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Better determination of equipment energy consumption for improved sizing of power plant

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Environmental Engineering (EE).

The opportunity for energy reduction in telecom network systems by re-sizing power plants and battery reserves merits examination for several reasons:

1) the increasing use of broadband equipment and the move to next generation systems;

2) the increasing sophistication of rectification equipment;

3) the increasing sophistication of control software;

4) pressure to utilize alternate energy sources.

This paper posits that better data on DC power consumption of equipment can assist in using power plant equipment at its most efficient loading. The difference in design point and operating conditions is especially wide for radio frequency equipment and potentially for next generation IP based systems as well. Hence, mobility equipment is used as an example of the savings attainable if operators had access to more precise and specific power consumption data. The proposal to use power plant equipment more efficiently offers a cost effective way to conserve energy resources.

Introduction

Telecom Network Operators have expressed great concern about the energy costs associated with the operation of their telecommunications networks [1], [2]. In parallel European and US bodies such as the EU's Joint Research Centre and the US Department of Energy are considering ways to legislate energy saving features and efficiency targets into broadband equipment [3], [7]. In addition, energy consumption during the customer use phase has been identified as the aspect with greatest environmental impact (global warming from electric utility greenhouse gas emissions) during the product lifecycle of a piece of broadband network infrastructure equipment [8], [9].

Historically, power plants for Network Infrastructure Equipment have been sized at the same power draw as protection equipment such as AC breakers. This same maximum figure was then used to estimate yearly energy usage and battery backup resulting in an overestimate of power consumption. Plants were also sized for growth. This was appropriate when the industry emphasized robust design and had a centralized telecom infrastructure design. More recent trends require that the telecom industry re-examine how power is sized to see if efficiencies can be gained. Examples of these trends include:

1) the development of broadband technologies;

2) advances in shelf power management;

3) the move to highly distributed telecom networks with smaller modular power supplies closer to the datacom equipment;

4) improvements in rectifier designs and the Code of Conduct for Uninteruptable Power Supplies [10].

Older DC power systems can be greatly improvement by adding automatic functionality into the supervisory control system, without hardware replacement [11].

Another motivation for taking a more aggressive approach to power management is that the number of batteries required for a given amount of battery backup is reduced. This gives one more area for improvement in the carbon emissions data telecom companies are asked to provide [12].

Designing a distributed network of information infrastructure equipment usually involves standardizing on a particular size of power and battery plan in order to streamline ordering and installation. A one-size-fits-all scheme invites excess conservatism.

One of the advances for classic wireline products (access equipment, POTS service, switching, etc.) is in shelf power management. Shelf units receive distributed power along with thermal management. In standardized architectures such as ATCA, the shelf controller provides this function. Many proprietary designs have the same function available. It is a short step from this to system configuration that can be set up to spread traffic load across cards providing better options for thermal management, system life and energy savings.

Broadband equipment such as wireless base station equipment has two complicating characteristics where energy efficiency is concerned: equipment consumes considerable power even in a quiescent state and the average power consumption will vary from expected if the output power calibration is set at a different point than the specified design point. The Broadband Code of Conduct aims to address this issue for DSL equipment, especially customer premises equipment [13]. There is less consensus on how to minimize power consumption for Network Infrastructure Equipment (NIE) [5], [7]. In fact, the power consumption for NIE equipment, especially mobility base station and next generation equipment may increase if telecommunications continues to be seen as a solution to global climate change [14] and [15].

In wireless base station equipment, there is an irony that the more efficient the RF amplifiers the more traffic patterns effect power consumption. Currently, only a small number of sites (~20 %) deployed in worldwide are near full traffic load. Busy hour traffic usually reaches 50 % of theoretical limit. Pilot, page and sync, those are 15-25 % quiescent.

Given the industry trend of convergent networks and the move to distributed systems, conservative power plant design may not be needed to the extent it was in the past. Monitoring software can adjust centralized power plants. In distributed systems "smart" rectifiers are capable of providing amperage above their average rated power on a short-term basis allowing engineers to reduce the number of rectifiers needed for peak loads and redundancy [16]. The efficiency of some rectifiers types drops considerably below 50 % loading. Above 50 % loading, the variation is modest, but measurable, ranging from ~85 % to 90 % when losses in connectors and cables are included. Today's rectifiers can be used on a wider range of power, so that low loads are more frequent. The need for rectifier redundancy, sizing for expected growth in capacity, battery recharge and short term peak power needs may add up to a power plant that is being utilized at less than 100 % loading.

DC rectifiers systems are dependant to load. Improvements are possible by adjusting the power load of the cabinet to get acceptable efficiency of each rectifier. The rectifier load depends on redundancy and battery autonomy. Battery autonomy impacts the power reserved to charge correctly the batteries, because it is often recommended for correct charge to have at C10 charge rate. For 10 h battery autonomy, the current equals C10/10.

EXAMPLE: A 100 A system with 10 hours autonomy has 1 000 Ah battery that needs 100 A to be correctly recharged. If the system supplies 50 A, the load will be of 25 % which is not the maximum efficiency point. This is a 1+1 system at 50 % load. Actual rectifier load rate is calculated for n+1 redundancy at different loads.

Figure 1 shows example of DC system and rectifier efficiency dependence to load.

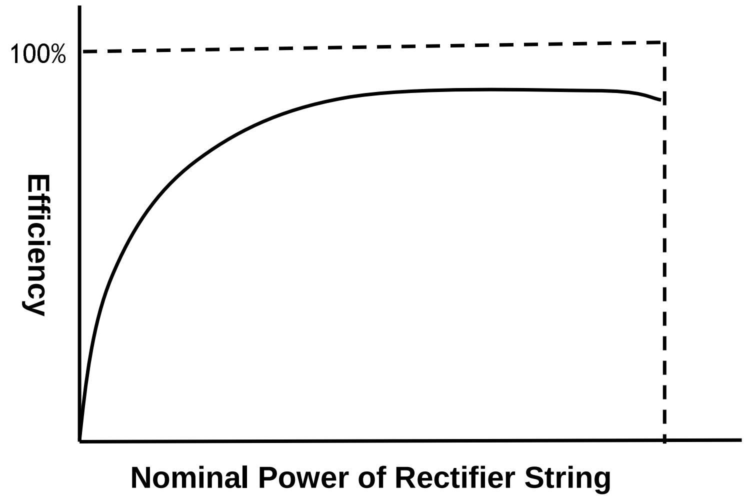

Figure 1: Rectifier Efficiency as a Function of Load

Industry trends point to the need to obtain accurate information on DC power consumption that can be used by Telecom Network Operators to size power plants and cooling systems and to forecast electric utility bills [1]. Forecasting electric demands will be particularly important with increasing pressure to move to renewable sources of fuel [17]. In this paper, one type of broadband equipment, mobility base station equipment, is used to provide a starting set of data with which to build a traffic model appropriate to next generation networks.

1 Scope

The present document presents an analysis of power draw data for mobile phone infrastructure equipment collected in the field. The power draw of in-use conditions of large systems at both lightly and heavily used sites is compared to the design points for the equipment in operation. The analysis and conclusions for this brief study has implications for other types of broadband and central office equipment.

2 References

For the purposes of this Technical Report (TR), the following references apply:

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

[1] ETNO's 2006 Sustainability Report (www.etno.be).

[2] US Telecom Carrier Group Energy Summit, March 13-14, 2007 Baltimore, MD. Press release published.

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[8] ISO 14001: Management Of Sustainable Product Design by Roger Olds, Kathleen Donnelly, Elizabeth Kujan. Proceedings of Sustainable Innovation 05, 10th International Conference, 24&25 October 2005, p.231-236. www.cfsd.org.uk.

[9] "Energy Efficiency Enhancements in Radio Access Networks" by Tomas Edler and Susanne Lundberg, Ericsson Review No. 1, 2004, p. 42-51.

[10] "Code of Conduct on Energy Consumption of Uniteruptable Power Supplies" http://re.jrc.ec.europa.eu/energyefficiency/index.htm.

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[13] Code of Conduct on Energy Consumption of Broadband Equipment; EUROPEAN COMMISSION; DIRECTORATE-GENERAL JOINT RESEARCH CENTRE; Institute for the Environment and Sustainability; Renewable Energies Unit; Final v1- 19 July 2006; http://re.jrc.ec.europa.eu/energyefficiency/index.htm.

[14] ETNO-WWF report titled: Saving the climate @ the speed of light. First roadmap for reduced CO2 emissions in the EU and beyond: http://www.etno.be/Portals/34/ETNO%20Documents/Sustainability/Climate%20Change%20Road%20Map.pdf.

[15] Global e-Sustainability Imitative Position Statement www.gesi.org.

[16] Improving Power System Efficiency as Much as Possible by Xie Yong Ming EE29TD36 and meeting presentation from Huawei Technologies Co., Ltd Sep. 30, 2006.

[17] Tackling Climate Change in the U.S,. Potential Carbon Emissions Reductions from Energy Efficiency and Renewable Energy by 2030; Charles F. Kutscher, Editor January 2007; www.ases.org/climatechange.

[18] Code of Conduct on Energy Consumption in Central Offices.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

3-sigma maximum = statistical maximum: value three standard deviations above the mean value for a set of measured numbers

NOTE: This is also the probabilistic maximum, i.e. it assumes that it not highly improbable that all components will operate at their maximum power draw simultaneously.

6-sigma maximum = absolute maximum: value six standard deviations above the mean value for a set of measured numbers

NOTE: For practical purposes, this is the absolute maximum and equivalent to the value of power draw for all components operating at their maximum simultaneously.

Advanced TCA (ACTA): industry initiative to create a new board and chassis form factor specification optimized for communications

NOTE: It is being developed within the PC Industrial Computer Manufacturers Group (PICMG).

broadband: systems delivering service to the end user with a bandwidth of greater than 2 Mbit/s

NOTE: Typically about 20 Mbit/s or more would be available "instantaneously" but not on a continuous basis, as this bandwidth would be shared between a number of users.

derated operation: operation below the design point

design point: calculated as the sum of the average power consumption for each system component

NOTE: Verified by system test.

mean: computed average value

Root Sum Square: statistical method where the average value

sigma = one standard deviation: parameter characterizing the dispersion of the result obtained in a series of n measurements of the same measured quantity, given by the formula: xi being the ith result of measurement (i = 1, 2, 3, ..., n) and x the arithmetic mean of the n results considered

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

3GPP	Third Generation Project Partnership
ACTA	Advanced Telecom Computing Architecture (Advanced TCA)
EUP	Energy Using Product
MHz	Mega Hertz
NIE	Network Infrastructure Equipment
POTS	Plain Old Telephone Service
RSS	Root Sum Square
US	United States (of America)

4 Study Design and Power Measurements

DC power was measured in 13 field sites under various use conditions. Sites used Flexent™ Modcell 4.0 equipment with high carrier counts. Equipment operated at 850 MHz and 1 900 MHz bands. Indoor and outdoor configurations were measured, although all were in a sheltered environment. Equipment used external power and battery backup.

DC power measurements were collected on a Hewlett Packard 34970A unit using current probes around the DC feeds. Measurements were recorded every 5 minutes continuously for 6-10 days. Where unusual traffic, weather or building air-conditioning failure conditions occurred they were identified through the system reports and noted. These data points were included in the analysis. Measured values were converted to spreadsheet form and analyzed with simple statistics.

Measured DC power draw values were compared with design values. The design point for operation is the calculated average power consumption for the each assembled configuration. A configuration's design point is defined by industry specification (3GPP) for the radio link and by the customer in terms of the number of sector/carriers employed. The design point for frame electrical design and power sizing is the 3-sigma maximum calculated by a root sum square method. Both average and maximum design values are verified through system test.

5 Data and Analysis

Data from field sites is plotted in figures 2 and 3. Figure 2 reports the average measured values plotted against the design points modelled for the specific systems measured. It can be readily seen that systems are being operated in a derated condition. Furthermore, even where the design point is identical, average power draw can show noticeable differences. Figure 3 reports the maximum measured value plotted against the 3-sigma maximum value. Note that the maximums measured and reported here are short-term excursions. While they do not represent an operating condition that a rectifier would need to supply for a long period of time, they show a real need for power above the mean value.

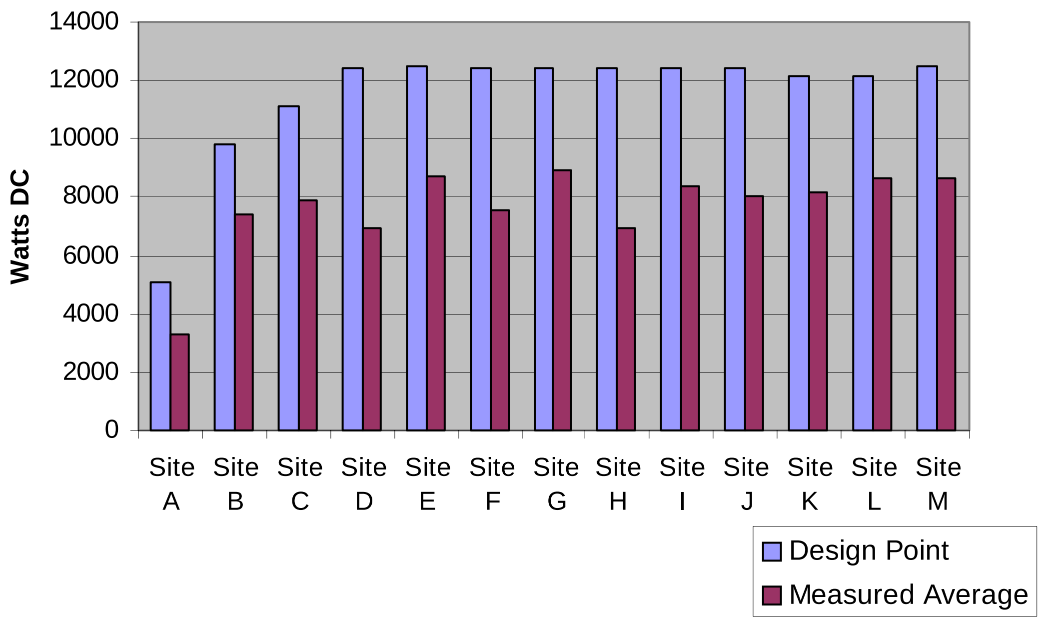

Figure 2: Average Power Draw

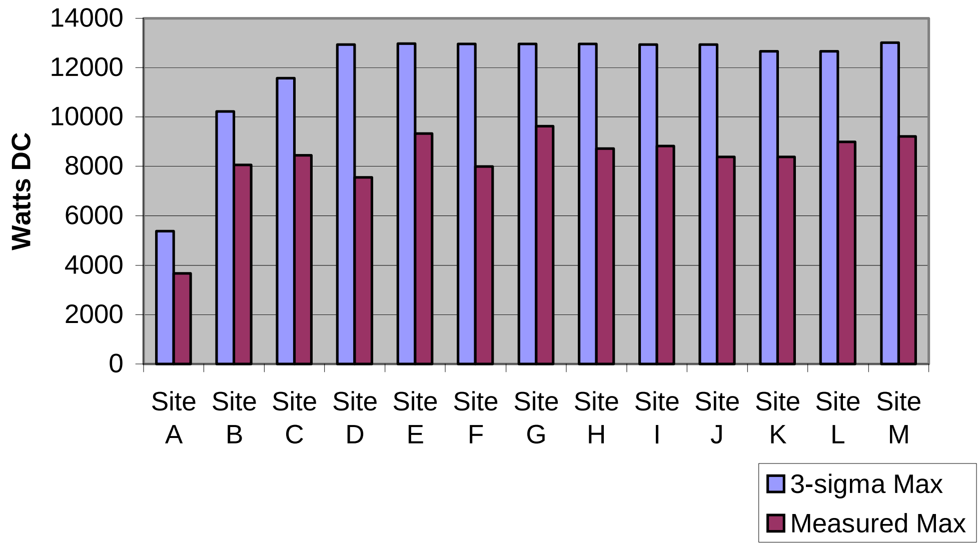

Figure 3: Maximum Power Draw

Data obtained from software integration test labs on both CDMA and UMTS air-interface technologies has shown results similar to the data plotted in figures 2 and 3.

To understand the average power draw vs. the published value for the equipment used to size the rectifiers, the 3-sigma maximum value is divided by the average power consumption. This gives a rough idea of what the loading of the rectifiers might be in a system where no margin was added and no rectifier redundancy is used. This calculation is provided for each site in table 1. If more conservative numbers are used and rectifier redundancy is included, loading on the rectifiers would be reduced from the values in table 1.

Table 1: Power Consumption and Rectifier Sizing

	Average Consumption/3-sigma Max
Site A	62 %
Site B	73 %
Site C	68 %
Site D	54 %
Site E	67 %
Site F	58 %
Site G	69 %
Site H	54 %
Site I	65 %
Site J	62 %
Site K	64 %
Site L	69 %
Site M	66 %

Data demonstrates that this broadband equipment power usage is a strong function of user-controlled operation. To understand how much of this function the RF amplification is, and how much variation comes from the digital and filter assets, measurements were made on the cables powering the non-RF amplifier portion of the base station (see note). Results are shown in figure 4.

NOTE: This power feed also includes variable speed fans to cool the digital assets.

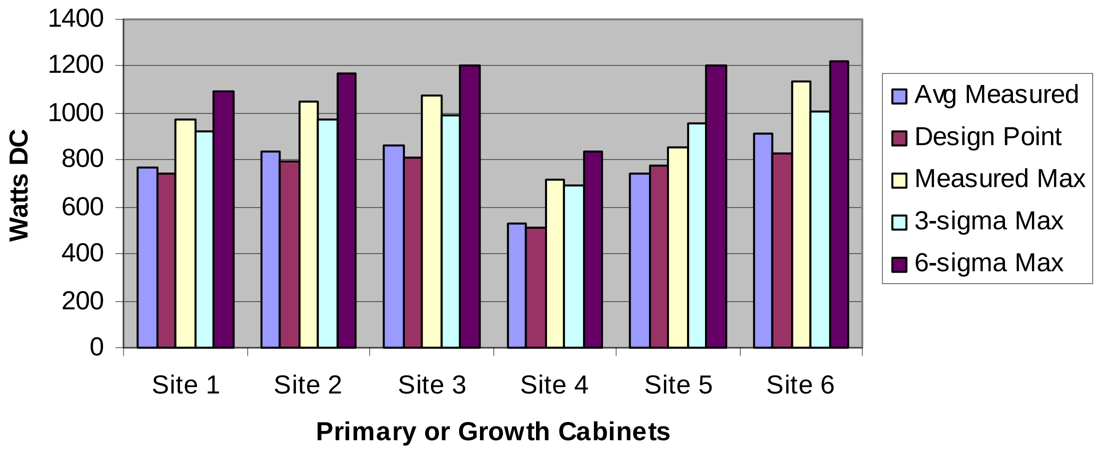

Figure 4: Power Draw for Digital and Filter Assets

Difference between the design points and measured values of digital and filter assets in primary cabinet ranges from -10 % to +5 %. For the growth cabinet, the difference is smaller at -3 %. The root sum square (RSS) 3-sigma maximum values difference from the measured maximum value is -11 % to +12 % for the primary cabinet and -5 % for growth cabinet. The 6 -sigma maximum value is shown for reference, although it is rarely used in design.

Design modelling for the digital and filter assets, while imperfect, is close enough to be assured that use conditions are not adversely affecting our ability to size power. It is the RF amplification and its use that is driving the large variations we observe.

6 Proposal for Standardized Power Draw Values

Results of this study, lead to a proposal for standardizing the power draw values requested by equipment operators. Three power draw values are relevant and can be used for different purposes:

1) A statistical maximum (3 sigma) for sizing protection equipment (although if batteries are involved, this often will be sized based on the current for battery recharge based on maximum number of rectifiers expected. Other parameters are lower voltage after restart of the system and inrush current is also to take into account). An absolute maximum, or 6-sigma maximum should not be used.

2) A typical power draw for design point use for sizing power plant.

3) If applicable, one or more values for expected field use for estimating yearly power consumption. The manufacturer would have freedom in defining this number(s.) Examples would be power draw at derated output, power draw for partially configured systems or system behaviour with differing traffic models. The belief here is that competition will be fostered by the identification of power saving modes of operation and features that better inform Telecom Network Operators about the differences between manufacturers equipment.

Comparing the spread between values 2 and 3 will help Telecom Network Operators understand how close or far they may be from operating the power plant at its maximum efficiency point. There may be opportunities making greater use innovations in rectification technology and power monitoring software algorithms. Similarly, if equipment will never be used at its design point, power plant equipment may be sized using derated power draw value(s) in the capacity calculation.

7 Conclusion

Telecom power plants for certain 3G mobility sites may not be operating at their most efficient loadings according to the data taken at 13 distributed telecom sites in the US. To tailor power plants without an impact to system reliability, better data on power draw at specific in-use conditions will be needed. Standardized definitions of power consumption would aid in communication between equipment manufacturers and equipment operators.

Annex A: Implications for Cooling Systems

As it continues, this study aims to produce power sizing models that can improve the efficiency of power plant operation as a function of traffic, and other applicable parameters. This also has implications for cooling systems. Power consumption for air conditioning can cause large fluctuations of draw in the AC mains. Cooling systems in Central Offices are proposed to come under a Code of Conduct [17].

History

Document history		
V1.1.1	April 2007	Publication