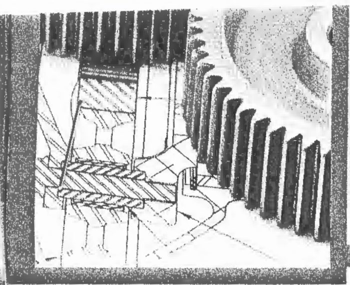

INTELLIGENT TRAFFIC MONITORING AND HYBRID ENERGY SYSTEMS FOR BTS OPEX REDUCTION

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Abstract

A predominant approach at developing a low cost system for GSM networks has been targeted at the power section due to its prime position in the overall financial requirement both at the CAPEX and OPEX. Ericson developed a hybrid network approach which involves the replacement of one of the generators required at the cell site with a bank of specially designed high capacity batteries. This approach reduced the cost of fuel required by 50% due to the utilization of only one generator. Its set back is in the requirement of specially designed batteries. Another low cost approach is the use of bio-diesels which was also pioneered by Ericsson. The use of Solar/wind power system to replace the diesel generators at BTS cell sites is an approach pioneered by Motorola, GSMA and MTC. The development of energy efficient equipment is another approach aimed at reducing the cost of a GSM network, prominent under this is the development of soft switches and low power transceivers. The use of intelligent traffic monitoring and hybrid energy supply systems where the variation in the telecom traffic both in the residential and business areas allow the use of renewable energy sources to provide energy for the BTS during periods of low traffic has been found to yield significant OPEX cost saving.

Keywords: CAPEX, OPEX, Softswitches, GSM Networks, Renewable energy

Introduction

The GSM networks are made up of three major sections which are the Transceiver Section, the Switching Section and the Power Supply Section. [1] Components of the GSM networks are classified either under capital expenditure or operating expenditure. The capital expenses can be defined as all the expenses incurred from the bidding process to the site commissioning phase while the operating expenses can be defined to include the cost required keeping the networks up, running and profitable. The capital expenses (CAPEX) due to the predictable nature can be predetermined and financing options and arrangements can be made for them [2][3] .The Operational Expenses (OPEX) on the other hand includes the maintenance costs, Advertisements and fuel costs. The fuel cost component is the most significant component of the OPEX especially in developing countries due to the insufficient or non availability of public power supply. The inadequate supply of electricity coupled with the seeming lack of capacity by governments to ensure nationwide supply has made it mandatory for operators to install two generators per cell site so as to be guaranteed of continuous operation of their cell sites. The Capital Expenses incurred in setting up mobile communication cell sites is increased by the additional cost of the 2 generators and the cost of installation while the OPEX cost is increased by the cost of fueling the generators and the maintenance. The convenience and reliability of installing a diesel fuel generator is however outweighed by the long term cost of the effect of these generating systems on the environment. The GSMA states that each base station using diesel powered generators contribute 6.8 Metric Tonnes of CO2 to the environment annually [4] and this has a very high negative impact on the environment. This paper presents a review of the different OPEX reduction strategies and shows the Intelligent Traffic Monitoring and Hybrid Energy systems as the most efficient form of OPEX reduction in BTS Cell sites.

GSM Network Roll Out

Traditional network infrastructure for a GSM BTS cell site includes the shelter containing the Transceiver equipment, the Tower, the antenna and cabling systems and the Generator/fueling systems. The most predominant source of electrical energy for BTS cell sites especially in developing countries is the diesel powered generators with most operators installing two 20KVA generators at cell sites. The estimate diesel consumption as against loading on each site is given by the Table 1.

Table 1. Generator fuel consumption chart [5]

Generator Size (kW)	1/4 Load (gal/hr)	1/2 Load (gal/hr)	3/4 Load (gal/hr)	Full Load (gal/hr)
20	0.6	0.9	1.3	1.6
30	1.3	1.8	2.4	2.9
40	1.6	2.3	3.2	4.0
60	1.8	2.9	3.8	4.8
75	2.4	3.4	4.6	6.1
100	2.6	4.1	5.8	7.4
125	3.1	5.0	7.1	9.1
135	3.3	5.4	7.6	9.8
150	3.6	5.9	8.4	10.9
175	4.1	6.8	9.7	12.7
200	4.7	7.7	11.0	14.4
230	5.3	8.8	12.5	16.6
250	5.7	9.5	13.6	18.0
300	6.8	11.3	16.1	21.5
350	7.9	13.1	18.7	25.1
400	8.9	14.9	21.3	28.6
500	11.0	18.5	26.4	35.7
600	13.2	22.0	31.5	42.8
750	16.3	27.4	39.3	53.4
1000	21.6	36.4	52.1	71.1
1250	26.9	45.3	65.0	88.8
1500	32.2	54.3	77.8	106.5
1750	37.5	63.2	90.7	124.2
2000	42.8	72.2	103.5	141.9
2250	48.1	81.1	116.4	159.6

The BTS cell sites consume an approximate value of 10000W, which are broken down into the BTS Electronics, cooling and the lighting systems. The major challenges faced by operators with regards to the fuel supply include scarcity of fuel, vandalization of generator and theft of the fuel and generator parts and also dubious supplier of fuel who do not supply the right quantity of diesel as paid for by the operators.[6]

These challenges introduce a measure of unpredictability to the total amount to be budgeted for OPEX costs and in extreme cases, theft of diesel or extended scarcity of diesel can lead to a shut down of the cell sites thus causing the operator to loose revenue. From Table 1, a 20KVA generator operating at 75% [7] loading will consume 1.3 gallons of diesel per hour. The total fuel consumed on each cell site per day is given by Eqn 1

$$Daily\ Fuel\ consumption = 1.3gal \times 4liters \times 24 = 124.8liters \quad (1)$$

From Eqn 1, each cell site consumes an approximate value of 125litres of diesel per day. This value will increase as the generators grow older due to the effect of reduced efficiency over time. Most cell sites also have fuel tanks with up to 500 gallons capacity installed thus the tanks get empty over 16 days requiring the services of a refueling tanker and all the attendant costs.
The typical electrical load of a BTS cell site is given by Eqn 2

$$BTS\ Electrical\ load = BTS\ Electronics + Cooling + Lighting \quad (2)$$

From Eqn 2, the BTS electronics require up to 3000W while the cooling load which comprises of two 2HP air-conditioning units also require up to 3000W.The lighting loads which include the high capacity security lights, the tower lights and other light fittings in the shelter also require up to 3000W with battery charging added, giving an approximate value of 10000W as the electrical power required at BTS cell sites [8]. Thus the Power equation for the BTS can be represented by Eqn3

$$Power\ input\ to\ the\ BTS = Power\ for\ the\ BTS\ Electrical\ load + P$$

Where Ploss is the power lost due to the cabling.
From the generator specifications in Table 1, the diesel consumption increases with an increase in the generator power output. Thus the first step to reducing the OPEX cost is by reducing the power requirement of the GSM network components.

OPEX reduction strategies include:

1. The Use of Low Energy Infrastructure

The GSM system which comprises of a large number of transceiver and switching infrastructure, most of which are hardware based will experience a lot of energy savings if low power infrastructure is deployed. A number of research efforts have resulted in the development of soft switches in which the MSC is implemented largely by software. This approach reduces the energy requirement of switching centers. Other OPEX cost saving advantages of the soft switches includes remote installation and management. This provides remote access for the operator's engineers or vendors whenever there is a need for troubleshooting and system maintenance. System upgrades can also be implemented by the downloading of newer software without having to change any hardware [9]. The use of soft switches do not affect the OPEX significantly due to the fact that the number of switching centers on an operators network is very small compared to that of the BTS.A reduction in the power consumption of the BTS on the other hand will have a very major impact on the OPEX of the operators as it will enable the use of renewable energy supply in the BTS cell sites. A major effort and result is in the development of a low cost bidirectional Transceiver by the author [10]. The transceiver achieved an energy savings of up to 40% while maintaining the GSM specifications

2. The Use of Renewable Energy Power Supply

Renewable Energy has a number of features ranging from the unpredictability of supply as in Wind Energy to the low conversion efficiency of solar panels for the solar energy to the current environmental and political issues with biodiesel Renewable Energy supply systems also need a battery bank to be included with the installation to ensure continuous power supply in the event of outage from the renewable energy source. A number of operators have deployed BTS cell sites using renewable energy as the energy source. Prominent among them is the Motorola/GSMA's deployment of BTS using a combination of wind and solar Energy System to power an operator's Network in Namibia. This system utilized a combination of the wind turbine and solar panels to provide energy for some base stations in Namibia. The system eliminated the cost of fuel and combined the high energy capacity of the wind energy system with the regularity of solar power system. This system is currently operational. A number of other operators have since followed their path and have satisfactory results to show [11] [12[13] [14]. Another low cost strategy is the use of biodiesels in place of the hydrocarbon based diesels. Biodiesel refers to a vegetable or animal fat-based diesel fuel. It is made by chemically regulating lipids e.g. vegetable oil, animal fat with an alcohol. [15] Biodiesel is clean, can be grown, made on site in villages or local communities using simple equipment that local stores can make and maintain. The major challenges with biodiesel is argument that biofuels contribute to food shortage as tropical forests and good farm lands are being used to raise biofuel crops instead of food, creating food shortages and driving up food prices[16]. However biofuels are also being produced from waste vegetable oils. Reports have it that only 10% of the waste vegetable oil (WVO) produced in the industrialized counties are collected leaving billions of gallons of WVO uncollected. [16]. In US, the restaurants produce up to 1.135 billion litres of WVO a year and most of this end up in landfills. An estimated 5.7 million liters of grease and oil also go into the sewage system as waste[16].

Local Biodiesel brewers are now reclaiming millions of liters of this WVO and converting them into clean fuel. Biodiesels can be used in blended form with the conventional hydrocarbon based diesel to produce blends. These blends contain different percentage of biodiesel and the higher the percentage of biodiesel, the more ecofriendly the fuel is. Biodiesels are currently being used in diesel engines. It however degrades natural rubber gaskets, and hoses and breaks down deposits of residue in fuel lines where petrol diesel has been used. Measures taken to counter those biodiesel effects include the use of gaskets that are not made with natural rubber. It is also recommended that fuel filters are changed shortly after switching to biodiesel. The advantages of biodiesel stems from the fact that it is renewable and not subject to the supply and demand economics associated with petrol diesel.

3. The Use of Hybrid Energy systems

A third OPEX reduction strategy is in the use of hybrid systems. This hybrid system involves the use of specially designed high capacity batteries which are used to replace one of the generating sets. These batteries supply the energy required by the cell sites for 12 hours while for the next 12 hours, the generator charges the batteries and at the same time carries the BTS electrical load. The major limitation with this system is the fact that these high capacity batteries are very expensive and will require a high charging current which means an increase in the capacity of the generator required to be used with the batteries. The life cycle of these batteries are also shortened due to the constant charging and discharging cycles. This approach was also pioneered by Ericson.[13]

4. The Use of Hybrid Energy systems and Intelligent Traffic monitoring

The use of intelligent traffic monitoring is based on the fact that the traffic distribution for cell sites is directly related with the movement of the users within the areas covered by the cells. The traffic in residential areas drops in the morning of week days from 8am to 5pm due to the fact that most residents would have moved to their offices in the business districts. While from 5pm to 10pm in the residential areas the traffic is high due to the return of residents from work. Table 2 shows an approximate GSM traffic pattern for residential areas and business areas, the output from the solar panels and the typical temperature distribution for a 24 hour period. With this pattern, the energy requirement for the BTS can be met by using a hybrid power supply system with the diesel generators providing power during periods of high traffic while renewable sources such as solar and batteries are used to provide power during periods of low traffic.

Table 2. Traffic pattern for residential and business areas, solar panel output and temperature pattern for a 24 hour period

Time band	Traffic pattern for Residential areas	Traffic pattern for Business areas.	Solar panel output	Temperature
8am - 5pm	Low	High	High	High
5pm – 10pm	High	Low	Low	Medium
10pm – 8am	Low	Low	Low	Low

The data in Table 2 can be represented graphically where the High is represented by the value 10 and Low is represented by the value 2 and medium is between the two values.

Results and Discussion

From Table 2, the traffic flow increases to a high value in the business area from 8am to 5pm (9hours) while it drops to its lowest from 5pm to 7am (14hours). For the residential areas the traffic distribution is low from 8am – 5pm (9hours), and then it rises to a peak from 5pm to 10pm and drops to a low from 10pm to 7am. The graph of this pattern is shown in Figure 1.

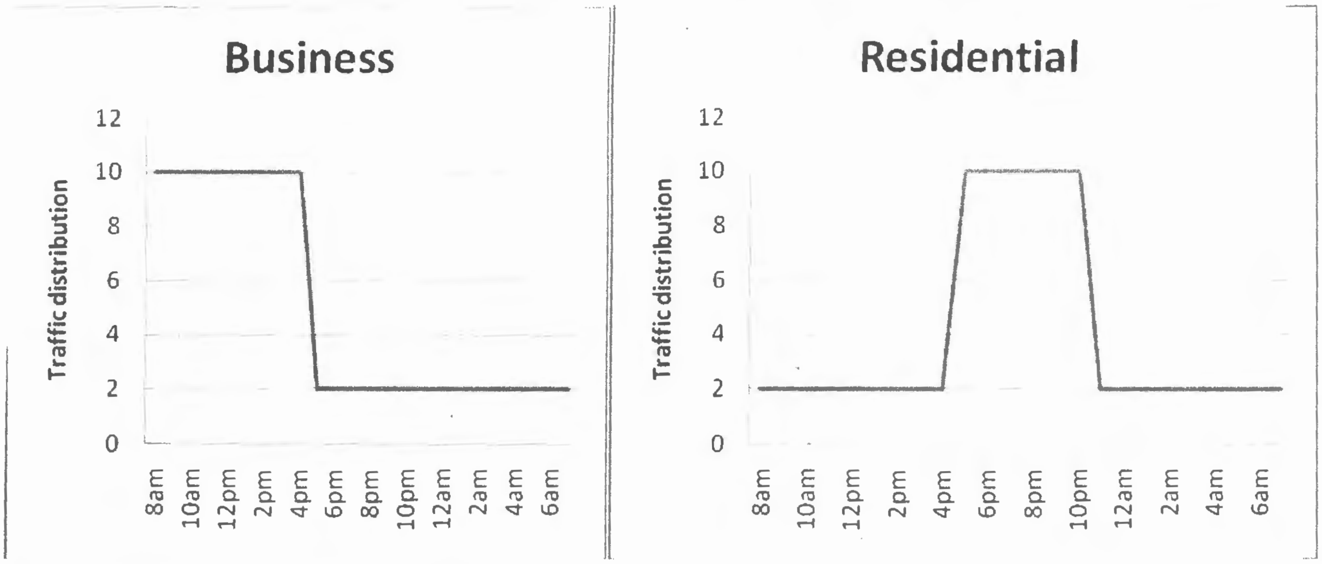

Figure 1.Graphical display of Business and Residential area traffic distribution

The traffic being handled by the BTS can be related to the energy consumption and the heat generation by Eqn 3. This is because, the higher the traffic flow, the higher the current flow through the transceivers. This also leads to a higher I^2R losses often represented as heat.

$$\textit{Traffic flow} \propto \textit{Energy consumption} \propto \textit{Heat generation} \qquad 4$$

The total heat in the BTS shelter is made up of the heat from the environment and the heat from the BTS electronic which from Eqn 3 is directly related to the Traffic flow. The contribution of the ambient heat can be controlled by the proper cladding of the shelter and therefore the main determinant of the BTS temperature is the traffic flow. From the results in Table 2, the traffic patterns and sunlight distribution patterns are fairly constant so an intelligent approach at utilizing the power supply systems can be developed. From Eqn 3 and 4, the change in the flow of traffic also corresponds to the change in the power requirement of the BTS. The transceiver system comprising of a number of transceiver cards can be switched on as the traffic demand increases [17]. The power amplifier block in the transceiver architecture requires the greatest amount of power and the use of an intelligent traffic monitoring algorithm will ensure that the number of power amplifiers switched on is based on the traffic flow requirements.

From the graphs in Figure 1, the cell sites in the residential areas can be run on solar arrays (from 8am to 5pm) due to the decreased traffic and the decreased heat generation. The Typical BTS electrical load for the residential areas in this time band is made up of only the BTS electronics. The solar arrays can provide energy for the BTS electrical load and at the same time charge the batteries. The cooling required is minimal as the amount of heat generation which is also proportional to the traffic flow is also minimal. Forced air cooling can be implemented using fans powered by the solar panels. In the 5pm to 10pm time band, the traffic increases as shown in the Table 2. The increased traffic flow results in increased energy requirement and increased cooling requirement. The generator conveniently meets these energy needs while at the same time charging the batteries. The traffic flow in the third time band lasting from 10pm to 8am (10hrs) is low and as such the batteries can be used to serve as the energy supply source. This is because the low traffic flow results in low cooling requirement coupled with the typically lower temperatures of night time thus the overall electrical load is reduced. The total electrical load and energy sources for the residential areas are listed in Table 3.

Table 3 Energy Supply for BTS in Residential Areas

Time band	Traffic pattern for Residential areas	Cooling required.	Load	Energy supply source
8am – 5pm	Low	Low	BTS Electronics	Solar panel
5pm – 10pm	High	High	BTS electronics + Cooling +Battery Charging	Generator
10pm – 8am	low	Low	BTS Electronics + Lights	Batteries

From the results in Table 3, the Energy Supply for BTS cell sites in residential areas is such that the generator runs for only 6 hours as against the 24hrs in the conventional design thus one generator can be installed in a cell site and that generator will run for 6 hours daily. Given that the same 20KVA generator is installed in the cell site, the daily fuel requirement of each cell site is determined from Eqn 5.

$$\textit{Daily Fuel consumption per BTS cell site} = 1.3gal \times 4liters \times 6 = 31.2liters \quad 5$$

This results in a 75% reduction in fuel consumption per site for all sites in residential areas. The cost of the generator is also reduced by half and replaced by solar arrays and charge controllers. The wind turbine system can also be used together with the solar arrays to provide energy for the cell sites.

In the business areas, the traffic distribution as shown in Figure 1 has a maximum between 8am and 5pm (9hrs) which is during office hours. An increase in traffic yields a corresponding increase in energy and cooling requirement thus the generator will be required to supply the BTS electrical load and to also charge the batteries. The traffic for the remaining 15 hours from 5pm to 8am can be supplied by the battery banks. During this period, the traffic is low because occupants of the offices must have returned to their homes in the residential areas and the heat generation is also low so cooling is achieved by forced air cooling using fans. With this approach the generators will be required to run for only 9 hours daily as against the 24hrs generator operation required in the cell site. The diesel fuel consumption in the business areas is represented by Eqn 6.

$$\textit{Daily Fuel consumption per BTS cell site} = 1.3gal \times 4liters \times 9 = 46.8liters \quad 6$$

This results in a 62.50% reduction in fuel consumption.

The capital cost of the DC power plant, including batteries and charging equipment, is 50% more with solar than with diesel. The investment in solar pays for itself in less than five years, or eight years and the solar panels have a 20-25 year lifespan.[17]

Conclusion

The use of intelligent traffic monitoring to switch off inactive transceivers and power amplifiers enable the use of forced air cooling using fans. This ultimately leads to a reduction in power consumption which makes it possible for renewable energy sources such as solar, or wind and even batteries to serve as energy sources for the BTS during periods of low traffic. Among the strategies discussed the use of intelligent traffic monitoring and the use of solar array hold the brightest promise for an appreciable reduction in OPEX values as biodiesel has still not been able to allay fears of the negative impact it will have on food security. The intelligent system reduces the number of diesel generators and diesel fuel consumption and this greatly reduces the OPEX of mobile communication operators.

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