Hybrid Renewable Energy Sources and Micro Hydro Energy System for Rural Area

Vikram Saxena [1], Pushpanjali Singh Bisht[2], Thakur Pranav Kumar Gautam[3]
[1]*Assistant Professor, EEE Department, RVS College of Engineering and Technology, Jamshedpur, India*

Abstract **-** The paper assesses the demand for rural electricity services and contrasts it with the technology options available for rural electrification. Project success is driven by economically viable technology choice. The main problem today is the shortage of energy and environmental pollution. These problems can be avoided by employing renewable energy schemes. The most common renewable energy resources include Wind Energy, Tide Energy, Solar Energy, Hydrogen Energy, Bio Energy, Terrestrial Heat Energy and Thermal Energy and so on. Apart from this in rural India Micro hydro concept may be used as it is more advantageous than renewable energy sources. A brief description is given in this paper as follows.

Keywords: *Rural Electrification, DPS, Micro hydro, Renewable energy, Biogas Generator, Turbine.*

I. INTRODUCTION

The electricity sector in India had an installed capacity of 229.51 GW as of Oct 2013, the world's fifth largest. Renewable power plants constitute only 12.45% of total installed capacity. Electricity consumption in India 778 Kwh as of Jan 2012 report, in which rural area consumed 280 Kwh. Rural electrification is the Process of bringing electrical power to rural & remote areas. Electricity is used in rural areas for lighting, household purposes, farming operations such as threshing, milking, hoisting grain for storage etc. The use of coal-based power is dangerous to the environment as it emits pollutants such as oxides of sulphurs, nitric oxides, carbon dioxides, carbon monoxides etc. among others. Here satellite pictures of India show thick haze and black carbon smoke above India and other Asian countries. Major sources of particulate matter and aerosols are believed to be smoked from biomass burning in rural part of India and air pollution from large cities in northern India.

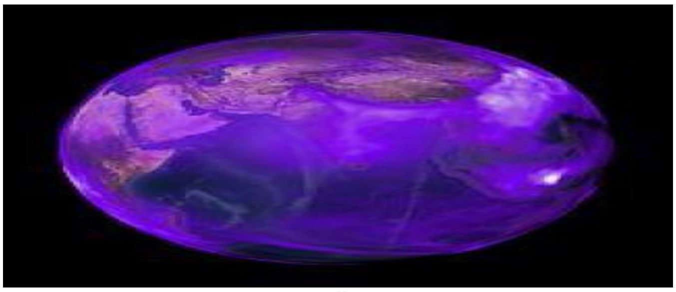

Fig.1: Satellite pictures

In recent years, renewable technologies have been in the Limelight and became highly favorable generation resources due to the rising of oil prices, uncertainty of fossil fuel or security of supplies in the future and concerns on the environmental impact due to the over consumption of fossil. Hence renewable sources of energy are the best way to get electricity in Indian rural areas such as solar, biogas & wind power.

Biogas Plant: The motivation behind building a biogas plant makes the best use of the space available on the farm. The biogas plant is situated near a residential area, and building the plant enabled the farmer to respond positively to increasing complaints about the smell associated with spreading liquid manure. Since the biogas plant became operational, the odor nuisance and complaints from the local residents have decreased noticeably.

Photovoltaic Cell: By photovoltaic cells usage, some applications can be mentioned: supplying electricity of remote areas, remote communication systems, pumping water, purification systems of water, supplying electricity of rural areas, calculators, watches and toys, compulsive systems, preservation refrigerator for blood and vaccine in remote areas, ventilation systems for pools, satellites and space equipment.

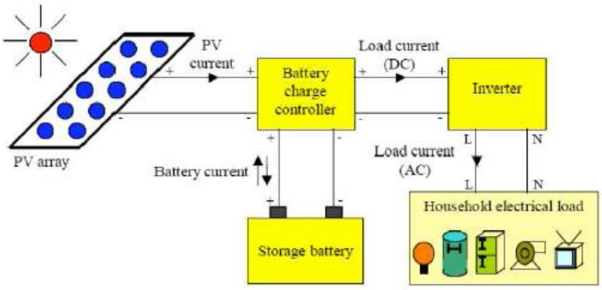

Fig.2: Stand – Alone PV System

Designing stand-alone systems is in the manner that acts Independent from electric grid and they are usually designed for producing ac or dc electric load. In order to produce electricity by stand-alone systems, wind turbines, generators or electric grid as aid system can be used. These systems are called "photovoltaic hybrid systems". In order to store energy and utilize it, during night and wherever that sunlight is not sufficient, battery is used in stand-alone systems. Components of stand-alone systems have been shown in Fig-2.

Wind Power: The wind is a free, clean, and inexhaustible energy source. It has served mankind well for many centuries by propelling ships and driving wind turbines to grind grain and pump water. Wind power may become a major source of energy in spite of slightly higher costs than coal or nuclear power because of the basically non-economic or political problems of coal and nuclear power. This is not to say that wind power will always be more expensive than coal or nuclear power, because considerable progress is being made in making wind power less expensive. But even without a clear cost advantage, wind power may become truly important in the world energy picture.

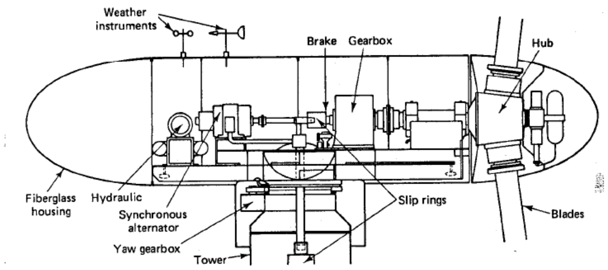

Fig.3: Wind Generator

II. DISTRIBUTED POWER SYSTEM

So we have to adopt a system which is pollution free and economically more efficient. Now the renewable energy resources like solar energy, wind energy and biogas power plants has made it possible to produce economic power which was available previously only with big power plants. Many small scale power plants utilizing both renewable and non-renewable energy resources can be combined together to produce steady electricity. This scheme is known as Distributed Power System. DPS can be designed by combining

- Thermal and Solar Energy;
- Biogas and Solar Energy;
- Biogas and Thermal Energy;
- Biogas, Thermal and Solar Energy etc.

The all above mentioned sources can be classified into two types, Controlled Sources and Uncontrolled Sources.

Controlled Sources

Output power can be controlled according to the load requirement by limiting the input power like biogas power plant.

Uncontrolled Sources

Output power cannot be controlled by limiting the input power as in solar system where output power is solely dependent on weather.

But controlled and uncontrolled sources can be combined together by means of DPS to get constant output power. In the first section of this research work, solar and thermal panels are combined together which are both uncontrolled. Then, in the second section, Biogas power system is joined with the above mentioned system to smooth the output power.

III. COMBINATION OF PHOTOVOLTAIC AND THERMAL DSP

Solar energy can be made useful by photovoltaic cells which generate electric power directly. Solar thermal panels can be utilized to produce heat energy. A system is suggested to convert a large portion of this energy into electric energy. The hybridization of the two schemes provides distinct advantages as far as cost, the small demand of the land area and installation are concerned. The main drawback of the system is that the overall efficiency of the combined system will be smaller than that of standalone system. A simple diagram describing a basic structure is shown in fig. 4. The thermal part consists of transparent plastic layers having cellular inner walls and working medium is made circular. Under the plastic layers, silicon photovoltaic cells are jointed and insulated thermally. The sun light enters through the plastic layers and the working medium produces electricity in the solar cells. The heat energy is absorbed by both working medium and plastic layers. Thermal insulation is present under the silicon layer. The overall construction is housed by a case and is covered with a glass layer composed of a specific filter coating to overcome the power loss due to reflection. The system suggested to convert a part of energy which is obtained from solar radiation, into electrical energy is shown in fig. 5. The combined photovoltaic/thermal panels are connected to a heat/electrical energy conversion unit consisting of a heat exchanger and a turbine generator and converter unit is connected to the grid either in parallel mode of operation or standalone mode of operation. In parallel mode, by introducing a static switch, ups operation can be achieved as well by employing energy storage devices like storage tank on the thermal side or battery in the dc link.

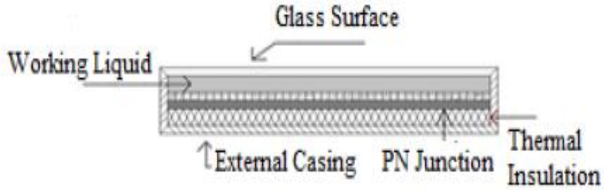

Fig.4: Combined PV/T Panel

It protects battery from over charging and deep discharging. The electrical energy produced by photovoltaic cells is used to supply to the grid by means of DC/AC converter and to charge the battery as well. The function of the charge controller is to sustain the battery voltage to a maximum value in case of excess charge and disconnect it from the load to prevent deep discharge in case of deficiency of charge.

As the temperature of the working liquid increases, steam will be produced directly hence the principle of binary cycle steam turbine is used. The actual working liquid is made to circulate by means of a pump through the thermal panel, heat exchanger and the storage tank in the secondary system, including a turbine and a condenser. An organic liquid of low boiling point is utilized. A steam generator having some heat input can be employed to achieve the safety of the energy supplied.

The direct electrical energy conversion can be achieved by incorporating a charge controller that receives the current supplied by the photovoltaic panel and ensures the conditioning of the battery.

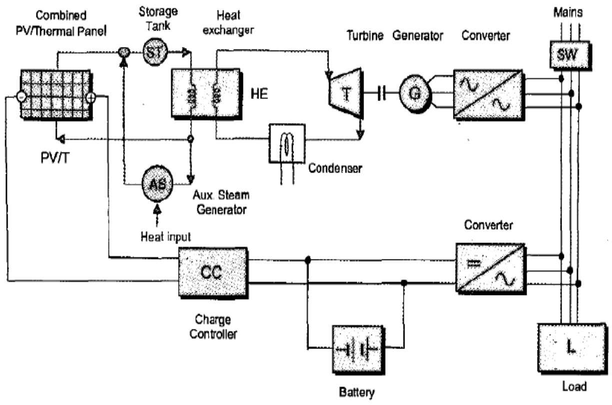

Fig.4: Block Diagram of Photovoltaic /Thermal DSP

IV. BIOGAS IN DISTRIBUTED POWER SYSTEM

In the modern world of social development, energy crisis and environmental pollution are getting high attention. Therefore it is high time to develop new energy and renewable energy resources such as bio-energy, solar energy, wind energy, tide energy, small waterpower, and terrestrial heat energy, and hydrogen energy etc. The comparatively dominant one for research is, distributed power system is the solar and wind power. The main drawback of the solar system is that it is the slave of weather and micro-net don’t provides the electricity steadily. Anaerobic biodegradation with the help of microorganism of organic material is the key producer of biogas. The plants, animal wastes, rubbish are main sources to generate biogas. The biogas production can supply electricity steadily and the power output is controllable. So the wind-biogas renewable energy distributed power system and the biogas generator is used to balance the output power of the system is necessary and this system can provide the constant power.

V. BIOGAS GENERATION WORK PROCESS

The biogas is generated from anaerobic biodegradation of organic materials during the absence of oxygen and the presence of microorganisms. The process includes a series of metabolic reactions among which various groups of microorganisms, executing in three different steps, hydrolysis, liquefaction acid genesis and methanogensis. The process produces mainly CH4, CO2 and a solid mixture. The biogas generation is developing with the biogas usage. The biogas produced by the industry wastage, agriculture and town is employed to drive the turbine engine to generate electricity. The biogas generation is composed by the biogas pool, desulphurizing tower, special pressure pot, gas engine and generator, which is shown in Fig. 5. The source of biogas is waste of industries, agriculture and Towns etc. This biogas is fired to drive some generator or turbine. The biogas power generation is controlled power generation mechanism and it can be used to balance the power output from PV/T panels. The block diagram of the combined PV/T and biogas system is shown below in fig. 5.

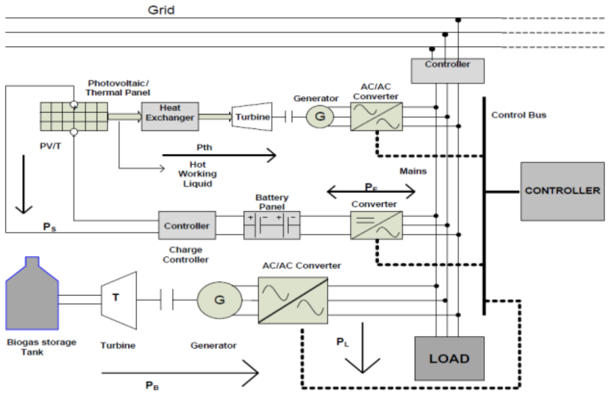

Fig.5: PV/T and Biogas DPS

VI. SIMULATION STUDIES

The working process of the overall system is quite complex. It is a great challenge to analyze this kind of system due to the presence of several energy storage devices and many nonlinear look up table blocks. This kind of system can be developed by doing the extensive modeling and adapting various simulation schemes. This research work consists of simulation which employs the energy balance in the energy conversion section, taking into account Photovoltaic Panels, charge controllers and battery module will be presented. Furthermore, the output of the battery system is fed to the PID controller which is used to control the opening and closing of the Biogas Engine Valve.

A simplified block diagram of Simulink model with a system of 120W, 24V battery having capacity of 2Ah, is presented. It contains three sections: Battery, Photovoltaic Cell and Charge Controller. The PID Controller realizes the voltage regulation and outputs current to the dc-dc convertor accordingly. The Photovoltaic Cell current is determined by the radiation intensity of sunlight which is represented by the look up table. The load profile with respect to time is also determined using a look up table. When pu value is multiplied by the rated value of the load current, we get the instantaneous value. The resulting current of the three sections described above is the battery current. When the battery current is integrated, we get the charge stored in the battery. This charge is then converted to battery voltage by means of battery q-v curve.

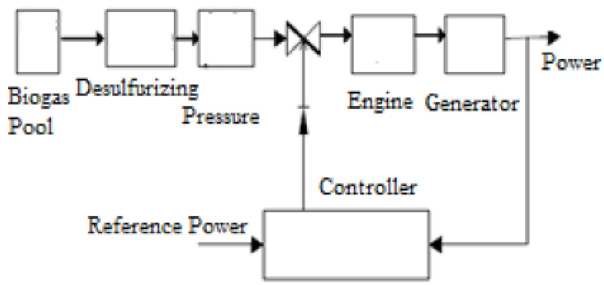

Fig.6: Unit of Biogas Generation.

VII. SIMULATION RESULTS

The simulation consists of a PV/T system in conjunction with a Biogas engine. The output of the battery is compared with a constant value and the error signal is given as input to a valve controller of a Biogas engine. The valve controller is basically a PID controller which controls the opening and closing of the valve hence limiting the fuel according to the fluctuations in the battery voltage and load requirement. The results of the simulation including the battery voltage and the biogas engine speed are shown below in fig. 7 and in fig. 8.

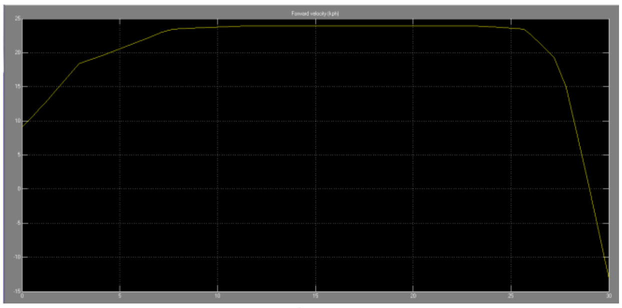

Fig.7: Battery Voltage vs. Time curve

The biogas engine speed is displayed as under in fig.7.

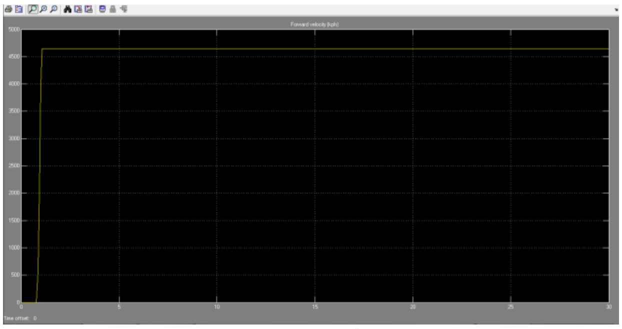

Fig.8: Biogas engine speed vs Time Curve

This engine is used to drive the generator at constant speed hence producing constant voltage. The biogas simulator diagram is shown in fig. 9.

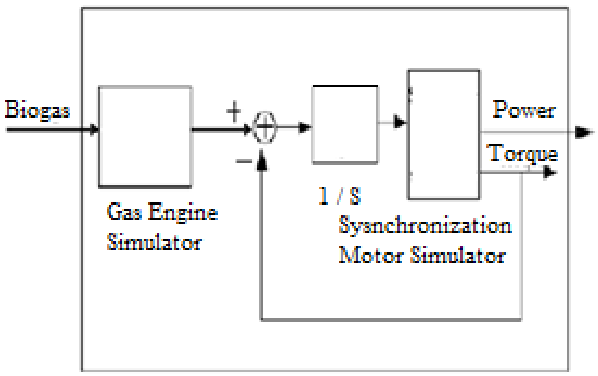

Fig.9: Biogas Simulator

The biogas simulator consists of a gas engine module, a controller and a synchronization motor simulator. The synchronization motor simulation can be carried out according to the following steps

$$v_{qs}^{s} = \frac{2}{3}v_{as} - \frac{1}{3}v_{bs} - \frac{1}{3}v_{cs} = v_{as} \quad \ldots\ldots 1$$

$$v_{ds}^{s} = -\frac{1}{\sqrt{3}}v_{bs} + \frac{1}{\sqrt{3}}v_{cs} \quad \ldots\ldots\ldots\ldots\ldots\ldots 2$$

$$v_{qs} = v_{qs}^{s}\cos\theta_e - v_{ds}^{s}\sin\theta_e \quad \ldots\ldots\ldots\ldots 3$$

$$v_{ds} = v_{qs}^{s}\sin\theta_e + v_{ds}^{s}\cos\theta_e \quad \ldots\ldots\ldots\ldots 4$$

These voltages in synchronously rotating reference frame are then used to evaluate the currents in the same reference frame according to the motor model given below

$$\begin{bmatrix} Vqs \\ Vds \\ 0 \\ 0 \\ Vfr \end{bmatrix} = \begin{bmatrix} Rs+sLqs & WeLds & sLqm & WeLdm & WeLdm \\ -WeLqs & Rs+sLds & -WeLqm & sLdm & sLdm \\ sLqm & 0 & Rqr+sLqr & 0 & 0 \\ 0 & sLdm & Rdr+sLdr & 0 & sLdm \\ 0 & sLdm & 0 & sLdm & Rfr+s(Lfr+Ldm) \end{bmatrix} \begin{bmatrix} Iqs \\ Ids \\ Iqr \\ Idr \\ Ifr \end{bmatrix}$$

……5

The torque and speed are then evaluated according to the expression

$$T_e = \frac{3}{2}\left(\frac{P}{2}\right)(\psi_{ds}i_{qs} - \psi_{qs}i_{ds}) \quad \ldots\ldots\ldots\ldots\ldots 6$$

$$T_e = T_L + \frac{2}{P}J\frac{d\omega_e}{dt} \quad \ldots\ldots\ldots\ldots\ldots\ldots 7$$

Phase currents are then found using the above expressions for currents. The simulation results are as under

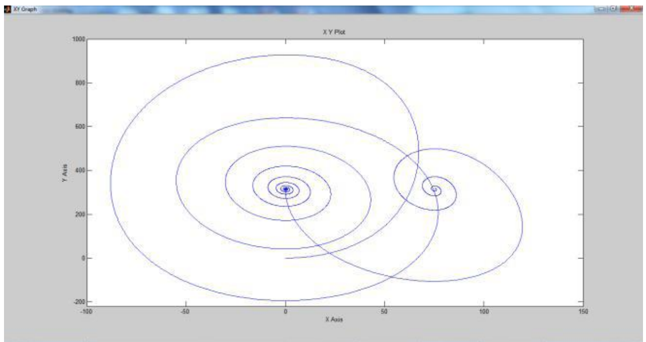

Fig.10: Torque vs Speed Curve

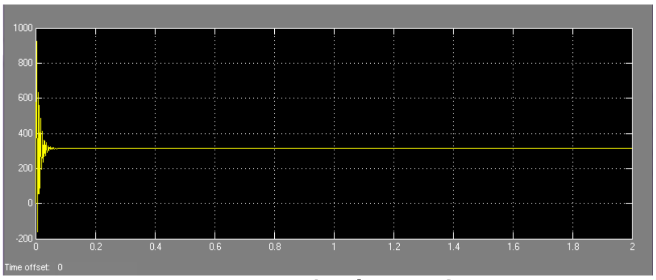

Fig.11: Motor Speed vs Time Curve

VIII. POWER FLOW OF THE SYSTEM

The power generated by Photovoltaic panel is DC which is converted to AC through a DC/AC convertor and then supplied to AC bus bar. The current from the Thermal part and Biogas part is AC and supplied to AC bus bar through an AC/AC convertor as shown below. Now there exist three relationships between power generated and power supplied to the load.

Case I:
If
PTH + PS> PE + PL
Then PG> 0 i.e. the system will supply power to grid
Case II:
If
PTH + PS> PE + PL
Now the controller will compensate the deficiency by the Biogas Generator such that
PTH + PS + PB> PE + PL
So again PG> 0
Case III:
If
PTH + PS + PB< PE + PL
Then PG< 0; Hence the grid system will remove the deficiency of power

IX. MICRO HYDRO PLANT

Residential-scale micro hydro-electric systems have the reputation of being the holy grail of home renewable energy (RE) systems. While they lack some of the hype, magic, and bling of solar-electric (photovoltaic) systems, micro hydro systems are a simple technology that most people can understand at least in general. Pelton and turgo wheels, the typical spinning waterwheel component, were invented in 1870 and 1919, respectively. The point is, this technology has proven its reliability and functionality with more than a century of performance. The cost of these systems, and thus the cost of the resulting electricity, also has the reputation for being very reasonable when compared to other renewable or home-generated sources. While PV module prices have recently dropped, they are still a high-tech and expensive commodity. Micro hydro systems can arguably be considered *low-tech*. Another element that keeps micro hydro-generated electricity low in cost, and thus high in desirability, is the system's continuous duty cycle. While PV systems only produce electricity when the sun is shining and wind electric systems when the wind is blowing, micro hydro systems aren't affected by nightfall or weather blocking the sun. Even a small hydro resource can provide electricity 24 hours a day, and often 365 days a year (if the water source is year-round).

Small pelton generates small energy at 300 watts at maximum, but works for 24 hours. So, why doesn't everyone have a micro hydro system? Herein lies the challenge. A viable hydro resource is dependent on the availability of falling water at, or near, the site of the electrical loads. It is the weight or pressure of that flowing water that spins the turbine to produce electrical energy. Not everyone has access to a stream or spring of adequate volume on their property, nor does everyone have the topography to create the vertical drop needed to pressurize that water with gravity.

"Micro hydro Rules"

The instantaneous power available from a micro hydro system is based on two main factors:
(i) The quantity of water (per unit time) moving in a river or stream, and that is available to be diverted through the turbine, is called *flow*. It is expressed as a rate such as cubic feet per second (cfs) or gallons per minute (gpm).
(ii) The pressure that drives that flow is caused by the vertical height between the intake and the turbine. The *head* is basically the weight of that water column and can be expressed as pressure (psi or bar), but is more often discussed in terms of vertical *feet* of head since that relates directly to the topography of the site—2.3 vertical feet of water will create 1 psi.

Together, head and flow are the driving forces that spin the turbine at the bottom of the system. A hydro system designer will use these two measurements to determine the pieces and parts necessary to optimize a system. Intake and turbine locations will be chosen to maximize head, while minimizing pipe and wire runs and other site-specific challenges. Pipe will be sized to balance reducing friction loss with keeping costs in check. The number of nozzles, runner type and size, and alternator size will all be carefully balanced to work with available flows without depleting the source (and ideally, without negatively impacting the local ecology). And the efficiencies (inefficiencies) of each component in the process will be calculated for an accurate estimate of the power available at the site.
But there is a simple formula to estimate a site's general

hydro potential without going through all of the formulas and variables of turbine choice and pipe sizing:

Head (vertical ft.) × Flow (gpm) ÷ Derate factor = Power (W)

The derate factor is commonly between 9 and 13. This range has been determined over the years from the measured real world performance of professionally installed hydro systems. A low derate factor like 9 would be appropriate for cases with good head and flow, and relatively short pipe runs and other inefficiencies. Higher derates, like 13, would be for cases where either head or flow (or both) is challengingly low, or other obvious inefficiencies will occur. This factor also takes into account the canceling out of units to arrive at watts; do not try this formula using cfs, psi, or other units of measurement.

X. CONCLUSIONS

From the above results, it is clear that a DPS has very great importance. Especially in countries like India where energy crisis are very severe, we have to adopt these kinds of schemes in rural areas to combine many renewable resources in such a way that the cost of the overall system is acceptable and the system provides consistent output power. Thermal Panels along with Solar Panels can be used to utilize Solar Energy in rural areas. The electrical energy can be extracted from solar energy directly by means of Photovoltaic cells but thermal energy is first converted to heat energy and this heat energy in turn is used to drive Turbine to get the electrical energy. If both these technologies are combined to work together, the solar energy can be absorbed by solar panel more efficiently. The research work demonstrates how these schemes can be combined together to achieve the desired goal. Furthermore, working of photovoltaic/thermal panels depend solely on weather conditions, so a biogas generator is used along with photovoltaic/thermal panels in order to maintain constant power. The output of the battery is compared with the constant value and the error signal is applied to the PID controller. As long as the error signal is zero, the input of the valve controller is zero and the biogas energy system remains idle hence no resource will be utilized and cost will be less. When the battery voltage undergoes change, the error signal is applied to the valve controller and the biogas valve open itself accordingly. The engine drives the generator in accordance with the load demand and fulfills the deficiency of the output power. Instead of it where water is available in adequate amount we can use micro hydro energy system , by which we can generate approximately 500 wh energy for 24 hours and it will be much beneficial than renewable energy sources.

XI. FUTURE SCOPE

There are many types of Distributed Power System possessing their own advantages and disadvantages. But as far as the undergoing type is concerned, the following aspects can be discussed:

- The controller which is used to control the power generated by the Bio gas generator can be replaced by a Model Predictive Controller because of its advantages over PI controller.
- The combination of wind power generator , diesel engines, solar cell, & Biogas may be possible.
- The design of the hardware of the above system can be done using smart grids.
- Micro hydro system can be combined with these renewable sources.

XII. REFRENCES

[1] B. Ozerdem, H.M. Turkeli,Wind energy potential estimation and microsittingonIzmir Institute of Technology Campus[J], Turkey, *Renewable Energy 30* (2005) 1623–1633.

[2] Z. Yanning, et al; Renewable Energy Distributed power system with WindPower and Biogas Generator; *Transmission & Distribution Conference & Exposition*: Asiaand Pacific, 2009.

[3] M.T. Iqbal,; “Simulation of a small wind fuel cell hybrid energy system*”,; Renewable Energy 28* (2003) 511–522.

[4] W.Z. Zehringer, Pieder, M. Suter, N. Celanovic: “Power Electronics Solutions for Distributed Power Generation”,; *International Symposium on Power Electronics EE 2001, Novi Sad, Yugoslavia*, Oct. 31-Nov. 2

[5] Jong, M.J.M: System Studiaon Combined PV *I* ThermalPanels, *Elfies Symposium Thermis & SalTenergie*, 9-1 1, May, 2001, Klaster Banz, Staffelstein, Germany

[6] Jardan, R.K.; Nagy, I.; Modeling of a combined Photovoltaic/Thermal.Energy System; *Power Electronics and Motion Control Conference*, 2004.

[7] Z. Yanning1, K. Longyun, C. Binggang; “Simulation of Biogas Generation” *Proceedings of IEEE T&D Asia conference,* 2009

[8] Bimal K. Bose, *Modern Power Electronics and AC Drives* (ISBN 0-13-016743-6)

[9] *James Cust, Anoop Singh and Karsten Neuhoff , “Rural Electrification in India:Economic and Institutional aspects of Renewables”, December 2007.*

[10] Ashok, S. (2007) Optimised model for community-based hybrid energy system. *Renewable energy* 32(7): P.1155.

[11] Banerjee, R. (2006) Comparison of options for distributed generation in India. *Energy Policy* 34(1): P.101-111.

[12] Barnes, D. F., K. B. Fitzgerald and H. M. Peskin (2002) The Benefits of Rural Electrification in India: Implications for Education, Household Lighting, and Irrigation. *Draft manuscript, July*.

[13] J. T. Mcmullan, R. Morgan and R. B. Murray, “Energy, Resources and Supply,” John Wiley & Sons, London, 1976.

[14] M. Slesser, “Dictionary of Energy,” Macmillan Press, London, 1982.

[15] D. H. Meadows and D. L. Meadows, “Beyond the Lim-its,” Chelsea Green Publishers, Burlinton, 1992.

[16] D. W. Pearce and R. K. Turner; “Economics of Natural Resources and the Environment,” John Hopkins Univer-sity Press, Baltimore, 1999.

[17] M. H. Ross and R. H. Williams; “Our Energy-Regaining Control,” McGraw-Hill, New York, 1981.

[18] R. Stobaugh and D. Yergin, “Energy Future,” Vintage, New York, 1983.

[19] OWEM Series Report, 2002. http://www.opec.org.FAQS/.HTM

[20] T. K. Ghosh, “Prospects of Biomass Energy,” Interna-tional Symposium on Bioconversion and Biochemical En-gineering, BERC, ITT, Delhi, 1980.

[21] R. M. Gifford, “Carbon Storage by Biosphere,” Austra-lian Academy of Sciences, Canberra, 1985, pp162-180.

[22] H. F. Lieth, “Patterns of Primary Productivity in the Bio-sphere,” Hutchison Ross, Stroudsburg, 1978.

[23] J. P. Cooper, "Potential Production and Energy Conver-sion in Temperate and Topical Grasses," Bureau of Pas-tures and Forage Crops, 1970, pp. 1-5.
[24] J. C. Menault, "African Savanna, Biological Systems of Humidification and Mineralization," Common Wealth Agricultural Bureaux, Melbourne, Australia, 1984.
[25] J. I. Casedy, "The Effect of Rainfall, Moisture and Har-vesting Intensity on Grass Production on Two Range Sites in Kenya," East African Agricultural and Forestry Journal, Vol. 39, 1973, pp. 26-36.
[26] R. G. Strugnell and C. L. D. Pigott, "Biomass, Shoot Production And Grazing In Uganda," Journal of Ecology, Vol. 66, No. 1, 1978, pp. 73-97. http://dx.doi.org/10.2307/2259182
[27] O. O. Osadolor, "Availability of Grasses, Weeds and Leaves as Energy Resource," Renewable Energy, Vol. 34, No. 3, 2009, pp. 486-491. http://dx.doi.org/10.1016/j.renene.2008.05.045
[28] C. E. Ohiagu and T. G. Wood, "Grass Production and Decomposition in Southern Quinea Savanna, Nigeria," Oecologie, Vol. 40, No. 2, 1979, p. 155.

Vikram Kumar Saxena received the B.Tech degree in electrical engineering from the Bengal Institute of Technology and Management, Santiniketan, West Bengal University of Technology, Kolkata (India), in 2010. He received the M.Tech degree in electrical engineering from the National Institute of Technology, Patna Bihar (India), in 2013. He is currently an Assistant Professor with the Department of Electrical and Electronics Engineering, RVSCET, Jamshedpur, Kolhan University, Jharkhand (India).His research interests are in power systems, renewable energy, Electrical Machines, and Power Electronics.

Puspanjali Singh Bisht received the B.Tech degree in electrical engineering from, Chitkara University, Punjab (India), in 2008. She received the M.Tech degree in electrical engineering from the Guru Nanak Dev Engineering College, Ludhiana (India), in 2013. She is currently an Assistant Professor with the Department of Electrical and Electronics Engineering, RVSCET, Jamshedpur, Kolhan University, Jharkhand (India).Her research interests are power systems, renewable energy, optimization methods, control systems and Power Electronics.

Thakur Pranav Kumar Gautam received the B.Tech degree in electrical engineering from the C.V.Raman College of Engineering, Biju Patnayak University and Technology, Bhubaneswar, Odisha (India), in 2008. He received the M.Tech degree in electrical and electronics engineering from the Institute of Technical Education and Research, SOA University, Bhubaneswar, ODISHA (India), in 2013. He is currently an Assistant Professor with the Department of Electrical and Electronics Engineering, RVSCET, Jamshedpur, Kolhan University, Jharkhand (India).His research interests are power systems, renewable energy, computational intelligence, optimization methods, control systems and Power Electronics. Currently he is perusing his Ph.D. work in the field of intelligence based economic operation of power system under Kolhan University, India