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"Design of PV System for Surface Water Irrigation Replacing Diesel Engine Powered Irrigation"

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***Abstract*-Among several photovoltaic applications, irrigation water pumping systems are installed to contribute in the socio–economic development especially agricultural based country. The photo voltaic panel is used to convert solar energy directly to electricity that derives the motor of pump to force water to irrigate farm land as well as to the water collector.**

The farm land to be irrigated, the quantity and quality of agricultural output to be improved since the land can be cultivated both in summer and winter. To achieve this, power needed to pump the total amount of water need to farm land is get from PV panel electricity generation and thus the panel is sized accordingly. The optimized number PV panels needed to irrigate the selected Legoma farm land 40 modules with small eight pumps to supply water for 20 hectare land in three days period. The total 25 year life cycle cost of the system done by using HOMER software shows two times lower than that of diesel engine system which can emit 19,049 kg of CO_2 per year.

When the Legoma village farm land using PV panel instead of diesel fuel for irrigation power need the health problem of the area, cost of fuel, continuous maintenance require of diesel engine, and stop of function when fuel lost problems to be solved and all crop species to be cultivated throughout the year. This is to meet the dwellers of area food secured and can modify the economic life standards of the peoples around the area.

***Keywords*-- Pumps, PV panel, farm land, diesel fuel.**

I. Introduction And Background

Irrigation is an artificial supplying of water to the soil. It is used to assist in the growing of agricultural crops, maintenance of landscapes, and re-vegetation of disturbed soils in dry areas and during periods of inadequate rainfall. Additionally, irrigation also has a few other uses in crop production, which include protecting plants against frost, suppressing weed growing in grain fields and helping in preventing soil consolidation. In contrast, agriculture that relies only on direct rainfall is referred to as rain-fed or dry land farming. Irrigation systems are also used for dust suppression, disposal of sewage, and in mining.

Types of irrigation

Various types of irrigation techniques and are differ how the water obtained from the source to distribute within the field. In general, the goal is to supply the entire field uniformly with water, so that each plant has the amount of water it needs, neither too much nor too little. The modern methods of irrigation are efficient enough to achieve this goal [1]. The main types of irrigation techniques are: Surface irrigation, Localized irrigation, Drip irrigation, Sprinkler type, Center pivot, Lateral move, Manual using bucket.

Ethiopia is known as a '*water tower of east* Africa' given its peculiar geomorphology, since it has a vast central high plateau surrounded by lowlands. However, most water sources of Ethiopia are not suitable for agricultural irrigation purpose due to its geometric flow through lowest place.

Ethiopia covers a land area of 1.13 million km^2, of which 99.3 percent is a land area and the remaining 0.7 percent is covered with water bodies of lakes. It has an arable land area of 10.01 percent and permanent crops covered 0.65 percent while others covered 89.34 percent. The agricultural sector is the leading sector in the Ethiopian economy 47.7 percent of the total GDP, as compared to 13.3 percent from industry and 39 percent from services (World Bank 2005). Though agriculture is the dominant sector, most of Ethiopia's cultivated land is under fully rain dependent agriculture. Due to lack of water storage and large spatial and temporal variations in rainfall, there is not enough water for most farmers to produce more than one crop per year and hence there are frequent crop failures due to dry spells and droughts which have resulted in a chronic food shortage currently facing the country. Ethiopia has an extremely varied topography. The complex geological history that began millions of years ago and continues, accentuates the unevenness of the surface; a highland complex of mountains and bisected plateaux characterizes the landscape. Interspersed with the landscape are higher mountain ranges and cratered cones.

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According to some estimates about 50 percent of African mountains, about 371,432 km2 above 2,000 meters, are confined within Ethiopia (FAO 1984). Altitude ranges from 126 meters below sea level in the Dalol Depression on the northern border, to the highest mountain, Ras Dashen in the Semien Mountains north of Lake Tana rising to 4,620m above sea level.

Solar water pumping system

Photovoltaic systems are sustainable, environmentally friendly, quiet, and light and require minimal or no maintenance since they have no moving parts. 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. It is then supplied either to a DC pump, which in turn pumps water whenever the sun shines in direct coupled system, or stored in batteries for later use by the pump in battery coupled system. In other case inverter used to convert DC output of panel to AC input of pump. AC input is used in high power system. Therefore inverter is used for is used for this system because of its high power requirement.

The other major component of these systems is the pump. Solar water pumps are specially designed to use solar power efficiently and pumps water imparting the rotation energy of shaft to fluids hydraulic or pressure head. Conventional pumps require steady AC current that utility lines or generators supply.

The need of high volume of water pumping keeps the cost of the system high by using number of solar panels and using the entire daylight period to pump water. Most solar water pumps are designed to use solar power most efficiently and operate on 12 to 36 volts.

Figure 1: PV pumping System configuration

A. Statement of problem

Irrigation is the important crunch for the development of agricultural economy based under developed country like Ethiopia. However, the power source of it should be friend to environment and economically feasible and optimum cost through the life of the power generation without any interruption of supplying water to the irrigating land.

Legoma village farm land near to Bahir Dar city uses diesel fuel as power source to run water pump and which the farm land is already in irrigation and these fed-ups the life of the area by pollution and unpleasant sound of diesel generator. There is also the interruption of irrigation water supply when the fuel of the system runs out. Due to time dependent cost of the fuel (both material and transport cost) make the life cycle cost of it is very complex and high.

Replacing this diesel powered irrigation system of Legoma farm land by photovoltaic solar irrigation system by designing optimal PV system to make the irrigation sustainable. Therefore there will be no power interruption, and environmental pollution with minimum life cost and zero maintenance and inspection cost.

B. Objectives of study

General objectives

The general objective of this project is design and optimal sizing of PV system and system optimized configuration to supply uninterrupted water supply to irrigate 20 hectare Legoma farm land near Bahir Dar city.

Specific objectives

Designing and optimizing of PV system for water pumping with dip water storage to irrigate 'Legoma village farm land on the way of nearby Abay River is to attain the following objectives:

- To design optimal PV system replacing diesel powered previous irrigation system of Legoma village farm land which is near Bahir Dar city
- To carry out feasibility study comparing it PV system with diesel system by using HOMER software
- To utilize near surface flowing Abay river water resource of the area for irrigation and its need of small power in low cost for long time.
- To do good system over all configuration. Having of good geometry of the land for the gravitational flow from the storage water to all area, thus PV panel is sized only for the power of pumping.
- High life and low or no maintenance cost, and environment friend PV panel rather than diesel fuel sized to make effective use for all area increase productivity with low cost.

C. General Methodology

The methodologies incorporated to achieve the listed specific objectives of the research project are listed in sequentially below.

- Meteorological data from Bahir Dar meteorological data center (solar radiation, mean environmental temperature, average wind speed).

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- Other primary data sources will be getting from direct observing the maximum height of the water storage for the head of pump and the position of water storage will be selected for gravitation flow of water to all irrigating land area.
- Revising previous study documents and literatures focusing on standalone solar PV system for irrigation.
- Data collected of solar energy and the daily water demand of the land the size and quantity of the pumps determined, the required number of PV modules estimated, wires joints and valves selected, the total life cycle cost and its feasibility study performed and accordingly final document compiled.

II. Parts Design Analysis

A. General Crops Water Need Estimation

In the absence of any measured climatic data, it is often adequate to use estimates of water requirements for common crops of one square meter area shown table below (Table-I). However, for a better understanding of the various factors and their interrelationship which influences the water demand of a specific plant, the following has been drawn from the FAO Irrigation Water Management Training center.

Table I:
Approximate Values Of Seasonal Crop Water Need [8].

Crops	*Crop water need (mm/total growing period)*
Beans	*300 - 500*
Citrus	*900 - 1200*
Cotton	*700 - 1300*
Groundnut	*500 - 700*
Maize	*500 - 800*
Sorghum/millet	*450 - 650*
Soybean	*450 - 700*

B. Factors influencing crop water requirements

i. Influence of climate

A certain crop grown in a sunny and hot climate needs more water per day than the same crop grown in a cloudy and cooler climate. There are, however, apart from sunshine and temperature, other climatic factors which influence the crop water need. These factors are humidity and wind speed. When it is dry, the crop water needs are higher than when it is humid. In windy climates, the crops will use more water than in calm climates.

ii. Influence of crop type on crop water needs

The influence of the crop type on the crop water need is important in two ways. The crop type has an influence on the daily water needs of a fully grown crop; i.e. the peak daily water needs of a fully developed maize crop will need more water per day than a fully developed crop of onions.

The crop type has an influence on the duration of the total growing season of the crop. There are short duration crops, e.g. peas, with duration of the total growing season of 90-100 days and longer duration crops, e.g. melons, with duration of the total growing season of 120-160 days. There are, of course, also perennial crops that are in the field for many years, such as fruit trees.

These data may be obtained from, for example, the seed supplier, the Extension Service, the Irrigation Department or Ministry of Agriculture.

Table-II
Indicative Approximate Values Of The Total Growing Period [8]

Crop	***Total growing period (days)***	***Crop***	***Total growing period (days***
Alfalfa	*100-365*	*Melon*	*120-160*
Barley/Oats/ Wheat	*120-150*	*Millet*	*105-140*
Bean, green	*75-90*	*Onion, green*	*70-95*
dry	*95-110*	*dry*	*150-210*
Citrus	*240-365*	*Pepper*	*120-210*
Cotton	*180-195*	*Rice*	*90-150*
Grain/small	*150-165*	*Sorghum*	*120-130*
Lentil	*150-170*	*Soybean*	*135-150*
Maize, sweet	*80-110*	*Squash*	*95-120*
grain	*125-180*	*Sunflower*	*125-130*

Crops water requirement of Legoma village farm land

The farm land near Bahir Dar is approximately semi-arid climate zone with average daily temperature of 15-25°C. The corps usually cultivate in are maize, sorghum, barely, oat, wheat, and other winter crops like onions, millet and so on.

To determine the total amount of water needed for irrigation is by considering the crop of highest water needing and largest growing period for this design purpose. Therefore, maize is selective crop for the area having of 500-800 mm/total growing period and 80-110 total growing periods.

The daily water need of maize is equal to max mm of water need/total growing period divided to the total growing period.

Thus taking average its water need, 650 mm/total growing period:

650/110=5.9 mm/day

=0.0059m/day→Water is required daily over one m^2

The total volume of water required daily to irrigate 20 hectare land of Legoma village near Bahir Dar is obtained by multiplying the value by the area of the land. So, the area of 20 hectare land is $200{,}000m^2$ and the volume of water requires is:

Discharge rate of water:

Q*= 0.0059m/day *200,000m^2

=1180.0m^3 →Water needed for each days of total 110 maize growing periods.

And considering loss of water from storage by evaporations and water at the flow ways of the gravity flow, the water amount in storage reservoir should be at least three times of that of the required amount.

Therefore, the total amount of water for pumping is

Q** = 3*1180.0m^3 =3540.0m^3/day.

The crops are irrigated three day gaps and the pumps should pump one day should be:

Q = 3540.0m^3/day /3
=1180.0 m^3/day

But there is no single pump capacity to pump 1180.0 m^3/day of water daily. Therefore the number of pumps used for water requirement and system should be optimized.

If the number of pumps is increased much, the cost of pump is increasing rather using a single or less number of pumps and the pipes and drainage cost, wiring of the PV system to be increased. In other case the number of PV panel is saved if a less quantity of pump is used. Whatever, the number of PV panel saved by increasing pump number is too small comparing with the system increase of pipes to drain it to storage, and wiring, and also increase system complexity. Therefore, it is better using low number of pumps rather increasing increased number of pumps and the idea is discussed in detail in section analysis result discussion.

Geometry and storage position

From the geometry of the area, the total head needed to the pump to pump water is the total vertical height that is the water from the base of river to the water storage area.

The river is flowing distributable over surface of earth which has no depth from farm land level but the storage should be some height from the level of farm land that is for free natural gravitational flow of water to irrigating land. Its height is approximately observed about 5-7m and the calculation must be in 7m head which is total distance from Abay river pump installation to water storage.

The source of water is the surface flowing Abay River near the farming land area. The area is irrigating before by diesel fuel based irrigation. The problem of replacing diesel fuel by free solar energy is to maintain environmental healthy, to reduce the cost of diesel engine system continuous maintenance and inspection, fuel cost and its transportation cost to bring it.

C. Power require of pump

The power out of the pump is the work that the pump does while pushing the water through the pipes line for certain height. Work input of pump on the fluid to be equal to the power that must be getting from PV panel. The input and output power of pump is related with the efficiency of the pump.

So, to size PV panel to derive pump to force the water for a certain height, the input power of pump should be known first and calculated by using the formula below [3].

$$\text{Pin} = \frac{hg\rho d}{\eta * 3600}(\text{wh/day}) \ldots\ldots\ldots\ldots\ldots (1)$$

Where;

h-the head that the pump wants to force water

g - Gravitational acceleration

ρ - Density of fluid

η - Efficiency of pump.

Figure 2: Pumping of water

The pump head is term derived from the Bernoulli equation, an energy balance around the pump. The total head developed by pump is:

$$h=\frac{v^2}{2g} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(2)}$$

Where v is the flow speed of fluid, h is the pump total head, and g gravitational acceleration.

$$V=\sqrt{2gh}.$$
$$=\sqrt{2*9.81*7}$$
$$=11.72\text{m/se}$$

The flow rate Q is also the product of flow speed and the flow area of pipe.

$$Q=v*A\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(3)}$$
$$A=Q/v,\ Q=147.5\text{m}^3/\text{day}=0.00409\text{m}^3/\text{se}.$$
$$=0.00409\text{m}^3/\text{se}/11.72\text{m/se}$$
$$=3.5*10^{-4}\text{m}^2$$

Then the inner diameter of the pump outlet flow is calculated as;

$$D=\sqrt{\frac{4A}{\pi}}$$

=0.0211m =22mm, D=25mm for standard selection of pipes.

D. Photo voltaic panel specification

Photovoltaic panels manufactured in different textured material and that make it most flexible to different activities and applications. Photovoltaic, in its simplest terms, means the conversion of sunlight into electrical energy directly.

Technical data selected photovoltaic module:

Type: JSTY230M-96; Module efficiency: 13.5%; Cell efficiency: 15.80%; Nominal voltage: 48VDC: Power peak: 230W; Vm: 48V; Cost: $402.5; Im: 7.60A; Voc: 58.6V; Isc: 5.15A; Power output tolerance: -0/+5W; Electrical parameters tolerance: +/- 6%; Dimension: 1575×1082×50mm.

Different size of PV modules will produce different amount of power. To find out the sizing of PV module, the total peak watt produced needs. The peak watt (WP) produced depends on size of the PV module and climate of site location.

This discussion illustrates the various assumptions and tradeoffs you need to make when designing a PV system. We begin by analyzing our electrical load requirements and minimizing these loads. Then, if cost were not an issue, we could over-design the system, assuming worst-case scenarios for solar insulation, and choosing the optimum battery discharge level. In this way we could attempt to make the system fail-safe. As our resources are not infinite, we chose to design a smaller system with the understanding that it could fail during poor conditions.

E. PV Sizing Calculations

The area of land wanted to irrigate is 20 hectare and the total water needed is 1180.0 m^3/day and there is no pump which can pump more than 2136 gph water daily by using PV panel. Therefore, the system needs at least eight small pumps satisfactorily to fulfill the water require of the land.

For system optimization need, let different number of pumps used:

A. If eight pump used for whole system:

Q=1180.0 m^3/day/8=147.5m^3/day=1597.92gph →From previous estimation and it is possible to get from a single pump.

The power input to the pump or the power required from the PV panel is calculated by using equation (1) as follows:

$$Pin=\frac{hg\rho d}{\eta*3600}$$
$$=\frac{7*9.81*1000*147.5}{0.7*3600}$$

=4019.37Wh/day →This is power require of one pump per day.

Load for size (EL): 4019.37Wh/day.

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Table-III
Solar Data Around Bahir Dar For Each Month (NASA)

Variable	I	II	III	V	VI	VII	VIII	IX	X	XI	XII
Insulation, kWh/m²/day	5.76	6.20	6.48	6.26	5.74	5.02	5.04	5.67	5.87	6.01	5.67
Clearness, 0 - 1	0.68	0.67	0.64	0.60	0.55	0.48	0.48	0.56	0.62	0.69	0.69
Temperature °C	21.10	22.43	23.45	21.39	19.00	17.92	17.90	18.81	20.29	20.56	20.56
Wind speed, m/s	4.14	4.28	4.13	4.10	5.09	4.98	4.21	3.50	3.06	3.83	4.09

The PV array output power (P_{Pv} array) is determined:

$P_{PVarray}$= EL/(ηb ∗ Kloss(I)*PPS………………………………..…...(4)

This is the PV output power which must be greater than the total power required to derive pump.

Where:

- ✓ ηb → wiring loss ∗ inverter loss efficiency =0.95*0.1=9.5%.
- ✓ $Kloss$→is temperature loss, circuit loss, and others…
- ✓ I → is average solar radiation incident near Bahir dar (KWh/m^2/day).
- ✓ PPS →is peak solar intensity (W/m^2).
- ✓ EL →is average daily load consumption (KWh/day).

- $Kloss \approx$ 90%.
- I=5.02 KWh/m^2/day
- PPS=1000W/ m^2.
- EL=4.0194kwh/day
- $P_{PVarray}$=4.0194/(0.095 ∗ 0.9 ∗ 5.02)*1000 =9.364KW

This is power output of the panel that can derive pumping of system and the photovoltaic panel sized to get this power. Inverter DC input voltage = 24V. That is making all panels in parallel connection and the output nominal voltage of the panel to be 48V, i. e. to make equal with the inverter DC input voltage.

Amp-h/day used by loads: The total PV panel energy needed divided by inverter DC input voltage.

$$=\frac{9.364KW}{48} = 195.08Amh$$

Array sizing:

Average Sun Hours/ day near Bahir dar is: PSH = 5.8*

Total Solar Array Amp = $\frac{195.08Amh/day}{5.8\ SH}$=33.63Amh

Optimum Amps of specified Solar Module Used = 7.8.

Total number of modules required: = $\frac{33.63Amh}{7.8}$ = 4.3≈ 5 modules.

The total number of panels needed for whole system is, N_T=5*8=40 modules.

B. If ten pumps are used:

Q=1180.0 m^3/day/10=118.0 m^3/day

$$Pin = \frac{hg\rho d}{\eta * 3600} = \frac{7 * 9.81 * 1000 * 118.0}{0.7 * 3600}$$

=3215.5wh/day →This is power require of one pump per day.

PV Sizing Calculations for a single pump:

Load size: 3215.5wh/day

- $Kloss \approx$ 90%.
- I=5.02 KWh/m^2/day
- PPS=1000W/ m^2.
- EL=4.0194kwh/day
- $P_{PVarray}$=4.0194/(0.095 ∗ 0.9 ∗ 5.02)*1000 =9.364KW

This is power output of the panel that can derive pimping of system and the panel sized to get this power.

Inverter DC input voltage = 24V. That is making all panels in parallel connection and the output nominal voltage of the panel to be 48V, i. e. to make equal with the inverter DC input voltage.

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Amp-h/day used by loads: The total PV panel energy needed divided by inverter DC input voltage.

$$= \frac{9.364KW}{48} = 195.08Amh$$

Array sizing:

Average Sun Hours/ day near Bahir dar is:

PSH = 5.8*

$$\text{Total Solar Array Amp} = \frac{195.08Amh/day}{5.8\ SH} = 33.63Amh$$

Optimum Amps of specified Solar Module Used = 7.8.

Total number of modules required: $= \frac{33.63Amh}{7.8} = 4.3 \approx 5$ modules.

The total number of panels needed for whole system is, $N_T=5*8=40$ modules.

C. If twelve pump are used to run the system:

$Q=1180.0\ m^3/day/12=98.34\ m^3/day$

The power input to the pump or the power required from the PV panel is calculated as follows

$$Pin = \frac{hg\rho d}{\eta * 3600} = \frac{7 * 9.81 * 1000 * 98.34}{0.7 * 3600}$$

=2679.6wh/day

(Power require of single pump among twelve pumps per day)

Load for size (EL): 8038.75wh/day.

$P_{PV\ array}=2.6796/(0.095 * 0.9 * 5.02)*1000.$

=6.243KW

The system uses DC pump and no loss at the inverter.

Inverter DC input voltage = 48 V.

Amp-h/day used by DC loads: The total PV panel energy needed divided by inverter DC input voltage.

$$= \frac{5.931KW}{48} = 123.5Amh$$

Array sizing:

Average Sun Hours/ day near Bahir dar is:

PSH = 5.8*

Total Solar Array Amps is:

$$= \frac{123.5Amh/day}{5.8\ SH} = 21.3Amp$$

Optimum Amps of specified Solar Module Used = 7.8

Total number of modules required: $= \frac{21.3Amp}{7.8} = 2.73 \approx 3$ modules /pump.

The total number of panel of the system to be $N_T=3*12=36$ modules.

Table-IV
Comparison Of Use Of Eight And Greater Number Of Pumps For System Optimization

Number of pumps	*Total number of module (N_T)*	*Number of modules saved*	*System cost increment($)*
8	*40*	*--------*	*---------*
10	*40*	*0*	*847.8*
12	*36*	*4*	*1695.6*
16	*48*	*-8*	*3391.2*
20	*40*	*0*	*4239*

As we see from table 5 above, if ten pumps used the number of panels are equal with using of eight pump system but two additional pumps used, and thus passage pipes and wires of the system are also will be other additional cost. It is quite proves the estimation I have done in section above by using different small pumps with different value of discharge and wattage require. In the case of 12 pump use four panels are saved which is (4*$402.5= $1610) which is less than that of the system cost as shown table 6 below. If the system uses 20 and above panels, more number of panels needed as that much the system is going to be complex. It is clear that the optimum number of pump is eight to run the whole system because there is no pump capacity below eight pump use.

F. Inverter Specification

An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total watt of appliances. The inverter must have the same nominal voltage as your battery for the applications of battery required.

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For standalone system the inverter must be large enough to handle the total amount of watts you will be using at one time. The inverter size should be 25-30% bigger than total watts of appliances.

Table-V
Specification Of Inverter

Specifications XW6048	***XW9048(Xantrex inverters)***
Nominal DC Input Voltage	*24VDC*
AC Output Voltage	*120/240 VAC*
Nominal Frequency	*60 Hz*
Continuous Power @ 25C	*6000W*
Efficiency (peak)	*95%*
Maximum Charging Rate	*100 amps*
Cost	*$1,500.00*

The pumping total watt is (P= 8.897KW) from previous calculations. Therefore the inverter capacity is, piv=1.25*P)/ηi=1.25* 8.897KW/0.95 =11.705KW with input voltage 48V. Therefore, two series (6 KW inverter) and two parallel totally four inverters used for single sub system of pumping.

Investment cost estimation and prices of parts

The cost of system installation of PV panels to get power to derive the motors of pumps is first getting the total cost for a single sub system of pumping and may be multiplied by the number of sub system. Some investments costs like time dependent and massive should to be assumed since there is no data. The quantity and cost of the whole system is summarized in table below.

Table-VI
Summarized Total Initial Material Cost

Items	***Quantity***	***Unit price ($)***	***Total price ($)***	***Specifications***
PV panel	*40*	*402.5*	*16100.0*	*Monocrystalline*
pump	*8*	*353.90*	*2,831.2*	*Submersible type*
Pipe/m and joints	*…..*	*…*	*138*	*Ø25mm*
Storage constru.	*1*	*2,60.00*	*260.00*	*Volume capacity 3540.0 m^2*
Distribution Flow lines		*1,00.00*	*100.00*	*Assumed value*
Inverter	*2*8=16*	*1,500.00*	*24,000*	*series Connected two inverters for individual sub system*
Total			***43,429.2***	

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G. Comparison of PV panel and diesel engine using HOMER software

A diesel generator is the combination of a diesel engine with an electric generator (often called an alternator) to generate electric energy to run the pump for irrigation. Diesel generating sets are used in places without connection to the power grid or as emergency power-supply if the grid fails. Small portable diesel generators range from about 1 kW to 10 KW may be used as power supplies on construction sites, or as auxiliary power for vehicles.

The packaged combination of a diesel engine, a generator and various auxiliary devices (such as base, canopy, sound attenuation, control systems, circuit breakers, jacket water heaters and starting system) is referred to as a generating set or a genset for short.

The economic viability of a stand-alone solar photovoltaic (PV) system with the most likely conventional alternative system for replacing other sourced system. A diesel-powered system, has been analyzed for energy demand through sensitivity analysis using a life-cycle cost computation. The sensitivity analysis allows estimation of the comparative viability of PV against a conventional alternative system based on particular country-specific parameters. The overall PV best and worst case viability, as compared to a conventional diesel-powered system, have been obtained from sensitivity analysis of the energy demand by using HOMER software. To do the comparison of diesel base irrigation and PV panel power generation system, assuming PV panel maintenance and operation cost zero through the 25 years of its life time.

- ✓ The maintenance and operation (O&S cost) is $ 3.0 per hour.
- ✓ The replacement cost is $ 1.0 per hour
- ✓ The cost of diesel fuel $ 0.8 per liter
- ✓ Fuel consumption of generator 0.4/KW

1. PV system HOMER cost optimization

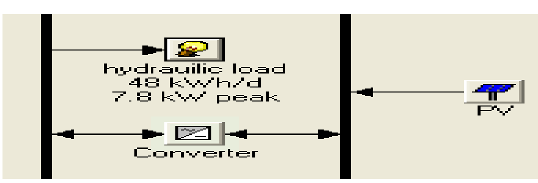

Figure 3: HOMER implementation of standalone system

PV (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage
9.00	11...	$ 16,531	3,957	$ 67,115	1.088	1.00	0.87

Figure 4: Optimizations result of HOMER

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	15,431	0	0	0	0	15,431
Converter	1,100	0	50,584	0	0	51,684
System	16,531	0	50,584	0	0	67,115

Figure 5: HOMER life cycle cost of the system

Since the cost of storage construction and distribution line is not included in HOMER calculation, the total investment cost of table above is greater.

2. Diesel engine power generation HOMER cost estimation

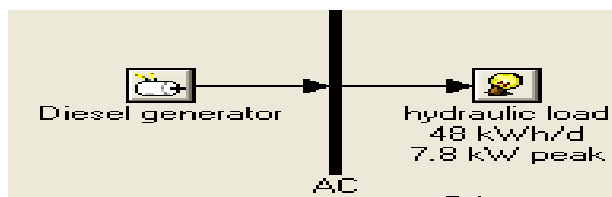

Figure 6: HOMER implementation of diesel generation system

Label (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
8.0...	$ 2,458	17,033	$ 220,198	0.977	0.00	7,234	4,379

Figure 7: Optimizations result of HOMER

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Diesel generator	2,458	345	143,417	73,978	0	220,198
System	2,458	345	143,417	73,978	0	220,198

Figure 8: HOMER life cycle cost of the diesel generation system

III. Result And Discussion

The HOMER optimization result of comparison of standalone PV system and diesel generation for the life of total 25 year is as shown from figure 5 and figure 7, the total life cycle cost of diesel engine system is more than three times greater than that of the PV system. This is only in the case of cost, but the defectives of diesel engine is not only cost it has environmental pollution, and sound disturbing of the area. The figure-9 below shows that the emission rate of pollutants in using of diesel for power generation which indicates its negative environmental effect. For example the emission of CO2 per year is 19,049 Kg is very huge amount which is disturbs the purity of the air. So for these all things defectives

Pollutant	Emissions (kg/yr)
Carbon dioxide	19,049
Carbon monoxide	47
Unburned hydrocarbons	5.21
Particulate matter	3.54
Sulfur dioxide	38.3
Nitrogen oxides	420

Figure 9: Pollution emission of diesel engine per year

IV. Conclusion And Recommendation

The PV system irrigation of surface water pumping is the use solar energy by the direct conversion of solar energy by PV cell to electrical energy to derive the motor of the pump. The PV system irrigation more flexible to use from small single module system to large hectares of land pumping is possible. Ethiopia has adequate solar energy habit, but is still not utilized and the system of utilization is also not developed well.

This project provides full data for the using of PV panel to irrigate 20 hectare Legoma village farm land with single water storage of capacity of 1180.0 m^3 to distribute water by gravitational flow to all area of irrigating farm land. System optimization and configuration has done and shown that PV system total life time cost is more than two times lower than that of diesel pumping system. For cost optimization, there are eight similar sub systems of pumping that pumps the water to a single storage. Types and quantity of the accessories and system configuration with total the investment cost is estimated for 25 life time of the system.

And it is better if the system is hybrid with other energy generation system, the cost of system less as much as the system irrigation may be without interruption that may happen when solar energy inadequate.

All the system calculation are by considering only to use the power of the panel for power of pumps, the number of modules for single system is large, it is better if it is grid tied or other system aided for the system optimization determining feasibility.

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