Architecture of a **S**implified **C**oncept for **E**nergy and the **T**echnical **E**nvironment: ASCETE

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Abstract : *One possibility for reducing costs, without compromising quality of service, consists in simplifying the architecture of energy and climate control installations.*
After setting out the advances in and the prospects for using new energy sources, this contribution presents an original architecture which has been the subject of a patent application.
The situation is that, mirroring data processing systems, telecommunications equipment will offer 230V/50Hz power supply interfaces which will require a redundant and high-efficiency uninterruptible power supply (UPS). With the architecture presented, this UPS will be drawn on directly in order to start up the source substituting for the local electricity grid. Conversely, the substitute source will be drawn on directly in order to maintain the charge in the batteries incorporated into the UPS.

1. Preamble

The acceleration in world-wide research into sources of energy production should eventually give telecommunications operators the opportunity to replace standby electrical generator sets with new, less polluting energy sources of higher performance.

In parallel, the evolution of the conditions for powering telecommunications equipment will promote the deployment of high-efficiency Uninterruptible Power Supplies (UPS).

These two perspectives offer the opportunity to upgrade the Technical Environment and the energy integrated into the equipment, in order to obtain maximum advantage on the technical and economic fronts.

After a survey of the current situation, and a progress report on the work on the global front, this contribution proposes a novel architecture of equipment power supply and climate control systems.

2. Evolution of standby sources

2.1 Survey of the current situation

Over the last two decades, the technology of power supply equipment has evolved substantially, with the exception of the standby source which still relies on electricity generator sets.

Today, the weak points of Diesel sets appear to be the constraints which are the hardest to accept:

- the operating noise, vibration and pollution due to the exhaust gases;
- the mediocre performance in the transient regime;
- the necessity to load the set at more than 50% of its rated power;
- the high operating and upkeep charges.

At France Télécom, the constant search for better-adapted standby sources has resulted in the commissioning of turbine-driven alternators of 600 and 800 kVA, originating from the aerospace industry, 70 examples of which have been deployed in the grids.

In point of fact, the gas turbine coupled to an alternator presents many advantages:

- mechanical simplicity and robustness, which guarantee very high reliability;
- very substantial kinetic energy which guarantees frequency stability and insensitivity to the impacts of loading;
- capability of starting at low temperatures;
- operation complying with the strictest environmental standards;
- reduced maintenance and a long technological lifetime, etc.

However, the fuel consumption proves to be heavier, and the costs of the investment in aerospace turbines combined with a mechanical gearbox are higher.
On the global front, the imperatives of environmental protection find expression in an acceleration of the search for new sources of energy, particularly in the motor industry. This research offers very encouraging perspectives, in the short and medium term, particularly in the telecommunications field.

2.2 Prospects for use of the turbine-driven generator

Very innovative work is being done on automobile propulsion, in particular the work which will come to fruition on the hybrid engine *(EU programme 209 AGATA)* developed by the manufacturers Renault, PSA and VOLVO, in partnership with Aérospatiale, the Microturbo company, etc.

The vehicle will be propelled by a 60 kW turbogenerator, intended for recharging the batteries which are coupled to the electric drive motors. The turbine, used essentially outside built-up areas, will operate at constant speed and in its optimum efficiency range, so as to lower fuel consumption and reduce the acoustic nuisance to a minimum, as well as the emission of polluting gases.

This hybrid vehicle, refilled with fuel like ordinary cars, should be mass-produced and marketed by about 2004, and should solve the problems of recharging and of severely limited radius of action of present-day electric vehicles.

At France Télécom, an original study aimed at dispensing with the mechanical gearbox of turbine-driven alternators was launched in 1996 in order simultaneously to reduce cost, weight and bulk.

The study gave rise to the development of an alternator rotating at high speed, designed to develop a power of 160 kVA, and subsequently 250 kVA. This narrow-diameter alternator, rotating at more than 50,000 rpm, delivers a current at high frequency, which is converted into direct current and then into industrial power (50 Hz) as required, by means of a very compact inverter.

The mechanical characteristics of the high speed turbogenerator (lightness, compactness, robustness, etc.) make it particularly attractive for use with mobile standby facilities. In fact, the 160 and 250 kVA models will be installed on a light vehicle of the Renault Master or Trafic type, which is easy to bring in and operate on the sites to be covered.

2.3 Prospects for the use of the fuel cell

Fuel cells are already used successfully in the field of space, shipping, etc., and the last few years have witnessed an acceleration in their development and a very substantial improvement in their performance.

In 1994, France Télécom launched an experiment to evaluate the potential of a 3 kW fuel cell. At that time, PEM *(Proton Exchange Membrane)* technology had been adopted in order to promote speed of starting. The trials proved the excellent behavior of the cell as an energy source, but the problems posed by the storing of the hydrogen and the prohibitive cost of the cell core made it impossible to envisage deployment in the grids.

Today, technical progress is spectacular and the cells on offer exhibit an energy density of 1.4 kilowatt per dm^3. That being so, the Canadian company Ballard, a specialist in the development of the cell core, doubled its turnover in 1997, and the GEC Alsthom Group has just taken a stake in that company to develop the production of stationary, non-polluting energy.

Moreover, automobile manufacturers *(DAIMLER-BENZ and CHRYSLER)* have developed an experimental vehicle (NECAR 3) propelled by a fuel cell. They are now incorporating the supplying of fuel into their studies, and have given themselves two years to develop an electric vehicle supplied with power from a service station, like an ordinary car.

The Ford group has come to join them on this project. In total, these three companies are going to devote almost 5 billion francs to the marketing, scheduled for 2004, of a non-polluting propulsion system which will solve the problems of recharging and of severely limited radius of action of present-day electric vehicles.

For its part, the American Energy Research Corporation (ERC) has developed cells with very high performance, which are well suited to static production of energy, and the recent inauguration of a two megawatt pilot plant in California makes the fuel cell a new candidate for the production of non-polluting and quiet electricity.

On the reliability front, the cell offers excellent prospects, since the cells installed in the course of space programs have exhibited no failures, despite the very severe conditions of use.

The principal drawback of fuel cells is related to the recent nature of this technology, since they appeared on the market only a matter of twenty years ago, and the low demand gives rise to oneoff production which leads to high costs. However, it is predicted that in less than 10 years the global production will reach 1000 megawatts and the investment costs will be divided by five.

In summary, the research is gathering pace and is developing along two main, complementary lines : optimizing the operation of the fuel cell, and minimizing the costs of producing and using it.

3. Evolution in the equipment power supply conditions

Traditionally, most telecommunications equipment has been powered with direct current at 48V, and the other equipment is supplied with alternating current. The alternating current power supply becomes permanent when the functionalities of the system so require *(auxiliary computers, operators' terminals, etc.)*.

Moreover, direct-current converters are incorporated into the systems so as to deliver the 5V, 12V, etc. voltages which are required for the electronics cards.

The evolution factors observed in recent years relate essentially to:

- the increasing part played by new equipment exhibiting an AC power supply interface, at the expense of the 48V interface;
- the substantial reduction in the power consumed by these items of equipment, which may be reduced by half by comparison with that of the preceding generation;
- the ability of this equipment to operate in a wide temperature range (5 to 40°C) without impact on their life expectancy or the quality of service.

The convergence, and later the amalgamation, of the new telecommunications systems *(ATM networks, routers, servers, etc.)* and data processing systems involving ever higher digital data rates, will tend to make stabilized and permanent alternating-current power supply interfaces commonplace.

Today it is observed that equipment manufacturers are standardizing on AC access, either by dispensing with the 48V bus internal to the equipment, or by incorporating the 48V rectifiers and the batteries into the systems.

These changes will lead to preference being given to Uninterruptible Power Supplies (UPSs) which deliver the alternating current with an efficiency of 97% in near-steady-state conditions. This is because the conventional solution employing inverters downstream of the rectifiers and of the associated batteries, with an intermediate voltage of 48V, increases the energy bill since the overall efficiency is limited to 72%.
At the margin of the changes relating to power supplies, the temperature variations tolerated by the new equipment allow a large reduction in cooling in equipment rooms and so procure a very substantial reduction in the energy bill.

4. Evolution in the architecture of power supply units

4.1 The centralized power supply unit

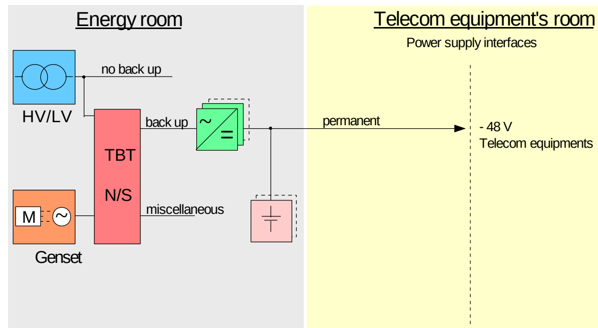

Figure 1: centralized power architecture

In the 60's, the centralized power supply unit was designed to supply electromechanical systems with direct current at 48V. The open batteries required special-purpose premises, all the power supply equipment being grouped together into special-purpose power rooms *(figure 1)*.

Supplying power to electromechanical equipment located on different floors within buildings dictated distribution cables of large cross-section in order to limit line losses.

4.2 The decentralized power supply unit

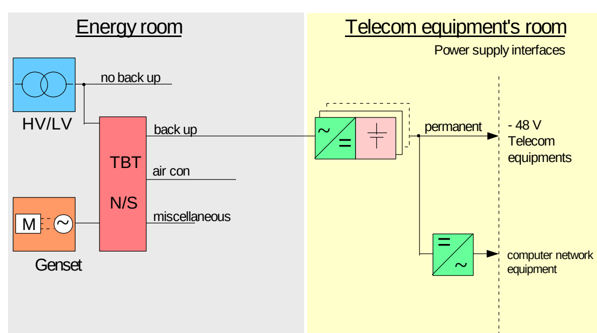

Figure 2: de-centralized power architecture

In the 70's, the introduction of electronic systems gave rise to new requirements, such as power inverters for supplying central computers and associated systems with uninterrupted alternating current.

In parallel, maintenance-free sealed lead accumulators have made an appearance, and the regulations in force have allowed the batteries, with their associated rectifiers and inverters, to be relocated into the rooms housing the equipment *(figure 2)*.

On top of the improvement in overall efficiency, decentralized power supply systems have allowed France Télécom to reduce the number and mitigate the consequences of interruptions in service, by virtue of the modularity and the redundancy of the power supply equipment.

Today, the principal objective consists in reducing the costs of these installations, without compromising the availability of the power supplies to the systems. One aspect of the action taken has been to upgrade the architecture of the power supply systems, taking the new requirements into account.

4.3 The power supply system arising from the TENOR concept (1)

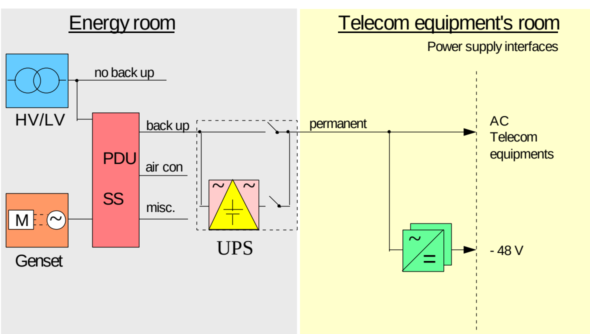

Figure 3: the TENOR architecture

The power supply system arising from the TENOR concept *(figure 3)* was proposed by CNET on the basis of the above survey, and its advantages may be summarized in the following way:

- the principle of the separation of the functions of power supply and energy storage, in high-efficiency UPSs, makes it possible to manage the batteries optimally in order to increase their lifetime and to allow timely detection of a loss of capacity due to ageing;

- the energy efficiency is markedly improved for alternating-current requirements : 97% in near-steady-state running, instead of 72% with a conventional power supply system;

- the distribution of the alternating current, from centralized UPSs relocated into plant rooms, is allowing a progressive disappearance of power supply racks from the equipment rooms, so eliminating a certain number of constraints on the operator:
  - the weight of the batteries in their cabinet, which poses problems in certain buildings;
  - the effects of the high temperature on the battery lifetime, if the cooling is deliberately turned down;
  - the risks of interference due to radiation, relating to the proximity of the UPSs;
  - the continued need for raised floors for hiding the cables of large cross-section;
  - the difficulty of finding surface space available on floors for administrative or sales activities.

Starting with this concept, the direct-current requirements (48V) can be satisfied with rectifiers interposed between the UPSs and the equipment, as shown in figure 3.

However, dispensing with the batteries downstream of the rectifiers makes it necessary to keep close control of the distribution of the 48V in order to guarantee the selectivity of the protective measures. This technical constraint counts in favor of the rectifiers being incorporated into the equipment items.

4.4 The proposed new architecture

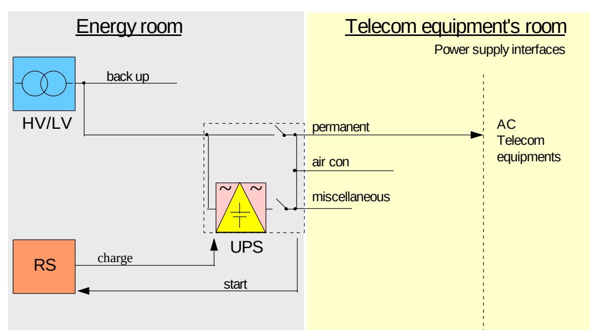

Figure 4: the ASCETE architecture

For the next generation of energy and air-conditioning installations, the proposed architecture constitutes an extension of the TENOR concept. It is centered around high-efficiency UPSs and takes account of the prospects for using turbogenerators and (or) fuel cells.

The proposal illustrated by figure 4 has been the subject of a patent application filed by France Télécom. It consists in calling on the UPS to undertake the automatic starting of the replacement source (RS). Conversely, the replacement source is drawn on directly to

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(1) Technique of energy optimization and redistribution : registered trademark of France Télécom and French patent no. 9207961 of 29/06/92, supplemented by US patent no. 548310 of 09/01/96.

recharge the batteries incorporated in the UPS, which entails dispensing with the function of Normal/Standby switching between the local electricity grid and the replacement source.

In the event of a failure of the local electricity grid, the protected outlets are transferred automatically, in less than 20 ms, to the terminals of the inverter. The batteries incorporated in the UPS supply the energy necessary for starting up the replacement source. Conversely, the replacement source, which is connected directly to the terminals of the batteries of the UPS, supplies the direct current necessary for recharging these batteries.

The economic advantage is amplified if the UPS and the replacement source are grouped together in the same plant room dedicated to the power supply installations. In this case, the cost of the electrical ducting is reduced to the minimum.

The Architecture of a Simplified Concept for Energy and the Technical Environment (ASCETE) takes account of the improvements made in the dissipation of new equipment and of its ability to operate at extreme temperatures. In fact, with the reduction in cooling, power can be supplied downstream of the UPS to the air conditioning, and without the UPS having to be of too large a design. In the event of failure of the local electricity grid, the climate control is powered by the redundancy module of the UPS, and this gives the benefit of the same independence on the thermal and electrical fronts.

Barring exceptions, two types of distribution of alternating electric current will continue to exist in an establishment:

- a current for domestic use, in the case of equipment tolerating interruptions in service. This current, delivered by the local electricity grid, is not backed by a replacement source;
- a current for industrial use, in the case of sensitive equipment *(telecommunications, data processing, etc.)* unable to tolerate interruptions in service, nor microbreaks of longer than 20 milliseconds. This current, delivered by the replacement source, is fully backed up by the high-efficiency UPS, which means that the rated power of the latter is comparable with that of the replacement source.

5. The advantages of the Simplified Architecture

Starting from the TENOR concept, the simplified architecture confers further advantages :

5.1 Reduction in the investment :

The reduction in the investment is based on the following items :

- simplifying the “low voltage” distribution, and dispensing with the Normal/Standby inverter *(inverter and shunting device);*
- dispensing with the starter system dedicated to the replacement source *(battery and charging rectifier*);
- optimizing the speed of the drive motor *(frequency not imposed);*
- dispensing with the devices for backing up the climate control *(exchanger, dedicated inverter*);
- dispensing with the commercially available UPSs protecting management data processing *(filtering of microbreaks and other disturbances);*
- reducing the capacity of the batteries without affecting the availability of the power supply *(rigorous management of the batteries and supervision)*.

5.2 Improvement in the operating conditions

The improvement in the operating conditions is summarized in the following way :

- disappearance of power failures causing upset to the operators *(Normal/Standby transfer);*
- constant quality of the AC power supply originating from the UPS *(low distortion level);*
- uniform operating endurance on the thermal and electrical fronts *(same energy storage in the batteries);*
- enhanced reliability of the power supply system *(dispensing with Normal / Standby switchover, large spare capacity on start-up).*

<u>5.3 Economic budget</u>

As the TENOR and ASCETE concepts are indissociable, the economic comparison is formed with respect to a conventional solution :

<u>Assumption 1 :</u> If the consumption of alternating current by the equipment remains marginal by comparison with the consumption of direct current, the conventional solution exhibits an economic advantage.

<u>Assumption 2 :</u> If the consumptions of alternating current and direct current are of the same order of magnitude, the hybrid solution is more economical : requirements for 48V satisfied by rectifiers associated with batteries, and

requirements for 230V satisfied by high-efficiency UPSs.

Assumption 3 : If the consumption of direct current, seen from the power supply interface of the equipment, becomes marginal by comparison with the consumption of alternating current, the ASCETE architecture exhibits an undoubted economic advantage.

For intermediate situations, the costs of investment and operation should be compared, without ignoring the improvement in the running conditions.

6. Implementation scenarios

Several scenarios can be envisaged in the implementation of ASCETE, depending on the arrival of the new sources of energy on the market.

6.1 Implementation of ASCETE (Phase 1)

Pending the widespread commercial availability of the new energy sources, ASCETE can be applied to conventional electrical generation sets. As the alternator delivers a current at 50/60 Hz, the connection is in fact made directly to the input of the charger of the UPS. All the advantages listed in chapter 5 are regained, with the exception of the Normal/Standby switchover which has to be reintroduced at the input of the UPS, and the frequency to be observed which determines the speed of the motor.

6.2 Implementation of ASCETE (Phase 2)

It may be assumed that, for the requirements of the automobile industry, low-power turbogenerators will be produced on a large scale before fuel cells, but the opposite situation cannot be ruled out. It may also be envisaged that these energy sources will be complementary, so as to cover a range of power from 1 kilowatt up to 1 megawatt.

a) Case of turbogenerators

The alternator, which rotates at high speed, delivers a high-frequency alternating current. After rectification and filtering, it is converted into direct current for constant-voltage recharging of the batteries incorporated in the UPS.

b) Case of fuel cells

The manufacturers offer basic modules, consisting of a certain number of individual cells. Placing these modules in series gives a direct current, at a high voltage, which can be used directly for recharging the batteries incorporated in the UPS.

In all the above scenarios, the batteries of the UPS are drawn on instantaneously by the output inverter in the event of failure of the local electricity grid *(power cut, voltage fluctuations, interference, etc.)*. This inverter delivers the voltage necessary to start up the RS, via a step-down transformer and a standard rectifier bridge *(localized subsystem instead and in place of the usual starter system)*.

In the worst case *(the case of the conventional electrical generator set)*, the instantaneous power necessary for starting up the RS does not exceed 10% of the rated power of the UPS, the instantaneous power of which is substantially higher.

It will be noted that the reliability of the power supply of the starting system is equivalent to that of the power supply of the sensitive equipment *(contractual non-availability around 3×10^{-7}).*

7. Conclusion

The work undertaken on the global front to avoid pollution of the environment, in the automobile industry as well as in other commercial sectors, will make it possible to replace heat engines by new sources of energy, as soon as mass production makes them competitive.

Under these conditions, and when telecommunications systems present the same power supply interfaces as data processing systems, ASCETE will become an offensive weapon for conquering new markets, that is to say an undoubted trump card in the world of telecommunications open to competition.

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[3] D. Jugan, J.P. Leblanc, D. Marquet : Powering architectures for new needs in telecommunications (INTELEC 95)

[4] CNET/DES : Results of the experiments with a power supply system of TENOR type