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Field Modeling of Meander Energy Conservation, Case Study Meander of Karon River in Shoushtar

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ABSTRACT

A river current energy conversion system could be defined as an electromechanical energy converter that employs a RCT to harness the kinetic energy of river water. The growing demand for electrical energy is one of the most important subjects today. Renewable energies give a good perspective to be an alternative to fossil and nuclear-fueled power plants, in order to meet growing demand for electrical energy. In this research, investigated the use of computational fluid dynamics in predicting the formation, development of meander current and with field studying and daily-monthly measurement of effective parameters present a field modeling of river's meander in Karoon River in shoushtar city domain to generate hydro electrical energy. The survey shows that in this case study can generate justifiable energy in meander and it show that can use the meander of rivers are one of the renewable source.

Keywords: **renewable energy, river meander, hydro electrical energy, field modeling, energy conservation**

I. INTRODUCTION

A river current energy conversion system (RCECS) could be defined as an electromechanical energy converter that employs a RCT to harness the kinetic energy of river water. In the field of hydrokinetic energy extraction, i.e. converting energy from water currents such as tides or in rivers, several models have been developed to study and understand the resource. One-dimensional analytical models have been used to study the effects on water level and velocity [1&3] whereas more advanced 2D and 3D models have been used to calculate the potential of tidal energy [4&6]. Some attempts have also combined analytical models with numerical ones to estimate the potential [4]. A large number of simulation models have been proposed in the past two decades to reproduce their planform dynamics (Ikeda et al., 1981; Blondeaux and Seminara, 1985; Crosato, 1989; Howard, 1996; Seminara et al., 2001; Luchi et al., 2007; Frascati and Lanzoni, 2009. In almost all these models the changes in planform of meandering rivers have been quantified through the spatial distribution of channel curvature. As a long-term requirement, these models assume that the river width remains constant in space and in time. River current energy conversion systems are electromechanical energy converters that convert kinetic energy of river water into other usable forms of energy. However, the potentials of this technology as an effective and renewable source of alternative energy have not yet been explored to a great extent. In this research, investigated the use of computational fluid dynamics (CFD) in predicting the formation, development of meander current and with field studying and daily-monthly measurement of effective parameters present a field modeling of river's meander in Karoon River in Shoushtar city domain to generate hydro electrical energy. The survey shows that in this case study can generate justifiable energy in meander and it show that can use the meander of rivers are one of the renewable source. However, some limitations and uncertainties exist that have to be clarified in future investigations.

II. NUMERICAL METHODS

2.1 Flow and turbulence simulation

The numerical model used in the present study was developed by [9]. The flow field for the 3D geometry was determined by solving the continuity equation and the Reynolds-averaged Navier–Stokes equations:

$$\frac{\partial U_i}{\partial x_i} = 0 \qquad with\, i = 1,2,3 \tag{1}$$

$$\frac{\partial U_i}{\partial t} + U_j \frac{\partial U_i}{\partial x_j} = \frac{1}{\rho}\frac{\partial}{\partial x_i}\left(-P\delta_{ij} - \rho\overline{u_i u_j}\right) \tag{2}$$

Where U is the velocity averaged over time t, x is the spatial geometrical scale, ρ is the water density, P is the pressure, δ is the Kronecker delta, and u is the velocity fluctuation over time during one time step Δt. The control volume method was used as the discretisation method [7], and the convective terms in the Navier– Stokes equations were solved by the second-order upwind scheme. The Reynolds stress term was modelled by the k–ε turbulence model (Rodi, 1980). This two-equation turbulence model computed the turbulent stresses $u_i u_j$ using the eddy viscosity relation:

$$-\overline{u_i u_j} = v_t\left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}\right) - \frac{2}{3}k\delta_{ij}$$

$$with\; v_t = \frac{C_\mu k^2}{\varepsilon} \tag{3}$$

where the turbulent kinetic energy k and its dissipation rate ε determining the eddy viscosity v_t were obtained from the following equations:

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$$\frac{Dk}{Dt} = \frac{\partial k}{\partial t} + U_j \frac{\partial k}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\left(\nu + \frac{\nu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right] + P_k - \varepsilon \qquad (4)$$

$$\frac{D\varepsilon}{Dt} = \frac{\partial \varepsilon}{\partial t} + U_j \frac{\partial \varepsilon}{\partial x_j} = \frac{\partial}{\partial x_j}\left[\left(\nu + \frac{\nu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right] + C_{\varepsilon^1}\frac{\varepsilon}{k}P_k - C_{\varepsilon^1}\frac{\varepsilon^2}{k} \qquad (5)$$

The production of turbulent kinetic energy P_k was defined as:

$$P_k = \nu_t \frac{\partial U_i}{\partial x_j}\left(\frac{\partial U_j}{\partial x_i} + \frac{\partial U_i}{\partial x_j}\right) \qquad (6)$$

An implicit method was used to solve transient terms, and the pressure field was computed with the SIMPLE method [9]. The Rhie and Chow (1983) interpolation was applied to compute the velocities and the fluxes at the cell surfaces. Zero gradient boundary conditions were used for all variables at the outflow boundary. The upstream velocities were defined by a Dirichlet boundary condition.

2.2 Energy Calculations

The transfer of lunetic energy from theeddies to the mean flow can be expressed as:

$$E = \rho\overline{u'v'}\frac{\partial \bar{v}}{\partial x} \qquad (7)$$

Where a bar represents a time average of a quantity, a prime represents a deviation from the time average, u and v are the velocity components in the cross-stream (x) and downstream (y) direction, and ρ is the density of the water. For case study, the data were divided into 4 zones across the current, each zone being 30 meters wide. The eddy momentum transfer $\overline{u'v'}$ was calculated by applying Simpson's rule to the value of $u'v'$**,** over the total time of observation, for each of the 4 zones. The value of $\frac{\partial \bar{v}}{\partial x}$ was calculated for each zone from the profile of average velocity $\bar{v}$**.** Table **I** show for each zone: $\overline{u'v'}$ the average transport of eddy momentum; $\frac{\partial \bar{v}}{\partial x}$ the shear of the average velocity; and the term **(7)** representing the production of mean kinetic energy by meanders. (ρ was assumed constant, and equal to one gram per cubic centimeter.)

The standard error of the means,$\bar{u}$, $\bar{v}$, and $\overline{u'v'}$ are given for each value in Table I. The standard error of a mean is defined, for large N, as$\sigma/\sqrt{N}$, where σ is the standard deviation of the sample from which the mean is calculated, and N is the number of individual observations.

2.3 Kinetic Energy Equation for the Mean Flow

The following model is a simple version of the Reynolds model, intended to provide an orientation. Better models may follow later. Let us consider an ocean current, with a mean flow in the y-direction, having velocity components u, v, and w in the x, y, and z directions, x being directed to the right of y, and z being directed downward

The momentum equations are

$$\rho\frac{\partial u}{\partial t} + \rho v.\nabla u = \rho f v - \frac{\partial P}{\partial x} - X \qquad (8)$$

$$\rho\frac{\partial u}{\partial t} + \rho v.\nabla u = \rho f u - \frac{\partial P}{\partial y} - Y \qquad (9)$$

Where ρ is the density of the water, f is the acceleration parameter, p is the pressure, and X and Y are components of a dissipative force. With the aid of the continuity equation, $\frac{\partial \rho}{\partial t} + \nabla.\rho v = 0$ we may write:

$$\frac{\partial \rho u}{\partial t} + \nabla.\rho u V = \rho f v - \frac{\partial P}{\partial x} - X \qquad (10)$$

$$\frac{\partial \rho u}{\partial t} + \nabla.\rho v V = -\rho f u - \frac{\partial P}{\partial y} - Y \qquad (11)$$

The quantities u, v, and w can be separated into mean motion and deviations as:

$$u = \bar{u} + u'$$
$$v = \bar{v} + v'$$
$$w = \bar{w} + w'$$

With solve this equation and is integrated over a cross-section of the current in the x-z plane, the result gives the balance of horizontal kinetic energy of the mean flow in a unit cross-section of the current:

$$0 = \iint V.\nabla\bar{k}dxdz - \iint \bar{u}\nabla.\rho\overline{u'v'}dxdz - \iint \bar{v}\nabla.\rho\overline{u'v'}dxdz - \iint (\bar{u}\frac{\partial P}{\partial x} + \bar{v}\frac{\partial P}{\partial y})dxdz - \iint ddxdz \qquad (12)$$

With the limited amount of information available now, it is not possible to evaluate each term in equation (12) for the river current. However, an estimate of the role of some of the terms can be made.

First, consider terms 2 and 3of above integral:

$$\bar{u}\nabla.\rho\overline{u'V'} + \bar{u}\nabla.\rho\overline{v'V'} = \bar{u}\frac{\partial}{\partial x}\rho\overline{u'u'} + \bar{u}\frac{\partial}{\partial x}\rho\overline{u'v'} + \bar{v}\frac{\partial}{\partial y}\rho\overline{u'u'} + \bar{v}\frac{\partial}{\partial y}\rho\overline{v'v'} + \bar{u}\frac{\partial}{\partial z}\rho\overline{v'w'} + \bar{u}\frac{\partial}{\partial z}\rho\overline{u'w'}$$

The axes were chosen so that the mean current is in the y-direction, so that $\bar{v} \gg \bar{u}$. In addition, the perturbations travel in the y-direction, so that for the time averaged velocity perturbation terms $\frac{\partial}{\partial y} \cong 0$. Hence, terms 2 and 3 become:

$$\bar{u}\nabla.\rho\overline{u'V'} + \bar{u}\nabla.\rho\overline{v'V'} = \bar{u}\frac{\partial}{\partial x}\rho\overline{u'u'} + \bar{v}\frac{\partial}{\partial x}\rho\overline{u'v'} + \bar{u}\frac{\partial}{\partial z}\rho\overline{v'w'} + \bar{v}\frac{\partial}{\partial z}\rho\overline{u'w'}$$

The terms in $\overline{u'w'}$ and $\overline{v'w'}$ represent contributions of kinetic energy to the mean flow by vertical perturbations. Since observations of vertical motions are not available, this term has not been calculated. It might represent an important contribution to the mean downstream kinetic energy.

The term $\bar{v}\frac{\partial}{\partial x}\rho\overline{u'v'}$ includes the expression used in the surface calculation of this study. It may be re-written as

$$\frac{\partial}{\partial x}\left(\rho\bar{v}.\overline{u'v'}\right) - \rho\overline{u'v'}\frac{\partial\bar{v}}{\partial x}$$

The term $\frac{\partial}{\partial x}\left(\rho\bar{v}.\overline{u'v'}\right)$represents an eddy advection across the boundaries of mean kinetic energy and can be integrated easily across a stream to become:

$$[\rho\bar{v}.\overline{u'v'}]_A - [\rho\bar{v}.\overline{u'v'}]_B$$

If the stream is bounded by walls, u' will be zero at the walls, or if the mean stream velocity drops to zero at each side of the current, $\bar{v}$ will be zero, and the term (a) is zero. River, where the current is not bounded by walls, and the observations did not cover the whole width of the current, calculation of the term (a) has revealed that its integral across the width of observations is zero. Hence the cross-stream integral of the term:

$$\rho\overline{u'v'}\frac{\partial\bar{v}}{\partial x}$$

is a measure of the increase of mean kinetic energy at the expense of kinetic energy of horizontal eddy motion.

Maximum values of $\frac{\partial}{\partial x}\rho\overline{u'u'}$ at the surface JX were observed to be almost as large as average values of $\frac{\partial}{\partial x}\rho\overline{u'v'}$. However, since $\bar{v} \gg \bar{u}$, the term $\bar{u}\frac{\partial}{\partial x}\rho\overline{u'u'}$ is negligible in comparison $\bar{v}\frac{\partial}{\partial x}\rho\overline{u'u'}$.

Term 1 of above integral represents the advection across the boundaries of the region under consideration of mean horizontal kinetic energy. Equation (12) states that this boundary advection 1 must be balanced by the generation of mean kinetic energy by meanders, 2 and 3,pressure forces,4, and by the frictional dissipation, 5.

Assuming only partial correlation, or more characteristic values of wind stress and meander velocity, the energy contributed to the meanders by the wind is about $1 \times 10^{-4}\ \mathrm{ergs/cm^2/s}$.

In comparison with the transfer of energy between meanders and mean flow of $80 \times 10^{-4}\ \mathrm{ergs/cm^2/s}$, the wind would appear to be eliminated as a significant source of kinetic energy for the meanders.

III. Area and Measurement Description

The data used to calculate eddy momentum fluxes were obtained from Karoon river in Shoushtar domain. The big and important Karoon River in Iran, Shushtar, is divided to two branches Shotait and Gargar, and Shushtar city as an island between these two branches. Shotait and Gargar rivers reach together in a place named Bandeghir. Figure 1 shows the location of these sections and their meander.

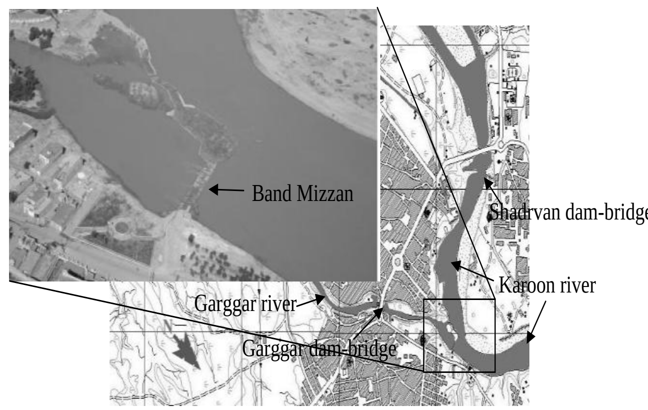

Figure 1. Meander of river in this place that divided to two branches Shotait and Gargar

The optimum design of a RCECS is a significant technical challenge. From cost and performance point of view, simple design using off-the-shelf materials is desirable. train with suitable gearing and bearing mechanism is also of due interest. Since these turbines are exposed to water and run on lower speed, selection of an electrical generator from asynchronous, synchronous, dc and brushless dc categories requires in-depth understanding of cost and performance indices of electric machines. Integrating these parts with the flotation/augmentation mechanism and designing a complete system requires structural and reliability analyses.

IV. Simulation Results

In different months of year in two season of winter and summer of deby in Karun River, in the two places before and after balance band, Shoushtar basin by Flow meter contain

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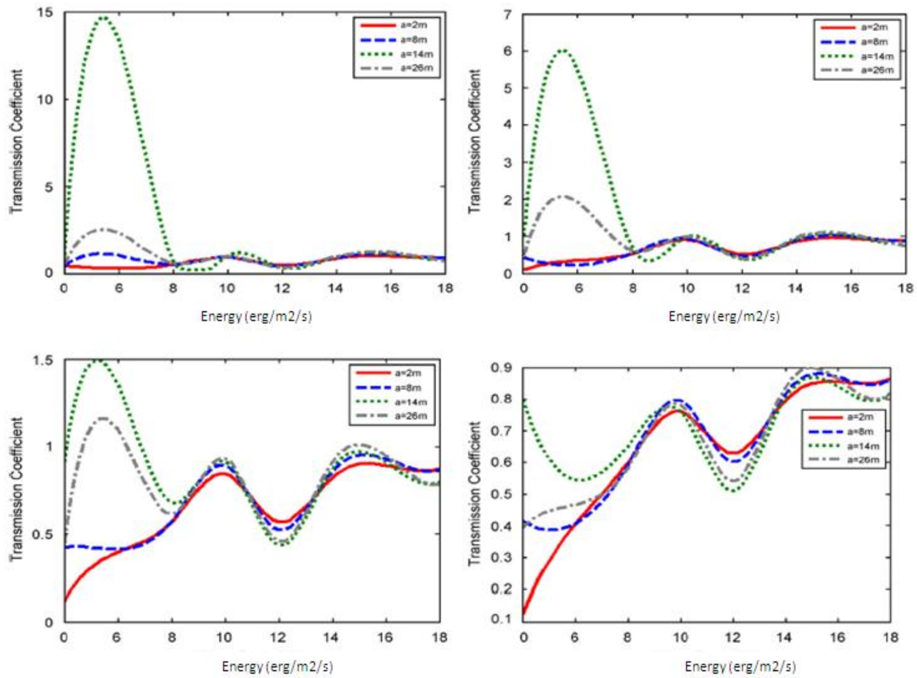

Fig. 2. Effect of channel width on the energy in four seasons (2011)

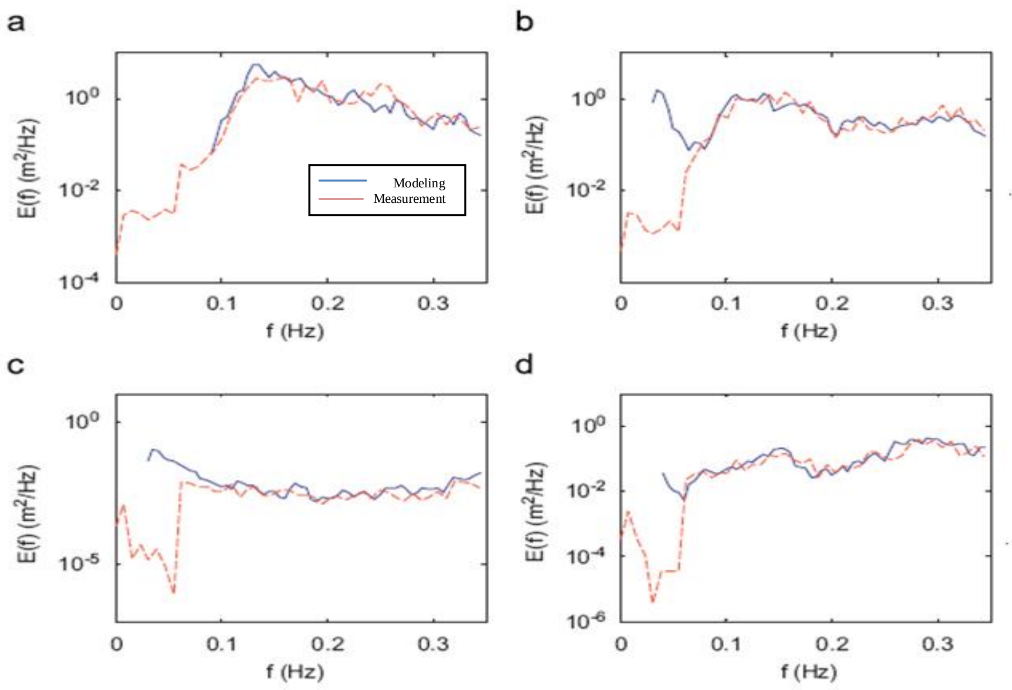

Fig. 3. Energy generation due to channel of the meander in four seasons (2011)

The effects of a power extraction device on the water level in a river site are studied here. As described in Section 2, the height drop along the channel is increased when energy is extracted. Main focus of this section is to study the magnitude of these effects and how they are altered when the water level at the downstream side of the channel varies. The turbine function which is inbuilt in MIKE was evaluated. In the numerical program, the turbines are described in a sub grid scale so that the turbines should be much smaller than the cell size. The turbines are assumed to exert a force on the flow which can be

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expressed using a drag coefficient according to Eq. (5). Since the turbines are modeled in a sub-grid scale, the cell size will affect the force calculations. For the considered channel, this meant that the force changed when the grid cell was altered, even maintaining the CD-value constant. Force and velocity through the turbine are the two output parameters for each turbine in MIKE. To calculate turbine power, Eq. (6) can then be used. However, the equation assumes the turbines are ideal and internal losses are not included. The actual energy capture would have to be multiplied with efficiency constant.

V. CONCLUSION

In this paper, we use data from Karoon River and simulation to further explore the concept of optimality in energy expenditure in meander of rivers to generate renewable energy. In this work the effects upstream on the water level has been studied. A special focus on river sites has been applied although the results are equally valid on any channel. Two main conclusions can be drawn from this work. The first is that a kinetic energy extractor causes a head loss upstream at an upstream power plant. This is important since it shows that a converter that is able to convert the total head loss would be much more efficient than an in-stream converter. The second conclusion was that the turbine function in the numerical program MIKE did not account for the power loss connected with in-stream energy converters. The river current energy conversion system technology is probably at its infancy. A set of more recent reports indicate that such devices are slowly entering into the implementation phase, graduating from the laboratory environment. This work shows that the meanders of river are one of the suitable renewable resources to generate energy.

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