A Model for Determining the Effect of Irregular Power Supply on Machining Foundry Products in a Developing Economy

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Abstract- In this paper, profit is maximized (or production cost is minimized) by developing an Integer programming (IP) model to determine, at a given respective unit cost, optimal numbers of outputs obtainable per production cycle (time) using public electricity generated from national grids and alternate electricity from generators subject to production output capacity or demand constraint. The results obtained showed that production cycle time has a great impact on the determination of optimal outputs for the respective conditions. Also, increase in cost of public electricity per unit product has an upper limit beyond which it has negative effect on the profitability. The results served as determinant factors for production industry in establishing the level of outputs that sustained the profitability by providing optimal cost of public electricity to operate without having any effect on the profit, at a given cycle time.

Keywords- Constraint, cycle time, integer programming, optimal number, model

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1 INTRODUCTION

Electric energy in all its ramifications has emerged in man's consciousness as a crucial factor in the world's socio-economic and political development. The fact that modern technologies are designed chronically on electricity for effective operation is a testimony of its importance. In other view, electricity as a development factor has been given its proper place as a principal parameter in the world's social stratification and change. However, it is not the important position of electric energy in world development that matters, but its availability for ready consumption as a basic requirement for socio-economic development process.

In developing economy, electric power supply reliability is on decrease everyday despite acclaimed relentless efforts of the Government of developing economy to revamp the electric power sector, this assertion is confirmed in a research by Doe & Asamoah, (2014); which reveals that, the unreliable electricity supply and its high tariffs was having negative effect on the quantity and quality of products from small scale industries, which had led to low profitability. Research by Wara *et al*., (2008) reported that the various reforms carried out in most developing economy power sector between the year 1999 and 2007 has no impact on the live of the average citizen and the research hypothesis (HR) stated that deregulations and reforms are not yet evidently improving the power sector of developing country like Nigeria. Many industries in developing country are not functioning properly and some of them have closed down as a result of their inability to meet minimum operation standards to support their sustainability. Irregular power supply has increased tremendously the production cost, with the introduction of electric power generating plant, which leads to the increase in prices of goods and services, even beyond the reach of common man.

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Even those industries that are operating on standby electric power generating plant are running at loss, due to substantial amount of money that goes into purchase of fuel (diesel) to power the generator besides the generator maintenance cost, this statement was corroborated by (Forkuoh & Li, 2015); they further shows that, generator is the key alternative power supply, and the high cost of running the generator was increasing the operational cost and reducing the firm's growth. The recent deregulation of the pump prices of petroleum products has worsened the situation. A previous research by Kareem (2007) showed that the use of generator accounted for about 30% increase in annual finance of many industries in developing country (Nigeria). The additional costs incurred with the use of generating plant; could be compensated for from proportional increase in cost price of output (products) to maintain or not to go too far from the expected profit margin. Also, study by Megbowon & Adewumi, 2002 established that despite the use of generating plant, capacity utilization is still on decrease. Besides, a lot of environmental hazards emanates from the use of generating plants (Popoola & Megbowon, 2007). Even with this hazardous nature, the use of it may not be ruled out completely; so that production of essential commodities and services can continue for the satisfaction of consumers.

2 METHODOLOGY

2.1 MODEL DEVELOPMENT

The basic relationship between profit, revenue and cost of any product is stated below: -

$$\text{Profit (Loss)} = \text{Revenue} - \text{Cost}$$

Then objective function Z is given as,

$$z = \sum_{k=1}^{m} \sum_{i=1}^{n} (t_{ik}{}^c c_{ik}{}^s p_{ik}{}^c - t_{ik}{}^c c_{ik}{}^c p_{ik}{}^c) \qquad (1)$$

Where P^e_{ik} , $Pg_{ik} \in P^c_{ik}$

$t_{ik}{}^c$ Product cycle time for i number of product and k number of shifts of production

$C_{ik}{}^c$ Established unit cost of production output (Naira) for i number of product and k number of shift of production.

P_{ik}^c Production capacity of machinery (units) per unit time (hour) for i number of product and k number of shift of production.

C_{ik}^s Selling price per unit item produced (Naira) for i number of product and k number of shift of production. Equation 1 evaluates the profit obtained when batch, shift, or parallel production scheduling system (k) is utilized for the production of products (i).

In formulating the constraint equations, four conditions were considered, which are:

(i) public electricity was utilized throughout the production cycle;

(ii) alternate (generator) electricity was utilized throughout the production cycle;

(iii) production started with public electricity and ended with alternate (generator) electricity

(iv) production started with alternate (generator) electricity and ended with public electricity.

The above four conditions were assumed to be the nature of electricity utilization and consumption in the developing economy. Production in all cases does not exceed the machine capacity or demand, and all the products produced were demanded or sold.

Therefore, the following equations were obtained as constraints respectively:

In the first condition, it was presumed that public electricity was used throughout the production cycle.

$$t^e c^e p^e_{ik} \leq t^c c^c p^c_{ik} \qquad (2)$$

Equation 2 relates the inequality condition of output when public electricity was utilized throughout the production cycle.

In the second condition, alternate electricity was used throughout the production cycle.

$$t^g c^g p^g_{ik} \leq t^c c^c p^c_{ik} \qquad (3)$$

Equation 3 is the corresponding equation for alternative (generator) electricity.

In the third condition, production started with public electricity and ended with alternate (generator) electricity.

$$t^e c^e p^e_{ik} + t^g c^g p^g_{ik} \leq t^c c^c p^c_{ik} \qquad (4)$$

In the fourth condition, production started with alternate (generator) electricity and ended with public electricity.

$$t^g c^g p^g_{ik} + t^e c^e p^e_{ik} \leq t^c c^c p^c_{ik} \qquad (5)$$

Equation 4 and 5 are similar in nature and give the output based on situation of shifting from public electricity to Generator and vice versa.

Integer programming non – negativity conditions

$$P^e_{ik} , P^g_{ik} \geq 0 \text{ and Integers} \qquad (6)$$

In all the conditions stated, fractions of outputs are not allowed as indicated by equation 6.

Finally, production output obtained from the use of public electricity, alternate (generator) electricity or both must not exceed machine capacity, and are demanded.

2.2 MODEL VALIDATION

. In order to effectively implement the developed Integer programming model, three production cycle times were considered on daily bases (i.e. 4hrs, 6hrs and 8hrs); in a single production system (i=1), where shift, batch or parallel production is allowed (k≥1).

For each cycle time, production time is assumed to follow normal distribution. The other cost elements and parameters were obtained from Machining unit, Foundry section of department of Mechanical Engineering Technology, Ondo State Polytechnic, Owo, Ondo state; as given in Table 1.

Table 1. Costs and production capacity data

Costs [Naira/Unit]				Production Capacity/hr
C^c	C^e	C^g	C^s	P^c
23	20	26	30	4

Where

C^c Established unit cost of production output (Naira)

C^e Unit cost of production using public electricity (Naira)

C^g Unit cost of production using alternate (generator) electricity (Naira)

C^s Selling price per unit item produced (Naira)

P^c Production capacity of machinery (units) per unit time (hr).

Two extreme cases were first determined by analytical method, that is, when public electricity is wholly utilized in a production cycle time and the alternate (generator) electricity. Thus equation 2 is used to get the optimal units output as 4 units; when Public electricity is used, while equation 3 is used to get the optimal units output as 3 units; when Generator (alternate electricity) is used. The respective optimal units output obtained for public electricity and alternate electricity are used to compute the profits at various cycle time; using equation 1.

Secondly, optimal units output are determined using equation 4 and 5, depending on whether the shifting is from public electricity to alternate (Generator) electricity and vice versa, with the values falling within the output of the two extreme cases firstly stated; for various cycle time. The values are used to compute the profit for each cycle time.

2.3 MODEL RELIABILITY

The model reliability was tested by using reliability formulae by Oroge, (1991) and this was done by using equations 7 and 8 as follows:

$$R(t) = e^{-\lambda t} \qquad (7)$$

$$P(t) = 1 - e^{-\lambda t} \qquad (8)$$

Where P(t) is the probability of failure at time t, and this is determined to be 0.5

$$0.5 = 1 - e^{-\lambda t}$$
$$e^{-\lambda t} = 0.5$$
$$ln(e^{-\lambda t}) = ln\,0.5$$
$$\lambda t = -ln\,0.5$$
$$\lambda = \frac{-ln\,0.5}{t} \qquad (9)$$

Equation 9 was used to calculate Failure rate (λ) for production time from 1hr to 8hrs.

2.4 SENSITIVITY OF THE MODEL

Data for Sensitivity analysis of the model was generated by increasing steadily the public electricity cost, generator electricity cost and the combined costs of both electricity at various production cycle times (that is 4 hrs, 6 hrs and 8 hrs)

3 RESULTS AND DISCUSSION

Table 2 shows the computed profit (Naira) for the three production cycles; using equation 1 and Figure 1 shows the plot of the profits, it can be deduced that profit made using alternate electricity (Generator) for production is lesser than that obtained with the use of Public electricity. When there is a switch – over from public electricity to (Generator) alternate electricity and vice versa; improvement in profits is noticed as compared with complete use of (Generator) alternate electricity in the production cycles. The profit margins found to be increasing steadily with attendant increase in production cycle times; as shown in figure 1.

Table 2. Profit [Naira] Results for production Cycle Times

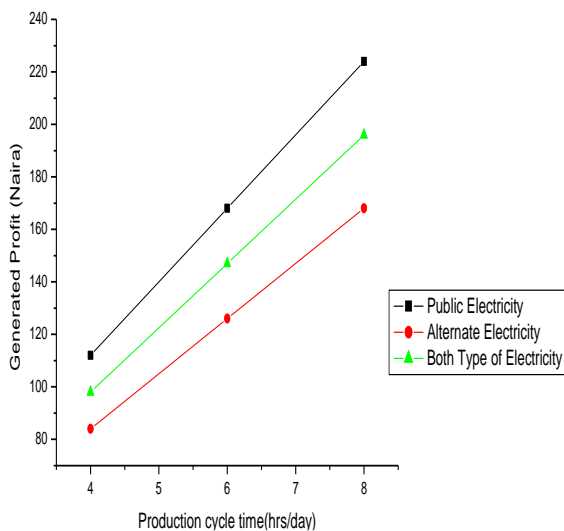| Type of electricity	Cycle time [hrs]			Optimal units Output [Packets]
	4	6	8	
Public electricity	112	168	224	4
Alternate electricity (Generator)	84	126	168	3
Public and Alternate electricity	98	147	196	4, 3

Fig. 1: Plot of Profits from using the Three Types of Electricity.

The results further show that the unit output of 4 is optimal when Public electricity is utilized completely and 3 units with the holistic utilization of alternate (generator) electricity. The reduction of output in the latter case is as a result of the fact that production capacity of the plant is not exceeded. Similar trend is followed in the other cycle times considered. If shifting is necessary at all from public

electricity to alternate (generator) electricity within the cycle, the optimal value still remain 3 or 4 units which does not violate capacity or demand constraint.

Table 3. Percent cumulative Profit/Loss margins for the production cycle times

Cycle time [hrs]	4	6	8
Using Public or Generator electricity fully	33.3%	66.6%	99.9%
Using both type of electricity	17%	34%	51%

Table 3 shows the cumulative profit/loss margins percent for various production cycle times; it is shown that profitability of the system increases with the increase in production cycle time and this increased to about 100% of its initial value when production cycle time is increased from 4 to 8 hrs. This indicates that off periods such as time to attend to breakfast, lunch, visitors, or weekend breaks have great adverse effect on the productivity of the organization.

Table 4. Probabilities of Power Failure for 4 hrs Production Cycle Times

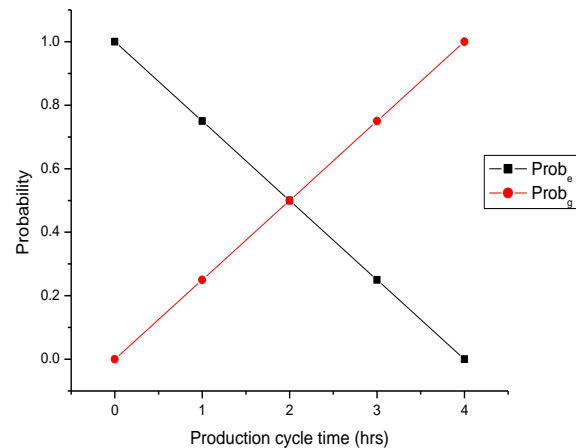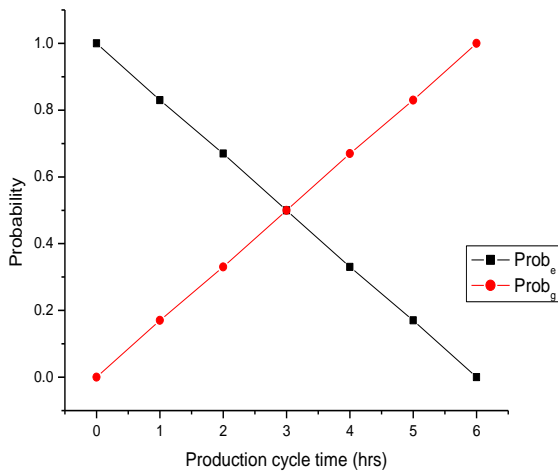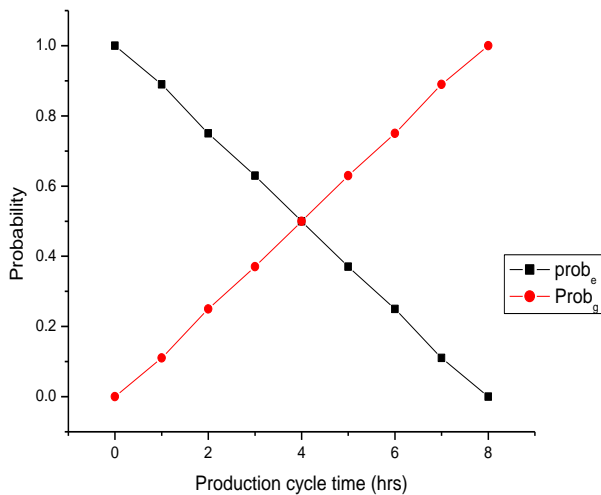| Time of using Public Electricity (t^e) in hr Time of using Alternate Electricity (t^g) in hr	Probability of Public Electricity Failure (($Prob_e$)	Probability of Alternate Electricity Failure ($Prob_g$)
4 0	1.0	0.0
3 1	0.75	0.25
2 2	0.50	0.50
1 3	0.25	0.75
0 4	0.0	1.0

Fig. 2: Probability of power failure during 4hrs production cycle time.

Table 5. Probabilities of Power Failure for 6hrs Production Cycle Times

Time of using Public Electricity (t^e) in hr	Time of using Alternate Electricity (t^g) in hr	Probability of Public Elctricity Failure (($Prob_e$)	Probability of Alternate Electricity Failure ($Prob_g$)
6	0	1.0	0.0
5	1	0.83	0.17
4	2	0.67	0.33
3	3	0.50	0.50
2	4	0.33	0.67
1	5	0.17	0.83
0	6	0.0	1.0

Table 6. Probabilities of Power Failure for 8 hrs Production Cycle Times

Time of using Public Electricity (t^e) in hr	Time of using Alternate Electricity (t^g) in hr	Probability of Public Elctricity Failure (($Prob_e$)	Probability of Alternate Electricity Failure ($Prob_g$)
8	0	1.0	0.0
7	1	0.89	0.11
6	2	0.75	0.25
5	3	0.63	0.37
4	4	0.50	0.50
3	5	0.37	0.63
2	6	0.25	0.75
1	7	0.11	0.89
0	8	0.0	1.0

Fig. 3: Probability of power failure during 6hrs production cycle time.

Fig. 5: Failure rate of public electricity and alternate electricity.

Fig. 4: Probability of power failure during 8hrs production cycle time.

Tables 4-6 show the computed probabilities of power failure for the three production cycles; using equation 8 and Figures 2-4 show the plot of the probabilities, from the 3 figures, it could be deduced that the average failure probability of public electricity is 0.5; irrespective of the production cycle time used.

Table 7 shows the computed value for failure rate of public electricity and alternate electricity between 1-8 hours production time; using equation 9 and Figure 5 shows the plot of the failure rate. It is observed that failure rate of public electricity (λ_P) is inversely proportional to time of production, which means failure rate decreases with increase in hours of production. This means that the profit margin is increasing steadily with attendant increase in production cycle times, which confirmed the statement earlier made; under the discussion of figure 2, that profitability of the system increases with the increase in production cycle time.

While the failure rate of (Generator) alternate electricity (λ_g) increases with increase in production time, i.e the smaller the production cycle time; the smaller the failure rate, in other words the more the generator is used for production for longer hour; the probability of it developing fault or brake-down increases, which will increase production cost; thereby reducing the profitability of the system. The break-even point is 1½hrs production cycle time, where profit made is equal; irrespective of the type of electricity utilized, as shown in Figure 5.

Table 7 Failure rate of Public Electricity and Alternate Electricity

Failure rate of Public Electricity (λp)	0.693	0.347	0.231	0.173	0.139	0.116	0.099	0.087
Failure rate of Public Electricity (λg)	0.307	0.653	0.769	0.827	0.861	0.884	0.901	0.913
Production time (t)	1	2	3	4	5	6	7	8

Table 8: Profits realized as Public Electricity and Alternate Electricity costs increases for 4-8 hrs Production Cycles

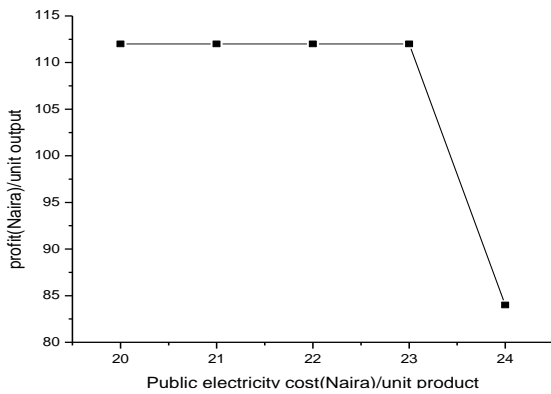| 4 hrs Production Cycle				6 hrs Production Cycle				8 hrs Production Cycle			
Cost of Pe (₦)	Profit (#)	Cost of Ae (₦)	Profit (₦)	Cost of Pe (₦)	Profit (#)	Cost of Ae (₦)	Profit (₦)	Cost of Pe (₦)	Profit (₦)	Cost of Ae (₦)	Profit (₦)
20	112	26	84	20	168	26	126	20	224	26	168
21	112	27	84	21	168	27	126	21	224	27	168
22	112	28	84	22	168	28	126	22	224	28	168
23	112	29	84	23	168	29	126	23	224	29	168
24	84	30	84	24	126	30	126	24	168	30	168

Fig. 6: Effect of public Electricity cost increase on profit at 4 hrs production cycle time.
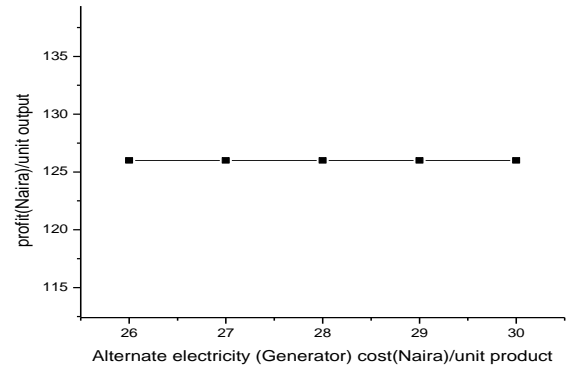

Fig. 9: Effect of Alternate Electricity cost increase on Profit at 6 hrs production cycle time.
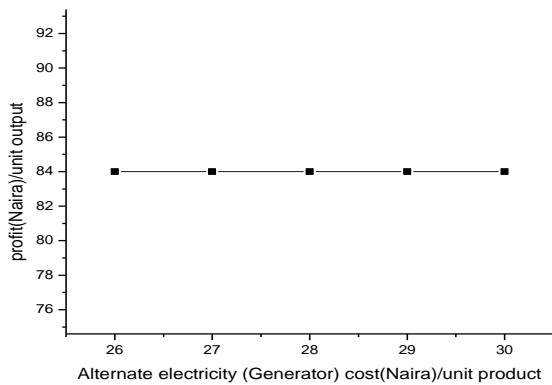

Fig. 7: Effect of Alternate Electricity cost increase on profit at 4 hrs production cycle time.
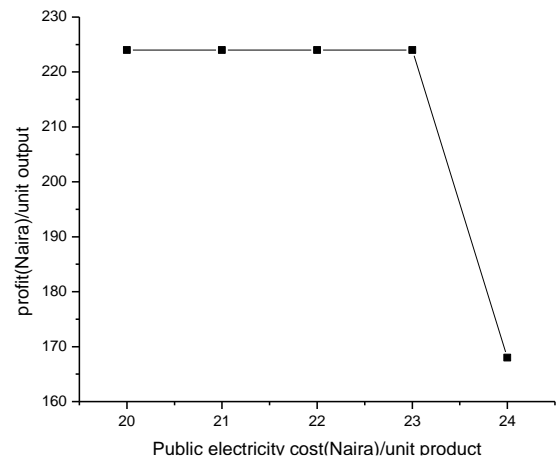

Fig. 10: Effect of Public Electricity cost increase on Profit 8 hrs production cycle time.
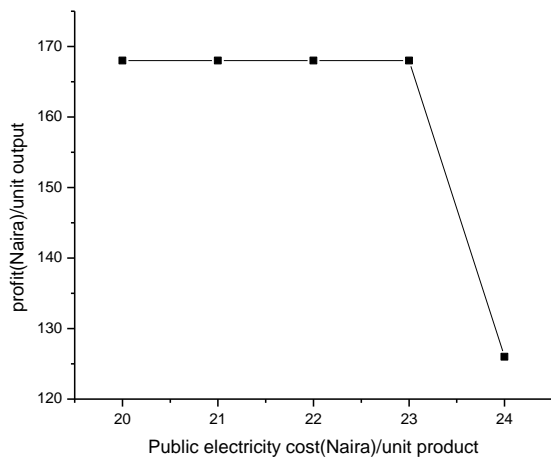

Fig. 8: Effect of Public Electricity cost increase on Profit at 6 hrs production cycle time.
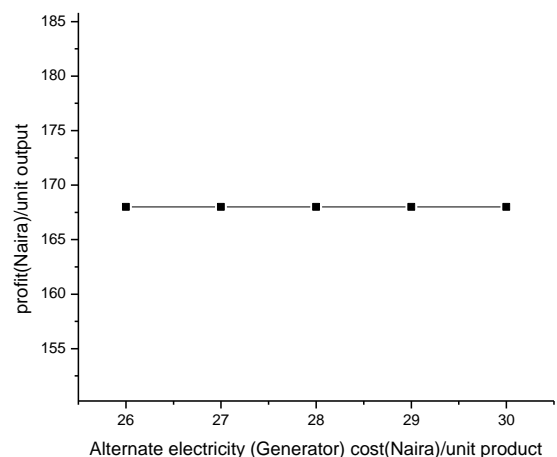

Fig. 11: Effect of Alternate Electricity cost on Profit at 8 hrs production cycle time.
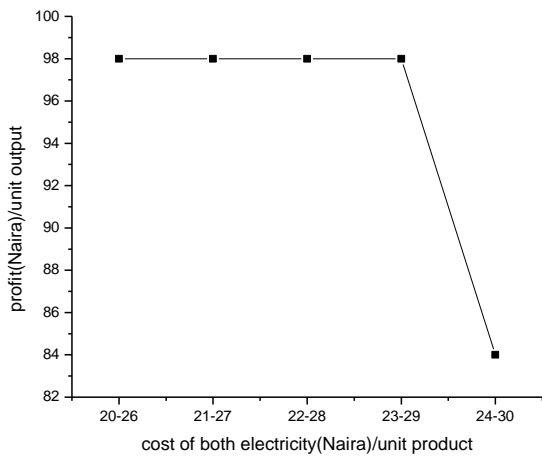
Fig. 12: Effect of both cost of Electricity increase on Profit at 4 hrs production cycle time.
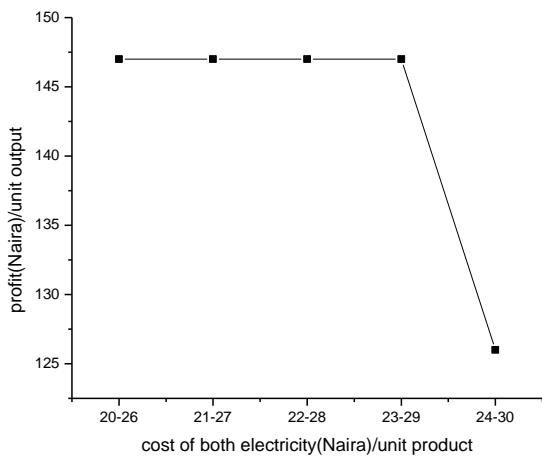

Fig. 13: Effect of both cost of Electricity on Profit at 6 hrs production cycle time.
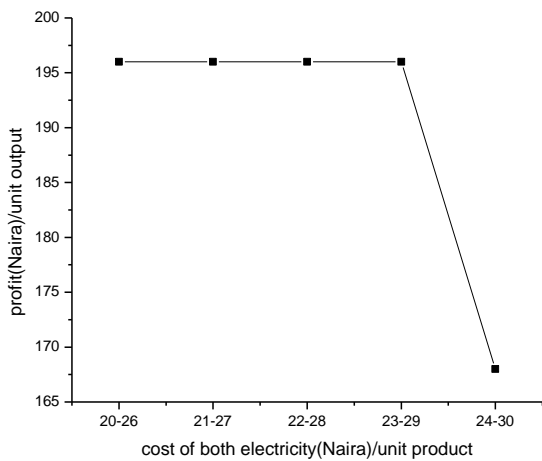

Fig. 14: Effect of both cost of Electricity on Profit at 8hrs production cycle time.

Table 8 shows the sensitivity of the model for the two type of electricity used for production for three cycle times, the data was generated by increasing steadily the public electricity cost, generator electricity cost and combined costs of both electricity for the three production cycles, equation 1 was used to compute their respective profits and Figures 6-14 show the plots respectively, the results indicated that profit can still be made, no matter the type of electric power utilized if there is no market competition that can force the price down beyond profitable level.

4 CONCLUSION

The utilization of public electricity can boost the profit the more, thereby improving the chance of hedging against competition. Profitability can also be improved with reduction in off time in a production cycle. About 100% improvement in profit is witnessed if a full time of 8hrs is used for production instead of lesser hours which is very common in developing countries where off time is created for personal activities such as breakfast, lunch and visitor attention. However, results indicated that profit can still be made, no matter the type of electric power utilized if there is no market competition that can force the price down beyond profitable level.

The study also, showed that cycle time has a significant effect on the productivity and profitability of an organization. It can also be concluded from the results that about 33% improvement in profitability was achieved with public electricity provided, for the full period of production cycles. The epileptic nature of public electricity has reduced the profitability to 17%. The result was very close to one obtained indigenously through survey by Megbowon & Adewumi, (2002), which indicated that an extra expenditure of 30% was incurred with the use of generator electricity in Nigeria agro – allied industries with attendant reduction in capacity utilization.

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