USE OF PHOTOVOLTAIC SYSTEM FOR STANDBY OPERATION OF A PETROL STATION

Case study National Oil Petrol Station at Nairobi West

By

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DECLARATION

STUDENT DECLARATION

This project is my original work and has not been presented for a degree/diploma in any other university. No part of this project may be produced without the prior permission of the author/University of Nairobi.

Signature……..

Date……..

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SUPERVISORS` DECLARATION

I confirm that the above student carried out this research under my supervision as University supervisor.

Signature……..

Date…….

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ACKNOWLEDGEMENT

I do give thanks to God who has made me reach this far. My appreciation goes to my supervisor Prof. J .A .Nyangaya for the many hours he spent in guiding and suggesting new approaches, correcting and final editing of the entire research project report. My gratitude also goes to Engineer Charles Rangara for the generous technical support and groundwork offered in coming up with the project.

I would like to thank National Oil Corporation of Kenya through Engineer Stephen Buku for having given me access to their petrol station to use as a case study.

DEDICATION

I dedicate this Research Project to my wife Evelyn , Sons Belyn Gweth and Benjamin Owiny ,May you live longto change this Planet and make it a better place than you found it.

ABSTRACT

The objective of the study was to compare the cost of using a standby diesel engine generator with that of a photovoltaic system to operate the equipments at a petrol station during a power blackout .

The total power consumption for operation of the petrol station was estimated from the rating of the installed equipments and subsequently a photovoltaic system of equivalent output was designed . The advantages and disadvantages of the two systems were contrasted.

The photovoltaic system was found to be viable for the petrol station in spite of a high initial cost. It has the advantagesof low maintenance cost, clean renewable energy and is noise free.

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CHAPTER ONE

1.0 BACKGROUND

Kenya has an installed Energy capacity of 1.48GW. Whilst about 57 % is hydro power, about 32% is thermal and the rest comprises geothermal and emergency thermal power. Solar photovoltaic and wind power play a minor role contributing less than 1%. However hydropower has ranged from 38-76% of the generation mix due to poor rainfall.(Kenya Energy Situation , 2013)

The hydropower is mainly affected when the level of water in dams start falling due to lack of enough rain which results in power rationing. The generators burning fossil fuels come into operation to salvage the deficiency of power. This is a very expensive source for the cost of fuel is high.

The rate of electricity consumption at peak hours is higher than the generation, hence some loads have to be switched OFF especially during the day in some residential areas in order to supply the most busy areas like industries and some offices

This fluctuation causes power blackouts in some areas especially during the day. Businesses like petrol stations experiencing power blackoutshave installed standby generators to sustain the load during power blackouts.

Photovoltaic system is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductors that exhibits the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing photovoltaic material

1.1 GRID VERSUS STAND ALONE SOLAR POWER SYSTEM

A grid solar power system is one which is connected to the local utility grid so that the surplus electricity produced by the solar panels is fed into the grid system. In a grid connected solar power system when the equipments require more power than what is supplied by the solar panels , then the difference is supplied by the utility grid.

In a stand alone solar power system, the solar panels are not connected to the grid but instead they are used to charge a bank of batteries. The batteries in the bank store power (D.C Charge) produced by the solar panels, which is then converted to A.C Charge and used to power electrical loads especially during non-daylight hours.

Stand alone solar system are of two types, without batteries and with batteries.

1. The systems without batteries provide power only during a sunny day and lack power at night or during a bad weather.
2. The system with battery bank provide solar power as long as the battery charge is above the minimum charge level.

   For this study the petrol station is to be designed to use a stand alone solar power system with batteries, which will be used as a backup system in the absence of the utility power.

1.2 NATIONAL OIL PETROL STATION

The National Oil Corporation of Kenya is a state Co-operation of Kenya by an act of parliament in 1981 with a mandate of participating in all aspects of the Kenyan petroleum industry. It is 100% owned by the Kenyan government, the company is known as National Oil Co-operation of Kenya with main offices located in Nairobi.The company is involved in upstream activities such as exploration, geological research and production and in downstream activities such as supplyof petroleum products, retail networking. National Oil operates 85 service stations across Kenya.

(National Oil of Kenya, 2012)

The most common fuels sold today are petrol, diesel fuel and kerosene. The filling station has underground storage tanks for the storing of the different types of fuels sold . Fuel is usually offloaded from a tanker truck into the storage tanks through a valve, located on the filling stations perimeter. Fuel from the tanks flows to the dispenser pumps through underground pipes

Nairobi West Petrol Station

Figure 1.1 Nairobi West Petrol Station

The facility chosen for study is located off Muhoho road and GandhiAvenue in Nairobi west. The petrol station has one overall manager. Operations at the petrol station are divided into two shifts per day and managed by a supervisor and four pump attendants. The equipment's that consume electricity at the site are in Table 1.1

Table 1.1Equipments at the Filling Station

Equipments	QUANTITY	DESCRIPTION
Compressor	1	Atlas Copco- 5.5kW
Generator	1	Massey Fergusion – 30kVA
Diesel Pump	1	Wayne fuel pump- 1.5kW
Petrol Pump	3	Wayne fuel pump-1.5kW
Fridge for colddrinks	1	520W
Security Lights	2	38W
Fluorescent fittings at the forecourt	6	38W

1.**3 RATIONALE FOR THE STUDY**

Power outage is mainly due to weather challenges and power rationing during peakhours when the generated capacity cannot fully supplement the rate of consumption .In filling stations standby generators are generally arranged tostart immediately there is an outage of commercial power from the utility company.The present study is designed to compare the cost of sustaining operations during outage using a stand alone photovoltaic system instead of a diesel engine generator.

1.4 OBJECTIVES OF STUDY

The specific objectives of the study were

1. Identify the energy consuming units and estimate the total energy consumption at the petrol station.
2. Estimate the duration of use of generator .
3. Design of photovoltaic systemunit as an option to use of generator
4. Carry out comparative costing of the options.

1.5 Limitations of the Study

The following constraint were experienced during the study,

1. There were missing records like ,records of fuel used to fill the generator and also records of spares bought and used for generator maintenance.

2. Some important information was not stored at the petrol station but at the company's headquarters and could not be accessed. This included the cost of some electrical equipments .

CHAPTER TWO

LITERATURE REVIEW

2.1 Energy consumption in Kenya

Kenya's electricity mix is dominated by hydro generation cover and this is highly vulnerable to weather conditions and climate change. The climate conditions of 1998-2000 and 2008-2009 curtailed hydropower generation and led to severe energy shortage which resulted into power rationing. Electricity demand in the country is significantly rising mainly due to the accelerated productive investment and increasing population.

Currently the electricity demand is 1,191MW against an effective installed capacity of 1,429MW under normal hydrology. The peak load is projected to grow to about 2500MW by 2015 and 15000MW by 2030. To meet this demand, the projected installed capacityshould increase gradually to 19,169MW by 2030. The use of petroleum for power generation does not offer a lasting solution due to fluctuations in global market prices of crude oil and the climate impacts of increased green house gas emission.(KenyaPolicy and Regulatory Overview, 2012)

To address these challenges the government has formulated strategies whose objectives are to rapidly expand installed electricity capacity ,expand and upgrade the transmission and distribution networks and develop renewable energy sources like Solar, geothermal and wind. Kenya being a tropical country receives sunshine throughout the year hence a good source of solar radiation is available .

2.2 Operation of machines in a petrol station

The operation of some of the main equipments at the petrol station as tabled in table 1.1 is described as below

2.2.1 The Fuel Storage Tank

The fuel sold at service stations is stored underground in storage tanks. Separate tanks store different types of fuel like diesel, petroleum and kerosene.

2.2.2 Fuel dispenser

A dispenser is used to pump the fuel from the underground storage tanks.

A modern fuel dispenser is logically divided into two main parts;-

An electronic head containing an embedded computer to control the action of the pump, drive the pump`s display, and communicate to an indoor sales system.

The mechanical section which in a ` self contained` unit has an electric motor, pumping unit , meters, pulser and valves to physically pump and control fuel flow.

2.2.3 Air Compressor

An Air compressor takes free air into an intake port, and using mechanical means whether pistons,screws or rotary sliding vanes, pushes that air into a smaller area . The compressor at the filling station is of 5.5KW and of make Atlas Copco. It is a rotary type compressor which has a continuous action. As more and more air is pushed into the smaller area the pressure continues to increase inside the tank. There is a pressure switch that monitors the air pressure inside the tank. When the air pressure reaches the high pressure level setting of 150bar, the compressor shuts off. When air is used from the tank, the air pressure inside the tank fall gradually and when it reaches the pressure switch low pressure setting of 80bar, it turns the compressor ON until the pressure inside the tank again reaches the high set pointand the sequence is repeated again.

Types of compressors

Reciprocating Compressors –use pistons driven by crankshaft. They can be either stationary or potable , can be single or multi-staged and can be driven by electric motors or internal combustion engines. Small reciprocating compressors from 5 to 30 horsepower (hp) are commonly seen in automotive applications and are typically for intermittent duty. Larger reciprocating compressors well over 1000 hp (750 KW) are commonly found in large industrial and petroleum applications. Discharge pressures can range from low pressure to very high pressure (>18000psi or 180MPa). In certain applications such as air compression, multi-stage double –acting compressors are said to be the most efficient available an are typically larger and more costly than comparable units.

Rotary compressors –Because of the continuous rotary action, the rotary positive displacement compressor is smaller for a given flow than its reciprocating counterpart. The machines in this category are generally uncooled and as the compression is carried out at high rate the conditions are approximately adiabatic. **(** Eastop and McconkeyA , 1993)

Table 2.2 Difference between reciprocating and rotary compressors

Reciprocating positive displacement compressor	**Rotary positive displacement compressor**
-Having the characteristic of low mass rate flow	- Has high mass rate of flow
-High pressure ratio	-Low pressure ratio
-It is pulsating in action which limits the rate at which fluid can be delivered	-It is continuous in action
	-Smaller in size for a given flow, lighter in weight and mechanically simpler than their reciprocating counter parts

Figure 2.2 Nairobi West Petrol station Standby Generator Rating 30KVA 41.7Amp 3phase

2.2.4 DieselStandby Generator

A diesel engine generator is the combination of diesel engine and an electric generator to generate electric energy .Figure 2.2 shows the standby Generator found at the petrol station. It has no automatic changeover hence it is switched ON when there is no utility power and switched OFF when there is utility power.

2.3 Photovoltaic energy science

Solar energy refers to the conversion of solar radiation to practical energy like electricity. Photovoltaic systems or solar cells are used to turn sunlight directly to electricity . Sunlight is made up of photons of varying amount of energy depending upon their wavelengths. When a photon reaches the surface of a solar cell, it may be reflected, it may pass through or it may be absorbed by the solar cell. The absorbed photon is the only one that can generate electricity. When absorbed the energy of the photons dislodge an electron from the solar cell. The electron carrying negative charge travel to the surface of the solar cell creating imbalance between the front and back surface of the solar cell. The imbalance becomes the voltage potential similar to the voltage potential between the positive and negative terminals of the battery. Connecting the two surfaces on load will cause the electrons to flow creating a current. This is now electricity generated by solar radiation.

2.3.1Solar System

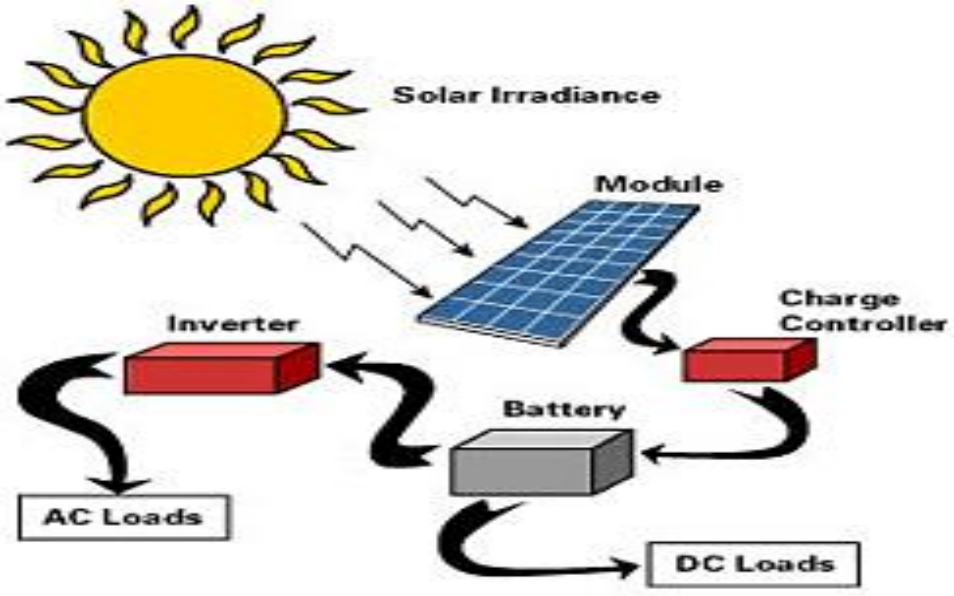

Figure2.3 Solar energy emission path

The main components that make up a complete solar system are

Photovoltaic Module – A collection of photovoltaic modules makes a photovoltaic array which converts sunlight to electricity .It produces DC power which is wired through a charge controller before it goes on to the battery bank where it is stored

Charge Controller- This is a current regulating device that is placed between the photovoltaic array and the battery. The primary function of a charge controller in a stand-alone photovoltaic system is to maintain the battery at the highest possible state of charge while protecting it from over charge by the arrays and from over discharge by the loads. It also eliminates any reverse current flow from the batteries back to the solar modules at night

Battery Bank- The battery bank stores the energy produced by the solar array during the day for use at any time of day or night.

Inverter- The inverter takes the DC energy stored in the battery bank and inverts it to alternating energy

2.3.2Photovoltaic Solar module

Photovoltaic or PV for short can be thought of as a direct current (DC) generator powered by the sun. When light photons of sufficient energy strike a solar cell, they knock electrons free in the silicon crystal structure forcing them through an external circuit (battery or direct DC load), and then returning them to the other side of the solar cell to start the process all over again.

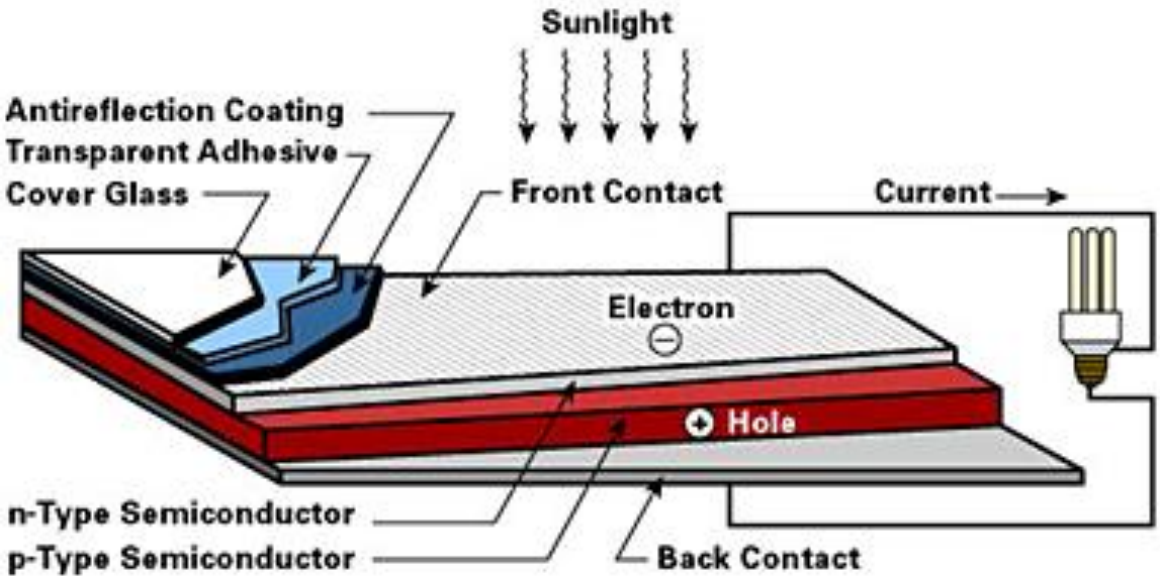

Figure 2.4 solar module

(Ubbink East Africa Ltd, “Solar Energy “)

Solar cells- Solar cells use the electronics properties of semi conductor material to convert sunlight directly into electricity. Major factors which when present in real solar cells affects theoretical efficiencies include : Reflection losses, incomplete collection of electron hole pair and voltage factor.(Turner W C & Doty S, 2009)

2.4Sun characteristics

-Mass= 1.991± 0.002 x 10^{30} kg

- Radius= 6.960±0.001 x 10^{8}m

-Average density= 1.410±0.002 x 10^{3}kg/m^{3}

- Average surface temperature 5762±50K

Solar energy arrives at the edge of the earths` atmosphere, part of this radiation is reflected back to space, part is absorbed by the atmosphere particles. As a result only about two-thirds of the sun`s energy reaches the surface of the earth

The amount of solar energy available to collect in a system depends upon whether the collectors move to follow or partially follow the sun or whether they are fixed. In the case of fixed collectors, the tilt from horizontal and the orientation of collectors may be significant.

Fixed solar collectors are usually tilted at some angle from the horizontal so as to provide a maximum amount of total solar energy collected

Advantages of solar energy

1. Solar energy is renewable – renewable energy is energy generated from natural resource such as sunlight, which is renewable (naturally replenished)
2. Non polluting , no carbon dioxide produced- Solar energy is an excellent alternative for fossil fuels like coal and petroleum because solar energy is practically emission free while generating electricity. The generation of electricity through solar energy produces no noise. So noise pollution is reduced.
3. The abundance of Solar energy- Sunlight is everywhere and the resource is practically inexhaustible
4. Low maintenance-solar panel require less upkeep, once a photovoltaic array is set up it can last for years. Once they are installed and setup there are practically zero recurring cost

Disadvantages of Solar energy

1. Availability of Sunlight- the position of solar arrays is very important in generating of electricity.
2. Initial capital expensive- the initial cost of installing solar energy system is considerably high .
3. Least power at night time- it is impossible to get power at night from solar arrays unless one has a power storage system
4. The presence of solar energy is influenced by the presence of clouds or pollution in the air

CHAPTER THREE

METHODOLOGY

3.1 Data Collection Methods

Data was collected from three main areas namely;-

1. From the generator- The duration of operation of the generator was recorded.
2. From the name plates of the energy installed equipments, the power consumption of the installed equipment's was obtained
3. Available electricity bills were used to estimate electricity consumption

The standbygeneratorwas filled with 20 litresof diesel , switched ON and monitored during power blackout and switched OFF when the commercial electricity resumed. The switch ON time and switch OFF time of the generator was recorded. This tabulation was done till the consumption of 20litres of diesel by the generator during power blackout , the exercise was repeated for a period of one month and the average time used by the standby generator to consume 20litres of diesel was noted.

Table 3.3 Rate of fuel Consumption of generator

Date of filling the tank	Time	Litres of Diesel used	Date of Power outage	Generator Switch ON Time	Generator Switch OFF Time	Total Time Taken
4/03/2013	10a.m	20 Litres	5/3/2013	9.30am	11.47am	2.17hrs
			7/3/2013	11.20am	12.52	1.32hrs
			8/3/2013	13.15hrs	15.25hrs	2.00hrs
			9/3/2013	14.17hrs	16.53hrs	2.36hrs
9/03/2013	16.20hrs	20Litres	12/3/2013	10.23am	12.37	2.14hrs
			15/3/2013	13.40hrs	17.27hrs	3.47hrs
16/3/2013	8.37am	20Litres	19/3/2013	08.36am	12.15hrs	3.39hrs
			22/3/2013	12.24	13.47hrs	1.23hrs
			23/3/2013	10.38am	11.58am	1.20hrs
24/3/2013	7.53am	20Liters	26/3/2013	9.23am	10.24am	1.00hrs
			28/3/2013	16.32hrs	17.18hrs	0.46hrs
			2/4/2013	11.12am	12.54	1.42hrs
			5/4/2013	17.43hrs	18.37hrs	0.54hrs
			7/4/2013	8.05am	10.15am	2.10hrs

Table 3.4 show the total time taken by the generator to utilize 20 liters of diesel.

Table 3.4 Duration of operation of generator

Diesel Filling date	Time taken (hrs)	Total time taken (hrs)
4/03/2013	2.17+1.32+2.00+2.36	7.85
9/03/2013	2.14 + 3.47	5.61
16/3/2013	3.39+1.23+1.20	5.82
24/3/2013	1.0+0.46+1.42+0.54+2.10	5.52
	TOTAL	**24.80**

Average Time = Total Number of hrs taken to use 20 liters/Number of filling times

=24.80 hrs/4= 6.2hrs

From the above data it is estimated that 20 litres of diesel was used on average 6.2hrs to run the generator to keep the petrol station fully in operation during a power blackout.

Table 3.5 Equipment consuming power at filling station

NO	EQUIPMENT DESCRIPTION	NUMBER	POWER RATING	INSTALLED CAPACITY
1	Fuel Dispensers	7	@1.5kW	10.5kW
2.	Lighting at the pumps	4	@38W	142W
3.	Air Compressor	1	5.5kW	5.5kW
4	Water Pump	1	0.75kW	0.75kW
5	Office fluorescent lights	4	@38W	142W
6	Lube bay lighting	6	@ 38W	228W
7	Fridge for soft drinks	1	520W	520W
	Total Power			**17782W**

3.2 Kenya Power and Lighting electricity bill

The consumption of electricity was also recorded and tabulated as below

Customer Name : Nairobi West Service Station Ltd

Supply Location :Gandhi Avenue37/60/1

Acc No. 166629-01

Table 3.6 Kenya Power and Lighting electricity bill

Consumption Period (Act)	**kWh Consumed**	**Cost of Consumption (KSH**
28/03/2012 – 28/04/2012	2302.4	43432.38
28/4/2012 – 25/05/2012	2274.3	42901.90
25/05/2012 – 26/06/2012	3029	57138.38
26/06/2012 – 25/07/2012	3033.2	57218.93
25/07/2012 – 25/08/2012	2764.14	52142.14
25/08/2012 – 26/09/2012	2399.7	45268.25
26/09/2012 – 28/10/2012	2332.5	44000.00
28/10/2012 – 26/11/2012	2496.8	47100.00
26/11/2012 – 27/12/2012	2746.0	51800.00
27/12/2012 -30/01/2013	556.62	10500.00
30/01/2013 - 28/2/2013	1330.59	25100.00
28/2/2013 – 28/3/2013	1871.7	31600.00
Total	27,136.95	518,208.4

3.3 Data Analysis

The data collected showed that 20litres of fuel was consumed by the generator in 6.2 hours . The cost of 20litres of diesel during the month of March was added to the operation and maintenance cost of the generator. The installed capacity of the petrol station was 17782W which was used for the designing and sizing of the solar system needed for the filling station .The electric power consumed from April 2012 to March 2013 was 27,136.95 kWh and the cost of electricity for that period was KSH 518,208.40

CHAPTER FOUR

Data Analysis and Discussion

4.1Site survey and discussion

The Nairobi West petrolstation islocated in a busy shopping center within Nairobi West estate . The site canopy is away from tall building and trees which can create shading significantly cutting the solar panels output, hence light from the sun fall directly on the canopy where the solar collectors will be mounted. The sun will shine on the collectors during all the parts of the year simply because Kenya being in the tropics and astride from the equator do receive considerably amount of solar radiation. The location and the size of the canopy covering the fuel dispensers as in figure 1.1 is best suited for mounting of the solar panels to receive a considerable amount of unblocked Sun light. Solar power method of producing energy rely heavily on the positioning of the solar panels which the station has a canopy with no obstacle at all.

From table 4.7of the equipments consuming power it can be seen that lighting systems has power rating of 512Wand 7 fuel dispensers rating 10500W this being the major equipments using a lot of power at the station. The Air Compressor of 5.5kW runs for about 20minutes to build pressure to 150bar then automatically stops. When the compressor pressure drops below 80 bar because of compressed air usage the system comes ON and builds pressure to 150 bar again the difference in pressure being detected by the pressure switch. It was established that within 6 hours the compressor takes 3 hours to build pressure to 150bar and discharge to 80 bar.

During a power cut at least 4 fuel dispenser pumps were fully operational using the diesel generator. The design of the system was as a backup system that could run the whole station for 7 hours at night or during the day during a power cut. Table 4.7 shows the total number of kWh expected to be ON during a power cut

Table 4.7Power demand during a power blackout

Equipment	Number	Power Rating (Installed Capacity)	Running Hours	kWh
Fuel Dispenser	4	6kW	6.2	37.2
Pump Lights	4	142W	6.2	0.880
Air Compressor	1	5.5kW	3	16.5
Water Pump	1	0.75kW	0.5	0.375
Office Lights	4	142W	1	0.142
Lube bay lights	6	228W	6.2	1.414
		12.762 kW		56.511

4.1.1 Fuel Consumption Cost

20 litres of fuel was being used in 6.2hours during the month of March 2013

1 litre of fuel cost = KSH 109.00

Hence total cost of 20 litres of fuel= KSH 2,180.00

For the Month of March 2013 the generator was filled with 80litres of fuel ,

Cost of fuel in March 2013= KSH 109.00x 80 = KSH 8,720.00

Assuming on average that the generator is filled with 80litres of fuel in a month, then projecting the cost of fuel in one year will be KSH 8,720.00 x 12 = KSH 104,640.00

4.1.2 Maintenance Cost of the Generator

The standby generator is serviced after every 3 months. During servicing, Air filter, Oil filter and diesel filter are replaced and Refilled with new clean oil.

Table 4.8 Generator Spares and Cost of Oil

ITEM	COST (KSH)
Air Filter	3900
Oil Filter	300
Diesel Filter	4200
7 litres of Oil @ KSH 290 to the next service	2030

Total Costof Air, Oil, Diesel filters and 7litresOil = KSH 10430.00

Labor Cost = KSH 2000.00

Maintenance cost in one year =KSH 12,430.00 x 4(Routine service) =KSH 49,720.00

Total cost of fuel and maintenance cost in one year

KSH 104,640.00 + KSH 49,720.00 = KSH 154,360.00

The initial purchasing and installation cost

Generator specifications

Rating 30KVA 41.7Amp 3phase

Initial Cost = KSH 800,000.00

Installation labor cost 15% of KSH 800,000.00 = KSH 120,000.00

Total Cost = KSH 920,000.00

4.2Photovoltaic system

The system will comprise of :- inverter, batteries , Solar Panels and Controller

Taking ascenario where all the equipments will be ON at the same time, we use a diversity factor of 60% on installed capacity.

Generator maximum Current is 41.7 Amps

Hence 60% of 41.7 Amps = 25Amps

If the Generator is ON for 6.2hrs

Then 25Amps x 6.2hrs = 155Ah

The power consumed in 6.2hrs from table 4.7 = 56511.0Wh

Battery Design- Battery storage sizing depends on the duration of uninterrupted power supply to the load when the photovoltaic system is in operation which occurs at night time or during cloudy days . The battery backup systems are used to store electric energy harvested from solar photovoltaic system for use during the absence of sunlight but for the study it will be used in the absence of commercial power and at night.

The system design voltage is 12 Volts

A 12Volts battery ratedin the battery bank is to be used. The batteries have depth of 80% discharge ,such that one cannot fully discharge the batteries .

56511.0Wh /12V= 4709.256

4709.25/0.8 discharge depth =5886.56AH

From the market a Battery which can discharge for between 6hrs to 10 hrs is of the model of 12V 200AH.

Number of batteries required for the system

5886.56AH/200AH =29.43batteries= **30 batteries of 12Volts**

Then 30batteries of12Volts are to be wired in parallel for the battery bank;-

The Solar battery type which are maintenance free are of the model 200AH which cost KSH 38,000.00 (Davis &Shirtliff Group, 2013)

Total cost of batteries 30 x 38,000 = KSH 1,140,000.00

4.2.1 Sizing of Photovoltaic Array

The solar panels willbe installed on top of the existing canopy. Hence given that there is no vegetations creating shade around the canopy, we assume that the panels will receive sunshine for at least 6hrs in a day

The power of the solar panels becomes;- The Panels are to charge at 12Volts

Power of equipment x Running Hrs / (0.85 (Loss factor)x 6 hrs of sunshine)

Energy Required Wh/(0.85 (Loss factor)x 6 hrs of sunshine)

Loss factor or system inefficiency include the humidity and high temperature in the equator zone, battery charging and discharging loss and inverter conversion loss

Hence 56511.0Wh / (0.85 x 6hrs)= 11080.6W

Power Rating of 12VDC panel is 280W

Hence number of panels needed 11080.6 W/280 W= 39.57 Panels = 40panels

Cost per Watt = KSH 120.00 (Davis &Shirtliff Group)

Hence cost of panel = KSH120 x 11080.6 =KSH 1,329,672.00

Cost of 30 batteries and 40 Panels

KSH (1,140,000.00 +1,329,672.00) = KSH 2,469,672.00

4.2.2 Inverter

An inverter will be used with the photovoltaic system to feed the loads.The inverter is to be 10% higher than the rated power of the total installed capacity .

The total installed load capacity using table 4.7 is 12.76 KW

The inverter rated power = 12.76 + (0.1 x 12.76) = 14.036 KW hence a 15000W is recommended

Thus the size is 15000Watts Victron inverter/charger (single or 3-phase Victron inverter/charger) at a cost of KSH 128,000.0000 (Davis &Shirtliff Group)

Cost of 30batteries + 40Panels + 1 Inverter

= KSH 2,469,672.00 + KSH 128,000.00 = KSH 2,597,672.00

Installation Cost 15% of KSH2,597,672.00 = KSH 389,650.80

Hence Total Cost =KSH 2,987,322.80

Hence the total cost of full Solar system Installation = **KSH 2,987,322.80**

Table 4.9 Photovoltaic System Design

System Design			
Battery Bank 30PCS 200Ah Maintenace free bataery			
	Parameters Considered here		**Unit**
1	Daily Energy Requirements	56511	Wh
2	System Design Voltage	12	V
3	Battery Rated Voltage	12	V
4	Expected System Capacity (Ah)	4709.25	Ah
5	Battery DoD	0.8	%
6	Recommended System Capacity	5886.5	Ah
7	Battery Capacity(Ah) Rating	200	Ah
8	Number of battery needed	29.43	No.
1 Solar Inverter-1 5,000W Inverters			
	Parameters Considered here		**Unit**
1	Maximum Power Demand for the System	9418.5	W
2	Recommended Size of the inverter	15000	W
3	Number of DC-AC Inverters/charger	0.6	No.

1 Battery Charge Controller- 15,000W Inverters			
	Parameters Considered here		**Unit**
1	Maximum Power Demand for the System	9418.5	W
2	Recommended Size of the controller	15000	W
3	Number of the Charge Controller	0.6	No.
40 Solar Panels- 280W			
	Parameters Considered here		**Unit**
1	Daily Energy Requirements	56511	Wh
2	System Design Voltage	12	V
3	Solar Insolations(kWh/m2/day)-average	6	
4	Expected System Capacity (w)	11080.6	W
5	Overall system Inefficiencies	0.85	%
6	Recommended System Capacity	11080.60	W
7	Power Rating of the Modules@12VDC	280	W
8	Number of PV modules required	40	No.

CHAPTER FIVE

5.1 Solar Energy as an alternative Source of power for the Petrol Station

This research was to design a solar system to be used as a backup source of power for 6.2hrs; however the station can use the solar system fully to run all the operation because the design of the battery is that they can store the charge between 6 to 10hrs when fully charged. The manufacturer gives a span of five years when one can start doing maintenance on the batteries. If the station is to use the solar fully then the payback period would be shorter.Kenya is in the tropics and being a stride the equator and extending four degrees on either side receives a considerable amount of solar radiation. This means that petrol station can still be in full operation using solar power when the solar insolation is low especially during a cold month like July or a cloudy day.

In any system there must be an alternative source or a backup system to come in during a worst case scenario. If by any case the charge on the batteries will not be enough to run the operations and the utility power is off then a stand by diesel generator is to be used as a backup system to provide auxiliary power. The output of the diesel generator is to be connected to the auxiliary input of the inverter to charge the solar batteries.

5.2 Conclusions

From the study photovoltaic system back up was designed to maintain the petrol station in full operation for a maximum of 6.2 hours during a power blackout . The system components includes:

1. PV Modules = 40PCS of 12VDC(280W)

2. Inverter = 1 PCS of 15000W

3. Charge Controller=1 PCS of 15000W

4. Batteries = 30 PCS of 200AH Maintenance free

The initial cost of Solar power installation is KSH 2,987,322.80

from the analysis and the cost of installation and that of operating the diesel enginegenerator in one year is KSH 920,000.00 . A sum of KSH2,067,322.80 (operational and maintenance cost of the generator) will be saved yearly when the solar system will be installed since the solar system is maintenance free .

In spite of the low initial cost of diesel the generatorin operating the station has some drawbacks . The generator need continuous maintenance and have a reduced life time and has to be constantly fueled . Itproduces a lot of noise to the surrounding business premises and pollutes the environment with smoke from the exhaust and if replaced by Solar to power the station there will be no noise and there will be no greenhouse gas emissions being released to the atmosphere

5.3 Recommendations

1. From the study a photovoltaic stand alone systems can be used in applications for petrol stations in remote areas and especially in areas not covered by the grid utility. In areas covered by the grid utility, the use of photovoltaic system as a standby system in a petrol station is a better option than using diesel engine generators.

2.Research on the intelligent inverters which can be switched ON from Battery bank when discharged capacity is reached and the mains electrical power can be carried out to fully automate the petrol station.

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