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State-wide Automated Electricity Rationing and Distribution in Delta State, Nigeria, using Regional Classification

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Abstract
Nigeria's current power generation output is insufficient to meet the country's demand for electricity. Not only is there a deficit in power supply, the electricity supply from the national grid erratic. This paper explored the use of automated rationing and disbursement of grid electricity based on region classification in order to cushion the negative effects of power shortage. The algorithm was employed in Delta State, Nigeria. 14 Local Government Areas (LGAs), were classified as Commercial Regions, while 11 LGAs were classified as Residential Regions. The results show that commercial LGAs can automatically receive grid electricity between 7:00 a.m. - 4:00 p.m. to enable businesses function normally, while Residential LGAs automatically received grid electricity between 6:00 p m. - 3:00 a m. to enable citizens enjoy their residential homes and rest well at night. The algorithm can be employed in other states of the country and can also be utilized for regions smaller than LGAs, such as towns and villages. Automated rationing and distribution of the current electricity generation output using region classification cushions the effects of power shortage and can ensure Nigeria's economy continues to thrive and flourish.

Keywords: Electricity Generation, Electricity Distribution, Power Rationing, Region Classification.

1. Introduction
It has been determined that (Emovon *et al.*, 2018; Ofualagba, and Ejofodomi, 2019). The factors affecting power generation in Nigeria include: poor plant maintenance, obsolete facilities, pipeline vandalism, inadequate funding, and Lack of energy mix (Emovon, and Samuel, 2017; Sule, 2010; Idigbe, and Igbinovia, 2010). Nigeria's population is above one hundred and eighty-three million and about 55% of the population have no access to grid-connected electricity (Kayode, *et al.*, 2018). Electricity from the national grid is erratic (Abanihi, *et al.*, 2018). This means that grid-connected residents and companies requiring electricity cannot predict when this electric power from the national grid will be available for their consumption. In many cases, erratic power

supply can be equated to no power supply as the work the power is needed for might have been done before the power supply is made available, or the power is interrupted before what it is to be used for, is gotten ready (Ohajuanya, et al., 2014).

About 80% of Nigerians with grid access use expensive diesel- and petrol fuelled back-up generators as an alternative to the unreliable grid supply (Roche, et al., 2019). Households and small and medium enterprises (SMEs) spend two to three times more on kerosene, diesel and petrol than they do on grid-based electricity (Roche, et al., 2019). The unreliability in availability of electricity supply has greatly hindered the development of economic activities in the country, from rural livelihoods to manufacturing and exports (Roche, et al., 2019; Etukudor, et al., 2015; Ajenikoko, et al., 2018). The cost of self-generating power has made Nigerian products about a third more expensive than imported products [9] and stunted the country's economic growth (Etukudor, et al., 2015; Daminabo, et al., 2018). Agwu et al., 2019, found that small and medium enterprises (SMEs) are most constrained by power shortages and that firms in Nigeria are willing to commit 15% of their annual sales to ensure uninterrupted power supply.

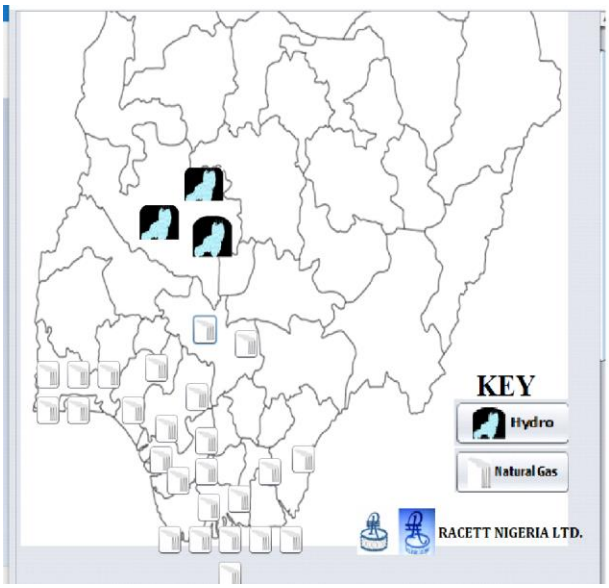
Effective and efficient rationing of the generated electricity would have a significant positive impact on Nigeria's economy. While the country seeks and employs various solutions to ensure adequate electricity is generated and distributed throughout its region, the current algorithm for distribution the generated electricity needs to be optimized, and implemented in such a way that Nigerians are able to know when they will be receiving electricity from the national grid, and to also ensure that Nigerians receive electricity during the hours when they most need it.

This paper presents the automatic rationing and distribution of electricity within a state in Nigeria (Delta State) using a region classification algorithm for effective distribution. The algorithm employed ensures that firms and residents in Nigeria receive electricity from the national grid during the hours they need it most, and is an effective means of eliminating the erratic component in the country's power sector. The algorithm was tested on Delta State, using Nigeria's current power generation output to perform automatic rationing and region-classified distribution of electricity

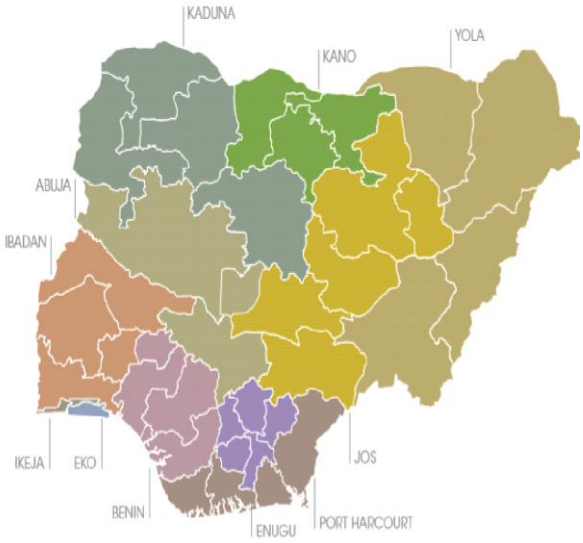
from the national grid (Ofualagba, and Ejofodomi, 2019). The impact of this algorithm on residents and companies/industries within the state are discussed.

Materials and Methods

The power generation system in Nigeria currently consists of 23 power generating stations located at remote locations in Lagos, Rivers, Abia, Edo, Bayelsa, Kogi, Akwa Ibom, Cross River, Delta, Ogun, Ondo and Niger States (see Figure 1a). It consists of 3 hydro power stations and 25 natural gas power generating stations with a combined electricity generation of 80,249.18MWH or 3,343.72 MWH/H for October 16, 2019 (Nigerian System Operator, 2019).



(a)



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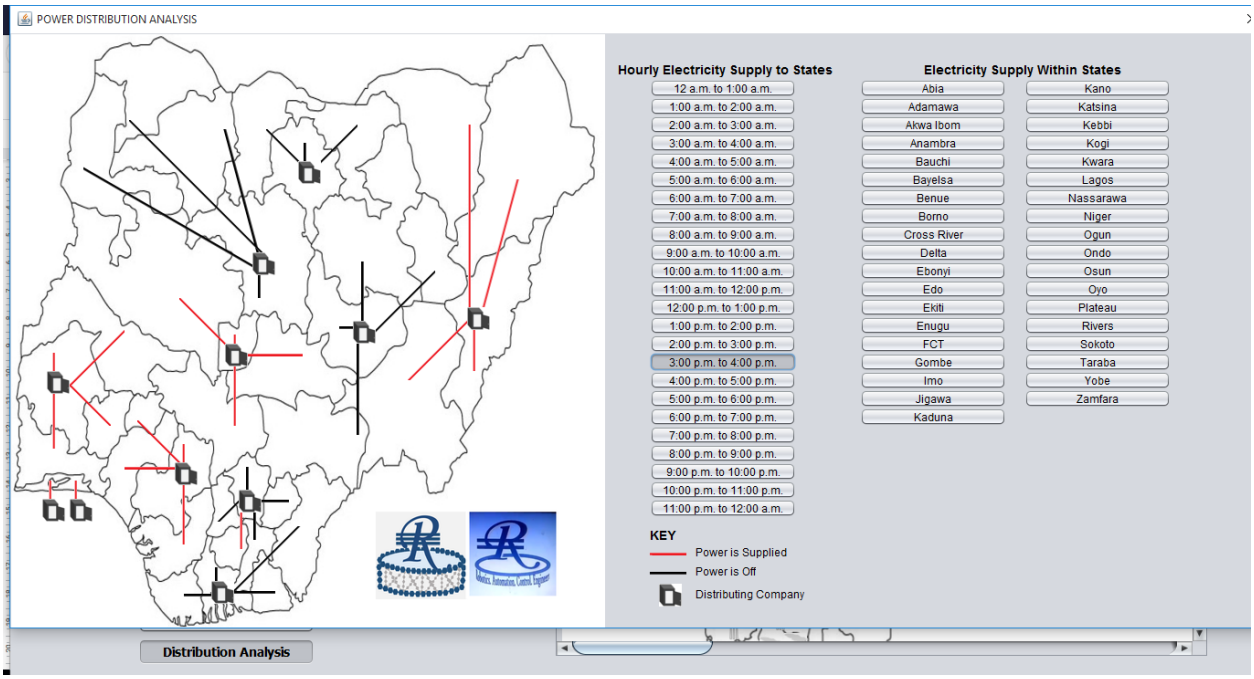


(c)

Figure 1. *(a) 28 grid-connected power generating stations in Nigeria (b) 11 Electricity Distribution Regions in Nigeria (c) Electricity Distribution to States within Nigeria on October 16, 2019.*

Once generated, power it is stepped up to 330 kV before it is transmitted to various parts of the country by the Transmission Company of Nigeria (TCN) (Transmission Company of Nigeria, 2019). The power is further stepped down to 132 kV as it gets to injections stations close to towns. At injection stations, the power is once again stepped down to 33 kV before it is passed on to distribution networks within the towns and cities. The distribution is split into 11 zones shown in Figure 1b, and the distribution networks comprise 33 kV, 11 kV and low voltage circuits (Transmission Company of Nigeria, 2019). Within towns, power is stepped down to 11 kV at substations and again finally to 415 V and 220-240 V by distribution transformers before reaching consumers within the towns and cities. Within each distribution region or zone, an electricity distribution company handles the distribution of power received from the Transmission Company of Nigeria to its constituent states. Each distribution company is allocated a certain percentage of the total electricity generated by the 23 generating stations in the nation's electricity grid.

Benin Distribution Company (BEDC) is responsible for distributing electricity from

the National Grid to Delta State, Edo State, Ekiti State, and Ondo State respectively, and is allocated 9% of the electricity on the national grid (Ofualagba, and Ejofodomi, 2019). On October 16, 2019, BEDC received 2,808.9 MWH of electricity from the national grid to distribute to Delta, Edo, Ekiti and Ondo states (see Figure 1c). This was the amount of power available for distribution to its constituent states after incurred 7.7% transmission and 58% distribution losses (Ofualagba, and Ejofodomi, 2019). The load requirement of the area where electricity is to be distributed depends on the nature of the area, the population of the town or village, and the standard of living of the people in the locality, and the Industrial development of that area (Chinwuko, et al., 2011). For Delta State, with a population of 5,663,662, the total daily power demand is approximately 1985.8 MW. Of the 2,808.8 MWH received by BEDC on October 16, 2019, only 898.9 MW allocated and distributed to Delta State. This means that on October 16, 2019, Delta State experienced a power deficit of approximately 1,086.9 MW.

Effective rationing of the power available for distribution within Delta State was performed using a Power Optimization Software owned by RACETT NIGERIA LTD (RACETT, 2020). The software was used to classify each Local Government Area (LGA) in Delta State as either a "COMMERCIAL REGION" or a "RESIDENTIAL REGION." Presently, there are 25 LGAs in Delta State. LGA classification was done based on the population residing within the LGA and the presence of large scale Industrial companies to signify a high level of industrial development within the LGAs. Fourteen (14) LGAs (Warri North, Warri South, Warri South West, Ughelli North, Ughelli South, Isoko South, Bomadi, Ethiope East, Ethiope West, Sapele, Udu, Uvwie, Oshimili North, and Oshimili South) were classified as commercial regions, while eleven (11) LGAs (Aniocha North, Aniocha South, Burutu, Ika North East, Ika South, Isoko North, Ndokwa East, Ndokwa West, Okpe, Patani, and Ukwuani) were classified as residential regions.

The 898.9 MW of power received from the national grid by Delta State on October 16, 2019 was automatically distribution to the 26 LGAs based on their region classification by the Power Optimization Software. The priority chart used for automated electricity distribution without n Delta State is shown

in Table 1. The lower the value given to an hour within each day, the higher the priority it is given when it comes to electricity distribution.

Table 1. Priority Chart for Hourly Electricity Distribution for Commercial Regions and Residential Regions.

	Priority Chart for Hourly Electricity Allocation	
Hour	**Commercial Regions**	**Residential Regions**
12 a.m. - 1:00 a.m.	18	7
1:00 a.m. - 2:00 a.m.	19	8
2:00 a.m. - 3:00 a.m.	20	9
3:00 a.m. - 4:00 a.m.	21	10
4:00 a.m. - 5:00 a.m.	22	11
5:00 a.m. - 6:00 a.m.	23	12
6:00 a.m. - 7:00 a.m.	24	13
7:00 a.m. - 8:00 a.m.	1	14
8:00 a.m. - 9:00 a.m.	2	15
9:00 a.m. - 10:00 a.m.	3	16
10:00 a.m. - 11:00 a.m.	4	17
11:00 a.m. - 12:00 p.m.	5	18
12:00 p.m. - 1:00 p.m.	6	19
1:00 p.m. - 2:00 p.m.	7	20
2:00 p.m. - 3:00 p.m.	8	21
3:00 p.m. - 4:00 p.m.	9	22
4:00 p.m. - 5:00 p.m.	10	23
5:00 p.m. - 6:00 p.m.	11	24
6:00 p.m. - 7:00 p.m.	12	1
7:00 p m. - 8:00 p.m.	13	2
8:00 p.m. - 9:00 p.m.	14	3

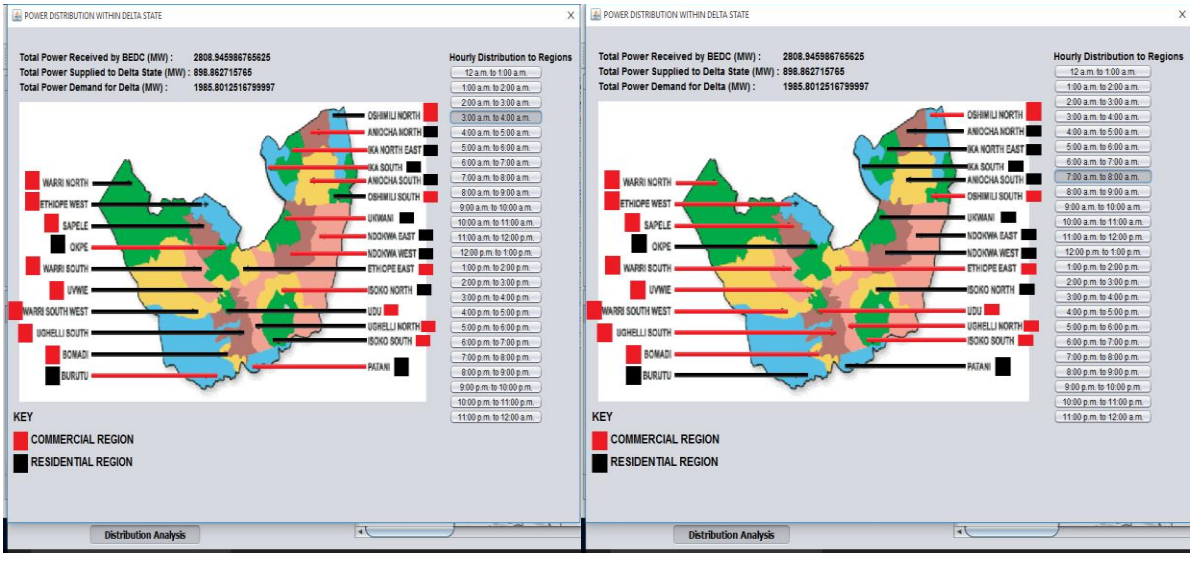
9:00 p.m. - 10:00 p.m.	15	4
10:00 p.m. - 11:00 p.m.	16	5
11:00 p.m. - 12:00 a.m.	17	6

For commercial regions or LGAs, priority was given to the hours between 7:00 a.m. and 7:00 p.m. during office hours, as this is the period of most businesses would be opening and operating daily. For residential regions, priority was given to the hours between 6:00 p.m. and 6:00 p.m. when people would have left their offices and would be at home in their residencies, requiring electricity from the national grid.

3. Results and Discussion

3.1. Presentation of Results

On October 16, 2019, BEDC was only able to provide 898.8 MW of electricity to Delta State. This was less than 50% of the electricity demand of 1,985 MW for this region. Consequently, Delta State could only receive 9 hours of grid electricity on October 16, 2019. Figure 2 shows the automated distribution of grid electricity for Delta State on October 16, 2019.



(a) (b)

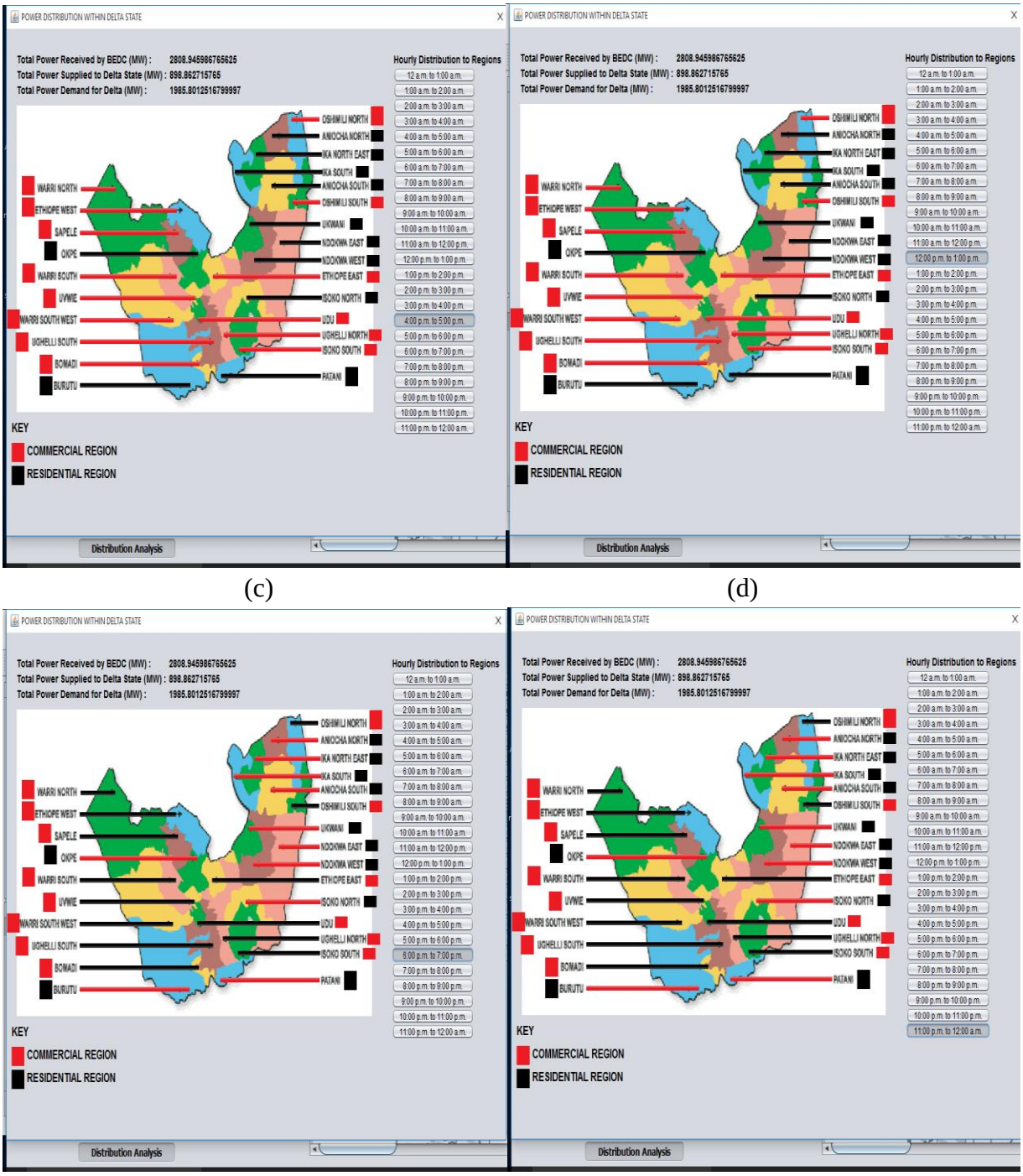


Figure 2. *Automated Electricity Rationing and Distribution for Delta State on October 16, 2019. (a) 3:00 a.m. - 4:00 a.m. (b) 7:00 a.m. - 8:00 a.m. (c) 12:00 p.m. - 1:00 p.m. (d) 4:00 p.m. - 5:00 p.m. (e) 7:00 p.m. - 8:00 p.m. (f) 11:00 p m. - 12:00 a.m.* ***(source: RACETT, 2020)****.*

Using the Hourly Priority Chart shown in Table 1, the Power Optimization Software rationed and distributed the available grid electricity for Delta State based on LGA region classification. Commercial LGAs received their available 9 hours of electricity between 7:00 a.m. - 4:00 p.m. Residential LGAs received their available 9 hours of electricity between 6:00 p.m. and 3:00 a.m. For both Commercial Regions and Residential Regions in Delta State, Grid Electricity was unavailable between 3:00 a.m - 7:00 a.m. and between 4:00 p.m. - 6:00 p.m.

3.2. Discussion of Findings

Nigeria's current power generation output is insufficient to meet the country's demand for electricity. It has been reported that Nigeria requires a daily generation of about 470,000 MWH of electricity to be able to provide 24 hours of continuous uninterrupted grid electricity to its citizens (Ofualagba, and Ejofodomi, 2019). As of October 16, 2019, Nigeria was only able to generate 80,249.18 MWH. While relevant solutions are being implemented to get increase the country's generation output, proper utilization of the current generation output must be implemented to ensure that Nigerians are able to access grid electricity as at when needed.

As of October 16, 2019, Delta State was able to receive only 45.3% of its electricity demand from the national grid. This translated to the state only receiving 9 hrs of energy from the grid. Rationed Disbursement of the electricity based on user's need will go a long way in mine mixing the current effects of insufficient power generation in the nation. By classifying a region based on it's pattern of electricity consumption, the electricity distribution system can be configured in such a way that the available power is disbursed during the hours when the users in that region require electricity. For Delta State, the 14 LGAs classified as commercial regions received their available grid electricity from 7:00 a.m. - 4:00 p.m., the peak hours when businesses require electricity to operate. This means that businesses in these commercial regions would only need to secure additional electricity for 1 hr (4:00 p.m. - 5:00 p.m.) from a backup source, if they operate from 8:00 a.m. - 5:00 p.m., which is the typical work day schedule. For businesses that run from 7:00 a.m. - 4:00 p.m., no investment in

a backup electricity source would be required.

The effect of this outcome will have a positive impact on Nigeria's economy. It will mean that despite the current low power generation output of the country, businesses operating in Nigeria will still be able to receive sufficient electricity from the national grid to function optimally, without needing to incur additional costs to provide electricity for themselves. Nigeria's products would no longer need to be more expensive than imported products, and this would make the country globally competitive. And this can be achieved, not simply by increasing the country's electricity generation output, but by proper automated rationing and distribution using region classification.

For Delta State, the 11 LGAs classified as Residential LGAs, received their 9 hours of available grid electricity from 6:00 p.m. - 3:00 a.m., enduring that individuals had electricity in their homes when they returned back from work. Residents could then relax at home, carry out all the activities needed electricity in order for them to prepare for work for the following day, and to enjoy the comforts of their homes. It also enabled residents to sleep comfortably in electricity-powered homes (i.e. with operating air conditioners, fans, e.t.c.) for most of the night.

Automated rationing and distribution of available grid electricity using region classification would enable Nigerians to know when exactly to expect power from the grid, and would guarantee that they receive grid electricity when they need it most. The region classification employed in this paper was done for LGAs in Delta State. However, it can easily be extended to other LGAs in the remaining states of the country. Furthermore, region classification electricity distribution can be performed on areas smaller than local government areas. Region classification can be done for LGAs individual towns and villages within each LGA, for example. And while this paper only explored classification into commercial and residential regions, other region classification models can be employed to optimize the distribution of available electricity supply from the national grid.

It is important for Nigeria to increase the country's electricity generation output by addressing the currently existing limitations identified (Emovon, and Samuel, 2017; Sule, 2010; Idigbe, and Igbinovia, 2010). However, automated rationing and

distribution of the current electricity generation output using region classification would effectively cushion the effects of power shortage and will ensure that Nigeria can remain globally competitive and an economic force to be reckoned with.

Conclusion

This paper explored a viable solution to address the electricity power deficit currently being experienced in Nigeria. By automatically rationing distributing available grid electricity based on region classification in Delta State, it was determined that commercial regions could receive grid electricity from the national grid between 7:00 a.m. - 4:00 p.m. to enable them conduct business normally. It was also determined that residential regions could receive grid electricity between 6:00 p.m. - 3:00 p.m. to enable citizens enjoy their homes when they return from work and to have a good night's sleep. Automated rationing and distribution of the current electricity generation output using region classification cushions the effects of power shortage and ensures Nigeria's economy continues to thrive and flourish.

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