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# Design and Implementation of ANFIS Controller Based Sensorless Control of BLDC Motor Drive for PV Array Fed Irrigation Pump

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**ABSTRACT:** An Integrating ANFIS controller into position sensorless control mode addresses the formidable challenge of precisely commutating the PMBLDC (permanent magnet brushless direct current) motor at first. In order to provide a wide-speed-range position sensorless control in a solar photovoltaic array-fed PMBLDC motor drive for irrigation water pumping, this work presents a peak current detection starting technique. The Incremental Conductance algorithm ensures accurate commutation and peak starting current control, eliminating the need for a rotor position estimation, use a position sensor and a current sensor. The system is small and perfect for farming applications because it has a current sensor and an elimination position sensor. Matlab/Simulink 2018a software can be used to examine the simulation results.

**KEYWORDS:** Maximum Power Point Tracking (MPPT) algorithm, Peak current detection based starting, Permanent Magnet Brushless Direct Current (PMBLDC) motor drive, Position sensorless control, Water pump and ANFIS Controller.

## I. INTRODUCTION

The Since solar photovoltaic (PV) arrays have grown significantly less expensive and fossil fuels are running out quickly, solar energy has emerged as one of the most reliable nonrenewable energy sources. Water pumping is critically needed since the lack of water is having a severe impact on agriculture and the availability of drinkable water, particularly during the summer in rural areas of India and other low-lying regions of the world.

The environment is polluted and diesel-energized pumps have ongoing operating costs. Their significance is diminishing as water pumps powered by solar PV arrays, particularly for irrigation, become more significant. The motor-coupled water pumps have also replaced hand pumps that provide drinkable water in rural regions these days. Water pump powered by solar photovoltaic cells, permanent magnet brushless DC. A water pumping motor drive application, known as PMBLDC, is provided [1].

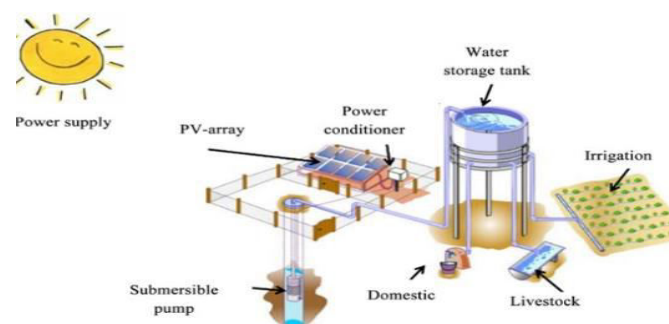


Fig.1. Water pumping by PV array connected motor.

But the solar-powered water pump with a DC motor connected can operate without a drive directly. But they're constantly having problems with commutator brushes that need maintenance. Since induction motors require very little maintenance, they can be used extensively, but their middling efficiency raises the solar panel's rating, which raises the system's cost [2]–[4]. Because Hall effect sensors are sensitive to temperature, there is a significant risk of sensor failure during severe weather, rendering the system unstable.

Therefore in order to overcome these issues, For both surface-mounted and submerged BLDC motor-based irrigation pumps, it is preferable to switch to position sensor-less control. [5] presents an efficient zero-speed startup with position sensor-free PMBLDC motor drive control. A trustworthy speed range position estimate function is provided here to start the motor from the stall state to the high speed range. In [6] and [7], the rotor starting position calculation is performed using an estimate of the Inductance of stator winding. The location of the rotor and stator core saturation information affect the inductance. The reverse electromotive force (EMF) zero crossover is detected using a resistor and a cascaded low-pass filter (LPF). By using torque estimates as a reference for rotor location and back EMF and rotor speed to estimate torque constant, position sensor-less control has been accomplished in [8] [10]. The irrigation water pump is driven by a PM-BLDC motor fed by a solar photovoltaic array through a wide speed range position sensor-less control algorithm based on peak current detection. The precise beginning commutation and peak starting current are controlled by this starting algorithm. Because it doesn't need a position sensor or a current sensor, the developed drive for rotor position estimation is small and affordable for agricultural use.

Advanced technology is widely available for water pumping systems that are powered by solar PV and brushless DC motors. Proposed is the BLDC motor supplied aqua pumping system with A neuro-fuzzy inference system that is adaptable (ANFIS). The ANFIS controller combines fuzzy and neural systems. Here, a controller is utilized as a high stepup maximum power point tracking, or MPPT, is controlled by the inverter. by an ANFIS-based effective particle swarm incremental conductance (INC) method.

An aqua pumping brushless dc motor with a soft start feature and a buck boost converter arrangement is shown in [12]. An INC approach with a buck boost converter was used to realize the MPPT. From the perspective of power electronics, this simplifies the system. However, because of reliability and cost-effectiveness issues, the system—which includes a position sensor—is not commonly accepted. Water pumping with solar PV has been shown using ANFIS controller-based MPPT implemented drives. Comparing an ANFIS controller-based MPPT to a fuzzy logic controller, it has been observed that the total system efficiency is increased. It is mentioned in [15] that a PMBLDC motor's position sensorless control has been enhanced during startup. The sensing circuit, which is based on an analog comparator, is not appropriate for submersible applications or for pumping. A multilevel BLDC motor drive coupled to an inverter has been presented for water pumping. System efficiency has increased as a result of the intermediate dc converter being removed because the multilayer inverter handles both motor commutation and MPPT.

## II. SYSTEM CONFIGURATION

The proposed model has PV panel, multilevel inverter, the electronic commutator and the PMBLDC motor. The ANFIS controller is used as the controller in this system. Peak current detection algorithm is used to commutate Brushless Direct Current Permanent Magnet Motor (PMBLDC) and it is connected by the PV solar panel as the input.

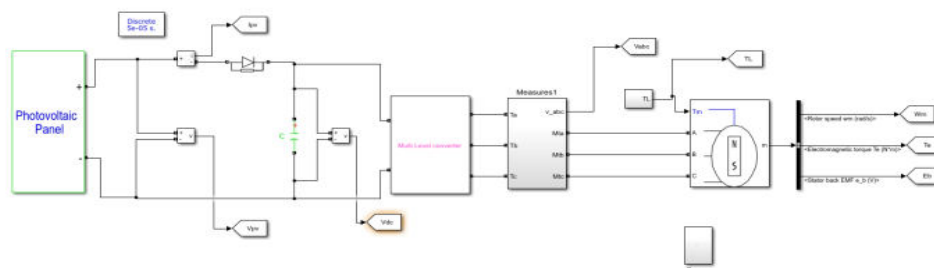


Fig. 2. System configuration of BLDC motor drive with ANFIS controller

The input given to the solar panel is in irradiance ( $\text{W/m}^2$ ). The input provided at the PV panel gives DC current. So the DC current need to convert as AC current. The inverter is used for the conversion of AC to DC. Multilevel inverter is used in the proposed model. An output that uses a voltage source inverter settles more slowly. A multilayer inverter can reduce the output's settling time when it replaces the voltage source inverter. By using the multilevel inverter the efficiency of the system is increased so power quality also increased.

### III. DESIGN SPECIFICATION AND SIZING

An effective PV array design is crucial for the water pump driven by a BLDC motor. A 4-pole, 1.3-kW, 3,000 rpm BLDC motor powers the water pump. The framework is constructed, to maintain the minimal speed necessary to keep the water pumping unaffected even in the face of fast variations in solar insolation. Table I provides the brushless DC motor's complete electrical specs.

#### A) Solar PV Array Sizing

At typical test conditions, a solar irradiation of  $1000 \text{ W/m}^2$  is taken into consideration for the steady-state optimal performance [17]. Despite the motor's 1.3 kW power rating, the photovoltaic array's power rating of 1.5 kW is taken into account to cover the system's intermediary losses.

A PV array operating at full load and  $1000 \text{ W/m}^2$  of It is believed that the voltage of irradiation is 310 V.

#### B) Water Pump Design

The motor shaft power or pump input power is determined using the basic pump power relationship [18].

$$P = \frac{Q \times H \times SG}{367 \times \eta}$$

where H is the dynamic water head, Q is the water flow rate in  $\text{m}^3/\text{h}$ , and P is the pump shaft power in kW. The specific gravity of water is 1, denoted by SG, whereas the pump efficiency is represented by  $\eta$ .

### IV. CONTROL ALGORITHM

#### A) Peak Current Detection Based Starting Method

During startup, this starting method commutates and accelerates the PM-BLDC motor based on the phase current. As the PMBLDC motor is accelerated and commutated during sensor-less beginning by the standard align and start approach in accordance with a predefined commutation sequence, which leads to incorrect commutation and a large initial inrush current. Fig. 5 displays the comprehensive flowchart of this initial procedure. Proper commutation also takes into account the processor internal time ( $T_{\text{internal}}$ ) and the phase commutation time ( $T_{\text{phase}}$ ).



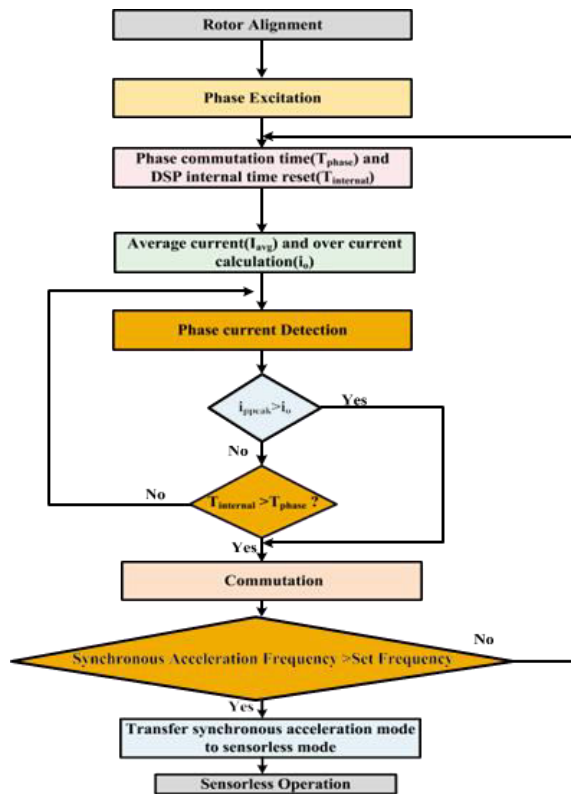


Fig. 3. Peak Current Detection Based Sensorless Starting Method

**B) ANFIS Controller**

An approach to solving function approximation problems using neural networks is represented by the data-driven adaptive network based fuzzy inference system (ANFIS). Fuzzy control and neural networks are used to create the ANFIS controller. Typically, data-driven methods for creating ANFIS networks involve clustering a training set of numerical samples of the unknown function that needs to be approximated. Applications of ANFIS networks to pattern recognition, rule-based process management, and classification tasks have proven successful.

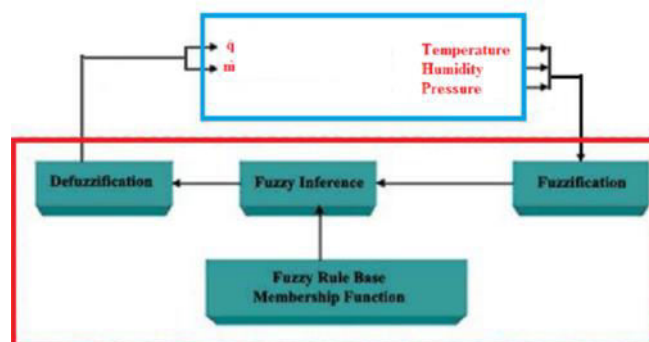


Fig. 4. Block Diagram of ANFIS Controller

The controller is able to learn from input data and generated the rules. In ANFIS controller it tunes the data and provides controlled output. The ANFIS controller boosts system efficiency, therefore the power quality also increases. While doing the simulation the Fuzzy block taken from the simulink library the data need to load and also tuned the data for the ANFIS controller.

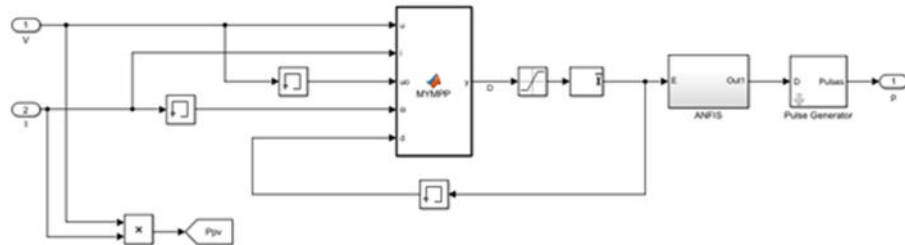


Fig.4.1. ANFIS Controller Connected in the System.

### V. OPERATION OF THE SYSTEM

The electronic commutator controls the operation of the BLDC motor fed by the PV array. Irradiance is given as the input for the PV panel. The motor must be connected to the PV panel's output. By installing the inverter, the DC is transformed into AC. In addition to converting DC to AC, the multilayer inverter boosts output efficiency and improves power quality. The response time is also very fast. If the sun radiation changes, it will affect the output. Based on the sun's radiation, there are two conditions. The input is high for some time and also it will reduce in the evening time. So static and dynamic conditions are considered. The insolation is varied and tested at both static and dynamic conditions. Between 1000 and 500 W/m<sup>2</sup> of solar insolation are used to run the simulation. Perfect tracking is seen in both dynamic and static circumstances.

### VI. SIMULATION RESULTS

MATLAB is used to simulate this position sensorless control of a water pump based on a BLDC motor. Between 1000 and 500 W/m<sup>2</sup> of solar insolation are used to run the simulation. This part evaluates and displays the initial performances in both steady state and dynamics. The evaluated parameters show that the system is performing steadily and satisfactorily.

The sun radiation is varying, so static case and dynamic case both cases are considered as illustrated in Fig. 5, the sensorless BLDC motor's steady state performance for the system is assessed at 1000 w/m<sup>2</sup> of irradiance. As seen in Fig. 6, the system's dynamic behavior is assessed at various insolation values of 500–1000 w/m<sup>2</sup>. The dynamic input is also given to the PV panel and needs to be verified and compared with static and dynamic conditions.

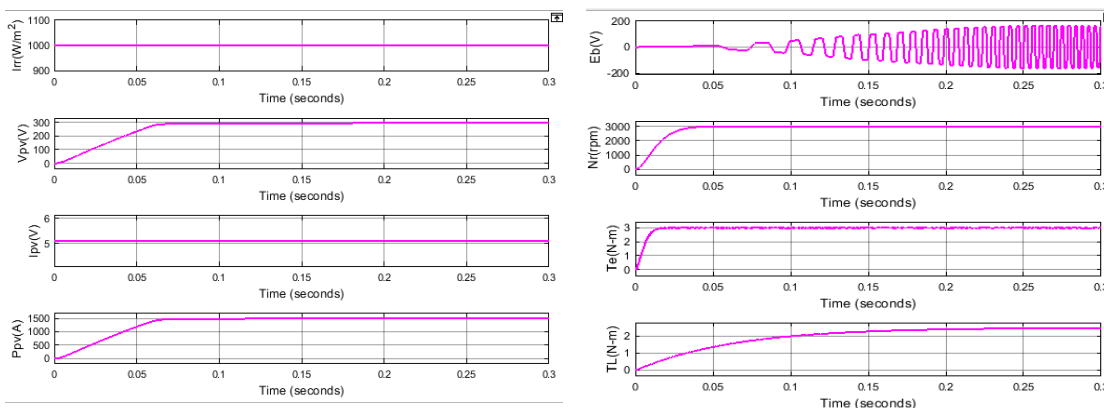


Fig. 6.1. Solar PV array performance. Steady-state and starting performance at 1000 W/m<sup>2</sup> insolation

Fig.6.2. BLDC motor performance at sensorless scheme. Zero starting and steady-state performance at 1000 W/m<sup>2</sup> irradiance.

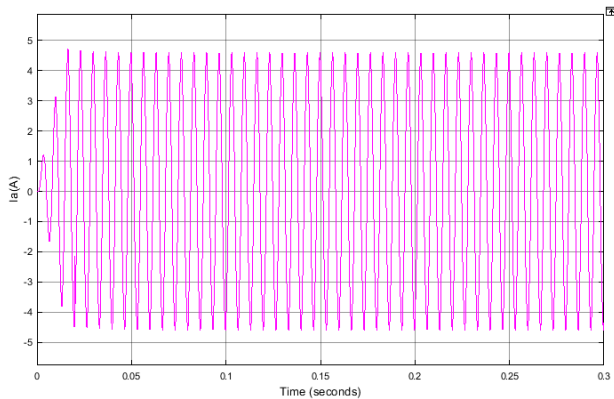


Fig. 6.3. Suppressed ripple current in phase A, Ia(A) in steady state

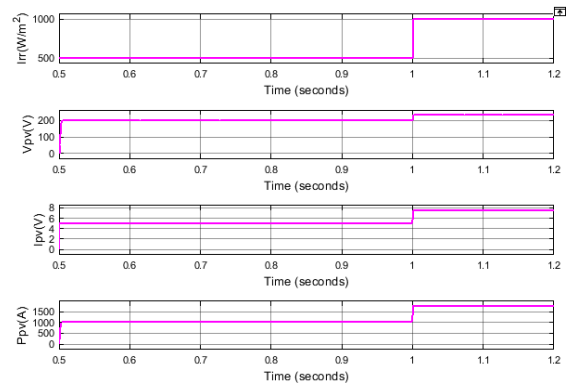


Fig.6.4. Dynamic performance varying from 500 to 1000 W/m2.

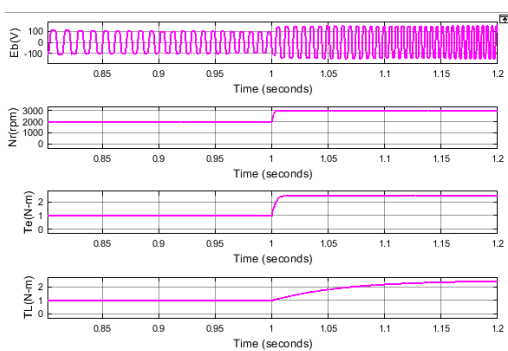


Fig. 6.5. Dynamic performance varying from 500 to 1000 W/m2 irradiance

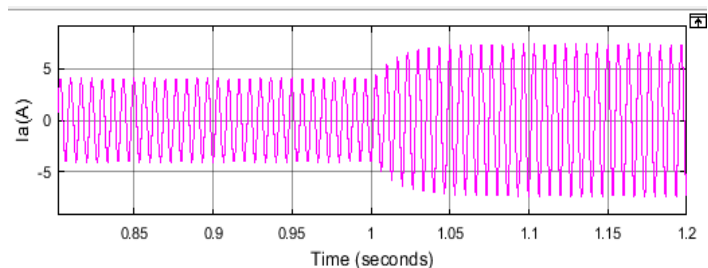


Fig. 6.6. Suppressed ripple current in phase A, Ia(A) in dynamic state

## VII. CONCLUSION

Solar powered water pumping is done by connecting BLDC motor. Sensorless control is done by using ANFIS controller in the system. The reduction of the position sensor and speed sensor makes the system compact and cost effective. Multilevel inverter used in the system reduces ripples and increases the efficiency, so the power quality also increased. It is also observed that fast settling in static and dynamic conditions. The behavior of the system is verified at both static and dynamic conditions. ANFIS-controlled drive is an ideal solution for affordable and efficient agricultural applications, catering to requirements for home water pumping as well as irrigation.

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