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Using Cost Saving Percentage Improvement Approach to Determine the Best Choice of Generation Expansion Plan: A Case with Egbin Power Plant

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ABSTRACT

Expansion planning is the determination of generation expertise needed to be included to hitherto available consumable power. The aim is to meet an increasing demand in energy availability with respect to a developmental period. In this paper, cost saving percentage improvement (CSPI) approach is used to determine the best choice of power generation expansion plan. Deterministic optimization is used in formulating the best optimization arrangements. The cost analysis of the different optimization plans was done followed by percentage cost savings computations. The best choice of power generation expansion plan was deduced and identified based on generated results. The research is Meta analytic.

Keywords: *Expansion Planning, Cost Saving Percentage Improvement (CSPI), Deterministic Optimization, Meta Analytic*

1. Introduction

Expansion planning involves the determination of the generation technology options to be added to those existing at present to meet a growing energy demand over a specified planning period. The purpose is to determine the optimal pattern of system expansion to meet the electric energy requirement given the time period under consideration. Cost saving is closely related to the capacity optimization. This is because optimization is essentially a process of minimization of cost factors and savings in the overall cost of generating electricity. According to Booma et al, (2015) the aim of electric power generation planning is to seek the most economical generation expansion scheme that is capable of achieving a certain electricity reliability level according to the forecast of increase in demand in a certain period of time. Generation Expansion Planning (GEP) is the most significant planning activity in the electric utilities industry. Khokhar (1997) also opined that in GEP, the following questions need to be answered:

I. When to invest in new generating units?
II. Where to invest in new generating units?
III. What type of generating units to be installed?
IV. What capacity of generating units to be installed?

The author continued by saying that proper planning ensures that resources are used most economically in addition to saving project time. Thus, analyzing the total cost and reliability of various GEP alternatives are required in making such planning decisions.

Sirikum et al (2007) also identified power generation expansion planning (PGEP) problem as a large-scale mixed integer nonlinear programming (MINLP) problem cited as one of the most complex optimization problems. It has also been adduced that electricity is the most important energy source but at the same time, most ephemeral, as it must be consumed as soon as it is produced otherwise it goes extinct soon after (Breeze, 2010). The author posits that there are two fundamental indices used in the determination of cost comparison namely, capital cost and levelized cost of energy (LCOE). The levelized cost is a lifetime cost measurement which applies lifecycle cost analysis with respect to the current cost of energy production. Assumptions about the future value of money are used to convert all costs and revenues relating to the future into prices with respect to the present. These two costs are the traditional approaches applied when estimating the future, and even present, cost of power. Generally, cost implication is a major consideration when power generation expansion plan is being embarked upon. This buttresses the place of this work.

In this presentation, painstaking cost analysis in the optimization of electric power generation expansion planning is carried out. The different optimization plans are used in computing the possible cost of optimization of each of the given plans. The percentage cost saving is then computed and used to choose the best choice of power generation expansion plan that should be embarked upon.

2. Related Works Review

Shan and Sarah (2009) presented a paper on Power Generation Expansion Planning under Uncertainties. In the work, they applied three different methodologies in order to solve the problem. Deterministic optimization assumed all the parameters were fixed without any uncertainty. Stochastic optimization took into account future uncertainties as indicated by different scenarios. Finally, robust optimization not only considered the uncertainties but also the risk over all scenarios. How the solutions realized by these three methods differ from fuel price uncertainty was examined in a numerical case study designed to represent renewable generation in addition to traditional fossil-fueled plants. The researchers used unrealistic data and opined that using a more realistic data would give a more dependable result. They also suggested carrying out an expansion planning much longer than one year duration done in the work.

Ozcan et al (2016) did a work on Generation expansion planning scenarios to reduce natural gas dependency of Turkey. In order to explore which between renewable energy sources or nuclear energy that can be an alternative to natural gas so as to reduce energy dependency, the authors presented three different scenarios. As a precursor to the work, genetic algorithm was used to realize the electricity generation expansion planning of Turkey for 2015-2030 planning horizon. In the model, besides all conventional energy sources, renewable energy sources were included as an input in the first scenario. The second scenario included repeating the first scenario but without natural gas. In the third scenario, besides natural gas and renewable energy source, all conventional energy sources are included in the first scenario. Results of the calculations led to the conclusion that since it has a high investment cost and leads to dependence on foreign resources, nuclear energy was not likely to have a significant place in Turkey's future energy policy. In addition, it was argued that considering the low capacity factor and high investment costs, renewable energy source cannot be an alternative to natural gas or other energy sources.

Heuberger et al, (2017) worked on a paper titled A Systems Approach to Quantifying the value of Power Generation and Energy storage Technologies in future Electricity Networks. A System model of electricity as a hybrid of generation expansion and a unit commitment model were developed. The role and value of (CCS) carbon Capture and Storage were quantified and qualified. A conceptual and mathematical framework for systemic power technology valuation was developed. The system value (SV) metric was based on an electricity systems optimization model combining generation expansion and unit commitment formulations and taking detailed environmental, reliability and operability, as well as economic constraints into account. The SV of the first available capacity unit of energy storage is an order of magnitude higher than the SV of wind and CCS capacity. However, the work did not include optimization techniques and aspects of cost analysis.

Taking the above into consideration, this paper is now continued by aggregating the results of the reviews as well as adding the new concept of the authors' inputs in this aspect of the cost analysis and its implications in choosing an optimization plan that best suits a particular instance.

3. Methodology

The methodology of this research is anchored under three strategies. These include the following:

I. Formulating the appropriate and best capacity optimization arrangements.
II. Computing the resulting cost analysis of the optimization plans.
III. Calculating the percentage cost savings
IV. Deducing and identifying the best choice of power expansion plan based on the results.

3.1 Formulating the Appropriate and Best Capacity Optimization Arrangements

I. The research work relied on the installed capacity of 1320MW which is also taken as the actual working capacity of the plant.
II. Capacity addition due to the twenty years projection = 3000MW

Activity 1: First Optimization Plan

Capacity combination (MW) → [200 250 300]

Number of generating units → $[2 \quad 8 \quad 2]^T$

Then, by the operation of decomposition:

$$[3000MW] = \underbrace{[200 \quad 250 \quad 300]}_{\text{Capacity}} \underbrace{\begin{bmatrix} 2 \\ 8 \\ 2 \end{bmatrix}}_{\text{Units}}$$

$$= 200 \times 2 + 250 \times 8 + 300 \times 2$$

$$= 400 + 2000 + 600$$

$$= \underline{\underline{3000MW}}$$

Activity 2: Second Optimization Plan

Capacity combination (MW) → [200 250 300]

Number of generating units → $[1 \quad 4 \quad 6]^T$

Then, by the operation of decomposition:

$$[3000MW] = \underbrace{[200 \quad 250 \quad 300]}_{\text{Capacity}} \underbrace{\begin{bmatrix} 1 \\ 4 \\ 6 \end{bmatrix}}_{\text{Units}}$$

$= 200 \times 1 + 250 \times 4 + 300 \times 6$

$= 200 + 1000 + 1800$

$= \underline{3000MW}$

Activity 3: Third Optimization Plan

Capacity combination (MW) → [200 250 300]

Number of generating units → $[5 \quad 2 \quad 5]^T$

Then, by the operation of decomposition:

$$[3000MW] = \underbrace{[200 \quad 250 \quad 300]}_{\text{Capacity}} \underbrace{\begin{bmatrix} 5 \\ 2 \\ 5 \end{bmatrix}}_{\text{Units}}$$

$= 200 \times 5 + 250 \times 2 + 300 \times 5$

$= 1000 + 500 + 1500$

$= \underline{3000MW}$

Activity 4: Fourth Optimization Plan

Capacity combination (MW) → [200 250 300]

Number of generating units → $[3 \quad 6 \quad 3]^T$

Then, by the operation of decomposition:

$$[3000MW] = \underbrace{[200 \quad 250 \quad 300]}_{\text{Capacity}} \underbrace{\begin{bmatrix} 3 \\ 6 \\ 3 \end{bmatrix}}_{\text{Units}}$$

$= 200 \times 3 + 250 \times 6 + 300 \times 3$

$= 600 + 1500 + 900$

$= \underline{3000MW}$

Activity 5: Fifth Optimization Plan

Capacity combination (MW) → [200 250 300]

Number of generating units → $[4\ \ 4\ \ 4]^T$

Then, by the operation of decomposition:

$$[3000MW] = \underbrace{[200\ \ 250\ \ 300]}_{\text{Capacity}} \underbrace{\begin{bmatrix} 4 \\ 4 \\ 4 \end{bmatrix}}_{\text{Units}}$$

$$= 200 \times 4 + 250 \times 4 + 300 \times 4$$

$$= 800 + 1000 + 1200$$

$$= 3000MW$$

3.2 Computing the resulting cost analysis of the optimization plan

In order to develop this model, a cost analysis was carried out. The cost analyses carried out was to enable the model to be developed bearing in mind the nature of the cost function in Naira per hour for the thermal plant under study. The analyses involved Egbin thermal power plant as proposed in this work.

The procedures for calculating the fuel cost function in ₦/h for the thermal plant are given as expressed in the presentations made here. As a prelude to the calculations, use was made of equation (2.3) already established in chapter two namely

$$C = \alpha + \beta P_G + \gamma P_G^2 \qquad 3.1$$

Where C is the cost of electrical power generation; α, β and γ are cost function coefficients with typical values given as

A $\alpha = 2506.69$

B $\beta = 4.418$

C $\gamma = 0.00184$ and

P_G is the value of the generated power under consideration. Thus, the expression of equation 3.1 as recalled was used in the calculations of the cost analysis with regard to the various capacity combinations of the network under study. This was carried out in this objective as shown for Afam, Sapele and Egbin Thermal Power generating Plants for a twenty years look ahead period.

Egbin Thermal Power Generating Plant

PLAN ONE (First Optimization Plan)

$$[3000MW] = [200\ \ 250\ \ 300] \begin{bmatrix} 2 \\ 8 \\ 2 \end{bmatrix}$$

$$= 200 \times 2 + 250 \times 8 + 300 \times 2$$

$$= 400 + 2000 + 600$$

$$= 3000MW$$

First Power Generation Cost, C_{1-1}

$C_{1-1}(P_{G1-1}) = \alpha + \beta P_{G1-1} + \gamma(PG_{1-1})^2$

$C_{1-1}(400) = 2506.69 + 4.418x400 + 0.00184x(400)^2$

$= 2506.69 + 1767.2 + 294.4$

= 4568.29MW/h. At 1MW for IUSD this becomes:

= $4568.29/h

Using an exchange rate of N400 to 1USD, this becomes

= **N1,827,316/h**

Second Power Generation Cost, C_{2-1}

$C_{2-1}(P_{G2-1}) = \alpha + \beta P_{G2-1} + \gamma(PG_{2-1})^2$

$C_{2-1}(2000) = 2506.69 + 4.418x2000 + 0.00184x(2000)^2$

$= 2506.69 + 8836 + 7360$

= 18702.69MW/h. At 1MW for IUSD this becomes:

= $18702.69/h

Using an exchange rate of N400 to 1USD, this becomes

= **N7,481,076/h**

Third Power Generation Cost, C_{3-1}

$C_{3-1}(P_{G3-1}) = \alpha + \beta P_{G3-1} + \gamma(PG_{3-1})^2$

$C_{3-1}(600) = 2506.69 + 4.418x600 + 0.00184x(600)^2$

$= 2506.69 + 2650.8 + 662.4$

= 5819.89MW/h. At 1MW for IUSD this becomes:

= $5819.89/h

Using an exchange rate of N400 to 1USD, this becomes

= **N2,327,956/h**

The total cost of power generation in this plan was evaluated as follows:

$C_{T1} = C_{1-1} + C_{2-1} + C_{3-1}$

= N1,827,316/h + N7,481,076/h + N2,327,956/h

= **N11,636,348/h**

For a look ahead period of 20 years this becomes:

20yrs x 365days x 24hours = T_1 = **175,200 hours**;

.$n_1 = C_{T1} \times T_1$

= **N11,636,348/h x 175,200 hours**

.n_1 = N2,038,688,169,600

PLAN TWO (Second Optimization Plan)

$$[3000MW] = [200 \quad 250 \quad 300] \begin{bmatrix} 1 \\ 4 \\ 6 \end{bmatrix}$$

$= 200 \times 1 + 250 \times 4 + 300 \times 6$

$= 200 + 1000 + 1800$

$= \underline{3000MW}$

First Power Generation Cost, $C_{1\text{-}2}$

$C_{1\text{-}2}(P_{G1\text{-}2}) = \alpha + \beta P_{G1\text{-}2} + \gamma(PG_{1\text{-}2})^2$

$C_{1\text{-}2}(200) = 2506.69 + 4.418x200 + 0.00184x(200)^2$

$= 2506.69 + 883.6 + 73.6$

= 3463.89MW/h. At 1MW for IUSD this becomes:

= \$3463.89/h

Using an exchange rate of N400 to 1USD, this becomes

= **N1,385,556/h**

Second Power Generation Cost, $C_{2\text{-}2}$

$C_{2\text{-}2}(P_{G2\text{-}2}) = \alpha + \beta P_{G2\text{-}2} + \gamma(PG_{2\text{-}2})^2$

$C_{2\text{-}2}(1000) = 2506.69 + 4.418x1000 + 0.00184x(1000)^2$

$= 2506.69 + 4418 + 1840$

= 8764.69MW/h. At 1MW for IUSD this becomes:

= \$8764.69/h

Using an exchange rate of N400 to 1USD, this becomes

= **N3,505,876/h**

Third Power Generation Cost, $C_{3\text{-}2}$

$C_{3\text{-}2}(P_{G3\text{-}2}) = \alpha + \beta P_{G3\text{-}2} + \gamma(PG_{3\text{-}2})^2$

$C_{3\text{-}2}(1800) = 2506.69 + 4.418x1800 + 0.00184x(1800)^2$

= 2506.69 + 7752.4 + 5961.6

= 16420.69MW?h. At 1MW for IUSD this becomes:

= $16420.69/h

Using an exchange rate of N400 to 1USD, this becomes

= **N6,568,276/h**

The total cost of power generation in this plan was evaluated as follows:

$C_{T2} = C_{1\text{-}2} + C_{2\text{-}2} + C_{3\text{-}2}$

= N1,385,556/h + N3,505,876/h + N6,568,276/h

= **N11,459,708/h**

For a look ahead period of 20 years this becomes:

20yrs x 365days x 24hours = $\mathbf{T_2}$ = **175,200 hours**;

$.n_2 = C_{T2} \times T_2$

= N11,459,708/h x 175,200 hours

$\mathbf{.n_2}$ = **N2,007,740,841,600**

PLAN THREE (Third Optimization Plan)

$$[3000MW] = [200 \quad 250 \quad 300] \begin{bmatrix} 5 \\ 2 \\ 5 \end{bmatrix}$$

$$= 200 \times 5 + 250 \times 2 + 300 \times 5$$

$$= 1000 + 500 + 1500$$

$$= \underline{3000MW}$$

First Power Generation Cost, $\mathbf{C_{1\text{-}3}}$

$C_{1\text{-}3}(P_{G1\text{-}3}) = \alpha + \beta P_{G1\text{-}3} + \gamma(PG_{1\text{-}3})^2$

$C_{1\text{-}3}(1000) = 2506.69 + 4.418 \times 1000 + 0.00184 \times (1000)^2$

= 2506.69 + 4418 + 1840

= 8764.69MW/h. At 1MW for IUSD this becomes:

= $8764.69/h

Using an exchange rate of N400 to 1USD, this becomes

= **N3,505,876/h**

Second Power Generation Cost, $C_{2\text{-}3}$

$C_{2\text{-}3}(P_{G2\text{-}3}) = \alpha + \beta P_{G2\text{-}3} + \gamma(PG_{2\text{-}3})^2$

$C_{2\text{-}3}(500) = 2506.69 + 4.418x500 + 0.00184x(500)^2$

$= 2506.69 + 2209 + 460$

= 5175.69MW/h. At 1MW for IUSD this becomes:

= $5175.69/h

Using an exchange rate of N400 to 1USD, this becomes

= **N2,070,276/h**

Third Power Generation Cost, $C_{3\text{-}3}$

$C_{3\text{-}3}(P_{G3\text{-}3}) = \alpha + \beta P_{G3\text{-}3} + \gamma(PG_{3\text{-}3})^2$

$C_{3\text{-}3}(1500) = 2506.67 + 4.418x1500 + 0.00184x(1500)^2$

$= 2506.69 + 6627 + 4140$

= 13273.69MW/h. At 1MW for IUSD this becomes:

= $13273.69/h

Using an exchange rate of N400 to 1USD, this becomes

= **N5,309,476/h**

The total cost of power generation in this plan was evaluated as follows:

$C_{T3} = C_{1\text{-}3} + C_{2\text{-}3} + C_{3\text{-}3}$

= N3,505,876/h + N2,070,276/h + N5,309,476/h

= **N10,885,628/h**

For a look ahead period of 20 years this becomes:

20yrs x 365days x 24hours = **T_3 = 175,200 hours**;

$.n_3 = C_{T3} \times T_3$

= N10,885,628/h x 175,200 hours

$.n_3$ = N1,907,162,025,600

PLAN FOUR (Fourth Optimization Plan)

$$[3000MW] = [200 \quad 250 \quad 300]\begin{bmatrix}5\\2\\5\end{bmatrix}$$

$= 200 \times 5 + 250 \times 2 + 300 \times 5$

$= 1000 + 500 + 1500$

$= \underline{3000MW}$

First Power Generation Cost, $C_{1\text{-}4}$

$C_{1\text{-}4}(P_{G1\text{-}4}) = \alpha + \beta P_{G1\text{-}4} + \gamma(PG_{1\text{-}4})^2$

$C_{1\text{-}4}(600) = 2506.69 + 4.418x600 + 0.00184x(600)^2$

= 2506.69 + 2650.8 + 662.4

= 5819.89MW/h. At 1MW for IUSD this becomes:

= $5819.89/h

Using an exchange rate of N400 to 1USD, this becomes

= **N2,327,956/h**

Second Power Generation Cost, $C_{2\text{-}4}$

$C_{2\text{-}4}(P_{G2\text{-}4}) = \alpha + \beta P_{G2\text{-}4} + \gamma(PG_{2\text{-}4})^2$

$C_{2\text{-}4}(1500) = 2506.69 + 4.418x1500 + 0.00184x(1500)^2$

= 2506.69 + 6627 + 4140

= 13273.69MW/h. At 1MW for IUSD this becomes:

= $13273.69/h

Using an exchange rate of N400 to 1USD, this becomes

= **N5,309,476/h**

Third Power Generation Cost, $C_{3\text{-}4}$

$C_{3\text{-}4}(P_{G3\text{-}4}) = \alpha + \beta P_{G3\text{-}4} + \gamma(PG_{3\text{-}4})^2$

$C_{3\text{-}4}(900) = 2506.69 + 4.418x900 + 0.00184x(900)^2$

= 2506.69 + 3976.2 + 1490.4

= 7973.29MW/h. At 1MW for IUSD this becomes:

= $7973.29/h

Using an exchange rate of N400 to 1USD, this becomes

= **N3,189,316/h**

The total cost of power generation in this plan was evaluated as follows:

C_{T4} = $C_{1\text{-}4} + C_{2\text{-}4} + C_{3\text{-}4}$

= N2,327,956/h + N5,309,476/h + N3,189,316/h

= **N10,826,748/h**

For a look ahead period of 20 years this becomes:

20yrs x 365days x 24hours = $\mathbf{T_4}$ = **175,200 hours**;

.n_4 = C_{T4} x T_4

= **N10,826,748/h x 175,200 hours**

.n_4 = N1,896,846,249,600

PLAN FIVE (Fifth Optimization Plan)

$$[3000MW] = [200 \quad 250 \quad 300] \begin{bmatrix} 4 \\ 4 \\ 4 \end{bmatrix}$$

$$= 200 \times 4 + 250 \times 4 + 300 \times 4$$

$$= 800 + 1000 + 1200$$

$$= 3000MW$$

First Power Generation Cost, $C_{1\text{-}5}$

$C_{1\text{-}5}(P_{G1\text{-}5}) = \alpha + \beta P_{G1\text{-}5} + \gamma(PG_{1\text{-}5})^2$

$C_{1\text{-}5}(800) = 2506.69 + 4.418x800 + 0.00184x(800)^2$

= 2506.69 + 3534.4 + 1177.6

= 7218.69MW/h. At 1MW for IUSD this becomes:

= $7218.69/h

Using an exchange rate of N400 to 1USD, this becomes

= **N2,887,476/h**

Second Power Generation Cost, $C_{2\text{-}5}$

$C_{2\text{-}5}(P_{G2\text{-}5}) = \alpha + \beta P_{G2\text{-}5} + \gamma(PG_{2\text{-}5})^2$

$C_{2\text{-}5}(1000) = 2506.69 + 4.418x1000 + 0.00184x(1000)^2$

= 2506.69 + 4418 + 1841

= 8764.69MW/h. At 1MW for 1USD this becomes:

= \$8764.69/h

Using an exchange rate of N400 to 1USD, this becomes

= **N3,505,876/h**

Third Power Generation Cost, $C_{3\text{-}5}$

$C_{3\text{-}5}(P_{G3\text{-}5}) = \alpha + \beta P_{G3\text{-}5} + \gamma(PG_{3\text{-}5})^2$

$C_{3\text{-}5}(1200) = 2506.69 + 4.418x1200 + 0.00184x(1200)^2$

= 2506.69 + 5301.6 + 2649.6

= 10457.89MW/h. At 1MW for 1USD this becomes:

= \$10457.89/h

Using an exchange rate of N400 to 1USD, this becomes

= **N4,183,156/h**

The total cost of power generation in this plan was evaluated as follows:

$C_{T5} = C_{1\text{-}5} + C_{2\text{-}5} + C_{3\text{-}5}$

= N2,887,476/h + N3,505,876/h + N4,183,156/h

= N10,576,508/h

For a look ahead period of 20 years this becomes:

20yrs x 365days x 24hours = T_5 = **175,200 hours**;

.$n_5 = C_{T5} \times T_5$

Thus,

n_5 = N10,576,508/h x 175,200 hours

n_5 = N1,853,004,201,600

Summary of Costs of Five Optimization Plans for a 20-Year Projection for Egbin Thermal Power Plant.

n_1 = N2,038,688,169,600

n_2 = N2,007,740,841,600

n_3 = N1,907,162,025,600

n_4 = N1,896,846,249,600

n_5 = N1,853,004,201,600

Table 3.2 Cost of Optimal Expansion Plans for Twenty-year look ahead period with optimization plans ($n_1 - n_5$) for Egbin Thermal Power Plant

Different Optimization plans (n)	Capacity combination (MW)			No. of units			Total (₦) (n), C_T = n= $C_1 + C_2 + C_3$ (₦)
	(MW) Pg_1	(MW) Pg_2	(MW) Pg_3				
n_1 = plan 1	200	250	300	U_1 =2	U_2 =8	U_3 =2	2,038,688,169,600
n_2 = plan 2	200	250	300	U_1 =1	U_2 =4	U_3 =6	2,007,740,841,600
n_3 = plan 3	200	250	300	U_1 =5	U_2 =2	U_3 =5	1,907,162,025,600
n_4 = plan 4	200	250	300	U_1 =3	U_2 =6	U_3 =3	1,896,846,249,600
n_5 = plan 5	200	250	300	U_1 =4	U_2 =4	U_3 =4	1,853,004,201,600

4. Presentation and Analysis of Data

The data realized from the activities are hereby presented.

4.1 Calculating the Percentage Cost Savings

For a reliable optimization plan, it has been established that $n_1 > n_2 > n_3 > n_4 > n_5$. From this condition, the following calculations are made.

Egbin Thermal Power Generating Plant

$n_1 - n_2$ = N2,038,688,169,600 – N2,007,740,841,600 = N30,947,328,000.

$n_2 - n_3$ = N2,007,740,841,600 – N1,907,162,025,600 = N100,578,816,000.

$n_3 - n_4$ = N1,907,162,025,600 - N1,896,846,249,600 = N10,315,776,000.

$n_4 - n_5$ = N1,896,846,249,600 - N1,853,004,201,600 = N43,842,048,000.

Also, total savings is given by the relation

$(n_1 - n_5) = (n_1 - n_2) + (n_2 - n_3) + (n_3 - n_4) + (n_4 - n_5)$ or, total saving equals

= N2,038,688,169,600 - N1,853,004,201,600

= N185,683,968,000

The foregoing is similar to directly calculating the value of $n_1 - n_5$.

First Percentage Cost Saving

$$\frac{n_1 - n_2}{n_1 - n_5} \text{ x } 100\% = \frac{\text{N30,947,328,000}}{\text{N185,683,968,000}} \text{ x } 100\%$$

= 16.6666…%

= 16.67%.

Second Percentage Cost Saving

$$\frac{n_2 - n_3}{n_1 - n_5} \text{ x } 100\% = \frac{\text{N100,578,816,000}}{\text{N185,683,968,000}} \text{ x } 100\%$$

= 54.1666…%

= 54.17%.

Third Percentage Cost Saving

$$\frac{n_3 - n_4}{n_1 - n_5} \text{ x } 100\% = \frac{\text{N}10{,}315{,}776{,}000}{\text{N}185{,}683{,}968{,}000} \text{ x } 100\%$$

= 5.5555…%

= 5.56%.

Fourth Percentage Cost Saving

$$\frac{n_4 - n_5}{n_1 - n_5} \text{ x } 100\% = \frac{\text{N}43{,}842{,}048{,}000}{\text{N}185{,}683{,}968{,}000} \text{ x } 100\%$$

= 23.6111…%

= 23.61%.

A pie chart representing the computation results of the percentage cost saving for Egbin thermal power plant is shown in Figure 4.1.

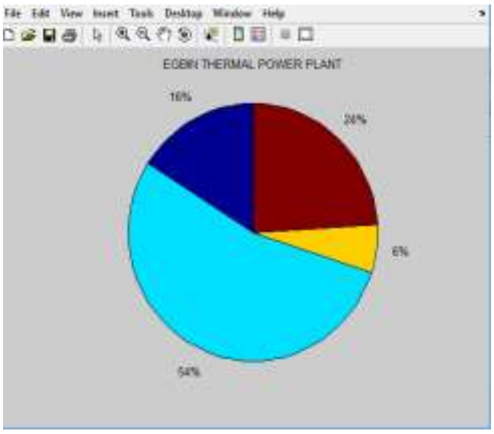

Figure 4.1 Pie Chart of the Percentage Cost Savings for Egbin Thermal Power Plant

4.2 Deducing and identifying the best choice of power expansion plan based on the results

These cost saving percentages were given as follows:

16.67%, 54.17%, 5.56% and 23.61% for plans 1, 2, 3 and 4 cost saving percentages respectively.

These percentage cost savings show how savings were made during the optimization expansion plans. These gave the optimization implementation advice as required. In this thermal power plant, the optimization plan with the highest cost saving percentage was noted to be the second optimization plan with 54.17% cost saving percentage. This gives it a choice over the rest for implementation in the twenty-year expansion plan.

5. Conclusion

It has been shown in this paper that the percentage cost saving can be used to make a choice of an appropriate optimization plan to be adopted in the event of a power expansion process. This usually involves the rigorous exercises of establishing the appropriate and best capacity optimization arrangements, computing the resulting cost analysis of the optimization plans and finally calculating the percentage cost savings. When all these are carried out painstakingly, the required choice of the appropriate optimization plan is normally arrived at. The result shown in this work justifies this approach.

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