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ANALYTICAL STUDY OF HYDROKINETIC ENERGY POTENTIALS IN SOME TIDAL-RIVERS OF KANO STATE NIGERIA

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ABSTRACT

Nigeria is heavily dependent on fossil fuel for electricity generation. With the rapidly diminishing of thefuel reserve and the increasingly negative effects of fossil fuels to the environment, government is considering exploiting alternative energy sources. However, the potential of harnessing other renewable sources, particular ocean energy, in Nigeria has not been fully realized. This study was carried out to identify the potential of harnessing ocean energy for electricity generation. Delft3D3D interactive modelling was used to create a three-dimensional numerical ocean model for some rivers in Kano State, Nigeria, which was calibrated against measurement by a means of adjoin data assimilation approach. A set of reliable tidal speed and tidal elevation data was therefore generated to determine the types of tides available in aimed locations, the potential areas of installing river current turbines (RCTs), the total amount of electricity to be generated by RCT, the economic viability and the environmental benefits of using RCT in the studied areas. It was discovered that Tiga and Challawa are the areas with terrific prospect for tidal energy extraction. The total amount of electricity that can be generated by RCTs on those areas is about 8.86 GWh/year.The total amount of CO_2 to be avoided is 1,333 tonnes per year. Owners of RCTs may be able to recover the cost of the system after 10 years and can make profits after that.The results are critical to public policy makers and potentialprivate investors on hydrokinetic energy in Nigeria for consideration.

INTRODUCTION

Nigeria to a great extent is reliant on the fossil fuels to meet its energy demands. The energy requirement is rising exponentially, but the existing installed capacity is 6,840 MW and actual generation capacity is 3941 MW(Dike *et al.,* 2011), hence causing the greenhouse gas emissions to grow extensively from 43 million tons in 2010 to 110 million tons in 2016(Akinlo, 2009). Such a speedy development of emissions has brought to the country to experience a number of adverse effects due to climate changes. For example, the floods in Lagos, Niger, Benue and other states in both northern and southern parts of the country. Nigeria from December 2015 to Jan 2018 were the worse compared to other years. These floods caused 90,000 people to leave their homes and killed many people. This natural occurrence happened in the country to undergo economical deficits of about NGN 50 billion (= US$163 million) (Akinlo, 2009). In addition, the oil reserve in Nigeria will be exhausted in the near future, because they are discovered and utilized Lawan *et al.*, 2016). As a result, Nigeria will progressively experience a diverse range of social and economic issues caused by climate change and the exhaustion of oil reserves. The government has consequently put in a great deal of attempts in utilizing the energy of solar radiation, wind, hydro and bio-fuel for electricity generation (Sharma *et al.,* 2012).

Hydrokinetic energy is yet another type of renewable energy readily available on the globe(Sharma *et al.,* 2012). . The prospective and the commercial feasibility of utilizing Hydrokinetic energyin Nigeria had been not examined extensively. Until not long ago, an initial study was performed to examine the potential of harnessing ocean energy for electricity generation in Nigeria (Pereira *et al.,* 2013). There are generally three types of Hydrokinetic energy (a) Tidal Energy (b) Wave Energy and (c) Thermal Energy. As described (James *et al.,* 2010), the wave power density needs to be more than 50 kW/m such that existing wave energy conversion technologies can generate sufficient power and so justify their commercial viability. However, the wave power density on Nigeria ocean and rivers is generally less than 50 kW/m. Therefore, the potential for harnessing wave power in Nigeria could be incredibly less. As for thermal energy, river thermal energy conversion (RTEC) would produce enough power to justify its commercial practicality if the temperature gradient is greater than 2^0C across the depth of the river. Nevertheless, as explained by (Boike, Wille, and Abnizova 2008), the temperature gradient is usually less than 2^0C if the depth of the river is less than 1000 m. The depth of the most Nigeria river is less than 500-900 m. Hence, RTEC is probably not commercially feasible in Nigeria(Longe and Omole 2008).

MATERIALS AND METHODS

As the river tidal routine is extremely foreseeable, it gets the potential to be a very efficient renewable energy source. Two most important strategies are being investigated worldwide to utilize the energy from tides: (a) Barrage Strategy and (b) Hydrokinetic Stream Technique(Yeh, Wang, and Member 2008). For the barrage strategy, a physical barrier, namely the barrage, is designed within the sea with Sluice Gates to control the flow of seawater. The Sluice Gates are to be closed at high tide so that the water level inside the barrage is kept at its maximum level. As the river tide recedes, a variation in water level in between the barrage and the river is produced. The prospective energy from the water level change will then drive turbines to produce electricity. In the hydrokinetic stream method, horizontal axis turbines are positioned in the path of hydrokinetic currents to produce electricity.

The preliminary assessment indicates that there are Four sites in Nigeria's coastal belt, -Akassa, Bayelsa State (Lat. 4.3167° N, Long. 6.0667° E); Bonny, Rivers State (Lat. 4.4500° N, Long. 7.1667° E); Calabar, Cross-River State (Lat. 4.9667°N, Long. 8.3167° E) and Lagos Bar Beach, Lagos State (Lat. 6.400°N, Long. 3.400°E), with a high tidal range based on tidal wave, These 4 sites distributed across south Nigeria can have the power availability of 70% of the time. Calabar has the highest tidal range of 3.07m. With a single turbine of 2.4 m long blade installed at Bonny Island as a pilot simulation study, 14,970 kWh of energy can be generated every month. This amount is sufficient for 75 households. However, the construction of the barrage system is too expensive and, hence, not economically viable(Longe and Omole, 2008).

. For the tidal stream simulation approach, the results indicated that Nigeria has four locations with high tidal stream energy, has the highest power availability, 80% of the time. The lowest is 79%, which happens in January and February. In March, August, September, October and December, the power availability is as high as 81% of the time. The average monthly yield per square meter of turbine sweeping area is 1209 kWh, translated to 14,502 k Wh per year. The cost of installing tidal stream turbines is much lower than that of the barrage system. Hence, the tidal stream approach should be economical viable. However, the assessments were based on ocean data from a database, known as OSU TOPEX/POSEIDON

Crossover database (TPXO). The data are not reliable enough because it is very much different from the measurement collected from 20 tidal stations installed around the country(Mohammed *et al.,* 2013). As a result, an alternative means of generating a reliable tidal data for the assessment is necessary.

The Princeton Ocean Model (POM) (Mohammed *et al.,* 2013)was used to simulate ocean phenomena in some parts of Nigeria. A three-dimensional ocean model of Nigeria was created in POM and calibrated against measurement by a means of adjoin data assimilation approach without the need of reducing the model into 2-dimensional as proposed in (Barron *et al.,* 2007). An optimization code, an enhanced method for the formulation of the tidal boundary conditions (Sannasiraj *et al.,*2004)was incorporated into POM to improve the convergence of the system. By using the POM software with the added on features, a set of reliable tidal speed and elevation data was generated to assess technical, economic and environmental aspects of installing marine current turbines (MCT) in Nigeria. This evaluation was assisted with the methods suggested in Akin-Osanaiye, Nzelibe, and Agbaji (2002), for developing the configuration of MCT, the capacity and the diameters of turbines for each potential location in Nigeria. The goal of this paper is to provide the results of the evaluation, which are significant to policy makers and the potential investors on tidal energy in Nigeria for decision making. The outcomes could help the bordering states and countries to fully grasp the possible potential of their river energy. This paper will start with a brief introduction to the means of generating tidal data, and then the characteristics of tides around Kano State, Nigeria and the potential amount of electricity generation by RCT. The economic and environmental positive aspects of using underwater current turbines will eventually be talked about.

Site Description and Data Collection

Three independent sets of data on tidal heights and tidal velocity are used to study the tidal phenomena around aimed areas, Wudil, Tiga, Challawa and Watari. These three sets of data were gathered from three sources: (a) River Tidal Observation Records 2015 obtained National Space Research and Development Agency, Abuja, Nigeria (NASRDA); the data were initially obtained from Water Resource and Engineering Company (WRECA) (b) TPXO Software Output; and (c) Delf3D Model with the Adjoint Data Assimilation Method. The following paragraphs elaborate further on each of the data sources.

River Tidal observation records 2015 to 2017

The River Tidal Observation Records is an annual publication by the NASRDA as shown in Fig. 1. It compiles the measured tidal elevation information from the 20 river tidal stations located at both north and southNigeria(Willis *et al.,* 2010). All the tidal stations are equipped with state of the art equipment for measuring, recording and storing of tidal data. The system is set to sample the data once every 10 s, with an average value written to the IC-Memory cassette every 50 s, executed by the built-in microprocessor. These recorded data, together with the statistical results and extracted harmonic components are recorded in the River Tidal Records. However, the River Tidal Records contain only the tidal information for 15 sites around Nigeria TPXO software and the Delft3Dmodel were used to simulate river tidal information from sites where there is no tidal station. The data from this Tidal Record were used to verify the output results from the TPXO software and the Delft3D model.

Figure 1: Nigeria Map(S. M. Lawan *et al.* 2016)

RESULTS AND DISCUSSION

A reliable database called Crossover database (TPXO) is a database of global tides properties (Abanades, Greaves, and Iglesias 2014). The database is generated using the Oregon State University Tidal Inversion Software package (OTIS), which applies the Laplace Tidal Equations ("Atmospheric Tides: Thermal and Gravitational - S. Chapman, R.S. Lindzen - Google Books" n.d.) for data intake working with the ocean and river data furnished by two satellites, namely Jason and TOPEX/Poseidon (Bonnefond et al. 2010). TPXO gives tidal data using a global model with the resolution of equal degrees spacing along the longitude and latitude or 1440 by 721 grid points across the model. The river tidaldata involves eight primary harmonic components (M2, S2, N2, K2, K1, O1, P1 and Q1) and two long period constituents (Mf and Mm) which are the various astronomical forcing constituents of the tide with individual periods and magnitudes. Initially, the TPXO database was used to examine the potential of harnessing hydrokinetic energy around Kano State Nigeria. It was determined that there are numerous places with high potential of river tidal velocities. Nevertheless, the further studies proved that the data from TPXO are not appropriate enough when in comparison with measured data from the River Tidal Record as shown in Table 1. Some of the errors are above 10%. For that reason, Delft3D was employed to model the rivers and study the river tidal phenomena around the case study areas.

Table 1: Comparison of Results from (a) TPXO Software Output; (b) Delft3D Model and (c) Tidal Observation Records 2015 on river tidal elevation

S/No	Location	Data from Nigeria Hydrological Services Agency (RMS) 2016	Delft3D output	Error	TPXO output	Error
1	Apapa Lagos	1.89	1.79	-5.291	1.78	-5.82
2	Bonny	1.25	1.29	3.200	1.35	8.00
3	Bakana New Calabar River	0.78	0.82	5.128	0.79	1.28
4	Lagos Bar	0.79	0.77	-2.532	0.82	3.80
5	Akassa, Bayelsa	1.89	1.99	5.291	1.76	-6.88
6	Bar Beach, Lagos	1.89	1.72	-8.995	1.79	-5.29
7	Kaduna River	0.87	0.79	-9.195	0.88	1.15
8	River Niger Lokoja	0.67	0.69	2.985	0.69	2.99
9	Niger Benue River	1.09	1.04	-4.587	1.19	9.17
10	NgaddaRiver,Borno	0.45	0.47	4.444	0.49	8.89

River model using Delft3D Software

Delft3D is a 1D/2D/3D flood and tidal model that has a wide range of applications with similar capabilities to other, more expensive flood models. When compared with leading flood simulation models, Delft3D boasts improved data handling and faster computations. Delft3D offers stable, robust and efficient hydrodynamic modeling at a fraction of the cost of other high-end models.Delft3D is specifically beneficial where the hydrodynamic behaviour in coastal waters, estuaries, rivers, floodplains and urban drainage environments have complex 2D flow patterns that would be awkward to represent using traditional 1D network models. It is suited to modelling flooding in major rivers through to complex overland and piped urban flows, along with estuarine and coastal hydraulics. A powerful feature of Delft3D is its 3D/2D/1D dynamic linking, first pioneered in 1990, and subsequently enhanced to the point where it offers unparalleled flexibility and robustness. Delft3D continues to develop and evolve to meet the challenges of hydrodynamic modelling. Severalresearchers have proven the capability of using Delft3D for river tidal modelling and prediction (Sloff and Mosselman 2012).

River and Ocean Wave Tides in Nigeria

River tides are the changes of the river envelope caused by the periodic variation of gravitational forces between the earth, the Moon and the Sun, hence creating a periodical rise and fall of river level at a location of the earth with highly predictable cycles. There are three main types of river tides, namely diurnal, semidiurnal and mixed tides. The period of semidiurnal tide is about 6 h 12 min. The period of diurnal tide is about 12 h 48 min. In most locations, the tides are a combination of the semidiurnal and diurnal tides, known as mixed tide. Some mixed tides are dominant in semidiurnal and some in diurnal. When the semidiurnal tide is dominant, the highest tidal current occurs at rainy tides and the lowest at the neap tides.

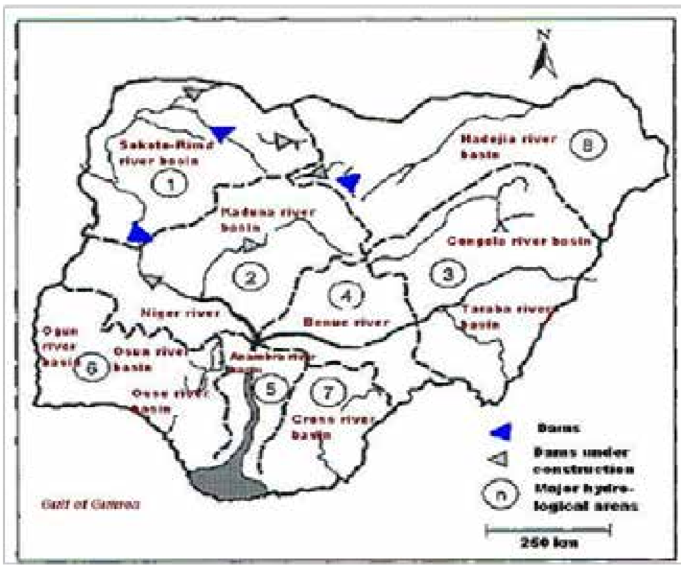

Figure 2: Map Showing Rivers With Tides (Ohunakin, MoAdarala, and Oyewola 2011)

When the diurnal is dominant, the highest river tidal currents occur at the extreme declination of the moon and lowest current at the zero declination (Dike *et al.,* 2011; Ashourian *et al.,* 2013; Basar *et al.,* 2011; Lee *et al.,* (2012; Rahman *et al.,* (2011); Sannasiraj *et al.,* (2004) . This means that the types of tides indicate the availability of minimum and maximum river tidal energy. Therefore, it is important to identify the types of tides available in Nigeria for us to examine the classification ratio in the targeted rivers.

The classification of river tides can be based on the values of the ratio (F) as given below (Mohammed *et al.,* 2013):

$$F = \frac{K_1 + O_1}{M_2 + S_2} \quad \text{.................................(1)}$$

whereK_1 and O_1 are the two main diurnal components and M_2 and $S_2$are the two main semidiurnal components.

If the ratio (F) is less than 0.25, then the tide is semidiurnal. If it is within the range of 0.25 and 1.5, then it is a mixed tide with dominant semidiurnal. If it is within the range of 1.5 and 3.0, then it is a mixed tide with dominant diurnal. If it is greater than 3.0, it is a diurnal tide. The components K_1, O_1, M_2 and S_2 for the rivers throughout four selected locations were generated by using the Delft3D model. The ratio F was then calculated and the types of river tides throughout Nigeria were identified as shown in Fig. 2. In South-South Nigeria, semidiurnal and mixed tide with dominant semidiurnal occurs on west coast, whereas mixed tide with dominant semidiurnal occurs on Southeast coast except that in Enugu where the mixed tide is dominant in diurnal. The tide in Southwest part of Nigeria is a mixed tide with either dominant semidiurnal or diurnal. There is no diurnal tide available in in the northern part of Nigeria. By knowing the types of tides in a particular location, the characteristics of power supply from RTCs at that location can be known. For example, if MCT is installed in the coastline of Lagos, it is expected to observe two rises in the power output of MCT within a day. The power output will become the highest during the extreme declination of the moon. If MCT is installed somewhere else in South-south, it is expected to see four rises in the power output of MCT within a day. The power output of RCT should become the highest during heavy rain, tide in the north.

Tidal Energy Harnessed by River Turbine

The energy density of river tidal current can be calculated by using the following equation.

$$E = \sum_{h=1}^{8760} \left[\frac{1}{2} \rho v^3 \right]_h \quad \text{.................(2)}$$

Where E= Yearly energy density (k Wh/m^2), r= Density of river water (1024 kg/m^3),
V=The component of river tidal velocity perpendicular to the cross section of river current turbine (m/s).

Equation 2 was used together with the river tidal data generated by the Delft3D river model to determine the energy density profile as shown in Fig. 3a and 3b. It is shown that Challawa and Tiga rivers are the locations with great potential for river tidal energy extraction. However, exactly how much river tidal energy that can be harnessed depends on the advancement of tidal technologies. Over the past few years, a number of innovative rivercurrent turbines have been developed and tested on several sites of the world. The River Flow device is a horizontal axis turbine device. It was first installed off Lynmouth in the Bristol Channel in 2003 with the rated power output of 300 kW (Khan *et al.,* , 2006). The Stingray system is an oscillating hydrofoil system (Güney and Kaygusuz, 2010). It was tested in Yell Sound, Shetland between 2002 and 2004. The hydrofoil is attached to an oscillating arm, which drives a hydraulic system. The hydrofoil oscillates due to the tidal current flow either side of the hydrofoil. This movement drives the hydraulic system which in turn generates electricity. The Hammerfest Strom system is a river-bed-mounted horizontal axis system installed in Norway in 2003 (Fraenkel 2006). Open-Centre Turbine is another tidal current turbine developed by a Scottish company called Open-Hydro (Güney and Kaygusuz 2010). It was installed off the Orkney island of Eday, Scotland. There are many other designs such as River Current Turbines, Lunar Energy, SMD Hydro-vision and Hydro-venturi system (Rourke *et al.,* 2010).

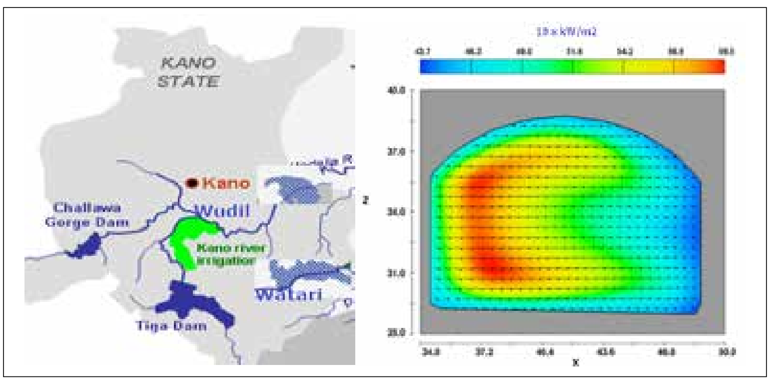

Figure 3a : Energy Density Profile in the Selected Rivers

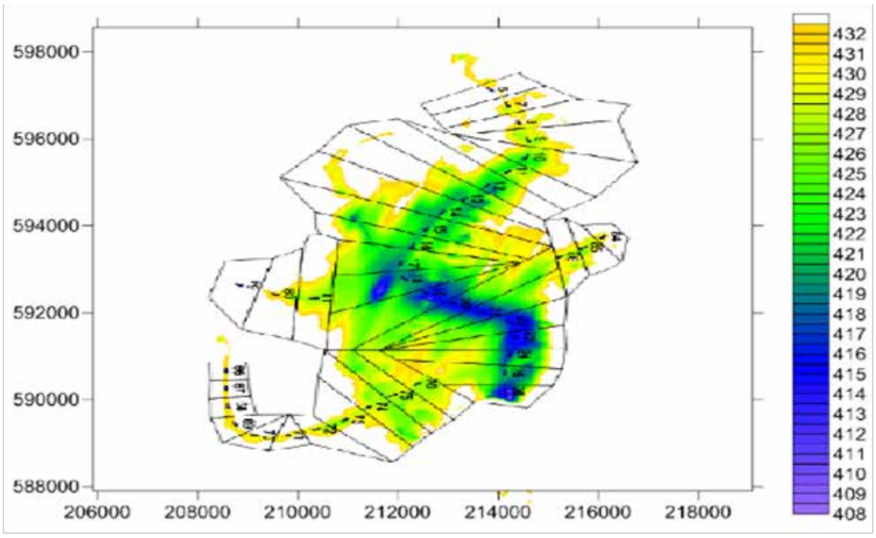

Figure 3b: Model TopographyGrid of the Two Rivers with high Tides

Each of the river tidal technologies is unique in the features and the conversion mechanisms. Which design is appropriate depends on the nature of river tidal current, topography and environmental constraints at the site of energy extraction (Singh Thapa, Thapa, and Dahlhaug, 2017.). However, in this study, it is assumed that twin horizontal axis turbines are used and its amount of energy supplied by the turbine is influenced by three factors, namely the cut-in speed of turbines, the swept area of RCTs, and the power efficiency Cp. If the power coefficient and swept area of RCTs are taken into account, then the following equation is derived.

$$E_{av} = \sum_{h=1}^{8760}\left[\frac{1}{2}C_p A_p v^3\right]_h \qquad \text{............................(3)}$$

whereEav= Yearly average energy (kWh), Cp= Power coefficient, A = Swept area of tidal turbine (m^2).

It is noticed that the cut-in speed of most horizontal axis turbine is 1.0 m/s (Xuesong *et al., 2*009). However, low river tides technology is being developed. The cut-in speed is the minimum speed that the river tidal flow has to be such that the turbine can generate power. If the turbine is installed at a location with river tidal velocity being less than 1.0 m/s, then the amount of electricity supplied by it can be negligibly small. To understand the exact amount of electricity supplied by RCTs, the distribution of river tidal velocities on several identified sites is derived as shown in Fig 4. The figure shows that the current velocities and frequency of distribution per hour at the areas of Watari and Wudil are less. While that the current velocities and frequency distribution of river tide atTiga and Challawa are high. This means that Challawa and Tiga are potential sites for river tidal energy extraction. But, a low river tidal turbine could be conveniently used in Wudil and Watari for small scale applications, such as water pumping and other agricultural applications that require small energy to operate. The power coefficient Cp is the percentage of power that can be extracted from the fluid stream by RCTs taking into account thelosses due to Betz's law and those given to the internal mechanism within the converter or turbine (Sarikprueck *et al.,* 2011).

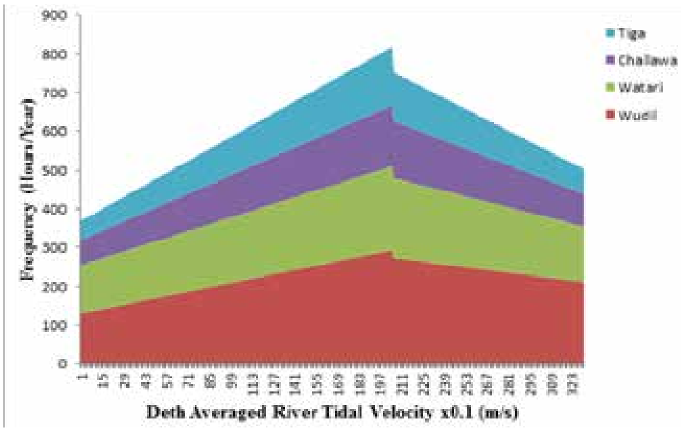

Figure 4: Frequency Distribution of River Tides at Four Selected Locations of Kano State

For wind generators, Cp has a typical value in the range of 0.25–0.3. For MCTs, Cp is estimated to be 0.52, but for RCTs the Betz's limit is kept 0.40(Salisu Muhammad Lawan *et al.,*2015). The swept area of RCTs depends on three parameters, namely depth of the river and the total number of turbines. Depth is an important parameter because it is essential to ensure that the blades of each RCT in the array must not only harness the high energy flow but also avoid large forces that may damage the turbines. The low velocity flow close to the river-bed should be avoided so as not to impart a cycle load upon the blades. The lowest point swept by the blades for the RCTs is 0.25*h where h is the depth. The upper part of the water column is unstable despite the great energy available. River waves can disrupt the upper of the flow and cause significant loading to occur. Therefore, it has been assumed that the blades cannot infringe upon the top 5 m of the depth. This value considers the effects of the 1.5 m river wave trough with an additional 0.5 m clearance(Darus *et al.,* 2003). Shortly speaking, RCT can only be installed on a site with the depth of being greater than 5 m. It is noticed that Tiga and Challawa are the only locations with the depths of being greater than 6 m. Therefore, selected RCTs can only be installed on those locations. However, small scale 0.5-5 kW water current turbine can be used in the other two locations (Sørnes 2010).

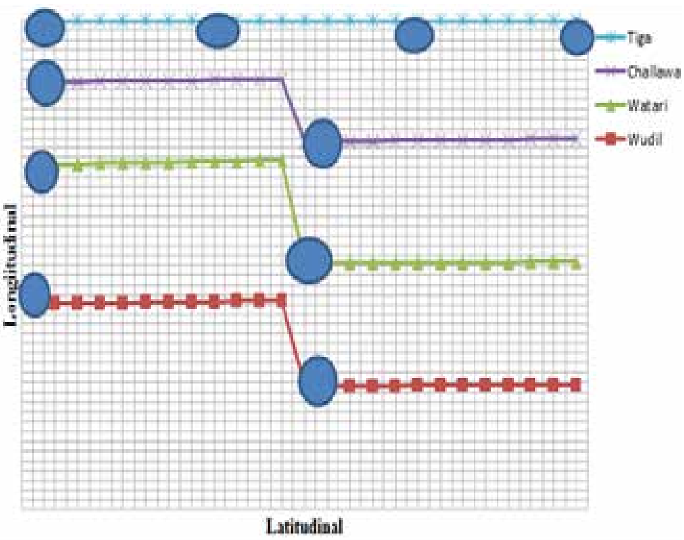

Figure 5: RTC Schematic Siting in the Four Locations

The proposed configuration of RCTs and small-scale water current turbines for river is shown in Fig. 5. The number of RCTs that can be connected for standalone will depends on the number of the RCTs and their ratings.

The total number of MCTs to be installed on each site is determined by three parameters; 1) longitudinal spacing, 2) latitudinal spacing and 3) the area under high river tidal speed. Longitudinal spacing is the distance from one sub-array of RCTs to another as shown in In the Fig. 6. And should be 8 times larger than the length of a turbine blade as proposed in (Yeh, Wang, and Member 2008). Latitudinal spacing is the distance between two adjacent machines and should be the length of the turbine blade. Knowing that the total areas of Challawa and Tigaunder high river tidal currents are approximately 0.5and 0.3km2, then the total number of RCTs on each site is estimated as given in Table 2.

Table 2: Location and Energy Output

Location	Energy (kw/m^2/year)	Nominal Depth	Rotor Diameter (m)	Number of RCT can be installed	Total swept Area (km^2)	Energy output (GWh/year)
Tiga	8.36	6.5	3	10	0.5	5.00
Challawa	6.44	5.5	2	10	0.3	3.86
Total (G Wh/year)						8.86

The power output of RCTs is shown in Table 2. The total amount of electricity to be generated by RCTs on Tiga, and Challawa is 8.86 GWh/year. This amount of electricity is higher than the targeted amount of diesel power generator systems to be achieved in 2012 which is 8.5GWh/year.

Sensitivity Analysis and Environmental Benefits

Net Present Value (NPV)

The Net Present Value (NPV) is a standard way of evaluating the financial benefits of long-term projects. The higher the value of NPV, the greater the financial benefits will be. This method has been used to evaluate the financial benefits of diesel project projects (Sauturaga 2008). It can be used to evaluate the economic benefits of installing RCTs. The equation of calculating NPV is given below.

$$NPV = -S + I_1 - \frac{E^*(1+g)^1}{(1+i)} + I_2 - \frac{E^*(1+g)^2}{(1+i)^2} + ... I_N - \frac{E^*(1+g)^N}{(1+i)^N} = -S + \sum_{j=1}^{N} I_j - \frac{E^*(1+g)^j}{(1+i)^j} \quad ..(4)$$

whereS =Capital cost of the project, I = Income of the project, E =Yearly maintenance and operation expenses, g =Inflation rate, i = Nominal interest rate, N = Lifespan of the project.

At present, there is no pilot or commercial RCT in Nigeria. Therefore, information on the costs of RCTs in Nigerian currency is not available in the public domain. To estimate the capital cost of the project, the costs of various electrical components in RCT quoted in ("River Current Turbine Range, River Hydrokinetic Turbine - Hydroquest" 2017) will be used as a reference in this research work. There are costs associated with various electrical components, such as power conversion system, structural element, subsea cable, turbine installation, river cable installation and onshore electric fr non-grid interconnection. It is assumed that all these components are directly imported from the China. The total cost for all those components are USD 1200 per kW which is equal to NGN 432,000 per kW. This amount will be used to calculate the capital cost of RCTs. It is assumed that the maintenance and operation cost is assumed to be NGN 12,000 per kW. The cost associated with shipping various electrical components is not considered in this case.

It is assumed that the capacity factor of each turbine is 45%. By using the total energy output for each site as given in Table 2, the rated total capacity of RCT at Tiga, Challawa,Watari and Wudil are 0.5 MW, 0.35MW, 0.30 MW and 0.25 MW respectively. The total capacity of RCT system is 1.4 MW. It is assumed that the tariff for electricity supplied by RCT is NGN 14/kWh. The inflation rate, g, and interest rate, i, are assumed to be 3%. The life span of RCT is assumed to be 30 years. Fig. 7 shows the values of NPV of MCT against the number of years. It is shown that the owners of RCT may recover their capital cost at the maximum period of 10 years and earn at least NGN 0.35 billion at the end of the lifespan.

Amount of Green House Reduced by RCT

As mentioned previously, natural gas is the most likely fossil fuel to be replaced by any distributed generation. Given that the emission factor of CO_2 for a gas-fired power plant is 0.53 kg/kWh (Abanades, Greaves, and Iglesias 2014), the total amount of CO_2 to be avoided is 1,333 tonnes per year. This data is not only valuable to the government, but also the owners of RTC because they can use the data to register their green projects as a Clean Development Mechanism (CDM) project (Adejuwon, 2016). Then, they are entitled to sell "Certified Emission Reduction (CERs)" to developed countries, hence creating additional income streams to the owners of marine current turbines.

CONCLUSION

Analytical assessment has been carried out to estimate the amount of electricity to be generated by RCTs and also to evaluate the economic viability and environmental benefits of installing RCTs in Kano State. It was identified that Tiga and Challawa are the locations with great potential for tidal energy extraction. The total amount of electricity that can be generated by RCTs on those locations is about 8.86GWh/year. The government or utility company can save about NGN 0.35 billion of natural gas and avoid a total greenhouse emission of 1,333 tonnes per year. Owners of RCTs may be able to recover the cost of the system after 10 years and can make profits after that. River tidal energy is a promising renewable energy source available in some promising rivers within Kano State. The results of this studycan encourage the government to provide additional research funding for design, development, erection and installation of marine current turbine prototypes. On the other hand, there are several environmental issues that need to be investigated and resolved. The environmental issues are the threat of RCTs on the river wildlife, conflicts with other users of the river and pollution. Therefore, additional research work is required to resolve several advanced technical and environmental issues before tidal energy can become a realistic renewable source in the future.

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