A Novel Hybrid Algorithm Controlled Modified Sepic Converter for Photovoltaic Fed Seventeen Level Multilevel Inverter

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Abstract: Multilevel inverter has various advantages such as less EMI issues, voltage stress and switching losses. Normally Variable voltage and power output of PV source necessitate maximum power point tracking (MPPT) and DC/DC converter. This paper proposes novel hybrid algorithm of Adaptive Neuro-Fuzzy Inference system (ANFIS) raindrop tuned Proportional integral controller (PI) for Maximum Power Point Tracking (MPPT) System. The performance of hybrid ANFIS-raindrop algorithm is analyzed by using MATLAB/Simulink software for simulation and compared with conventional incremental conductance MPPT system. The results of simulation and analysis have clearly show that Proposed hybrid algorithm reduces settling time and steady state error.

Keywords: Multi-level inverter (MLIs), DC-DC Converter, PV Cell, ANFIS-Raindrop tuned PI, MPPT, ModSEPIC.

I. INTRODUCTION

In the past decades, a huge amount of natural resources has been limitlessly dissipated, and our existing atmosphere has been rigorously polluted [1]. The growing concern about the depletion of fossil fuel reserves and global warming makes many to move towards are sustainable energy solutions to protect the globe for the upcoming generations. Excluding hydropower, the photovoltaic, and wind energy holds the most potential to meet the energy demands. Wind energy alone is competent of delivering analyzed massive quantity of power, but its accessibility in typical velocity is extremely random [2].

In a renewable energy system, the energy storage devices play a significant role to execute both purposes of releasing and storing energy at a sufficient time. The electric energy is stored in the battery in the form of DC Modified and it needs rectifier circuits for AC-to-DC conversion, charging circuits, and inverters for DC-to-AC conversion to exchange energy stored in the battery with the AC system.

Many DC-DC converters are existing for renewable energy systems such as buck, boost, buck–boost, Cuk and SEPIC converters. M.H. Taghvaee (2013) [3] analyzed that SEPIC converter is effective to compare to all other controllers in the aspects of efficiency, Input current ripple, Output voltage polarity and switch, Sara Hasanpour et.al [4] analyzed high gain SEPIC converter in steady state in continuous conduction mode for micro grid applications. Many researchers analyzed the performance of SEPIC converter for renewable energy applications [5,6].

The step-down - and step- up the static gain of the SEPIC converter is an attractive operation characteristic for an extensive range of input voltage application. Though, as the voltage across the switch is equal to the sum of the output and input voltages, this converter is not preferred for a high power application.

The incorporation of a voltage multiplier cell with a typical single-ended primary inductance converter (SEPIC) is proposed in this paper in order to acquire a high step-up static gain working with the low input voltage and a low step-up static gain for the high input voltage operation. The operation characteristics acquired with this alteration makes the proposed structure an attractive another for the extensive input voltage range applications, working with high efficiency. The proposed Mod SEPIC converter functions with a switching voltage lesser than the output voltage, and with an input current ripple lesser than the classical boost converter.

The harmonics and values of output filter are decreases when it is multilevel in an output voltage. Many multilevel schemes are usually characterized by a strong reduction in switching voltages across power switches, permitting the reduction of switching power losses and electromagnetic interference (EMI) [7], [8], [9], [10]. A single-phase seventeen-level inverter integrated with a PV power is proposed for dc/AC power conversion. This topology used in the power stage gives an imperative enhancement concerning lower component count and reduced output harmonics. In this paper, 17 level output is proposed using cascaded multilevel inverter.

II. PV panel

The PV solar photovoltaic cell modules produce DC electricity whenever it subject to sunlight. Solar radiation from the exists for a long time of day. According to calculation, the daily solar energy radiation varies from 4-7 kWh per m2, the sun radiates 1.74×10^{17} W of power per hour to earth, and in a year there are 270-300 sunny days. The Very small voltage produced by single PV cell has the less practical use. In a real time, many cells are integrated to produce required voltage [11].

Diode quality factor n , Light-generated current inside the cell I_L, Saturation current of the diode Io, PV panel internal resistance named as Series resistance Rs and Shunt resistance Rsh is in parallel with the diode are the parameters used to find Net current from the PV panel I.

In an ideal cell Rsh are infinite and Rs is 0. The difference between the output current from the PV cells and the diode current is the net current of the PV cells which is given by [12-13].

$$I = I_L - I_Q \left[\epsilon^{\left(q \frac{V+IRs}{nkT} \right)} - 1 \right] \qquad (1)$$

Where I_Q is the diode current, V is the voltage across the PV cell, n is the diode quality factor (1.62), k is the Boltzmann's constant (1.381×10^{-23} J/K), T is the junction temperature in Kelvin, q is the electron charge (1.602×10^{-19} C).

PV panel output is given to the DC-DC Mod SEPIC Converter. Two different MPPT algorithms are applied in this analysis to control DC-DC Converter to produce Constant output voltage.

III. Raindrop MPPT

The block schematic of the proposed maximum power point tracking controller is depicted in Fig. 1. ANFIS and Raindrop tuned PI controller are connected as MPPT to control duty ratio power switch in Mod SEPIC converter. In an ANFIS for the input training data set Temperature and Solar irradiance are considered. To specific temperature and solar irradiance conditions corresponding maximum available power from the Solar PV module is produced as crisp value output of the ANFIS controller. By means of multiplication algorithm of measured operating currents and voltage the actual output power from the PV module is estimated. The difference between output of ANFIS and actual power is the power error is processed using a proportional

integral (PI) controller tuned using rain drop algorithm. The control duty signal from the PI controller is fed to the PWM block. Controlled signal from PI controller is compared with high frequency carrier signal to produce the PWM signal. In this analysis 10 kHz carrier is used. The PWM signal produced by the MPPT decides DC-DC converter voltage and makes it suitable for load.

A general optimization problem is as follow.

$$\min_{x \in R^n} f(x)$$

$$s.t. x \in S \subset R^n \qquad (2)$$

Where S is a set with finite measure and x is an n-dimensional vector. The raindrop algorithm is designed to solve this general optimization problem.

Firstly, N raindrops arbitrarily fall on the "ground", where in (1) S is the "ground". The location of ith raindrop is denoted as xi □ S. After the raindrop falls, at each time interval they will move.

Algorithm 1
Raindrop Algorithm
1: N raindrops arbitrarily fall on S. The velocity and multilevel ith raindrop are vi and $x_i \in S$ respectively. Initialize a $0 < \varepsilon \ll 1$. Assume x = [x1, x2, · · · , xN] and v = [v1, v2, · · · , vN].
2: **while** kvk2 > " **do**
3: **for** ith raindrop **do**
4: Find the candidate direction by (3).
5: **if** f(xi,j + vidi,j+1) < f(xi,j) **then**
6: Update location by (4).
7: **else**
8: Update the velocity by (5).
9: **end if**
10: **end for**
11: **end while**
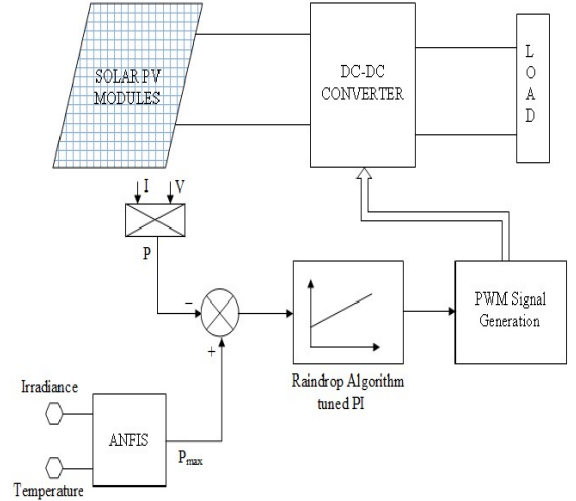12: Find the global optimal solution among the local optimal solutions.

Fig.1. Block diagram of Proposed Rain drop-ANFIS MPPT

IV. PROPOSED CONVERTER

Single-Ended Primary Inductor Converter (SEPIC) is a type of buck-boost converter able to stepping down or up input voltage and belonging to the class of converter that has two inductors. The characteristic of SEPIC is similar to buck-boost converters but it produces non-inverting outptut. In a SEPIC converter the gate-drive circuitry is simple because switch control terminal being connected to ground, it is desirable feature of the converter. Compare to Cuk converter voltage stresses in C is less in a SEPIC because energy transfer of the converter operates via two devices such as inductive (L1) and capacitive (C1). The converter also has non-pulsating input current [14, 15]. The significant for effective PPT in the SEPIC topologies is the input currents are continuous, and they can draw ripple-free current from an energy source. The basic principle of SEPIC converter is similar to buck–boost converter, so the characteristics SEPIC converter is similar to buck–boost converter.

The step- down and step- up static gains of the SEPIC converter is a fascinating function characteristic for a extensive input voltage-range

application. Though, as the sum of the output and input voltages is equal to the switch voltage, this configuration is not applied for a universal input HPF rectifier.

With the intention of increasing the static gain of multiphase and single-phase boost dc–dc converters the voltage multiplier technique was presented in [16]. The combination of the voltage multiplier technique with the SEPIC converter is shown in Fig. 2. The addition of the capacitor CM and the diode DM is accomplished with the modification of the SEPIC converter. It is stated as Modified SEPIC (Mod SPEIC) converter. In the proposed modification numerous functioning characteristics of the classical SEPIC converter are changed.
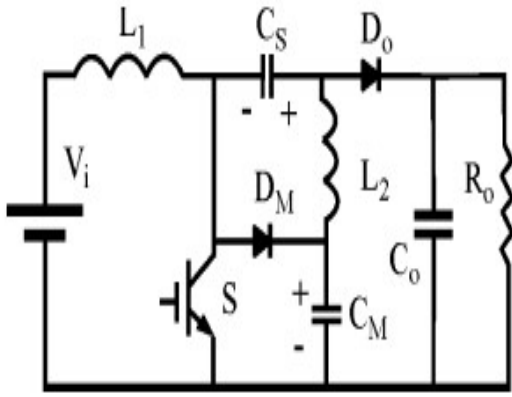

Fig. 2 Modified SEPIC converter

In the range of output voltage of the classical boost converter the CM capacitor is charged. As a result, during the conduction of the power switch (S) the voltage applied to the inductor L2 is greater than that in the traditional SEPIC, thereby raising the static gain. In the proposed converter the voltage stored in the capacitor CS the polarity is inverted, and the equations of the capacitors voltages and others function characteristics are presented below.

The following two operation stages present continuous conduction-mode (CCM) operation of the modified SEPIC converter.
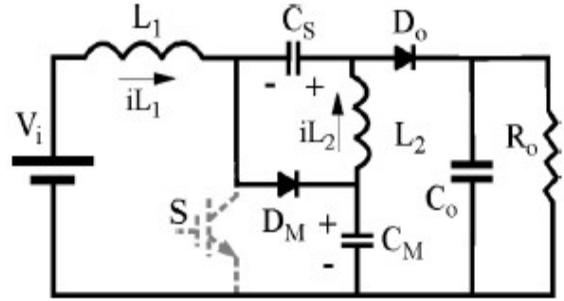

Fig. 3 First operation stage

1) *First stage ([t0, t1] Fig. 3)*—At the time t0 , the switch S is turned-off and the energy stored in the input inductor L1 is transmitted to the output through the CS capacitor and Do output diode , and also to the CM capacitor through the DM diode. Consequently, the switch voltage is equal to the voltage of CM capacitor. The energy stored in the inductor L2 is transferred to the output through the diode Do.
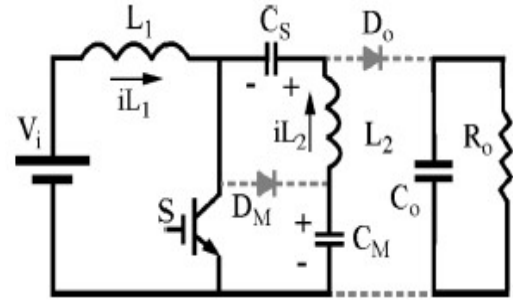

Fig. 4 *Second* operation stage

2) *Second stage ([t1, t2] Fig. 4)*—At the time t1 , the switch S is turned-on and the DM and Do diodes are blocked, and the L1 and L2 inductors store energy. The input inductor L1 receives input voltage and the inductor L2 receives voltage VCS − VCM. The voltage VCM is greater than the voltage VCS.

The voltage in the power switch and all diodes is equal to the capacitor CM voltage. The sum of the CS and CM capacitors' voltages is equal to the output voltage. The average L1 inductor current is equal to the input current and the average L2 inductor current is equal to the output current.

V. STATIC GAIN

At the steady state by considering that the average inductor voltage is zero the static gain of the proposed converter can be attained. Consequently, the relation offered in (3) must happen for the inductor L1 at the steady state

$$Vi \, t_{ON} = (VCM - Vi) \, t_{OFF} \qquad (3)$$

$$ViD = (VCM - Vi)(1 - D) \qquad (4)$$

Thus, the voltage of CM capacitor is defined by (5), which is the similar equation of the traditional boost static gain specified by

$$VCM/Vi = 1/1 - D. \qquad (5)$$

The diodes DM and D0 are in conduction state during the period where the power switch is turned-off (t_{OFF}), and the following relation can be defined:

$$Vo = VCS + VCM \qquad (6)$$

The L2 average voltage is zero at the steady state, and the following relations can be considered:

$$(VCM - VCS) \, t_{ON} = (Vo - VCM) \, t_{OFF} \qquad (7)$$

$$(VCM - VCS)D = (Vo - VCM)(1 - D) \qquad (8)$$

Replacing (5) and (7) in (9), the static gain of the proposed converter is acquired and presented in equation number (10).

$$VCS = Vo - VCM \qquad (9)$$

$$Vo/Vi = (1 + D)/(1 - D). \qquad (10)$$

$$D = (Vo - Vi)/(Vo + Vi) \qquad (11)$$

The highest static gain is presented in the voltage doubler boost converter [16] and is fascinating for the function with the lower input voltage. Though, the least output voltage (D = 0) is the twice of the input voltage. As a result, this configuration cannot be utilized for applications of universal input. The static gain of the voltage doubler boost is twice of the classical boost converter, and classical boost converter can be used in a universal input application. The modified SEPIC converter presents a static gain closed to the voltage doubler for high values of duty cycle, and the static gain closed to the classical boost for low values of the duty cycle. Consequently, the static gain is greater than the traditional structures in the function with high values of duty cycle that happen in operation with low input voltage. The operation with a higher static gain results in an improvement in the operation with the lower input voltage.

VI. CASCADED MLI

The series H-bridge inverter or cascaded multilevel inverter is the one more option for a multilevel inverter. The series H-bridge inverter appeared in 1975 [17]. Lai and Peng are two researchers they patented cascaded MLI and offered its different benefits in 1997, until that it was not fully realized. As then, the CMI has been applied in an extensive variety of applications. With its flexibility and modularity, the CMI confirms dominance in high-power applications, particularly series and shunt connected FACTS controllers.

The cascaded-inverter requires individual DC sources for real power ac to dc and dc to ac conversions. The scheme of individual DC sources is optimum for several renewable energy sources such as photovoltaic, fuel cell, and biomass, etc. Connecting separated dc sources converters in a back-to-back fashion is not possible because a short circuit will be introduced when two back-to back converters are not switching synchronous. Hence in this paper each

inverter is fed from a PV panel connected with Mod-SEPIC converter. The schematic of proposed PV fed multi level inverter model is shown in figure 5.
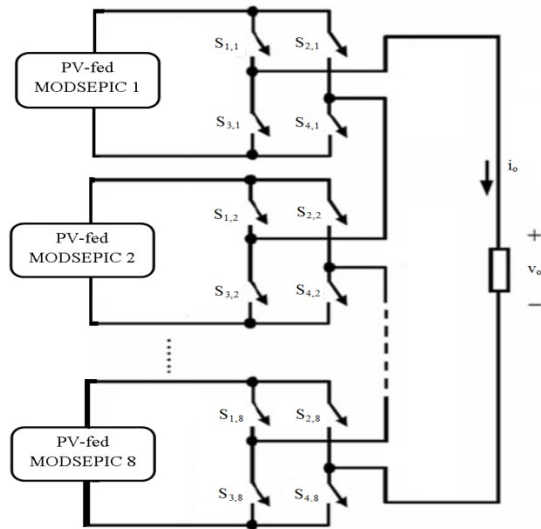

Fig.5. Schematic of proposed 17 Level Solar fed multilevel inverter

VII. SIMULATION ANALYSIS

Performance of proposed converter, MPPT and multilevel inverter are analyzed using Matlab/Simulink. Simulation model of proposed converter and PV fed MLI system are shown in figures 6 and 7.
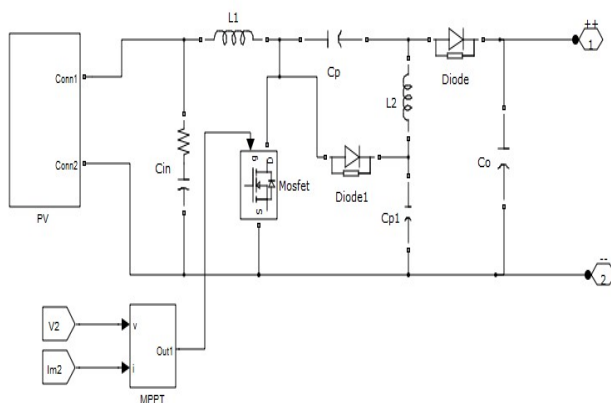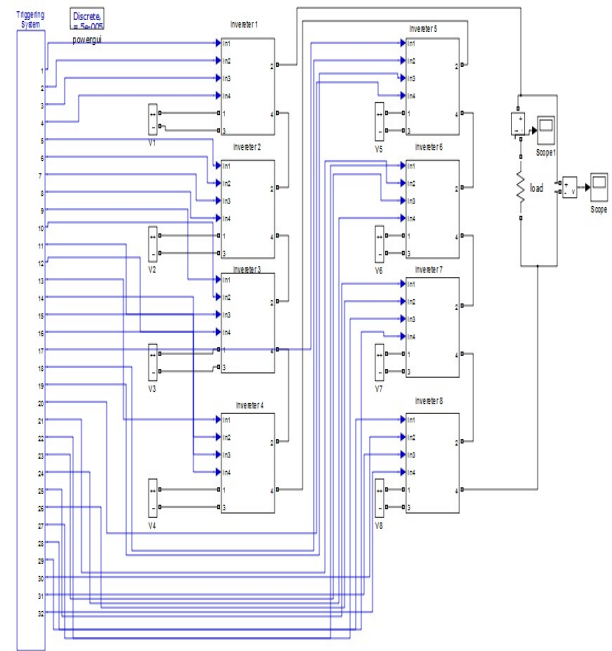

Fig.6. Simulation model of proposed converter

Fig.7. Simulation model of proposed 17 Level Solar fed MLI system
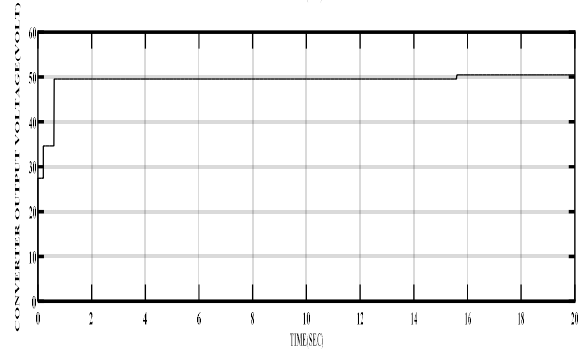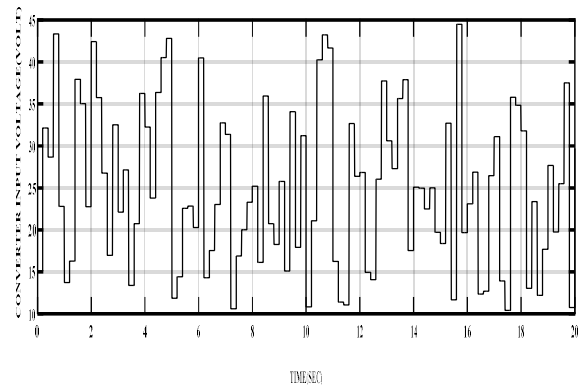

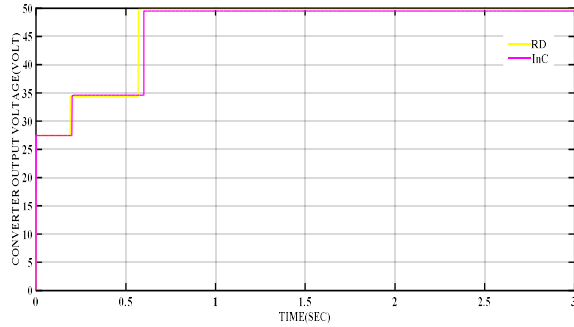Fig.8. performance of Mod SEPIC converter

Fig.9. Performance comparison of raindrop and InC algorithm in MPPT

From the figure 9 analyzed it is noted that rain drop algorithm tuned MPPT controller settles output voltage quickly compare to the conventional Incremental conductance MPPT. The comparison performance conventional and proposed MPPT is shown in Fig. 10.
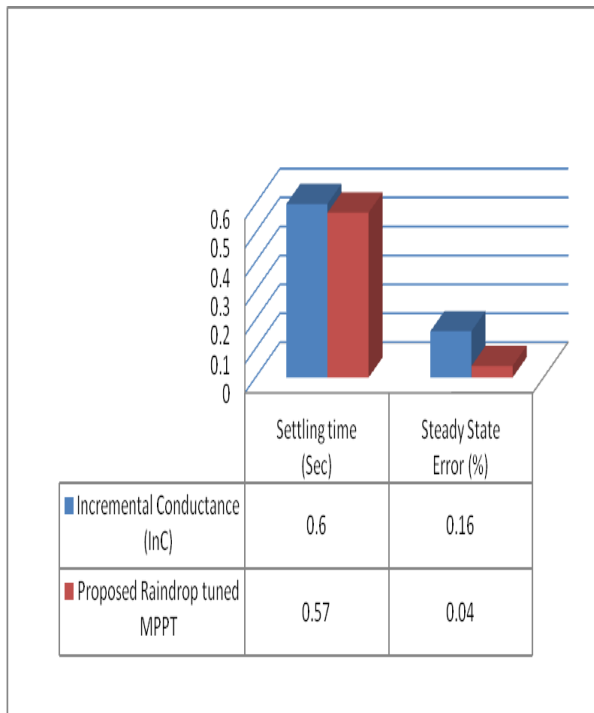

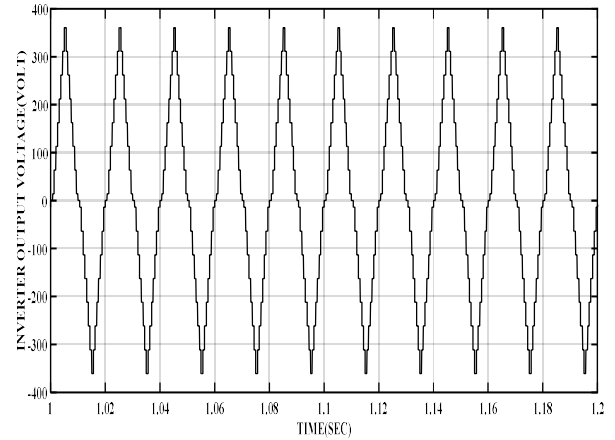Fig.10. Comparison graph for Conventional and Proposed MPPT

Fig.11. Output voltage of 17 Level MLI

VIII. CONCLUSION

To improve the efficiency of PV systems, different techniques of MPPT control have been used to search of Maximum power point. The paper introduces proposed modified SEPIC Converter with hybrid ANFIS-raindrop algorithm tuned PI controller to track maximum power. Modified SEPIC converter gives high voltage gain, Based on the floating switch structure of the Modified sepic converter. The response of proposed hybrid ANFIS –raindrop tuned PI controller is fast with good dynamics. The simulation results shows effective tracking of maximum power with reduced settling time and steady state error compared to existing conventional incremental conductance MPPT algorithm. Simulation results also illustrate the performance and effectiveness of the proposed circuit for generates a high quality seventeen level multilevel inverter output voltage waveform.

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