A NONLINEAR CONTROLLER FOR LIQUID LEVEL CONTROL SYSTEM

K.Ashokkumar
P G scholar,
Department of EEE
Anna University Chennai
Regional centre Coimbatore
ashokpalanieee@gmail.com

Abstract— The aim of this paper is to investigate the coupled tank system that is supplied with a photovoltaic generator. Controlling variables in any process is very important so as to achieve the desired output A nonlinear control of an induction motor (IM) supplied with a photovoltaic generator to assure the level control of two coupled tanks. The proposed systems are separated into two independent models so that the coupled tanks are assured by discontinuous command by using the proposed methods. In the first step, we propose a sliding mode technique to make the speed and the flux control of the IM robust to parameter variations. Thus, the aim is to assure the stability of the system autonomously towards a desired region of water level, by varying the speed of the induction motor.

The use of the nonlinear sliding mode provides a very good performance for motor operation and robustness of the control law despite the external and internal perturbation. Simulation results are given to highlight the performance of the proposed control method for load disturbances and parameter variation. A nonlinear control of an induction motor (IM) supplied with a photovoltaic generator to assure the level control of two coupled tanks is designed with sliding mode and fuzzy logic.

Keywords— Sliding mode control, photovoltaic energy, Nonlinear control, coupled tanks, speed control, water level control, water pumping system.

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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, we are interested 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].

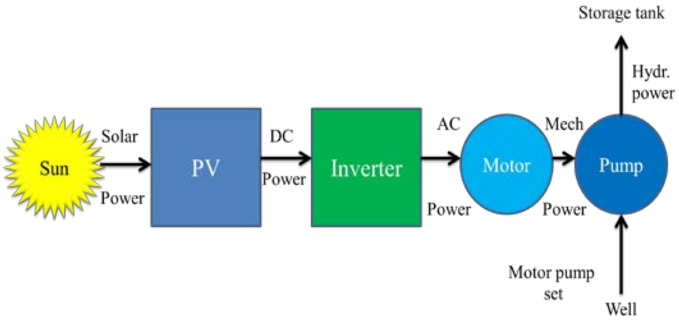

Fig 1.Block Diagram of the photovoltaic water pumping system

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.

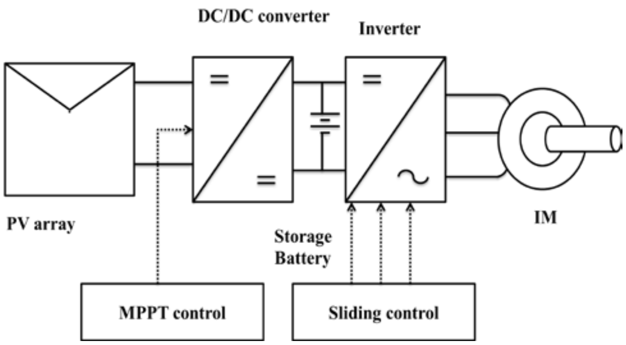

Fig 2 .proposed model

2.1 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

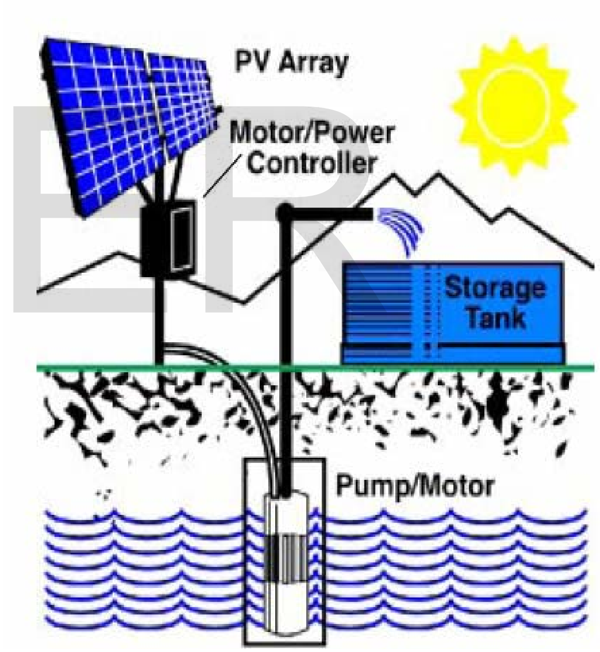

Fig 3. A typical solar powered stock watering system

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

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

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 (.) 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):

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

Where $x=[x(t)\,\dot{x}(t)....x^{(n-1)}(t)]^T$ 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 $e^{(i)}(t)=y_d{}^{(i)}(t)-y^{(i)}(t)$

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

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).

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

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 *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

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

2.4 Dynamic Model of Hydraulic System

The control of liquid level in tanks and flow between tanks is a basic problem in the process industries.

The twin-tank system consists of two small tanks coupled by an orifice and a pump that supplies water to the first tank. The pump only increases the liquid level and is not responsible for pumping the water out of the tank.

The second part of the global procedure is formed by a coupled tank, considered as a benchmark for the study and the analysis command of hydraulic systems. This device, allows examining the law order in the liquid level reservoirs, while varying the debit from the variation of the speed of the pump[1].

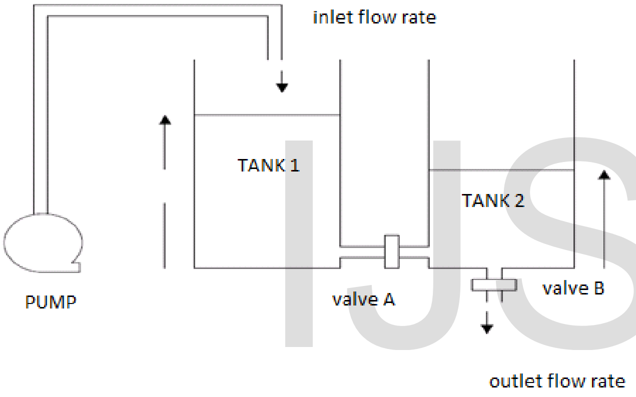

Fig 4. Block diagram of proposed coupled tank

This process behaves two vertical tanks coupled by a flow canal, a manual valve used to change the canal section, in consequently, to change the characteristics of flow between the reservoirs (Figure 4). A level sensor is installed in the top of every reservoir. The relation between the speed of the IM [2] and the entry debit of the second reservoir q_2:

$$Q_2 = a_1.a_2\,.Gp.W$$

$$y = K.h_2$$

$$\frac{dh_2}{dt} = \frac{1}{S}\left(a_1.a_1.G_p.\Omega - s_2.a_0\sqrt{2g\left(h_2 - h_1\right)}\right)$$

$$y = K.h_2$$

h1: the level in the first tank
h2: the level in the second tank,
q1: the inlet flow rate,
q2: the flow rate from Tank 1 - Tank 2,
q12: the flow rate out of Tank 2,
g: the gravitational constant,

III SIMULATION RESULTS

The controllers designed 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.

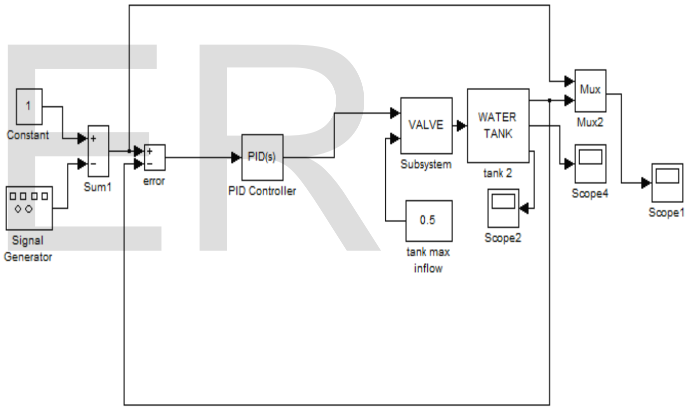

Fig 5. Simulation for PID controller

Robust control design for coupled tanks is investigated in this paper. The main objective is to propose an effective robust method for coupled tanks.

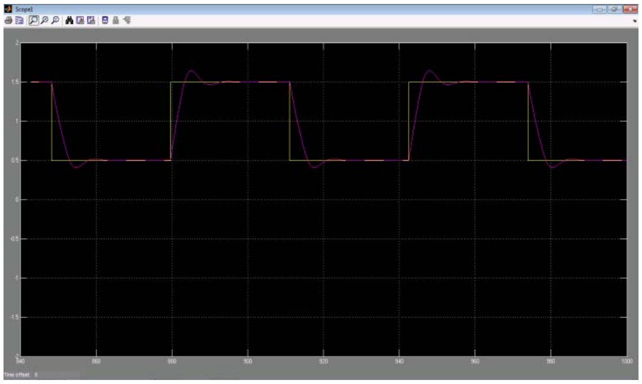

Fig.6.Simulation result using PID controller

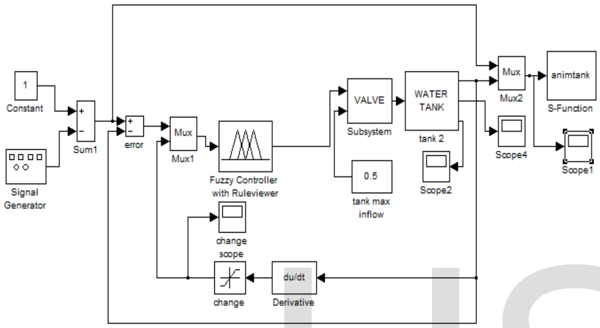

Fig 7.Simulation using fuzzy logic controller

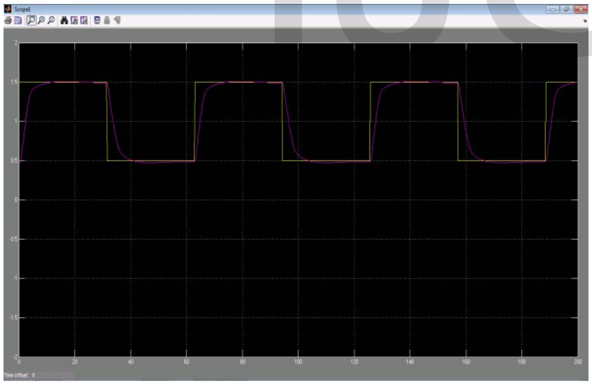

Fig 8. Simulation result using Fuzzzy Logic Controller

It can be seen from these responses that the output converges to its desired value in all two cases. Therefore, it can be concluded that the proposed control schemes are robust to disturbances acting on the system and stabilizes the water levels to the desired level.

IV CONCLUSION

In my research compare PID and fuzzy controller after simulation result fuzzy controller gives accurate controller. The control of two coupled tanks is addressed in this paper. 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. The control of two coupled tanks is assured by the speed variation. The performances of the controlled system are studied under variations in system parameters and in the presence of external disturbance .The simulation 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 global system.

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