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DC Voltage Regulation by Buck Converter Applicable for Stand Alone Micro Hydro Power Generation

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Abstract

This paper is aimed to present the design of a DC voltage regulator applicable for micro hydro power generation for standalone system. Special consideration given to the fact that, optimization of natural resource like hydro power within specified voltage and frequency variation limits, is feeding lighting loads. The prototype module of system are fulfilled and tested through the practical implementation of the regulated DC link. In addition, in this document the reference voltage fixation method for AC-DC, switching techniques by a transistor based circuit operation with proper filtering and finally power delivery to the load with proper isolation has been shown with both simulation and practical test outputs. The achievements of the practical testing of system lies in successful AC-DC conversion with regulated output. The DC link removes the problem of frequency and voltage variation due to change in input variables (turbine intake). Along with the capability of matching inverter output voltage and frequency with continuous fluctuating synchronous generator's output voltage and frequency. It also provides isolation of circuit if there is over loading / faults in Inverter side.

Keywords: Micro Hydro Power Generation, inverter, Pulse width modulation, Duty cycle.

1. Introduction

With rapid growth of population on the earth, the growth of Energy requirement is raising so high that, it made engineers bound to think alternative to fossils and other natural resources. Our present world is demanding the use of green energy. Hydro energy has great potential to supply energy with minimum impact on the environment, since it is clean and pollution free.In hydro power generation, energy that convert potential energy or water into electricity, the water after generating electrical power is available for irrigation and other purposes. Although present generation had successfully benefited from large and small scale hydro power to generate electricity but no effort had been made to utilize hydro generation in the range of micro or Pico hydro power systems. If this potential is fully utilized, the power can be generated from a clean energy and this will provide a good solution for the problems of energy supply in remote and hilly areas where the extension of grid system is already proven to be comparatively uneconomical. Small hydropower systems are the application of hydroelectric power on a commercial scale supplying small loads and are classified by power and size of waterfall. This system can be divided into mini, micro and Pico hydropower and recognized as key technologies in bringing renewable electricity to rural populations. In the developing countries where funding is of primary concern, the micro and Pico hydro power had already proven to be a practical and potential low cost option for generating electricity at remote sites, particularly for small villages in hilly areas. During the last years, innovations in micro hydro technology have focused on the development of low cost implementation of standalone Pico hydropower to improve the affordability for low income households[4-5].

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Major function is to convert variable potential energy of the hydro power to AC energy with regulated output, which will allow the system to deliver power to connected load. This attempt will take the use of green energy to a level must for near future. The inverters are capable of producing energy from free flow of water without any environmental pollution.

2. Micro Hydro Power Generation Scheme

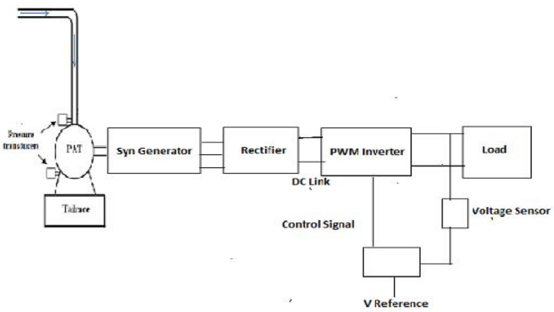

Fig. 1: Schematic block diagram for Micro Hydro Power Generation using Synchronous Generator

As shown in the figure -1 the free flow of water passesing kinetic energy, will rotate the turbine and coupled synchrounous generator. The frequency of power generation is propotional to the speed of rotor. And the voltage is depend upon excitation as well as torque available to rotor. The natural source of water flow will change as per the season this will affect the output frequency and voltage of synchrounous generator if it is directly given to load. The output of synchrounous generator is fed to uncontrolled rectifier for converting it to DC**.** The uncontrolled rectifier unit removes the problem of variation in voltage and frequency of AC output depending on torque and speed of turbine of Synchronous generator. Before designing a system two major facts must be kept into consideration. One is, operate hydro generation at maximum power output and another one is inverter must be able of deliver sinusoidal waveform within permissible limits of voltage and frequency variation.

3. Design of Buck Converter

A dc-dc converter is used to increase the efficiency of the system by matching the supplied voltage to the voltage required by the load. In this application shown in Fig. 2,the buck converter is used for keeping, the output voltage to be constant, regardless of changes in the input voltage due to variations in input water flow to turbine, or in the effective load. This is accomplished by building a circuit that varies the converter control input, in such a way that the output voltage is regulated to be equal to a desired reference voltage.

The modeling begins as usual, by determining the voltage and current waveforms of the inductor and capacitor Fig. 2. The operating mode of a buck converter circuit can be divided into two modes. Mode 1 begins when the switch is in position 1, the circuit of Fig. 3(a) is obtained. The current flow through inductor L, diode D, capacitor C. In Mode, the switch is in position 2, the circuit of Fig. 3(b) is obtained.

During this mode, the energy stored in the capacitor is then transferred to the battery. Therefore, the output voltage is less than the input voltage and is expressed as:

$$V_{out} = DV_{input}$$

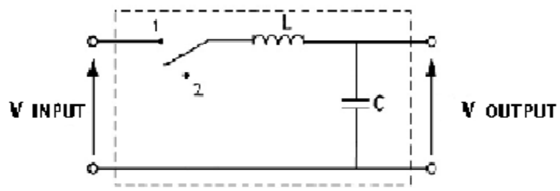

Fig. 2: Circuit diagram of Buck Converter.

The system can be divided into two parts for simplicity of implementation.

(A) Turbine-Synchronous Generator set with DC link and (B) Inverter with regulated output voltage control with closed loop operation.

(A)Turbine-Synchronous Generator set with DC link :-The operating voltage and frequency of the generation will depend upon the turbine power output, the excitation and the load connected. There is some flexibility as to the choice of operating voltage and frequency which can be used to advantage to improve the efficiency of the system. [4]

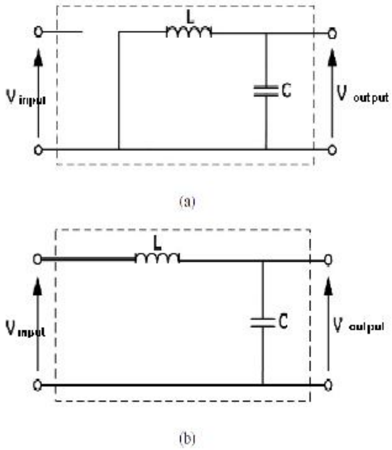

Fig. 3: Buck Converter Circuit (a) when switch is in position 1, (b) when switch is in position 2,

4. Buck Converter Design

The data taken :- Vin = 30 V, Vout = 14 volts, I load = 2 amps, Fsw = 400 Khz ,D = Vin / Vout = 30V /14V = 0.4666 Calculation for Inductor $V = L \cdot \Delta I / \Delta T$ Rearrange and substitute:

$L = (Vin - Vout) \cdot (D / Fsw) / I\ ripple$, gives: $L = 26\ V \cdot (0.466 / 400\ kHz) / 0.6A$ & L = 50.54 uH

Calculation for a capacitor:- $\Delta V = \Delta I \cdot (ESR + \Delta T / C + ESL / \Delta T)$, Ripple voltage: 50 mv ,ΔI = 0.6 amp, ESR = 0.03 ohm, ESL = 0, ΔT =.466 / 400 kHz = 1.165 usec, Simplify (assume ESL = 0), $\Delta V = \Delta I \cdot (ESR + \Delta T / C)$

Rearranging the above equation,

$C = (\Delta I \cdot \Delta T) / (\Delta V - (\Delta I \cdot ESR))$ Calculate: Cout = (0.6A · 1.165 usec) / (0.05V-(0.6A · 0.03))

Cout = 21.84uF (minimum).

5. DC Buck Conversion and Regulation Technique

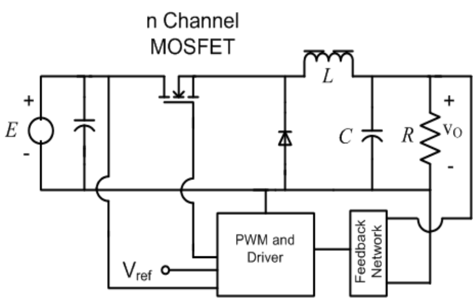

Fig. 4: Buck Converter Circuit

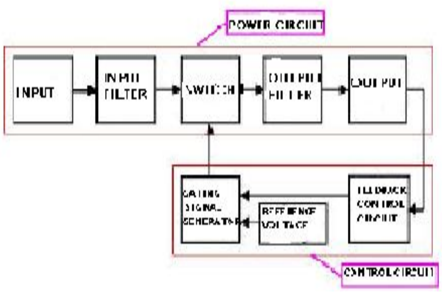

Fig. 5: Block diagram of DC link voltage regulator.

6. Implementation

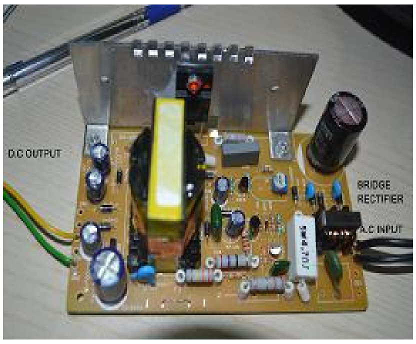

Fig. 5: a) DC link voltage regulation Circuit

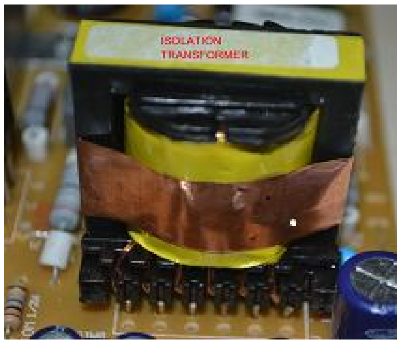

Fig. 5: b)isolation transformer

7. Conclusion

The Micro hydro power generation system consisting DC-DC buck converter with regulator closed loop has been described and the hardware tested on prototype model. From the proposed design, the buck converter is able to produce a constant DC output voltage and will remove the variation in magnitude of frequency and Voltage of AC generation. The well designing of DC link will produce high quality performance of this scheme. Micro Hydro power generation scheme may give the possibility to electrify remote areas using locally available renewable energy sources with efficient and economical power ,with better voltage and frequency regulation.

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