IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 13, Issue 4, April 2023, ||Series -I|| PP 01-07

Comparative Cost Analysis of an Alternative Power Supply for GSM Base Station

W. A. Akpan[1] E.J. Awaka-Ama [2] O.O. Udoh [3] P.M. Pius [4]
[1,2,3]*Mechanical and Aerospace Engineering Department, University of Uyo, Nigeria.*
[1] ***Corresponding author****: email: whiteakpan@uniuyo.edu.ng. (08024297786)*

Abstract
The rapid growth of global systems of communication (GSM) is witnessed in many countries of the world. There have been a lot of challenges associated with its growth, especially in developing countries, like Nigeria, where public power supply is a epileptic. Right from its introduction in Nigeria in 2001, most of the GSM operators used diesel generators to run their base stations. This problem has persisted. An economic cost of running base stations with diesel generators was carried out using a base station of one of the GSM operators in Akwa Ibom state as a case study..The cost of powering a base station located at Gibbs street in Uyo, Akwa Ibom state was investigated for a period of four years. The average annual cost (AAC) was obtained and the accounting rate of cost (ARC) evaluated. Data was also obtained from other sources of power: solar, windmill and mini-hydro to run the base station as an alternative. The (AAC) and (ARC) were also applied to these power supply sources and cost comparison was made. The yearly cost of power generation by diesel, solar, windmill and mini-hydro were: ₦ 42,282,880, ₦ 1,687,850, ₦ 4,297,550 and ₦ 5,100,000. The average costs from was : ₦ 10,570,720; ₦ 421, 962.50, ₦ 859,510 and ₦ 1,275000 respectively. The accounting rate of costs was: 423%, 16.9%, 42% and 51%. for diesel, solar , wind and mini-hydro respectively. The renewable sources have lower cost of power generation compared to diesel power generation. The adoption of renewable energy as a source of power for GSM stations in Nigeria is strongly advocated to make the industry globally competitive.
Key words: Cost, GSM base station, power source, diesel, mini-hydro, solar, windmill,

I. Introduction

Global system for mobile communication (GSM) started in Nigeria in August 2001. This has brought a great change in the face of information and communication technology (ICT) in Nigeria. Since it was launched, mobile telephony has rapidly become the most popular method of voice communication in Nigeria. Growth in the sector has been so rapid that Nigeria has been rightly described in various media as one of the fastest growing GSM market in the world.GSM industries are having the problem of power supply around the globe, especially in undeveloped countries like Nigeria. Zain, now called Airtel, As at 2007 needed 92903.23 litres of diesel a week to supply steady power for each of her GSM stations[1] and required 288,000 litres of diesel a month to power its GSM stations in Akwa Ibom State[2]. [3] reported that MTN, GLO, Starcoms, Visafone and Mtel needed an average of 217,000 litres of diesel a month to run its base stations in the state. GSM stations are increasingly been located in the rural areas to meet the increasing demand by the rural subscribers[4].Alternative power sources become increasingly necessary in these rural areas without grid power supply and even in urban areas where power supply for the population of more than 200 million people is epileptic and less than 4000MW.

Most of these base stations are run with diesel. With technological development it is necessary to consider renewable power sources that do not destroy the ozone layer couple with the increasing global cost of diesel, especially in Nigeria where the Naira has plunge as low as ₦730 to a dollar.

Alternative power sources put across solar, wind and water (micro hydro plants) generation are being feasible in many places as a combination of alternative energy source.

The development of high efficiency and affordable solar power has progressed to a point that domestic solutions are feasible in areas of high sunlight. New solar cell technologies are moving the price point steadily own at a time when fossil fuels are increasing in cost. Many countries have incentives such as grants to encourage people to buy and use these systems. Wind velocity is mainly determined for considering a wind project. Economic viability is determined not only by wind velocity but also by the quality of the wind resources (sustained velocity, duration of turbulence). On the global scale, winds result from temperature gradients between the equator and the poles and between land and sea. On the smaller scale, thermal winds can be generated by local thermal effects. Local factors such as high altitude, unobstructed terrain, lofty air flow height, and natural wind tunneling features causes some areas to have inherently higher wind speeds.

Regional wind, resource trends for the united State are catalogued in the wind energy resource Atlas of the

United States published by the national renewable laboratory [6].The largest potential resource for power generation in Nigeria is natural gas currently estimated at 187trillion

MWh. This can support over 10,00 MW capacity power plants operating at a factor of 80% for 22000 years. However, the gas wells mostly located in the Niger Delta region are mostly flayed off by the oil companies. There are regions of the world with high seasonal rainfall at times, where not only there is low solar radiation but also low average wind speeds, steep flowing streams or rivers are sources of energy and experimental hydropower solutions have been tested in some locations with promising results [7]. One benefit of such system is that much of the civil work can be done by local people, and the turbine and the generating system are not high technology and are easily maintained.

Coal is the cheapest source of electricity. It is not easily available and has environmental problem due to the emission of carbon dioxide and sulphur dioxide into the atmosphere. Biomass is another source of energy. However, its cultivation and harvest requires the use of fuels such as gasoline which may increase the carbon dioxide level. Biomass is much reactive than coal, making it attractive as a feedstock for thermo-chemical gasification .

[8] envisioned that 118,00 base stations are to be powered by solar, wind and bio-fuel by 2012 in the developing world. He maintained that adding alternative energy sources to 118,00 GSM base stations would save 2.5 billion litres of diesel a year. GSM base stations will be powered with green energy sources. This is quite a jump from 1,500 renewable base stations already in operation.

The power sources which could be used as an alternative compared to the usage of generators are: solar power, wind power, fuel cells, biomass, coal, hydropower and natural gas.

Power generating systems can broadly be divided into two: renewable systems and non-energy systems.. The renewable energy systems are those power generation technologies in which the energy sources are not depleted by their use. Most renewable energy sources such as solar, wind, biomass and some ocean resources, have the sun as the ultimate source of energy. The non-renewable energy systems are those power generation technologies in which the energy is depleted by usage. Examples of non-renewable energy sources are: biomass, coal, natural gas and fuel cells.

Two generic types of solar electric power systems are available-photo voltaic and solar thermal electric. Solar thermal electric system uses a working fluid that is heated by solar energy and expanded through turbine or heat energy. Photovoltaic on the other hand uses a quantum process to convert solar radiation directly to electricity solar energy is very attractive because its non-polluting, non depletable, reliable and free.Solar energy is very dilute and constant. The low solar energy flues dictated the use of large surface area collectors and systems to collect and concentrate the energy. While the collective systems can be relatively expensive, another possible problem arises from the fact that terrestrial systems cannot expect to receive continuous supply of solar energy, this means that some sort of energy storage system or another conversion system is required to supply energy at night and during prolonged cloudy weather.

Solar energy can be converted directly into other energy forms in three separate process: heliochemical process, helioelectrical process, and the heliothermal process. The principal of heliochemical process is the photosysnthesis, this process the source of all fossil fuel.

The backbone of helioelectrical process is the production the production of electricity by solar cells while heliothermal process is the absorption of the solar radiation and the conversion process that has a conversion efficiency of 100%. The amount of solar radiation on a surface is called the solar insulation. Solar collection systems can normally be divided into three categories.These include those system that produce low temperature (less than those system that produce low temperature (less than $150^{\circ}C$), thermal energy for the heating and cooling of buildings, the solar cells conversion system that produce electricity directly from thr electromagnetic energy for the generation of electric energy. A solar collector for heating water for a house hold achieves a temperature around ($433^{\circ}C$). Solar radiation reaching the earth amounts roughly 100 watts for each square metre of the surface of the sun. At an overall conversion efficiency of 10% for generating electricity, producing 10 million watts of electric power would require collecting area of around 100,000 square meter. Considering also the peripheral equipment for the collectors, the area needed for solar energy collection approaching a square area of nearly a mile on a side.

Wind power is also another source of energy suited for the base station. Wind velocity is the main determinant for considering a wind project. Even a small increase in wind velocity can substantially increase potential energy generating capacity. Also the overall economic viability is

not determined by the velocity alone but also by the quality of the wind resource(Example- the sustained velocity duration, turbulence). These wind quality factors are very site specific. On the wind map of Nigeria, the average wind speed varies from 5.5 m/s to 2.0 m/s onshore. Much higher values are available offshore. Velocity and quality of wind to support onshore wind farms are better in the northern latitudes of Nigeria, A few wind demonstration power plants. Such as the 5kW wind electricity generator in Sokoto State had been commissioned bt the energy commission of Nigeria and is in operation.

Energy from Fuel cells also serve for base stations. Fuel cells are devices that convert fuel directly to electricity through electrochemical reactions. Although working fuel cells have been in existence since 1930's, their primary industries are still in the developmental and demonstration stage. Fuel cells are galvanic devices. They are not limited by the Carnot efficiency. This fundamental differences offers significantly higher conversion efficiency than for technologies using thermal cycles, even at part loaf conditions. Fuel cells are inherently modular; therefore, relatively small units generating a few megawatts of power can be sited near centres of load growth. Fuel cells have low emissions, relatively small land area requirements, and relatively low profiles. Furthermore, they exhibit rapid response to load changes. Advance fuel cells concepts have the potential for integration with coal gasification plants and with steam bottom cycles.

Hydro power project uses the natural power created by the flow of a river to produce electricity. It means It means there is no need to build impounding dam with a large reservoir and the project will hardly disrupt the natural environment or the water quality. The water from the intake system is divert by a tunnel or a pipe to create pressure that exit at the power station. The hydro power station components include: diversion weir, desanders, pressure tunnel and power station,

The diversion weir is designed to divert water. As it does not create a reservoir any size or significance, flooding is kept minimal and the project on both the environment and the local communities should limit the weir to 10 m deep and 20 m wide and reinforce concrete firmly joined to solid rock below the river bed

The river bed redirects the water from the river channel into screened intake steel rails line – the weir inner surface to protect it from damage by gravel and other water borne debris from here the water flows through a short tunnel into two large V-shaped underground called ' desanders'. The desanders slow the flow of water and allow the collection and removal of any pebbles, sand and silt. Each unit has special sensors which detect the build- up of this kind of rubble, When it reaches a set level, the drainage vents automatically open to flush the system clean. This operation as well as the main entrance of the water level in the desanders. Are controlled by state of the art systems f hydraulics, electronics sensors and computerized switches. The monitoring and control of these systems can be done annually at the weir site or by remote commands from the power station. After the sand, silt and pebbles are removed, the clean water is allowed to floe into pipeline or main tunnel. This diversion tunnel create pressure before ending up at the power plant at a reasonable metre lower than the weir elevation. The first few kilometers of the tunnel are not very steep and passé through good rock requiring little structural support. The remainder of the tunnel dips more sharply an passes through weaker rock, so extra rock bolts and reinforced concrete are needed.. A steel pipe extends from the tunnel into the power station where it directs the water through high pressure jets, onto the blades of the turbine. The turbine rotates at a very high speed via a connected shaft to an electric.

Coal is the cheapest source of power generating power supply, which is not common everywhere. Available data shows that coal of sub-bituminous grade occurs in about 22 Coal

Fields, spread in over 33 states of the federation. The estimated coal deposit for the country is at about 1.487 million tones. While the inferred reserves is about 2.75 billion tones. Given that one ton of coal deposit can support 15,700 MW capacity at 80% capacity utilization for over 50 years. The potential area for locating coal power plants are indicated in the map of Nigeria. Develop sites such as Enugu (Enugu state), and Okaba (Kogi state). The challenges facing coal power generation include uncertainties in the actual reserves of coal on which long term projects could be based, low productivity of coal mines, low level of mechanization of production facilities, and absence of cost effective transportation system.

Biomass is regenerative (as opposed to fossil fuel) organic material use for energy production. Sources for biomass fuel include terrestrial and aquatic vegetation, agricultural and forestry residues and municipal and animal wastes. Like most renewable energy sources, biomass is distinct from thermal processes in that energy has been transformed by photosynthesis and stored as chemical energy of the organic material. Biomass can either be collected and burned ddirectly or converted to other useable energy forms such as gaseous or liquid fuels, or energy-intensive chemicals feed stocks. The term biomass as a fuel category includes many of the waste categories. Biomass has a number of advantages over traditional fossil fuels. Its primary advantage is that it is renewable. It is also a low-cost fuel. Many biomass sources are agricultural or industrial residues that, if not used for energy production, would result in disposal costs. It has low sulphur content, less than 0.1% by weight compared to a range of about 1% t0 5% for coal. Biomass also has a low 1% ash content..This ash may be a saleable byproduct that can be returned to the soil as a fertilizer and soil conditioner, Furthermore, the growth and combustion

cycle of biomass does not increase the atmospheric carbon dioxide level, recalling that the cultivation and harvest of biomass requires the use of fuels such as gasoline, which may increase carbon dioxide the level. Biomass is much more reactive than coal, making it attractive as a feedstock for thermo-chemical gasification .One disadvantages of fuel cell is that some chemical constituent found in many biomass fuels can cause fouling problems form unacceptable air pollutants. Biomass is generally bulky and expensive to transport, thus, it must

be produced, collected and combusted or converted on a local basis.

The largest potential resource for power generation in Nigeria is the natural gas. Current estimate of total proven Nigerian natural gas reserves as 187 trillion MWh, even 100% 0f this can support over 10,000MW capacity power plants operating at a capacity factor of 80% for 22,000 years.

All the power sources mentioned above are available in Nigeria. However only grid power supply from gas turbines, steam turbines are mostly available This has caused many GSM operators to rely on running their base stations with diesel generators in the event of grid failure, This research is focused on comparing the cost of using diesel generators to run a base station with the cost of using alternative power supply mostly solar, wind and mini hydro-plant.

II. Methodology

[9] cost analysis is an important tool in engineering especially in design and production and most important in investment analysis to determine the profitability of engineering venture. It is normally aimed at establishing the least cost. There are many number of ways where cost analysis are performed. The accounting rate of cost is also known as the cost on investment and cost on capital employed and is calculated by dividing the average annual cost from a project into the average investment cost. It differs from other methods in that profits rather than cash flows are used. The costs are not equal to cash flows because financial accounting represents the only non-cash concept.. The use of accounting rate of cost can be attributed to the wide use of the cost on investment measure in financial statement analysis.

$$AAC = \frac{TCC}{AI} \quad (1)$$

where AAC is the average annual cost, TCC is the total cumulative cost and AI is the average investment.

$$ARC = \frac{AAC}{AI}. \quad (2)$$

where :ARC is the accounting rate of cost, ACC is the average annual cost and AI is the average investment.

These equations were used in the comparative cost analysis in the research.

Data Energy System

Data in this research was gathered from several sources. The alternative energy source of power components were carefully obtained and analyzed.

The renewable energy source of power captured in this research comprise: solar power, wind power and mini-hydro-power, with different capacities. The replaced parts, labour cost, logistic cost and their annual cost were also analyzed from (Airtel) in Uyo, Akwa Ibom State..

In a base subsystem controller (B.Sc), we have three types of subsystem sides: the hupside, backbone side and normal side. A base station is installed with either hupside, back bone or normal sub-system side.

In Akwa Ibom State which had 150 sites as at 2007

III. Results and Discussion

Table 1: Cost of acquisition and maintaining diesel generator 2018

S/N	Item Description/ Amount ₦	Annual Amount ₦
1	Oil filter per month (2,800)	33,600
2	Fuel filter per month (1,800)	21,600
3	Engine oil (10,000)	120,000
4	Water coolant (1,000)	12,000
5	Diesel-100 litres daily at 219/litre	7,993500
6	Cost of 30kva diesel generator (2)	6,000,000
Total	14,180,700	

Table 2: Annual cost of maintaining diesel generator from 2019 to 2021

S/N	Item Description	Amount ₦ (2019)	Amount ₦ 2020	Amount ₦ 2021
1	Oil filter per month/ annual	3,400 (40,800)	4,600 (55,200)	12,000 (144,000)
2	Fuel filter per month/ annual	2,500 (30.000)	3,600 (43,200)	3,800 (45,600)
3	Engine oil per month/ annual	12,000 (144,000)	14,000 (168,000)	20,000 (240,000)
4	Water per month/coolant/ annual	1,100 (13,200)	1200 (14,400)	1250 (15,000)
5	Diesel/ annual per day/annual	226,000 (8,249,000)	230 (8,395,00)	289 (10,545,500)
6	Total	8,436,200	8,675,800	10,990,100

The total cost for 4 years is ₦ 42,282,880

Table 3 : Cost of installation and maintaining solar energy 2018

S/N	**Item Description**	**Quantity**	**Unit Price ₦**	**Amount(₦)**
1	5kva Inverter	1	130,000	13,000
2	200 watt PV panels	17	42,000	799,000
3	Charge controller	1	47,000	47,000
4	200 Ah Battery	10	65,000	650,000
5	Rolls of solar cables	5		20,000
6	Solar rank	1	15,000	15,000
7	Maintenance cost		0	0
8	Total			1,544,000

Table 4: Annual cost of maintaining solar power from 2019 to 2021

S/N	Item Description	Amount ₦ (2019)	Amount ₦ 2020	Amount ₦ 2021
1	O and M value (5% of total cost)	47,950	47,950	47,950
2	Fuel	0	0	0
3		47,950	47,950	47,950

The total cost for 4 years is ₦ 1,687,850

Table 5 : Cost of installation and maintaining windmill 2018

S/N	**Item Description**	**Quantity**	**Unit Price ₦**	**Amount(₦)**
1	Acquisition cost	1	2,7000,000	2,700,000
2	Installation cost	Lump sum	1,000,000	1,000000
3	Maintenance cost (1% of acquisition and installation	Lump sum	37,000	37.000

	cost			
4	Total			3,737,000

Table 6: Annual cost of maintaining windmill from 2019 to 2021

S/N	Item Description	Amount ₦ (2019)	Amount ₦ 2020	Amount ₦ 2021
1	O and M 5% of total cost in 2018	186,850	186,850	186,850
2	Fuel	0	0	0
3	Total	186,850	186,850	186,850

The total cost for 4 years is ₦ 4,297,550

Table 7 : Cost of installation and maintaining mini-hydro power plant 2018

S/N	**Item Description**	**Quantity**	**Unit Price ₦**	**Amount(₦)**
1	Acquisition cost	1	3,000,000	3,000,000
2	Installation cost	Lump sum	1,000,000	1,000,000
3	Maintenance cost (1% of acquisition and installation cost)	Lump sum	200,000	200,000
4	Fuel cost	0	0	0
5				4,200,000

Table 8: Annual cost of maintaining mini-hydro power plant from 2019 to 2021

S/N	Item Description	Amount ₦ (2019)	Amount ₦ 2020	Amount ₦ 2021
1	O and M value	5,706,500	5,706,500	5,706,500
2	Fuel	0	0	0
3	Total	300,000	300,000	300,000

The total cost for 4 years is ₦ 5,100,000

IV. Discussion of Results

Similarly, total cost for installation and maintenance of diesel generator, solar plant, wind mill and mini-hydro are: The total cost for 4 years is ₦ 42,282,880,-₦ 1,687,850,-₦ 4,297,550 and ₦ 5,100,000. The average costs from equation 1 are:-₦ 10,570,720; ₦ 421, 962.50,-₦ 859,510 and ₦ 1,275000 respectively

With an average cost of investment of ₦10,00.000, the accounting rate of cost for power generation using diesel was 423%, solar , wind and mini-hydro were: 16.9%, 42% and 51%. Solar energy and wind energy have greater potentials for applications in Nigeria and should be harnessed. Rivers are natural located, and one may have less control to its adoption for power generation for the base stations. The power generation cost using diesel must be transferred to the customers. This has contributed to the cost of Mobile phone communication in Nigeria. It is on record that most companies, mostly indigenous with financial muscles have close shop, as they cannot cope with the cost of operation of their base stations using diesel generator as a source of power generation, both in the urban and rural areas. Providing power using river as a source of water may limit this option to some particular areas in Nigeria The availability of wind and sunlight around in Nigeria make the solar and wind power generation more attractive, The renewable source of power apart from having lower costs are environmental friendly.

V. Conclusion

The average cost of power generation by diesel, solar, windmill and mini-hydro are:-₦ 10,570,720; ₦ 421, 962.50,-₦ 859,510 and ₦ 1,275000 respectively

From the above, the cost of power generation using diesel is the highest, followed by mini-hydro windmill, solar. The renewable sources of power have lower cost of power generation compared to diesel power

generation. The accounting rate of costs were: diesel was 423%, solar , wind and mini-hydro were: 16.9%, 42% and 51%. respectively. Diesel power generation has the highest cost of power generation. The least is solar, followed by wind and finally mini-hydro. The adoption of renewable energy as a source of power for GSM stations in Nigeria is strongly recommended.

References

[1]. Harvey, M: Renewable and Sustainable Energy Review Available: www.renewableenergy.com , Volume 2 issue 4, May 4,2007.
[2]. Williams A.B and John, A. D.:Solar Heating Design, 2006
[3]. Aduge, A.D.:'Sorry the Network is not Available' Nigerian Newsworld Magazine, August, 6, 2007..
[4]. Ray, B. Performance Evaluation of GSM in Nigeria, 2008
[5]. Patrick, B. :Cost and Management Accounting, Offason Printers, Calabar, 2003
[6]. Elliot, P. The Methodology of Engineering Design for Students, Centano Publishers, Calabar,
[7]. Sampson, H.: Micro Hydropower Resources Available: wwwhyropower.com, July 11, 2009

W. A. Akpan, et. al. "Comparative Cost Analysis of an Alternative Power Supply for GSM Base Station." *IOSR Journal of Engineering (IOSRJEN)*, 13(4), 2023, pp. 01-07.