

A Nonlinear Controller for Photovoltaic Water Pumping System

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Abstract : The aim of this work is to supply an energy for photovoltaic cell and that energy will go to the inverter and then went to induction motor to be operating certain speed then water pump process achieved. Main target is to design and simulation of pulse width modulation (PWM) based sliding mode (SM) controller for DC/DC boost converter operating in continuous conduction mode. This research aim is to be applied an application of the sliding mode control addressed in this paper. It is shown that this control approach can give good results in terms of robustness toward load and input voltage variations motor. A controller design based on sliding mode control has been tested on this process model. The sliding mode algorithm provides robust control of the process and performs far superior to conventional PI control.

A nonlinear control of an induction motor (IM) supplied with a photovoltaic generator to assure the level control of two coupled tanks is designed. The global system is decomposed into two separate models thus, coupled are assured by discontinuous command.

The use of the nonlinear sliding mode method provides a very good performance for motor operation and robustness of the control law despite the external/internal perturbation. Simulation results are given to highlight the performance of the proposed control technique under load disturbances and parameter uncertainties.

Key words: Sliding mode control, photovoltaic energy, DC-DC boost converter, Pulse width modulation, tanks, Induction motor, water pumping system.

I INTRODUCTION

The demand of Energy increases these last year considerably on the one hand, as the conventional energy sources are dwindling and have a negative impact on the environment (greenhouse gases effect) in the other hand, considerable attention is being paid to other alternative sources as known the renewable energies. The proposed system will make use of a clean and renewable source of energy. From economic point of view, the photovoltaic energy source is suitable for energizing systems established in remote area. Since the operating point of the photovoltaic systems varies accordingly with the solar irradiation, the temperature and the load, they may be designed to operate at the required voltage and current easily. In our application to overcome the problem of the variation of the operating point, one brings back oneself to exploit the maximum power provided by the photovoltaic system by using a technique of maximum power point tracker (MPPT) and we have to size the photovoltaic system supplied the induction motor.

variable speed control of motors is one of the key technologies that support modern industry. Both DC and AC machines have served industrial needs for nearly a century. However, the electrical structures of induction motors are highly nonlinear and involve multivariable inputs and outputs, the electric rotor variables are not measurable, and the physical model parameters are most often imprecisely known. Therefore, additional effort is required to decouple and linearize the control of these machines. Henceforth, the control of the induction motors has attracted much attention in the last two decades.

II DESCRIPTION

The sliding mode controller is designed for a class of nonlinear dynamic systems to tackle the problems with model uncertainties, parameter fluctuations and external disturbances. By this design, the bounds of the uncertainties are not required to be known in advance.

The variable structure control (VSC) possesses this robustness using the sliding mode control that can offer many good properties such as good performance against unmodelled dynamics, insensitivity to parameter variation, external disturbance rejection and fast dynamic (Utkin, 1977). These advantages of sliding mode control can be employed in the position and speed control of an alternative current system.

In this paper, we begin with the IM oriented model in view of the vector control, next the rotor flux $r F$, is estimated. We, then, present the sliding mode theory and design the sliding mode controllers of rotor flux and motor speed. Finally, we provide some conclusion remarks on the control proposed of IM using sliding mode. The induction machine is largely used in industry, mainly due to its reliability and relatively low cost. The control of the induction machine (IM) must take into account machine specificities: the high order of the model, the nonlinear functioning as well as the coupling between the different variables of control.

In the second stage for my future is interest in the level control in the coupled tanks. Several researchers have investigated the problem of controlling liquid flow of a single or multiple tanks. The speed variations of the IM carry the level regulation control, the relation between speed and the flow of pumped water system.

III Materials and Methods

The increasing demand of water in rural zones and isolated sites made that a growing interest is done to the utilization of photovoltaic (PV) generator as energy source for several motor-pumps. In fact, the realization of autonomous, reliable pumping systems with a good efficiency, gives a practical and economical solution to the water lack problem in desert regions [9].

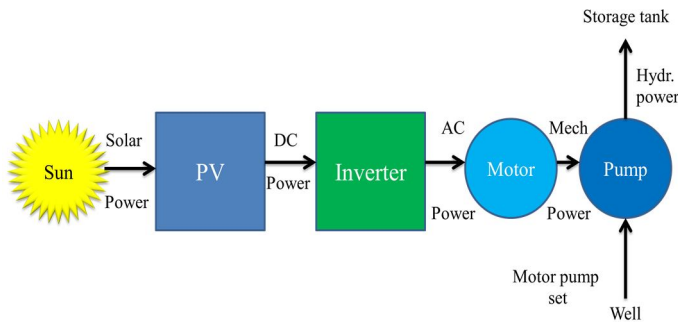


Fig 1. Block Diagram of the photovoltaic water-pumping system

The figure 1 shows the proposed structure. It is composed of an asynchronous motor powered by a photovoltaic generator and storage of batteries towards a voltage inverter, controlled by a Sliding mode control.

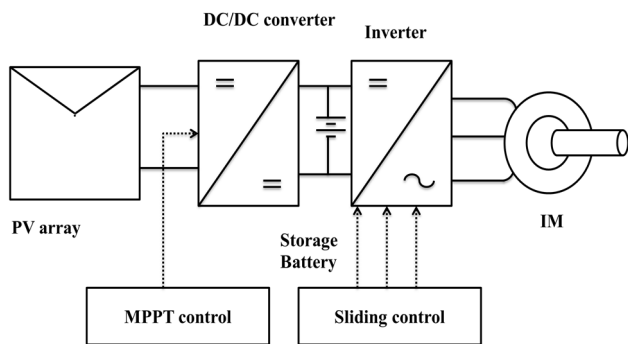


Fig 2 .proposed model

Direct current (DC-to-DC) converters are circuits which convert sources of direct current (DC) from one voltage level to another by changing the duty cycle of the main switches in the circuits. Since DC–DC converters are nonlinear systems, they represent a big challenge for control design.

Since classical control methods are designed at one nominal operating point, they are not able to respond satisfactorily to operating point variations and load disturbance. They often fail to perform satisfactorily under large parameter or load variations. The boost type DC-DC converters are used in applications where the required output voltage needed to be higher than the source voltage. The control of this type DC-DC converters are more difficult than the buck type where the output voltage is smaller than the source voltage. The difficulties in the control of boost converters are due to the non-minimum phase structure since, the control input appears both in voltage and current equations, from the control point of view the control of boost type converters are more difficult than buck type.

2.2 Control principle:

A popular technique involves modeling only the switching elements of the power stage. An equivalent circuit for these elements is derived and is called the PWM Switch Model where PWM is the abbreviation for the pulse width modulated [9]. As shown in Figure 3, the power stage has two inputs: the input voltage and the duty cycle. The duty cycle is the control input, i.e., this input is a logic signal which controls the switching action of the power stage and hence the output voltage. The three major components of the power supply control loop (i.e., the power stage, the pulse width modulator, and the error amplifier) are shown in block diagram form in Figure3

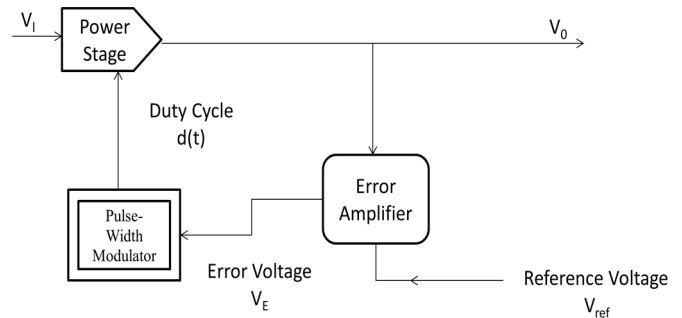


Fig 3 Power supply control loop components

Main solar powered stock watering system Components

A typical solar-powered stock watering System includes a solar array, pump, storage tank and controller in fig 3.

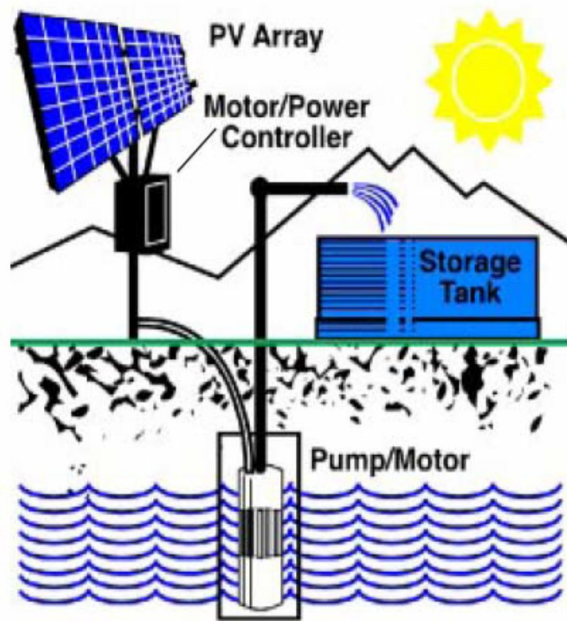


Fig 4. A typical solar powered stock watering system

2.2 Dynamic Model of Induction Motor

The first part of the global system investigated in this article consists mainly of a photovoltaic generator (PV), a three phase inverter MLI, and an induction motor-pump. We suppose; the inverter behaves as a perfect transferring power organ. Similarly, the characteristic of the generator PV is supposed ideal that we can assimilate in a classic power source.

$$(\phi_{rq} = 0) : \frac{di_{ds}}{dt} = -\gamma i_{ds} + \omega_s i_{qs} + \frac{K}{T_r} \phi_{rd} + \frac{1}{\delta L_s} u_{ds}$$

$$\frac{di_{qs}}{dt} = -\omega_s i_{ds} - \gamma i_{qs} - p\Omega K \phi_{rd} + \frac{1}{\delta L_s} u_{qs}$$

$$\frac{d\phi_{rd}}{dt} = \frac{M_{sr}}{T_r} i_{ds} - \frac{1}{T_r} \phi_{rd}$$

$$\frac{d\phi_{rq}}{dt} = \frac{M_{sr}}{T_r} i_{qs} - (\omega_s - p\Omega) \phi_{rd}$$

$$\frac{d\Omega}{dt} = \frac{pM_{sr}}{JL_r} (\phi_{rd} i_{qs}) - \frac{f}{J} \Omega - \frac{1}{J} C_r$$

With:

$$T_r = \frac{L_r}{R_r}, \delta = 1 - \frac{M_{sr}^2}{L_s L_r}, K = \frac{M_{sr}}{\delta L_s L_r}, \gamma = \frac{R_s}{\delta L_s} + \frac{R_r M_{sr}^2}{\delta L_s L_r^2}$$

Where the electromagnetic torque is given in d-q frame:

$$C_{em} = p \frac{M_{sr}}{L_r} (\phi_{rd} i_{qs})$$

Where, stator current components and leakage factor and poles are used to control the speed of the induction motor.

2.3 Sliding Mode Control Design

The basic principle of sliding mode control consists in moving the state trajectory of the system toward a predetermined surface called sliding or switching surface and in maintaining it around this latter with an appropriate switching logic [5]. This is similar to a feed-forward controller that provides the control that should be applied to track a desired trajectory, which is in this case, the user-defined sliding surface itself. So, the design of a sliding mode controller has two steps, namely, the definition of the adequate switching surface $S(\cdot)$ and the development of the control law or the switching logic U [6].

Consider a nonlinear system which can be represented by the following state space model in a canonical form (Slotine and Li, 1998):

$$\dot{x}^{(n)}(t) = f(x(t), t) + g(x(t), t)u + d(t)$$

$$y(t) = x(t)$$

Where $x = [x(t) \dot{x}(t) \dots x^{(n-1)}(t)]^T$ is the state vector, $f(x(t), t)$ and $g(x(t), t)$ are nonlinear function u is the control input(t) is the external disturbance.

The objective of control law $u(t)$ to force the system output $y(t)$ in above equation and reference signal.

Tracking error $e(t) = y_d^{(i)}(t) - y(t)$ and its forward shifted value is defined as $e^{(i)}(t) = y_d^{(i)}(t) - y^{(i)}(t)$

$$= x_d^{(i)}(t) - x^{(i)}(t), (i = 1, \dots, n-1)$$

The design of SMC involves two tasks. The first one is to the design of SMC involves two tasks. The first one is to select the switching hyper plane to prescribe the desired dynamic characteristics of the controlled system. The second one is to design the discontinuous control such that the system enters the sliding mode $s(x, t) = 0$ and remains in it forever (Slotine and Li, 1998).

$$s(x, t) = \left(\frac{d}{dt} + \lambda\right)^{n-1} e(t)$$

In which $e = x_d(t) - x(t)$

It remains to be shown that the control law can be constructed so that the sliding surface will be reached. The surfaces are chosen as functions of the error between the references input signal and the measured Signals (Utkin, 1993). Then, a sliding hyper plane can be represented as $s(x, t) = 0$.

Consider a Lyapunov function:

$$V = \frac{1}{2} s^2$$

From Lyapunov theorem we know that if \dot{V} is negative definite, the system trajectory will be driven and attracted toward the sliding surface and remain sliding on it until the origin is reached asymptotically (Buhler, 1986).

$$\dot{V} = s \dot{s}$$

The simplified 1st order problem of keeping the scalar $s(x, t)$ at zero can be achieved by choosing the control Law $u(t)$ [12]. A sufficient condition for the stability of the system is

$$\frac{1}{2} \frac{d}{dt} s^2 \leq -\eta |s|.$$

III SIMULATION RESULT AND DISCUSSION

The controllers designed in Sections 2 are simulated using the MATLAB/Simulink software. The parameters of the system are the parameters of the coupled tanks apparatus which is used to implement the proposed control schemes.

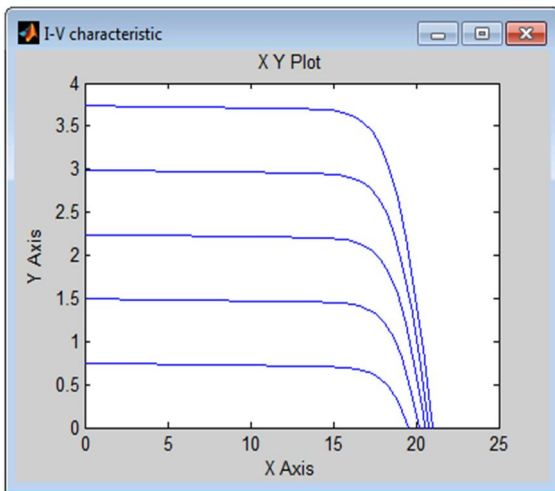


Fig 5. VI characteristic of PV module

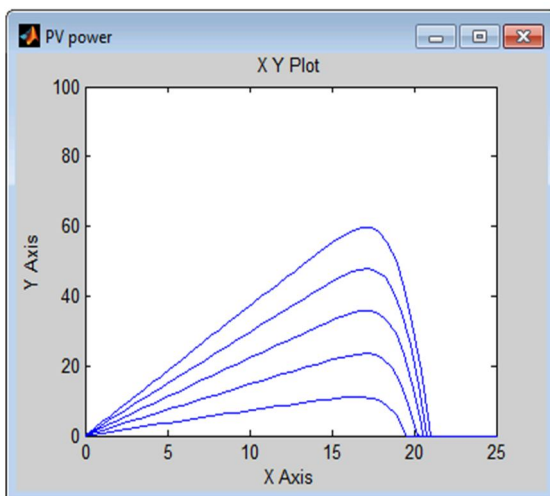


Fig.6 Power-V Charateristics of PV module

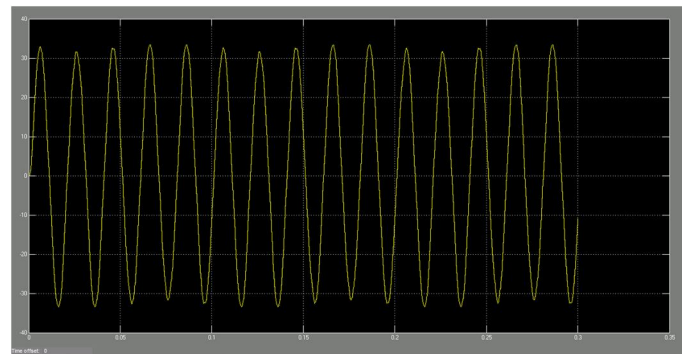


Fig.7 simulation result for inverter using sliding mode

IV CONCLUSION

A comparison between the PWM based sliding mode controller, PID and PI controllers for dc-dc boost converter are highlighted. Performance analysis for controlling of dc-dc boost converter is evaluated in simulation under the internal losses and input voltage variation. Sliding mode controller and PI controller have the same overshoot voltage but voltage drop is more using PI controller. PID controller has maximum settling time as compared to sliding mode controller and PI controller. Four sliding mode control schemes are proposed to assure autonomously the stability of the system. The performances of the controlled system are studied under variations in system parameters and in the presence of external disturbance. The simulation results as well as the experimental results indicate that the proposed control schemes work very well and are robust to change in the parameters of the system as well as to disturbances acting on the system. The implementation results indicate that the proposed sliding mode controller gave a best result. A sliding mode control method has been proposed and used for the control of an induction machine. It has shown the robustness of proposed control. The speed control operates with enough stability and has strong robustness to parameter variations.

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