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Study of Application of Small Hydropower for Nile River in Egypt

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ABSTRACT

This article investigates the Riverine hydrokinetic technology application in Nile River and its impacts on river characteristics especially on the chosen sites. GIS technique is used to extract the cross sections from the contour maps and a huge data are collected by field trips. Technical and economic studies are performed; suitable cross section and location of turbine, turbine selection and extracting the electricity power. The effect of emerging the turbine along the study area is analyzed. The generation cost of the proposed system is estimated. Based on the analysis; the water profile and the Reynolds number are changed. Study recommendations towards large scale implementation of hydrokinetic technology in Egypt are highlighted.

Key words: Nile River, Morphology, Small hydropower Application, Water Current Turbines

Introduction

Water and energy are essential for alleviation of poverty. The population in Egypt is rapidly growing therefore; there is a large and continuously increasing energy demand. Rising of demand for electricity and increase in fossil- fuel prices increasing the need for clean, or renewable energy sources. The common types of renewable energy sources that knew are: the solar and the wind. But there is another abundant renewable resource covering 75% of the planet that is water. In spite of Egypt have the Nile River, mostly meets its energy demand from imported fossil fuel sources. The participation of hydropower energy in Egypt represented around 5.5% from total electricity generation up to now. Hydropower stations which existing on Nile River is five only; they operate depending on the head and the discharge. Egypt is lacked of the technology application especially in hydropower generations. Nile River flows from Aswan in the south to Rosetta and Damietta in the north. It is divided into four reaches. The first from Aswan to Esna, the second from Esna to Nag Hammadi, the third from Nag Hammadi to Asuit, and the fourth reach from Asuit to delta. Nile River characteristics is changed from reach to other. Each reach has its own hydrological and morphological characteristics which are induced in the velocity of flow and the bed level.

The rivers not only for fresh water but also it is play an important role in Energy sources, the energy in the flowing river streams, tidal currents or other artificial water channels is considered as a viable source of renewable energy. Historically small hydropower has played an important role in the development of the region, but since mid-1960s the emphasis has been mainly on fossil fuel based electricity generation. Recently small and micro-hydro power is getting attention again from developers and policy makers, (Klunne, 2012). Hydrokinetic conversion system, in early stage of development may appear suitable in harnessing energy from such renewable resources, (Bhuyan *et al*., 2009). This technology have been applied in many countries; such as; Tanzania, Canada, USA and other countries. Approximately 10% of the global hydropower potential is located on the African continent, with the majority of that in Sub-Saharan Africa. Small hydropower can play a pivotal role in providing energy access to remote areas in Africa, either in stand-alone isolated mini grids or as distributed generation in national grids. The potential role of small hydropower in eradicating energy poverty has been recognized by a number of national governments and multilateral donors. An example is the new draft energy strategy for the World Bank, which does specifically highlight small scale hydropower as an important component of future World Bank activities in Africa, (Klunne, 2014). On other hand; any device that extracts energy from a flow causes a reduction in the momentum of the downstream flow. The flow affected by the device is defined as the wake,(Bahaj *et al.,* 2007) The specific form of a wake is likely to be complicated and device specific. The magnitude of this change in momentum will affect the initial velocity deficit within the wake.

There are many researchers studied the impact of hydrokinetic turbine from different visions. Author (Luke and Bahaj, 2007), concluded that; a clear difference can be seen in the water surface elevation once the rotor is extracting upstream of the rotor decreased downstream for 2 diameters, a pronounce increase in water surface elevation occurred between 3 and 4 diameters downstream and the expanding wake flow may reach the

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surface and increase the depth further downstream of the rotor. Author (Mercier *et al.,* 2014), shows a direct effect of the momentum source distribution, the complex distribution used by the author seems to produce an over estimated level of turbulence. Results of author (Gunawan, *et al.,* 2014), gives; the depth-averaged longitudinal velocity recovers to 97% of the inflow velocity at 35 turbine diameter downstream of the turbine. Guided by the previous studies and the available data which are gathered from the field, this work is accomplished.

The main goals for this paper are studying in overview vision the appropriateness of the Nile River to the application of hydrokinetic technology and study its impact on selection site in Nile River.

Materials and Methods

Hydrokinetic Technology
Concept and Definition

Hydro-kinetic technology allows us to harness the energy from all kinds of water movements and turn it into electricity. Hydro-kinetic technology or water current turbines (WCT's) are integrated turbine generator is used to produce electricity in a free flow environment. It does not need a dam; that means zero head. The concept is similar to wind energy system, although smaller scale, the information can be mutually valuable for both research areas.

Hydrokinetic; theoretically and actually

Water has two types of energy that can be harnessed to generate electricity; hydrostatic and hydrokinetic. Hydrostatic is the potential energy of water due to its height Hydrokinetic is the kinetic energy of a water mass due to its movement. There are two types of hydrokinetic energy from water movement; current-based and wave-based hydrokinetic energy. Current-based hydrokinetic can be found in river streams, artificial waterways, tidal and ocean currents, (Long, 2014). The hydrokinetic power theoretically available in a river having velocity v can be expressed as:

$P_{theory} = (1/2)\ \rho\ A_t\ v^3$ (w) (1)

The function of hydrokinetic turbines is to capture the kinetic energy of flowing water, but the turbine can only capture a fraction of the water that pass through its cross section, so the power captured by a hydrokinetic turbine can expressed as:

$P_{capture} = C_p\ P_{theory}$ w (2)

Where; C_p is the power coefficient and is estimated by 0.6, and it depends on the Tip Speed Ratio (TSR) λ

TSR define as the ratio of the speed of the blade at its tip, to the speed of the flowing water

$\lambda = (\omega * R)/V$ (3)

$\omega = (\pi * n)/60$ (4)

$n = (60 * \rho * V)/(\pi * R)$ (5)

Hydrokinetic is classified into; vertical-axis turbine, which turning axis is perpendicular to stream flow. The axial turbine, which rotational axis follows the direction of flow. Vertical-axis turbines are preferable in situations where flow direction changes such as in tidal systems. In rivers axial turbine is preferred.

Water Current Turbine Criteria

To specify the suitable turbine to emerging in any stream; two classifications must be consider;

The first one is corresponding to electric view; there are many types of turbine system; Axial, Vertical axis, Cross-flow, Venturi and Gravitational Vortex (Ladokun, *et al.,* 2013). Figure (1) represents the classification of turbine system. Turbine system will have a set of requirements and specification. A typical hydrokinetic turbine system may contain a variety of components; the turbine rotor, the power converter, the gearing and drive train and the protection devices.

The second one is corresponding to geometrical characteristics of the stream; the specification of the chosen site, table (1) shows the classification of the location of hydrokinetic system. This will include either site conditions; hydrological, morphological, bathymetric, velocity, status of navigation path and flow rate, and output power requirements. The velocity is the main factor in the electric generation, where the output is exceeding according to the higher values of velocity. There will be environmental requirements, for example the site may be in an accessible location, be subject to extremes in temperature or have to comply with fishery regulations. The turbine may be able to have regular maintenance checks from an onsite operator, or it may be required to be operated remotely and therefore should require minimal maintenance and have a high reliability. Using the requirements, a set of turbines selection criteria can then be developed. Table 1 shows the criteria of selection turbines, where the value of generated power depending on the velocity and the diameter of the turbine.

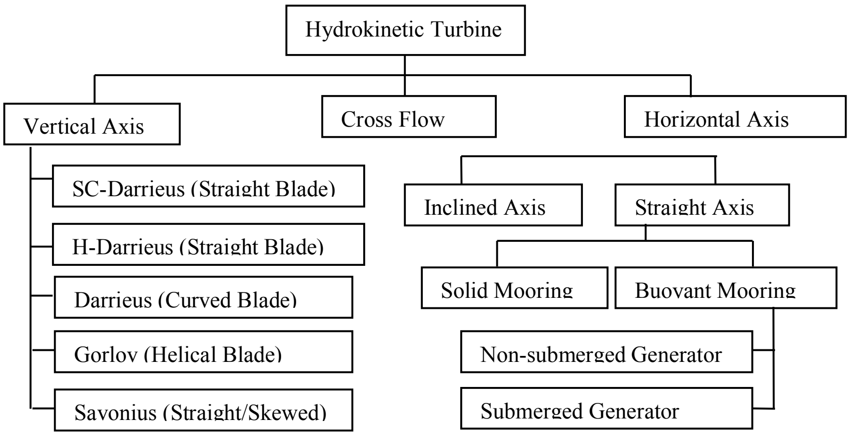

Fig. 1, Classification of hydrokinetic turbines (source: (Ladokun*, et al., 2013*))

Table 1 : Selection Turbine Criteria Corresponding to Hydraulic of Chosen Sites

Classification Of Hydrokinetic System Location	Depth / Width Ratio	Effect the Navigation on the System	Velocity m/s
Ocean, Seas	Large	Not Much	More Economic
Natural Stream (Rivers)	Moderate	Some Extend	Economic
Main Canal With Navigation	Small - Large	Major Effect	Less Economic
Main Canal Without Navigation	Small - Large	-----	Depended on the Discharge
Sub Canal	Small	-----	Depended on the Discharge

Table 2: Selection Turbine Criteria Corresponding the Electric System Design

Company	Device Name	Turbine Types	Velocity (m/s)	Depth (m)	No. of Turbine per unit	Power (kW)	Diameter of Turb .(m)
GCK Technology	Gorlov Helical turbine	Cross- Axis F low	0.6	At least 5	1 or more	5	1
New Energy	"EnCurrent Hydro Turbine"	-----	2.5	At least 6.5	-----	14 - 35	2.8
Thropton Energy Services	Water current turbine	Axial F low	0.5 to 1.5	. 1.8, 3.4, 2.8, 2.2, 1.8	1	2	1.8, 3.4, 2.8, 2.2, 1.8
Marlec	Axial, unducted	Axial F low	1.5	3.5	1 or more	0.5	1.8
PEEHR	Hydroreactor ducted	Axial F low	2.75	---	1	30	1.2

Hydrokinetic Energy System

The turbines can installed in a variety of ways, multiple banks set pilings driven into the river beds or mounted on existing river structures such as bridge piers. The turbines are deployed in arrays of multiple units spaced equal twice from the diameter of turbine. Exact depth and spacing is determined based on site conditions, including current flows and water depth according to every type from water current turbines. The power will be transmitted by cable to conversion equipment located on shore. The conversion equipment will convert the power from DC to AC, adjust the voltage and connect to the grid or not as required. This approach is better to River where the flow is in one direction, (Gunawan, *et al.,* 2014). Figure (1) illustrates the hydrokinetic energy system. It is worth mentioning that; this system has been tested at least five different WCT configurations since the mid 1980's in Ontario, Canada (Mercier *et al.,* 2014).

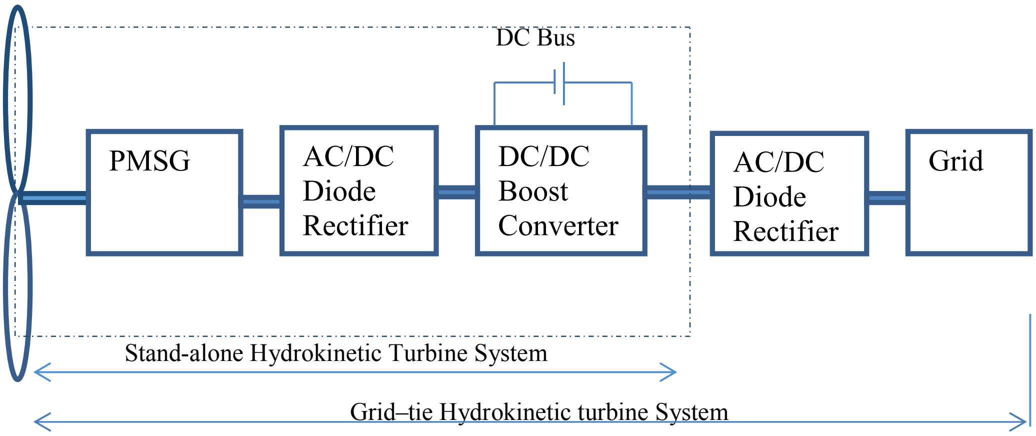

Fig. 1: Hydrokinetic turbine Systems, (source :(Zhou, 2012))

-Site Description and Data Collection

Nile River is characterized by its tendency to meander; this has led to the change in the value of velocity, water levels, discharge, and bed material varying from reach to the other. The flow rate in Nile River is varying at each reach; it is ranged from 2893.5 to 578.7 m^3/sec in first reach, in second reach the flow rate is ranged between 2083.3 to 493 m^3/sec, at third reach it is ranged between 1736 to 347.5 m^3/sec, and the value at fourth reach is ranged between 1446 to 289 m^3/sec. Third reach is chosen to be study area, where the data is available. The main data needed to applied the Water Current Turbine technologies are classified into; hydrographical (bathymetric), hydrological (water levels), and hydraulically data (water velocity), in selected reach. Third reach covers a distance of 185.24 km and locates between km 567.5 to km 382.3 upstream El-Roda gauge. The study area covers around 1.85 km, it is specified from Km 538.780 to Km 540.211 upstream El-Roda gauge. This area is characterized by this specification; The river average width varies between 700 m and 300 m, there is a big island called Shoranya island where the width is about 300 m. Generally the main channel depth ranges between 3.0 to 10.0 m. The channel geometry for the applied technology was based on their data obtained from comprehensive field reconnaissance and contour maps with 1:5000 scale provided by NRI with an interval of 0.5 m and from field data for project studies. Figure (2) represented the concerned area,(NRI, 2005).

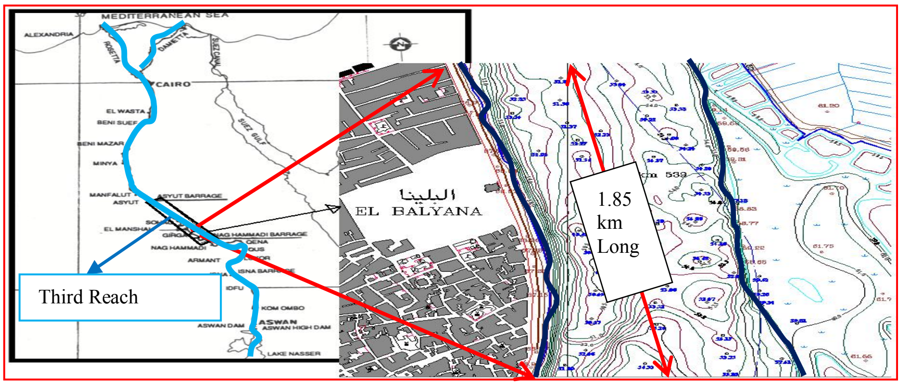

Fig. 2: Study area location

Data Collection

When considering the possible use of a water current turbine on river applications, several issues are of concern with regards to the power production performance The volumetric flow information may be available for the location, the discharge is stable and not change along the reach. The water velocity varies from one site to the other depending on the cross-sectional area. The collected data for the chosen sites classified as follows

- Provide velocity Data.
- Bathymetric data
- Navigation issues.

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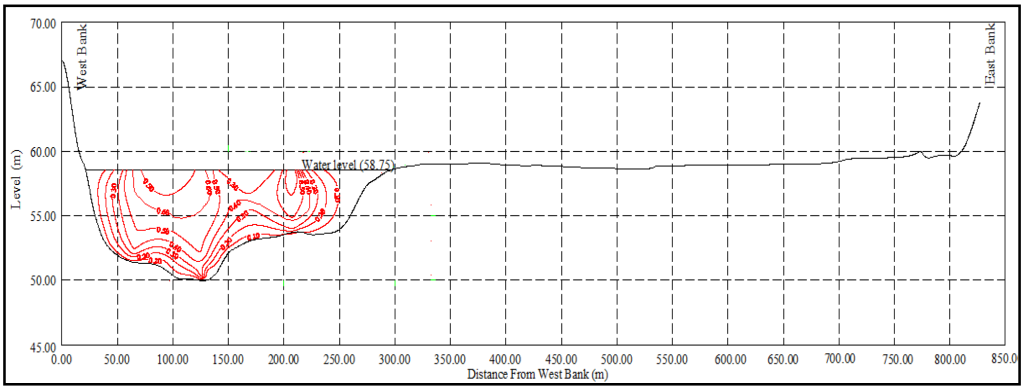
Velocity Data

In field trips, the velocity is measured as following: the selected cross sections of the River; is divided to three verticals, (east, west, and middle of the cross-section), In each vertical three locations is measured and generate the contour map of velocity to specify the best location of turbine. These steps as following:

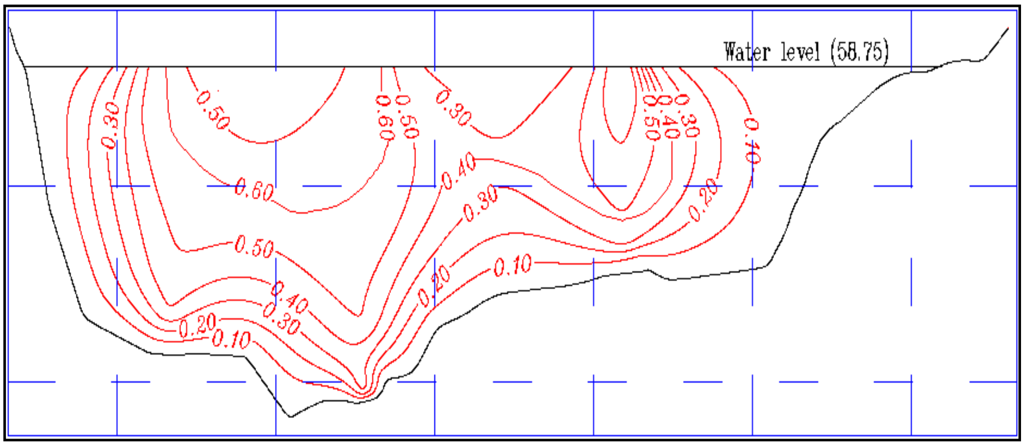
1. 0.50 m under the surface water.
2. 0.75 m above the river bed.
3. 25%, 50%, 75% of the total depth.
4. Generate the contour of velocity to describe the status of the selected site along the year. This contour is generated from the measured data, figure (3) a, and b represent the flow velocity contours.



(a)

(B)

Fig. 3: a and b represent the contour of velocity in a cross section in second site of study area in measured case



Bathometric Data

The bathymetric data describe the geometry of river beds in the study area, were based on data obtained from comprehensive field reconnaissance and contour maps, produced from the recent hydrographic survey of year 2005 provided by the Nile Research institute. The measurements tools for measuring the cross section consists of hydrographical system installed inside the boat of survey consists of a GPS (global positioning system) receiver with a built-in radio and an omni directional antenna with unit for data correction, a dual frequency depth sounder, a helmsman display for navigation, a plotter, a computer, and hydrographical system software for collecting the bathymetric data.

Water level and Discharge Data

Water level and discharge measurements at site were checked with the readings of gauge stations. Water level gauge station at El-Baliana area is located at km 540.0 upstream El-Roda. For maximum and the minimum water level at El-Baliana area especial attended have been focused at Min water level. The objective of defining the water levels covering a period of time is to estimate the water depths and consequently Min.

water depth have been estimated. Discharge at third reach it is ranged between 1736to 347.5 m^3/sec, (NRI, 2012).

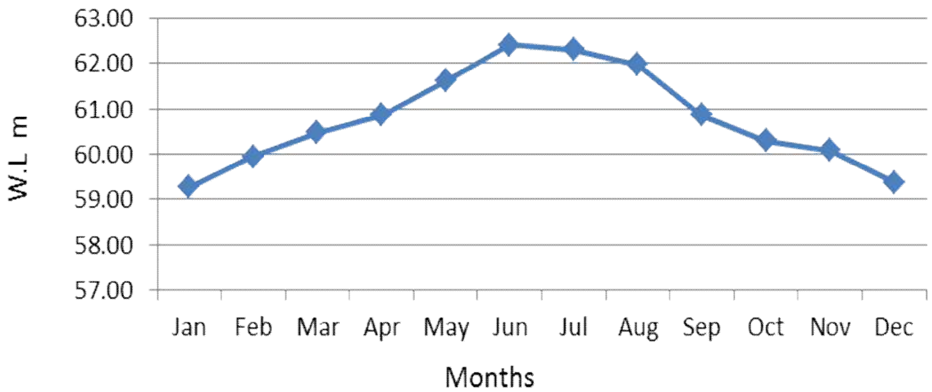


Fig. 4: Average Water Level at study region

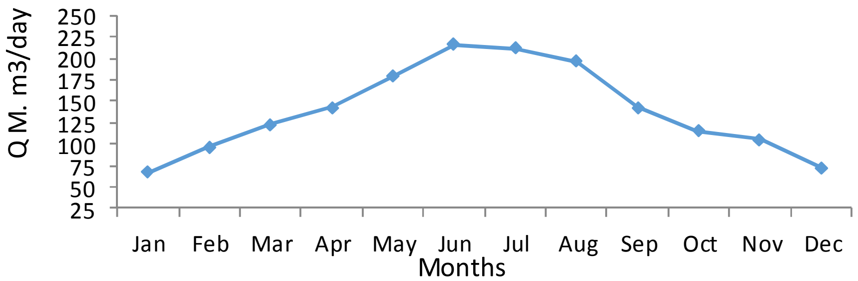


Fig. 5 Average discharges of study reach

Preparation of Study Area

There are two methods are following to extract the cross sections; theoretically, from the contour maps for the region the study area is divided into three sites, three cross section in every sites is extracted by using GIS technique, which is including many processing steps took place as following:

- Using hydrographic survey maps with scale 1:5000.
- Converting the maps to spatial format.
- Using 3D analysis tool to carry out the suitable environment
- Extract the shape of cross sections.

The second way is the achievement from the cross sections in the field. The first site from selected area study; covers a distance of 396 m located between km 538.304 to 538.700 UP stream El-Roda. In this site, three cross sections were surveyed, the distance between the cross sections varied from 120 to 150 m. *At the second* site, three cross sections were surveyed to cover a distance of 450.0 m located between km 538.780 to 539.225 UP stream El- Roda. *At third site*, three cross section were surveyed to cover a distance of 561.0 m, located between km 539.65 to 540.211 UP stream El-Roda. Figure (6) illustrates the traverse in study area. Taken into consideration the navigation path is very important factor to avoid any obstacles for the existing the selected turbines. Application of navigation path in study area as following; The thalwag line and navigation path are located at the East side in south, and transit to the middle and then return to the East side in the north of El-Baliana studying area, Figure (6) illustrates the traverse in study area including the navigation path.

The Electric Power Extraction

Hydrokinetic turbine has the variable speed capability for optimal energy extraction. Turbine performance is determined through the performance of the devices in the system; design of blades, the efficiency of rotor, tip speed ratio, and power coefficient. Tip speed ratio of the turbine is effected by the blade design and number of blades employed. To calculate the extraction power from every site in the study area the equations 2, 3 4, and 5 and table 3 are used. The calculations can be occurred in two scenarios; the first depending on the actual values of velocity which is measured in field and the second depends on the velocity due to the maximum value of discharge in the region. In the study we will depend on the measured value in spite of maximum discharge case give more generated power but it can't be base of the system operation.

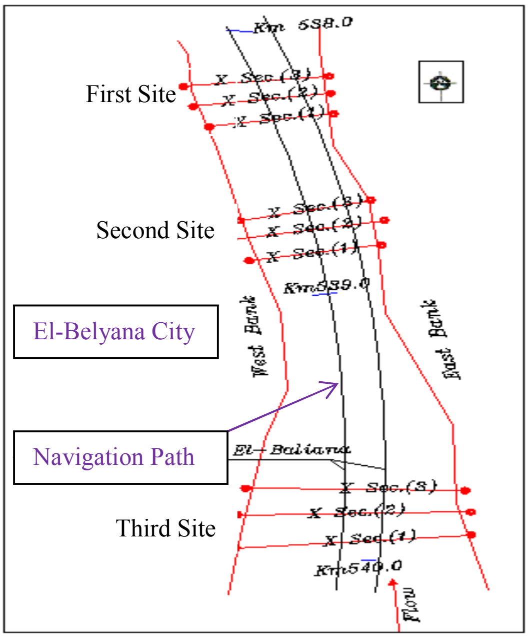


Fig. 6: The traverse illustrates the cross sections in study area and the navigation path

Table, 3. Different factors are used to extract the power from the riverine hydrokinetic system in three sites

Factors Name	First Site	Second Site	Third Site
The power coefficient (C_p)	0.6	0.6	0.6
The length of blade (r in m)	2.5	2.5	2.5
Velocity of flow V (m/s)	0.66	0.52	0.8
The velocity of turbine rotor N (r.p.m)	45	45	50

Turbine Influence

To understand the effects of turbine on stream, there are some previous studies in different countries addressed this issue, (Bahaj and *et al.,* 2007, Mercier *et al.,* 2014) estimated; how the water level and velocity along the channel are affected by the energy extraction. Article (Hill, *et al.,* 2013), studied the effects of model axial flow hydrokinetic turbines on scour and bed forms; local scour depths and water surface fluctuations increased compared to those observed without turbines. Other study (Chime and Malte, 2014), investigated the possibility of using hydrokinetic turbines for both power generation and flow control, it is concluded that; Froude number varies from 0.18 to 0.24 and the turbines extract more power as blockage ratio increases. Guided by these studies; it is expected to two forces effected on the stream in study area; these forces defined as; resistance to flow encountered by an object moving through a fluid is known as the (F_{DF}). Physically the general relation can be expressed as, (Lecture in "Sediment Transports", 2014):

$$F_{DF}=C_D(\rho V^2/2)*a \quad (6)$$

The other drag force will be occurred due to the turbine (F_{DT}), (George E. Hecker, *et al.,* 2014);

$$F_D=(C_{T*}a*\rho*V^2)/2 \quad (7)$$

After substitution of the factors; C_T, ρ, A the equation reduced to:

$$F_{DT} = 0.78\ D^2\ v^2$$

Other factors can be affected by the turbine emerging as Reynolds number and Froude number;

$R_e=(\rho*N*h)/\mu$ (8)

$F=v/(g*h)^{\wedge 1/2}$ (9)

Table 4, Data; Assumption and available measurements

Factors Name	The value
Drag force coefficient due to turbine (C_T)	1.0
Gravity due to acceleration (g)	9.81 m/s^2
Density of water (ρ)	1000 kg/m^3
Cross sectional area exposed to flow (a)	Π $D^2/4$, f[illegible]ameter of grain size in study area =0.37 mm
The angular velocity of turbine (N)	45 r.p.m.

Economics of Hydrokinetic (In-Stream) Energy

The investment of riverine hydrokinetic technology has not yet been tested at full scale. Determine the price per kilowatt hour using hydrokinetic system close association to every environment, so the cost is varying from country to other. Reference (Burt Hamner, CEO. 2014) gives a comparison between the cost of kw/h by hydrokinetic energy and the other resources: cal. & new England > 16 cents, UK renewable > 25 cents, global average 15 cents, and remote sites > 80 cents. The cost of small hydropower system depends on a number of factors including costs of equipment, preparation of the necessary conditions of concerning area, flow rate type and class of the system. Economically; the cost is divided into capital cost (K) and running cost (R). Capital cost generally can be divided into station-keeping, structural, energy conversion components and sub-assemblies. The running cost including planned and unplanned maintenance, licenses to be stationed and generate electricity at the location (often referred to as consents and permits), and ongoing monitoring activities. The system which it is concerned can be generating around 1.5 - 12 kw, depending on the velocity and the turbine area. According to some application studies in different countries (Mangold 2012 and Karimov *et al.,* 2013), the range of capital cost of the hydrokinetic turbine is estimated by 30,000 $ and the maintenance cost is estimated by 1000 $/year, the life time of the system is estimated by 20 years. The cost of other devices can estimated according the operation conditions in Egypt as 20% from the turbine price. So the operation cost can be estimated as 3600 $/year. So the cost of generation 1 kw by this system can be calculated as following:

Total cost = K + R

K = turbine price + devices price

R = Operating cost + Maintenance cost

The generated energy by the system =Total generated power * no. of working hours in year * life time

Table 5, Assumption of Financial Data

Turbine Cost in $	Device Cost in $	Operating Cost in $	Maintenance Cost in $	Working.No hours	Life Time
30000	20%from turbine price	3600/year	1000 /year	20/day	20 year

With noted that; capital cost depending on the number of turbines, if the number of turbines are increased the capital cost will be exceed.

Results and Discussion

This paper introduces an overview to apply the hydrokinetic energy technology in Nile River. Two visions are drawn, as following;

- Technical view.
- Economical view

Firstly: The Technical view; is included three main points; suitable cross section in suitable site selection, the appropriate turbine and generation the power, and the operation and the arrangement impact of turbines on the chosen region

Suitable cross section and location of turbine: El-Baliana region is divided into three sites surveyed through 9 cross sections. The maximum velocity in three sites as following; first site is 0.66, second site is 0.52, and third site is 0.8 m/s. The contour map of velocity is generated to specify the best location for the emerging of the turbines. The average depth in minimum water level ranged between 3.29 to 10.75 m in the study area, and the navigation path is near to the eastern bank, western side to middle is more appropriate for applying the kinetic energy technology, because the average depth is big and it is far from the navigation path. The velocity is in within required range and more. The results of Geometrical characteristics study are tabulated in table (4) and figure (7) show that.

Turbine Selection and Extracting the electricity power: based on the specification of the site which is selected and depending on the criteria of turbine which is tabulated in the two tables table (1, and 2) and the figure (1) The suitable turbine for this study is the horizontal axis (axial flow) type, the diameter of turbine is 5 meters and the average velocity is ranged from 0.52 m/sec to 0.8 m/sec. By using equation (2) with consider c_p = 0.6 and the area of turbine is 19.6 m^2 the output for one turbine estimated by 2 kW in first site, this value is variable according to two main factors; the area of turbine and the velocity in the site. In this system the specification of turbine not changed in three sites. But the velocity is varied, so the output on second site is estimated by 0.78 kW in second site and 3kW in third site. All study area contained 10 turbines with total power 19.5 kW

Impact of The Turbines Operation: Ten turbines is arranged in two rows between the row and other around 10D of turbine and the vertical distance between the turbines is 2D, these values is estimated according to the previous studies The effective of emerging the turbines is studied in brief method due to the shortage of data related this topic. The calculation of the turbine's influence was occurred for one particle. This particle can be exposed to two groups of forces; the first group tries to move it and is expressed about two drag forces, one due to the movement of flow and the other force due to turbine. Other group is expressed about the opposite forces which are; submerged weight force, fraction force, and blocker movement force. The two drag forces; (F_{DF} and F_{DT}) are estimated by 0.0000151, and 0.000000068x10 N respectively on one particle. So it is expected to the bed form is changed. Furthermore Reynolds is changed from ($4x10^6$) to be ($22.5x10^7$). In addition Froude numbers expected to increase also, equations (8, 9). According to the previous studies other impact is expected; profile of flow will be changed, water level upstream the turbine is increased by x of diameter (xD) and the water level downstream of the turbine is decreased by y of diameter (yD), where ($x > y$). Figure (8) represents the arrangement of the ten turbines and the navigation path in the study area.

Secondly The Economical View: The generation cost of kw by the hydrokinetic system which is proposed is calculated depending the available data and assumption data, table (3), this table include the expected price of turbine and the required devices and accessories which the system need according to the figure (1), the maintenance cost is estimated by 1000 $/y, these values is taken from previous studies. The operation cost is estimated related to the operation condition in Egypt. The life time of the system is estimated by 20 years.

Table 6, Specification of cross Sections in each Site of study region

Site No.	Cross Sections	Min. W.L. (m)	Bed Elevation (m)	Depth in Min W.L. (m)	Dist. Of Nav. Path (m)	Velocity m/s
First	1	57.06	52.0	6.65	505	0.50
	2	57.06	48.0	10.75	449	0.53
	3	57.06	52.2	6.5	343.4	0.66
Second	1	57.52	54.3	4.3	325	0.52
	2	57.52	53.5	4.8	285	0.48
	3	57.52	52.1	6.2	285	0.48
Third	1	57.16	51	6.2	240	0.41
	2	57.16	50	7.2	242	0.60
	3	57.16	51.1	6.10	247	0.8

Table 7: Results of Study; The specification of Suitable sites, Type of used turbine, Value and cost of the Generation

Site Name	Km from Roda	Min W.L. (m)	Bed Lev. (m)	Depth in Min. W.L. (m)	Bank	Dist. From Navig. path (m)	Velocity (m/s)	Power Gen (kW)	Cost of 1kw ($)
First Site	537.9	57.06	48.0	10.75	West	120	0.66	8 from 4 units	0.187
Second Site	547.1	57.52	53.5	4.8	West	230	0.52	2.5 from 3 unit	0.50
Third Site	539.7	57.16	54.0	3.29	West	240	0.8	9 from 3 unit	0.065

Environment study must be occurred but it is neglected due to the shortage in data. Cost of generation related to output in inverse relationship, the cost of 1 kW in first site estimated by 18.8, in second site is 50, and in third site is estimated by 6.5 cent. The average price of 1kW for all the system is estimated by 25.1 cent. Table (7) tabulated the final results of the study.

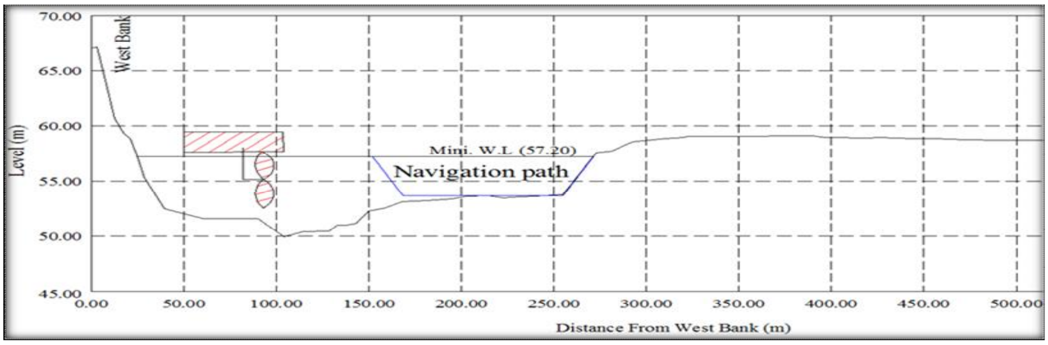


Fig. 7: Location of selected turbine in cross section

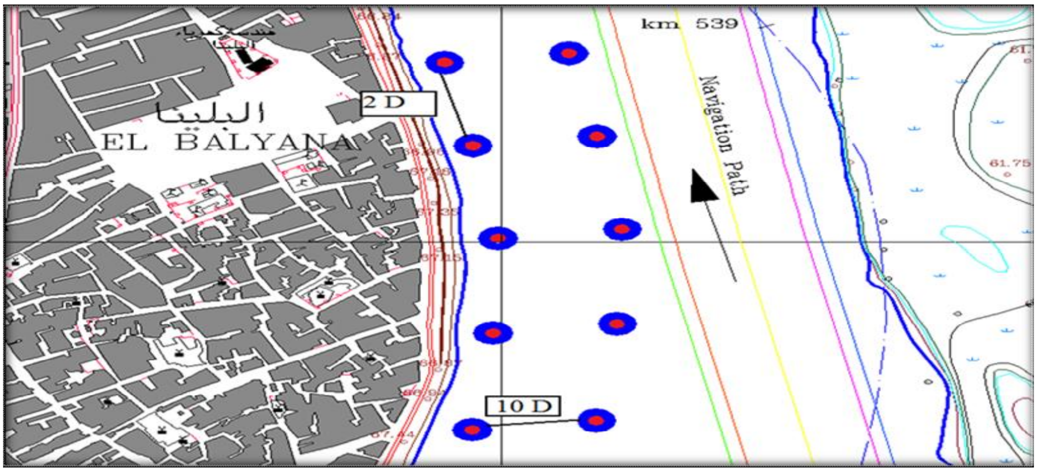


Fig. 8 Turbine's Arrangement in Study region

Conclusions and Recommendations

The chosen site is applicable to hydrokinetic energy technology, it is one from a huge sites in Nile River characterized by the velocity and the depth, that is means the potentially of Nile River should be take more attention to exploited. The results of the study drew this conclusion;

1) The hydraulic characteristic of the Nile River is appropriate to Kinetic energy application
2) The generated hydropower from this system in the selected area is around 19.5kw which is equal to around 2.8 giga watt hour per year.
3) Emerging of ten turbines can be caused drag force is estimated by 0.00001578 N on one particle which help to change in bed form
4) Reynolds number with emerging the turbine will be change to be $22.5x10^7$, also Froude number expected to exceed.
5) The cost of 1 kW by using this system is estimated by 15.5 cent.
6) Accurate economic and environment studies for the application of this technology should be done.
7) Accurate monitoring and measurements for the morphology and hydrology at the river after the emerging this system.

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Abbreviations

P_{theory}	*The hydrokinetic power theoretically*
ρ	*Density of water*
A	*Cross section area to pass the flow*
V	*Velocity of flow*
$P_{capture}$	*The power captured by hydrokinetic turbine*
C_p	*The power coefficient*
λ	*Tip Speed Ratio (TSR)*
ω	*The angular speed of shaft*
r	*The length of blade (radius of turbine)*
N	*The velocity of turbine rotor (r.p.m)*
PMSG	*The permanent Magnet Synchronous Generator*
F_D	*The drag force due to flow movement*
C_D	*The drag force coefficient of flow depending on the Reynolds number*
a	*The cross sectional area of the grain exposed to flow*
R_e	*Reynolds number*
F	*Froude Number*
K	*The capital Cost*
R	*Running cost*
NRI	*Nile Research Institute*

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