ELECTRICAL DESIGN OF DATA CENTER

Even if from its role point of view a data center represents “the entity” that reunite the most storage resources, the software calculation and applications of an organization, interconnected and accessed by the users through a network infrastructure with total availability, a data center is not all about the IT domain. A data center is first of all a special equipped construction. From the walls thickness, to seismic resistance, to the Faraday cage type screening, as far as the firefighting systems, power supply and the cooling system, all of them contribute to safe and correct functioning of the high-end equipment. From the point of view of the power supply, a data center is a critical consumer.

Up Time Institute, the only worldwide organism that release certification in the domain, has generate a series of criterions (related to the location architecture, redundancy, availability) through which it ranks the data centers on 4 levels of performances viewed in 3.1 table.

The redundancy refers to some parallel connected equipment toward which, the system services in case of fault, will automatically redirect, without stopping.

The availability of a data center refers to ensuring of a certain level of accessibility of the network services in a time interval and it is defined as the sum of the success probabilities of an equipment that simultaneously request the same services in one second interval.

Table 3.1 – Data Center Standardization

Level	The supply and cooling line	The redundancy components	The availability	Obs.
Tier 1	1	No	99,671%	
Tier 2	1	Yes	99,741%	
Tier 3	2 where only 1 is active	Yes	99,982%	The maintenance not imply the system shutdown
Tier 4	>2 active lines	Yes	99,995%	Tolerant on defects

Therefore, besides location (and the expansion possibility), internal security (access control and monitoring systems), connectivity (referring to the data providers numbers, not the bandwidth) and informatics security, the power supply system is a very important aspect that need to be take into calculation of these heterogeneous platforms. The specialists approaches a series of elements for that: the electric network topography of its entering points in the data center building, the generators, the Automatic Switch Transfer systems type, power distribution units[1], etc., going up to taking into

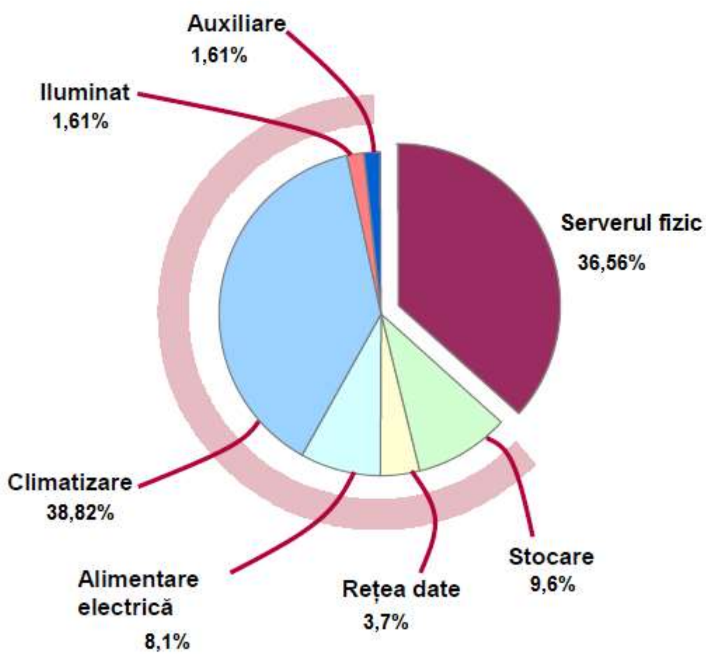
[1] A Power Distribution Unit (PDU) is an electrical distribution cabinet, free-standing or rack-mounted, whose main function is to provide a required point of power distribution. The PDU houses circuit breakers that are used to create multiple branch circuits from a single feeder circuit, and can also contain transformers, electrical panel boards, surge protection devices, and power monitoring/controls.

consideration of the UPS[2] battery age. The special attention given to that aspect is explained by the fact that the essential role of a Data Center is to ensure the business continuity.

Data center facilities rarely achieve the operational and capacity requirements specified in their initial designs. The advent of new technologies, such as blade servers, that require substantial incremental power and cooling capacity; the pressure to consolidate multiple data centers into fewer locations; the need for incremental space; changes in operational procedures; and potential changes in safety and security regulations converge to impose constant facilities changes on the modern data center. The overarching rule in data center facilities is to design for flexibility and scalability. This rule embraces several key principles in the site location, building selection, floor layout, electrical system design, mechanical design, and the concept of modularity that enables the data center facility to change and adapt as needed, with minimum renovation and change to basic building systems.

Indicators of energetic performance of a data center

The electric energy is vital in the operating of a data center, and the consumption is rising (in the last 6 years it doubled [Orgerie 2010]) because of the raised need for servers, of high power, for data processing, archiving and storing. As these servers generate a large amount of heat, a good part of the consumed energy is destined for cooling system for both every storage system and the building where it is. (example in fig. 3.1).



[2] The uninterruptible power supply (UPS) converts unconditioned power to provide conditioned power to critical loads without interruption. It contains an energy storage system, such as a bank of batteries, which supply power to the load when utility power is unavailable.

There are two parameters that allow the appreciation of the energy use efficiency in a data center: PUE (Power usage effectiveness) and DCIE (Data Center Infrastructure Efficiency) computed after the following formulas [Green 2008]:

$$PUE = \frac{Puterea\ totala\ a\ instalatiei}{Puterea\ echipamentelor\ IT} \qquad DCIE = \frac{1}{PUE} * 100 \qquad (3.1)$$

In most of the data centers, PUE is higher than 2, which it means that the reduction of the used energy in the physical infrastructure, procentual, is as important as the reduction of the IT load [Rasmussen 2012].

A value of 1.6 for PUE, respective 62.5% energetic efficiency, is ideal for the actual function regime of the data centers: 24x7x365 [Dănilă 2012].

In financial terms, monthly, 45% of the maintenance costs of a data center is represented by the consumption of electrical energy, the rest being allocated in proportion of 47% for servers maintenance and 8% security and telecommunication equipment [Pau 2010], which denote an operating mode far from the sustainable development principles. Recently, it started to be adopted a series of action to reduce the energy consumption and implicitly the carbon emission, as: stop the unused servers, the reset/restart command, the physical reconfiguration of the space, the control if the storage equipment in excess or low loaded through collocated equipment, or the visualization of the servers (the transformation of the hardware in software). Because most of the servers work physical at 30% capacity, must be mentioned that the virtualization represent a huge opportunity for energy save, bringing up to 80% reduction depending to maturity level of the data center [Green 2009]. More, the virtualization allows the accessing of ten times more physical resources because of the possibility to run simultaneously of the virtual machine [Orgerie 2010].

The most important is the fact that most of these actions do not need any financial investment, only a lasting behavior of the user through an intelligent management. As the speed transforms the opportunities in money it is desirable that this IT systems to work safe, at maximum capacity and availability.

3.1.1 The availability of the back-up systems with storage units for energy

Basically all users connected to a low voltage network have individual loads or groups of loads that require a quality of supply or a reliability of it higher than the one offered by the public network supply. Often the user's demands are strict and can be fulfilled using an auxiliary source. The market offer a wide range of such sources, so the choice depend on the load characteristics and the type, time and severity of the supply fault that can be tolerated. The voltage quality in the common point of these sources is reduced because of the effects that other loads in networks have, and because of the cable impedance, so that the quality of the voltage at the equipment terminals is even lower. This situation is more serious when the loads present a nonlinear voltage-current characteristic.

The important characteristics of a back-up electrical energy source are:

- The storage power and energy
- The type of transfer
- The maximum supply time
- The efficiency
- The installation and maintenance cost

The ideal source must have infinite power and energy, the connection time zero, infinite supply time and reduced cost. Because this source does not exist, are used different solutions of compromise. The choose of a source depends on the consumer and some requirement that are asked. The IT equipment, for example, asks for a continuous supply, which means the commutation time zero in order to avoid data lose. After the transfer, the equipment may require to be supplied enough time until its turn-off safe or it may require a continuous supply. In the first case a uninterrupted source (UPS) may be enough, but in the second case, it would be necessary an auxiliary energy source, for example a diesel-generator group, as lasting source and a UPS source to ensure the supply in starting time of the group [Markiewicz 2003].

The availability of an electrical energy supply system is given by:

$$Availability = 1 - \frac{\sum_{i=1}^{n} t_{Di}}{\sum_{i=1}^{m} t_{Fi} + \sum_{i=1}^{n} t_{Di}}$$

where: t_{Fi} – the functioning time i between interruptions

t_{Di} – interruption time i,

m – the number of functioning time between interruptions,

n – the number of observed interruptions in the given time

Also, the energy storage system with back-up role must be resilient**,** it means to support a number of interruptions of its components in time it continues the normal functioning. This desideratum it is realized through the installation of redundant subsystems which eliminate the singular fail point. The solution is one efficient from technical point of view, but expensive and can be done only after analyzing the costs and the benefits. From suppliers point of view, may be cheaper to ensure the maintenance continuity, but form supplying point of view, the insurance of the resilient systems is more efficient. On their turn, the storage energy systems with back-up role are active redundant equipment or a parallel for the power source.

For the most critical loads, operational availability is the primary objective for the physical infrastructure. All data center power designs are based on an underlying assumption that power disturbances (such as transients, voltage fluctuations, outages, and other power quality abnormalities) are inevitable, whether originating from the electric utility or from within the facility. Any of these conditions can damage equipment and/or interrupt operations. Therefore equipment to mitigate such disturbances is built into every design. The addition of these devices increases energy consumption through added efficiency losses. Power system component layout and level of redundancy affect the losses within the power system. Built-in redundancy is perceived to be necessary to achieve maximum availability. To achieve greater levels of redundancy, more components are used to provide the same amount of backup power. These additional components, even when operating in standby mode, consume energy and therefore reduce the overall data center efficiency, as defined by PUE or DCIE. Designers should be aware of the trade-off between redundancy/availability and efficiency. They should also consider solutions in which the power system can be reconfigured to provide the needed power and redundancy within the required time, while not needlessly operating standby equipment [Bell 2005].

- Autonomy:

In addition to location, internal security, connectivity and data security, the power system is a very important issue to be taken into account in achieving a data center. Regarding this, professionals point out a number of important elements: grid topography, entry points into the data center's building, generators, Automatic Transfer Switch type systems, Power Distribution Units, air and cooling distribution system, up to considering the age of batteries inside the UPS which supply the servers. This particular attention to the supplying power system is explained by the essential purpose of a data center that has to ensure business continuity, independently on the main power supply failure.

The efficiency of energy storage systems used in UPS depends on charging and discharging cycles and on idling losses. In practice, idle losses are dominant as UPS systems - operating in most of the time in backup mode - are supplied continuously to be kept at the parameters of availability, which indicates that a percentage of consumed energy will never reach to power IT equipment. Such losses occur in relation to specific stored energy and have a negative impact on data center global efficiency parameters - PUE and DCIE.

From a functional perspective, the storage systems included into the UPS provides stability on voltage curve (to the short interruptions, peaks and dips appearance), transient stability and ways for power management (according to the pricing plan, differentiated by time zones and duration of use). The more autonomy the backup source has, the more efficiently and safety is the system. To that effect, using supercapacitors in backup sources can lead to better performances and the paper analyses the particular case of a data center. Even this hybrid battery-supercapacitor UPS is a well documented subject in literature, the offer with such products on the market remains poor. An energy storage unit based on supercapacitors not only provides continuity of supply, but also filters any power fluctuation (with auxiliary devices, inverter, filter) which provides additional protection to any electronic system. Autonomy depends on the device's size and on the consumption level.

- Residual current devices (RCD) or residual-current circuit breakers are commonly incorporated in or associated with the following components:
  - Industrial-type moulded-case circuit-breakers (MCCB) and air circuit-breakers (ACB)
  - Household and industrial type miniature circuit-breakers (MCB)
  - Residual load switch
  - Relays with separate toroidal (ring-type) current transformers

RCDs are mandatorily used at the origin of TT-earthed installations, where their ability to discriminate with other RCDs allows selective tripping, thereby ensuring the level of service continuity required.

3.2 The electrical functioning and structure of the Zipper Data Center, Romania

This data center is realized according to TIA-942 standard regarding the space geometry (fig. 3.2), the cabling mode and the materials used (copper and fiber), the insurance of data security and accessibility, and it is level Tier 3. So, to reach 99,982% availability, the supply network is designed to insure totally the electrical energy continuity at the necessary quality parameters. The location is powered through a principal line and a secondary one in cold back-up, equipped with a switch and a separator, for two different grids (fig. 3.3). When a disturbance occurs or a voltage drop, the supply is automatically commuted by the bypass panel (MBP) to back-up systems, which are UPS. These sources take the total supply of the IT equipment, the safety systems, to a lower capacity, of the lightning and cooling systems. The autonomy of these sources, by 26 minutes, allows the data center operator to notify the problem to the energy supplier and to ask to be commuted on back-up supply PT2. If this action is estimated to last longer than 26 minutes, the generator is put into operation to sustain the power until the problem is solved.

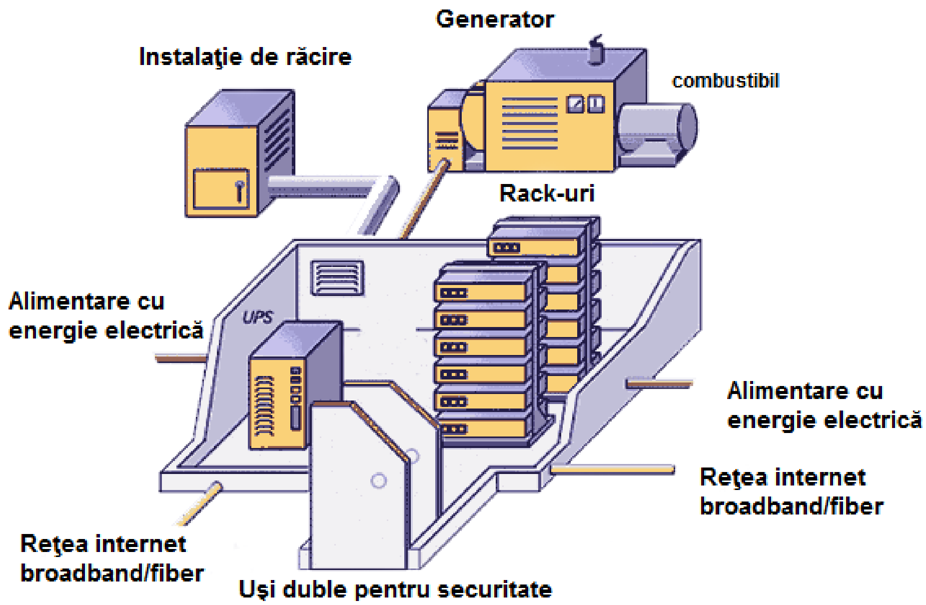


Fig 3.2 – The Constructive Scheme of the Zipper Data Center, Romania

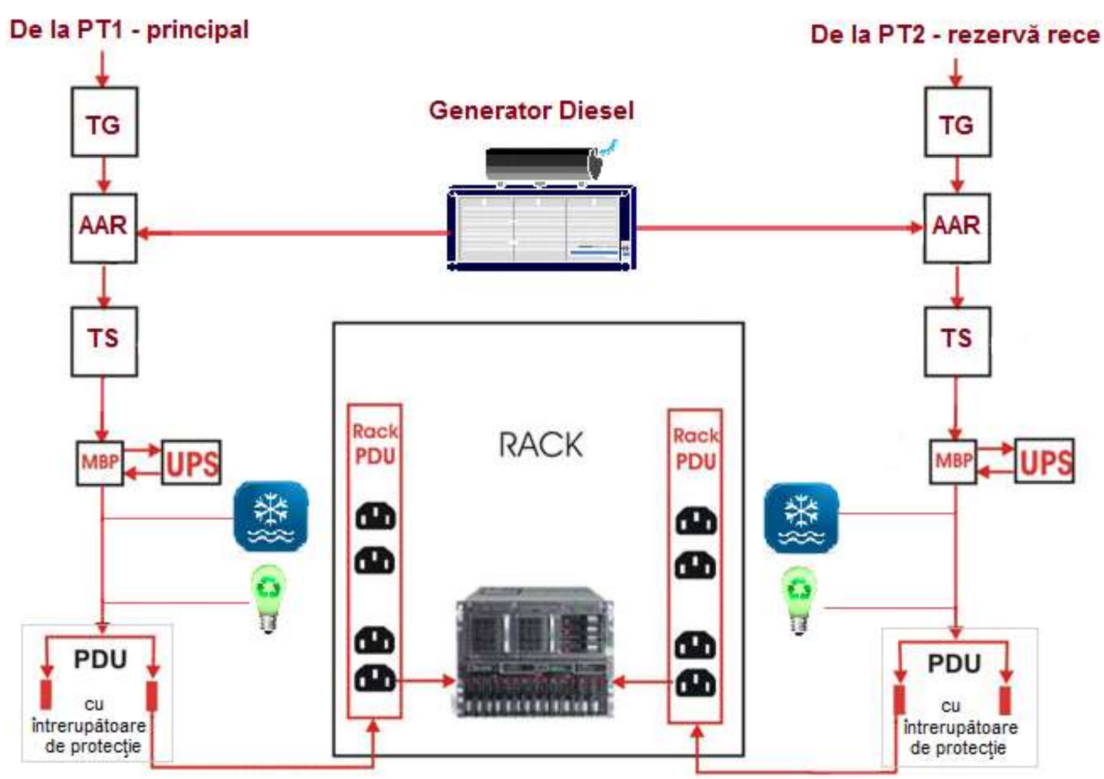


Fig 3.3 – The supply scheme of the Zipper Data Center Romania
TG – General panel, TS - Secondary panel, MBT – Bypass maintenance panel, PDU – Power distribution unit, AAR – automatic panel for back-up switching

The power system diagram can be used to show the entire power system from end to end and in some cases can do so all on one concise sheet. At one end is the incoming power source. At the other end are the loads. Power system diagrams, though electrical in nature, can provide information about system and subsystem function and location. Functional details called out in the power system diagram can include system redundancy, the type of energy storage elements, emergency backup generators, maintenance bypass devices, protection devices (circuit breakers, breaker panels, and fusing), and metering points.

This power system architecture is configured with two sides (figure 3.3.), each operating at less than 50 percent load. Each side can include multiple UPSs. Either side can handle 100 percent of the system load. If one of the sides has a problem, the load is connected or switched to the other operational side. The tie of the two sides requires a combination of switching devices and synchronization of all components downstream of the UPS. Switches can reside upstream of the UPS for maintenance isolation purposes. Also known as a catcher system, this configuration can include any number of UPSs and includes a standby UPS prepared to back up the primary UPS. The redundancy is provided by virtue of a transfer to the catch side.

Transformers (from PT1 and PT2) can appear in many places within the power train. For purposes of this `case study, the focus is on “stand-alone” transformers rather than transformers embedded in the equipment (such as UPSs or PDUs), as the performance of those transformers is factored into the performance of the device in which they are installed.

Currently data centers have numerous isolation transformers because of the need to reduce the size and weight of conductors. Primarily for safety reasons, the loads within a data center presently tend to be operated at lower voltages (100 – 240 V ac). As the number and size of the loads increases, the current draw increases. Higher currents require larger conductors. Larger conductors require more space and weigh more. Since electrical power is proportional to system voltage multiplied by current, at some point it becomes more cost effective to distribute power at higher voltages since the current levels (and therefore conductor sizes) will be smaller. In alternating current systems, a transformer is used to “transform” the voltage level. The block diagram from figure 3.4 serves as a basis for illustrating different components of the CIM model for a transformer.

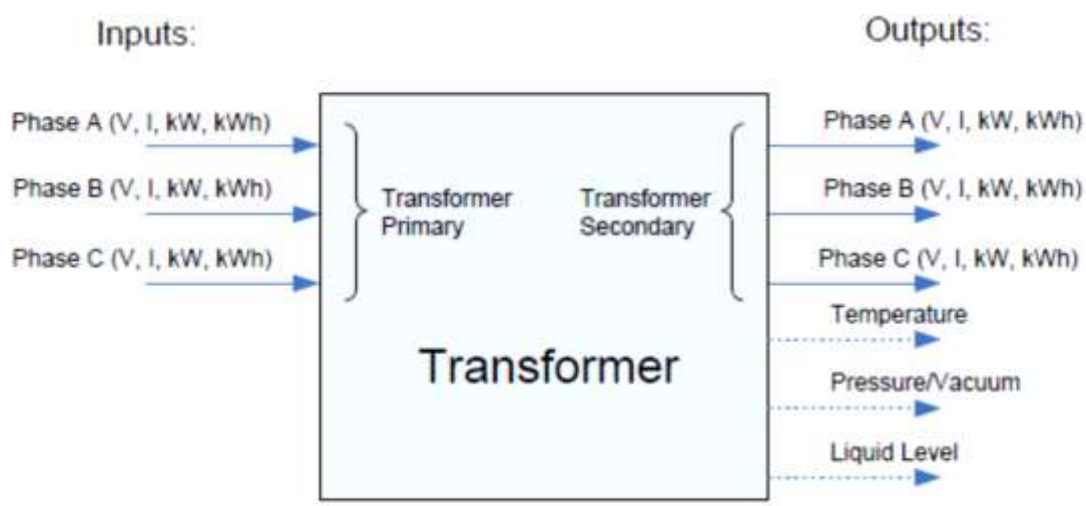


Figure 3.4 – Measurement and control points of transformer

A more efficient practice would be to use fewer transformers or to use autotransformers throughout the data center. This is done by using end devices that will tolerate operating at higher voltages. However, this can pose a safety issue at the rack because of lower impedance and higher fault currents. Designers need to be aware of the tradeoffs when determining the voltage for their data center equipment.

Transformers can be metered for many reasons. These include providing signals for protection, data for diagnostics, and data for energy management. The type of transformer instrumentation selected is typically the result of a trade-off between the cost of the instrumentation versus the importance of the transformer, or of the importance of the data or loads fed by the transformer. The instrumentation selected may include the monitoring of current, voltage, and the various signals derived from those two (power, energy, power factor, distortion, etc.), as well as temperature. In the case of dry-type transformers, the temperature monitoring may be done at multiple points on cores (a single transformer has one core per phase) or windings. In the case of liquid-filled transformers, temperature monitoring is usually only done at the top of the fluid.

Typically liquid level and tank pressure or vacuum are also monitored in liquid-filled transformers. Transformers with forced cooling, either air and/or liquid, may have additional monitoring of the motor driving the fans and/or pumps. This fan/pump monitoring may include voltage, current, and values from those signals.

Large, critical transformers will typically also have sensitive transformer differential-current monitoring where the total current flowing into the transformer is compared to the total current flowing out of the transformer, adjusted by the turns ratio. This particular monitoring, called transformer differential protection, looks for small differences in the calculated value versus the actual value of the ratio of input to output current. Small differences can indicate a short within the transformer winding. This particular type of monitoring may not be cost efficient in a typical data center, however.

Although transformers can be paralleled to increase available capacity as long as the turns ratios, phase shift (from primary to secondary), and phase rotation are matched between units, this is almost never done in practice. However, there is a particular type of distribution system called a network (either spot or grid) that does rely on paralleled transformers, but these are coupled with special types of protective devices called network protectors that monitor the direction, type (real vs. reactive), and magnitude of current flowing through each transformer [Loucks2012].

A system could be built with network protectors in anticipation of paralleling transformers (figure 3.3). However, paralleling transformers increases available fault current and may over-duty the electrical distribution system unless it is installed with the thought that future upstream transformers may be paralleled.

A generator is made up of an engine (sized in kW) which spins an alternator (sized in kVA) to produce AC electric power. Several generator sets may be connected to work together (in parallel) to provide the required power for the connected load. Generators may be portable or fixed and are available in a variety of sizes ranging from a few kW or kVA to several MW or MVA each. Generators can be connected to data center power systems using either transfer switches, paralleling switchgear, or both, depending on the needs and design of the installation.

The Diesel generator Kipor KDE 6700TA comes with an automatic panel AAR. It monitors the voltage and frequency of the main network, and one of this parameters varies, the generator gets the starting command (the tolerance for frequency and voltage is ±10% compared to the reference value. After starting the generator and achieving normal regime of work, during which power was supported by back-up systems, AAR is transferring the load from the UPS on it. Meanwhile, the network parameters are monitored, and when return to normal, AAR power switches from the generator back on the network, it will continue to run a predefined period of time (1 to 30 seconds) without supply voltage and then stops automatically. Preventive maintenance of the generator is made monthly by a special boot, which can be programmed from the display generator. The generator has the following characteristics: a nominal apparent power S_n=4500 VA, P_n=4500 W, U_n=230V, I_n=19,6A, a DC output of 12V / 8,3A and an autonomy of 6.5 hours [clickbox.ro].

A source **APC Smart UPS 5000** accompanied by one **APC Smart 3000** provides redundancy for the entire data center. Thus, until the generator starts, gets in operation first source UPS, and if it fails, the load is automatically taken over by the second source UPS. Their characteristics are given in Table 3.2. Typical battery operating time depends on the load and is shown in Figure 3.5, made after [apc.com1]. Sources efficiency under load is inversely proportional to the percentage of power lost in the conversion from AC to DC and therefore also depends on the load factor (Figure 3.6 made after [apc.com2]). UPS efficiency curves should be as flat as possible, operating efficiently at any load. This allows data centers to move away from modules. Efficiency should be 95 percent or higher when operating between 25-75 % of load. Must be mentioned that scalability affects reliability.

Fan loads represent a big portion of a UPS's inefficiency. Ventilation is a particular design aspect of a given UPS and should take fan airflow into consideration in order to provide precise thermal management.

Understanding a UPS fan arrangement and reasons for its design and construction can help identify system inefficiencies. Look for underlying thermal management that shares fan airflow across multiple power train sections. At times the number and size of fans relates to a design target for fan redundancy. The use of large fans that provide a broader airflow stream can provide degrees of redundancy similar to multiple smaller fans and reduce the system fan load.

Nearly all new UPSs are fully instrumented to provide real time operating power and performance data. Efficiency for most UPSs is statically known based on lab measurements, but might not be gathered in real time.

Table 3.2 – Technical specification of the back-up sources [APC 2012]

	APC Smart 5000 RM 5U	**APC Smart 3000 RM 2U**
P_n	4000 W	2700 W
S_n	5300 VA	3000 VA
U_n	230 V	230 V

f	50/60 Hz +/- 3 Hz (auto sensing)
Typical recharge time	3 hours

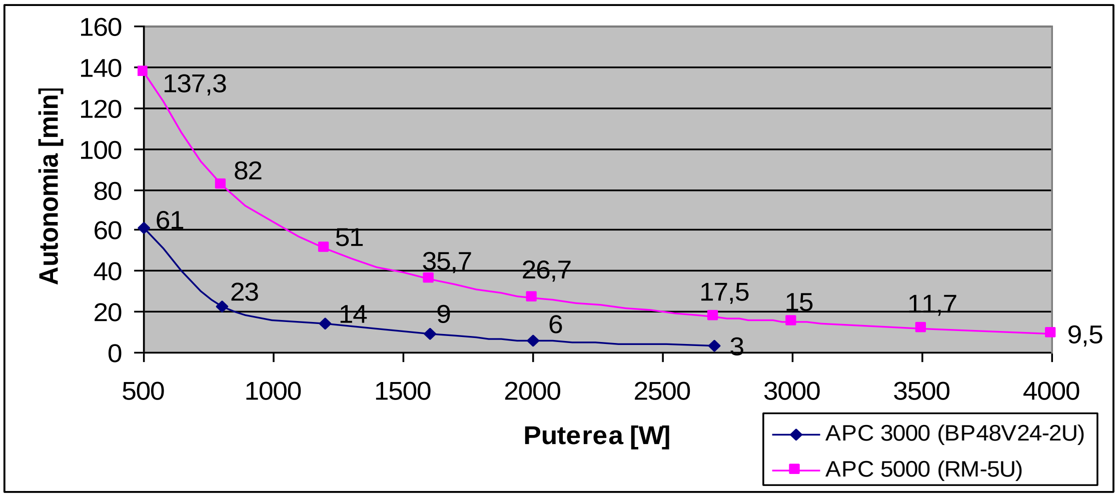


Figure 3.5 - Variation UPS autonomy depending on the power output

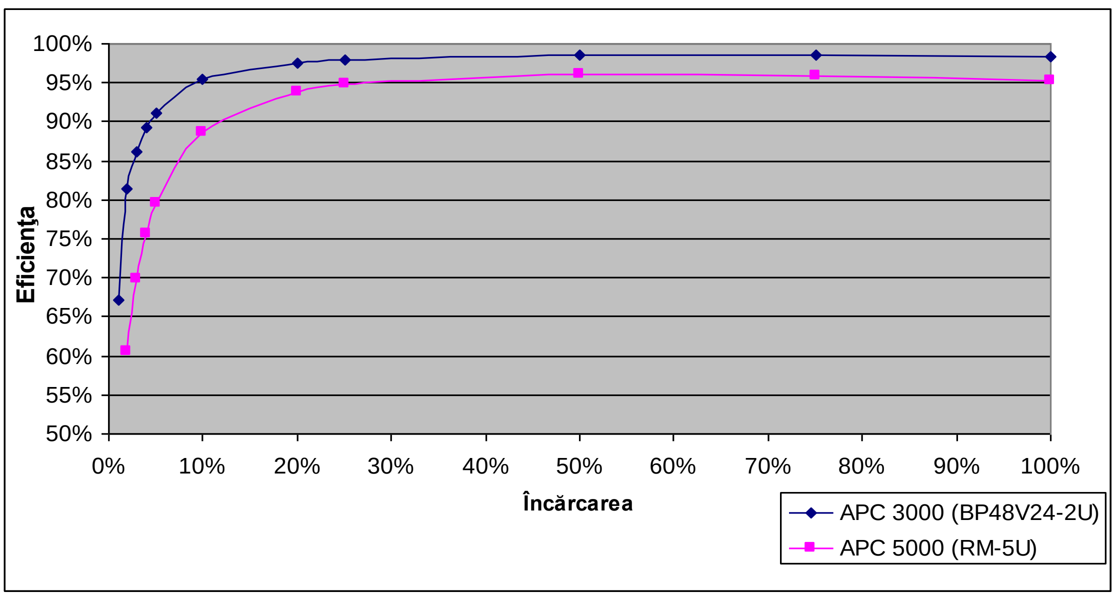


Figure 3.6 - UPS efficiency depending on the load factor

Management through data network system APC Smart UPS 5000 is done using SNMP card (Simple Network Management Protocol) with its own IP, with whom they can read and remotely control from distance the source parameters (voltage, load level, temperature). Also through this SNMP protocol can be commanded the closing of the source in case of failure [Lidong 2011]. Operating modes are announced and controllable. Units communicate instantaneous monitoring and predicting the efficiency in each mode.

Maintenance bypass panel (**MBP**) completely isolates equipment from the power distribution unit when disturbances appear, automatically switching their supply from UPS.

Data centers face challenges in power protection and management solutions. This is why many data centers rely on **PDU** monitoring to improve efficiency, uptime, and growth. A secondary function of PDUs is to convert voltage. The AC voltage–converting PDUs contain either an isolation transformer or an autotransformer to step the AC distribution voltage down (figure 3.7). DC voltage converting PDUs contain DC/DC converters. For simplicity, multiple PDUs are modeled as a single block. Where appropriate, isolation is indicated in the block diagrams. Typical Power Distribution Unit specifications are: rating: 30 - 300kVA, transformer type: Isolation transformer or autotransformer, input voltages: 208, 480, or 600 Vac, output voltages: 208/120Vac.

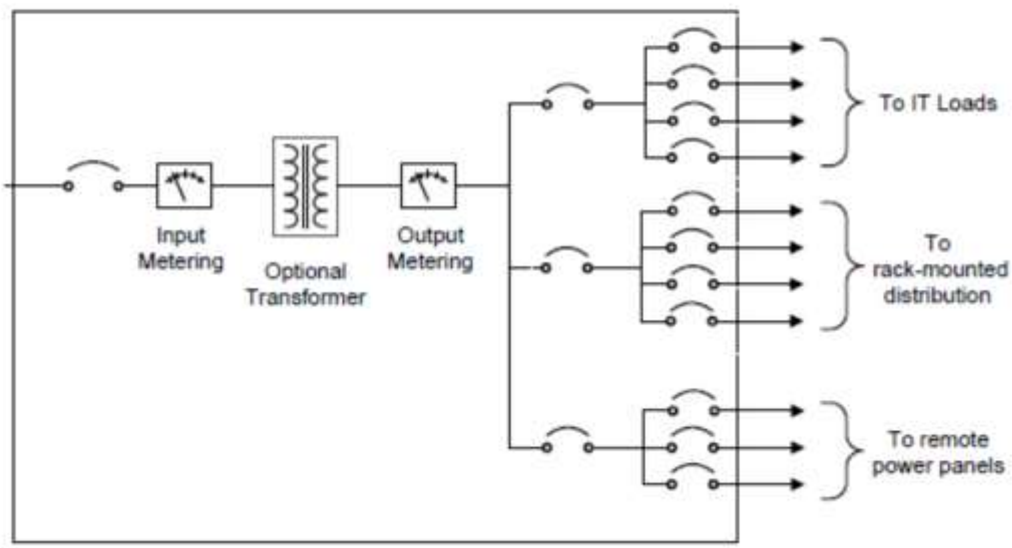


Figure 3.7 - Representative single-line diagram of a floor-mounted PDU

A large data center typically contains a large number of PDUs. A single site can contain over 100 PDUs. The location and number of distribution points depends on the power system layout and design and can take on many more forms depending on their location and function in the overall power system

Trends in data center design

Beyond the systems described above, other technologies are emerging that may provide more mainstream solutions in the future. These types of systems, most conducive to cloud technologies, move the redundancy out of the site power distribution line and into other areas, such as software or mirrored data centers. Reliability may be affected from a power system standpoint but is addressed elsewhere in the company's larger data center picture.

Several examples of this exist today. At a basic level, ITE[3] can be fed with two feeds, one on a UPS and one with utility only on the other. Battery backup function can be moved from the central

[3] Information Technology Equipment

UPS location to inside each server. Backup time can be reduced to less than 5 minutes. This can reduce overhead for a full UPS, but can lead to issues when dealing with batteries that need to be replaced prior to a server's end of life. A combination between the two is available: at the power supply level, the main AC input can come directly from the utility (the "efficiency input"), with second PSU input of a DC battery backup (the "availability input"), where batteries are racked near the ITE unit.

Further outside the box come newer energy storage technologies. Lead acid batteries are the most common today, but other battery chemistries (such as lithium-ion) may become available that aid in more efficient, reliability, or economical storage. Other technologies like supercapacitors (or ultracapacitors) or flywheels could help with removal of batteries all together.

Any level of accuracy can be measured today. However, to measure with high accuracy is quite costly. Individual component built-in meters are typically not accurate enough for good PUE measurement (built in meters are around 95 to 98 percent accurate), but externally available bolt on type meters can be attached to obtain the desired level of accuracy. However, because of costs, this accuracy of metering is neither common practice on purchased powertrain components or at an installed data center facility. The accuracy of the measurement varies by use. If the measurements are used for tracking changes in performance within a facility, the built in meters are generally accurate enough. If certification or comparison to other facilities is required, more accurate supplemental meters should be installed at appropriate points in the power path.

All equipment obtains a timestamp from one location. Accuracy of the timestamp improves over time. One second accuracy is required for efficiency purposes. More accuracy is required for fault analysis. All measured and calculated values are available to the centralized management console, including but not limited to volts, amps, watts, VA, apparent power factor. Energy (kWh) is calculated by the centralized management console.

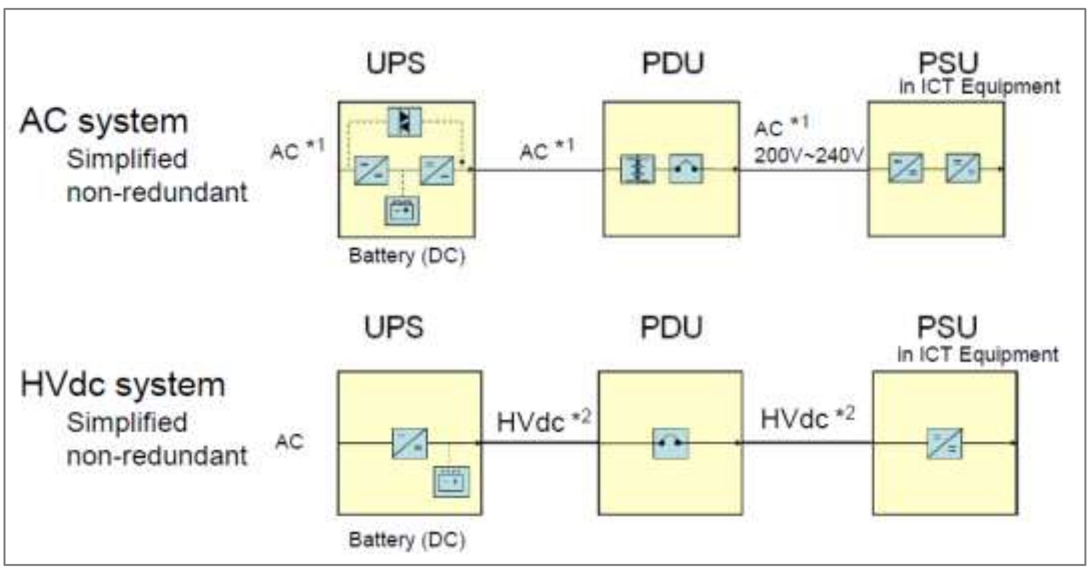
Provisioning power quality (that is, how and where the power is supplied from) should be based on the equipment type to reduce efficiency losses and cost where not required. Components in the power chain thus will be:

- The centralized management console will calculate, report, and use the average, minimum and maximum values of volts, amps, watts, VA, power factor, energy.
- The centralized management console will take all inputs to optimize the overall efficiency of the power chain, specifically using PUE, predicting the most optimal path to efficiency.
- Utility pricing and carbon awareness

- Future forecasted; adjustments made to components of powertrain (shift workloads, shift to generator, etc.) based on forecast.

Systems designed from the outset as a spot network may provide more scalability and higher reliability than conventional primary selective systems; because the system can be designed as N+1 (or more) without having to add any switching. Adding transformers increases capacity and redundancy, but it also adds available fault current. A distribution system designed with that in mind will be braced and rated for the higher fault currents. Efficiency can be increased by using fewer series isolation transformers or replacing them with autotransformers [Loucks2012].

Most data centers today use alternating current (AC) power systems, which distribute electricity somewhere between 100Vac and 600Vac throughout the facilities. However, a growing number of direct current (DC) advocates are promoting *the use of DC power in the data center*. Higher voltage direct current (HVDC) power distribution configurations (<600Vdc) have the potential to reduce energy consumption and increase efficiency in the data center. Higher voltage direct current power systems may involve fewer components (figure 3.8), which can result in higher reliability and lower total cost of ownership when compared to AC power systems.



*1 – 480V:US, 600V:Canada, 380V~415V:Europe, 415V:Japan

*2 – "higher voltage DC (HVdc)" higher than 200V, lower than 600V

Figure 3.8 – Comparison between the number of components of AC and HVdc systems [Yamamura2010]

A typical North American AC system drops the incoming AC voltage down through a series of conversions to 480Vac. At that point a double conversion uninterruptible power supply (UPS) converts AC to DC for battery charging, typically resulting in losses of 3% or greater. An inverter then converts the voltage back to AC, typically adding 1% to 3% losses for this second conversion. A power distribution unit (PDU) - which, if it has a transformer, is a third conversion, typically with 1% to 2% losses - distributes AC voltage to power supply units (PSUs) in each of the various IT equipment loads. The PSU finally converts the voltage to 12Vdc, currently with 6% to 10% losses. A typical HVDC system first uses a rectifier to convert the incoming 480 VAC to 380VDC. Then a PSU converts it directly to 12Vdc. Eliminating the extra conversions means that HVDC power distribution configurations generally need no inverters and fewer step-down converters or intermediate voltages.

With fewer individual components, HVDC systems are less complex and likely to be more reliable than AC systems. In addition to conversion-related hardware, HVDC removes other elements, such as the sensing mechanisms that AC systems must use to ensure that equipment is in synchronization. Paralleling of sources in a DC system is simplified because synchronization is unnecessary.

Nevertheless, the transition to DC systems would be prohibitively expensive and its security should be increased, as the arc flash is more dangerous than AC with no zero-crossing and longer duration.

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