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Feasibility of Superficial Small and Micro-Hydro Power Plants in Egypt

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Abstract – *Clean energy such as hydroelectric power plant, solar power, wind power, etc. is becoming more important for lowering the global warming as the world becomes hotter every day as a result of global warming. This paper presents the technical and economic details of the surface hydroelectric power plant towards the production of 100% electricity for Ashmoun village in Menoufia governorate in Egypt. Nowadays, the hydroelectric power plants are becoming more popular and will be used in a larger range in the future. More energy is collected by the end of the day because the system is working all the time. This type of clean energy, which collects more energy and also can charge the largest number of batteries. This feature outperforms the solar energy that operates during the day only.*

Key Words: Hydroelectric power plants, Power Factor, inverter, batteries.

1. INTRODUCTION

Energy and water are essential to human beings and inseparable from all aspects of human activities. These two basic resources are strongly related to human life and production. On the one hand, energy production, transportation, and utilization affect water resources. For example, coal mining, washing, transportation, and utilization affect the quantity and quality of water resources. However, water extraction, purification, and utilization entail energy consumption. Processes such as seawater desalination also involve high energy usage. The relationship between energy and water is currently facing new conditions and challenges beyond the traditional relations of influence and constraint. With mass fossil fuel consumption and continuous greenhouse gas (GHG) emissions, critical global climate change, the continuing rise in average global temperature, and frequent extreme weather events have greatly transformed global hydrological systems and thus the environment is at risk, resulting in increased demand for clean sources of energy. Deviation of hydrological systems worsens regional imbalances by adjusting the amount of water resources in the regions [1]. From the perspective of the relationship between energy and water, water in hydropower plants and cooling water supply to thermal power plants will have a negative impact [3], while the difference in the distribution of water resources will reshape the use of energy to extract and transfer water [2]. Power generation is a major starting point for relationship research between power and water. According to the International Energy Agency's 2016 Global Energy Outlook (IEA) [4], energy and water depend on each other. Management of the links between energy and water is essential for achieving success in achieving different development and climate goals.

Hydroelectric power plants are the most important renewable energy source of the world's electricity supply, due to low environmental impacts and low operating and maintenance costs. Hydraulic power has much potential that have not been used yet. Hydroelectricity is one of the most sustainable sources of clean energy that is best suited to environmental legislation such as Kyoto Protocol [5]. Hydroelectric power plants do not produce greenhouse gas emissions because they do not use fuel thereby pollute the air and the surrounding environment. They contribute prevention actions against global warming about 16% of the world's electricity production is provided by hydroelectric power [6]. Hydroelectric power plants do not pollute the environment as much as thermal power plants. In hydropower plants, the amount of energy to be generated from the water source depends on the amount of the water and the water flow. According to these two main parameters, the turbine type to be used is determined. The turbine varieties are grouped into two main categories as impulse turbines and reaction turbines [7]. The method of generation depends on transforming the water's energy capacity into kinetic energy first, where the water is wasted from the top to move the turbine, and thus a generator rotates and produces electricity. The amount of energy produced depends on the amount of water flowing per second and on the height of the water. The higher the water flow in the turbine, the greater the energy produced. The higher the water, the greater the energy produced. Fossil fuels will not be enough to meet global energy demand. Countries should start thinking increasingly about using renewable energy and developing the use of energy sources such as nuclear resources, hydropower and renewable energy (solar, wind, waves and tides, geothermal energy). Unlike fossil fuels used to generate electricity, all these other sources require energy storage methods in order to take full advantage of their total energy potential. It is evident, therefore, that pumped storage which is a well proven highly flexible and efficient (70--75%) method of banking energy will be required on a rapidly increasing scale in the years ahead. There are many previous studies, research and international experiences in this area, perhaps the most important of which is the Chinese, Indian, United Kingdom and Brazilian experience, and we will declare these studies to use the result of experiment for these countries in Egypt and use the same ideal in this research.

A comprehensive review of small hydro power installations in India is pretended and discussed the future plans till 2050 for harnessing the most possible amount of hydropower, as it has high potential to alleviate the energy poverty in rural and remotes area [8]. Another comprehensive review of potential at hydro power is available in the shores of the United Kingdom is pretended and also discussed and examined the general requirements for selection and planning of such pumped storage installations around the shores of the U.K. and gives some tentative recommendations for possible sites available for further more detailed study [9]. However, a comprehensive review of electricity usage for the water production and supply in Brazil discussed five categories of indicators that were proposed that is per capita, water losses, energy, greenhouse gases (GHGs) and financial/economic.

This paper presents an adaptability analysis of the Beijing–Tianjin–Hebei region in 2013–2030 based on the current situation [11] and discuss water evaluation and planning and long-range energy alternative planning systems are used to simulate changes in water and energy systems, respectively in addition to that the impacts on the electricity sector under two climate scenarios and three development scenarios are also discussed. On this basis, a study explores the potential of power structure adjustment and technological advancement in easing baseline water stress and promoting sustainable development in the region. Findings show that the Beijing–Tianjin–Hebei region is under high water stress, which will be aggravated under global climate change.

2. A. worldwide installations of superficial hydro plants

Large-scale hydroelectric power stations are more usually seen as the largest power producing facilities in the world, with some hydroelectric facilities capable of generating more than double the installed sizes of the current largest nuclear power stations. While no official definition exists for the capacity range of large hydroelectric power stations, facilities from over a few hundred megawatts are generally considered large hydroelectric facilities [12]. Currently, only four facilities over 10 GW (10,000 MW) are in operation worldwide, see table (1) below as well as in figure.

Table -1: Rank of country.

Rank	Station	Country	Location	Capacity (MW)
1.	Three Gorges Dam	China	30°49′15″N 111°00′08″E	22,500
2.	Itaipu Dam	Brazil Paraguay	25°24′31″S 54°35′21″W	14,000
3.	Xiluodu Dam	China	28°15′35″N 103°38′58″E	13,860
4.	Guri Dam	Venezuela	07°45′59″N 62°59′57″W	10,200

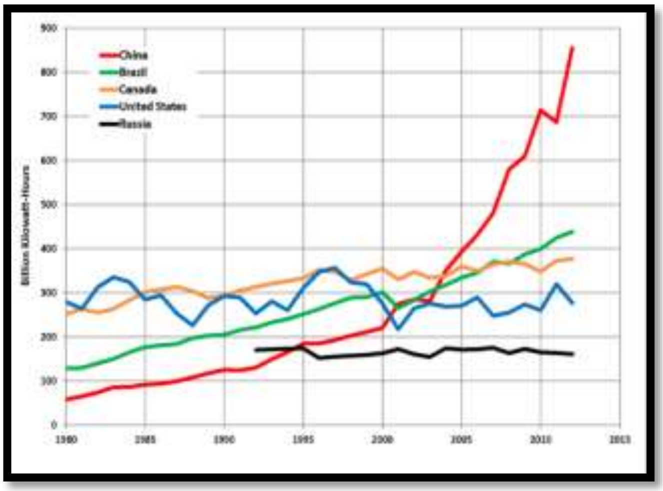

Fig – 1: Top 5 Hydropower-Producing Countries.

Small hydro is the improvement of hydroelectric power on a scale serving a small community or industrial plant. The definition of a small hydro project varies but a generating capacity of up to 10 megawatts (MW) is generally accepted as the upper limit of what can be termed small hydro. This can be stretched to 25 MW and 30 MW in Canada and the United States. Small-scale hydroelectricity making grew by 29% from 2005 to 2008, raising the total world small-hydro capacity to 85 GW. Over 70% of this was in China (65 GW), followed by Japan (3.5 GW), the United States (3 GW), and India (2 GW) [12]. The small hydro stations can be connected to conventional electrical distribution networks as a source of low-cost renewable energy. Otherwise, small hydro projects may be built in isolated areas that would be uneconomic to assist a network, or in areas where there is no national electrical distribution network. In 2015 hydropower generated 16.6% of the world's total electricity and 70% of all renewable electricity. Hydropower is produced in 150 countries, with the Asia-Pacific region generated 32 percent of global hydropower in 2010. China is the largest hydroelectricity producer, with 721 terawatt-hours of production in 2010, representing around 17 percent of domestic electricity use. Brazil, Canada, New Zealand, Norway, Paraguay, Austria, Switzerland, Venezuela, and several other countries have a majority of the internal electric energy production from hydroelectric power. Paraguay produces 100% of its electricity from hydroelectric dams and exports 90% of its production to Brazil and to Argentina.

Norway produces 96% of its electricity from hydroelectric sources [13]. Ten of the largest hydroelectric producers as at 2014 see table (2) below.

Table -2: Ten of the largest hydroelectric producers as at 2014.

country	Annual hydroelectric Production (TWh)	Installed Capacity (GW)	Capacity factor	% of total Production
China	1064	311	0.37	18.7%
Canada	383	76	0.59	58.3%
Brazil	373	89	0.56	63.2%
USA	282	102	0.42	6.7%
Russia	177	51	0.42	16.2%
India	132	40	0.43	10.2%
Norway	129	31	0.49	96.0%
Japan	87	50	0.37	8.4%
Venezuela	87	15	0.67	68.3%
France	69	25	0.46	12.2%

B. Hydro Power in Egypt

The common of Egypt's electricity supply is generated from thermal and hydropower stations. [14] The main hydroelectric generating stations currently operating in Egypt are the Aswan Low Dam, the Esna Dam, the Aswan High Dam, and the Naga Hamady Barrages. The Asyut Barrage hydropower plant is scheduled to added as a fifth station in 2016 [15]. All hydroelectric generation in Egypt comes from the Aswan High Dam. The Aswan High Dam has a theoretical generating capacity of 2.1GW; however, the dam is rarely able to operate at full design capacity due to low water levels. A current refurbishment program is being enacted to not only increase the generating capacity of the dam to 2.4GW, but also extend the operational life of the turbines by about 40 years [14, 16].

C. Description of Egypt's Geography and Water resources

Egypt's water resources management relies on a difficult set of infrastructure along the river. The key element of this infrastructure is the Aswan High Dam that forms Lake Nasser. The High Dam protects Egypt from floods, stores water for year-round irrigation and produces hydropower. With a live storage capacity of 90 billion cubic meters the dam stores more than one and a half the average annual flow of the Nile River, thus providing a high level of regulation in the river basin compared to other regulated rivers in the world [17]. Figure 2 shows the Nile in Egypt.

Egypt depends for 97% of its water supply on the Nile. Rainfall is minimal at 18 mm per year, occurring mainly during autumn and winter time. The 1959 Nile waters treaty between Egypt and Sudan allocates 55.5 billion cubic meter of water per year to Egypt, without specifying any allocation for upstream riparian besides Sudan (18.5 billion cubic meters per year). Actual water use by Egypt is widely believed to be in excess of the allocation under the 1959 agreement. There is no water sharing agreement among all ten riparian countries of the Nile. However, the riparian countries cooperate through the Nile Basin Initiative.

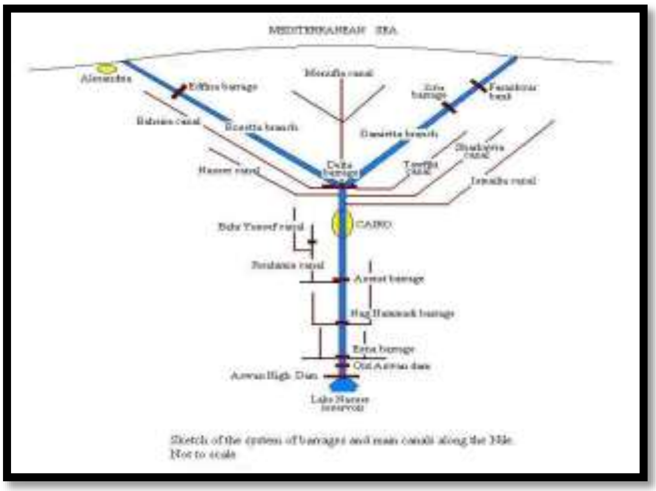

Fig – 2: The Nile in Egypt.

D. Possible locations in Egypt for superficial power plants

1. superficial Hydro-power plant

This project is based on the use of the surface water power plant machine, which is usually used for plant irrigation. It usually operates 6 hours a day and is usually used and found mostly in villages and agricultural areas. For example, agricultural machinery used in this project is located in Ashmoun village, Menoufia Governorate.

2. Hydro-power plant in Water and sewage station

I. Water station

Egypt has 2705 water station and total production capacity of about 25000,000 M3/ day (9.1 billion M3/ year).

II. Sewage stations

Egypt has 400 sewage stations. Fig. 3 shows the Distribution of water and sewage stations at the level of the Egyptian Republic.

Fig – 3: Distribution of water and sewage stations at the level of the Egyptian Republic.

3. The economy of the proposed system

The energy sector is playing a vital role in Egypt's economy. However, the Egyptian government currently faces a real challenge to make a strategic choice between satisfying the ever increasing national primary energy demand (depending more than 90% on oil and gas) that is being offered to end users with subsidized prices, and maintaining a certain level of hard currency revenues from oil and gas exports at world prices, even with a growing risk of accelerated depletion rates of national proven reserves. For the electricity sector, the load and energy demand grows by more than 10 % per year where the load is expected to reach 39703MW and the energy 220450 GW by year 2020. Meeting the ever increasing demand on electricity with a high degree of reliability and sustainability has been one of the main issues addressed by the strategy developed and implemented by the Ministry of Electricity and Energy. Therefore, the Egyptian government has developed a plan to rely on renewable energy sources to meet the increasing needs of electricity. The most important of these renewable sources is the hydropower, which works efficiently throughout the day and throughout the year, and differs with solar energy, which works efficiently during daylight hours only. The Egyptian state is characterized by the existence of more than one source of water and therefore can rely on all these water resources to obtain a high percentage of electric power and at a very simple cost, unlike any other renewable energy source.

In this research, a study and project was conducted on the Hydroelectric power plants whether from water stations or irrigation machines to get renewable energy with less cost. The total cost for this project is 4500 LE. Comparisons of these processes are described below. The study is divided into two parts: first part is superficial Hydro-power plant it normally used to irrigation the plant so you can have used too in this project. Second part is Hydro-power plant it normally used in Water and sewage station; in this work we use it to get clean power and low-cost.

4. The technique of proposed system

4.1 Design of superficial power plants

In superficial power plants, the amount of energy to be generated from the water source depends on the amount of the water pumped. According to these two main parameters, the turbine type to be used is determined. in this project, Francis turbines is used. The method of generation depends on transforming the water's energy capacity into kinetic energy first, where the water is pumped in the direction of the turbine, and thus a generator rotates and produces electricity. The amount of energy produced depends on the amount of water pumping per second. The turbine in turn turns the generator into the generator and generates electricity. The output of this process depends on the efficiency of rotation of the turbines and the amount of wasted energy by friction during rotation. The electricity that is generated goes by wires into the transformer unit (AC – DC Inverter) and then stores these charges in a battery. Show block diagram project in figure 4.

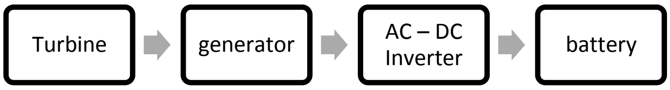

Fig – 4: Block diagram the project.

4.2 Turbine

All turbines are driven by a fluid acting as an energy carrier. Other types of turbines are driven by wind or falling water (falling from altitude).

4.3 Turbine Renewable energy sources

Water (hydropower) - In this process the turbine blades are affected by the flowing water, produced by hydropower dams or tidal forces. The prime movers or turbines in hydroelectric power plants converts the kinetic energy of the water into mechanical energy which in turn converts into electrical energy. As per the action of water on the turbines, they are classified as impulse turbine and reaction turbine. In case of impulse turbine, the pressure energy of water is converted to kinetic energy when passed through the nozzle and forms the high velocity get of water. The formed water jet is used for driving the wheel. In case of reaction turbine, the water pressure combined with the velocity works on the runner. The power is in the turbine is the combined action of pressure and velocity of the water that completely fills the runner and water passage. The casing of the impulse turbine operates at the atmospheric pressure whereas the casing of the reaction turbine operates under high pressure. The pressure acts on rotor and vacuum underneath it. This is why the casing of the reaction turbine is made completely leak proof.

4.4 Francis Turbine in Hydro power plant

In Francis turbine, the water enters into the casing with relatively lower velocity, passes through the guide vanes located around the circumference and flows through the runner and finally discharges into the draft tube sealed below the tailrace water level. The water passage from the headrace to tailrace is completely filled with water which acts upon the whole circumference of the runner. A large part of the power is obtained from the difference in the pressure acting upon the front and back of the runner buckets, only a total part of the power is delivered from the dynamic action of the water. There are two types of Francis turbines known as open flume type and closed flume type. In open flume type, the turbine is immersed under the water of the headrace in a concrete chamber and discharges into the tailrace through the draft tube. The main disadvantage of this type is that, the runner and the guide-vane mechanism is under the water and they are not open for either for inspection or repair without draining the chamber. In closed type, the water is led to the turbine through the penstock whose end is connected to the spiral casing of the turbine.

The guide vanes are provided around the runner to regulate the water flowing through the turbine. The guide vanes provide gradually decreasing area of flow for all gate openings, so that no eddies are formed and efficiency does not suffer much even at part load conditions. The majority of the Fracis turbines are inward radially flow type and most preferred for medium heads. The inward flow turbine has many advantages over the outward flow turbines:

- ✓ The chances of eddy formations and pressure loss are reduced as the area of flow becomes gradually convergent.
- ✓ The runaway speed of the turbine is automatically checked as the centrifugal force acts upwards while the flow is inwards.
- ✓ The guide vanes can be located on the outer periphery of the runner, therefore better regulation is possible.
- ✓ The frictional losses are less as the water velocity over the vanes is reduced.
- ✓ The inward flow turbine can be used for fairly high heads without increasing the speed of the turbine as centrifugal head supports the considerable part of the supply head.

Fig – 5: The Francis turbine is used in this work.

4.5 Battery

Solar batteries are used to store electricity, in order to reduce the waste of electrical energy obtained from wind, sea, sun and night cover.

Difference between car batteries and solar batteries:

Solar batteries are shipped throughout the sun's brightness, and 3000 cycles when discharged 50%, while batteries do not live more than 100 cycles when discharged 50%.

Solar batteries give a long amount of charge, and the batteries are spoiled shortly after they are designed to give a large amount of electric charge in a short period.

Solar batteries can discharge their entire capacity without being damaged 200 times, and the batteries will be damaged after the full charge is discharged between 12 and 15 times only.

4.6 Prototype of superficial Hydro power plants

Figure 6 shows the turbine design already used in this project in order to get the maximum efficiency from the hydropower plants.

Fig – 6: Turbine design.

5. Experimental Results

5.1 Superficial Hydro-power plant

Superficial Hydro-power plant machine it normally used to irrigation the plant, it works usually 6 hours every day so you can have used too in this project. Water is pumped at different rate so the charging time to the battery different and the power rate is change too. Table 3 is shown the result of some machine working to charging the battery.

Example

Battery charging time = Battery capacity / charging capacity = 14 / 6.5 = 2.15 hours. Water is pumped at a rate of 93 cubic meters per hour (m3/H), the total water pumping is 197.8m3to fully charge the battery. The following table shows some of the results that the researcher conducted on some hydroelectric production processes in the first part of the research, namely, hydroelectric power generation through agricultural irrigation machines, where 10 different irrigation machines were tested for each machine with different flow rate. The flow of water and the number of different operating hours of the other machines according to the table 3.

The same luminaries were used and only the lamps were replaced. The voltage, current and power factor were measured before and after the replacement. Also, the luminance was measured.

Table-3: Result of some machine working to charging the battery.

Flow rate	Output of Amp	charging time	Water pumped rate
100 m^3 /Hours	7 Amp	2 Hours	200 m^3 /Hours
100 m^3 /Hours	7 Amp	2 Hours	200 m^3 /Hours
95 m^3 /Hours	6 Amp	2.33 Hours	209.7 m^3 /Hours
93 m^3 /Hours	6.5 Amp	2.15 Hours	199.95 m^3 /Hours
93 m^3 /Hours	6.5 Amp	2.15 Hours	197.8 m^3 /Hours
94 m^3 /Hours	6.5 Amp	2.15 Hours	202.1 m^3 /Hours
95 m^3 /Hours	6.5 Amp	2.15 Hours	201.25 m^3 /Hours
100 m^3 /Hours	7 Amp	2 Hours	200 m^3 /Hours
93 m^3 /Hours	6.5 Amp	2.15 Hours	199.95 m^3 /Hours
93 m^3 /Hours	6.5 Amp	2.15 Hours	199.95 m^3 /Hours

The following table shows the total results after the project experiment on the irrigation machines, where the table shows the total capacity and the number of hour's q however, and Performance curve for machines as shown in figure 7.

Table-4: Total results after the project experiment on the irrigation machines.

Output of One battery	Time	Current
590 watt	7 Hours	1.5 Amp
295 watt	14 Hours	0.75 Amp

Fig – 7: Total power for machine.

5.2 Hydro-power plant in Water and sewage station

Egypt enjoys many water resources, perhaps the most important of which is the Nile River. The exploitation of this resource is one of the best and cheapest resources for generating energy because the cost of generating electricity is not comparable to traditional methods of generating electricity. This method can also generate power and charge throughout the day, other than solar and wind power, which have a specific time and vary according to climatic conditions throughout the year, so we get a higher charge rate and energy than water power. Table 4 shows the result of the operation of the machine and the amount of battery charge time.

Table 4 shows some of the results that the researcher conducted on some hydroelectric production processes from the second part of the research, which is the generation of hydropower through some water and sewage stations. The experiment was done on seven different flow equipment for a sewage plant to produce electricity.

Table-4: Result of some machine working to charging the battery.

Flow rate	Output of Amp	charging time	Water pumped rate
140 m^3 /Hours	10 Amp	1.4 Hours	196 m^3 /Hours
165 m^3 /Hours	11.7 Amp	1.33 Hours	221 m^3 /Hours
230 m^3 /Hours	16.4 Amp	1.24 Hours	286 m^3 /Hours
280 m^3 /Hours	20 Amp	1.2 Hours	336 m^3 /Hours
340 m^3 /Hours	24.2 Amp	1.16 Hours	396 m^3 /Hours
370 m^3 /Hours	26.4 Amp	1.15 Hours	426 m^3 /Hours
400 m^3 /Hours	28.5 Amp	1.14 Hours	456 m^3 /Hours

Table 5 shows the total results of hydropower in terms of flow rate and time taken to produce electricity. At end the day has been charged 22 batteries from one turbine so this energy can be used to operate simple household loads as shown in Figure 8.

Table-5: Total results of hydropower in terms of flow rate and time.

Water pumped rate	Time
196 m3/Hour	24 Hour

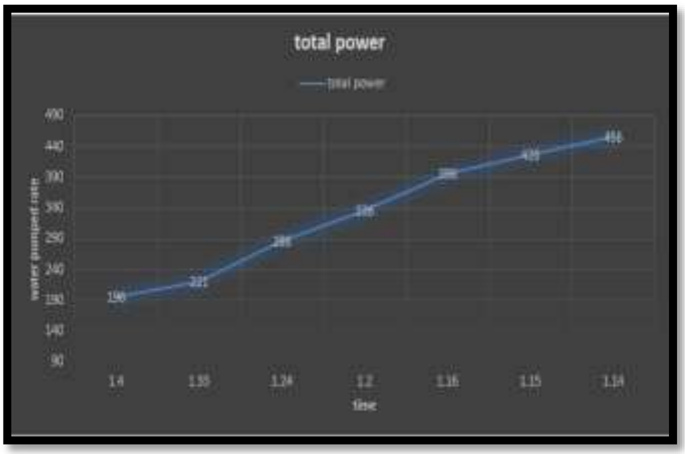

Fig – 8: Total power for machine.

6. Results

In table 6, some calculations and measurements, some values of electrical consumption for loads and machines in the simple home.

Table-6: Electricity consumption for some loads in house.

Load	Electricity consumption of watts
Fridge 16	475 watt/Hour
Washing Machine	300 watt/Hour
TV	150 watt/Hour
LED	12 Watt/Hour

7. Calculations

7.1 superficial Hydro-power plants

The total number of batteries charged per day is 23 batteries.

Power at hour = 484.6

Total power at 12 hour = 484.6 * 12 = 5815.71 Watt.

Ampere at hour = 1.23 Amp.

Total Ampere at 12 hour = 1.23 * 12 = 14.78 Amp.

Volt at 12 hour = 220 V.

7.2 Hydro-power plant in Water and sewage station

The total number of batteries charged per day is 22 batteries from one machine.

Power at hour = 463.57

Total power at 12 hour = 463.57 * 12 = 5562.85 Watt.

Ampere at hour = 1.23 Amp.

Total Ampere at 12 hour = 1.23 * 12 = 14.78 Amp.

Volt at 12 hour = 220 V.

8. Statistics

Machine	Total power	Total time	Total station in Egypt
irrigation machines.	43614 Watt Total machine in village is 15 machine = 654210 Watt.	6 Hour	4740 Village
Water station	11125.68 Watt Total machine in station is 4 pump = 44502.72 Watt.	24 Hour	2705 Station
Sewage station	11125.68 Watt Total machine in station is 4 pump = 44502.72 Watt.	24 Hour	400 Station

6. CONCLUSIONS

The main objective of this study is use its results in the field of renewable energy, especially since the cost of designing such a project is simple in order to benefit from the amount of energy produced. The main conclusion from this work can be summarized as follows;

1- Firstly, for water pumping machines (irrigation machines) 10 different irrigation machines were tested and a set of batteries were charged up to 23 batteries where the total power in 12 hours is (5815.71 W) By circulating this idea to the total villages at the level of the Republic (up to 4740) will get a very large rate of energy.
2- Secondly, for the production of electricity from water and sewage plants at different flow rates starting from (140-400) was tested on sewage stations by putting the number of four devices by two devices at the beginning and two devices at the end of the station was obtained (11125.68 watts) through the plant One experiment has been to generalize this idea at the level of the Republic where the sewage plants up to (2705) stations have a total capacity (44502.72 Watt) Similarly in drinking water stations of different numbers.

The study also aims to use the results and apply them to road lighting systems, so the cost is very low compared to the cost of the design of the solar lighting column. With all these results and realistic studies, a participation in solving the energy problem in Egypt will be achieved.

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