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A Solar Powered Microgrid Fish Farm Experience

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Abstract: Many types of grids are developed to address the fast growing demand such as smart grid and Microgrid. The main objectives of this paper were to explore the implementation of Microgrid in a fish farm, to show the benefit of adding a renewable source; the photovoltaic system. The Micro-grid consisted of old Indian diesel pumps- which caused all types of pollution diesel spill engine oil spill, noise and utility supply. Photovoltaic system is added after a catastrophic accident by contamination a fish pond by mix of diesel and engine oil killing tens of thousands of fishes. The Photovoltaic system panel was connected directly to a DC centrifugal solar pump. The solar pump produced an average flow rate of 0.0073 m^3/s (210.65 m^3 per day). The data sheet showed that the selected pump should produce 200 m^3 per day, and this means that the design performance and experiment results are in close agreement. Furthermore, this grid shows a good actual experience of using solar pump for fish ponds as replacement of the traditional diesel-based method.

Keywords: *Microgrid, fish Farm; Renewable Energy; Photovoltaic system; Diesel pumps, DC Solar Pump*

1. INTRODUCTION

Renewable energy is generally defined as energy that comes from resources which are naturally replenished on human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat [1]. Renewable energy resources exist over wide geographical areas, in contrast to other energy sources, which are concentrated in a limited number of countries. To feed the energy appetite of the word renewable energy technologies are becoming feasible and offer alternative generation options that enable consideration of the impact on the environment and other social and economic factors. The main reasons is that, there are fast continues grow of the worldwide demand for electricity even that energy conservation measures and advance in power conversion efficiency reduce the consumption of individual loads and the traditional generation portfolio is dominated by non-renewable hydrocarbon fossil fuels whose excessive usage results in increased production of carbon dioxide and air-borne particulates [2].

2. MICROGRID

A micro-grid is a contiguous section of the grid and its interconnected energy resources can operate as an independent electrical island disconnected from the rest of the grid. The major steps in microgrid evolution take place along several key directions [3].

– **Physical microgrid boundaries**: A Basic microgrid typically has predetermined boundaries that correspond to its footprint in the island mode. The viability of island operation needs to be assessed during normal operation for each predefined microgrid.

– **Interactions between microgrid and main grid operations**: A classical microgrid has a backup generator that is often not designed to operate in parallel with utility supply. the major benefits of microgrids include :

  – Providing energy services tailored to the requirements of microgrid end users, such as service continuity in times of main grid outage and increased renewable generator.
  – Operating more efficiently and reliably within the microgrid, as compared with dedicated backup generation in a classical microgrid model.
  – Enabling parallel operations with the main grid for improved financial performance through economic exchange of energy and ancillary services between the two.
  – Enable parallel operations with the main grid for improved service reliability through coordinated response during emergency situation to serve critical loads and reduce outage impacts.
  – Enable innovation in new energy technology and services that have broad social impact beyond local energy delivery.

The types of micro-grid can be set in these categorizes

- **Private plants and commercial organizations**: there are privately owned and operated by facility managers with limited utility interaction.
- **Government organizations**: Government-owned microgrids often seek to improve economics by operating in parallel with utility grid.
- **Electric utility companies**: To serve customers with special localized requirements.

Soba fish farm can be set on the first sector.

3. FISH FARM

A fish farming is the principal form of aquaculture, while other methods may fall under mariculture. Fish farming involves raising fish commercially in tanks or enclosures, usually for food. A facility that releases juvenile fish into the wild for recreational fishing , or to supplement a specie's natural numbers is generally referred to as a fish hatchery. Worldwide, the most important fish species used in fish farming are carp, salmon, tilapia and catfish.[4].There is an increasing demand for fish and fish protein, which has resulted in widespread overfishing in wild fisheries, China holds 62 percent of the world's fish farming practice [5]. Fish farming offers fish marketers another source. However, farming carnivorous fish, such as salmon, does not always reduce pressure on wild fisheries, since carnivorous farmed fish are usually fed fishmeal and fish oil extracted from wild forage fish. The global returns for fish farming recorded by the FAO in 2008 totalled 33.8 million tonnes worth about 60$ billion [6]. In 2005, aquaculture represented 40% of the 157.5 million tons of seafood that was produced, meaning that it has become a critical part of our world's food source even though the industry is still technically in its 'infancy' and didn't really become well known until the 1970s. Because of this rise in aquaculture, there has been a rise in the per capita availability of seafood globally within the last few decades [7].

4. SOBA FISH FARM

Soba fish farm is located 40 Km far from the centre of Khartoum, with cross area of 42000 m^2, this area consists of 11 fish ponds sorted by age, the main type of the fish is Tilapa **Fig. 1**. The fish are growing in many stages the starting ponds has tiny fish and the following ponds have bigger fish, the tiny fish transmitted from a pond to other till they are ready for marketing, the journey takes about 6-7 months and half (each pond has about 24000 tiny fish) of the tiny fish will continue that journey and the other half die for many reasons.

The dimensions of the pond is 60×40 m × 2.5 m figure (4), the depth of the water must be above 1 m. The rest farm area is left for small house for the employees. Figure (2) show Google earth photo of Soba farm and figure (3) show schematic presentation draw for the farm.

The farm shares other farms on the main canal, 2 sources of water feed the farm canal figure (5), the first one is a submersible pump set in water well 500 m away using

Fig. 1. Tilapa fish

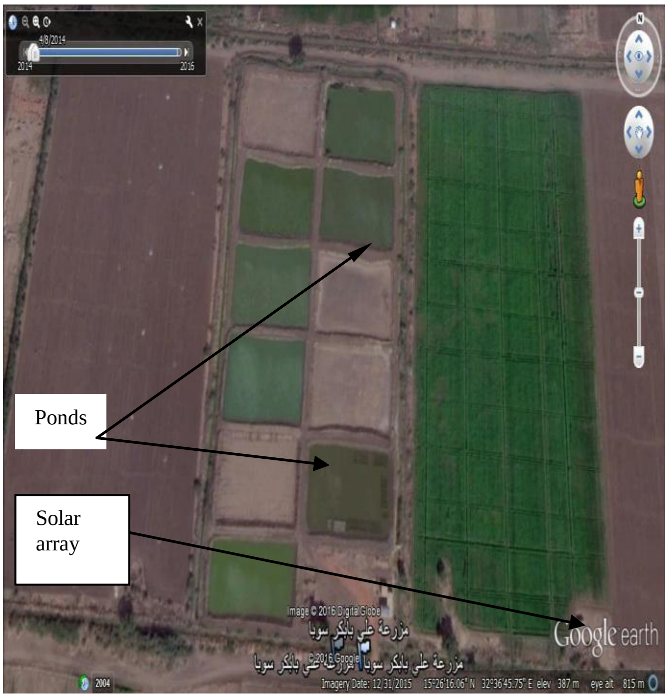

Fig. 2. Google earth photo of Soba fish farm

electricity from the national network, however, instability of electrical current and long distance from the source are the disadvantages, the other water resource is water from the main canal (Soba farm project canal) and the traditional way for pumping widely used is diesel pumping.

The ponds have internal water net consisting of diesel pump causing a catastrophic accident by contaminating fish pond by mix of diesel and engine oil killing tens of thousands of fish **Fig. 6**. Due to these reasons and lack of wind turbines –speed of wind is less than 4m/s and this value is not enough to generate electric current - an effective and smart way for the farm was a solar pumping. A DC centrifugal solar pump, 2 HP with 1800 rpm consuming 1500 watt generated from panel consisting of 12 PV modules was selected. The oil pump is now rarely used. The diameter of the pipes of the internal net is 0.0762 meters and it rounds the farm to feed all ponds, and in addition there is a direction valve centred in the farm, the purpose of this valve, is to pass water from each source while the pond is being filled. There is small oil pump used to spill the water out from the canal when the canal is empty of fish. The start of this project was on 9 July 2015, in spite of the short time the solar pump worked very well, this gave moral support to future project view.

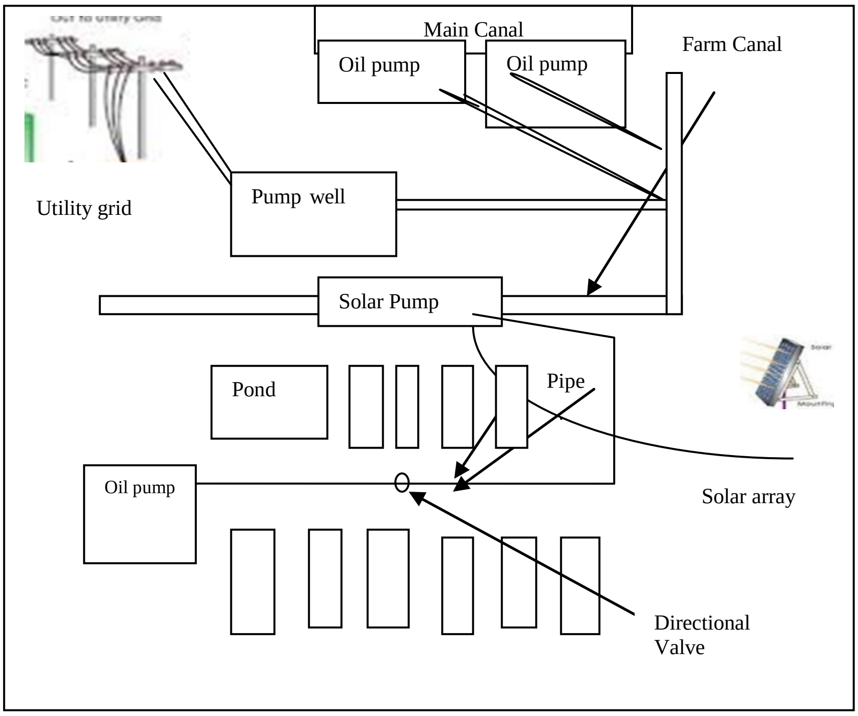

Fig. 3. Schematic presentation of Soba fish farm

Fig. 4. Soba Fish ponds

Fig. 5. Sources of water

Fig. 6. Farm diesel pump

5. SOLAR PHOTOVOLTAIC WATER PUMPS SIZING

Like most of the world , the most highly distributed source of renewable energy in Sudan is solar , PV solar energy is the most easily scalable type of renewable energy generation ;it can be produced in amounts from a few kilowatts at the residential scale up to multiple megawatts at the utility scale .the major disadvantages of a PV system is the intermittence from the diurnal and seasonal cycles of the sun , which made variability of power generation , that depends on the level of insulation-incident solar radiation- which can vary due to atmospheric conditions. The output of the array depends on the annual or global solar radiation of the PV array (kWh/m²) of the site. The sun peak hour is equal to 1 kWh/m² of energy available per day. In table (1) , Values of the daily (sun peak hours) and yearly average of global solar radiation at 16 stations in Sudan have been computed .

The size of photovoltaic (PV) panels can be calculated in soba with sun peak hours equal to 6.3 hours (nearest town is Shambat) [8].

Table 1. Average and total peak sun hours at selected location in Sudan

Town	Ava.(hours)	Total (year)
Portsudan	5.8	2116
Aroma	6.0	2174
Shambat	6.3	2312
Wad Madani	6.3	2315
Abu Naama	6.3	2282
Dongola	6.7	2438
Hudeiba	6.2	2268
Elfasher	6.3	2309
G.Gawazat	6.0	2201
Zalingei	6.4	2328
Babanusa	6.1	2233
Kadogli	5.9	2159
Malakal	5.6	2045
Juba	5.4	1981
Toker	4.88	1792
Elshowak	6.36	2425

Source: www.ijstr.org

A. *Solar Array*

Solar photovoltaic water pumps have the advantages of easy installation, low operation cost and long life [9]

A solar-powered water pumping system is made up of two basic components. The first component is the power supply consisting of photovoltaic (PV) panels; the other major component of these systems is the pump. Solar water pumps are specially designed to use solar power efficiently [10].

For a specific volume the size of photovoltaic (PV) panels can be calculated as follows:

$$HE = V \times \rho w \times g \times H / 3.6 \times 10^6) \quad (1)$$

where HE: Hydraulic energy (kWh/day)
V; Volume of water (m^3/day)

ρw : Density of water (1000 kg/m^3)
H : Total head (m^3)
g : Gravity (9.81 m/s^2)

$$P_{PV} = HE/((\frac{S}{days} of\ operation) \times F \times E) \quad (2)$$

where Ppv : is the nominal power of PV at standard test condition (STC) in (kW)
S : peak sun hours
F : array mismatch factor = 0.85 on average
E : daily subsystem efficiency=0.25 - 0.40 typically

The daily volume of water required for the farm is about 200 m^3 with 3 m head the hydraulic energy needed =

HE = V×ρw ×g×H /(3.6×10^6)
= 200× 1000×9.81×3/((3.6×10^6) = 1.635000 kWh/day
Ppv : HE / ((S / days of operation) x F x E)
= 1.635000 kw/(0.25 × 0.85× 6.3) = 1.22 kW (3)

In practice, the nominal size of the PV array should be chosen based on the load size and the budget. The required PV power is calculated from the chosen nominal PV power using the formula Epv = Ppv / η

η = is a decreasing factor (0.9- 0.8), which takes into account phenomena such as modules temperature, dust, array imbalance, and circuit losses.

Nominal PV power = 1.22/0.8 = 1.52 KW

Fig. 7 shows the PV farm system which consisting of 12 modules with the same specifications, arranged in series-parallel configuration array to meet the power need for the solar pump, 4 in series to enforce the pump voltage, and the 3 arrays are then connected in parallel to supply the current to the pump. The panel is tilted at 13.6 degree facing to south. The maximum PV power is 1.800 kW connected directly to the solar pump without need to battery storage. Table (2) shows the normal ratings of each module. There is a small module for lighting the farm rooms **Fig. 8**.

B. DC Pump

A DC solar electric centrifugal pump was used to supply water to the ponds, the maximum suction head lift was 10 feet, The PV system was directly connected to the pump, because there was no need for water storage. When using surface solar pump, it is necessary to describe the pumping station Characteristics using the following terms:[11]

Table 2. Normal ratings of the each module

Max. power	150 W
Current Max power (I_{mp})	8 A
Voltage Max power (V_{mp})	18.8 V
Short circuit current (I_{sc})	8.5 A
Open circuit voltage (V_{oc})	22.7V

Fig. 7. photovoltaic (PV) panels

Fig. 8. Small module

1. Total dynamic head: Vertical distance from water surface in the source to the discharge or top tank+ pipe friction losses.
2. Minimum DC voltage rating: voltage at the pump × 2.
3. Ampere rating: amps at the pump + 15-25-%.
4. Minimum PV Array watts: pump load × 1.3 .

Figs 10 and 11 show the solar pumping station. With referred to **Fig. 12**, the selected pump had the curve number 9. **Table 2** shows the Characteristics of the selected pump.

Table 2. Characteristics of selected pump

Curve number	Nominal voltage	Voltage at the pump	Amps at the pump	Pump array watts	Min. array watts
9	24 V	30 V	24.4 A	732 W	952 W

Fig. 10. DC solar electric centrifugal pump

Fig. 11.. DC solar electric centrifugal pump

From data sheet and for 10 feet dynamic head the pump produce about 70 gallons per minute or 1.17 gallons per second and this equal to 0.0047 m^3 per second. The total flow rate is being equal to 201.6 m^3 per day.

6. EXPERIMENTAL WORK

Experimental field analysis techniques are methods in which the real system is tested in order to validate the results obtained from data sheet, and discuss the benefit of solar pumping in fish farm. Tests are carried out for two days 5, 6 October 2015. For the intermittence diurnal of the sun irradiance the flow rate on 5 October reached 0.0087 m^3/s in the afternoon and fell down at the end of daylight to 0.0049 m^3/s, and for 8 hours work (9 am to 5 pm) – before 9 am and after 5 pm the flow rate was almost zero- whereas on 6 October reached 0.0082 m^3/s in afternoon and fell at the end of daylight to 0.0051 m^3/s.

The total flow rate was found between 0.0568 m^3/s and 0.0602 m^3/s for the two days and the average flow rate for the two day was 0.0073 m^3/s. The maximum daily flow rate was 241.28 m^3 on 5 October and 237.57 on 6 October, with average of 204.48 m^3 on 5 October and 216.81 m^3 on 6 October, the average per day for the two days was 210.65 m^3. This result was close to what in the data sheet. The minimum amount of water needed for each pond was about 2400 m^3 and maximum was about 6000 m^3 but there was schedule depending on the age of the fish to fill the ponds. Depending on the average daily flow rate the pond need 10 to 20 to be ready to receive the new fish, to fill all ponds three months days average enough for minimum amount of water, while 6 months are enough for the maximum amount of water. but the problem was that the farm canal in which the pump is laid is

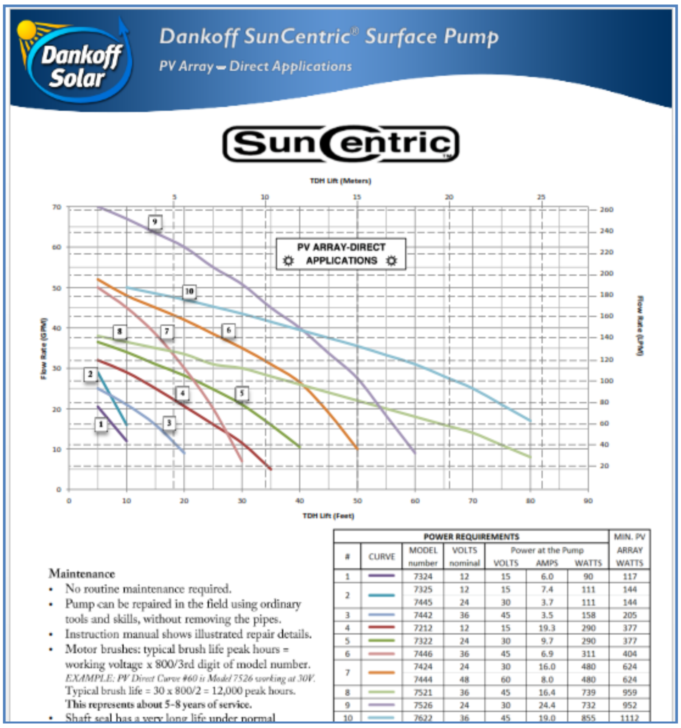

Fig. 12. A typical characteristics for the solar pump

fed from the main cancel by two diesel pump and a well connected to main grid , this two sources are shared with other farms , this situation made some difficulties for the farm canal to have water continuously. As mentioned above the ponc Working point pendent on the solar pump, the old diesel pump is operate with much care and for emergency reasons.

Table 3. Experiment results on 5-6 October 2015

Time	5 October 2015		6 October 2015	
	Q(m^3/s)	Q(m^3/day)	Q(m^3/s)	Q(m^3/s)
9-10 A.M	0.0065	186.13	0.0066	189.93
10-11 A.M	0.0078	225.72	0.0077	222.71
11-12 A.M	0.0079	226.45	0.0087	251.43
12-1 P.M	0.0068	196.59	0.0082	237.57
1-2 P.M	0.0084	241.28	0.0082	237.13
1-2 P.M	0.0076	220.11	0.0079	228.16
3-4 P.M	0.0069	198.93	0.0076	219.85
4-5 P.M	0.0049	140.64	0.0051	147.73
Total	0.0568	1635.85	0.0602	1734.49
Average	0.0071	204.48	0.0075	216.81

7. CONCLUSIONS

The microgrid in Soba fish farm is a good example of a hybrid solar power system, the solar irradiance in the area was enough for the project.

For further studies storage can be added to the system for continuity of water supply to the ponds, and used of tracking system may enhance the micro grid system.

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REFERENCES

[1] Omar Ellabban , Haitham Abu-Rub, Frede Blaabjerg " Renewable energy resources : current status , future prospects and their enabling technology " Renewable and sustaiable energy Reviews 2014.

[2] Babak Fahimi *etal.*, "Powering a more electrical planet," IEEE power & energy magazine , july/august 2001 pp5.

[3] Laurent Schmitt *etal.*, " Micrgrids and the future of the european city " IEEE power & energy magazine , july/august 2013 pp23.

[4] Benson ,Tess, "Advacing aquaculture fish of farm at Slaughter," Humane socity of the United States 12-6-2011.

[5] Hastein ,T., "Animal walfare issues relaing to aquculture," Proceedings of the global conference on animal walfare , 2011 , pp.219-12.

[6] Jhingran VG., "Introduction to aquculture," Nigeriaearch ,FAO, Institute for oceanography and marine Rom.

[7] Swift,DR., "Aquculture training manual," Edition 2, John Wiley &Son . ISBN 9780852381946.

[8] OMER, A. M.,"compilation and evaluation of solar and wind energy resources in Sudan", Renewable energy, Vol.12, No, 1, pp. 39-69, Elsevier 1997

[9] Ali Omer , Mahmoud Onsa , Hyder Mohammed " Econmic Evaluation on Photovoltaic and Wind pump"Sudan Engineering Socity Jornal 2014.

[10] Abu-Aligah "Design of Photovoltaic Water Pumping System and Compare it with Diesel Powered Pump" Jordan Journal of Mechanical and Industrial Engineering 2011

[11] Sun Centric solar pump manual .