International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 3 Issue 7‖ July 2014 ‖ PP.56-61

Hybrid Islanded Micro Grid Employing Smart Switching Of Loads

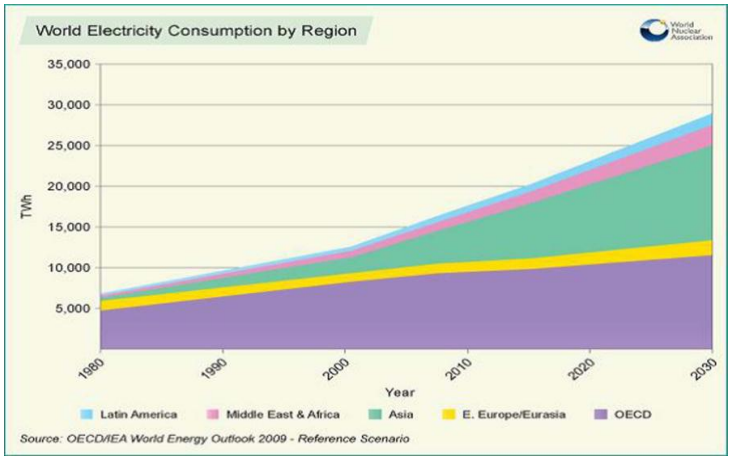
Kusum Tharani[1], Pratima Kapoor[2], Gaurav Chopra[3]
[1,2,3,]*Department of Electrical and Electronics Engineering, Bharati Vidyapeeth's College Of Engineering, New Delhi*

ABSTRACT: *This paper presents a precursory realization of a hybrid micro grid operating in islanded mode. Along with emphasis on generation of power using hybrid of three renewable resources of energy (Solar, wind and bioenergy), the project also concentrates on smart switching of critical and noncritical loads in order to fulfill crucial load requirements. The utilization of these three different resources of energy is explicitly mentioned. The employment of Programmable Logic Controller (PLC) in controlling the supply to load unit enhances the reliability of this system. An explanation for different components used, aids in understanding this project well. The significance of this innovative model has been clearly proved by explaining the need to use renewable resources of energy owing to the current power scenario of the world.*

KEYWORDS: *Renewable resources, microgrid, islanded mode, programmable logic controller (PLC), critical load, non-critical load.*

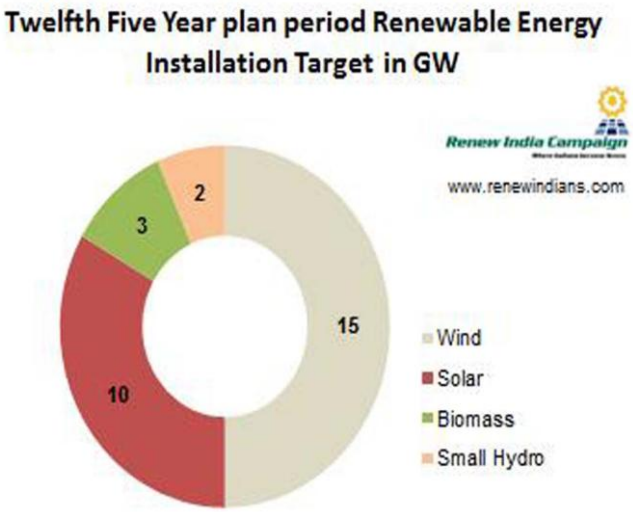
I. INTRODUCTION

Electricity generation from conventional energy resources such as coal, gas or water impacts the environment in some form or the other and the power sector is continuously exploring various options to address these concerns. Along with setting benchmarks India's electricity reforms, there is a constant endeavor to contribute towards a greener and cleaner world. As per International Energy Agency (IEA), there are around 1.3 billion people round the world who have no access to electricity. In India more than 400 million people do not have access to electricity. The government is coming up with a number of rural electrification schemes; despite that still India has nearly 54000 un-electrified villages. Even in the electrified villages, the availability of power is just around four hours on an average per day A penetration level of 20% in renewable energy is the utmost requirement in the coming decade (2020).So the challenge is to produce, transmit and utilize this green energy efficiently without aggravating the nature.[1] Power Generation through utilization of fossil fuels has also resulted in a significant increase in carbon emissions and worsening the issue of global warming. With such devastating and profound impacts in the present, it has also contributed in threatening the future of our planet. With the fossil fuels getting evanesced and world facing enough power crises, time has come to stress on the need for utilization of renewable energy efficiently, reliably and affordably. Industrialization of developing nations and excessive exploitation of electricity by developed nations, have enormously contributed in the growth of electricity consumption worldwide.



Source- OECD/IEA World Energy Outlook 2009
Fig.1. World Electricity Consumption

In the recent past, the world has encountered a series of developments in deploying renewable energy to meet the increasing energy demand.In Europe, there has been tremendous increase in renewable power generation, especially wind and solar. But due to generous and unlimited subsidy schemes in some countries, the future investors and policymakers have started to express concerns. In the United States, the renewable energy market has been growing strongly because of the stimulus policies such as the provision of cash grants upto 30% of investment costs. [2].An accurate weather forecast is required to access the energy produced by Solar PV and Wind installations. Systems using maximum power point tracking are employed to reduce variability in the production of electricity by these two sources. On the other hand energy generated by Biofuels do not entirely depend on the day to day environmental conditions. Therefore some countries like China, India and Brazil have utilized their agricultural and forest wastes effectively and shown an extended use of Biofuel consumption. Demand for Biofuels in transportation and building sector is growing at the fastest rate.An increasing share of India in renewable energy is evident from the fact that today it stands among the top five countries in the world in terms of renewable energy capacity. A report prepared by Ernst & Young states that investments in clean energy in India had increased by 54 per cent year-on-year, that represents the highest rate of growth across any significant global economy.[3]



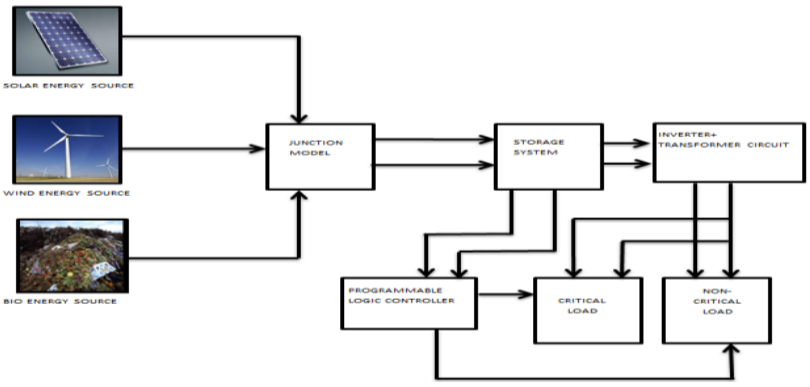
Source- Renew India Campaign

FIG.2 India's 12th Five year Plan Period Renewable Energy Target

This paper aims at implementing a project of micro grid working in off grid mode by using renewable sources of energy (Solar, wind, bioenergy) in hybrid to cater the load requirement of the consumers. This paper also introduces the concept of critical and non-critical load which can be relayed on-off with the help of Programmable logic controller (PLC).

II. DESIGN CONCEPT

It is a preliminary implementation of a hybrid micro grid operating in off-grid mode. The renewable resources (wind, solar and biomass) are agglomerated using an appropriate junction model to generate electricity to feed the load unit respectively. The hybrid configuration reduces intermittency, thereby ensuring better reliability.



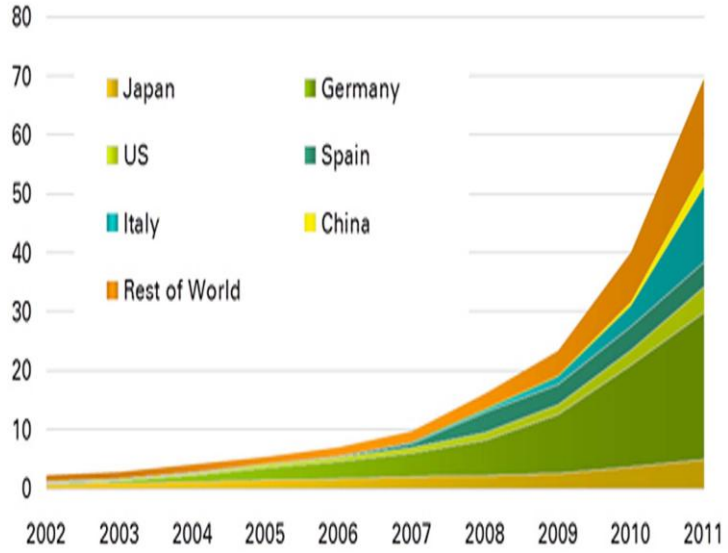
This conglomeration of resources improves sustenance in case of failure of a resource. DC power is extracted from the sources as it eliminates the problem of frequency synchronization. Battery of suitable rating is chosen for storage purpose in case of surplus generation or diminished consumption. Combination of MOSFET based square wave inverter rated 6V to 220V and transformer circuit is used to supply ac power to loads at 220volts, 50Hz as per Indian standard. Loads rated as 4W are categorized into critical and non-critical loads on the basis of their importance. The load switching is accomplished with the help of an applicable control circuit, programmable logic controller (PLC) in this case.

III. SOURCES

SOLAR ENERGY

Solar energy has proved it's potent to aid the ever-increasing energy needs of the world. Various steps have been taken by the developed and developing countries to efficiently harness this source of energy. India's National Solar mission set up under the National Action Plan on Climate Change (NAPCC) is reportedly targeting 20,000 MW from solar power by 2022.The mission has come up with a policy framework which aims at deploying the following:[4]

- Promoting programmes for off grid applications with capacity upto 2000MW.
- Use of Solar Thermal Collector up to 20 million square metres.
- Use of lighting systems for rural areas up to 20 million.



Source- 2012 British Petroleum Statistical Review of World Energy.
Fig.4. Global Solar PV Generation Capacity

Solar cells made up of semiconductor material are used to generate electric field. When photons hit the cell, a number of electron hole pairs (Lorenzo, 1994) are formed. The Shockley equation which gives the relation between voltage and current produced in a solar cell. [5]

$$I = I_{pv} - I_0\left(e^{\frac{qU}{kT}} - 1\right) \quad (1)$$

$$U = \frac{kT}{q} \ln\left(1 - \frac{I - I_{pv}}{I_0}\right) \quad (2)$$

here:
T - Reference temperature of solar cell;
U - Solar cell voltage (V);
I_0 - Saturation current of the diode (A);
I_{PV} - Photovoltaic current (A);
k - Boltzmann constant;
q - Elementary charge;
Efficiency of utilization is enhanced with the solar tracker circuit used in unison with the photovoltaic panel.

WIND ENERGY

Emergence of wind energy as a successfully operational and commercially viable source of power generation over the years has made India the 5th largest producer globally. An average growth rate of around 30 per cent has been seen resulting in cumulative installed capacity accounting to 194000 MW in 2010.After analyzing the data, GWEC is projecting an 18 per cent share of electricity for wind energy in India in 2020, requiring 134 GW. With current growth rate, wind power will contribute less than 3 per cent of the total electricity demand even by 2020.[6] Energy Alternatives India (EAI) has done an autonomous analysis with reference to the potential for wind energy in India through confabulation with industry experts and researchers, and estimated that the total onshore potential for wind energy has reached 120 GW[6].

Wind energy is exploited to generate electricity using wind mills. Special type of blades (aero foiled) are used so that maximum amount of energy can be procured from wind even at low speeds. Motor is put into action by rotating its shaft using mechanism of gear system. DC stepper motor is used as dynamo in order to generate DC power from the windmills. This averts the problem of synchronization of the power derived from other renewable sources of energy.

TABLE 1 GLOBAL WIND INSTALLED CAPACITY

Country	Installed Capacity up to Dec. 2010
China	44,733
USA	40,180
Germany	27,214
Spain	20,676
India	13,065 (now 14,989)
Italy	5,797
France	5,660
UK	5,204
Canada	4,009
Denmark	3,752
Rest of world	26,749

Source- Global Wind Energy Council www.gwec.net

The equation below shows the relation between mechanical power and wind speed :[7]

$P_w = 1/2\pi r R^2 C_p(\lambda, b)v^3$ (3)

Numerical approximations have been developed to calculate Cp given by

$Cp=(0.0007391v^3+0.023649v^2-0.26584v+1.2934)*(1-44.292\exp(-1.0762*v))$. (4)

Where

v = wind speed (m/s)

λ= tip speed ratio

r= air density (kg/m^3)

Pw = power extracted from the wind (W)

b = pitch angle of the rotor blades (degrees)

Cp = power (performance) coefficient

R = blades radius (m)

BIOENERGY : Power generation based on bioenergy is a promising alternative for fulfillment of future needs. In this implementation, bio energy has been utilized as electrical energy with the use of bio cells. Owing to the biochemical reaction between the electrodes and the electrolyte (domestic waste in this case), electricity is directly generated in these cells. The current capacity of the cell is dependent on its size, electrolyte, electrodes (and distance between them). Twenty such cells with Biowaste appoximately 30grams can be arranged to get required voltage. Desired DC power can be generated by series or parallel combination of these cells.

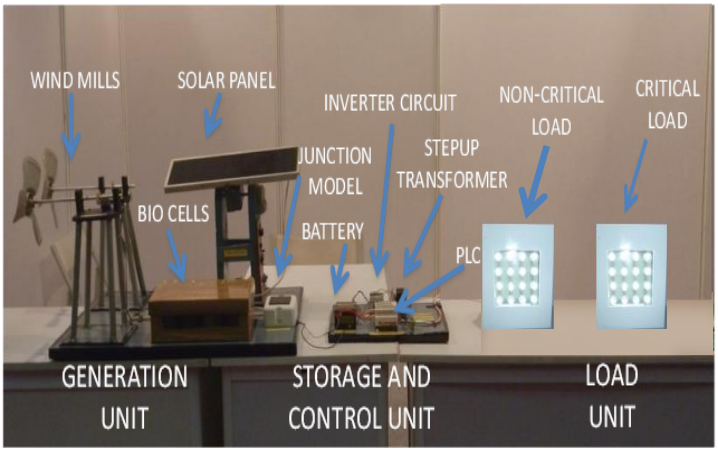


Fig.5.Experimental Setup of a Low Voltage Microgrid

IV. LOAD UNIT

As interruption in electric power disrupts certain indispensable services in banks, hospitals and offices, loads have to be supplied with non-stop power on account of their necessity. The load is fed using the power obtained at the output of inverter circuit. There is a great demand for non-stop electric power. The power supplied to the non-critical loads can be cut-off when adequate amount of power is unavailable.

V. STORAGE UNIT

Economic feasibility of this system is largely dependent on the efficiency of the storage system. In this system, lead acid battery bank is operating as the storage unit of surplus electrical energy generated. A steady and dependable power is fetched from batteries incorporated with renewable energy generation units. This provides better support for crucial loads. Proper maintenance of storage system prolongs the life of the entire unit.The charging of the battery should be monitored so as to prevent it from overcharging. For this purpose, a charge controller circuit is employed which controls the charging of the battery and hence protecting it from getting damaged.

VI. CONTROL UNIT

The PLC (Programmable logic controller) devices are used for automation of electromechanical processes. In this system, PLC executes switching of critical and noncritical loads on account of interruptions in power generation. It performs its respective function by sensing the voltage at the output terminals of the battery. Values of upper and lower threshold voltages are defined depending on the ratings of the system. If PLC senses a voltage lower than the upper threshold voltage, non-critical load is switched off with the help of it's relaying action. A lower threshold voltage is set to prevent deterioration of storage unit.

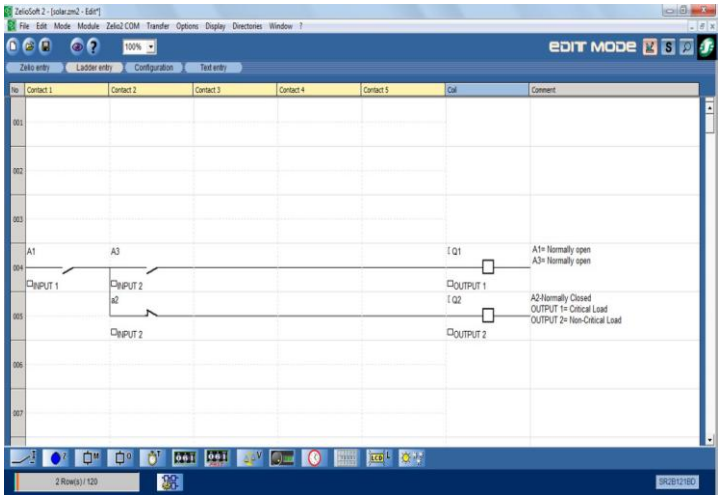


Fig.6. PLC Ladder Diagram

VII. OTHER COMPONENTS

Other important components involved in this system are inverter and transformer. These were chosen with suitable ratings for successful operation.

RESULT : Emphasis was laid on the sustenance of the entire system with the generating unit in off-grid mode.When there is no supply of power from the generating end, the prototype can operate in standalone mode for approximately 8 hours. With the help of smart switching through PLC the running time of the prototype is increased to 9 hours approximately.

TABLE 2. OUTPUT VOLTAGE AND CURENT FROM PROTOTYPE

RENEWABLE ENERGY SOURCES	OUTPUT VOLTAGE AND CURRENT (APPROX.)
1)SOLAR ENERGY	12V, 1 Amps
2)WIND ENERGY	10V, 1Amps
3)BIO ENERGY	10V, 800mAmps

VIII. CONCLUSION

The scarcity of fossil fuels coupled with destructing impacts on the planet has compelled to exploit renewable resources of energy for power generation. This paper is just an initiative to head towards elimination of deficiencies of power generation systems in the world. The concept of utilization of renewable resources of energy in amalgamation with smart switching of loads has been well emphasized upon. If the implementation of micro grid in islanded mode presented in this paper is rightly developed and ameliorated, it can prove to be a proficient solution to many of our power problems.

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