Original Article

Design and Analysis of Hybrid Power System

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ABSTRACT

This paper proposes a Hybrid Power generation which provides power supply to PURA villages with the help of hybrid power systems. It leads to provides standardization of the systems. Design and fabrication of portable Biomass Gasifier with Solar Power System is done here and the thermal output is verified using fuels such as Juliflora and Casuarina junghuhniana. The case study was taken to design and analyze Biomass Gasifier – Solar Power Plant in Providing Urban Amenities in Rural Areas (PURA) Villages of Periyar Maniammai University, Vallam. In future it extends power generation and provides power supply to the PURA villages.

Keywords: Biomass gasifier, Solar power, Demand analysis, TNEB, PURA.

INTRODUCTION

Periyar Maniammai University is one of the leading institutes in India. It was started during the year of 1988. It is the first institute in this world for girl students to offer technical degree education. There are sixty seven (67) PURA (Providing Urban amenities to Rural Areas) villages adopted under this institute. It provides education, Job opportunity and fulfils the basic needs of the villagers.

Providing Urban amenities to Rural Areas (PURA): Thanthai Periyar suggested that a rural area should be provided with urban amenities such as schools, hospitals, parks, libraries, roads, good transport facilities, police stations and departmental stores etc.

The same thinking has echoed in His Excellency Dr. A.P.J.Abdul Kalam"s speech at the dedication ceremony of J.S.S Academy of Technical Education complex, Noida on 01.08.2003. He said that physical connectivity has to be done by providing roads electronic connectivity by providing communication network and knowledge connectivity by establishing professional and Technical institutions all will have to be done in an integrated way so that economic connectivity will emanate. Thus the concept of the two great leaders towards rural upliftmen is similar and their ideals are being implemented under Periyar PURA scheme. The PURA has to be business proposition managed by entrepreneurs, and small-scale industrialists. This scheme makes cluster of villages developed in health, power, transport etc and it also maintains a clean and green environment.

This is a rain-fed and drought prone area consisting of abundant lands, which are unutilized. As this is predominantly an agrarian region, large-scale industrialization has not taken place and the manpower remains idle. Socioeconomic status of the people remains in an extreme poor condition. Women folk of this region are totally ignored by all means.

At present Tamilnadu suffers from insufficient power generation. PURA villages also suffer due to lack of power, hence PMU decided to provide the power to their adopted villages. This motivated to develop hybrid power system for generating power for PURA. It focussed to fulfil their minimum electricity demand. A consumer requires 2 kW to 4 kW electrical powers to fulfil the basic needs[16]. In these aspects the hybrid system is designed to partially fulfil the demand.

Current status and future potential of biomass gasification technology in Sri Lanka[1] To study the effect of pollutants in the gasifier gas on methanation, a test rig, with a plant capacity adapted, to the gasifier was designed and the fuel input is designed as 5 kW[2]. It focused mainly the ongoing research projects and further technology development in future and to improve their efficiency in European region[3]. The objectives of the study are to examine the future potential of biomass and solar power for rural electricity generation to reduce the fuel oil dependency, to assess the electricity demand, and to mitigate CO2 emission by using the Long-range Energy Alternative Planning system (LEAP) model for the study period of 2007 to 2030. Results are presented of biomass potential and solar energy for Cambodian rural electrification and CO2 mitigation[4]. The system consists of a 20 kW gasifier-engine generator system with all the accessories for fuel processing and electricity distribution. The system to meet all kinds of electricity needs of the village[5,6]. Standalone wind – solar hybrid system was proposed and the total harmonic distortion has been reduced 5 % for the IEEE Standards by using D-STATCOM and the output result have been verified through MATLAB Stimulation[13].

STATEMENT OF THE PROBLEM

The PURA villages suffer from lack electrical power; and the problem has to be addressed keeping in view the poor economic status of the villagers. It is therefore required to develop a suitable system which can meet the electrical requirement of the villagers keeping the cost within their reach. The problem at hand is to design a Hybrid power system which can use locally available material like cow dung, wood chips, solid waste etc., making it economically viable. The LT Net work segregated in two feeders for the purpose of analysis.

Indian Electricity Board (TNEB) 11KV Distribution feeder is taken for proposed approach. It is a medium radial feeder, serving loads at – Ayothipatti village and the near one. The line impedance of the system is Z1 =0.038018+0.146173 Ω/1000 ft per conductor. The base MVA used in the computation is 1MVA and the base KV used is the same as the nominal voltage of 11KV.The feeder is supplying a total of 3MVA. Note: 60 % to 80 % load has been connected.

Impedance calculation Z= Base MVA/Base KV2*100

Reference: The data's has been collected through Field Visit.

From table 3 and table 4 clearly shows the power shutdown. From this the villagers are suffered due to the insufficient power at minimum 10 hours to the maximum duration. Hybrid system is one of the solutions to meet their demands.

Note: The sample data collection during the period of September – 2013.

Minimum energy requirement

Let assume there are 350 households in the proposed village each having 2 living rooms to installed each room for 1(one) light and 2 (two) external lights then the total number of installed lights are = 4 nos. note all lamps are working 4 hrs per day. There is a centralized power generation system each house hold is supplied with one 12V batteries to drive lighting system with 85 % of efficiency.

Total power consumed by each household= 12 *1(Hour) = 12 watts assume 15 watts

Total power consumed by the village = 350X 15 = 5250 watts

Assume lighting load for other facilities such as schools, health care, police station = 500 watts.

Total requirement of energy = 5250 +500+ 500 (emergency usage) = 6250 watts consider it 6500 watts. It can be written as 6.5 kW.

Therefore the minimum energy requirement of the villagers is around 6.5 kW + 10 % of increment / year without urbanization. To meet their minimum demand, design a suitable hybrid power system.

Hybrid power system

Hybrid power system defined as to connect two or more than two different kind of energy source like solar –wind, wind – hydro power etc.

Why biomass gasifier and solar hybrid power: The potential availability of primary energy source is more and the cost of the fuel is also very less. Similarly the available of solar energy source is also high and there is no primary fuel cost. Hence it chooses the biomass and solar power hybrid power system.

METHODOLOGY

See figure – 3.

The design process is made up of two steps

Step 1: Is to design 5kw bio mass gasifier.
Step 2: It deals about design of 5 kW solar power.
Step 1: Is to design 5kw bio mass gasifier

Biomass gasifier design

Bio mass gasification means incomplete combustion of biomass resulting in production of combustible gases consisting of carbon monoxide, Hydrogen and traces of Methane[7]. This mixture is called producer gas. Producer gas can be used to run internal combustion engines can be used as substitute for furnace oil in direct heat applications and can be used to produce, in an economically viable way, methanol an extremely attractive chemical which is useful both as fuel for heat engines as well as chemical feedstock for industries. Since any biomass material can undergo gasification, this process is much more attractive than ethanol production or biogas where only selected biomass materials can produce the fuel.

Sample calculation

Design for 5 kw biomass gasifier:

Let us consider the Bore 88 mm, stroke is 64 mm, Displacement is 0.3892 l, Efficiency 40%, Speed (rpm) 3600[8].

Intake gas ratio: 1.0:1.2

Then the maximum gas intake =

$$\frac{1.0 * (1/2) * \text{Speed of the engine} * \text{Displacement}}{60 * 1000}$$

$$= \frac{1.0 * (1/2)*3600*0.389}{60000}$$

$=5.55*10^{-3}$

Volumetric efficiency = 80 %

Therefore the real gas intake is= Maximum gas intake * volumetric efficiency = $5.55*10^{-3} * 0.8 = 4.44*10^{-3} m^3/s$

The heat value of gas is taken as 4800 kJ/m^3

Therefore the thermal power of the system is given by (Pg)

Pg = total quantity of gas intake * Heat value of the gas

$= 4.44*10^{-3} * 4800 = 21.312$ kW

Mechanical out is given by = Pm =Thermal power * Efficiency Pm =21.312 * 0.4 = 8.52 kW

The maximum output of electrical power is = Mechanical Power * Power factor $P_{E\,max}$ = 8.52 * 0.8 = 6.81 kvA

Biomass consumption for gasifier

Thermal Efficiency of the gasifier is 60 %

Therefore full load thermal power consumption is = P_g / Efficiency = 35.52

Heating value of biomass (14% moisture) 17000 kg/kJ

Fuel consumption of gasifier =35.52 / 17000 = 0.00208 * 3600 = 7.521 kg

Therefore installed capacity = 7.521 / 6.81 = 1.1045 produced 1 kWh

Reactor design[12]

$$D = \left(\frac{1.27 * FCR}{SGR}\right)^{0.5}$$

Where:

D – Diameter of reactor m

FCR – Fuel consumption rate, kg/hr

SGR – Specific gasification rate of wood 200 – 310 kg/m^2 - hr (Assume)

$$D = \left(\frac{1.27*7.521}{200}\right)^{0.5} = 0.22 \text{ m}$$

Height of the gasifier

$$H = \frac{SGR*T}{\rho}$$

T- Time required consuming wood kg/hr

ρ – Wood density kg/m^3 (assume) 100 kg/m^3

H = 2 m.

Thermal characteristics of the designed gasifier have been verified by using different fuels.

The following table shows the producer gases produced by the designed gasifier and the calorific values of the fuels also been find out through the help of gas analyzer.

Thermal output of the designed gasifier has been verified by using various fuels, the following table 7 shows that the output of producer gas with various combinations.

Specification of Gas analyzer

Portable infrared coal gas analyzer

Model No: Gas board 3100P

Serial Number: 11203200 3021 1161 9348

Step 2: It deals about design of 5 kw solar power

Solar energy directly received from the sun and the solar radiation has been converted into electric energy or any other useful form of energy.

5 KW SOLAR POWER DESIGN

Sample calculation:

Let us consider to design 5 kW solar power plant.[9,11] Hpt- Peak temperature received by the panel

Take mean horizontal insolation in normal temperature to take maximum amount of the region is 5.59 kWh/m^2

$$Hpt = \frac{\text{Yearly insolation } wh/m^2}{\text{Number of days in a year}}$$

Consider the system losses is 20% then the system output can be written as

System output =

$$\frac{\text{Daily operating load in watt hours + System Losses}}{\text{Peak temperature received by the Panel}}$$

$$\text{System current} = \frac{\text{System output}}{\text{Voltage output}}$$

By using 24 v battery then the system current is given by = 8586.7/ 24 = 357.7 amps/hr

Load in watt hr/day = Generated power * Number of operating hours

Load in watt hr/day =5000*8 = 40000 kwh/day

The system output =

$$\frac{40000 + 40000*0.2}{5.59} = 8586.76 \text{ kW}$$

Then the maximum module voltage is $V_{oc\ max}$ = V_{oc} + Temperature difference in percentage * V_{oc}

Voc max = 26.04 vdc

The maximum DC voltage of the battery is 600 V DC

The total required module is given by

$$N_{max} = \frac{\text{Maximum voltage of the battery}}{\text{Open circuit voltage (Voc max)}}$$

= 600/ 26.04 = 23.04 = 24 modules

Minimum Required modules

Maximum Power (Vmpmin) = Vmp + (Temperature difference * Temperature coefficient in Percentage* Vmp)

= 28.64 VDC

The inverter minimum input voltage is 250 VDC

The total required module is given by

$$Nmax = \frac{\text{Maximum voltage of the battery}}{\text{Open circuit voltge (Voc max)}} = 250 / 28.64 = 8.72 \approx 9$$

The output power = Number of modules * PTC *CEC Weighted efficiency

Number of modules = 5000 / (175.5* 0.96)

Number of modules=29.67 ≈ 30 modules

Therefore to design a 5 kw solar power generation, it requires 30 modules.

Social impacts of the proposed work:

- It creates job opportunity
- Peoples encouraged to plant new types of feed stocks and they will get extra income.
- Education level, health care and security will be improved.
- The dependence on conventional and fossil energy will be reduced

CONCLUSION

A hybrid biomass – solar power system was designed for partial fulfilment of the electric power requirements of PURA villagers which are subjected to acute problem of a unavailability of electrical power from the conventional source of electricity. In this part discussed in detail about that the thermal output of the designed gasifier and the result has been verified with different kinds of fuels. In future the research work to extend to find out the electrical power generation and the utilization of PURA Villages / connected with the LT networks to the utility grid.

ACKNOWLEDGMENT

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Table 1. Bus Voltage / Power

S. No	FEEDER - A		
	Bus	Load (KW)	Impedance (PU)
01	01	20	0.002
02	02	24	0.006
03	03	18	0.003
04	04	22	0.004
05	05	28	0.005
06	06	16	0.006
07	07	32	0.0032
08	08	18	0.0035
09	09	18	0.0065
10	10	28	0.004
11	11	16	0.0042
12	12	32	0.0024
13	13	18	0.0032
14	14	26	0.0025
15	15	24	0.0024
16	16	20	0.0032
17	17	36	0.0042
18	18	18	0.0012
19	19	20	0.0012
20	20	20	0.006
21	21	28	0.0027
21	21	36	0.0034
22	22	24	0.0032
23	23	18	0.0043
24	24	28	0.0042

Table 2. Bus Voltage / Power

S. No	FEEDER – B		
	Bus	Load (KW)	Impedance (PU)
01	01	12	0.0032
02	02	22	0.004
03	03	36	0.0023
04	04	16	0.0046
05	05	36	0.0031
06	06	20	0.0028
07	07	28	0.0026
08	08	22	0.0042
09	09	32	0.0015
10	10	16	0.00231
11	11	24	0.00421
12	12	32	0.0012
13	13	20	0.00320
14	14	28	0.0213
15	15	28	0.0122
16	16	32	0.0210
17	17	20	0.023
18	18	36	0.0124
19	19	20	0.0140
20	20	12	0.0021
21	21	22	0.0035
21	21	36	0.0043
22	22	16	0.00231
23	23	36	0.00412
24	24	20	0.0029
25	25	28	0.0034
26	26	32	0.006
Total		682	

It shows that the normal energy demand of the village.

Table 3. (Day – 01) – Power Shortage

S. No	Village Name	Time in Hours				
		5 a.m 7 a.m	7 a.m 9 a.m	9 a.m 11 a.m	11 a.m 1 p.m	1 p.m 3 p.m
01	Achampatti	1		1		1
02	Avarampatti	1				1
03	Ayothipatti		1		1	1
04	Ayyasamipatti			1	1	1
05	Chidambarapatti	1	1		1	1
06	Kadhatipatti			1		1
07	Keelathiruvilapatti	1		1	1	1
08	Kosavapatti		1	1		1
09	Malayapatti	1		1		1
10	Manaiyeripatti	1		1		1

Table 3(A). (Day – 01) – Power Shortage

S. No	Village Name	Time in Hours				
		3 p.m 5 p.m	5 p.m 7 p.m	7 p.m 9 p.m	9 p.m 11 p.m	11 p.m 0.0
01	Achampatti	1	1		1	
02	Avarampatti	1	1			1
03	Ayothipatti	1		1		1
04	Ayyasamipatti	1			1	
05	Chidambarapatti	1	1			
06	Kadhatipatti	1	1			1
07	Keelathiruvilapatti	1		1	1	
08	Kosavapatti	1			1	1
09	Malayapatti	1			1	1
10	Manaiyeripatti	1		1		

Table 3(B). (Day – 02) – Power Shortage

S. No	Village Name	Time in Hours				
		5 a.m 7 a.m	7 a.m 9 a.m	9 a.m 11 a.m	11 a.m 1 p.m	1 p.m 3 p.m
01	Achampatti	1		1	1	1
02	Avarampatti			1	1	1
03	Ayothipatti		1	1	1	1
04	Ayyasamipatti			1	1	1
05	Chidambarapatti	1	1	1	1	1
06	Kadhatipatti			1	1	1
07	Keelathiruvilapatti	1		1	1	1
08	Kosavapatti		1	1	1	1
09	Malayapatti	1		1	1	1
10	Manaiyeripatti	1		1		1

Table 3(C). (Day – 02) – Power Shortage

S. No	Village Name	Time in Hours				
		3 p.m 5 p.m	5 p.m 7 p.m	7 p.m 9 p.m	9 p.m 11 p.m	11 p.m 0.0
01	Achampatti	1	1		1	
02	Avarampatti	1	1			1
03	Ayothipatti	1		1		
04	Ayyasamipatti	1		1	1	
05	Chidambarapatti	1	1			
06	Kadhatipatti	1	1			1
07	Keelathiruvilapatti	1		1	1	
08	Kosavapatti	1	1		1	
09	Malayapatti	1	1		1	1
10	Manaiyeripatti	1		1		

Table 4. Requirement for Design

S. No	Parameter	Scale
01	Diameter	0.22 m
02	Height of the gasifier	2 m

Table 5. Fuel–Casuarina Junghuhniana

S. No	Time in Minutes	CO	CO_2	H_2	CH_4	C_nH_n	O_2	CV
01	12.20	6.27	2.03	6.97	12.50	0.07	4.71	598
02	12.25	6.38	1.87	5.07	13.25	0.10	4.96	598
03	12.30	6.74	2.77	4.59	13.08	0.17	5.68	643
04	12.35	6.88	3.04	4.98	12.92	0.18	5.59	676
05	12.40	7.05	2.91	5.79	12.90	0.15	5.54	684
06	12.45	7.08	2.40	6.69	12.65	0.15	5.77	668
07	12.50	7.35	2.91	7.56	12.27	0.17	6.33	754
08	12.55	8.55	3.30	7.30	12.60	0.15	5.42	813
09	01.00	8.12	3.04	7.81	12.65	0.13	5.54	790
10	01.05	7.90	2.56	7.75	12.40	0.12	5.85	730
11	01.10	6.65	2.58	6.50	12.33	0.13	6.09	650
12	01.15	7.96	2.23	7.98	11.43	0.10	6.19	708

Table 6. Fuel–Juliflora

S. No	Time in Minutes	CO %	CO_2 %	H_2 %	CH_4%	C_nH_n%	O_2%	CV
01	02.35	9.14	1.61	8.12	12.41	0.07	4.46	678
02	02.40	7.04	1.75	7.58	12.90	0.07	5.16	595
03	02.45	4.84	1.61	4.34	13.30	0.13	5.75	460
04	02.50	6.94	2.27	7.34	12.70	0.13	5.63	687
05	02.55	7.32	2.25	7.91	12.67	0.10	5.57	690
06	03.00	6.75	1.68	7.50	11.85	0.10	6.50	601
07	03.05	5.54	1.55	7.05	11.44	0.16	7.11	525
08	03.10	4.11	1.78	3.92	12.51	0.15	7.29	428
09	03.15	3.55	1.47	3.00	10.76	0.17	8.74	361
10	03.20	3.94	1.55	3.27	11.27	0.22	8.39	404
11	03.25	4.58	2.03	1.04	11.33	0.20	9.01	404
12	03.30	3.45	1.82	0.77	10.15	0.22	10.06	331

Table 7. Measuring Parameter of Gas Analyzer

S. No	Content	Range in %
01	Co	0 – 40
02	H_2	0 – 25
03	CnHm	0 – 10
04	Co_2	0 – 25
05	CH_4	0 – 10
06	O_2	0 – 25

Table 8. Required quantity of solar panels

S. No	Description	Rating
01	Generated power	5 Kw
02	Required Module (Minimum)	24 Nos
03	Required Module (Maximum)	30 Nos
04	Panel output	175.5 watts
05	Output voltage	24 volts
06	Inverter voltage (Maximum)	600 vdc

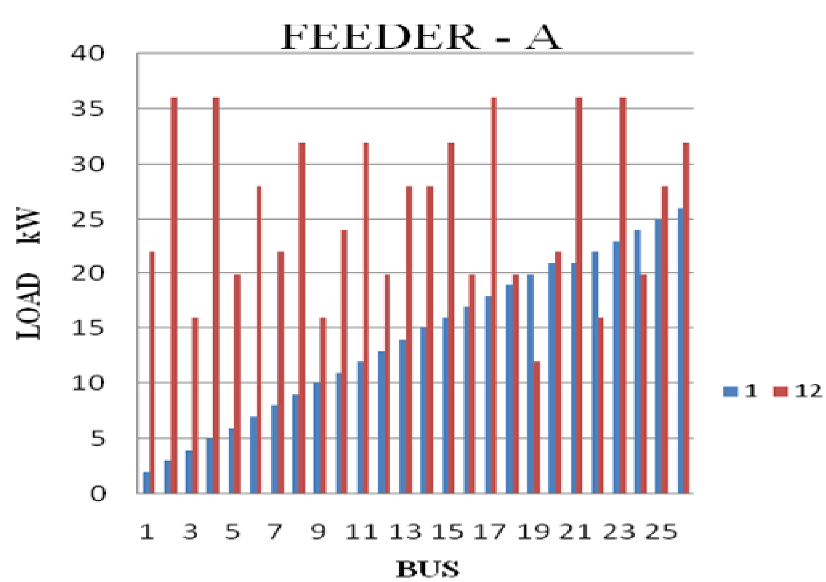

Figure 1. Load flow analysis in LT network at feeder A

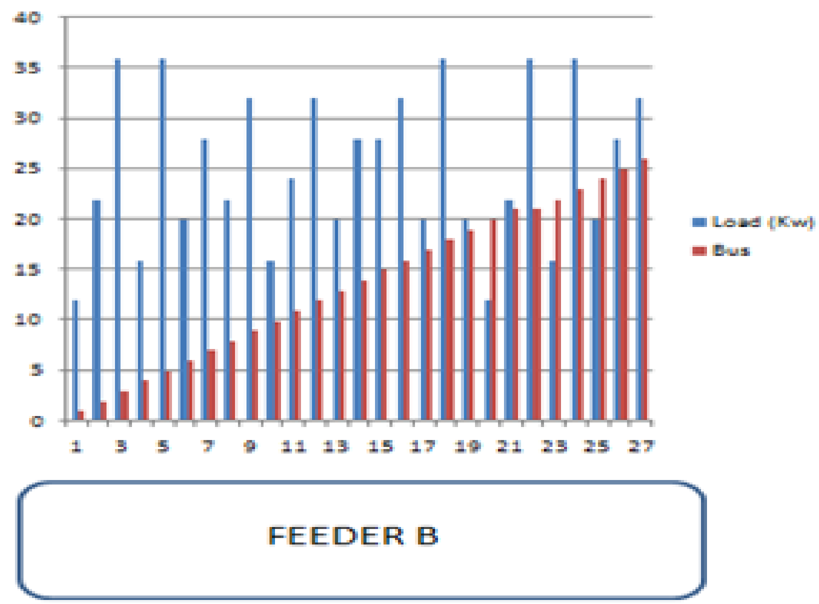

Figure 2. Load flow analysis in LT network at feeder B

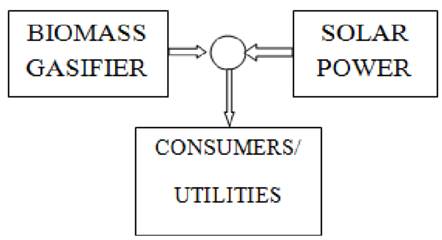

Figure 3. Block diagram -Hybrid power system

Figure 4. Laboratory set up

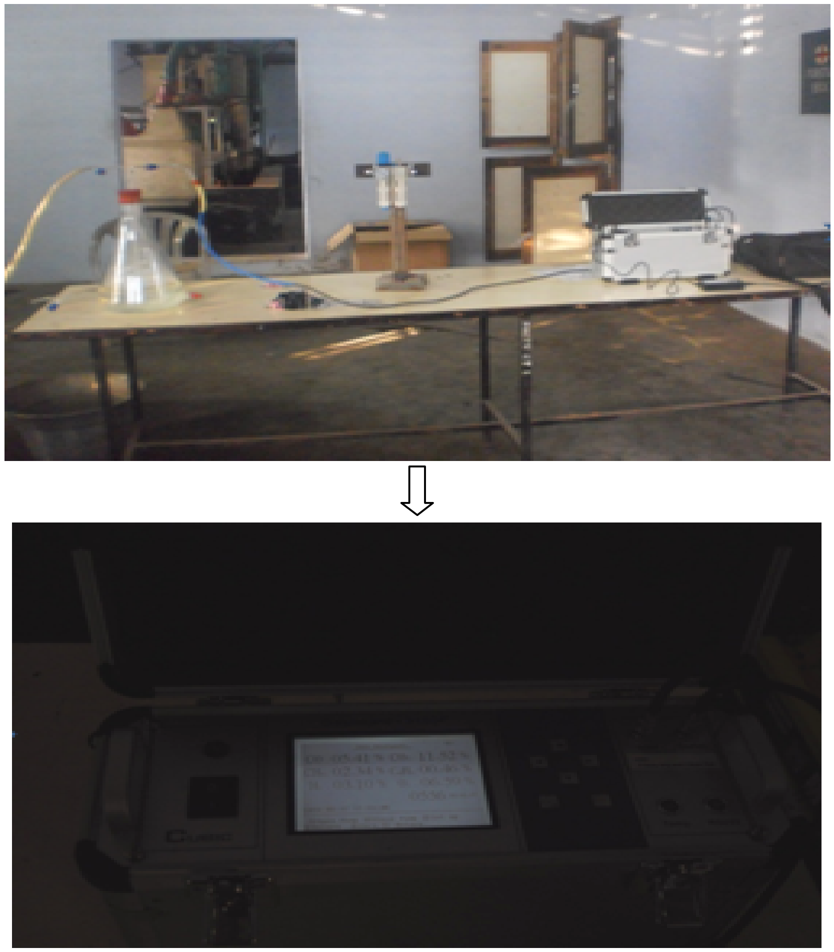

Figure 5. Gas analyzer with display