition not only as an opportunity to catch up on the latest technology in the field, but also as a chance to meet fellow professionals from the industry and expand their network of expert contacts.

A range of ABB’s UPS products were on display at the exhibition, with a team of sales and technical experts on hand to explain the features of the products. For example the unique advantages of the decentralized parallel architecture of our DPA 500 UPS.

UPS products were on show again in October at the Seoul International Electric Fair (SIEF), in the same venue. This event, hosted by the Korean Ministry of Trade, Industry and Energy, attracted around 15,000 visitors to 500 booths to witness the very latest in electrical products.

SIEF, co-hosted by Korea Electrical Manufacturers Association (KOEMA) and Korea Electric Power Corporation (KEPCO), offers visitors a first-hand view of new products for transmission, distribution, generation, nuclear, railway electrification and LED lighting.

Meanwhile, in Yangon, Myanmar, Mr. Zaw Lin, Executive Director of ABB’s partner in Myanmar, the Asia Pacific Quality Electric Co., launched ABB’s UPS products to an expert user audience of uninterruptible power supplies. About 80 participants from resellers and end-users attended this event that created some credible follow-up leads. The event attracted much interest - even the MRTV4 TV Station came to interview the team.

These events are very valuable in highlighting the advantages of ABB’s UPS to a range of new professional users, and it is hoped to run similarly successful events in the region in 2016.
Conceptpower DPA 500 makes North American debut

Over 700 attendees witness the newly released 480V system.

ABB’s Conceptpower DPA 500 UL UPS made its North American public debut to data center integrators at the 2015 7x24 Exchange End-to-End Reliability Conference in San Antonio, Texas, from November 15–18. Over 700 attendees were the first to see the 480V system during three days of exhibition.

7x24 Exchange is a leading provider of conferences enabling collaboration and knowledge sharing amongst industry professionals. The 2015 fall forum topics focused on “Commitment to Excellence” in data centers. Building on this theme, the Conceptpower DPA 500 UL UPS was the focal point of a collaborative showcase of ABB’s broad range of products and integrated solutions that ensure data centers operate with optimum reliability and efficiency. Attendees that visited the booth demonstrated much enthusiasm over the 480V modular UPS technology and the ABB team secured over 80 key prospects from the conference networking activities.

In addition to the exhibit demonstrations, ABB lead a panel discussion on best practices for achieving comprehensive sustainability in data centers. The panel also provided best practices for assessing data center productivity and managing the lifecycle of a data center. These insights will enable end users to look at all different aspects of a data center – from upstream, to operations, to end-of-life for parts and systems – and how to effectively weigh tradeoffs.

ABB plans to return to the spring conference in June of 2016 where conference topics will focus on “Navigating the Future” in mission critical facilities.

Watch the DPA 500 UL UPS video here.
Preventing transformer saturation in static transfer switches

Introduction:
Static Transfer Switches (STS) are essential components in data center power system configurations. Mainly relying on transformers primary side switching, these devices are the bridge between the power sources and the power distribution units. This architecture offers many advantages to the customer in terms of smaller footprint and lower costs; however, if not properly switched high transient inrush in downstream transformers will occur.

The inrush currents produced degrade the power quality of the preferred source, overload upstream UPS's and trip protective circuit breakers. The inrush currents can also create intolerable forces in the windings, which in turn reduce the lifecycle of power transformers as these currents can reach the short circuit rated value and can last many cycles before they dissipate.

This paper will explain the saturation phenomena in detail, derive appropriate equations to understand this behavior and present a state of the art method used by the SuperSwitch®4, static transfer switch, to successfully eliminate and limit the inrush should a transfer be required.

What are we solving?
The typical data center system design incorporates two separate Uninterruptible Power Supplies A and B feeding the preferred and alternate sources of the SuperSwitch®4, this is shown in figure 1. These devices are the bridge between the power sources (UPSs) and the power distribution units (PDUs) where a transformer is needed to typically switch the 480V side (primary) to the 208V side (secondary). The primary side switching (480V) is the most common and cost effective architecture to the customer in terms of smaller footprint and lower costs, because only one transformer is needed. The alternative architecture would be to switch to the secondary, which would require each source to have its own fully rated transformer and increase the rating of the SuperSwitch®4.

![Figure 1: Primary Switching Architecture](image)

Typically UPS A and B are fed from the same utility grid and thus their inverters will synchronize to their inputs and accordingly will be in phase. However, during battery operation, each UPS runs on its own internal clock and the sources will drift apart in phase. The problem is more obvious if each UPS has its own dedicated emergency generator. When a 480V SuperSwitch®4 needs to conduct an emergency transfer during an out of phase condition, large inrush currents drawn from downstream PDU transformers can occur if the method of switching is improper. Depending on the transformer used, the inrush produced is capable of reaching 11x the rated current during an emergency transfer, the SuperSwitch®4 and its components are designed to handle this extreme overload situation but there are some significant problems triggered elsewhere, threatening the data center reliability and availability:

- Breakers will likely trip depending on their sensitivity and the inrush magnitude
- Upstream UPSs should enter some “current limit mode” and might transfer to Bypass
- Stress caused to all upstream infrastructure
Some solutions
Few solutions exist to this problem; one would be to have a topology where each source is connected to its own PDU. This approach would not suffer from inrush as the downstream transformer is completely eliminated; however, more space is required and the additional magnetics is costly. Some UPS manufacturers have worked on solutions to force UPSs to be synchronized, however this adds complexity and single points of failure which would threaten the reliability and availability of the data center.

The best solution: A real time switching method
With state of the art digital signal processors and a newly developed algorithm that will be introduced in this paper, an innovative approach was created: Real Time Flux Control™ for dynamic inrush restraint (DIR), this approach makes it possible to switch the primary side of the transformer while exceeding the CBEMA/ITIC standards regardless of the phase difference of the two sources or the failure type. The method computes the flux trapped in the transformer in real time and continuously determines which SCRs to fire independently should a power quality event occur.

The next sections will introduce some transformer principles and derive appropriate equations to solve the problem discussed, results will be examined and peak inrush investigated so as to evaluate the method.

Transformer saturation and the inrush equation
To understand the transformer saturation and how it produces inrush currents a simplified equivalent circuit for an unloaded transformer is shown in figure 2.

Figure 2: Equivalent Circuit of an unloaded transformer

Where:
V1 is the supply voltage.
Lm is the core magnetizing inductance.
Rm is the core loss resistance.
L1 is primary winding inductance.
R1 is primary winding resistance.

Assuming the transformer supply voltage has a sinusoidal waveform:

\[ v1(t) = Vm \cdot \sin(2 \cdot \pi \cdot f \cdot t + \alpha) \]  (1)

Where:
Vm is the voltage Amplitude.
f is the frequency in Hz.
\( \alpha \) is the energizing angle, this parameter as it will be shown later, is of great importance.

Writing KVL² for the circuit shown above:

\[ L \cdot \frac{di(t)}{dt} + R \cdot i(t) = Vm \cdot \sin(\omega \cdot t + \alpha) \]  (2)

Where:
i(t) is the instantaneous no-load current, L = L1 + Lm and R = R1 + Rm.
Alternatively:

\[ L_m \cdot i(t) = N_1 \cdot \Phi(t) \quad (3) \]

Where:

\( N_1 \) is the number of primary turns.

\( \Phi(t) \) is the instantaneous magnetic flux.

Substituting (3) in (2) produces a first order differential equation:

\[ N_1 \cdot \frac{d\Phi(t)}{dt} + N_1 \cdot \frac{R}{L} \cdot \Phi(t) = V \cdot m \cdot \sin(w \cdot t + \alpha) \quad (4) \]

The solution to equation (4) takes on the following form:

\[ \Phi(t) = -\varphi_m \cdot \cos(w \cdot t + \alpha) + C \cdot e^{-\frac{R}{L} t} \quad (5) \]

Where:

\( \varphi_m \) is the flux amplitude and can be obtained from the applied voltage.

\( C \) is a constant that is derived from the initial power up.

When the transformer core is magnetized in a specific direction, it will not drop back to zero magnetization when the initial field is removed. It can be driven back to zero by a field of opposite direction. This causes the magnetizing curve of the transformer (or any ferromagnetic material) to trace out a loop called the hysteresis loop or the B-H curve, as shown in figure 3.

The amount of flux trapped in the core material of any transformer is called the original flux density and can take either a positive or a negative value (\( B_r \)) as shown in figure 3. At first power up the transformer will still hold this amount of flux noted \( \Phi_r \).

In this case:

\[ \Phi(0) = \pm \Phi_r \quad (6) \]

Using equations (5) and (6) and solving for the constant \( C \):

\[ C = \varphi_m \cdot \cos(\alpha) \pm \Phi_r \quad (7) \]

Replacing \( C \) in equation (5) yields:

\[ \Phi(t) = -\varphi_m \cdot \cos(w \cdot t + \alpha) + (\varphi_m \cdot \cos(\alpha) \pm \Phi_r) \cdot e^{-\frac{R}{L} t} \]

Knowing the instantaneous flux the current can easily be calculated by:

\[ i(t) = \frac{N_1}{L} \cdot \Phi(t) \quad (9) \]

From equations 8 and 9, it is clear that the transformer saturation depends on the firing angle \( \alpha \) and the residual flux \( \Phi_r \) trapped in the core. As power transformers are operated at a peak flux \( \varphi_m \) close to the knee of the transformer's B-H curve, only a modest flux increase beyond saturation, or a symmetry shift of the flux will result in very high magnitude current “pulses,” because at that instant the slope and therefore the inductance is very small. In figure 3 the slope at any point is proportional to the winding inductance \( L \).

Transformer switching theory

Equation 8 can further be split into a DC component and an AC component:

\[ \Phi(t) = \Phi_{AC}(t) + \Phi_{DC}(t) \quad (10) \]
Where:

\[ \Phi_{AC}(t) = -\Phi_m \cos(\omega t + \alpha) \quad (11) \]
\[ \Phi_{DC}(t) = (\Phi_m \cos(\alpha) \pm \Phi_r) e^{-\beta t} \quad (12) \]

As explained in the previous sections, in order to avoid any inrush currents the transformer core needs to be kept away from saturation, which implies that the DC component represented by equation 12 has to be mitigated. The residual flux \( \Phi_r \) is uncontrollable and is mainly dependent on the transformer geometry and the instant of de-energization. On the other hand, the firing angle can easily be controlled since the power supply \( V_1 \) is usually connected to the transformer through some power semiconductors SCRs, IGBTs, etc. In that context \( \alpha \) will be of highest importance in the inrush restraint algorithm. It should be observed that the DC component of the flux has an exponential term which is responsible for the decaying nature of the inrush current.

Figure 4 shows instances of optimal transformer energizing or re-energizing. At these two instants, the prospective flux and the residual flux are equal, eliminating the DC component of the flux thus preventing the transformer saturation and inrush currents.

The static transfer switch architecture

As stated in the introduction of this document, Static Transfer Switches (STS) are devices that bridge the power sources and the power distribution units (PDUs) by using SCRs as switching devices as described by figure 1. The theory of transformer saturation was covered in the previous sections. From this point and forward the SuperSwitch®4 performance and how it handles transfers will be the focus. To avoid saturating the transformer, a controlled switching method needs to be implemented to eliminate the DC flux component described by equation 12 in the previous paragraphs. To maintain acceptable power quality the SuperSwitch®4 needs to transfer the load from being fed by a preferred source to an alternate.

The missions that the SuperSwitch®4 needs to accomplish when performing a transfer are summarized by the following points:

1. Suitable primary switching method for three phase power systems
2. Compatible with all types of transformers
3. Meets or exceeds the CBEMA or ITIC standards
4. Inrush in all three phases

To overcome all the shortcomings and achieve the targets discussed herein, the Real Time Flux ControlTM method was developed as the ultimate flexible solution. Taking advantage of proprietary state of the art printed circuit board (PCB) developed, powerful digital signal processors (TMS320C6746) were used for the necessary computation and power detections algorithms. The PCB used, communicates via high speed fiber links with gate drive boards controlling all the SCRs at each source, the embedded controls is in charge of finding the optimal firing angles limiting the inrush in case a transfer is needed.

Real Time Flux ControlTM method

Taking advantage of the internal architecture of the SuperSwitch®4 and cutting edge technology available, a method was invented to dynamically reduce the transformer inrush. This method controls the amount of flux induced in the core should a transfer be needed, accordingly given the name Real Time Flux ControlTM for dynamic inrush restrain.

![Figure 4: Optimal firing angles](image-url)
As the goals discussed in the previous section must be met and the transformers used in these applications are delta to wye, the algorithm will have two optimal firing angles.

The DSP receives the voltage samples via high speed communication links and computes the normalized flux in real time. Should a transfer decision be made, the processor will have to fire the SCRs at the optimal closing times given by:

\[
\begin{align*}
\lambda_1 &= \int v_1(t) \, dt \\
\lambda_2 &= \int v_2(t) \, dt
\end{align*}
\Rightarrow |\lambda_1 - \lambda_2| \leq \epsilon
\tag{13}
\]

Where:
- \(\lambda_1\) is the normalized three phase fluxes of source 1
- \(\lambda_2\) is the normalized three phase fluxes of source 2
- \(\epsilon\) is the error allowed and should be kept as small as possible

The fact that the fluxes are normalized makes the SuperSwitch\textsuperscript{®}4 compatible with any transformer type and size, no changes are needed should the customer require a new Power Distribution Unit with a different transformer. If an emergency transfer is required, the SuperSwitch\textsuperscript{®}4 would first issue an un-gate command to disconnect the load from the failing source. This is shown by step 1 in figure 5 where all the SCRs are turned off\(^3\). Once the SCRs have completely commutated off, the algorithm then starts monitoring the very first phase that satisfies equation 13. Once that phase is found it has to be fired as fast as possible; this is represented by step 2. The algorithm was designed such that it does not miss an optimal time to fire, thus enabling to transfer the load within a cycle and thus exceeding the CEBMA and ITIC standards.

Finally, the system monitors the other two remaining phases, once equation 12 is satisfied all phases are fired, completing the transfer from the preferred to the alternate source, step 3. The total time required to finish all these steps cannot violate the CEBMA or ITIC standards as stated before. The next section will demonstrate this performance further.

The algorithm can fire all the phases at the same time as well if the fluxes of the alternate source are deemed satisfactory to equation 13. This is possible only under certain cases if the phase difference between the two sources allows for such a condition to happen. If this is done, then the transfer is accomplished very quickly and called a super transfer. This makes the combined sense and transfer time less than 8 milliseconds as shown in figure 6.
How well does the novel method work

Currents and voltages were measured at the different probing points shown in figure 1. Figures 7–12 show the performance of a 480V, 600 amp SuperSwitch®4 feeding a 225kVA PDU transformer. No inrush was observed, in addition the combined sense and transfer time is given below each waveform and is measured to be less than a cycle even under severe test corners, like a complete loss of source or loss of one phase.

Figure 7: Phase: 120 degree, outage time: 11.50 ms
Condition: Loss of source 2

Figure 8: Phase: 60 degree, outage time: 5.50 ms
Condition: Loss of source 1
Figure 9: Phase: -120 degree, outage time: 8.00 ms
Condition: Loss of source 1

Figure 10: Phase: 0 degree, outage time: 14.50 ms
Condition: One phase loss of source 2
Power protection – UPS

Figure 11: Phase: -60 degree, outage Time: 14.50 ms
Condition: Manual transfer

Figure 12: Phase: 180 degree, outage time: 11.50 ms
Condition: Manual transfer
The waveforms shown in figure 7–12 clearly prove that the SuperSwitch®4 is capable of successfully transferring the load under multiple fault condition in less than a cycle. Note that in figure 8 a super transfer was possible and all the alternate source SCRs were fired at the same time making a complete transfer possible in less than 8 milliseconds. The lowest RMS drops observed during all the transfers taken for phases A, B and C were computed by:

$$\% \text{ RMS drop} = \frac{\text{Rated RMS Voltage Bus} - \text{Lowest RMS drop measured}}{\text{Rated RMS Voltage Bus}} \times 100$$  (14)

For the case of a 480V RMS load we get:

$$\% \text{ RMS drop} = \left(1 - \frac{\text{Lowest RMS drop measured}}{480}\right) \times 100$$  (15)

These values were then plotted against the outage time, figure 14 shows that all the data points obtained are located well inside the acceptable power zone and thus exceeding the CBEMA and the ITIC requirements.

The Real Time Flux Control™ for dynamic inrush restraint also does a phenomenal job limiting the inrush peak value in transformers to below 1.2x. This value is calculated as shown in figure 13 where the peak transformer current rating is always a constant depending on the KVA of the system.

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**How is the SuperSwitch®4 set to handle transfers?**

As explained before, the SuperSwitch®4 constantly monitors the power quality of both sources taking into account the customer specified thresholds. In addition three transfer modes are available to customers to choose from: A9, DIR always and DIR Limited.

1. **A9**: is a proprietary algorithm that is used only when the phase difference between the sources is less than a user-defined phase angle, the range of this setting is adjustable up to a maximum of 30 degrees. This method is not recommended for larger phase differences and customers are recommended to make this window as small as their application permits. To explain this method further and limiting the study to only one phase instead of three for the sake of simplicity, the layout of the SCRs and sources is shown in figure 15. If A9 was the chosen transfer mode and the two sources were synchronized then the first step is to un-gate both Source 1 positive and negative SCRs. The algorithm then detects which SCR is safe to fire on source 2 as an alternate depending on the phase difference of the two UPSs, if the sinusoidal voltage happens to be positive then the negative SCR will be fired because it is not conducting and no chances of cross connect exist.
In a third and final step the SuperSwitch®4 would then wait until the next zero crossing to fire the positive SCR completing a seamless transfer. These steps are clearly depicted in figure 16.

2. DIR always: implies that the SuperSwitch®4 will always transfer using the approach described before and should result in no inrush no matter how far the two sources are drifted apart.

3. DIR limited: is the setting recommended for the SuperSwitch® 4 to determine which of the previous two methods to pick from depending on the phase difference.

Most customers use the recommended setting of DIR limited because the SuperSwitch®4 will auto select when, and if, the DIR function is needed depending on the phase difference as illustrated by figure 17.

Conclusion

The data that was collected and presented in this literature proves that the Real Time Flux Control™ method for dynamic inrush restraint prevents the transformer from saturation while the SuperSwitch®4 transfers the critical load from a failing to an alternate source.

The following are some key points that this method achieves:
- Makes secondary switching (one PDU transformer) reliable
- Eliminates the need for complex inverter control schemes
- Maintains true independence between UPS systems (higher reliability)
- Keeps inrush value lower than 1.2x
- Exceeds the ITIC and CBEMA curves standards for critical loads
- Smoothly transfers the load without creating unnecessary voltage discontinuity and disturbances to the load

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