Advanced Power Supply Architecture for UMTS Networks

V. Esteve, E.J. Dede, E. Sanchis-Kilders, J. Jordán, R. García, E. Maset
Department of Electronic Engineering
ETSE, University of Valencia
Burjassot, Spain

J. A. Carrasco
Bioengineering Institute
University Miguel Hernández, Elche, Spain
J.L. Ramírez
Telefónica Móviles, Spain

Abstract— **The future development of the cellular telephony of third generation (3G) implies a great growth of the electric feeding necessities of the radio access network equipments and of its adaptation to the new requirements. In this line, it is necessary to redefine the basic configuration of these power systems.**

Keywords- power supplies, telecom applications, UMTS.

I. INTRODUCTION

The future UMTS standard will be, together with the expansion of Internet, the technological revolution that will change more our lives since the arrival of the personal computer (PC). The initials UMTS responds to Universal Mobile Telecommunications System, a standard that researchers and companies (3GPP - 3rd Generation Partnership Project) are developing for years to get a global system of mobile telecommunications, compatible with the fixed telephony and the satellite communications. [1]

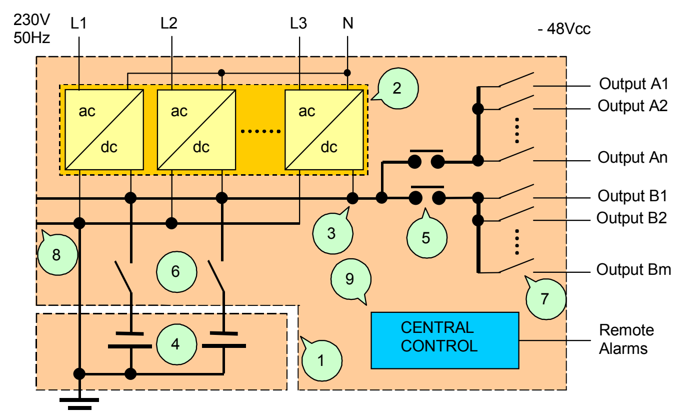
It seems evident that the expansion of the UMTS will make grow the production of new terminals and the offer of services related with this new technology and also the installation of the new mobile telephony base stations (nodes B). This means that a great increase of the necessities of electric supply will be necessary.

These new systems have to be based on the actual ones having as a main objective the optimization of the security and reliability of the electric power supply. Also, new factors will be included in their design as high efficiency, fulfilling actual applicable standards and, mainly, high degree of remote accessibility of their operation variables in order to guarantee the optimal use of the system resources minimizing the maintenance costs. This will only be possible endowing the system with a modern and complete control system and communications.

II. SYSTEM CONFIGURATION

The power supply system consists in a number of ac/dc converters powered by the voltage of the commercial mains. Hereafter we will call rectifiers to this type of converters. The output power of the rectifiers is determined by the necessities of consumption of the elements of the base station; it ranges from some hundreds of watts in minimum configurations to powers of several dozens of kilowatts in big stations.

To avoid the influence of fluctuations or lost of electric quality of the mains, the power system needs a group of back up batteries that can assure the energy supply to the consumer circuits of the system during blackout time. Last, the –48V dc voltage (accepted as standard in UMTS), will be distributed to each of the load circuits. The system will be endowed with the necessary protections to guarantee its reliability. Even this way, all the vital elements of the installation, especially the rectifiers and the batteries, will have a redundant configuration, it means that it will install enough units in order to keep the energy supply without restrictions in case of failure. Figure 1 shows the general block diagram of the proposed supply system.



1 Cabinet	4 Batteries	7 Load circuit breakers
2 Rectifiers	5 UVD switch	8 Connection to another cabinet
3 Bus bar	6 Battery circuit breakers	9 Main control

Figure 1. Block diagram of the supply system.

From the block diagram in Figure 1, it can be defined a basic system that would consist of a standard cabinet that includes the rectifiers powered by the 230V commercial mains and –48V output dc voltage, the back up batteries, the power switches and circuit breakers for the distribution and protection of the loads and the batteries, protection and measure devices and a control unit that guarantees the continuous work of the system according to the specifications. In these power system two completely parts have to be differentiated.

Rectification module. It is usually located in the upper part of the cabinet or in an independent cabinet and it can contain:

- Rectification section composed by several rectifiers connected in parallel.
- Power bus bars.
- Circuit breakers for the ac distribution.
- Circuit breakers and shunts for the dc distribution
- Circuit breakers and shunts of batteries.
- Under voltage disconnection (UVD) switch of the batteries.
- Circuit breakers for the distribution of groups of loads.

Figure 2 shows a practical implementation of one of these systems.

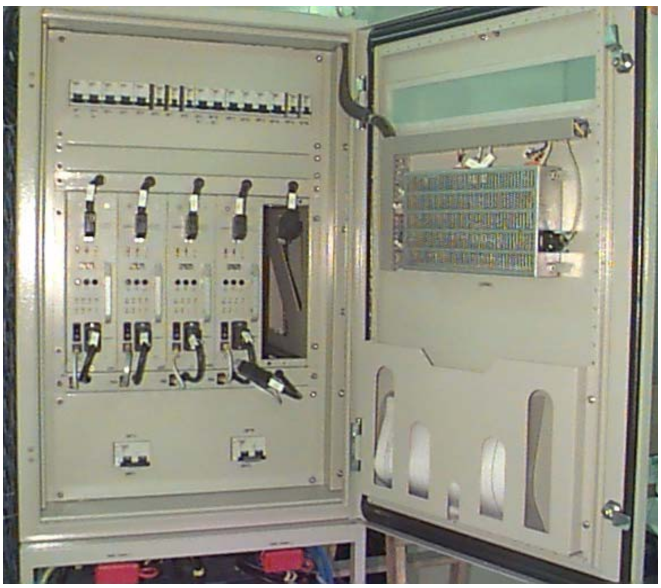


Figure 2. Basic power supply of –48V/250 A.

Battery module. Within the base of the cabinet, or in an annexed one, the batteries are located, usually in two or more groups to assure the redundancy. Each group is built by the association in series of standard voltages batteries (2V, 6V or 12V) necessary to get the nominal voltage of the system with the appropriate capability to assure enough autonomy (usually 1 hour with full load conditions). Optionally, additional groups of batteries can be installed in a annex cabinet to maintain the needed autonomy in future applications.

III. DESCRIPTION OF THE SYSTEM COMPONENTS

Next the different basic elements of the system will be described.

Rectifiers Rack. It is the backbone of any supply system of these characteristics. It contains some rectifiers connected in parallel that are supplying the energy to the load under normal conditions (with mains presence). A careful design has to be made in order to allow a simple and sure assembly of the rectifiers. The rectifiers have to be hot-plug, this means that one or more rectifiers can be connected or disconnected without any interruption of service.

Rectifier. The rectifier is a ac/dc converter with good efficiency (bigger than 92%) and a good input power factor (bigger than 0.95). It is the most important component of the system and it determines the main features of the complete system like EMC specifications, safety standards and MTBF. Their weight and dimensions have to allow an easy manipulation. Also, it must have a plugging system that facilitates a quick and sure electric connection to the system.

The output power range is variable so that it is possible to deliver rectifiers to the market from 600W up to 6000W with a design that maximizes the relationship between the output power and the total rectifier volume, getting superior values than 0.3W for cubic centimetre. The dimensions are also variable although they adapt, in general, to standard dimensions. For example, in a rack of 19 inches of width with 6 or 7UD of high (1UD = 44.75mm) it is possible to connect up to a total of 5 rectifiers of 3000W. Natural convection cooling is used in rectifiers of up to 2000W. For higher power forced ventilation is usually used. The weight of a rectifier can oscillate between 5 and 10 kg depending on the cooling system and on the output power.

Regarding the electronic design, it has to be taken into account the efficiency specifications, input power factor, low electromagnetic emission and high reliability. Therefore, these rectifiers should have an input section with power factor correction (PFC) and a high frequency and soft switching inverter. Figure 3 shows the basic block diagram that describes the usual structure of the rectifier.

Figure 3. Basic block diagram of the rectifier.

Nowadays, the most accepted solution is the circuit boost PFC [2] [3] [4] for the input section, the full bridge ZVT [5] [6] [7] for the inverter section and the current-doubler rectifier circuit for the output section [8].

To increase the reliability of the rectifier, a complete control system must be designed with protections and limitations to guarantee the operation without damage in the case of overload and short circuit at the output or under bad cooling conditions. This system should also allow hot plug connection and the correct distribution of the rectifiers output currents (from 5 up to 25 or more) when they are connected in parallel (current share) with a maximum error of 10%.

The selection of the components and their working conditions should guarantee a high life time (bigger than 30 years) with low failure index (MTBF bigger than 15 years), being able to work in extreme conditions of ambient temperature, relative humidity and height, keeping a high immunity and a low electromagnetic emission.

As mentioned before, the choice of the total number of rectifiers of the supply system is carried out taking into account the redundancy concept. This means that the maximum power that the group of installed rectifiers can deliver should always be bigger than the maximum power demanded by the load circuits. Further, this power is not constant since the energy consumed in a base station depends on the demand of service. Due to these two considerations, in some intervals the power coming from one or more rectifiers is not necessary. In this case, these units can pass transitorily to a stand-by mode, and they can substitute, later, of recurrent and periodic way the others units that are already operating. This cycling process allows to minimize the total time of rectifiers operation and, therefore, to maximize their reliability.

With the purpose of simplifying and reducing the cost of the maintenance works and installation, the rectifiers should have a complete system of digital communication (bus RS485 or CAN) and supervision elements, identification, configuration and diagnosis. In this way, the access to the working parameters, status and failure or warning indications should be allowed in local or remote mode.

Figure 4 shows the developed rectifier and Figure 5 shows the experimental results of its most important electrical characteristics (efficiency, input power factor and total harmonic distortion of the input current).

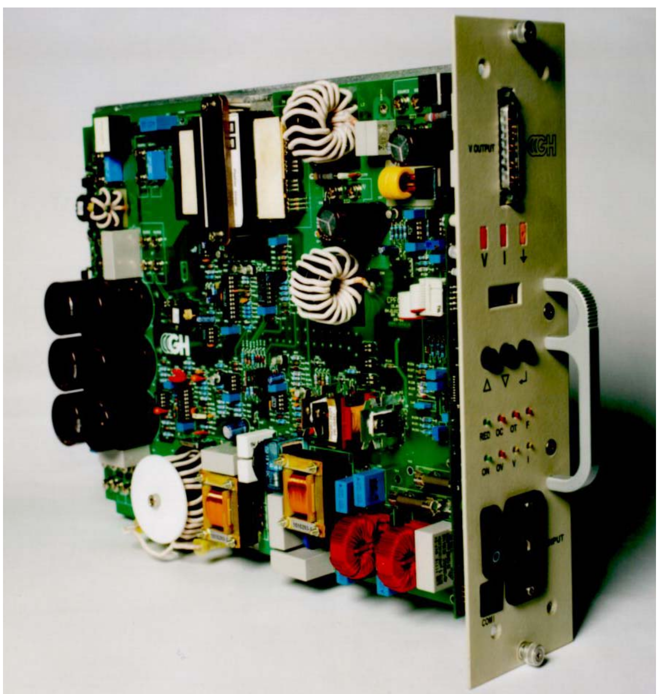


Figure 4. Developed rectifier. (2500W, 60V, 50A).

AC distribution. The feeding of the system can be single phase of 230V (hot to neutral) or tree phase of 400V (three phases and neutral). Anyway, the rectifiers input should be protected by means of bipolar circuit breakers with a double objective: to protect the system from possible overcurrents and to facilitate the individualised connection of the rectifiers to facilitate in this way the installation and maintenance works.

DC Distribution. The distribution of the output voltage of the system is carried out through a copper bus bar of appropriate section in order to reduce voltage and power losses. This bus bar puts in parallel all the rectifiers and it connects them to the batteries through circuit breakers used as protection elements and individualised connection of the groups of batteries. It allows, also the connection to other contiguous cabinets to increase the total power and autonomy of the supply system.

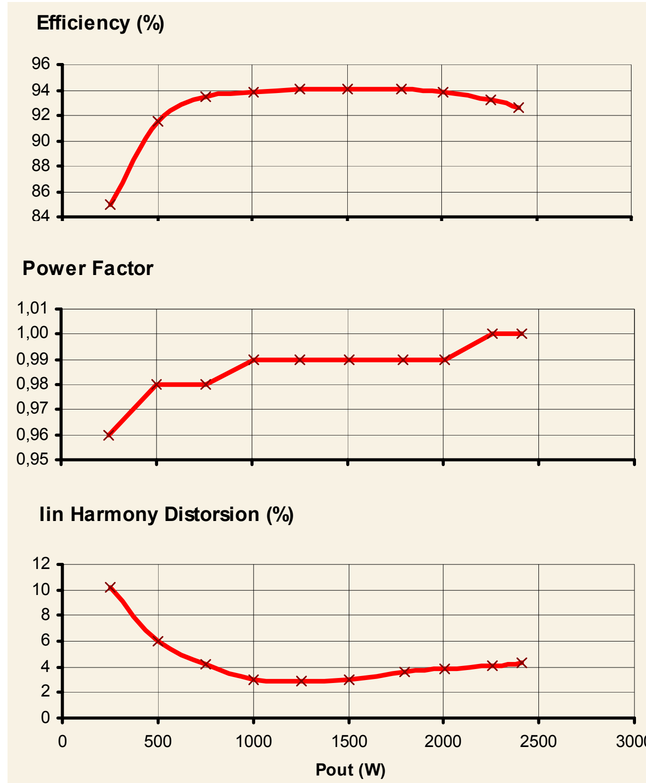


Figure 5. Most important electrical characteristics of the rectifier.

The connection of the batteries to the bus bar is made with an electromechanical switch that carries out a automatic disconnection in case of excessive discharge of the batteries (UVD, under voltage disconnection). In this way damages in the batteries are avoided and it is possible to increase their life time.

The top side of the bus bar connects the rectifiers to the elements of the load distribution. Circuit breakers or fuses are normally used, although the most extended solution at the moment is the first one to protect and to distribute the dc output voltage to the different load circuits. In future, the electromechanical circuit breakers could be substituted by solid state ones.

In many cases it is interesting to distribute the load circuits in function of their importance from the strategic point of view with the purpose of giving priority to certain circuits in the case of long fails. These groups of loads are connected to the batteries by means of individual bus bars and switches. In case of failure, the groups of smaller priority can be disconnected to prolong the powering of the vital groups.

Batteries. The battery module will give the power demanded to the load when the rectifiers stop. This happens when the mains has a failure or when maintenance works are carried out. The selection of the technology of these batteries has a big importance it order to get a good compromise between life time, cost, size, weight, load capability and autonomy.

Normally lead-acid batteries are used. For this application the batteries must be without liquid losses to sure manipulation, low emission of gases and of reduced maintenance. Traditional batteries of liquid electrolyte do not meet the above requirements. The use of sealed batteries VRSL (Valve Regulated Sealed Lead-Acid) is recommended. The gel batteries (gell-cell or gelled electrolyte battery) improve these benefits but they are inadequate under work conditions with deep cycles (charges or discharges of a great percentage of the battery capacity). The present time better adapted technology to this application is the AGM (Absorbed Glass Mat)[9].

IV. SYSTEM CONTROL AND SUPERVISION

The control system is specifically designed and implemented to monitor and control the power system. It has to be absolutely reliable and perturbation immune and has to appropriately respond to any contingencies along its life. It should allow system parameters adjustment, threshold levels settings and alarm definition either from a local or a remote connection [10].

The basic features of the control system are:

1) Modular hardware structure: The control system is made out of several units interconnected through a local digital data network. We may find:

   - A central processing (control) subsystem connected to several satellite data acquisition subsystems, the power rectifiers and the outer world through a GSM modem.

   - A battery monitoring subsystem that acquires data on the battery status and operates the safety breakers in case of malfunction (usually overcurrents through the battery bus).

   - An acquisition board for the AC input voltage and another one for the output DC side.

2) This structure adds flexibility to the system since any acquisition or monitoring subsystems may be designed to fulfill specific requirements, may be upgraded in any system or even redesigned if system specifications are upgraded during the lifetime of the equipment. Further, the central processing unit is able to completely upgrade its software through remote connections.

3) Modular software structure: The software running in the central processing unit is built up from several parallel processes that may be individually (and independently) updated.

4) High reliability and security: The units are to comply the electrical and electromagnetic standards. Class 1 measurements are required within the system [11].

5) Service friendly: The central processing unit is designed to offer remote information of the system operation in order to facilitate a remote diagnosis of system malfunctioning. States visualization, operation, upgrading and diagnosis are provided by a Windows based remote man-machine interface. The system is manufactured for easy service by allowing quick (and in some cases hot) replacement of its electronic subsystems.

All acquisition subsystems are based on a microcontroller based PCB that retrieves the analog information, translates it to digital an sends it to the central processor by using the digital bus. The information is encoded into the CAN protocol data packed that permits the definition of the origin and destination subsystem and the data length.

The different subsystems are connected through a digital communications network that may connect also other subsystem to the installation [11]. We have chosen a multimode differential serial communication over a two wire cable based on the CAN 2.0 specification. With it, up to 128 subsystems may be connected with a maximum separation of 2 km and an speed of 1 Mbs, far over our requirements. The CAN specifications provides all the layers of a real network and results in a transparent flow of information to the network from the applications developer point of view.

The control system provides a local TCP/IP connection and a serial interface with capabilities to offer TCP/IP over point to point protocol connection. This last interface may be connected through a modem to the conventional telephony network or to the mobile GSM, GPRS or the newest UMTS services.

We describe hereon the hardware architecture of the different subsystems of the power supply:

DC distribution control unit. This section monitors the state of the DC circuit breakers and the local presence in each one of the DC lines. Each circuit breaker has an auxiliary circuit that outputs its open or closed state. An optically isolated current sensor in each one of the DC lines monitors the presence or absence of load at each output.

AC distribution control unit. This section senses the AC distribution: AC voltage and current, active and reactive input power, power factor and total harmonic distortion.

Batteries control unit. This subsystem monitors and evaluates the state of the batteries attached to the power system: current through each one of the strings, voltage at each string, temperature and level of charge. All these data are sent to the central processing unit, through the digital network, to estimate the flotation voltage to be set at the DC distribution unit after an approximation of the charge characteristic curve of the batteries that models its behavior. Moreover, this unit knows the state of the batteries circuit breakers and has autonomous capabilities to act on them in case of overcurrent or after a command is received from the central unit.

Rectifiers control unit. Each rectifier has one of these units to connect to the digital bus from where they receive their output voltage command, the configuration parameters and present their state to the central unit.

Central control unit. This is the real control unit of the whole system, drain of the data from the acquisition subsystems and source of commands and configuration parameters for all them. Figure 6 presents a visual rendering of the structure of the system. The subsystem implements the main control loop that involves the data taken form the DC distribution unit and the batteries unit, the calculation of the flotation voltage and the actuation over the rectifiers control units that eventually command the control loops within the rectifiers. Besides, takes care that all the systems parameters are within limits and in case of out of limits takes automated actions to correct them and sets warning and alarm messages.

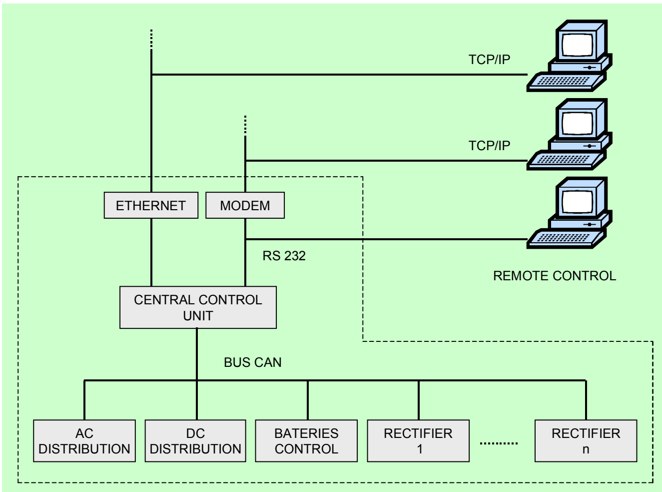


Figure 6. Supervision and control system.

The central control unit has an user interface made out of a 320 times 240 black/white dots monitor and a reduced keyboard to navigate through several configuration menus. It has also several voltage free outputs, optocoupled inputs and warning leds.

The central control unit has been implemented by using an industrial PC104 computer running a custom Linux distribution. The operating system provides the required level of reliability and security, allows running parallel process and offers secure remote connections via TELNET, FTP and HTTP that permit easy configuration and system update. Moreover, it has the possibility of initiating a phone contact and sending email on a regular basis or either after system warning conditions or malfunctioning.

The operating system is stored in a flash disk with enough capacity to store historic databases that can be locally or remotely retrieved.

V. CONCLUSIONS

The enormous development expectation of the UMTS telephony in the present decade indicates a great possibility of growth of the power electronics in this area. The power supply system described in this article is based in three big reference points that are the modularity, the reliability and the accessibility. The future investigations should advance taking into account these concepts.

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