POWER CONTROL UNIT OF A HYBRID PV-UTILITY SOLAR PUMP

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Abstract:— This work proposes to develop a novel power control unit (PCU) using Texas Instruments microcontroller TMS320F28027 for a hybrid PV-utility solar pump that employs a squirrel cage induction motor (SCIM) replacing the Permanent magnet DC motor (PMDCM)which is normally used in the most of the existing solar pump applications . The cost of SCIM is several times cheaper than that of PMDCM. The power circuit consists of a single stage inverter whose output drives the three phase SCIM. The Inverter is controlled in such a fashion by the PCU, so that the frequency of the inverter is modified based on the available DC link voltage which is fed from PV array. The PCU will provide a output voltage such that v/f remains constant despite of the variations in PV voltage caused due to change in irradiation. The unique feature of the proposed PCU is, it is possible to operate the pump with utility supply also whenever the PV voltage fails due to low irradiation or during nights. The priority is given to PV mode of operation which is decided by the controller. The power circuit of the PCU includes a three phase inverter and a parallel three phase AC voltage controller circuit using back-back scr's in each phase, while the control circuit includes a C2000 launch-pad, DAP signal conditioning board, Hall effect Voltage sensors and 430BOOST-SHARP96 - Sharp Memory LCD Booster Pack for display of parameters. The proposed PCU will be validated using a 2.4 kW PV panels available with the institution.

Keywords—PWM, PV, LCD, PCU, DAP, SCIM, PMDCM, ADC and EPWM.

1. INTRODUCTION

The main reason for the reduction in food materials production is lack of water supply. Even though we have Motor-Pump set for irrigation it can work for 3 hours per day in summer because of power crisis. In Tamil Nadu we are receiving solar energy throughout the year. So if we replace Utility operated Motor Pump with Solar operated water pump we can supply water from morning to evening. At the same time we can reduce the major part of our utility demand which further enhances the power quality by providing uninterrupted power supply. This thought made us to work on Solar operated water pumps. The Solar pumps available in markets were driven by DC motors. Since motors have to be placed in open space DC motors need frequent maintenance. Also the costs of DC motors are much higher than Induction motors of same operating range. Squirrel Cage Induction Motor (SCIM) is one of the most robust motor and it doesn't need frequent maintenance. Hence we replaced DC motor by Induction motor. The main disadvantage of solar pump is we can't use it during night time, rainy season and cloudy days. In order to overcome this we've decided to implement automatic changeover between PV and Utility. For implementing this we've designed a hybrid controller using Texas Instruments microcontroller TMS320F28027. Our ultimate aim is to help our farmers by designing a controller for the energy efficient operation of solar pump driven by existing Induction motors for cultivating crops throughout the year. As a result our nation's productivity and GDP will be improved.

2. PROPOSED SOLUTION

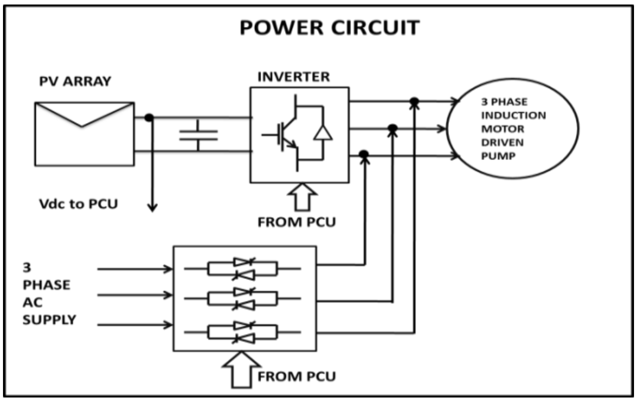


Fig. 1 Power Circuit of a Pump

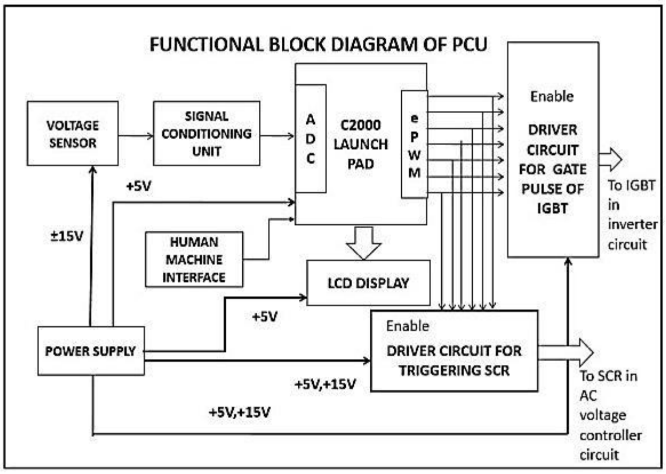


Fig. 2 Functional Block Diagram of PCU

The SCIM is proposed to replace the PMDCM used in the present solar pump, which will reduce the cost. The power circuit of the proposed solution is shown in Fig. 1. The pump is fed by a three phase inverter which in turn if fed by the PV arrays. The functional block diagram of the PCU (power control unit) of the proposed hybrid solar pump is shown in Fig. 2.Functional features of PCU – 1.Provide variable frequency variable voltage output by maintaining v/f constant which will improve the efficiency of motor 2. Once the irradiation falls below a certain level, automatic changeover to utility 3. Maximize the frequency of SCIM by maintaining v/f constant.

2.1 Description for Sub-Systems:

PV Array- 2.4 kW
3 Phase Inverter: Rating of the Inverter is 7kVA
SCIM: Power rating of Squirrel Cage Induction Generator is 5HP
Voltage Sensor: Sensor used here is a Hall Effect Sensor, for sensing dc link voltage of inverter
Signal Conditioning Unit: one DAP Signal Conditioning Board (Unipolar) is used to interface the sensor signals with ADC of the TMS320F28027.
C2000 Launch Pad: Evaluation Module from Texas Instruments is used as a controller
LCD Display: Sharp Memory LCD Booster pack for displaying various parameters
HMI: Human Machine Interface unit for operating the pump
Driver Circuit: It boosts the Microcontroller output voltage of 3.3V to 15V and given to the gates of IGBT's
Power Supply: Power supply is designed from *Webench tool* from Texas. It supplies
i. LCD Display (+5V), ii. Voltage & Current Sensor (±15V), iii. C2000 Launch Pad (5V), iv. Driver Circuit (+5V, +15V)

In the functional block diagram of PCU, the voltage sensor senses the voltage accordingly to the voltage from PV solar panel, which is given to the Signal Conditioning Unit. The purpose of SCU is convert bipolar to unipolar signal. The power supply unit is made for the functioning of SCU, C2000 Launchpad, LCD display, driver circuits and level shifters. The level shifters shifts the 5v to 15v.Human Machine Interface acts as a interface between user and controller to provide inputs.

The Power Circuit holds the responsible for powering of pump. The input from PCU's fed to the inverter, which takes supply from solar PV panel, if the solar power is available. Otherwise, the supply would be taken from 3 phase 440v supply. The operation of motor is being controlled by C2000 Launchpad by means of ADC and ePWM Signals. Hardware implementation for the same setup could be explained in implementation Section.

3. IMPLEMENTATION

3.1 Hardware Implementation

3.1.1 Voltage Sensor:

Fig.3 Voltage Sensor

The implementation V/f control for the energy efficient operation of induction motor is done. Since the PV voltage varies from time to time we are using voltage sensor for sensing the variation in PV voltage.

3.1.2 Signal Conditioning Circuit:

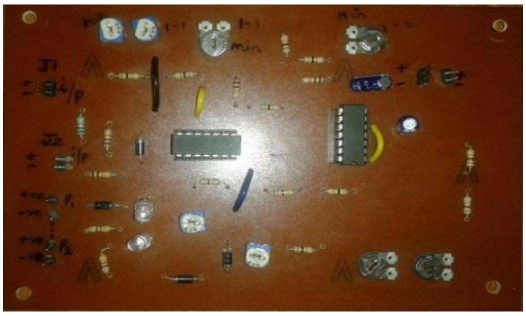


Fig.4 Signal Conditioning Circuit

The purpose of signal conditioner is to convert bi polar signal into unipolar signal. It performs both clipping and clamping operations to maintain the input to processor within limit.

3.1.3 C2000 Launchpad:

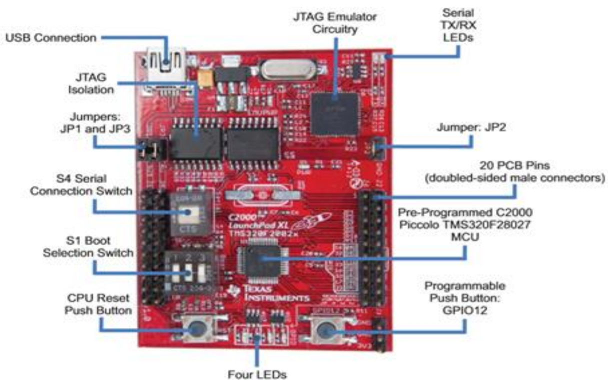


Fig. 5 C2000 Piccolo Launchpad Processors

For implementing V/f control and to produce sinusoidal PWM pulse for gate we've used C2000 Launchpad from TEXAS INSTRUMENTS.

3.1.4 Level Shifter:

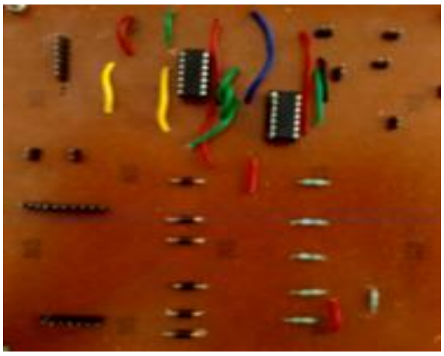


Fig. 6 Level shifter Circuit

The magnitude of output pulse from controller is 3.3V. To trigger the gate we need 15V. In order to shift the level from 3.3V to 15V we use level shifter IC CD4504BE from TEXAS INSTRUMENTS.

3.1.5 LCD Display:

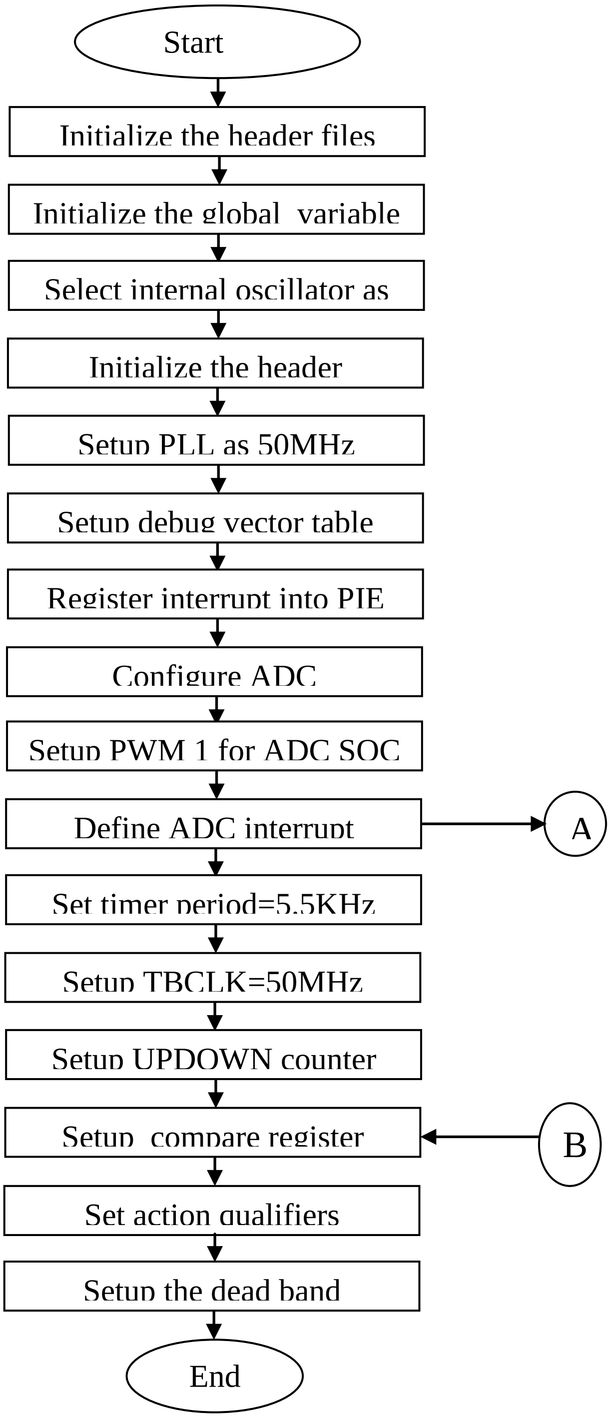
Fig.7 LCD Display

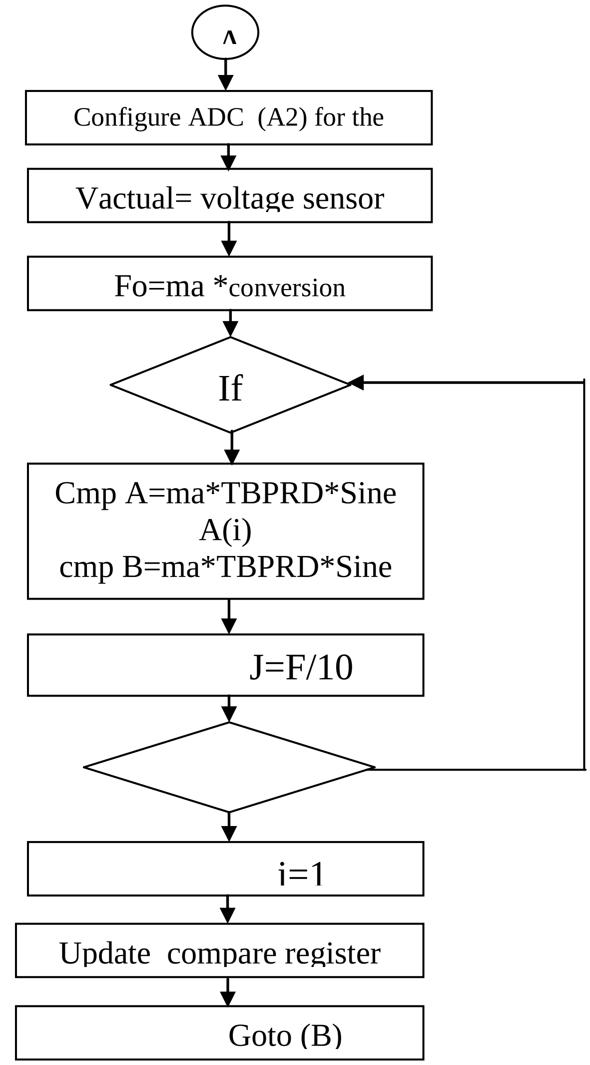
To display the measured digital values we are using 430BOOST-SHARP96 - Sharp Memory LCD Booster Pack from TEXAS INSTRUMENTS.

3.2. Software Implementation

The flow chart (a) and (b) inserted in proposed solutions.

Initializations of the software implementation starts with initialize the header files and global variables. Select internal oscillator as clock pulse. Set Phase Lock Loop as 50MHZ. To save a memory we select a interrupt that store a values in temporary registers to avoid congestions. Triggering of ADC is done by PWM signal.PWM signal is given to A4 pin of c2000 processors. Here we use PWM module 1.Time period we taken is 5.5KHZ.To generate triangle wave we had used a UPDOWN counter. These blocks fed into the compare registers. We draw another flowchart (b) that fed in compare register in flowchart (a).In flowchart (b) it shows the changing voltage corresponding to frequency. Voltage value is sensed by voltage sensor for which, frequency changes by C2000 processor. ADC signal is given to A2 pin of the C2000 processor.





MATLAB Simulation:

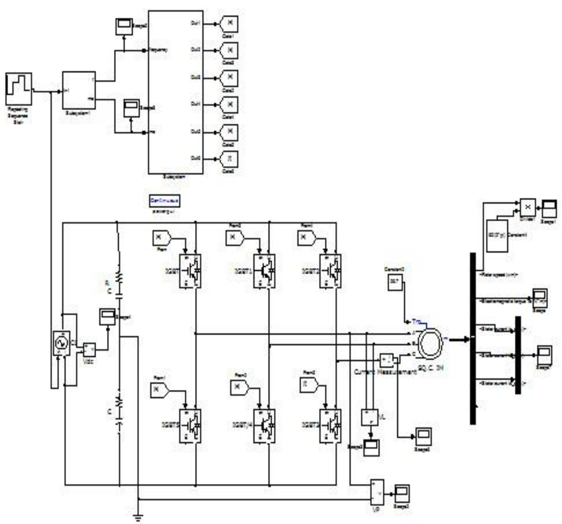


Fig. 8a MATLAB/Simulink Model for inverter fed induction motor supplied by a variable voltage source.

Values are compared using cmp variable corresponding to voltage These compared values of cmp is given to flowchart (a).Here we got the voltage corresponding to frequency was done.

List of Formulae:

$$V01\_line\_line\_rms = \sqrt{3} * \frac{Vdc}{2\sqrt{2}}$$

$$f = (V01\_line\_line\_rms)/8$$

Where,
Vdc = DC input voltage
F=frequency
V01_line_line_rms = Line to line output rms voltage.

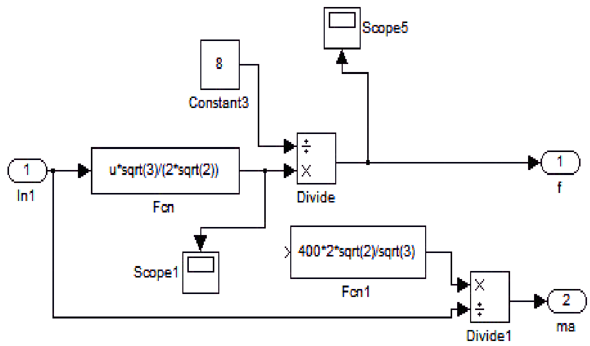


Fig. 8b conversion involved in implementing V/f control in MATLAB Simulink.

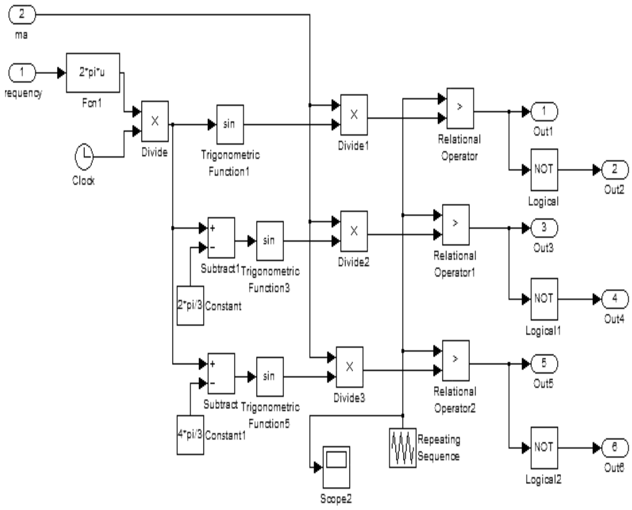
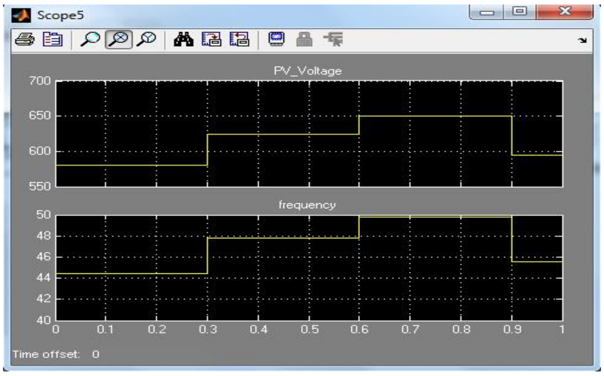


Fig. 8c shows producing sinusoidal PWM in MATLAB Simulink model.

4. RESULTS

The simulation is done using MATLAB/Simulink of a PV fed inverter fed induction motor. The operation of the induction motor based pump has been depicted in Fig. 2, which shows the different variables like motor voltage, frequency, V/F ratio, PV voltage under varying conditions of Irradiation. From below Fig.1 it can be observed the speed (and hence the power and flow) of the pump varies with change in irradiation. The change in irradiation causes the PV voltage and hence the inverter voltage fed to the motor changes. The controller in the PCU automatically changes the frequency of the inverter in order to maintain v/f constant as shown in below Fig. Maintaining v/f and hence flux of the SCIM constant, the efficiency is increased. This figure shows the variation of frequency corresponding to voltage.



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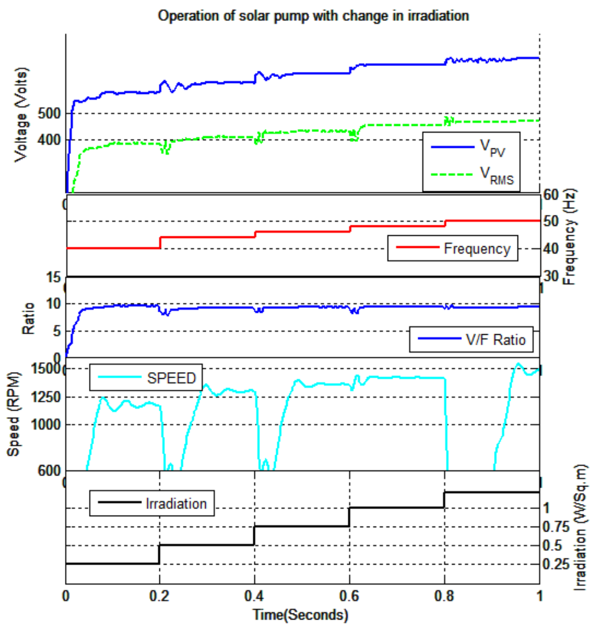

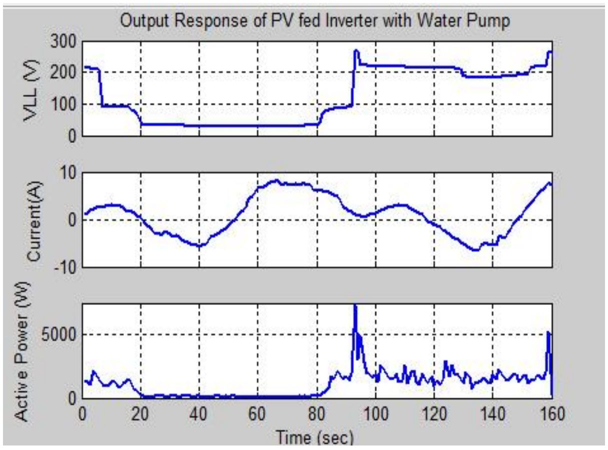

5. CONCLUSIONS

The present solar pumps driven by DC motors are very costlier and they need proper maintenance. By replacing the DC motors with Induction motor we can reduce the cost. Some solar pumps driven by AC motors need special construction and normal motors can't be used during night time. All these problems can be rectified by replacing DC motors with Induction motors and converting the system into a Hybrid one by adding provision for operating it with utility service.

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