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DESIGN AND IMPLEMENTATION OF A PI CONTROLLER FOR AN AUTOMATED BUILDING WATER SUPPLY SYSTEM USING PLC TECHNIQUES

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ABSTRACT

High stories in multistory buildings in most of the Middle East countries suffer from water shortage due to bad and old designs in water supply systems. An automatic regulation water supply system based on PLC (Programmable Logic Controller) & VFD (Variable Frequency Drive) is proposed.This paper explains water supply system's energy conservation principle of a pump with speed control according to disturbances. The system can supply the building with water with constant pressure and save energy efficiency.

The system was tested for 24 hours a day for three weeks with capacity of (20 -120) L/min of water, and about 10 meters building height. The pressure of the supply network is about 1.2 Bar.

KEYWORDS: *Controlled System, Programmable Logic Controllers (PLC), PID Controllers.*

1. INTRODUCTION:

With the rapid changes in industrial automation and information technologies in recent decades, the control of all equipments has been performed through the use of industrial computers. Most applications use PLCs to connect with computers for monitoring and controlling loads and electricity consuming devices. Programmable Logic Controllers (PLC) and Variable Frequency Drives (VFD) are commonly used , these days , in controlling the speed of induction motors in a wide range of industry and building automation because they are inexpensive , easy to install and very flexible in applications [1].

This paper presents a PLC based monitoring and controlling system for a three phase induction motor via a VFD unit. The paper describes the design and implementation of the configured hardware and software. The test results of the simulated and implemented system show improved efficiency and increased accuracy in the variable loads of the water consumed in a multistory building with a constant pressure controlled operation. The PLC correlates and controls the operational parameters to the speed requested by the system and monitors the system during normal and abnormal conditions (overloading and dry running) [2].

2. AUTOMATION TASK:

To provide a good comprehensibility, the features of a PLC based controlling and monitoring system are explained using an example of an automation task.

As shown in figure (1), an automated water supply system for a large building is used to supply consumers by water via PLC based system. Several consumers may be simultaneously connected .For optimizing the supply capacity and reducing failure, it should be insured that a constant pressure is always available for the central supply (all consumers), independent of the number of active consumers. The pump conveying current Q, and thus the pressure is to be adjusted continuously. It is also to be ensured that the pump is only operated with sufficient supply of water. The current pressure (actual value) is to be shown on a Text Display (TD) .The required pressure for the consumers (set point value) must also be shown on the same TD and editable.

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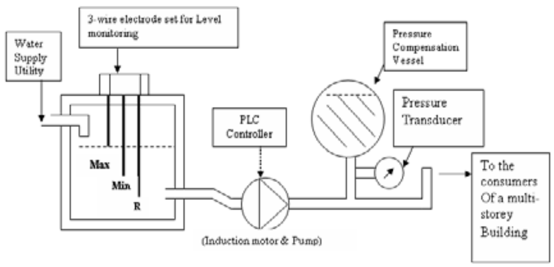

Fig (1) Automated Water Supply System

3. HARDWARE DESCRIPTION :

In figure (2), the block diagram of the experimental system is illustrated.

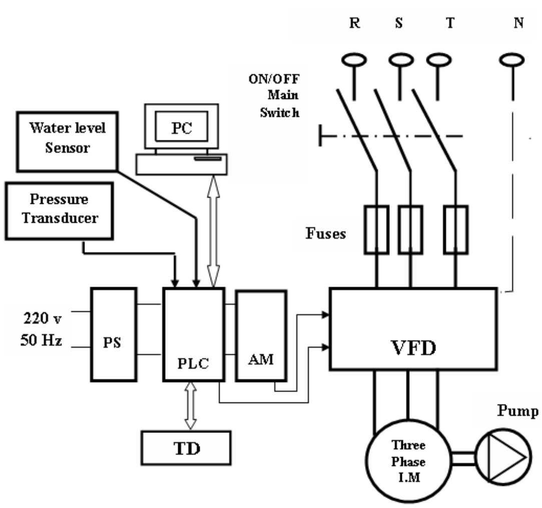

Fig (2) Hardware Of The Automated System

Where:
PC: Personal Computer.
PLC: Programmable Logic Controller (main unit).
AM: Analog Module
PS: Power Supply
TD: Text Display
VFD: Variable Frequency Drive

As shown in figure (2), the system uses a PLC with a connected pressure measuring transducer for recording the current pressure in the supplying water circulation. A PI controller in the PLC regulates the pressure by varying the speed of the motor depending on the currently measuring pressure [3][4][5].

The three phase induction motor of the water pump is connected to a VFD getting the set point speed as a frequency set point value via the analog output of the PLC. The speed of the induction motor is adjusted continuously via the VFD.

An electrode set for monitoring the level of water in the storage tank is connected to a monitoring relay to monitor whether the pump is supplied with water during operation. The state of the monitoring relay is passed on as a digital input of the PLC**.**

The current pressure of the water supply system and the set point pressure are directly displayed on the TD of the control system [5].

4. PI CONTROL SYSTEM :

The function principles flowchart, Fig. (3), shows the steps used in designing the software of the control system to insure high reactive speed and high accuracy.

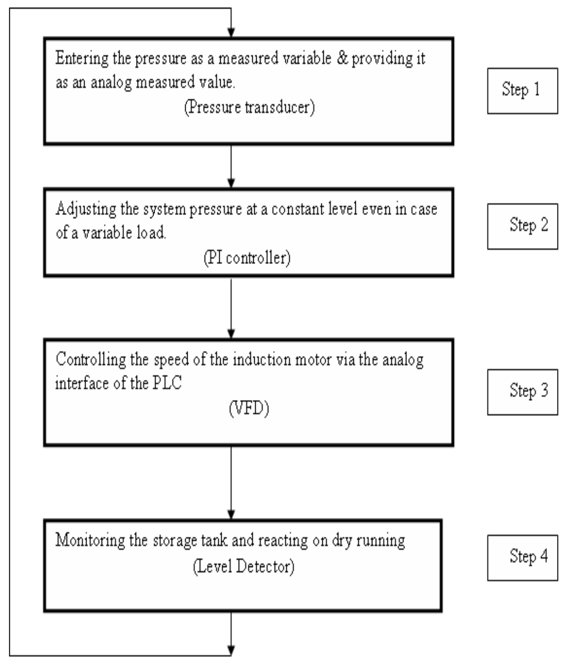

Fig (3) Function Flowchart Of The System

STEP 1

The pressure, measured in bars, by the pressure transducer is fed to a repeater and converted to an output voltage of (0 - 10 Vdc), the output voltage is linearly proportional to the input pressure [3][4].Via the integrated analog input in the PLC, the voltage output of the pressure measuring transducer (0 -10 Vdc) is continuously picked up and scaled with the input range of the pressure transducer (0 – 1.6 bar)**.**

STEP 2:

To provide the consumers of the water system with the same pressure even in case of variable loads, a PI controller is employed as shown in Fig (4)**.**

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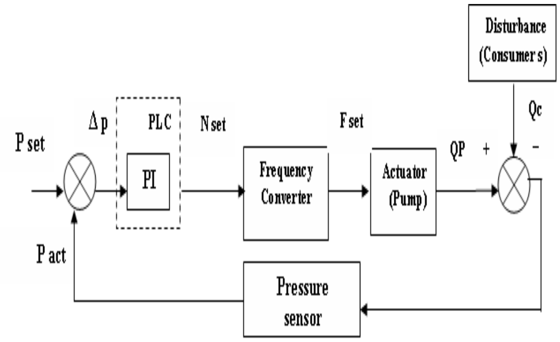

Fig (4) Block Diagram For The Closed Loop Control Of The System

The measured actual pressure value (P act) is compared to the set point value (P set) and stored in PLC .The PI controller compensates for the difference ΔP by calculating a new set point speed (N set).
The difference (Δ p) is compensated by increasing or decreasing the motor speed (N set) and thus the conveying current of water (Qp). If the speed of the motor (N set) is increased, more water (Qp) will be conveyed and the pressure (P act) in the system will rise, but if the speed of the motor (N set) is decreased, less water (Qp) will be conveyed and the pressure (P act) in the system will go down.
The difference (Δ p) is caused by the variable load (consumers current of water Qc) of consumers.
If more consumers are connected, the consumer current of water Qc will increase and the pressure (P act) in the system will go down, but if consumers are disconnected, the consumers current of water (Qc) will go down and the pressure (P act) in the system will increase.

STEP 3:

The setting (0 – 10 Vdc) for the motor speed (N set) is continuously transferred by the analog module of the PLC to the VFD and there it is scaled to a frequency set point value (0 – 50Hz) [6].The induction motor which is connected to the VFD accelerates or decelerates due to the frequency set point value stated by the frequency converter.

STEP 4:

To prevent the pump of the water system from running dry, a three-pole wire electrode set for monitoring the level of water of the storage tank is employed. The three-pole wire electrode set is connected to a monitoring relay. The function of the monitoring relay is to measure the electrical resistance of water between two immersed probes (Min, Max) and a reference terminal (R) as shown in ig (1). If the measured value is lower than the setting sensitivity of the relay, then the monitor relay will change its switching state [4].
The monitoring relay is wired to a digital input of the PLC which will switch off the frequency converter when a dry run is established and stops the pump

To optimize the control process. KP (the gain of the P- part of the PI controller) and KI (the I - part of the PI controller) were adjusted using Ziegler-Nichols tuning rule [7], by the following equations:

$$K_P = 0.9 * \frac{T}{L} \quad \text{…. (1)}$$

$$K_I = 0.27 * \frac{T}{L^2} \quad \text{...... (2)}$$

Where:
T: time constant (seconds)
L: Delay time (seconds)
} Of the S shaped reaction curve

According to the above test , the results of our system were :
Kp = 1
KI = 2 sec^{-1}.
The acceleration and ramp - down times of the induction motor were set to 3 seconds according to the VFD parameters [6].

5. RESULTS:

The system was tested during operation with varying loads. The PLC monitors the motor operation speed and correlates the parameters according to the software. The process values were displayed in percent to insure a better overview as show in Fig (5).

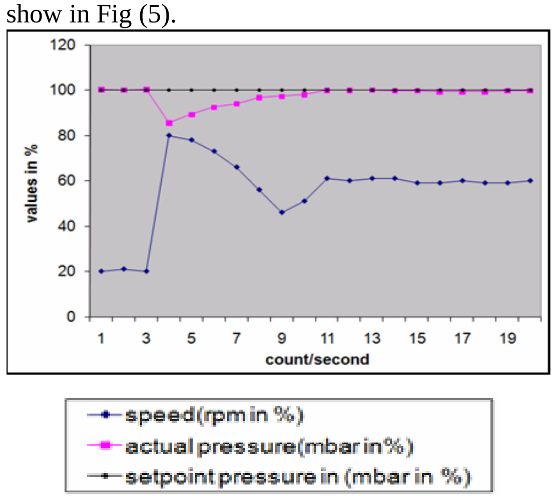

Fig (5) System Response

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In the first moment, the actual pressure (P act) will drop .The PI controller of the PLC will compute the disturbance variable (Quantity of water consumed by consumers) and increases the set point speed (N set). The actual speed (N act) will be adjusted to the quantity of water consumed by new set point value after approximately 8 seconds.

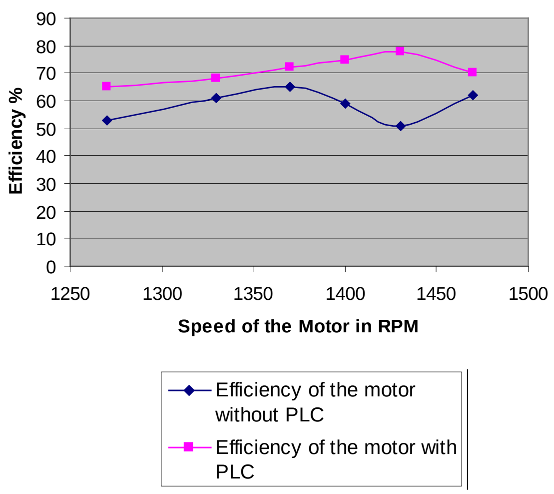

Fig (6) Efficiency Of The PI Control System Vs Efficiency Of Standard System

At the beginning, for reference purposes, the performance of the induction motor of the water pump supplied from a standard 380V,50Hz power supply was tested. Then the control system was applied. From figure(6), it can be shown that the obtained efficiency of the induction motor with PI technique is higher than its efficiency when operated from a standard power supply (380V,50Hz) without the control of PLC &VFD. According to figure(6), the efficiency of PI – controlled system is increased up to 10-12 % compared to the standard motor operation . from a theoretical point of view , if the magnetizing current is neglected, an approximate value of the efficiency is

$$Efficiency = \frac{1-S}{1-S.R_S/R_R} \quad ....(3)$$

Where:
S is the slip
RS & RR are stator and rotor winding resistances respectively.
As a result, the control signal of the implemented control (PI type) is sent to the VFD to control V/F ratio variations .

6. CONCLUSIONS:

The PLC – based control system with PI technique and VFD has proved to be an efficient control tool in automated electric drives applications. It presents:
1-The efficiency of PLC-controlled system is increased up to 10 -12 % as compared to the configuration of the induction motor supplied from standard electrical network.
2-The transient performance of this system is limited due to oscillation on torque; and this behavior restricts its application to process that only require slow response variations(water supply and temperature control systems).
3-The controller parameters KP and KI must be calculated very carefully to get an efficient controller which controls our process successfully
4-The ratio V/F is constant for a wide speed range.

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REFERENCE:

[1]. Maria G., "Design and Implementation of PLC – Based Monitoring Control System for Induction Motor", *IEEE TRANSACTIONS ON ENERGY CONVERSION*, VOL.19, NO.3, SEPTEMBER 2004.
[2]. Yasar.B, H.S.Nogay, " Design and Implementation of PLC – Based Monitoring Control System for Three – Phase Induction Motor Fed by PWM Inverter ,"*INTERNATIONAL JOURNAL OF SYSTEM APPLICATION ENGINERRING & DEVELOPMENT* , Issue 3,Vol. 2 , 2008.
[3]. Bryan L .A.Bryan E.A., *Programmable controllers, theory and implementation*, published by Industrial Text Co., USA, 2nd Ed., 1997.
[4]. Jack. H , Automating manufacturing systems with PLCs , *Published by The Free Software Foundation* , USA , 2nd Ed. , 2005 .
[5]. 0BA6 Simatic LOGO! Manual, Siemens, 2009.
[6]. Astrom K.J. and Haggland T.H., "New tuning methods for PID controllers", *Proceedings of 3rd European control conference*, 1995.
[7]. SV-iG5 Inverter User Manual, LG, 2007 .