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Regulation of Voltage and Frequency in a Grid Connected System Using Renewable Energy Resources

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***Abstract*— this project deals with Regulation of voltage and frequency in smart grid using Sepic and MPPT using Fuzzy Logic Controller. This method allows effective control over active and reactive power available from the system. A battery increases the reliability and flexibility of the system. The PV/storage plant provides constant updates on its current KW/KVar capability and the grid transmits the demand for specific amounts of power and for specific lengths of time. Sepik converter is used to improve the performance of the system and also increasing the efficiency in better manner. Fuzzy logic rules is one of the PWM techniques which is used to generating the signal given to the MOSFET to regulating the voltage level. The control techniques will be adopted are simple, autonomous and easy to implement, and the controller is used to regulate the frequency. Bidirectional flow of active and reactive powers can be achieved. Controllers integrating energy sources respond to the received signals and attempt to fulfill the grid demand. The system response is almost instantaneous and thus can be very helpful in frequency and voltage regulation**.

I. INTRODUCTION

In today’s dynamic world, electric utilities are facing challenges like rising energy demand, increasing fuel costs, aging assets, and pressure to adopt renewable portfolio standards, etc. Much of this can be tackled without compromising the overall performance and service quality of the utility system. In recent years, the presence of photovoltaic (PV) generations on the utility grid is on the rise. With increase in PV penetration and the progress of the global PV market, there is a need to enable the PV systems with features which make them smart to create an effective business model. Further, by leveraging the Smart Grid technologies, and taking advantage of the distributed nature of PV, new opportunities to unlock value can be created. With the implementation of advanced energy storage techniques, effective two way communications and a robust demand response program, a grid-tied PV system can create additional value, primarily by enabling increased PV participation in grid support functions, such as frequency and voltage regulation.

The purpose is situated to design and optimize a SEPIC dc/dc converter (Single Ended Primary Inductance Converter).The SEPIC converter allows a range of dc voltage to be adjusted to maintain a constant voltage output.

There are five main types of dc converters. Buck converters can only reduce voltage, boost converters can only increase voltage, and buck- boost, Cuk, and SEPIC converters can increase or decrease the voltage.

II. EXISTING SYSTEM

The buck–boost converter is a type of DC-to- DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a back converter using a single inductor instead of a transformer. Both of them can produce a range of output voltages, ranging from much larger (in absolute magnitude) than the input voltage, down to almost zero. The inverting topology. The output voltage is of the opposite polarity than the input. This is a switched mode power supply with a similar circuit topology to the boost converter and the buck converter. The output voltage is adjustable based on the duty cycle of the switching transistor. One possible drawback of this converter is that the switch does not have a terminal at ground; this complicates the driving circuitry. Another drawback is of any consequence if the power supply is isolated from the load circuit (if, for example, the supply is a battery) because the supply and diode polarity can simply be reversed. The switch can be on either the ground side or the supply side.

III. PROPOSED SYSTEM

The proposed work comprises of a photovoltaic exhibit, dc/dc converter with an inverter, intended for accomplishing the MPPT control with Incremental Conductance (In Cond) calculation. In this model, though the information sources are the sun powered illumination and cell temperature, the yields are the photovoltaic voltage and current. At the point when the PV framework with a MPPT is associated with the power electronics converters (PEC), a programmed input controller will be expected to adjust the power and keep up the immediate voltage consistent particular when the framework is running under different conditions. In three phase inverter electronic switch utilized is MOSFET as it can deal with extensive power, which is appropriate for this nearby planetary group. The PWM inverter yield waveform is then shifted to deliver a sinusoidal AC waveform.

IV. WORKING OPERATION

4.1 SOLAR PANEL

A straightforward sun oriented comprises of strong state p-n intersection manufactured from a semiconductor material (generally silicon).In 2014, prices for residential 5 kilowatt systems in the United States were around $3.29 per watt, while in the highly penetrated German market, prices for rooftop systems of up to 100 kW declined to €1.24 per watt. Nowadays, solar PV modules account for less than half of the system's overall cost, [leaving the rest to the remaining BOS-components and to soft costs, which include customer acquisition, permitting, inspection and interconnection, installation labor and financing costs. One set of modules connected in series is known as a 'string'. A single diode model of the PV cell is used to simulate PV characteristics in Matlab. The effect of temperature on panel voltage is taken care of in the model.

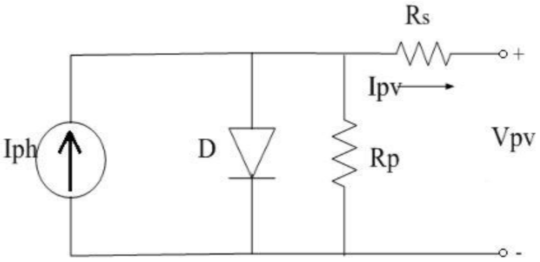

Fig.1 Single diode model of PV cell

Current Ipoh is a direct function of irradiance and temperature and the diode exhibits the cell’s p-n junction characteristics. AGE-PV 200W solar panel is used to build a 2 kW PV array. To build a 2 kW array, five panels are connected in series in order to reach the desired voltage 26.3*5=131.5 V), and two such strings are connected in parallel to deliver the desired amount of current (7.6*2 = 15.2 A).

4.2 THREE PHASE INVERTER

Devices that convert dc power to ac power are called inverters. The purpose of an inverter is to change a dc input voltage to ac output voltage which will be symmetric and will have desired magnitude and frequency. The output voltage can be varied by varying the input dc voltage and keeping constant inverter gain, however, if the input dc voltage is fixed and cannot be controlled, the gain of the inverter has to be varied to obtain variable output voltage. Varying the gain of the inverter is mainly done by a scheme which is known as Pulse Width Modulation (PWM). The inverter gain is basically the ratio of ac output voltage to the dc input voltage. Based on the power supply, inverters can be broadly classified into two types: Voltage Source Inverter and Current Source Inverter. A VSI has small or negligible impedance at its input terminal that is, it has a stiff dc voltage source, whereas for a CSI, it is fed with adjustable current from a dc source with high impedance in this case. For the purpose of our project, all analysis throughout this paper has been done for Voltage Source Inverters (VSI). These can be classified into two types which are Single Phase Inverters and Three Phase Inverters. Either type can use controllable turn-on and turn-off devices e.g. BJTs, MOSFETs, IGBTs etc. Generally PWM control is used to obtain ac output voltage of desired frequency and magnitude.

4.3 SEPIC CONVER

The single-ended primary-inductance converter (SEPIC) is a DC/DC-converter topology that provides a positive regulated output voltage from an input voltage that varies from above to below the output voltage. This type of conversion is handy when the designer uses voltages (e.g., 12 V) from an unregulated input power supply such as a low-cost wall wart. Unfortunately, the SEPIC topology is difficult to understand and requires two inductors, making the power-supply footprint quite large.

Recently, several inductor manufacturers began selling off-the shelf coupled inductors in a single package at a cost only slightly higher than that of the comparable single inductor. The coupled inductor not only provides a smaller footprint but also, to get the same inductor ripple current, requires only half the inductance required for a SEPIC with two separate inductors. This article explains how to design a SEPIC converter with a coupled inductor.

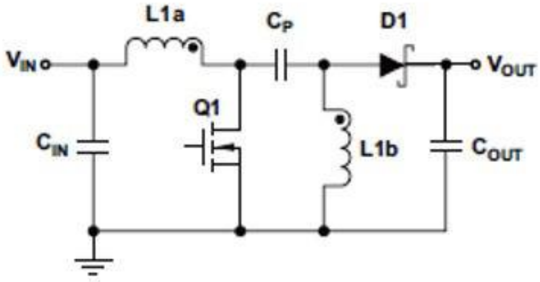

Fig. 2 Simple Circuit Diagram Of Sepik Converter

4.3.1 BASIC OPERATION

Fig.2 shows a simple circuit diagram of a SEPIC converter, consisting of an input capacitor, CIN; an output capacitor, COUT; coupled inductors L1a and L1b; an AC coupling capacitor, CP; a power FET, Q1; and a diode, D1. Figure 2 shows the SEPIC operating in continuous conduction mode (CCM). Q1 is on in the top circuit and off in the bottom circuit. To understand the voltages at the various circuit nodes, it is important to analyze the circuit at DC when Q1 is off and not switching. During easy-state CCM, pulse-width modulation (PWM) operation, and neglecting ripple voltage, capacitor CP is charged to the input voltage, VIN. Knowing this, we can easily determine the voltages as shown in Figure 3. When
Q1 is off, the voltage across L1b must be VOUT. Since CIN is charged to VIN, the voltage across Q1 when Q1 is off is VIN + VOUT, so the voltage across L1a is VOUT. When Q1 is on, capacitor CP, charged to VIN, is connected in parallel with L1b, so the voltage across L1b is –VIN. The currents flowing through various circuit components are shown in Figure 4. When Q1 is on, energy is
Being stored in L1a from the input and in L1b from CP. When Q1 turns off, L1a’s current continues to flow through CP and D1, and into COUT and the load. Both COUT and CP get recharged so that they can provide the load current and charge L1b, respectively, when Q1 turns back on.

4.3.2 DUTY CYCLE

Assuming 100% efficiency, the duty cycle, D, for a SEPIC converter operating in CCM is given by,

$$D = \frac{V_{OUT} + V_{FWD}}{V_{IN} + V_{OUT} + V_{FWD}}$$

Where VFWD is the forward voltage drop of the Scotty diode. This can be rewritten as, D (max) occurs at VIN (min), and D (min)
Occurs at VIN (max).

$$\frac{D}{1-D} = \frac{V_{OUT} + V_{FWD}}{V_{IN}} = \frac{I_{IN}}{I_{OUT}}$$

4.3.3SELECTING PASSIVE COMPONENTS

One of the first steps in designing any PWM switching regulator is to decide how much inductor ripple current, ΔIL, to allow. Too much increases EMI, while too little may result in unstable PWM operation. A rule of thumb is to use 20 to 40% of the input current, as computed with the power-balance equation,

$$\Delta I_L = 30\% X \frac{I_{IN}}{\eta} = 30\% x I_{IN}'$$

In this equation, IIN from Equation 2 is divided by the estimated worst-case efficiency, at VIN (min) and IOUT (max) for a more accurate estimate of the input current, IIN′. In an ideal, tightly coupled inductor, with each inductor having the same number of windings on a single core, the mutual inductance forces the ripple current to be split equally between the two coupled inductors. In a real coupled inductor, the inductors do not have equal inductance and the ripple currents will not be exactly equal. Regardless, for a desired ripple-current value, the inductance required in a coupled inductor is estimated to be half of what would be needed if there were two separate inductors, as shown in

Equation 4:

$$LI_{a(MIN)} = LI_{B(MIN)} = \frac{1}{2} x \frac{V_{IN(MIN)} x D_{(MAX)}}{\Delta I_L x f_{SW(MIN)}}$$

To account for load transients, the coupled inductor’s saturation current rating needs to be at least 20% higher than the steady-state peak current in the high-side inductor, as computed in Equation 5:

$$I_{L1a(PEAK)} = I_{IN}' + \frac{\Delta I_L}{2} = I_{IN}'\left(1 + \frac{30\%}{2}\right)$$

Note that IL1b (Peak) = IOUT + ΔIL /2, which is less than IL1a (Peak). Figure 5 breaks down the capacitor ripple voltage as related to the output capacitor current. When Q1 is on, the output capacitor must provide the load current. Therefore, the output capacitor must have at least enough capacitance, but not too much ESR, to meet the application’s requirement for output voltage ripple, ΔVRPL:

$$\Delta V_{RPL} \le \frac{I_{OUT} x D_{(\max)}}{C_{OUT} x f_{SW(\min)}} + ESR x \left[I_{L1a(Peak)} + I_{L1b(Peak)}\right]$$

If very low-ESR (e.g., ceramic) output capacitors are used, the ESR can be ignored and the equation reduces to

$$C_{OUT} \ge \frac{I_{OUT} x D_{(\max)}}{\Delta V_{RPL} x f_{SW(\min)}},$$

Where, fs (min) is the minimum switching frequency. A minimum capacitance limit may be necessary to meet the application’s load- transient requirement. The output capacitor must have an RMS current rating greater than the capacitor’s RMS current, as computed in Equation 8:

$$I_{C_{OUT}}(RMS) = I_{OUT} X \sqrt{\frac{D_{(\max)}}{1 - D_{(\max)}}}$$

The input capacitor sees fairly low ripple currents due to the input inductor. Like a boost converter, the input current waveform is continuous and triangular; therefore, the input capacitor needs the RMS current rating,

$$I_{C_{IN}}(RMS) = \frac{\Delta I_L}{\sqrt{12}}$$

The coupling capacitor, CP, sees large RMS current relative to the output power:

$$I_{C_P}(RMS) = I_{IN}' X \sqrt{\frac{1 - D_{(\max)}}{D_{(\max)}}}$$

From Figure 3, the maximum voltage across CP is VQ1 (max) – VL1b (max) = VIN + VOUT – VOUT = VIN. The ripple across CP is,

$$\Delta V_{C_r} = \frac{I_{OUT} x D_{(\max)}}{C_p x f_{SW}}$$

4.3.4 SELECTING ACTIVE COMPONENTS

The power MOSFET, Q1, must be carefully selected so that it can handle
The peak voltage and currents while minimizing power-dissipation losses. The power FET's current rating (or current limit for a converter with an integrated FET) will determine the SEPIC converter's maximum output current. As shown in Figure 3, Q1 sees a maximum voltage of VIN (max) + VOUT. As shown in Figure 4, Q1 must have a peak-current rating of

$$I_{Q1(peak)} = I_{L1a(Peak)} + I_{L1b(peak)} = I_{IN}' + I_{OUT} + \Delta I_L$$

Where triose is the rise time on the gate of Q1 and can be computed as Q1's gate-to-drain charge, QGD, divided by the converter's gate- drive current, IDRV. Q1's RMS current is

$$I_{Q1(RMS)} = \frac{I_{IN}'}{\sqrt{D_{(\max)}}}$$

The output diode must be able to handle the same peak current as Q1, IQ1 (Peak).

4.4 FUZZY LOGIC CONTROLLER

FLC contains three basic parts: Fuzzification, Base rule, and Defuzzification. FLC has two inputs which are: error and the change in error, and one output. Fuzzier converts a numerical variable into a linguistic label. The FLC takes two inputs, i.e., the error and the rate of change of error. Based on these inputs, The FLC takes an intelligent decision on the amount of field voltage to be applied which is taken as the output and applied directly to the field winding of generator.

V. SIMULATION RESULTS

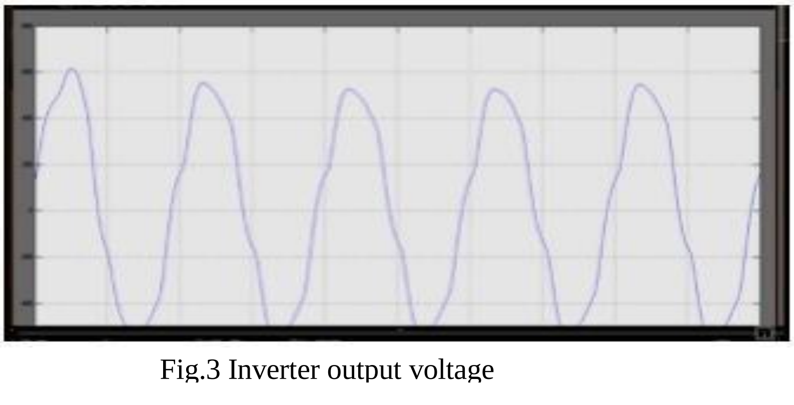

Fig.3 Inverter output voltage

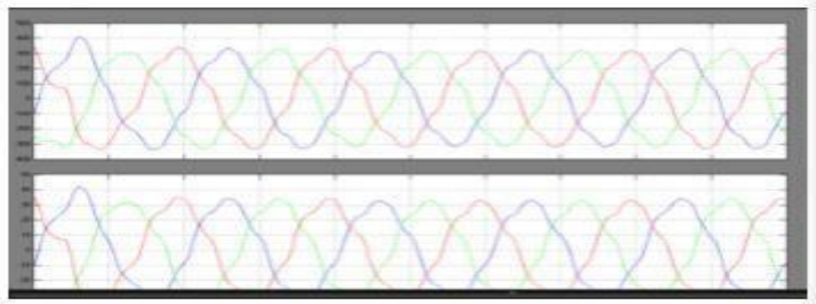

Fig.4 Output voltage and current waveforms

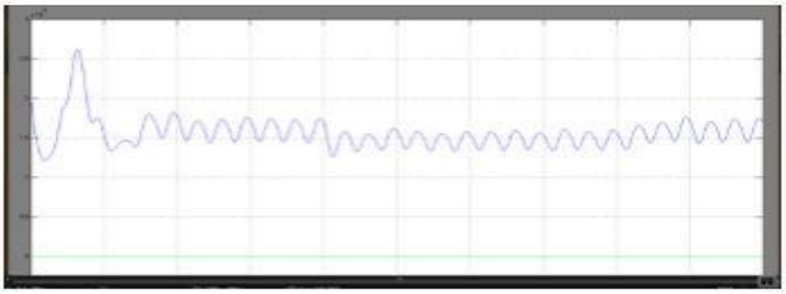

Fig.5 Active and reactive power from PV to grid

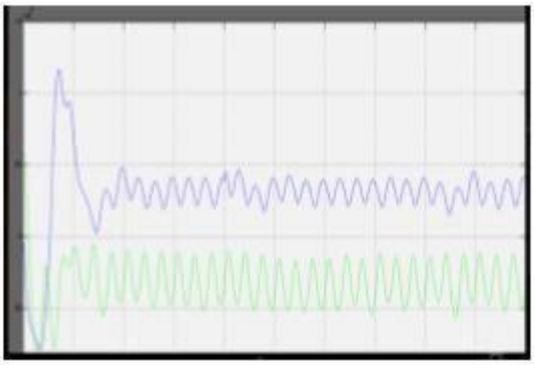

Fig.6 Active and reactive power from grid to PV

VI. CONCLUSTION

The performance of a system is demonstrated with the help of MATLAB. It is concluded that the frequency and voltage regulation capability in Renewable Energy Sources in the framework of the Smart Grid is discussed. This method achieved effective control over active and reactive power available from the system. This technique is implemented and simulated using MATLAB.A battery increased the reliability and flexibility of the system. The control techniques adopted are simple, autonomous and easy to implement. The most important factor in regulation is the size of the system. Depending on the size of the feeder, market economics, geographical conditions etc. PV and batteries can be properly sized. The system proposed is very useful if used as a community based PV system. This method allowed effective control over active and reactive power available from the system. A battery increases the reliability and flexibility of the system. Sepik converter was used to improve the performance of the system and also increasing the efficiency in better manner. Fuzzy logic rules is one of the PWM techniques which is used to generating the signal given to the MOSFET to regulating the voltage level. The control techniques adopted are simple, autonomous and easy to implement. And the controller is used to regulate the frequency. Bi directional flow of active and reactive powers was achieved. Controllers integrating energy sources respond to the received signals and attempt to fulfill the grid demand. SEPIC converter in order to improve the efficiency and performance of the maximum power racking. The system response is almost instantaneous and that was very helpful in frequency and voltage regulation.

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