AN INTEGRATED DATA CENTER SOLUTION ON MEDIUM VOLTAGE LEVEL

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ABSTRACT

Outsourcing, co-location and cloud computing, energy and cost-efficiency, environmental and legislative issues: running a data center in a constantly changing world is a huge challenge.
In terms of electrical needs, scalability and speed to installation are second only to the absolute need to maximize uptime – the availability of power at all times. Also the power consumption is rising in this segment rapidly, so the distribution voltage levels become higher. Power consumptions of 15MW and higher are no exceptions anymore.
Hitec Power Protection, a leading manufacturer of rotary Uninterruptible Power Supply (UPS) systems using flywheel energy storage is active in the data center business for over 20 years. One of their integrated solutions operates on medium voltage level and is the perfect green and efficient solution for high power data centers.
Looking at high power data center applications on medium voltage level, the biggest challenge was to find a green (SF6 free) switchgear with a small footprint, a maintenance free mechanism with a high number of operations, high reliability and that is easy to scale. With Eaton's new modular switchgear type Power Xpert FMX, Hitec found their switchgear. The switchgear is modular in design. Besides that it contains a very reliable Electromagnetic mechanism that can switch more than 30.000 operations which is very suitable for high power rotary UPS systems, but also for the (smart)grid connection, where intelligent switching algorithms might be requested.
This paper describes the challenges in designing a complete integrated high power data center application, with in- and output on medium voltage level, a solution Hitec and Eaton developed together.

AN INTEGRATED SOLUTION

Society and business are becoming more IT dependent. This requires construction of more and larger data centers all over the world. Their design and operation need to meet the highest requirements regarding reliability, availability, security, energy efficiency and cost-efficiency. It is therefore no surprise any more that the IT industry becomes one of the largest energy consumers, the total electricity use by data centers in 2010 was about 1.3% of all electricity usage worldwide. That is the total power consumption of around 31GW with a projected rate of increase of 19% into 2012 [1].

A large data center requires not only tents of megawatts of power, it requires also a secure, continues and conditioned high power supply for its critical processes, which are primary computing processes and secondary supporting facilities such as cooling. The need for reliability, high efficiency, low environmental impact, scalability of capital investments, modularity in the design approach and increasing power density, influence the power supply infrastructure of the high power data centers.
The Integrated High Power Solution consist of medium voltage Diesel Rotary Uninterruptable Power Supply (DRUPS) and integrated medium voltage high performance switchgear (Figure 1). The system is situated between the power grid and the critical load at medium voltage level and provides the conditioned, uninterruptable and continuous power supply to the critical load independently from the status of the grid. The active core of the systems are DRUPS modules working parallel connected to the input and output by means of integrated medium voltage switchgear. The number of the DRUPS modules is N+1 as required by the design standards of Data Centers, N+1 provides the required redundancy. By means of the high performance medium voltage switchgear, the High Power Solution is completely Integrated in the existing medium voltage power supply.

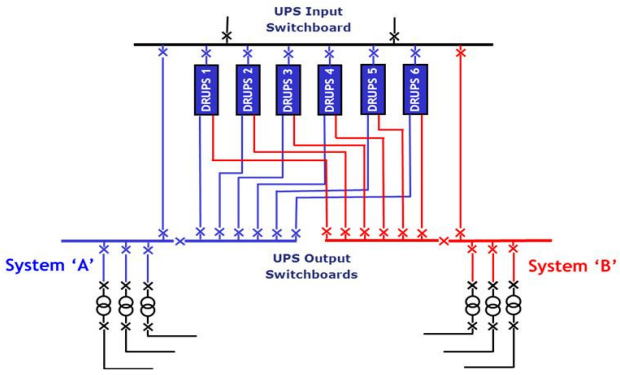

Figure 1 A typical configuration with Input Switchboard, Output Switchboard and DRUPS.

The DRUPS module is an unique rotating machine designed to provide conditioned and secure UPS power to a facility's Critical Loads and Standby power to a facility's less critical Essential Loads.

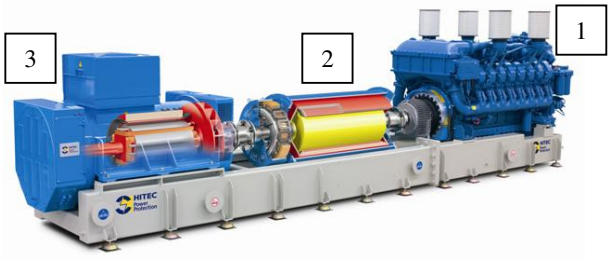

Figure 2 A Hitec DRUPS Power Module

A DRUPS power module consists of (1) a diesel engine, (2) induction coupling (including flywheel energy storage) and (3) alternator mounted on a solid base frame. In utility mode the DRUPS system acts as a power conditioner and active filter in combination with the reactor (or choke coil), eliminating brief interruptions, spikes and sags from the utility supply. If the utility supply fails, the UPS system takes over the supply of power immediately, without any interruption or disturbance. It can provide back-up power as long as there is diesel fuel available. The system is fully automated and the DRUPS control system provides the total control of the units and the circuit breakers of the integrated medium voltage switchgear based on the conditions of the utility network and the load. The system therefore requires high performance switchgear that contains circuit breakers, suitable to do a high number of the operations.

The Integrated High Power Solution with DRUPS replaces the battery backed static UPS equipment required to support the critical loads and the standby diesel generating equipment needed to support the essential loads. By combining these two functions within a single piece of equipment, the Integrated High Power Solution with DRUPS modules provides many advantages, tangible and measurable benefits for high power data centers. A few examples of these measurements are: TCO, System efficiency, CO_2 production, outage time.

The infrastructure of such High Power Solution is simple, fully automated and therefore reliable, compact and easy to scale, green / environmental friendly and safe.

RELIABILITY

Reliability is an essential requirement of an UPS system, since the main reason for having one is that the mains power supply is not reliable enough. The UPS should ensure that the critical load remains in operation, despite the unreliability of the mains. The unique concept and design of the Integrated High Power Solution with DRUPS maximizes its reliability and provides the customer with the highest available uptime. The concept requires limited maintenance.

The high reliability of the Integrated High Power Solution is achieved due to the total simple infrastructure and high reliability of the main components, built up out of proven technologies. The main components are: DRUPS units, medium voltage switchgear and the central UPS control.

The superior reliability of DRUPS is achieved by using only a few principal components (electrical machines and diesel engine) and no power electronics, inverters, rectifiers, static bypass-switches, batteries –chargers and power factor correction (PFC) equipment. Extra reliability is achieved by additional technical features, for example gravity led fuel supply to the engine, redundant starting system of the engine, complete monitoring and built in N+1 redundancy.

The reliability of the applied medium voltage switchgear is influenced by the design philosophy of the critical components. From practice it is shown that one of the most critical components in medium voltage switchgear are the moving parts in the mechanism and the cable connections. Traditional spring-charged mechanisms contain a lot of moving parts. Besides that a conventional, spring charged mechanism has force-stroke characteristics (-) that differ greatly from the required characteristics. An electromagnetic mechanism has a force-stroke diagram (-) that already resembles the force-stroke characteristic that is required for vacuum switchgear [1]. Therefore electromagnetic mechanisms can be very simple in their construction. They consist of a minimum amount of parts and can be coupled directly to the vacuum interrupter, because of the favorable force-stroke characteristics. Due to this direct coupling, maximum rigidity is reached, which is advantageous for the rate at which contact pressure is reached and the effectiveness of contact breaking. Result is a maintenance free mechanism that can switch 30.000 operations.

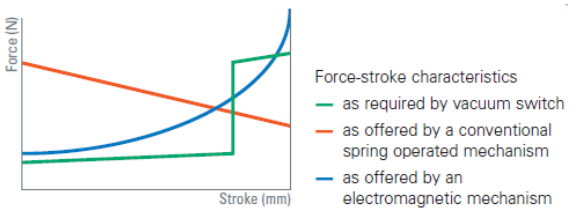

Figure 3 Force-Stroke diagram of Electromagnetic mechanism

COMPACT AND EASY TO SCALE

The Integrated High Power Solution with DRUPS modules requires approximately 40% to 60% less space than an equivalently sized conventional UPS system with standby diesel generator arrangement. This high level of space efficiency is achieved through the absence of standby batteries and their air condition equipment, power factor correction panels, generator paralleling/synchronizing panels and an overall simplification of the distribution switchgear. A number of low voltage switchboards are replaced by one integrated compact medium voltage switchgear controlled by the DRUPS system.

The parallel configuration of the integrated High Power Solution enables easy scalability of the systems by means of

adding new DRUPS modules. This is possible due to the construction of the medium voltage switchboard. The applied switchgear is modular and easy to extend.

Figure 4 Switchgear type Eaton PowerXpert FMX integrated in Hitec Power Protection Data Center solution at Achmea Campus, Apeldoorn, the Netherlands

By using a combination of cast resin technology, electrical field control and vacuum technology, panels can be constructed with a width of 500 mm at 24 kV rated voltage. Because a typical switchgear installation normally consists of a large number of panels, this compact design significantly reduces the switch room size, which is beneficial for the 'white space'.

GREEN / ENVIRONMENTAL FRIENDLY

Environmental care is getting increasingly important. Data centers are one of the largest power consumers and therefor seen more and more as companies affecting the environment. With respect to the design of the Integrated High Power solution including their main components DRUPS and medium voltage switchgear, the vision "the less number of components the better" applies. By the very nature of having fewer active components, the Integrated High Power Solution with DRUPS is far more efficient than other systems using technology of conventional UPS. While DRUPS modules can achieve energy efficiency levels up to 97%.

Besides the impact of energy efficiency of the solution, also the individual materials of the different components have a huge impact on the environment. SF6 for example is a material that has a huge negative impact. So material selection is even more important to develop an environmental friendly product [2].

No use of SF6 gas for insulation or switching

In many cases SF6 gas is used within medium voltage switchgear, because of its good insulating properties. However, emissions of SF6 gas from switchgear contribute significantly to the threat of the greenhouse effect and associated climate change. SF6 is the most potent of the six main greenhouse gasses, with a Global Warming Potential (GWP) of 23,000. SF6 is on the list of greenhouse gasses in the Kyoto protocol [3].

The medium voltage switchgear integrated in the High Power Solution uses no SF6 as switching and insulation medium.

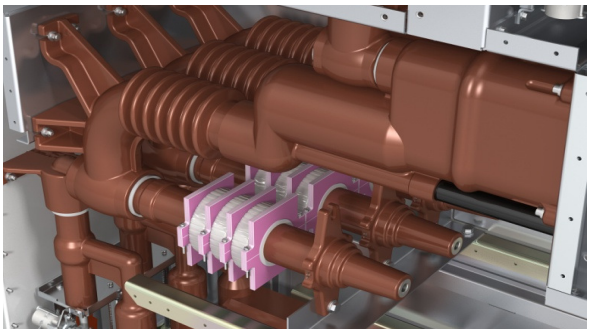

Figure 5 Environmental friendly design: cast resin in combination with air as insulation medium instead of SF6

No use of batteries to support the Critical Load

Unlike classical static UPS systems the DRUPS modules of the High Power System use stored kinetic energy to bridge the diesel engine start time when there is a utility power failure. It is a battery-free concept. In High Power Datacenters (>20MW), designed with conventional UPS, the amount of batteries can be huge. To cover a 5 minutes mains outage, needed batteries can amount to several thousands of NiCad or lead Acid batteries. This has not gone unnoticed by the EU, which already classes both Lead Acid and Nickel Cadmium batteries as hazardous waste. Furthermore, the EU is currently proposing a new 'Battery Directive' to ensure the safe and proper disposal of such batteries [5]. The fact that a DRUPS module does not use environmentally damaging and hazardous materials for the support of the critical load, means that its environmental impact is considerably less than that of conventional UPS systems.

SAFETY

The best way of preventing an operator being hurt by any accident inside a switchgear is of course providing that there is no need to be in front of the switchgear while operating the panels. The High Power Solution is fully controlled autonomous. All switching sequences are done automatically and there is no need for operating personnel to be in front of the medium voltage switchboard.

In the rare situation that operating personal is standing in front of switchgear, the probability of internal faults is very low because of its di-electrical design [6]. However, arcing energies (up to tens of MJ's), resulting in ejection of hot gases and pressure rise, could affect personal safety seriously. With the introduction of internal arc tests in IEC 60298 and IEC 62271-200 users are focusing on operator safety. Even if a very few incidents are recorded,

manufacturers are still required to prove the ability of switchgear to withstand the internal arc tests.
The overpressure and hot gasses, created by an internal arc will, in standard switchgear, be channeled out of the switchgear by means of a pressure relief duct. This duct is normally an additional compartment to the switchgear and therefore increasing the panel dimension. As an alternative to the duct, a complicated and expensive arc channel can be installed, which guides the arc output into the switch room. Latest design switchgears are designed in such a way that both impacts are significantly reduced, and therefore in essence no complicated and costly arc channels are needed. The switchgears make use of integrated arc absorbers. These are ceramic blocks with an absorbing surface of 9m2 that breaks and filters gasses and fire significantly.

Figure 6 Integrated arc absorbers at the backside of the medium voltage switchgear panel

CONCLUSION

The amount of data is growing rapidly, and its availability is becoming critically important. This is why data centers are getting bigger and the use of secured electrical power increasing. Important design criteria are reliability, compactness and easy scalability, green & environmental friendly and safety. A lot of big data companies are very visible and are carefully building their green image (The Green Grid).
An high power integrated design, in which a Diesel Rotating UPS (DRUPS) is connected between critical load and supply grid on medium voltage level has the advantage that with the "less is more" philosophy the above design criteria are met. A high performance medium voltage switchgear links input, DRUPS and output together and is able to perform a large number of switching operations. DRUPS, switchgear and automation form together an integrated, fully automated high power distribution and back-up system. This system has been applied with success in several datacenters within Europe Middle East and Africa.

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