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Rural Agricultural Water Pumping using BLDC Motor with Solar Fed Water Pumping System by Zeta Converter with Simulation Modeling

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Abstract- **Renewable energy is the energy which comes from natural resources such as Sunlight, wind, rain, tides and geothermal heat etc. This paper proposes brushless DC (BLDC) motor drive for solar photovoltaic (SPV) array fed water pumping system using a zeta converter. Zeta converter is utilized in order to extract the maximum available power from the SPV array. There is no additional control or circuitry is used for speed control of the BLDC motor. The speed is controlled through a variable DC link voltage of VSI. An appropriate control of zeta converter through the incremental conductance maximum power point tracking (INC-MPPT) algorithm offers soft starting of the BLDC motor. The proposed water pumping system is designed and modeled such that the performance is not affected under dynamic conditions. The suitability of proposed system at practical operating conditions is demonstrated through simulation results using MATLAB/ Simulink.**

Index terms**: Zeta converter, SPV array, BlDC motor, MPPT.**

I. INTRODUCTION

Apart from the rapidly decreasing reserves of fossil fuels in the world, another major factor working against fossil fuels is the pollution associated with their combustion. Contrastingly, renewable energy sources are known to be much cleaner and produce energy without the harmful effects of pollution unlike their conventional.

The maximum power point tracking is basically a load matching problem. In order to change the input resistance of the panel to match the load resistance (by varying the duty cycle), a DC to DC converter is required. It has been studied that the efficiency of the DC to DC converter is maximum for a buck converter, then for a buck-boost converter and minimum for a boost converter but as we intend to use our system either for tying to a grid or for a water pumping system which requires 230 V at the output end, so we use a boost converter.

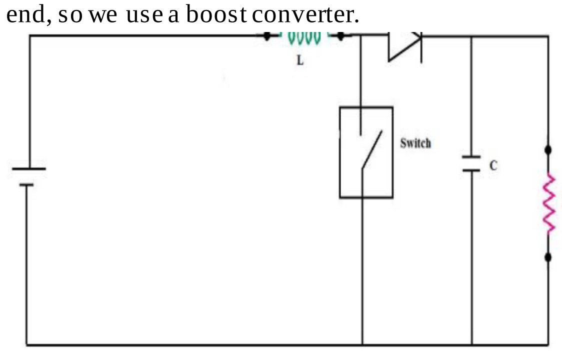


Figure 1.1 Circuit diagram of a Boost onverter

1.1 MODE 1 OPERATION OF THE BOOST CONVERTER

When the switch is closed the inductor gets charged through the battery and stores the energy. In this mode inductor current rises (exponentially) but for simplicity we assume that the charging and the discharging of the inductor are linear. The diode blocks the current flowing and so the load current remains constant which is being supplied due to the discharging of the capacitor.

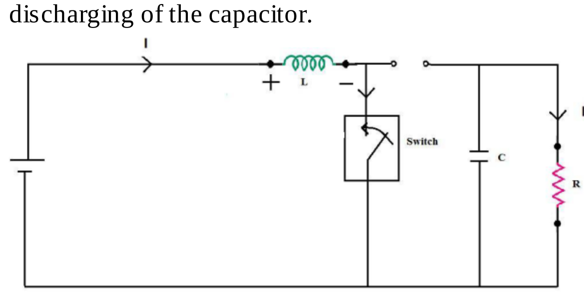


Figure 1.2 : Mode - 1 operation of Boost Converter

1.3 MODE 2 OPERATION OF THE BOOST CONVERTER

In mode 2 the switch is open and so the diode becomes short circuited. The energy stored in the inductor gets discharged through opposite polarities which charge the capacitor. The load current remains constant throughout the operation.

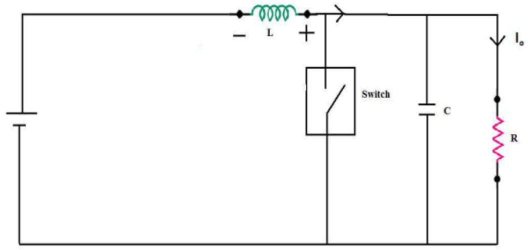


Figure 1.3 Mode 2 operation of Boost Converter

II.ZETA CONVERTER

A zeta converter is a fourth order non linear system being that, with regard to energy input, it can seen as buck-boost-buck converter and with regard to the output, it can be seen as boost-buck-boost converter.

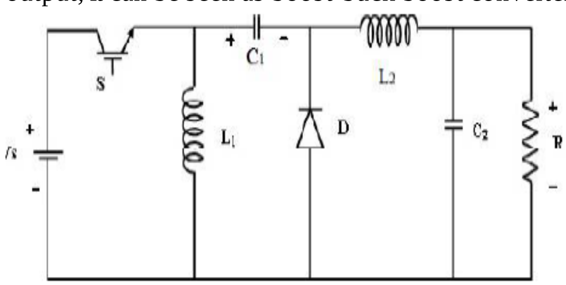


Fig.2.1 Basic Zeta converter circuit

The ideal switch based realization of zeta converter is depicted. A non-isolated zeta converter circuit is shown in the fig.2.1. Although several operating modes are possible for this converter depending on inductance value, load resistance and operating frequency, here only continuous inductor current „iL_1 ‟ analyzed using the well known state-space averaging method[3] . The analysis uses the following assumptions.

1. Semiconductors switching devices are considered to be ideal.
2. Converter operating in continuous inductor current mode.
3. Line frequency ripple in the dc voltage is neglected.

MODES OF OPERATION OF ZETA CONVERTER

Zeta converter exhibits two different modes as follows:

Mode1: The first mode is obtained when the switch is ON (closed) and instantaneously, the diode *D* is OFF. An equivalent circuit shown in Fig.2. During this period, the current through the inductor *L*1 and *L*2 are drawn from the voltage source Vs. This mode is the charging mode.

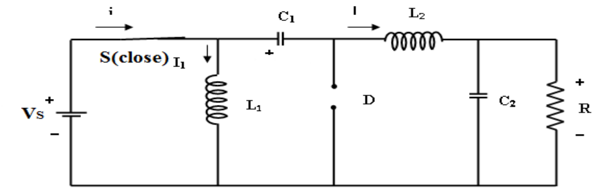


Fig.2.2 Equivalent circuit of converter (switch ON)

Mode2: The second mode of operation starts when the switch is OFF and the diode *D* is ON position, the equivalent circuit shown in Fig.3. This stage or mode of operation is known as the **discharging** mode since all the energy stored in **L2** is now transferred to the load **R.**

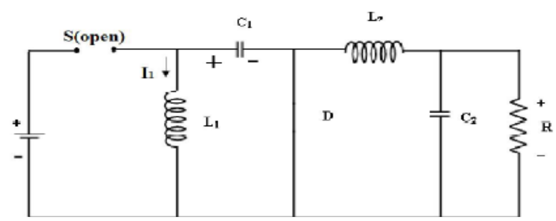


Fig.3 Equivalent circuit of converter (switch OFF)

III MPPT -MAXIMUM POWER POINT TRACKER

MPPT or Maximum Power Point Tracking is algorithm that included in charge controllers used for extracting maximum available power from PV module under certain conditions. Maximum power varies with solar radiation, ambient temperature and solar cell temperature. Typical PV module produces power with maximum power voltage of around 17 V when measured at a cell temperature of 25°C, it can drop to around 15 V on a very hot day and it can also rise to 18 V on a very cold day. MPPT or maximum power point tracker is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid. To put it simply, they convert a higher voltage DC output from solar panels (and a few wind generators) down to the lower voltage needed to charge batteries.

The Power point tracker is a high frequency DC to DC converter. They take the DC input from the solar panels, change it to high frequency AC, and convert it back down to a different DC voltage and current to exactly match the panels to the batteries. MPPT's operate at very high audio frequencies, usually in the 20-80 kHz range. The advantage of high frequency circuits is that they can be designed with very high efficiency transformers and small components. The design of high frequency circuits can be very tricky because the problems with portions of the circuit "broadcasting" just like a radio transmitter and causing radio and TV interference. Noise isolation and suppression becomes very important. There are a few non-digital (that is, linear) MPPT's charge controls around. These are much easier and cheaper to build and design than the digital ones.

They strictly an electronic process - no real smarts are involved except for some regulation of the output voltage. Charge controllers for solar panels need a lot more smarts as light and temperature conditions vary continuously all day long, and battery voltage changes.

IV BRUSHLESS DC MOTOR

The rotor part of a brushless motor is often a permanent magnet synchronous motor, but can also be a switched reluctance motor, or induction motor. Brushless motors may be described as stepper motors; however, the term "stepper motor" tends to be used for motors that are designed specifically to be operated in a mode where they are frequently stopped with the rotor in a defined angular position. This page describes more general brushless motor principles, though there is overlap.

Brushless motors fulfill many functions originally performed by brushed DC motors, but cost and control complexity prevents brushless motors from replacing brushed motors completely in the lowest-cost areas. Nevertheless, brushless motors have come to dominate many applications particularly devices such as computer hard drives and CD/DVD players. Small cooling fans in electronic equipment are powered exclusively by brushless motors. They can be found in cordless power tools where the increased efficiency of the motor leads to longer periods of use before the battery needs to be charged. Low speed, low power brushless motors are used indirect-drive turntables for gramophone records.

V CENTRIFUGAL PUMP

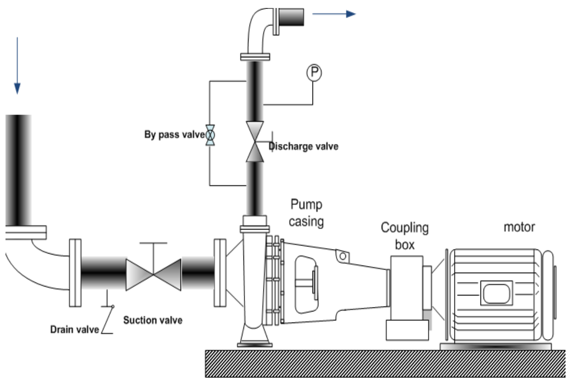
With fluid transporting devices which are mainly "PUMPS". All chemical process industries have the basic and the mostly optimized device know as centrifugal pump.

It is a superb piece of equipment where most of the fluids which are viscous and coarse form are handled easily and it is cheaper when compared to other pumping devices, even maintenance cost is much lesser than reciprocation pumps. When coming to its standard operating procedure, there are sequences of steps to be followed for every centrifugal pump. Which may vary in some situation based on design but mostly the following procedure is well practiced:

Standard operating procedure to operate centrifugal pump is:

1. Suction valve of the pump to be opened which cause fluid flow to the impeller and fill the volute of the centrifugal pump.
2. Open the vent valve which is on the discharge line before the discharge valve of the centrifugal pump which cause all air to move out of the casing and filled with the pumping fluid only.
3. When some quantity of the fluid comes out from the vent valve close the valve.
4. Now open the bypass valve of the discharge valve which is near or side of the discharge valve on discharge line.
5. Now start the pump and let it attain its capacity in the pressure gauge on the discharge line.
6. When the pressure gauge is stable it is time to open the discharge valve of the centrifugal pump.

These steps are considered as standard operating procedure for most of the centrifugal pumps in chemical industries.



Centrifugal pump system

Centrifugal pumps are classified as rotary dynamic type of pumps in which a dynamic pressure is developed which enables the lifting of liquids from a low datum height source to a higher position. The basic principle on which a centrifugal pump works is that when a certain mass of liquid is made to rotate by an external force, it is thrown away from the central axis of rotation and a centrifugal head is impressed which enables it to rise to a higher level. Now if more liquid is constantly made available at the center of rotation, a continuous supply of liquid at higher level may be ensured. Since in these pumps the lifting of the liquid is due to centrifugal action, these pumps are called centrifugal pumps. In addition to the centrifugal action, as the liquid passes through the revolving wheel or impeller, its angular momentum changes, this also results in increasing the pressure of the liquid.

According to the general direction of flow of liquid within the passage of the rotating wheel or impeller the roto dynamic pumps are classified as,

(i) Centrifugal pumps,

(ii) Half axial or screw or mixed flow pumps

(iii) Axial flow or propeller pumps.

VI SIMULINK

Simulink is a software add-on to mat lab which is a mathematical tool developed by The Math works,(http://www.mathworks.com) a company based in Natick. Mat lab is powered by extensive numerical analysis capability. Simulink is a tool used to visually program a dynamic system (those governed by Differential equations) and look at results. Any logic circuit, or control system for a dynamic system can be built by using standard building blocks available in Simulink Libraries.

Various toolboxes for different techniques, such as Fuzzy Logic, Neural Networks, dsp, Statistics etc. are available with Simulink, which enhance the processing power of the tool. The main advantage is the availability of templates / building blocks, Which avoid the necessity of typing code for small mathematical processes.

Simulink is an interactive tool for modeling, simulating, and analyzing dynamic systems, including controls, signal processing, communications, and other complex systems. The version of Simulink included in MATLAB & Simulink Student Version provides all of the features of professional Simulink, with model sizes up to 1000 blocks. It gives you immediate access to the high-performance simulation power you need. Simulink is a key member of the MATLAB® family of products used in a broad range of industries, including automotive, aerospace,electronics, environmental, telecommunications, computer peripherals, finance, and medical.More than one million technical professionals at the world's most innovative technology companies, government research labs, financial institutions, and at more than 3500 universities, rely on MATLAB and Simulink as the fundamental tools for their engineering and scientific work.

Simulation result of Constant Irradiation

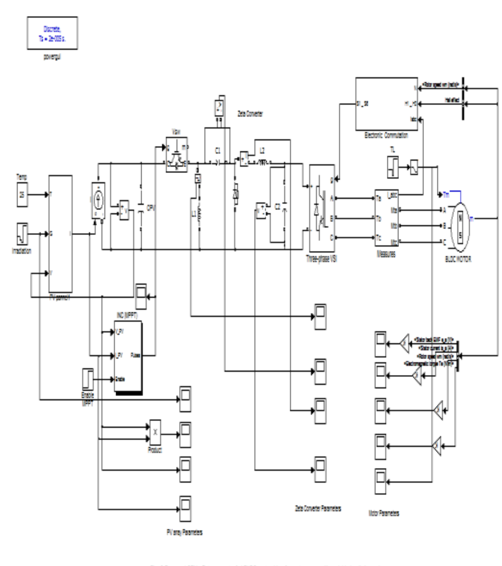


Fig 6.0 Simulation Block Diagram

The simulation block diagram for variable irradiation zeta converter fed BLDC motor driven pump which is simulated via simulink practically as shown in fig.6.0

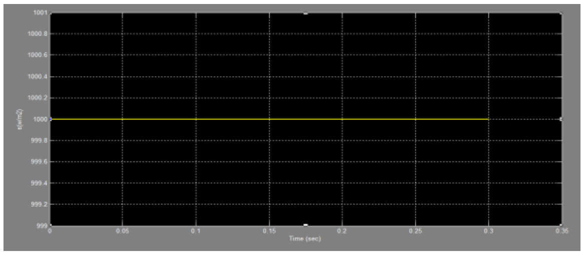


Fig. 6.1. Simulation result of Constant Irridation (w/m2)

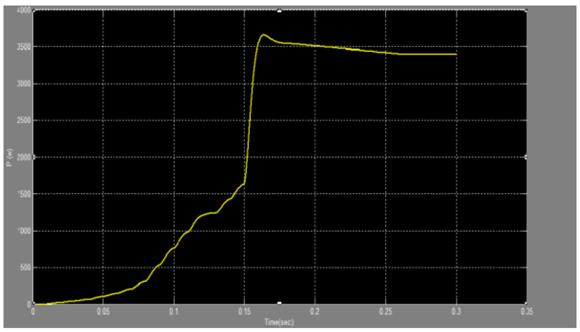


Fig 6.2.PV current(A)

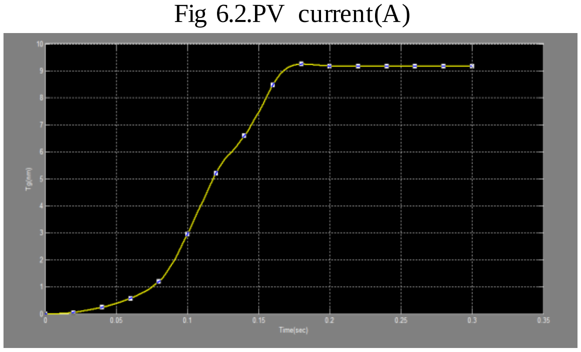


Fig 6.3.speed(rpm)

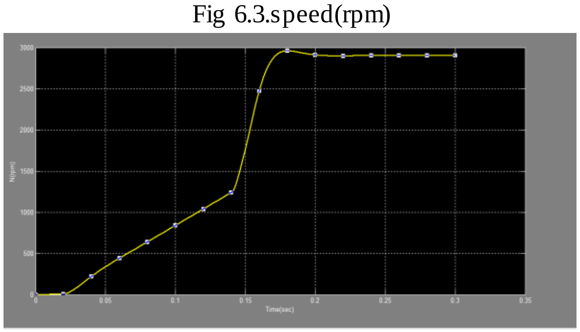


Fig 6.4 Torque(n/m)

VII CONCLUSION

The SPV array-zeta converter fed VSI-BLDC motor-pump per has been proposed and it is suitability has been demonstrated through simulated results and experimental validation.the proposed system has been designed and modelled appropriateiy to accomplish the desired objectives and validated to examine varies performances under starting, dynamic and steady state conditions. The performance evaluation has justified the combination of zeta converter and BLDC motor for SPV array based water pumping. The system under study has shown various desired functions such as MPP extraction of the SPV array, soft starting of BLDC motor, fundamental frequency switching of VSI resulting in a redu switching losses, speed control of BLDC mot additional control and an elimination of phase current and DC voltage sensing, resulting in the reduced cost and complexity. The proposed system has operated successfully even under minimum solar irradiance.

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