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A Study of SEPIC Converter Based Fuzzy Logic Controller For Hybrid System

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ABSTRACT

This paper presents the study of integrated hybrid renewable energy system. The wind and solar are used as input sources for the hybrid system. The proposed system involves the design of photovoltaic (PV) and wind energy conversion system (WECS).The system is designed for constant wind speed and varying solar irradiation and insolation. Maximum power point tracking (MPPT) algorithm is used to extract the maximum power from PV array. The integration of two input sources is done by single-ended primary-inductor converter. Fuzzy logic controller is used to control the duty cycle of one of the converter switch thereby extracting the maximum power from solar array. The system consists of photovoltaic (PV) array, wind energy conversion system (WECS), single-ended primary-inductor converter, voltage source inverter (VSI), LC filter and three phase load.

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I. INTRODUCTION

Renewable energy sources have attracted wide attention because of its abundant nature. Wind power can be easily captured by generators with high capacity. It is one of the promising and clean energy sources. Photovoltaic (PV) power is global and it can be extracted without using rotational generators. PV power is also another clean energy resource. PV and wind power are complementary in nature. During sunny days the winds will be weak and strong winds blow during nights and cloudy days. Hence, to get an uninterrupted supply wind-PV hybrid power generation system [1] [2] can be implemented. It provides higher reliability and continuous supply of power from any one of the resources either solar or wind. The wind energy conversion system consists of wind turbine and PMSG. WECS converts the mechanical energy into electrical energy. Wind turbine gives mechanical output which is converted into electrical energy by permanent magnet synchronous (PMSG) generator. It is a directly driven generator. It does not require any dc field excitation. The ac output from WECS is converted into dc by three phase diode rectifier. This paper uses a current-source-interface multiple input cuk converter [4] for integration of PV and wind resources. The MI cuk converter reduces unnecessary redundancy of additional parallel converters in each input source. The MI cuk converter is a DC-DC converter [14]. It provides decentralized control. It has two switches. Since the wind speed is constant, the duty cycle of one of the switches of the converter corresponding to PV input is controlled by fuzzy logic controller [19]. The inputs to the fuzzy logic controller are provided Maximum power point tracking algorithm (MPPT). The output voltage of VSI is regulated by PI controller. The gating pulses to VSI are generated by the PI controller.

II. SEPIC CONVERTER

The SEPIC is a DC to DC converter in which the output voltage is having same polarity as that of input voltage. One benefit of the SEPIC converter is that the input ripples current in the input capacitor is continuous. This reduces the amount of input capacitance necessary for low-ripple voltage, which reduces EMI (Electro Magnetic Interference).SEPIC converter maintains a fixed output voltage regardless of whether the input voltage is above, equal or below the output voltage.

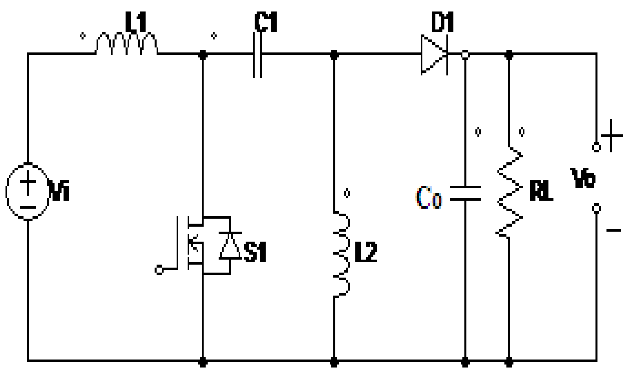

Fig.1SEPIC converter

Fig.1. shows the SEPIC basic diagram. Vi is the input voltage of the converter, Vo is the output voltage, L1 is the inductor connected at the input end and the maximum load current flows in this inductance. L2 is connected in parallel to the load. The switch s1 is connected parallel with the input voltage. The switch can be made on and off during the operation.C1 is the coupling capacitor which stores the voltage. The duty cycle D is defined by the general equation:

$$M = \frac{V_o}{V_i} \qquad (1)$$

$$D = \frac{T_{on}}{T} \qquad (2)$$

Where TON is the on-time of the switch and T is the switching period. The duty cycle is a function of M, where M is the voltage conversion ratio

$$D = \frac{M}{M+1} \qquad (3)$$

From the equation (3) the M as function of D,

$$M = \frac{D}{1-D} \qquad (4)$$

From the equation (4), the output voltage can be defined as

$$V_o = \frac{D}{1-D} V_i \qquad (5)$$

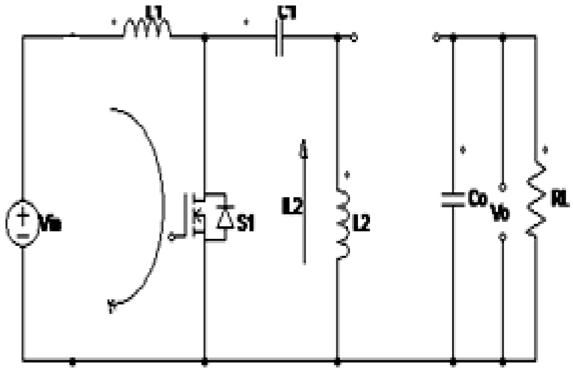

Fig. 2 SEPIC current flow when S1 is in ON condition

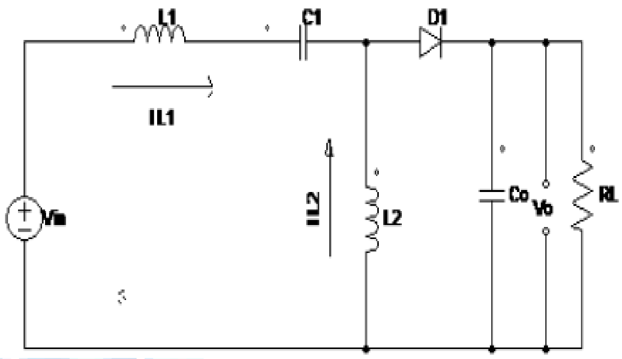

Fig. 3 SEPIC current flow when S1 is OFF condition.

A SEPIC is said to be in continuous conduction mode if the current through the inductorL1 never falls to zero. During a SEPIC's steady state operation, the average voltage across capacitor C1 is equal to the input voltage. Because capacitor C1 blocks direct current, the average current through C1 is zero, making inductor L2 the only source of load current. Therefore, the average current through inductor L2 is the same as the average load current and hence independent of the input voltage. The voltages are the same in magnitude as well as above or below. The ripple currents from the two inductors will be equal in magnitude. Fig 4. Shows SEPIC current flow when S1 is turned on, current IL1 increases positive direction and the current IL2 increases in the negative direction. The energy to increase the current IL1 comes from the input source. Since S1 is a short while closed, and the instantaneous voltage VC1 is approximately VIN, the voltage VL2 is approximately −VIN. Therefore, the capacitor C1supplies the energy to increase the magnitude of the current in IL2 and thus increase the energy stored in L2.Fig.5. Shows SEPIC current flow when switchS1 is turned off, the current IC1 becomes the same as the current IL1, since inductors do not allow instantaneous changes in current. The current IL2 will continue in the negative direction, in fact it never reverses direction. It can be seen from the diagram that a negative IL2 will add to the current IL1 to increase the current delivered to the load. Using Kirchhoff's Current Law, it can be shown that ID1 = IC1 - IL2. It can then be concluded, that while S1 is off, power is delivered to the load from L2, L1 and C1 of energy storage elements. And maintain the load voltage in constant.

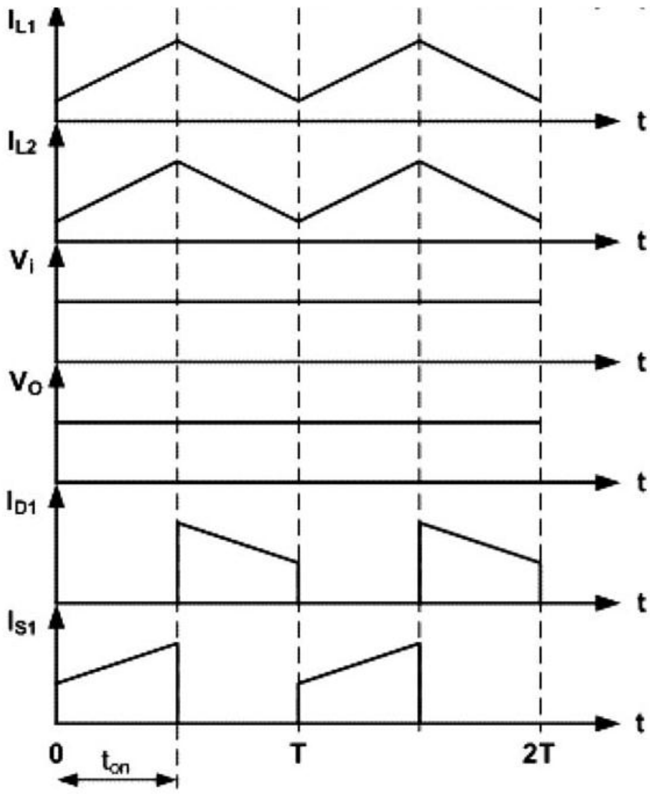

Fig.4.Theoritcal waveform of SEPIC converter

III. PROPOSED SCHEME

Fig.5. illustrates the overall block diagram of the proposed system with wind and PV resources. The main energy sources of the hybrid system are transformed into wind generator and PV modules. A multiple input sepic converter allows the integration of the wind and PV energy resources because this type of converter is more effective in maximum power point tracking (MPPT) in PV modules and input current control method used in the proposed system .MICS were chosen for their cost effective and flexible method of interfacing the two renewable energy sources.

The output voltage from the PV module is DC. Since the output voltage of the wind generator is ac, three-phase diode rectifier converts it into dc voltage. The dc voltages from the PV module and three phase diode rectifier are given as inputs to the switches of the sepic converter. The dc voltage is again converted into ac by PWM inverter. The output voltage from the inverter is given to the LC filter to reduce the harmonic voltages in the ac load.

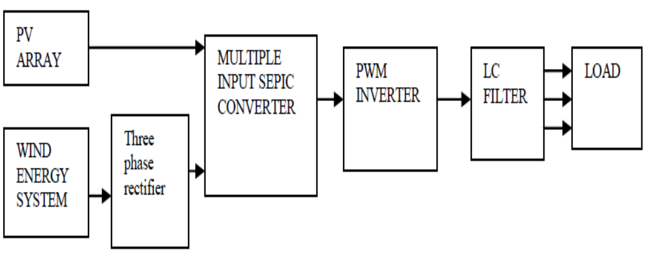

Fig .5 proposed scheme

IV. LITRATURE REVIEW

A. *Maximum Power Point Tracking Using Fuzzy Logic Control For Photovoltaic System*

PongaskorTakun,SomyotKaitwandidvilaiandChaiyanJettanasen proposes Maximum Power Point Tracking using Fuzzy Logic cotrol for Photovoltaic systems. In this paper, a fuzzy logic control (FLC) is proposed to control the maximum powerpoint tracking (MPPT) for a photovolaic (PV) system. The proposed TEcnique uses the fuzzy logic control to specify the size of incremental current in the current command of MPPT. As results indicated, the convergence time of maximum power point (MPP) of the proposed algorithm is better than that of the conventional Petrub and Observation (P&O) tecnique.

In our world tody, the problems caused by global warming and polution effect become the important issues for research. Renewable energy sources are considerd as a tecnolgical option for generating clean energy. Among them, photovoltaic (PV) system has received agreat attention as it appears to be one of the most promising renwable energy sources. Recently,due to its development and cost reduction, PV system becomes an efficient solution to the environmental problem. However, the development for improving the efficiency of the system is stilla challenging field of reserch. PV system cannot be modelled as constant DC current source because its output power is varied depending o the load current, temprature and irradiation.

Generally, MPPT is adopted to track the maximum power point in the PV system. The efficiency of MPPT depods on both the MPPT control algorithm and the MPPT circuit. The MPPT contol algorthim is usually applied in the DC-Dc converter, which is normally used as the MPPT circuit.

One of the most popular algorithms of MPPT is P&O (Petrub and Observe) technique however, the convergence problem and oscillation are ocured at certain points during the tracking. To enhance the performance of the P&O algorithm, this paper prsents the application of Fuzzy Logic Control (FLC) to nthe MPPT control. The simulation study in this paper is done in MATLAB and simulink.

This paper prsents an intelligent control strategyof MPPT for the PV system using the FLC. Simulation results show that proposed MPPT can track the MPP fater when compared to the conventional P&O method. In conclusion, the proposed MPPT using fuzzy logic can improve the performance of the system. For the future work, we intend to implement the proposed technique in the real PV system.

B. *Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques*

Hairul Nissah Zainudin ,Saad Mekhilef proposes the many different tecniques for maximum power point tracking of photovoltaic array are discused. The techniques are taken from the literature dating back to back to the earliestmethods. It is shown that at least 19 distinct methods have been introduced in the literature, with many variations on implementations. This paper shold serve as convenient refernce for future work in PV power generation.

Tracking the maximmum power point (MPP) of a photovoltaic (PV) array is usually an essntial part of PV system. As such, many MPP tracking (MPPT) methods have been developed and implemented. The methods vary in complexity, sensors required, convergence speed, cost, range of effectiveness, implementation hatdware, populaity, and in other respects.

They range from the almost obvious to the most creative. In fact, so many methods have been developed that it has become difficult adequately determine which method, newly proposed or existing, is most appropriate for a given PV system. Given the large number of methods for MPPT, a survey of the methods would be very benfical to researchers and practioners in PV system. The total number of MPPT paper from our biblography per year since the earliest MPPT paper we found. The number of papers per year has grown considerably of the last decades and remains strong. However, recent papers have generally had shorter, more cursory literatue reviews that largly summarize or repeat what seems to be conventional wisdom that there are only a handfull of MPPT, when in fact there are many. This is due to the sheer volume of MPPT literatue to review, conflicting with the need for brevity.

Several MPPT techniques taken from the literature are discussed and analysed herein, with their pros and cons. It is shown that there are several other MPPT techniques than those commonly included in literature reviews. The concluding discussion and table should serve as a useful guide in choosing the right MPPT method for specific PV systems.

C. Generalized Neural Network Approach for Global Solar Energy Estimation In India

Rizwan, M. Jamil, M. Kothari, proposes the many different tecniques for maximum power point tracking of photovoltaic array are discused. The techniques are taken from the literature dating back to back to the earliestmethods. It is shown that at least 19 distinct methods have been introduced in the literature, with many variations on implementations. This paper shold serve as convenient refernce for future work in PV power generation.

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D. A New MPPT Method For Low-Power Solar Energy Harvesting

Oscar López-Lapeña, Maria Teresa Penella, Manel Gasulla, introduces this paper describes a new maximum-power-point tracking (MPPT) method focused on low-power (<1W) photovoltaic (PV) panels. The static and dynamic performance is theoretically analysed, and design criteria are provided. A prototype was implemented with a 500-mW PV panel, a commercial boost converter, and low-power components for the MPPT controller. Laboratory measurements were performed to assess the effectiveness of the proposed method. Tracking efficiency was higher than 99.6%. The overall efficiency was higher than 92% for a PV panel power higher than 100 mW. This is, in part, feasible due to the low power consumption of the MPPT controller. The time response of the tracking circuit was tested to be around 1 s. Field measurements showed energy gains higher than 10.3% with respect to a direct-coupled solution for an ambient temperature of 26° C higher gains are expected for lower temperatures.

Low-power devices mainly use either primary or secondary (rechargeable) batteries. Primary batteries are cheaper and are suitable whenever they survive the life cycle of the device. On the other hand, secondary batteries are used in mobile devices that must often be recharged from the mains, such as, for example, mobile phones. However, in some devices, such as the nodes of wireless sensor networks (WSNs), this solution is not practical. Energy harvesting constitutes a feasible alternative and has been proposed in order to power autonomous nodes using optical mechanical or thermal energy or even a combination of them.

In order to extract the maximum power from a photovoltaic (PV) panel, several maximum-power-point-tracking (MPPT) methods have been proposed and used for high-power systems. Their application to low-power PV panels.

A new MPPT method that is suitable for low-power PV panels has been proposed and tested. The MPPT controller is used as an external control loop of a PFM dc/dc converter placed between the PV panel and the load. In contrast to other true MPPT controllers, such as the P&O method, the current has not to be measured, and no multiplier operator has to be used to calculate the power. Therefore, the control circuit is simpler, and its consumption is lower than using those conventional techniques. Consequently, high energy efficiency can be achieved even for low-power sources. The static and dynamic performance of the proposed MPPT method has been theoretically analysed, and design criteria have been provided. The static performance is assessed through the power efficiency.

The analysis demonstrates that a high tracking accuracy can be achieved even using low power comparators whenever their propagation delays are matched or the charge cycle is long enough. The dynamic performance is assessed by the time response of the tracking voltage, which can be approximated by a first-order linear function. A prototype MPPT circuit has been implemented using a commercial PFM dc/dc boost converter and low-power components for the MPPT controller. Laboratory measurements have been carried out using a custom PV array simulator in order to assess the static and dynamic performance. The tracking efficiency is higher than 99.6%. The overall efficiency is higher than 92% for a PV panel power over 100 mW. This is, in part, feasible due to the low power consumption of the MPPT controller, which is kept lower than 350 µW. The time response of the tracking circuit was tested to be around 1 s. Field measurements have also been performed in order to compare the proposed solution with a direct-coupled circuit.Utilization of low-power indoor devices such as remote sensors, supervisory and alarm systems, distributed controls, and data transfer system is on steady rise. Due to remote and distributed nature of these systems, it is attractive to avoid using electrical wiring to supply power to them. Primary batteries have been used for this application for many years, but they require regular maintenance at usually hard to access places.

E. Indoor Power Harvesting Using Photovoltaic Cells For Low-Power Applications

Javanmard, N. ; Mazandaran Tel. Co., Sari, Iran ; Vafadar, G. ; Nasiri, A.This paper provides a complete analysis of a photovoltaic (PV) harvesting system for indoor low-power applications. The characteristics of a target load, PV cell, and power conditioning circuit are discussed. Different choices of energy storage are also explained. Implementation and test results of the system are presented, which highlights the practical issues and limitations of the system. Designing a photovoltaic (PV) energy harvesting system involves complex trade-offs due to the existence of several factors such as the characteristics of the PV cells, chemistry and capacity of the storage element used, power supply requirements, energy levels and power management features of the system, and nature of the application. For every system, the ultimate goal is to maximize the energy efficiency of the PV harvesting system. Each PV cell has an optimal operating point at which the output power will be at its maximum. The harvesting circuit should always ensure operation at this maximum power point (MPP) or near to it, which is typically performed by clamping the terminal voltage of the cell to a fixed voltage. Energy harvesting method exploiting PV cells provides high power density, which makes it a desirable choice to power an embedded system that consumes several mill watts of power using a reasonably small harvesting unit.

The power densities of different energy harvesting technologies per volume of total system. Harvesting nearby natural sources of energy for supplying power in indoor industrial and biomedical applications faces serious challenges. The light intensity under artificial lighting conditions found in hospitals and offices is much less than 10 W/m2 (6.830 klx) compared with 100–1000 W/m2 (68.3–683 klx) under outdoor conditions.

Utilization of indoor PV cells to harvest energy for low power electronic devices has been discussed in this paper. First, the nature of the load and its instantaneous and average power Consumption was discussed. The tests performed on the indoor PV cells at different light illumination levels were described. Various energy storage options, including battery and ultra-capacitors, were discussed, and different architectures of the systems were described. The results of the testing of various architectures were also provided. For the system described in this paper, an integrated system of a rechargeable battery and PV cell has been selected as a final solution due to lower cost and higher reliability.

F. Fuzzy Controller Design Using Soft Switching Boost Converter For MPPT In Hybrid System

T.Balamurugan and S.Manoharan are introduces in this paper, a fuzzy logic control (FLC) is Proposed to control the maximum power point tracking (MPPT) for a photovoltaic (PV) system and to control the maximum power point for a wind turbine (WT) system. Hybrid integrated topology, fed by photovoltaic (PV) and wind turbine (WT) sources and suitable for distributed generation applications,

It works as an uninterruptible power source that is able to feed a certain minimum amount of power into the grid under all conditions. PV is used as the primary source of power operating near maximum power point (MPP), with the WT section (block), acting as a current source, feeding only the deficit power.

The unique “integrated” approach obviates the need for dedicated communication between the two sources for coordination and eliminates the use of a separate, conventional dc/dc boost converter stage required for PV power processing. The conventional boost converter decreases the efficiency because of hard switching, which generates losses when the switches are turned on/off. During this interval, all switches in the adopted circuit perform zero-current switching by the resonant inductor at turn-on, and zero-voltage switching by the resonant capacitor at turn-off. This switching pattern can reduce the switching losses, voltage and current stress of the switching device.

A Fuzzy based Hybrid system improve the efficiency of the energy conversion systems because of reducing the switching losses The importance of renewable energy, renewable energy based energy conversion systems, and distributed power generation has been reiterated. The major principle of MPPT is to extract the maximum available power from PV panels by making them operating at the most efficiency voltage

G. Fuzzy Logic MPPT Controller With Energy Management System for Solar-Wind-Battery Diesel Hybrid Power System

K.Sekar and V.Duraisamy proposes Effective utilization of power is more important than generation of power because power scarcity is the major problem at present in India. It leads many industries to utilize the diesel generator results pollution and demand to fossil fuel.So nowadays many industries and government passions on renewable energy. A wind solar hybrid power system plays a crucial role today in renewable power resources because it uses solar energy combined with wind energy to create a stand-alone energy source that is both dependable and consistent. This paper proposes effective energy management controller for solar wind hybrid renewable power system for telecommunication industries. In power systems apart from power generation managing of power without wastage is imperative.

This paper proposes Fuzzy Logic Controller based Effective Energy Management Controller to monitor the power from all resources and load demand consistently and to control whole hybrid power system. Fuzzy logic controller makes accurate selection of sources in right timing. Fuzzy Logic Maximum Power Point Tracking is proposed in this paper for solar and wind power system to provide a constant voltage with the help of DC-DC Single-Ended Primary-Inductance Converter. Absence of telecommunication devices per day is unimaginable in current trend.

Main objective of this paper is to supply uninterruptible power for telecommunication loads from standalone solar-wind-Diesel hybrid power system with efficient energy storage system. It provides uninterrupted power, effective utilization of sources, improves life time of battery and minimized usage of diesel. The wind and solar hybrid power system is simulated using MATLAB.

Fuzzy Logic MPPT Control is applied for wind and solar sources make the system efficient. Hybrid power system supplies AC and DC load so it is suitable for all applications like remote areas, villages and hill stations. Fuzzy logic based Effective Energy Management Controller controls hybrid power system to provide uninterrupted power, minimizing usage of diesel, effective utilization of sources and improves lifetime of battery. Since the usage of diesel generator is minimized emission of harmful gases from it is minimized. So it is a pollution free green energy system applicable to any location and any country.

H. Fuzzy Logic Controller Based SEPIC Converter for Maximum Power Point Tracking

Ahmad El Khateb, Nasrudin Abd Rahim, Jeyraj Selvaraj and M. Nasir Uddin, proposes a fuzzy logic controller (FLC)-based single-ended primary-inductor converter (SEPIC) for maximum power point tracking (MPPT) operation of a photovoltaic (PV) system. The FLC proposed presents that the convergent distribution of the membership function offers faster response than the symmetrically distributed membership functions. The fuzzy controller for the SEPIC MPPT scheme shows high precision in current transition and keeps the voltage without any changes, in the variable-load case, represented in small steady-state error and small overshoot. The proposed scheme ensures optimal use of PV array and proves its efficacy in variable load conditions, unity, and lagging power factor at the inverter output (load) side. The real-time implementation of the MPPT SEPIC converter is done by a digital signal processor (DSP), i.e., TMS320F28335. The performance of the converter is tested in both simulation and experiment at different operating conditions. The performance of the proposed FLC-based MPPT operation of SEPIC converter is compared to that of the conventional proportional–integral (PI)-based SEPIC converter. The results show that the proposed FLC-based MPPT scheme for SEPIC can accurately track the reference signal and transfer power around 4.8% more than the conventional PI-based system.

An FLC-based MPPT scheme for the SEPIC converter and inverter system for PV power applications has been presented in this paper. A prototype SEPIC converter-based PV inverter system has also been built in the laboratory. The DSP board TMS320F28335 is used for real-time implementation of the proposed FLC and MPPT control algorithms. The performance of the proposed controller has been found better than that of the conventional PI-based converters. Furthermore, as compared to the conventional multilevel inverter, experimental results indicated that the proposed FLC scheme can provide a better THD level at the inverter output. Thus, it reduces the cost of the inverter and the associated complexity in control algorithms. Therefore, the proposed FLC-based MPPT scheme for the SEPIC converter could be a potential candidate for real-time PV inverter applications under variable load conditions.

I. Literature Review on Solar MPPT Systems

Kumaresh.V, Mridul Malhotra, Ramakrishna N and SaravanaPrabu.R use of electricity is increasing day by day. The electricity finds its application in all the domains. Converting solar energy into electrical energy is one of the best ways to reduce fossil fuel consumption. Owing to the cost and efficiency of the solar cells, it is not used in most of the electrical applications. But the introduction of Maximum Power Point Tracking (MPPT) algorithms has improved the efficiency of the solar cells. The various MPPT algorithms are discussed in the paper. The applications supported by these MPPT algorithms are also.

It is noted that perturb and observe and incremental conductance is superior to all other MPPT algorithms. Though fuzzy and neural networks are developing in the present days, the efficiency remains high in perturb and observe and Incremental conductance methods. The converters such as buck, boost, buck-boost, cuk converters are being used in MPPT systems. PWM inverters are used for grid interconnection and standalone AC loads. The selection of converters is based on the load connected to the system. The ripples in dc voltage and current also influence the selection of converters. With the above mentioned converters and MPPT algorithms, solar panels can be configured to feed any kind of load. The vast development in improving efficiency of MPPT algorithms can encourage domestic generation of power using solar panels.

J. Hybrid Fuzzy Logic Controllers for Buck Converter

Behrouz Safarinejadian and Farzaneh Jafartabar said that In order to control the output voltage of a Buck converter, hybrid fuzzy logic controllers are investigated in this paper. A fuzzy proportional-integral (PI) controller is proposed to improve the performance of the converter instead of a conventional digital PI controller too. The model of the power system is developed using Sim Power System toolbox and the control part is realized using Fuzzy Logic Toolbox in MATLAB. Simulation results show the better performance for buck with a fuzzy PI in comparison with conventional PI, also less settling time and less steady state error with two-level hybrid and fuzzy, PD+I respectively.

This paper has investigated fuzzy logic controllers for a buck converter. The system performance has been investigated in relation to the voltage regulation. First a classical PI controller is designed. Then in order to have the better performance three fuzzy logic controllers are proposed: fuzzy PI, two-level fuzzy hybrid, fuzzy PD+I. These results show that fuzzy PD+I is a proper controller when minimizing the steady state error is the purpose and two-level fuzzy hybrid is the appropriate control method when having the lowest settling time is important.

V. CONCLUSION

This paper presents the study of hybrid system consisting of wind and solar. These renewable energy sources are integrated through a MI current source interface dc-dc converter. These diverse micro energy resources can improve the hybrid system performance. The power converter proposed in this paper is designed at low cost to avoid redundancy of components. The wind generator used in this proposed hybrid system runs at a constant speed. The PV array uses fuzzy logic control algorithm and a fuzzy logic controller to capture the maximum power. In contrast to the previous works, this paper has explored the wide performance of the hybrid system with fuzzy controller and MI dc-dc converter is proves that the control strategy proposed in this paper is feasible while developing a hybrid system with CSI MI dc-dc converter which can reduce its production costs.

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