Design A Run Of Libyan's Man-Made River Hydroelectricity Model (LMR HEM)

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Abstract— Water is the most important part of human day-to-day life and natural limited resource. The micro-hydro power plant is both an efficient and reliable form of a clean source of renewable energy and also being clean as well as environment-friendly, easy to be operated and low operation cost. Could Run of Libyan's man-made river hydroelectricity model (LMR HEM) or run-of-the Libyan's man-made river hydroelectricity retrofit its already vast network of drinking water pipes with turbines capable of producing hydropower? It's an enticing question, but one that is yet to be answered on any significant scale. However, the work in this paper will try to answer this question, where Run of Libyan's man-made river drinking pipes have been ignored as a source of potential power. The run of Libyan's man-made river [LMR] has miles of drinking water pipes running beneath them; in Libya alone, there are 3700 Km of drinking water pipes from Libyan's man-made river [LMR]. In this work run of Libyan's man-made river hydroelectricity model (LMR HEM) will be designed and analyzed in the renewable lab at the Bright Star University. A micro-pipe turbine (MPT) installed in a tap-water pipeline was gradually developed and utilized. Its working principle is as follows: this micro-pipe turbine is designed to be driven by water kinetic energy, where, through the connecting shaft, the MPT drives the generator to produce usable electrical power. Then the generator charges the battery of the sensor after sending out an AC electric signal, thus providing power for the detection equipment of the water supply pipeline (WSP). Finally, the conversion of fluid kinetic energy, mechanical energy, and electric energy is realized.

Keywords—Renewable energy, Libyan's man-made river hydroelectricity model, flow drinking pipes, hydro-turbines. turbine, micro-hydro-electric power plant, design step

I. INTRODUCTION

Libyan's man-made river [LMR] was considered the most important water supply project in the world as shown in Figs. 1a, b and c. The aim of the Libyan authorities was to exploit the Sahara aquifer. This aquifer is made up of four large basins of freshwater trapped under the Sahara desert for 38,000, 14,000, and 7,000 years; and was discovered during oil exploration in 1953. The Libyan authorities, who were in power at the time, began exploiting this immense freshwater reserve, estimated at more than 30,000 km^3, in the 1960s, with work in several phases [1].

The first phase allowed the creation of the Tazerbo pumping field, which consists of production wells and piezometric observation wells, supplying about one million m^3 of water per day. Only 98 of the 108 production wells in the Tazerbo field were in use in 1991, the rest being in reserve.

The second phase of the Sahara Aquifer Megaproject brought one million m^3 per day from the Fezzan region in the south-west to the fertile Jeffara plain in the north-west, on the western coastal belt, and supplied the capital Tripoli. The system starts from a borehole field in Sarir Qattusah, consisting of 127 wells distributed along three collector pipes, and feeds a terminal reservoir in Souk El Ahad, with a capacity of 28 million m^3 [1].

Fig. 1.a

Fig. 1.b

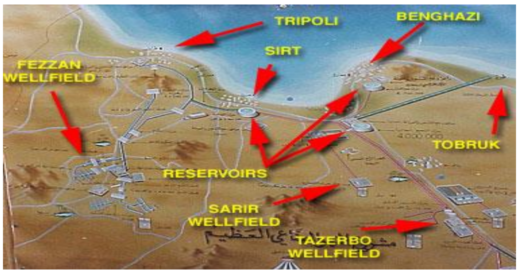


Fig. 1.c. map of wellfild & reservoris - Tazerbo wellfield, Sarir wellfield, Fezzan wellfield. Reservoirs are in Benghazi, Tobruk, Sirt and near Tripoli.

To accelerate the implementation of this mega-project, the Libyan government decided early on to build a pipeline manufacturing plant in Brega, in the Gulf of Sirte. The aim of the third phase, launched in the early 2000 s, was to supply water to the city of Tobruk from a new well field at Al Jaghboub. This involved the construction of a reservoir south of Tobruk and the laying of an additional 500 km of pipeline.

The last two phases of the mega-project also included the extension of the distribution network and the construction of a pipeline from the Ajdabiya reservoir to Tobruk, as well as the connection of the eastern and western systems into a single network in Sirte. The last two phases of the project were to allow for the development of agriculture in the desert [1].

II. LIBYAN'S MAN-MADE RIVER (LMR) WATER SUPPLY PROJECT

The Man-Made River is a network of pipes that supplies fresh water obtained from the Nubian Sandstone Aquifer System fossil aquifer across Libya. It is the world's largest irrigation project.

Fresh water trapped in the underlying strata. Most of this water was collected between 38,000 and 14,000 years ago, though some pockets are only 7,000 years old. [2].

First conceived in the late 1960s, the initial feasibility studies were conducted in 1974, with work starting ten years later. The project, which still has an estimated 25 years to run, was designed in five phases as shown in Fig. 2. Each one is largely separate in itself, but will eventually combine to form an integrated system.

PHASE I: Provides two million cubic metres along 1,200km of pipeline from As-Safir and Tazerbo to the Ajdabiya reservoir to Benghazi and Sirte.

PHASE II: Pumping from the south western aquifer (Fezzan) to Tripoli and Jeffara Plain.

PHASE III: Expansion of existing Phase I system, additional 1.68 million cubic metres a day (increasing total capacity to 3.68 million cubic metres a day), eight new pumping stations, 700km of new pipeline supply 138,000 cubic metres a day to Tobruk and the coast, new well field at Al Jaghboub, reservoir south of Tobruk, 500km of new pipeline.

PHASE IV: Extension of distribution network, construction of a pipeline linking the Ajdabiya reservoir to Tobruk.

PHASE V: Connection of the eastern and western systems into a single network in Sirte.

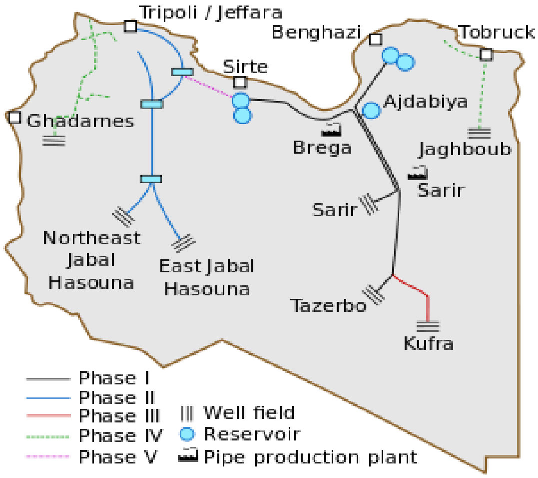


Fig. 2. Schematic drawing of the project. Note that different routes have been proposed for the not-yet-implemented phases (dashed). Tobruk may for instance end up connected to Ajdabiya instead of to the Jaghboub well field [2].

Micro hydro power plants are generating electrical energy utilizing water energy as an energy source initially, with output power in the range of 5-100 kW [3].

Mechanical energy is the energy produced by the water is used to turn turbines; this rotating turbine connected to a generator so that is produced electrical energy. Based on the operation of power plant, This MHPP within the classification of the hydroelectric plant run off river type. Simply, a runoff river hydropower utilizing the flow of river water that is partially passed on a channel, turn a turbine and then discharged back to the main river.

The components contained in plants run off river are: dam or weir diversion and intake (diversion weir and intake), like sedimentation (settling basin), the channel carrier (headrace), like tranquilizers (forebay), the pipeline exploded (penstock), turbines and generators, home generator (power house) and sewer (tail race) [4].

There is no international consensus on the definition of SHP. The general practice all over the world is to define SHP by power output. Different countries follow different norms keeping the upper limit ranging from 5 to 50 MW [5].

Energy is one of the most fundamental elements of our universe. It is inevitability for survival and indispensable for development activities to promote education, health, transportation and infrastructure for attaining a reasonable standard of living and is also a critical factor for economic development and employment [6].

In the last decade, problems related to energy crisis such as oil crisis, climatic change, electrical demand and restrictions of whole sale markets have a risen world-wide. These difficulties are continuously increasing, which suggest the need of technological alternatives to assure their solution. One of these technological alternatives is generating electricity as near as possible of the consumption site, using the renewable energy sources, that do not cause environmental pollutions, such as wind, solar, tidal and hydro-electric power plants [7, 8]. Hydro-electric power is a form of renewable energy resource, which comes from the flowing water. To generate electricity, water must be in motion. When the water is falling by the force of gravity, its potential energy converts into kinetic energy. This kinetic energy of the flowing water turns blades or vanes in a hydraulic turbines, the form of energy is changed to mechanical energy. The turbine turns the generator rotor which then converts this mechanical energy into electrical energy and the system is called hydro-electric power station [9].

The first hydro-electric power systems were developed in the 1880's. According to the international energy agency (IEA), large-scale hydro-electric plants currently supply 16% of the world's electricity. However, such kind of projects requires tremendous amounts of land impoundment, dams and flood control, and often they produce environmental impacts [10]. Micro-hydro-electric power plants are one of an alternative source of energy generation.

They are the smallest type of hydro-electric energy systems. They generate between (5) and (100)

Kilowatt of power when they are installed across rivers and streams.

Hydropower is based on the principle that flowing and falling water has a certain amount of kinetic energy potential associated with it. Hydropower comes from converting the energy in flowing water, by means of a water wheel or a turbine, into useful mechanical energy. This energy can then be converted into electricity through means of an electric generator. The energy from the flowing/falling water can also be used directly by suitable machines to avoid the efficiency loses of the generator. Recently, small-scale hydropower systems receive a great deal of public interest as a promising, renewable source of electrical power for homes, farms, and remote communities. Microhydro systems refer specifically to systems generating power on the scale of 5 kW to 100 kW [11].

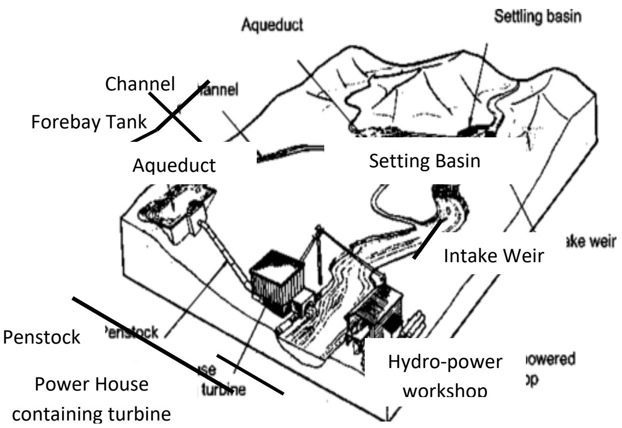


Fig. 3. General components of micro-hydro power plant [1].

The micro-hydro system includes a water turbine that converts the energy of flowing water into mechanical energy. This mechanical energy drives a generator which produces electrical power. The efficiency of the overall system, given the pipe friction loses and turbine deficiencies, is generally on the range of 50% of theoretical power associated with the energy of the flowing water. Micro-hydro has been in use for many years in many applications.

The turbine varies from site to site according to the given pressure head and design flow at each site [11]. Fig. 1 shows a typical system and details components generally found at a micro-hydro facility. Water flow in upstream will be diverted in intake weir and it will flow into the channel.

The channel transports the water to forebay tank before going to penstock pipe. In the tank, debris will be filtered and prevented from being drown to the turbine by means of penstock. Power conversion is done inside the power house, and turbine will transfer mechanic energy to generator, then generator produces electric energy.

Some investigations have been done to study the hydro energy harvest in the water pipelines, and several attempts have been made to select or design proper turbines [12,13]. For example, Du et al. [14] investigated the impact of the runner inlet arc angle on the performance of an inline cross-flow turbine in urban water mains. Sinagra et al. [15] suggested a cross-flow with positive outlet pressure (a power recovery system), which could provide potential energy consumption service with additional significant hydropower production.

Generally, in line with the placement mode of the main shaft, micro hydro turbines can be divided into horizontal axis and vertical axis types, which are derived from the wind turbines [16].

Renewable sources of energy are predicted to contribute almost one third of total electricity generation globally by 2035, with 50% of this from hydroelectric power (HEP) [17].

Run-of-river HEP schemes are electrical power plants that use the flow within a river channel to generate electricity, without the need for water storage. A proportion of river flow is taken from the river (usually on a weir or a side channel), diverted down a secondary channel towards a HEP turbine, before being returned to the main channel further downstream [18, 19].

Energy usage worldwide, the distribution is approximately 40% industry, 20% transportation, 40% residential/commercial. In developing countries, industries take up most of the energy uses. Energy used by agricultural sector is usually small, only about 2 to 5 % of total energy uses.

In this paper, we have explored the potential of micro hydropower plant as a source of renewable energy in order to tackle the power crisis of Bangladesh with in-depth analysis of Bamerchara micro-hydropower unit as a model. Section 2 deals with the complete energy scenario in Bangladesh, Section 3 explains the necessity of exploration of alternative sources other than fossil fuel.

Section 4 describes micro hydro as a source of green power generation, Section 5 demonstrates the parameters needed to be considered to explore new potential sites for micro-hydropower generation, Section 6 explains the economic considerations, Section 7 shows the potential micro-hydrosites already identified, Section 8 describes the socioeconomic impacts due to the establishment of micro-hydropower plant and economic feasibility of installing these plants, and Section 9 draws the conclusion[20].

There are five villages in the capital of Hink district located close each other and furthermost the distance is about 3 km. Official resource has mention that 650 people live in the villages and it has been provided in table 1 [37].

Table 1. Population data of Hink district [37].

Name of village	Family head	Popula tion	Hou se
Demunti	25	141	12
Menyememut	23	81	20
Mbeigau	29	89	25
Leihak	50	154	44
Kisab	39	185	16
Total	**166**	**650**	**117**

It can be seen from the table that in a house can contain more than a family head. This is caused by the local tradition that men can marry in very young and they can live in the house with their big family. Local people work as farmer, but the harvest is only for self consumption since there is no local market [37].

III. DESIGNED AND MANUFACTURED LIBYAN'S MAN-MADE RIVER HYDROELECTRICITY MODEL (LMR HEM).

This research aims to study the possibility of utilizing the hydroelectric power from Run of Libyan's man-made river drinking pipes as shown in Fig. 4.

Hydroelectric power is a renewable energy source which harnesses the power of moving water to produce electricity.

Large scale hydroelectricity projects typically involve dams. The run of Libyan's man-made river of drinking water pipes can also harness the power of moving water to generate renewable electricity and this is the aim of this manuscript.

The hydroelectric process starts long before it receives the target cities through which the Run of Libyan's man-made river (LMR) passes.

A hydroelectric dam converts the potential energy stored in a water reservoir behind a dam to mechanical energy—mechanical energy is also known as kinetic energy. As the water flows down through the dam its kinetic energy is used to turn a turbine. The generator converts the turbine’s mechanical energy into electricity.

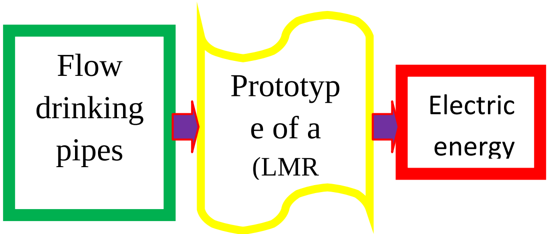


Fig. 4. Diagram of research project

IV. THE OBJECTIVES OF THIS PAPER

i. -to develop the integration of the power plant in the ecological environment.

ii. - to limit the costs and to improve the competitiveness compared to the others sources of energy by developing adapted technology and procedure for small hydro.

iii. - to open new markets related to marginal hydro potential and improve rehabilitation projects.

iv. - to develop the adequacy of power plants related to the electric power needs and available hydrology.

V. EXPERIMENTAL WORK

The Figs. 5.a, b, c, d, e, f, g, h and i below showed the equipment's parts and the steps of the designed and manufactured prototype of a Libyan's man-made river hydroelectricity mode (LMR HEM).


Fig. 5.a Fig. 5.b


Fig. 5.c Fig. 5.d


Fig. 5.e Fig. 5.f

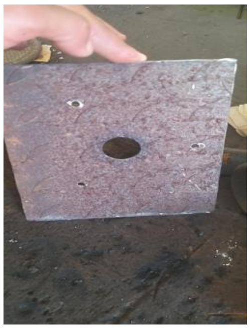



Fig. 5.g Fig. 5.h

Fig. 5.i

The Figs. 6.a, b c and d below showed the designed and manufactured prototype of a Libyan's man-made river hydroelectricity model (LMR HEM).

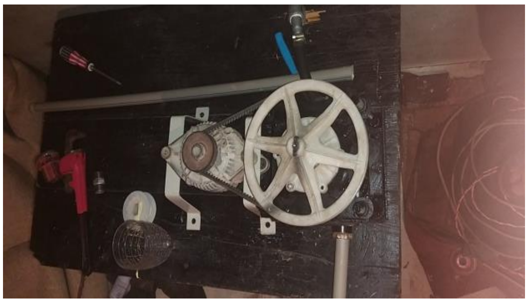


Fig. 6.a

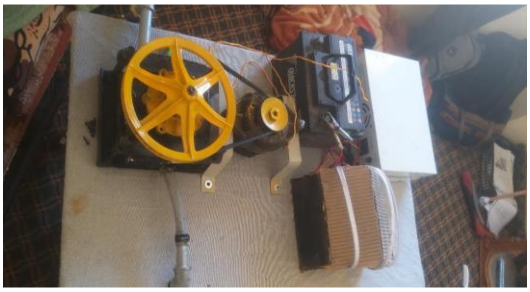
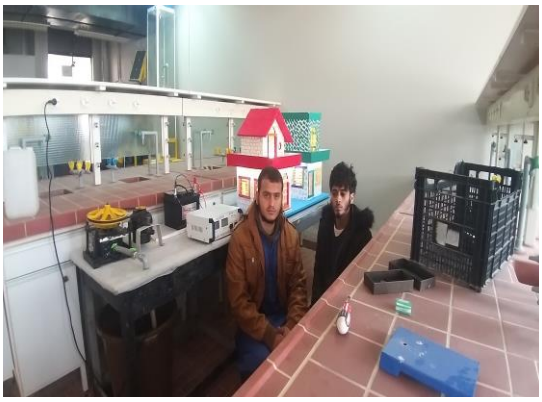


Fig. 6.b

Fig. 6.c

Fig. 6.d



In this paper the volume flow rate (Q) (in cubic meters per second), the mass flow rate (ṁ) (in kilograms per second), the discharge velocity (V) (in meters per second) and the power available from falling water will be calculated and discussed.

VI. RESULTS AND DISCUSSIONS

A. *Design Discharge*

The volume flow rate (Q) method can be used, where:

$$Q = \ddot{V}/t \ (m^3/s) \qquad (1)$$

The area and speed method can be used. This method will calculate the pipe's cross-sectional area (A). Then, water speed flow (V = V2) can be calculated from equation 2, where volume flow rate (Q) is equal to the speed of water flow and the pipe's cross-sectional area. This method can be formulated as follows [22].

$$Q = V \times A \ (m^3/s) \qquad (2)$$

The mass flow rate (ṁ) can be determined from equation 3.

$$\dot{m} = V \times A \times \rho = Q \times \rho \ (Kg/s) \qquad (3)$$

B. *Hydro Power*

The theoretical power produced by a Libyan's man-made river hydroelectricity mode (LMR HEM) system depends entirely on the flow rate of the water, vertical height (or head) and the acceleration of water due to gravity through following equation [23-31].

$$P = \rho \times g \times Q \times H_p \ (W) \qquad (4)$$

Where P is the power in units of watts, ρ is density of water that equal to 1000 kg/m3, Q is the volume flow rate in m3/sec, Hp is the head in meters and g is gravity in 9.81 m/s2. Because water density and gravity are constant, the equation can be simplified as in eq. 5 with ɣ is (specific weight) the product of both content parameter.

$$P = \gamma \times Q \times H_p \ (W) \qquad (5)$$

Finally it was found that the power (P) = 246.52 Watt

C. *Power generated in the turbine calculation*

All hydro-electric generation depend on falling water. Stream flow is the fuel of hydro-power plant and without it generation ceases.

Regardless of the water path through an open channel or penstock, the power in a turbine (lost from water potential energy) is given as [32, 33]:

$$Pt = \gamma \times Q \times H_p \times \eta_t \quad (W) \qquad (6)$$

Where P_t = power in watt generated in the turbine, η_t = turbine efficiency (normally 90%).

Then generated power in the turbine will be lower than theoretical power, where it was found that (P_t = 221.87 Watt).

D. *The pressure (Ƥ) calculation*

The pressure (Ƥ) can be determined from Bernoulli Equation as the following:

$$P_1/\gamma+(V_1)^2/2g+Z_1 = P_2/\gamma+(V_2)^2/2g+Z_2+Hp \qquad (7)$$

Where:

$Ƥ_1 = Ƥ_o$ = 1atm, $Z_1 = 0$ (at the datum) V_2 can be calculated from eq. 2 and $V_2 >> V_1$ then V_1 can be neglected ($V_1 = 0$), Z_2 can be measured, finally it was found that:

The pressure ($Ƥ_2$) = 4.0594 bar

VII. CONCLUSION

Micro-hydro power continues to grow around the world, it is important to show our government how feasible micro-hydro systems actually are in a suitable site.

The only requirements for micro-hydro power are water sources, turbines, generators, proper design and installation, which not only helps our country but also helps the world and environment as a whole because the burning of fossil fuels has very negative environmental consequences.

Nowadays, the whole world is much more concerned than ever before about not only the depletion of various energy resources but also environmental degradation caused by the existing pattern of fossil fuel use.

In this paper, the current power crisis of Libya has been discussed. The necessity of exploring energy from alternative sources and the impact of micro-hydro as an alternative source has been presented, where Run of Libyan's man-made river drinking pipes has been ignored as a source of potential power.

Since micro-hydro power plant requires terrain and availability of high stream flow rate, so, Libya has a good run-off man-made river.

A design and manufacture of a Run of Libyan's man-made river hydroelectricity model (LMR HEM) have been planned as visualization. The improved version of the Run of Libyan's man-made river hydroelectricity model (LMR HEM) has been experimentally tested.

According to the model test results, the (LMR HEM)-generated theoretical power reached (246.52 W) while the generated power in the turbine reached (221.87 W) at the design flow rate and the flow velocity in the pipeline is (3.4255 m/s).

The results of the study concluded that the natural conditions around the Run of Libyan's man-made river hydroelectricity model (LMR HEM) feasible for the construction. Therefore electrical energy from number of (LMR HEM) models is planned to be transferred to many villages.

VIII. RECOMMENDATIONS

i. Preparing awareness programs on the importance of renewable energy and the need to reduce dependence on traditional energy sources.

ii. Establishment of research and experimental stations to develop renewable energy sources in Libya.

iii. Introducing renewable energy as a scientific course taught in Libyans universities.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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