International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-2 Issue-2, December 2012

Design of Micro Hydel Power Plant

Vineesh V, A. Immanuel Selvakumar

***Abstract:** The asynchronous condition of hydro power plant depends upon the speed variation in turbine generator set which is effected by the gate states of hydraulic turbine. This paper deals with the technical feasibility of a small hydropower plant for domestic use (micro-hydro), how it can be implemented in Valara waterfall, Kerala, India. Included within this document is an introduction to micro hydro system, design and simulation of hydraulic turbine and generator and how they apply specifically to power generation. The proposed site has a very large potential for power generation, yet the source of micro hydro energy remain untapped.*

***Keywords:** Micro hydro power, hydraulic turbine, alternator, rural electrification.*

I. INTRODUCTION

Hydropower is a renewable, non-polluting and environmentally benign source of energy. Hydropower is based on simple concepts. Moving water turns a turbine, the turbine spins a generator, and electricity is produced. The use of water falling through a height has been utilized as a source of energy since a long time. It is perhaps the oldest renewable energy technique known to the mankind for mechanical energy conversion as well as electricity generation.[1-3]. Small-scale hydropower was the most common way of electricity generating in the early 20th century. The first commercial use of hydroelectric power to produce electricity was a waterwheel on the Fox River in Wisconsin in 1882 that supplied power for lighting to two paper mills and a house. The first hydro power plant was of 130 kW set up in Darjeeling during 1897,which marked the development of hydropower in the country. Similarly, by 1924 Switzerland had nearly 7000 small scale hydropower stations in use. Even today,small hydro is the largest contributor of the electricity from renewable energy sources, both at European and world level. In India, hydro projects up to 25MW station capacities have been categorized as Small Hydro Power (SHP) projects. The Ministry of New and Renewable Energy, Government of India is the agency responsible for planning, financing and installation of SHP upto 25MW. Most of the small hydro power plants are run of river scheme, implying that they do not have any water storage capability. The power is generated only when enough water is available from the river. When the stream flow reduces below the design flow value, the generation will reduce as the water does not flow through the intake structure into the turbine[3].

Manuscript published on 30 December 2012.
* Correspondence Author (s)
Vineesh V, Master Degree in Renewable Energy Technologies from Karunya University, Coimbatore, India.
A. Immanuel Selvakumar, Associate Professor and HOD Dept of Electrical and Electronics, Karunya. University Coimbatore, India.,

Small hydro plants may be stand alone system in isolated areas but could also be grid connected. The connection to the grid has the advantage of the easier control of the electrical system frequency of the electricity, but the disadvantage of being tripped off the system due to problems outside of the plant operator's control.

II. MODEL OF HYDRO POWER PLANT

Power generation from the water depends upon the combination of head and flow. Both must available to produce electricity. Water is diverted from a stream into a pipeline (penstock) where it is directed downhill and through the turbine. The vertical drop creates pressure at the bottom end of the pipeline. The pressurized water from the end of the pipe creates the force that drives the turbine. The turbine in turn drives the generator where electrical power is produced. More flow or more head produces more electricity. Electrical power output will always be slighter less than water power input due to turbine and system inefficiencies. Head can be expressed as vertical distance or as pressure such as pounds per square inch(psi)[3]. Net head is the pressure available at the turbine when water is flowing which will always be less than the pressure when water flow is turned off, due to the friction between water and pipe

A. Modellng of Penstock and Gate

The turbine and penstock characteristics can be determined from three basic equations[4-5];

a) Velocity of water in penstock.
b) Turbine mechanical power and,
c) Acceleration of water.

A schematic diagram of hydroelectric plant is shown in Fig. 1

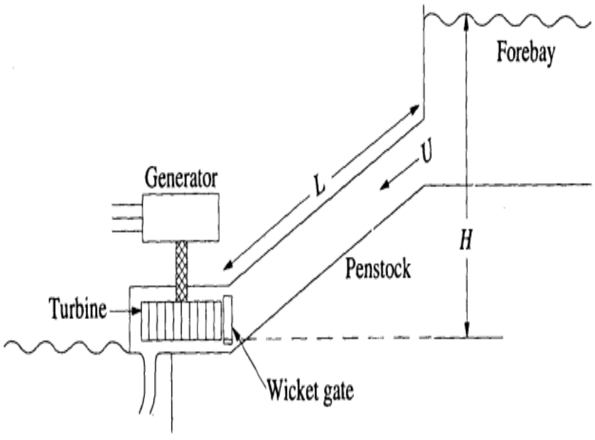

Fig 1 Model of hydro electric power plant

The model given in Fig.2 is used to simulate the steady state output of the turbine for given gate position. The simulation model which is shown below is used to compute turbine output for any gate position.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Besides this the integrated model of gate, penstock turbine/generator is also used to study the deviation in power output and speed for a change in gate position. The steady state out power P_m for various gate positions can be computed from the differential equation of the simulation diagram given in Fig.2. Equations (4), (5) and (6) completely describes the water and hydraulic turbine characteristics.

Assuming a rigid conduit andincompressible fluid, the basic hydrodynamic equations are

$$U \propto GH^{\frac{1}{2}} \quad (1)$$

$$P_m \propto HU \quad (2)$$

Where,

P_m = mechanical power produced in the turbine in W

U = velocity of water in penstock (m/sec)

H = head in metre

Expressing the above equations about the rated values

$$H = (U/G)^2 \quad (3)$$

$$\frac{dU}{dt} = (1 - H + H_0) \times \frac{1}{Tw} \quad (4)$$

Ideal gate opening(G) is related to real gate opening(g) as follows;

$$G = A_t \times g \quad (5)$$

$$A_t = \frac{1}{gFL - gNL} \quad (6)$$

Where

A_t = turbine gain

gFL = Gate Opening at full load

gNL = Gate Opening at no load

H_0 = loss of water in conduit length and Tw is the water starting time

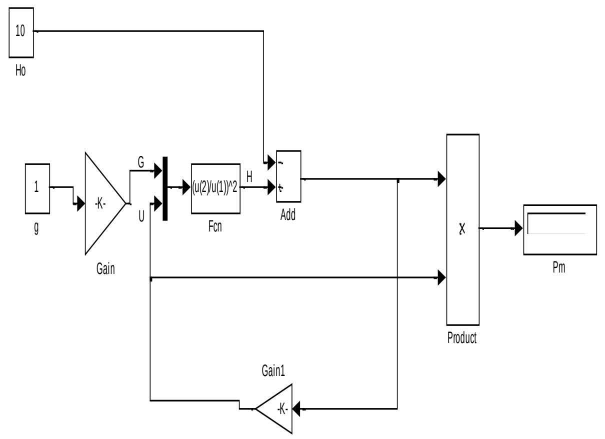

Fig 2 Simulation Model of Hydraulic Turbine

B. Modelling of Generator

Machinery can be driven directly by a turbine as in traditional grain mills and many modern timber sawing mills, but converting the power into electricity has several additional advantages. For instance, it enables the use of all types of electrical appliances from lighting to electric motors and also the flexibility of having the appliances at any point either near or far from the turbine. The device which converts mechanical energy into electrical energy is called a generator[6-8]. The most common type of generator produces alternative current and is known as an alternator.

Synchronous generator is used to produce the electric power. Alternators generate electricity using the same principle as a DC generator, i.e when the magnetic field around a conductor changes, a current is induced in the conductor. Typically, a rotating magnet called the rotor turns within a stationary set of conductors wound in coils on an iron core, called the stator. When the field cuts across the conductors, an EMF (electromotive force) is induced, as the mechanical input causes the turning of the rotor. The rotating magnetic field induces an AC voltage in the stator windings. The rotor's magnetic field may be provided by stationary field winding, with moving poles in the rotor. Brushless AC generators are usually larger machines than those used in automotive applications.

Simple design for alternator

$$N = 120 \times f/P \quad (7)$$

Where, N= rotor speed (in rpm)

f = frequency in Hz

P = number of pole

$$\Delta\omega(t) = \frac{1}{2H} * \left(\int_0^t (Tm - Te)dt - K_d\, \Delta\omega(t)\right) \quad (8)$$

$$\omega(t) = \Delta\omega(t) + \omega_0 \quad (9)$$

Where Δω is thespeed variation with respect to speed of operation

H= Constant of inertia

Tm = mechanical torque

Te =Electromagnetic torque

K_d= Damping factor represents the effect of damper winding.

ω(t)= Mechanical speed of rotor

ω_0 = Speed of operation

Fig.3 shows the simulation diagram for parameter determination for a three phase alternator. The input to the generator is considered as mechanical power, which is the output of hydraulic turbine. From the simulation it is clear that a sinusoidal voltage and current is produced as shown in Fig.9 and Fig.10 respectively. A constant excitation is needed for the alternator. The rotor is excited with a dc supply so that a rotating field type alternator is produced. A three phase RLC load is introduced to imitate the possible loads of the system. Electric torque is calculated after considering electric power and rotor speed. The simulation is done for a three phase synchronous generator[9]. The input to the alternator is a mechanical power which is taken from the output of a waterwheel turbine. The electric power and electrical torque produced is shown in fig 11 and fig 12. From the figure it is cleared that after a starting transient a constant torque and power is produced just like a typical alternator.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

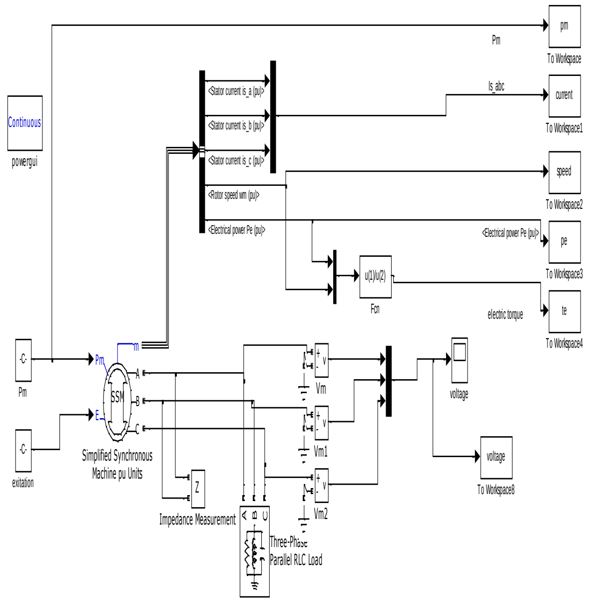

Fig 3 Simulation model of generator

III.PROPOSAL OF MICRO HYDEL POWER PLANT AT VALARA WATERFALL

This module is based on the technical feasibility of the implementation of micro hydro electric power plant in Valara waterfall, which is located in Idukki district in Kerala state. This section mainly focused on geographical details of the site, catchment area of the waterfall and climate of the region The initial project proposal envisaged only a detailed hydrological investigation of the catchment of the Deviar river with an aim to help in establishing a micro hydel power plant. The catchment of the valara waterfall is located in Idukki district of Kerala State between10°18′36 ″N.and 76°29′45″ E the waterfall as such is located in between the two towns Neriamangalam the east side border of Ernakulam in Idukki district, Kerala. Fig 4 shows the index map of the proposed site. The different components of work carried out are furnished below:

1. Collection of all available datas on morphometric and hydrologic parameters from existing sources.
2. Hydrological observations in the field using instruments.
3. Arriving at different alternatives and selection of the optimal scheme.
4. Preparing the design details of the scheme.

A. Hydrological Study

The catchment of valara stream has an area of 61.5 Km^2. The valara waterfall is originated from deviar river, which is a sister river of Vaigai River.The area is subjected to two monsoon: south – west (June – Aug) and north – east (Oct-Nov), the former contribute 75% of annual rainfall and later 30%. The average rainfall of the proposed site is around 440cm based on data available from the nearby station Fig 5 gives the average monthly rainfall in the site for last 10 years.

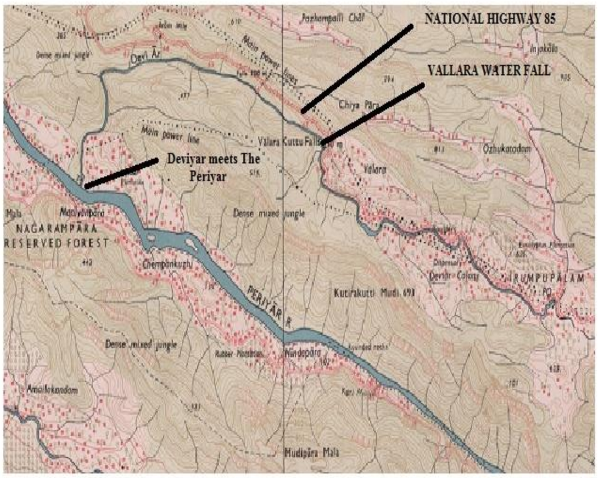

Fig 4 Index Map of the site

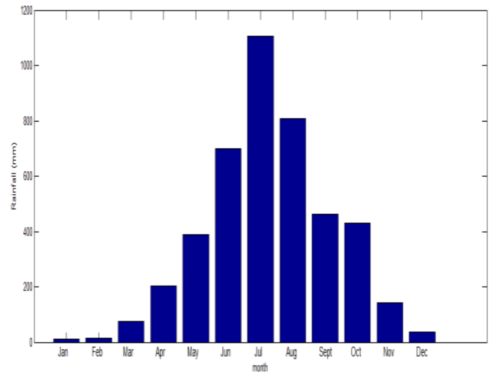

Fig 5 Average Monthly Rainfall

Runoff is that balance of rain water, which flows or runs over the natural surface ground surface after losses by evaporation, interception and infiltration[8-10][13]. The yield of a catchment is the net quantity of water available for storage, after all losses for the purposes of water resources utilization and planning, like irrigation, water supply etc. The runoff from rainfall may be estimated from the Empirical formulae method i.e

$$R = a \times P - b \quad (10)$$

Where R = runoff in cm, P = rainfall in cm a and b are constants which varies with region

$$R = 0.85P-30.4$$

Fig.6 shows the average monthly hydrograph of flow in the stream in the past 10 years. The maximum average stream flow is about 19.82m^3/sec and minimum is about 0.2581m^3/sec. Two peaks are clearly indicated that one during south – west monsoon and another during north – east monsoon. There is decrease in flow from months from Nov to May is about 0.67m^3/sec, the large gap between monsoon and summer poses problem in utilizing 75% of the flow for uniform power generation to cater to the domestic needs of the people in the locality.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

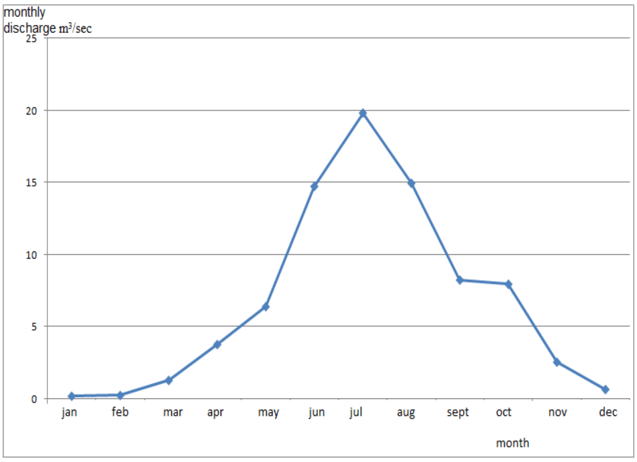

Fig 6 Hydrograph of Site

Discharge(m^3/sec) can be calculated by using water flow rate and seconds

Water Discharge(in m^3) = monthly runoff x catchment area (11)

Water discharge(in m^3/sec) = water discharge/no.of seconds (12)

B. Estimation of Electric Power

Micro hydro power is a site specific type of renewable energy. Each different site require a separate evaluation in order to determine the energy output. A micro hydro applications installed in home areas or any place where a small stream can be harnessed for power. This means that each individual site will most likely have a low head and a low flow. The higher head a site has, the higher the final energy output will be. Higher heads require less water to produce a given amount of power. In some instances the flow rate of a stream can be determined through the access of Government records of stream flow[11]. Once both the head and flow data are measured the potential power of an application can be obtained using equation

$$P = Q \times H \times E \times 9.81 (\text{kW}) \quad (13)$$

Fig 7 shows the estimated monthly electric potential of the proposed site for the past 10 years.

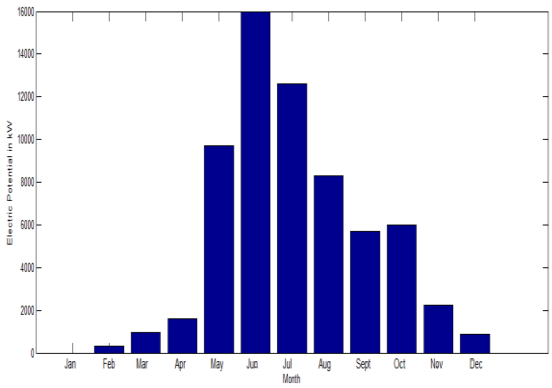

Fig 7 Estimated monthly electric potential

IV.SIMULATION RESULTS

The model shown in the fig 2 is used to simulate the steady state output of the turbine for gate position. Fig.8 shows steady state output characteristic of the turbine for various gate positions. The output of turbine is 1.035 pu for 1.0 pu of gate opening. Besides the steady state simulation as stated above, the operation of turbine for other various operating condition is also simulated[5][12]. It is assumed that machine is initially operating at 1.035 pu output corresponding 1.0 pu gate position.

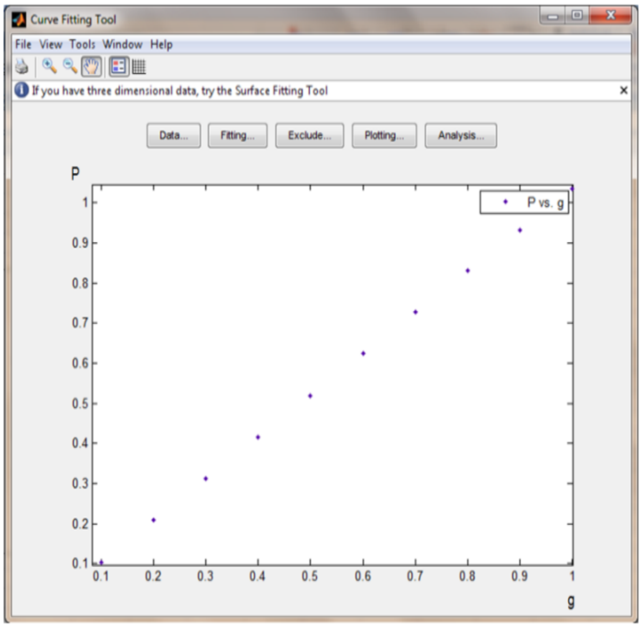

Fig.8 Simulation Results using cftool

The simulation is done for a three phase synchronous generator[9][12]. The input to the alternator is a mechanical power which is taken from the output of a waterwheel turbine. The electric power and electrical torque produced is shown in fig 11 and fig.12. From the figure it is cleared that after a starting transient a constant torque and power is produced just like a typical alternator.

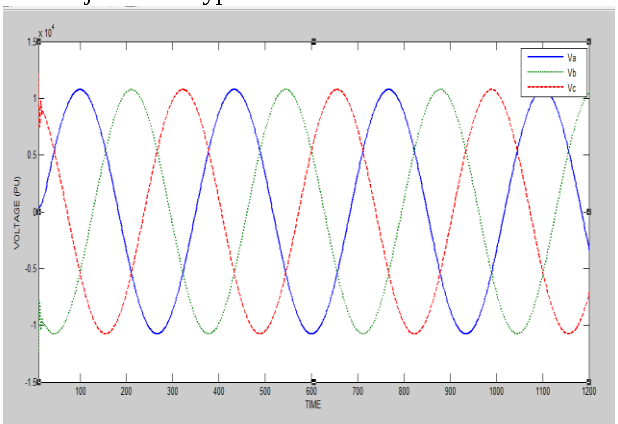

Fig.9 Output Voltage Waveform

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

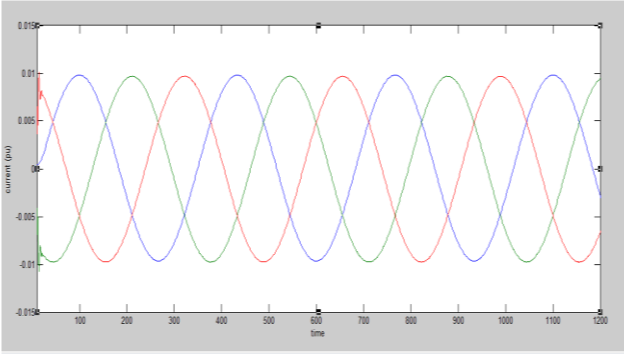

Fig.10 Electrical Output Current

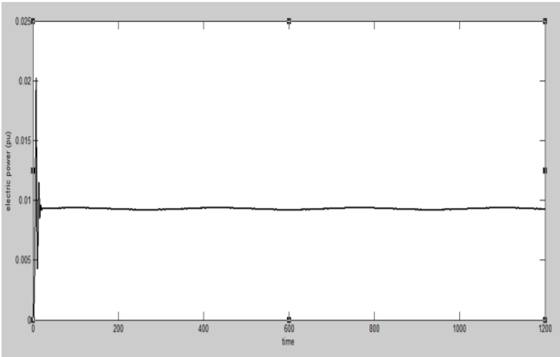

Fig.11 Electrical Power

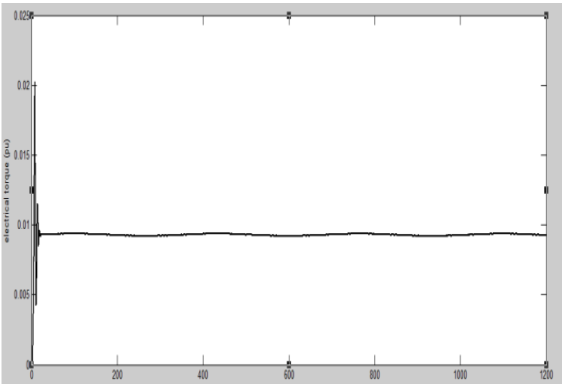

Fig.12 Electrical Torque

V.CONCLUSION

Micro hydro is a primary source of energy in India especially in the southern regions. Promoting renewable energy sources for energy requirements in conjunction with alleviation of rural poverty, diversification of energy resources and reduction of oil imports are needed to shift the economical growth towards greater sustainability, as well as environmental and social stability. This paper presents the feasibility of micro hydro power plant in domestic needs. This paper also deals with simulation of both hydraulic turbine and alternator and their clearly shows the steady state output for various gate position. The feasibility of small hydro power for domestic needs is justified by giving a proposal of the implementation of small hydro power in Valara waterfall in Kerala.

ACKNOWLEDGEMENTS

At the outset we express my gratitude to the ALMIGHTY GOD who has been with us during each and every step that we have taken towards the completion of this project. I take immense pleasure in conveying my thanks and deep sense of gratitude to my Supervisor Dr. A. Immanuel Selvakumar, Associate Professor and HOD, for his guidance and valuable suggestions during all phases of this work.We would take this opportunity to thank Dr. Anitha A B, Director of Hydrological Dept, Centre For Water Institute, Calicut, for providing us detailed informations about the site. We would like to convey gratitude to our Parents whose prayers and blessings were always there with me.

REFERENCES

[1]. Sakurai.T, Fuanto.H 'Fundamental Characteristics of Test Facility For Micro Hydro electric Power Generation System' IPEMC 2009.
[2]. Okonkwo, G N, Ezeonu S O "Design and Installation of Mini Hydro Electric Power Plant", Scholar Journal of Engineering Research Vol 1(1), April 2012
[3]. Chauhan D S, Gagan Singh "Simulation and Modelling of Hydro Power Plant to study Time Response during Different Gate States" International Journal of Advanced Sciences and Technologies Vol 10 Issue No. 1, 42-47 2007
[4]. Priyano Sutikno, Ibrahim Khalil " Design, Simulation Simulation and Experimental of the Very Low Head Turbine with Minimum Pressure and Free Vortex Criterions', International Journal of Mechanical and Mechatronics Engg IJMME – IJENS Vol 11, 2011
[5]. Yin Chin Choo, Kashern M Muttaqi, Negnevitsky M 'Modelling of hydraulic governor – turbine for control Stabilization', ANZIAM J 49 (EMAC2007) pp C681-C698, 2009
[6]. Angus Simpson, Michael Gibbard, John Pheat " Development of an integrated Hydraulic Electrical Model for Hydro Power Plant", Water Power pp1150-1159, 1997
[7]. Yu, Yao-nan 'Electric Power System Dynamics' Academic Press, New York, 1983
[8]. Oliver Paish, "Small Hydro Power- Technology and Current Status: Elseiver Journal Renewable and Sustainable Energy Reviews
[9]. Fraenkal P Paish, O Bokalders V, Harvey A, Brown A, Edward R," Micro Hydel Electric Power Plant- a guide for development workers" IT Publications Ltd. London, 1991
[10]. Arun Kumar, Verma H K "Performance Testing of Small Hydropower Plant" International Conference on Small Hydro power- Hydro Srilanka 22-24 2007
[11]. Renata Archetti , 'Microhydro electric power: Feasibility of domestic plant', International Conference on Green Buildings and Sustainable Cities, Elseiver journal Procedia Engineering 21 pp 8-15 2011.
[12]. Wazed M A, Shamsuddin Ahmed,'Micro Hydro Energy Resources in Bangladesh - A Review', Australian Journal of Basic and Applied Sciences2(4):11209-1222, 2009.
[13]. CWRDM, "Micro Hydel Scheme at Kakkadampoil- Project report by Centre For Water Resource Development and Management, Calicut.

Vineesh V was born on 4thfebrvary 1989. He completed his Bachelor Degree from SaintGits College, Mahatma Gandhi University in Kerala. Currently he was doing his Master Degree in Renewable Energy Technologies from Karunya University, Coimbatore. His research interest include Renewable Energy, Power Electronics and Power System

Dr. A.Immanuel Selvakumar is Associate Professor and HOD of Electrical and Electronics Dept, Karunya University,Coimbatore. He has Bachelor Degree in Electrical Engg. and Master Degree in Power Electronics and Drives and earned his PhD(Power System Operation Modern Optimization Technique) from Karunya University.He has published many papers in both national and international Journals and he has IEEE professional membership.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)