ENERGY EFFICIENT SOLUTIONS FOR GREEN CELLULAR NETWORKS – A SURVEY

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ABSTRACT

In recent years, Energy – Efficiency in Cellular Networks is an important concern for network operators. The growing awareness of Energy – Efficiency as well as economic concern of network operators provides the new technologies in designing Green Cellular networks. The green cellular network has become the most popular research topic for the future. The Energy – Efficiency solution can be achieved by improving the design of certain hardware or by providing renewable energy sources (RES) like solar or wind. According to the technical analyst, the Base Stations (BSs) are the most energy intensive part of the Cellular Network. As the BSs consume more power of the total energy used in cellular network, a survey on techniques to obtain energy saving in BSs and powered by renewable energy sources in the area where there is no public and stable power supply to obtain the Green Cellular Networking is considered first. In this survey, the realities which gives the importance of green mobile networking and review of the existing methods to obtain Energy – Efficiency is presented.

Keywords: Energy – Efficiency, Base Station, Green Cellular Network, sleep mode, Renewable Energy Sources (RES).


http://www.iaeme.com/IJECET/issues.asp?JType=IJECET&VType=9&IType=5

1. INTRODUCTION

The rapid growth of mobile users and the network devices creates a severe consequence. The growing awareness of global warming and environment consequences of Information and Communication Technology (ICT), researchers have been finding ways to reduce energy consumption [1], [2], [3]. In ICT, the cellular network become a significant component which has considerable concentration of many researchers to reduce the energy in cellular networks, since it increases the energy bills for telecommunication service providers and it increases the emission of (CO2) carbon foot print [4]-[8]. The increase of energy bill depends on the usage
of Android and iPhone devices, use of ebook readers such as iPad and Kindle and the success of social networking giants. It increases the demand for cellular data traffic and motivates new high – speed (more energy consuming) network standards like 4G LTE.

![Figure 1 Number of Smart Phone users in India from 2015 to 2022](image)

Such extraordinary growth in cellular industry has pushed the limits of energy consumption in wireless networks. There are currently more than 4 million base stations (BSs) serving mobile users, each consuming an average of 25MWh per year. The numbers of BSs in developing regions are expected to almost double by 2022 as shown in Fig. 1. Information and Communication Technology (ICT) already represents around 2% of total carbon emissions (of which mobile networks represent about 0.2%), and this is expected to increase every year. In addition to the environmental aspects, energy costs also represent a significant portion of network operators’ overall expenditures (OPEX). While the BSs connected to electrical grid may cost approximately 3000$ per year to operate, the off-grid BSs in remote areas generally run on diesel power generators and may cost ten times more [9]. Due to this tremendous growth, Energy efficiency is becoming increasingly important for cellular mobile network operators due to environmental and economic concerns [10–12]. Reduction in energy consumption reduces pollution and greenhouse gas and brings cost-saving benefits to the operators and consumers.

![Figure 2 Power consumption of a Cellular Network](image)

Figures 2 shows a power consumption of various components in a distinctive cellular network and gives the understanding into the possible research avenues for reducing energy consumption in wireless communications [9]. A typical cellular network consists of three main elements; A core network that takes care of switching; base stations providing radio
frequency interface; and the mobile terminals in order to make voice or data connections. The power consumption is distributed across the different functionalities of the network like mobile switching, core transmission, data centre etc. [13,14]. But the base stations are the most energy intensive part of the cellular network. A typical 3G base station which uses 500W of input power to produce 40W of output RF power will consume more than 50GWh a year in a network with 12,000 base stations. This causes a large amount of CO2 emission as well as contributes to the network's operating costs [15]. In Cellular network, base station power feeding is the major power issue concerning. Saving power in base stations is therefore the primary focus in green cellular network development [16]. In this paper, a brief survey on some of the work that has already been done to achieve power efficiency in cellular networks, discuss some research issues and challenges and suggest some techniques to enable an energy efficient or “green” cellular network is provided.

2. METHODOLOGIES

There are various distinctive approaches to reduce energy consumptions in a mobile cellular network. Approaches in previous research can be broadly classified into the following categories.

- **Architecture Level.**
  - Hardware Components
  - Base station Sleeping
- Enhancing energy efficiency of the radio broadcast process.
- Deployment of heterogeneous cells.
- Implementing renewable energy resources.

2.1. Hardware Components

Approaches of the first category aim to improve hardware components (such as power amplifier) with more energy efficient design (e.g. [17]–[21]). The performance of most components used in current cellular network architecture is unsatisfactory from the energy efficiency perspective. Considering, for example, the power amplifier, the component consuming the largest amount of energy in a typical cellular base station (BS), more than 80% of the input energy is dissipated as heat. Generally, the useful output power is only around 5% to 20% of the input power [22]. Studies showed that the potentially optimized ratio of output power to input power for power amplifiers (power efficiency) could be as high as 70% [22]. Accordingly, substantial amount of energy savings can be achieved if more energy efficient components are adopted in the network. However, the implementation cost for these approaches is high. For example, a power amplifier module with 35% power efficiency for small cell WCDMA or LTE BSs (cover at most an area of a radius of 2 km) costs around $75 [23]. The cost will be even higher for larger coverage or higher power efficiency. Therefore, careful consideration in both operational and economical aspects by network operators is required before decisions on hardware replacement are made.

The Flexi base station (BTS) - An industry-leading, cost and energy-efficient multi-radio base station for Single Radio Access Network (RAN) advanced mobile broadband networks is an example of efficient site design and management by Nokia Siemens Networks [24]. The Flexi base station acts as a software-defined base station for technologies like Global System for Mobile Communications (GSM)/ Enhanced Data rates for GSM Evolution(EDGE), Wideband Code Division Multiple Access(WCDMA)/ Evolved High-Speed Packet Access(HSPA+), and 3rd Generation Partnership Project(3GPP) - Long Term Evolution(LTE) (i.e Frequency division duplex(FDD)/ Time-division duplex(TDD) systems). The benefits of a
Flexi base station are as follows: reduced installation time and materials costs, compact size and reduced weight - only 20% of a conventional cabinet base station, up to 70% reduction in site power consumption, flexible location either indoor or outdoor without the need for air conditioning, shorten antenna feeders. The Flexi base station carbon footprint is further diminished by its software-based capacity to remotely manage tuning the running capacity, upgrade, cancelling the need for site visiting. Its upgrading capability enables flexibility for sites to upgrade and adapt to future radio technologies with maximum re-use of legacy site infrastructure.

The Ericsson’s Tower Tube- Tower Tube is an award-winning solution by Ericsson with latest technology and innovative design to reduce construction cost, decrease carbon emission, energy optimization and for pleasant look [25]. In tower tube the radio base station is positioned at height for improved network’s coverage, capacity and low feeder loss. It is space efficient with all slim designed equipment encapsulated in the tower. It does not require cooling. Thus, with cutting edge design and building materials like concrete with post-tension reinforcement technology, the Tower tube lowers the amount of carbon dioxide in the manufacturing process also.

2.2. Switching off Components

The second category covers approaches that selectively turn off some resources in the existing network architecture during non-peak traffic hours (e.g.,[26]–[32]). Approaches in this category generally try to save energy by monitoring the traffic load in the network and then decide whether to turn off (or switch to sleep mode, also referred as low-power mode or deep idle mode in some literature), or turn on (or switch to active mode, ready mode or awake mode) certain elements of the network. Unnecessary energy consumptions, for example, air conditioning under-loaded BSs, can be avoided by adopting such sleep mode mechanisms. These approaches generally involve switching certain elements including but not limited to power amplifiers, signal processing unit, cooling equipment, the entire BS, or the whole network back and forth between the sleep mode and the active mode [32]. Most often, sleep mode techniques aim to save energy by selectively turning off BSs during “off-peak” hours. As shown in Fig. 2, BSs consume the highest proportion of energy in cellular networks. On the other hand, dense BSs deployments today lead to small coverage area and more random traffic patterns for individual BS, which make sleep mode operations more desirable. The sleep mode techniques are based on current architecture, they have the advantage of being easier to test and implement as no replacement of hardware is required and the performance can be evaluated by computer simulation. One more practically implementable switching on – off based energy saving algorithm (SWES) that can be operated in a distributed manner with low computational complexity. [34].

2.3. Optimizing energy efficiency

In the current cellular network architecture based on WCDMA/HSPA, BSs and mobile terminals are required to continuously transmit pilot signals. Newer standards such as LTE, LTE-Advanced and WiMAX have evolved to cater ever-growing highspeed data traffic requirements. With such high data requirements, although BSs and mobile units (MU) employing newer hardware (such as multiple-input and multiple-output (MIMO) antennas) increase spectral efficiency allowing to transmit more data with the same power, power consumption is still a significant issue for future highspeed data networks and they require energy conservation both in the hardware circuitry and protocols. A fairly intuitive way to save power is to switch off the transceivers whenever there is no need to transmit or receive. The LTE standard utilizes this concept by introducing power saving protocols such as discontinuous reception (DRX) and discontinuous transmission (DTX) modes for the mobile
handset. DRX and DTX are methods to momentarily power down the devices to save power while remaining connected to the network with reduced throughput. Continuous transmission and reception in WCDMA/HSPA consumes significant amount of power even if the transmit powers are far below the maximum levels, and therefore power savings due to DRX and DTX is an attractive addition. IEEE 802.16e or Mobile WiMAX also has similar provisions for sleep mode mechanisms for mobile stations [35]. The device negotiates with the BS and the BS will not schedule the user for transmission or reception when the radio is off. There are three power-saving classes with different on/off cycles for the WiMAX standard. Unfortunately, such powers saving protocols for BSs have not been considered in the current wireless standards. The traffic per hour in a cell varies considerably over the time and BS scan regularly be under low load conditions, especially during the night time. In wireless standards, energy saving potential of BSs needs to be oppressed by designing protocols to enable sleep modes in BSs in the future. The authors in [36] suggest making use of downlink DTX schemes for BSs by enabling micro-sleep modes (in the order of milliseconds) and deep-sleep modes (extended periods of time). Switching off inactive hardware of BSs during these sleep modes can potentially save a lot of power, especially under low load conditions [6].

2.4. Deploying heterogeneous cells

The next category tackles the problem by deploying small cells, including micro, pico and femto cells, in the cellular network [37]. These smaller cells serve small areas with dense traffic with low power-consuming cellular BSs (e.g., [26], [38]–[45]), which are affordable for user-deployment and usually support plug-and-play feature. The area covered by base station signals is called cell [3]. Based on the amount of area covered the base stations can be classified as Macro cell base station, Micro cell base station, Pico cell station and Femto cell base station. Femto cells cover the smallest area and they are deployed in a room. Pico cells are deployed in offices or shopping malls and they cover more area than femto cells. Micro cells can cover blocks of buildings in an urban locality and cover area more than pico cells. Macro cells cover the largest area among all the cells and generally they are deployed in rural areas or on high ways. [46] In contrast to conventional homogeneous macro cell deployment, such heterogeneous deployment reduces energy consumption in the network by shortening the propagation distance between nodes in the network and utilizing higher frequency bands to support higher data rates. The major constraint of these approaches is the extra small cells bring additional radio interferences as compared to conventional homogeneous macro cell networks, which might negatively affect user experience.

2.5. Renewable Energy Sources

The last category includes approaches that adopt renewable energy resources. Compared to current widely used energy resources such as hydrocarbon which produces greenhouse gases, renewable resources such as hydro, wind and solar power stand out for their sustainability and environmental friendliness [47], [48]. Telecom manufacturers have planned the supply of solar power operated cellular BSs in under developed areas such as Bangladesh and Nigeria, where roads are in poor condition and unsafe, so delivering traditional energy resources for off grid BSs (e.g., diesel) cannot be guaranteed [49], [50]. Energy harvesting techniques, namely exploiting available energy from such renewable resources to complement existing electrical infrastructure will be the long term environmental solution for the mobile cellular network industry.
In general, green cellular network is a relatively new area of research. Most of existing publications are based on ideal models. The fundamental aim, as its name implies, is to make cellular networks “greener” by reducing total power consumption through various approaches described above.

### 3. THE GREEN METRICS MEASUREMENT

The notation of “green” technology in wireless systems can be made evocative with a comprehensive evaluation of energy savings and performance in a practical system. This is where energy efficiency metrics play an important role. These metrics provide information in order to directly compare and evaluate the energy consumption of various components and the overall network. In addition, they also help us to set long term research goals of dropping energy consumption. With the upsurge in research activities relating to green communications and hence in number of diverse energy efficiency metrics, standards organizations such as European Technical Standards Institute (ETSI) and Alliance for Telecommunications Industry Solutions (ATIS) are currently making efforts to define energy efficiency metrics for wireless networks [51], [52]. In general, energy efficiency metrics of telecommunication systems can be classified into three main categories: facility-level, equipment-level and network-level metrics [53], [54]. Facility-level metrics relates to high-level systems where equipment is deployed (such as data centres, ISP networks etc.), equipment level metrics are defined to evaluate performance of an individual equipment, and network level metrics assess the performance of equipment while also bearing in mind features and properties related to capacity and coverage of the network. The Green Grid (TGG) association of IT professional’s

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**Table 2 Comparison of Various Techniques for Energy Reduction**

<table>
<thead>
<tr>
<th>S.No</th>
<th>Methods</th>
<th>References</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Hardware Components</td>
<td>Z. Hasan, H. Boostanimehr, and V. K. Bhargava Ref [6]</td>
<td>Upto 70% reduced using switch mode power amplifiers</td>
</tr>
<tr>
<td>2.</td>
<td>Flexi Base station</td>
<td>Chethana R Murthy Ref [13]</td>
<td>Up to 70% reduction in site power Consumption</td>
</tr>
<tr>
<td>4.</td>
<td>Base station Sleeping</td>
<td>E. Oh, K. Son, and B. Krishnamacharri Ref [34]</td>
<td>Upto 80% energy saving</td>
</tr>
<tr>
<td>5.</td>
<td>Cell Deployment</td>
<td>Z. Hasan, H. Boostanimehr, and V. K. Bhargava Ref [6]</td>
<td>up to 60% savings compared to a network with macro-cells</td>
</tr>
<tr>
<td>6.</td>
<td>Renewable Energy Sources</td>
<td>Mohammed H. Alsharif and Jeong Kim Ref [64]</td>
<td>up to 0.35% of global diesel consumption</td>
</tr>
</tbody>
</table>
first proposed facility-level efficiency metrics called PUE (Power Usage Efficiency) and its reciprocal DCE (Data Centre Efficiency) in [55] to evaluate the performance of power hogging data centres. PUE which is defined as the ratio of total facility power consumption to total equipment power consumption is although a good metric to quickly assess the performance of data centres at a macro level, it fails to account for energy efficiency of individual equipment. Therefore, in order to quantify efficiency at the equipment level, ratio of energy consumption to some performance measure of a communication system would be more appropriate. However, grading the performance of a communication system is more challenging than it actually first appears, because the performance comes in a variety of different forms (spectral efficiency, number of calls supported in block of time, etc.) and each such performance measure affects this efficiency metric very differently. Some suggested metrics including power per user (ratio of total facility power to number of users) measured in [Watt/user], and energy consumption rating (ECR) which is the ratio of normalized energy consumption to effective full-duplex throughput and is measured in [Watt/Gbps] [56]. While power per user can be a useful metric for a network provider to evaluate economic trade-offs, network planning etc., metrics such as ECR provide the manufacturers a better insight into performance of hardware components. However, even the busiest networks do not always operate on full load conditions, therefore it would be useful to complement metrics such as ECR to incorporate the dynamic network conditions such as energy consumption under full-load, half-load and idle cases. In this regard, other metrics such as ECRW (ECR-weighted), ECR-VL (energy efficiency metric over a variable-load cycle), ECR-EX (energy efficiency metric over extended-idle load cycle), telecommunications energy efficiency ratio (TEER) by ATIS, Telecommunication Equipment Energy Efficiency Rating (TEEER) by Verizons Networks and Building Systems consider total energy consumption as weighted sum of energy consumption of the equipment at different load conditions [56], [57], [58], [59]. As an example, for TEEER, the total power consumption \( P_{\text{total}} \) is calculated by the following formula

\[
P_{\text{total}} = 0.35P_{\text{max}} + 0.4P_{50} + 0.25P_{\text{sleep}},
\]

where \( P_{\text{max}} \), \( P_{50} \) and \( P_{\text{sleep}} \), are power consumption at full rate, half-rate and sleep mode, respectively, and the weights are obtained statistically. However, these metrics such as ECR, TEER, TEEER etc. are unable to capture all the properties of a system and research work is still active to suggest different types of metrics. [9]

**Table 2** Units of Energy Efficiency Metrics at Various Levels

<table>
<thead>
<tr>
<th>Metric</th>
<th>Units</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUE (Power Usage efficiency)</td>
<td>Ratio</td>
<td>Facility – level</td>
</tr>
<tr>
<td>DCE (Data Centre efficiency)</td>
<td>Percentage</td>
<td>Facility – level</td>
</tr>
<tr>
<td>Telecommunication Energy Efficiency Ratio (TEER)</td>
<td>Gbps/Watt</td>
<td>Equipment – level</td>
</tr>
<tr>
<td>Energy Consumption Rating(ECR)</td>
<td>Watt/Gbps</td>
<td>Equipment – level</td>
</tr>
<tr>
<td>ECR – Weighted (ECRW)</td>
<td>Watt/Gbps</td>
<td>Equipment – level</td>
</tr>
<tr>
<td>ECR – Variable load (ECR-VL)</td>
<td>Watt/Gbps</td>
<td>Equipment – level</td>
</tr>
<tr>
<td>Performance Indicator in rural areas (PIrural)</td>
<td>Km2/watt</td>
<td>Network-Level</td>
</tr>
<tr>
<td>Performance Indicator in urban areas (PIurban)</td>
<td>Users/watt</td>
<td>Network-Level</td>
</tr>
</tbody>
</table>
4. ENERGY EFFICIENCY METRICS FOR BASE STATION SITES

Energy efficiency has become an important issue for base station sites, where specific performance metrics, requirements and technologies to improve energy efficiency must be taken into consideration. For site infrastructure, a simple metric used to verify the efficiency of base station site facilities is considered sufficient and has the advantage of being relatively simple to calculate as well as allowing remote measurements to be carried out. Renewable energy usage is considered an important factor to reduce the effect of climate change. Consumption of more energy from renewable sources including local or dedicated grid power and the use of fuels with lower carbon contents are ways to reduce carbon emissions. Electricity from renewable energy sources shall be included in the total energy consumption on site. The site energy efficiency (SEE) metric described in ITU-T Recommendations helps mobile network operators (MNOs) to assess important sustainability aspects on cell sites as well as helping them to compare results and determine opportunities to increase energy efficiency or reduce power consumption.

The total energy consumption of the base station site will include the grid electricity as well as local energy sources such as diesel generators or solar systems.

4.1. Base station site energy efficiency assessment

Figure 4 shows a base station site diagram illustrating the energy measurement points considered in ITU-T Recommendations.

Figure 3 An example of a radio base station site with energy flow and measurement points

Figure 4 does not take into account the fact that the power system is always a separate entity with respect to the telecom equipment, nor does it take into account the following configurations:

- The AC/DC conversion may be integrated into the telecom part and the air cooling unit may be not present, e.g., for a pole mounted base station site.
- The battery may be present if power backup is required.
- Multiple functions (telecom AC/DC conversion, battery and cooling) may be integrated in a single box as is typical for outdoor equipment.
- Functions may be realized as separate physical units.

Site energy efficiency metric definition Site energy efficiency (SEE) represents the site efficiency of the measured site. Site energy efficiency (SEE) is the ratio between the total energy consumption of telecommunication equipment and the total energy consumption on site.
SEE = ECT/ ETS x100% \hspace{1cm} (2)

The definition proposed here is selected employing the same philosophy as the power usage effectiveness (PUE) indicator used in data centre technologies. The total energy consumption of telecommunication equipment is indicated as ECT in Figure 3. ECT is the energy consumption of telecommunications equipment present in the base station site under consideration during the measurement time period. ETS is the sum of different input energy sources such as from a public grid, a diesel generator present on the site or from a different type of local generator or a renewable energy source, etc.

ETS = EGE + EFE \hspace{1cm} (3)

where ECT is the energy consumption of telecommunications equipment present in the base station site under consideration during the measurement time period.

EGE is the input electric energy (in kWh) from the public grid during the measurement time period.

EFE is locally produced electrical energy (in kWh) generated by a genset or other type of local generator with a renewable energy source on the site during the measurement time period. [63]

5. OPTIMAL POWER SYSTEM FOR MOBILE BASE STATION

Currently, there has been an observed extraordinary growth in the number of mobile subscribers in rural areas, which has prompted mobile network operators to expand their cellular networks to provide mobile service to subscribers in rural areas, increasing the profitability of the operators [65]. However, operational expenditures and greenhouse gas emissions are a major concern of the mobile network operators because diesel generators are typically used to power the off-grid cellular base stations in remote areas [66], which challenge mobile network operators to find an economically feasible alternative power source that is also environmentally friendly. With the current progress in renewable energy, the key features of a power source, such as the cost effectiveness, sustainability, and reliability, as well as reduction of the greenhouse gas emissions, can be met [64].

In recent years, society’s energy demands are fulfilled using conventional energy sources such as water, coal, oil, natural gases or uranium. The production of energy using these conventional sources is a cause of concern of many environmentalists. The major problems can be quoted as follows:

- It causes atmospheric pollution, climate changes or nuclear waste and thus can endanger our living condition on the earth.
- The extensive use of these limited conventional energy sources may result in complete depletion of energy sources and hence, there is no guarantee of energy supply for future.

The above-mentioned problems can be solved by using renewable energy sources such as Sun and Wind. The renewable energy sources use natural resources and do not cause any pollution. Hence, they are termed as Green Energy sources. Moreover, these renewable energy sources only use a small part of the flow that is why they cannot damage natural surrounding and also do have the risk of being depleted.[46]

Traditional Global System for Mobile communications (GSM) equipment is targeted to the urban environments only. Vendors and operators of the GSM equipment have been facing difficulty to meet certain challenges in remote rural areas such as it costs much, expensive to run, uses much power and is difficult in deploying in rural areas with limited electricity.
energy supply, lack of skilled engineers and poor roads. Hence it is very important to take into consideration all these problems before deploying solar powered base stations.

It is very essential to get an estimate of not only the number of the photovoltaic (PV) cells, inverters, batteries and generators required but also the cost of production of energy per unit before the actual deployment of the solar powered base stations. In order to do so it is always suggested to design and simulate the deployable solar powered base stations using software. The average daily solar radiation in Chennai, which is located at latitude between 13° N latitude and 80° E longitude, is estimated to be 5.32 kWh m−2 and varies from 4.09 kWh m−2 in December to 6.51 kWh m−2 in April. [67]

![Figure 4 Monthly Average Global irradiance at 13° N latitude and 80° E longitude](image)

According to figure (5), this study attempts to determine the criteria for the solar energy systems for different values of solar radiation to cover all possible areas of Chennai: 5.4 – 5.6 kWh m−2. The monthly average solar radiation values used in this study are obtained from the NASA Surface Solar Energy using the longitude and latitude of Chennai.

### 5.1. SYSTEM MODEL

A typical model of a solar energy system integrated with an LTE-macro base station is shown in Figure 6. The solar panels feed the required energy to the LTE-macro base station. However, in case of the malfunction of the solar panels, resulting in an inability to provide the energy required to the LTE-macro base station, the battery bank compensates for the shortage of energy. If the battery bank reaches its maximum depth of discharge (DOD) and loses the ability to supply the LTE-macro base station the required energy, backup diesel generator supplies energy to the LTE-macro base station. Hence, the diesel generator is suggested as a backup power source to secure the power supply during maintenance or in case of a malfunction in the system. The static switch monitors the power of the solar power system. If the output power is less than required to meet the AC loads, the AC loads switch to draw energy from the backup diesel generator.
Figure 5 A model of a solar energy system integrated with an LTE-macro base station

The elements of the solar power system are listed below; these elements are designed for easy installation and disassembly. Moreover, due to the significant development in solar technology, these components are designed with high efficiency and low losses to contribute to energy saving.

a. Solar panels: absorb shortwave irradiance and convert it into direct current (DC) electricity.

b. Solar regulator charger: control unit responsible for the regulation of the unregulated DC output voltage of the solar array to regular DC voltage that is compatible with the load and the battery. In this study, the DC load (LTE-macro base station) voltage is 48 Vdc.

c. Batteries: store excess energy from the solar arrays to be used at night or when the power output of the solar panels is not sufficient to cover the LTE-macro base station load. A charge control unit is added to protect the batteries by regulating the charging and discharging process and maintaining the battery lifecycle.

d. Inverter: converts the 48 DC voltage of the DC bus-bar into 220 alternating current (AC) voltage that is used to feed the AC load in the base station.

e. Control unit: key element in the solar power system that manages and controls the power flow of the different elements in the solar power system to meet the demands of the LTE-macro base station load.
The implementation of a Grid–connected solar power system within the PVSYST simulation software and the configurations for the various elements in the system are shown in Figure 7. The system design for standalone system is more complicated compared to grid connected as the standalone system contains batteries and generators apart from inverters and PV modules. This adds extra constraint to the design.

Grid connected systems are suitable if the supply of solar energy is reliable. In other words, it is suggested to use grid connected system in summer in India. If the supply of solar energy is not reliable like during monsoon season in India then it is suggested to use standalone system though it is costly compared to grid connected system. Hence there is always trade-off between reliability and cost efficiency while deploying solar powered cellular base stations.

6. CONCLUSION

In this paper, the inclusive survey of current green techniques for mobile networks with their merits and demerits. Also, this paper has surveyed recent progression in the research of BS sleep mode methods in cellular networks, which is one of the major methods to reduce total energy consumption, have presented. Growing energy consumption has been a major concern and many revisions on energy saving approaches in networking and telecommunication sectors have been published after the first work concerning the energy issue in the mainstream networking area published in 2003, which refers to the greening of the Internet [68]. The fact that cellular networks were designed with the main goal of maximum throughput and coverage indicates significant advances are possible by effective power managing schemes. It is now widely accepted that the energy consumption reduction in cellular networks will bring both operating profit for mobile operators and environmental benefit for the planet. In
summary, the sleep mode technologies as well as the whole green cellular network are auspicious areas of research. It will undoubtedly remain a popular research topic for the coming years, since there is bright potential as well as issues waiting to be solved.

REFERENCES


Energy Efficient Solutions for Green Cellular Networks – A Survey


http://www.ericsson.com/ourportfolio/products/ericsson-tower-tube


Energy efficiency metrics of a base station site, Recommendation ITU-T L.1350

Optimal Solar Power System for Remote Telecommunication Base Stations: A Case Study Based on the Characteristics of South Korea’s Solar Radiation Exposure Mohammed H. Alsharif * and Jeong Kim


http://www.google.com/search?q=pvsyst+v4.33&rlz=1R2ADRA_enS_E336&aq=7&oq=PVSYS&aqi=g3-s1g6