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A PV Array SEPIC Fed Single Phase Induction Motor Drives designed for Water Driving

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Abstract- In this work a PV (Photo Voltaic) array SEPIC fed single phase induction machine for water driving is demonstrated. A SEPIC employed to maintain continuous DC link voltage through governing duty cycle. A single phase induction motor drives the centrifugal water pump which is served by the output of the single phase inverter. Constant V/F SPWM (Sinusoidal Pulse Width Modulation) controls the single phase inverter. The variable solar irradiation obtains the performance of the proposed system. The SIMSCAPE and Sim Power System tool boxes is preferred for the MATLAB/SIMULINK environment for the modelling of water pumping system. The result of the system is examined and verified with simulation.

Keywords- SEPIC, MATLAB, SIMULINK, SPWM, SIMSCAPE, capacitor start induction motor, THD.

I. INTRODUCTION

Technical improvement of the present power system is moving towards diminishing the carbon emission. Renewable energy sources are the major providers of the above advancement. Photovoltaic cell (PV cell) technology plays vital role on integrating the solar energy to the electrical grid. Large solar power plants are integrated interlinked to the electric grid in the present-day[1]. PV technology is very auspicious substitute to thermal based power generation. The benefits of the solar power generation are such as zero gas (neither toxic nor non-toxic) emission, zero operation charge, low routine maintenance and single time investment. With the advancement in semiconductor practice the efficiency of PV modules improved and has been improving. It improves up to 20%. Additionally, the concentrated PV cell is capable of achieving efficiency of about 43%[2].

In developing countries nowadays the solar based water pumping system are continuously achieving popularity. The water pumping has an important factor of India for an agricultural based economies. The rural and remote areas are long felt need for an uninterrupted power supply and water for drinking, irrigation and other purposes. Standalone PV arrays fed water drives will be quite beneficial for such areas[3].This work offers a standalone PV based induction machine for water driving system.

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In the projected controlling scheme the duty cycle of the Cuk converter[4] is being controlled to uphold the DC voltage at the obligatory level. Induction motor is being controlled by means of leaning vector controlling scheme. The solar irradiation function of the induction machine drive is speed. With the aid of Simulation the projected PV system performance is analysed.

IGBT with the parallel diode with single phase VSI is employed and its switching is provided according to the V/F controller based SPWM control[5]. V/F controller aid in minimizing the inrush current having very high value in the starting. The particular work is divided into five sections. Section 2 deal with the configuration of the proposed system and its constructional criteria in Section 3 deals with controlling strategy including INC MPPT technique Section 4 deals with result and the discussion and the conclusion in Section 5.

II. THE CONFIGURATIONAL DESIGN OF PROPOSED SYSTEM

The water pumping system based on solar with SEPIC converter as shown in figure 1. A pump for driving water from ground is in association with 2Hp single phase induction machine. The electrical energy is generated through PV cells, it converts solar energy into electrical energy. SEPIC converter technology is employed for the output voltage regulation of PV array and being monitored to uphold DC link voltage.

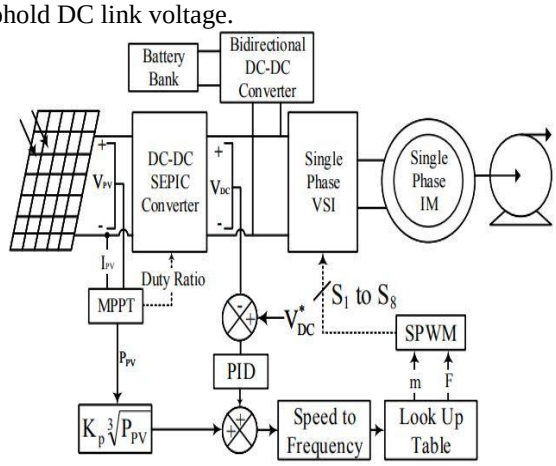

Figure 1: Projected model

To assist variable speed functioning for attaining MPPT, the induction motor has been compelled by PWM inverter. Constant V/F controlling has been employed for the control of induction motor. A SEPIC converter is employed to control the PV system's DC link voltage.

The induction motor drive's speed is being controlled by a PWM inverter as per the MPPT scheme.

PV Array Design Characteristics

	Single Module SPV Array	Complete SPV Array Module
Power at MPP (P_{mp})	160.2W	1602W
Voltage at MPP (V_{mp})	35.6V	356V
Current at MPP (I_{mp})	4.5A	4.5A
Open Circuit Voltage (V_{oc})	43.8V	438V
Short Circuit Current (I_{sc})	5A	5A
Fill Factor	0.7315	0.7315
No. of Series Module (N_s)	10	
No. of Parallel Module (N_p)	1	

III. DC LINK VOLTAGE

The required DC link voltage is estimated as

$$V_{dc} = \sqrt{2} \times V_{rms} = \sqrt{2} \times 230 = 325.26V \quad (1)$$

Hence, DC link voltage is chosen to be 350V.

Design of Cuk Converter

$$D = \frac{V_{dc}}{V_{dc} + V_{mp}} = \frac{350}{350 + 356} = 0.4957 \quad (2)$$

$$L_1 = L_2 = \frac{V_{mp} \times D}{\Delta I_L \times f_s} = \frac{356 \times 0.4957}{0.2 \times 5 \times 5000} = 35.29mH \quad (3)$$

$$C_1 = \frac{I_{mp} \times (1 - D)}{\Delta V \times f_s} \quad (4)$$

$$C_1 = \frac{4.5 \times (1 - 0.4957)}{325.26 \times 0.25 \times 5000} = 5.582\mu F$$

$$C_2 = \frac{I_{DC}}{6 \times \omega \times \Delta V_{DC}} \quad (5)$$

$$C_2 = \frac{1602/350}{6 \times \frac{2 \times \pi \times 1500 \times 4}{120} \times 0.08 \times 350} = 867\mu F$$

Parameter	Data Calculated	Data Selected
V_{dc}	325.26V	350V
D	0.4957	0.4957
L_1	35.29mH	40mH
L_2	35.29mH	40mH
C_1	5.582µF	10µF
C_2	867µF	900µF

Bidirectional DC-DC converter and battery characterstics

$$D_{buck} = \frac{V_b}{V_{dc}} = \frac{12}{350} = 0.0348 \quad (6)$$

$$D_{boost} = \frac{V_{dc} - V_b}{V_{dc}} = \frac{350 - 12}{350} = 0.9657 \quad (7)$$

Parameter	Data Selected
D_{buck}	0.0348
D_{boost}	0.4914
$L_{bidirectional}$	2.3mH
V_b	12V
AHr Capacity of Battery	375Ahr

Design of Water Pump

$$T_L = K_p \times \omega_r^2 \quad (8)$$

$$K_p = \frac{9.94}{(2 \times \pi \times 24)^2} = 0.00043712 Nm/(rad/sec)^2$$

Where, D is duty ratio, C is DC link capacitor, T_L is load torque, K_p is pump constant, ω_r is speed of IM.

IV. CONTROLLING APPROACH OF PROPOSED SYSTEM

The proposed control plan block diagram is as appeared in the Fig. 1. The PV framework is controlled through two individual control plans. Single controlling loop for Ćuk Converter controls a DC interface voltage dependent on INC (Incremental Conductance) MPPT technique. The other control plot for the VSI to work in consistent V/F mode directs the speed of the drive under change in powered powered irradiation.

INC MPPT Algorithm

The MPPT methodology depend on an INC that is received to follow an ideal point on the current–voltage (IPV-VPV) attributes of the sunlight based PV cluster[6]. This strategy investigates that the power incline of a PV cluster qualities is invalid at MPP (dPpv/dVpv = 0), negative at right of MPP and positive at left of MPP. Hence, an ideal working point is inferred dependent on an INC. INC calculation stream outline is given in fig.2.

V/F Control of Induction Motor Drive

For steady transition task of IM V/F ought to be consistent all through the activity. The working pace is given by info power as indicated by referenced connection. This will create balance list and recurrence reference for V/F control. The combination of speed gives.

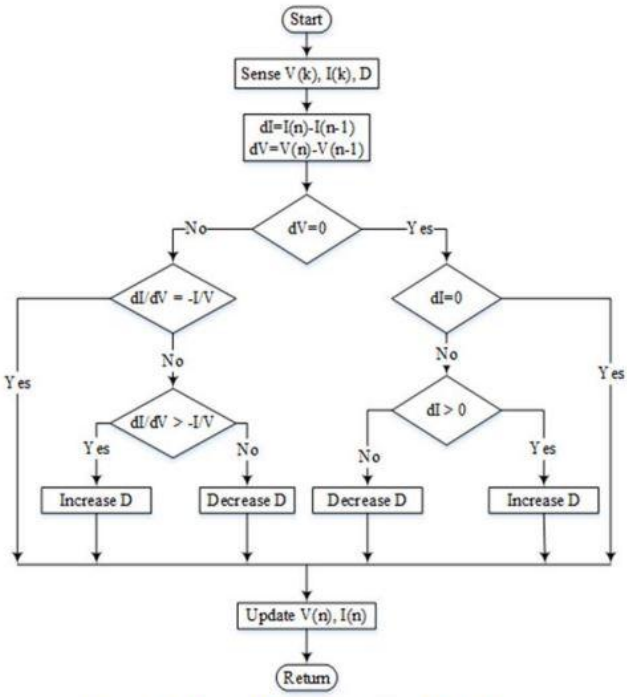

Figure 2: INC MPPT Algorithm Flow Chart

Φ which control the frequency of reference sinusoidal wave.

$$\phi = \int \omega^* dt \quad (8)$$

$$V^* = a \times \sin(\phi) \quad (9)$$

Where, 'a' is modulation index.

To generate reference speed following step is taken

The DC link voltage error

$$V_r = V_{dc}^* - V_{dc} \quad (10)$$

This error voltage is passed to PID controller which gives speed error as follows

$$\omega_{r(n)} = \omega_{r(n-1)} + K_P \times \left\{ V_{r(n)} - V_{r(n-1)} \right\} + K_I \times V_{r(n)} \quad (11)$$

Pump speed is given as $\omega_{pump} = K_p \sqrt[3]{P_{pv}}$

Reference speed is given as $\omega^* = \omega_{pump} + \omega_r$

Where, ω^* is reference speed of pump and ω_r is error speed.

V. RESULT AND DISCUSSION

The result of the simulation of proposed system is provided here. The Matlab/Simulink 2016 a platform is preferred for 3 sec simulation time with the varying irradiance significance from 1000 W/m2 to 600 W/m2 and 350OC temperature. The performance of the system is made known below in the figures with a capacitor start induction motor.

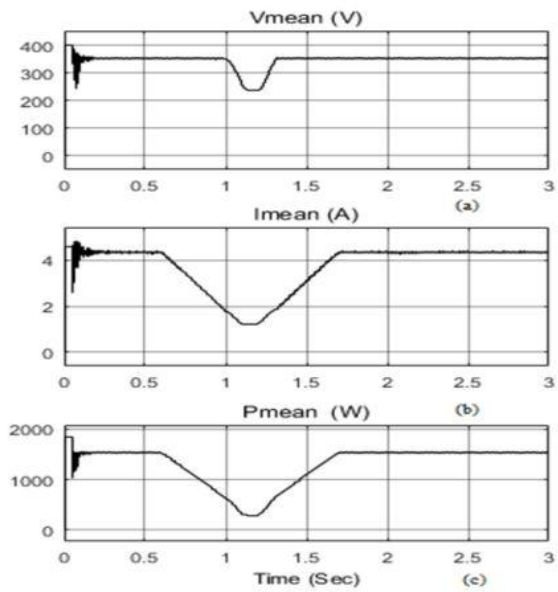

Figure 3. PV Performance (a) PV Voltage (b) PV Current (c) PV Power Generated

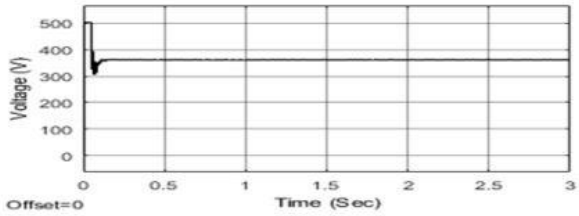

Figure 4. SEPIC Converter Output Voltage

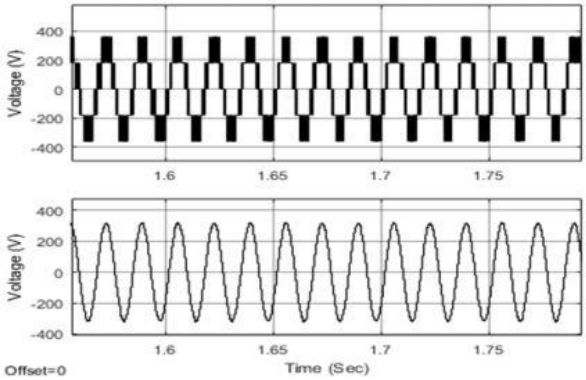

Figure 5. VSI Output Voltage

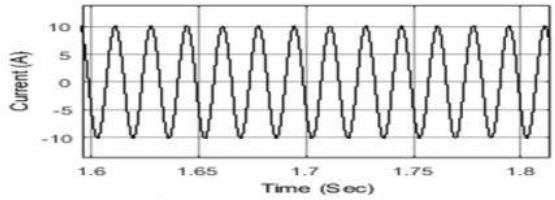

Figure 6. Capacitor Start Single Phase IM Steady State Current

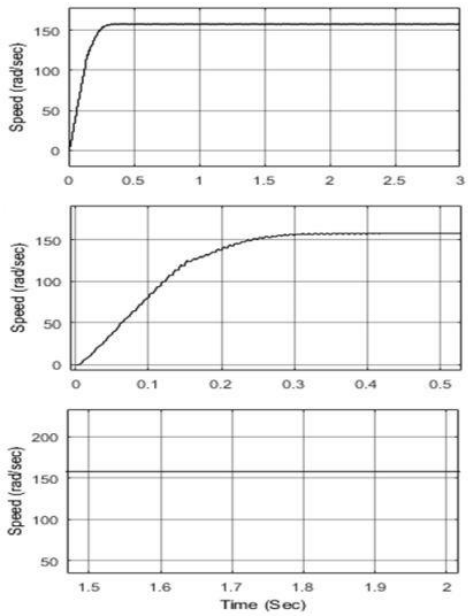

Figure 7. Single Phase Capacitor Start IM Performance

VI. CONCLUSION

As made known in the Section 4 about all simulation result of a capacitor start IM and it verifies the theoretical conclusion. The complete analysis of the capacitor start IM is taken out and simulation result provides desired solution as provided in the theoretical assumption. The "capacitor start machine demonstrates 0.63% THD" as into the current & 1.92% THD into the voltage of which is into tolerable boundary figured by the IEEE standards by means of Simulation result. The initiating enactment by "capacitor start indication machine" as per above speculative investigation. Consequently, this work accomplishes as "SPV array SEPIC" nourished one phase capacitor start IM capable of working very well as per different conditions & it can be utilized by agriculture purpose.

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Ms. Anjali Gupta was born in Gwalior, India 1980. She received the B.E. degree in Electrical Engineering and M.E. degree in Industrial Systems & Drives from MITS (Madhav Institute of Technology & Science) Gwalior India, in 2003 and 2006. She is persuing Ph.D from RGPV (Rajiv Ganghi Prodhyogiki Vishwavidhyalaya) Bhopal India. She has 13 years teaching experience in the field of Electrical Engineering. Her area of research is Congestion Management in Transmission Line in Power System. She attended many FDPs, Workshops in her area. She is acting as Deputy Head in the department of Electrical and Electronics Engineering at NIET, Greater Noida.

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