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COLLEGE OF ENGINEERING AND TECHNOLOGY
Electrical Engineering Department

Industrial Automation Engineering Program

GRADUATION PROJECT REPORT

USING VFD IN PUMPING SYSTEM WITH SCADA

Project Team

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ABSTRACT

The use of variable frequency drives (VFD) in pumping variable-duty requirements provides the user with a variety of benefits, including potentially significant energy saving and improved reliability achieved by means of speed reduction. Energy saving are primarily realized by running the equipment at high levels of efficiency and optimal operating speeds, matching the generated pump head to exact system requirements without the use of energy consuming control valves. Running pumps at lower operating speeds also positively influences component life and between maintenance intervals.

Supervisory Control and Data Acquisition (SCADA) solutions provide a base for more reliable operation of water systems and significant operating and financial benefits, both, which are important to utility management. They provide means for increased productivity, reducing the number of failure events, reduced losses due to damages and minimal losses of potable water. System parameters, which are communicated via Ethernet network present true conditions, and commands sent from SCADA Centrals to remote sites that are aimed to achieve optimal, reliable. and safe operation.

الملخص

محركات مضخات التردد المتغير تستخدم في عمليات الضخ المتغيرة التدفق حسب الطلب وتوفر للمستخدم مجموعة متنوعة من المزايا من حيث توفير الطاقة والوثوقية وذلك بحصل عن طريق التحكم في السرعة .

التوفير في الطاقة يتم من خلال تشغيل المضخة في النقطة التي تكون فيها أقصى كفاءة عند سرعة معينة حسب تركيبة نظام الضخ دون الحاجة الى استخدام صمام لتقليل التدفق وبذلك نكون قد فقدنا كمية من الطاقة . تشغيل المضخة في قمية سرعة معينة بالاعتماد على التدفق يزيد من عمر المضخة ويزيد فترة الصيانة الدورية .

استخدام نظام الاشراف والتحكم والحصول على البيانات (SCADA) , في أنظة ضخ المياه ,يوفر قاعدة من الوثوقية في شبكات المياه , من حيث توفير المال , وزيادة الانتاجية , والحد من أعطال النظام , وايضا توفير في المياه ,يتم الجصول على المتغيرات المختلفة من النظام عن طريق نظام اتصال شبكات سلكية او لاسلكية في الوقت الفعلي لها وبذلك نحصل على تشغيل امنا للنظام بوثوقية عالية وبشكل آمن.

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Description	Abbreviations
Supervisory Control and Data Acquisition	SCADA
variable frequency drive	VFD
variable speed drive	VSD
Programmable logic controller	PLC
Net positive suction head	NPSH
Waste water treatment planet	WWTB
Industrial control system	ICS
Personal computer	PC
Remote terminal unit	RTU
Field data interface	FDI
Master terminal unit	MTU
Man machine interface	MMI
Human machine interface	HMI
Bit per second	BPS
Input /output	I/O
Communication module	CM
Gallon per minute	GPM
Revelation per minute	RPM
Best efficiency point	BEP
Horsepower	HP
Master control center	MCC
Return of investment	ROI
Time off use	TOU
Delano-Earlimart Irrigation system	DEID
Saualito irrigation district	SID

Chapter one

General Background

1.1 Introduction

1.2 Project aim

1.3 Literature review

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1.1 Introduction

Pumping systems account for nearly 20% of the world's energy used by electric motors and 25% to 50% of the total electrical energy usage in certain industrial facilities [1]. The aim of this work is to design a Supervisory Control and Data Acquisition (SCADA) system for managing the water pumping rate according to water consumption requirements [2]. Also significant opportunities exist to reduce pumping system energy consumption through smart design, retrofitting, and operating practices. In particular, the many pumping applications with variable-duty requirements offer great potential for savings. The savings often go well beyond energy, and may include improved performance, improved reliability, and reduced life cycle costs.

Most existing systems requiring flow control make use of bypass lines, throttling valves, or pump speed adjustments. The most efficient of these is pump speed control[1]. When a pump's speed is reduced, less energy is imparted to the fluid and less energy needs to be throttled or bypassed. Speed can be controlled in a number of ways, with the most popular type of variable speed drive (VSD) being the variable frequency drive (VFD).

A SCADA system has been designed into the water pumping system that will allow for the most efficient operation of pumps and together with the VFD's control pump speeds based on flow rates and levels[1]. These features will help optimize system performance and provide for increased efficiency. Additionally the system will allow for automatic and remote monitoring and control of the system components from a central location.
It can be assumed that the additional annual savings in electrical usage due to the installation of SCADA to increase electrical efficiency of the VFD's is 5%[3].

1.2 The proposed project aiming at:

1) Get familiar to SCADA system application , and its use in some applications.
2) Reduce the consumption of electric power.
3) Verification of positives uses VFD pumps compared with the primitive manner.
4) Use a PLC and a SCADA to control a system.

1.3 Literature review

There are several studies that describe SCADA and VFD pumps system some of there:

1. Control valve versus variable speed drive for flow control

Control valve versus variable speed drive for flow control is study for Muhammad. H. Al KHalifa and Gregory K.Millan[4] An introduction to process system and centrifugal pump curves ,a variable speed drives overview , affinity laws ,when to use variable speed drives , loop performance advantages , and application watch-outs. Variable speed drives can increase process efficiency by reducing energy use and process variability. the saving and greatest for large flow systems high turndowns , difficult process fluids , and extremely sensitive processes , however, engineer with mechanical , electrical and control skills are needed to ensure the total system design and implementation will not result in bearing or noise problem and process oscillations or overheating at low flow Selection of centrifugal pumps for an application requires evaluation of pump performance characteristics against the process requirement or system curve . pump characteristics are typically delivered by pump manufacture in the form of graphical format called characteristics curve. These curve provide information about pump performance in term of total dynamic head , brake horsepower , net positive suction head required(NPSHR), and efficiency for the capacity range of the pump plotted figure (1.1)

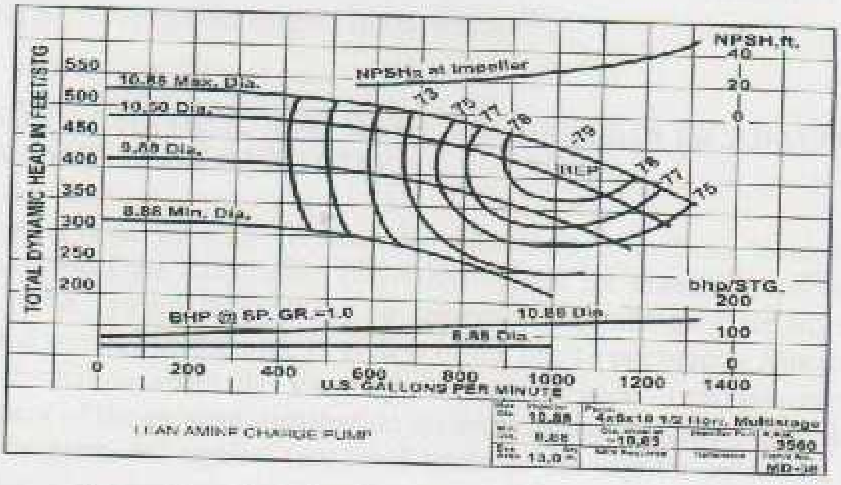


Figure 1.1: Centrifugal Pump Performance Curve [4]

Before proceeding to pump selection, the head – flow curve for the piping system that is being pumped into must be defined. This type of curve is called a system curve as shown in figure (1.2) and typically represents the sum if the static head and dynamic head that you need to pump against . The static head is a function of the elevation difference between suction and discharge and the back pressure that the pump is operating against. The dynamic head represents the friction losses from the fluid that results from the piping[5].

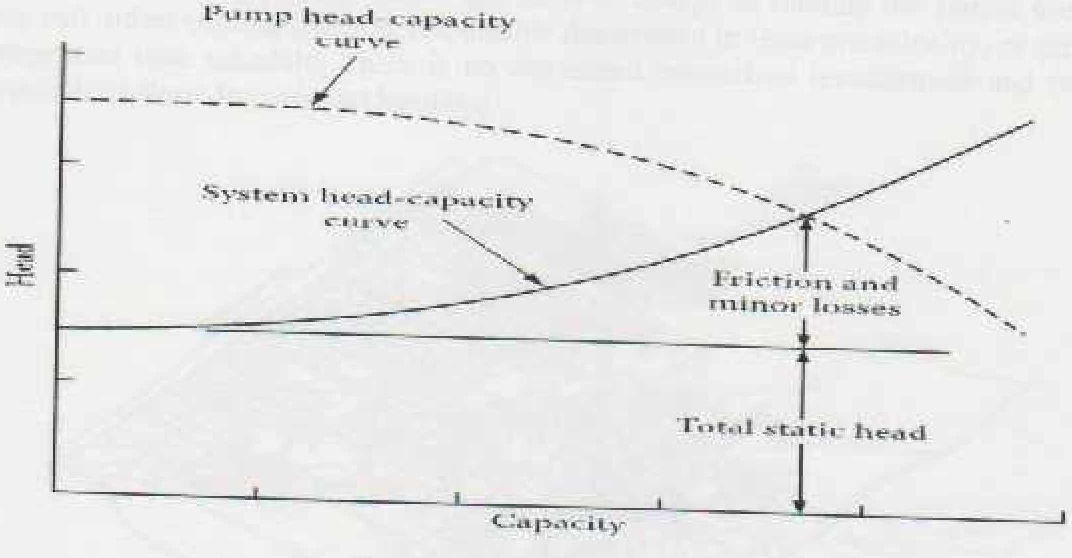


Figure 1.2: System curve [4]

2. Beit Lahia Wastewater Pumping Station

Palestinian Water Authority conducted a Northern Gaza Emergency Sewage Treatment (NGEST) project[4]. It targets to drain the existing effluent lake and convey its partly treated effluent to the new wastewater treatment plant site (WWTP). This project controlled and monitored by SCADA system implemented by Prof. Mohammed Abdelati. This system is considered the first SCADA system applied in Gaza strip [6].

3. A SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA) FOR WATER DISTRIBUTION SYSTEM OF GAZA CITY

This project is done by Eng. Ayman M. Alihussein from Gaza it consider design a Supervisory Control and Data Acquisition (SCADA) system for managing the water pumping stations in Gaza. This system is expected to increase customer satisfaction, reduce water distribution cost and provide an accurate overview of the plant's operations. Moreover, SCADA stores valuable information about the water system performance. This data is necessary for efficient development of the existent distribution system in a way that meets population growth. The pumping set is protected against low level water in the aquifer by means of dedicated sensors. Every year, Gaza municipality installs new well pumping stations to compensate the increase consumption of water due to the overpopulation , so through two or three years, the number of well stations may reach 60 well stations or more. The water wells are conventionally comprises of a pump, a chlorine dosing unit, a water manifold, an electrical switchboard, a sand trap and a standby diesel generating set.

The distribution system depends mainly on direct pumping from the wells to the distribution network. These pumping stations are managed manually through operators who are located as three consecutive 8-hour shifts along the day. Decisions are made according to observations and feedback which is delivered through phone calls between humans. An operator is allocated for each pumping station and he is in charge of running the station according to phone call orders coming from the responsible department in Gaza municipality, or according to a predefined time schedule. There is no automated centralized management and there is no computerized alarm logging and handling.

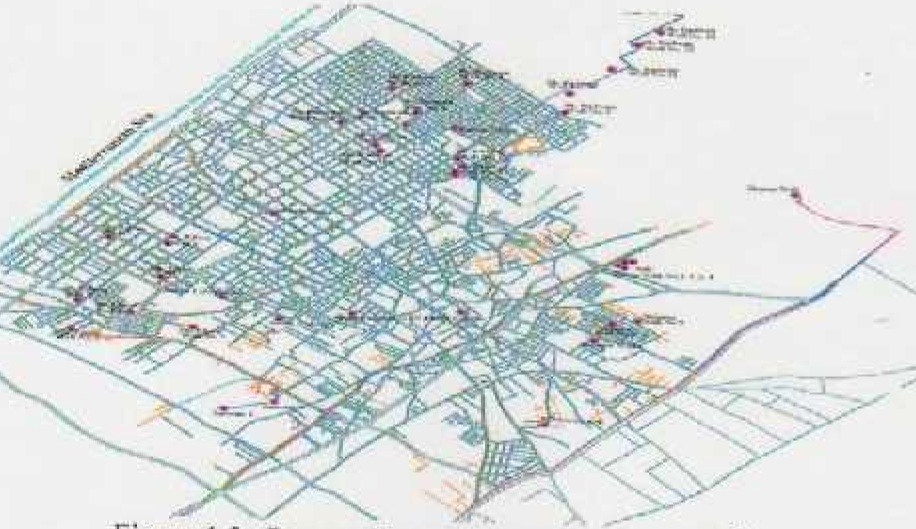


Figure 1.3: Gaza well pumping stations location[6]

1.4 Project main components:

1) Electrical control system
2) Overall mechanical structure

Both sides consisting the following:

1) VFD (Variable Frequency Driving unit)
2) Pump (Centrifugal pump).
3) PLC Twido (Hardware & Software)
4) SCADA system
5) Accessories :
    1) Pressure transducer.
    2) Water installation system.
    3) Electrical panel.
    4) Liquid level relay .
    5) Tanks.

1.5 Project cost :

Table (1.1): component cost :

No.	description	Amount " NIS "
1.	VFD	700
2.	Pump	230
3.	PLC+ Analog module	2750
4.	Reservoir(2)	250
5.	Electrical panel	-
6.	Pressure sensors	1050
7.	SCADA software	300
8.	Pipeline + Pipeline connector	150
9.	Stand	-
10.	Contactors ,CB,OL,….etc	300
11.	Labor work (in hours)	450
12.	Wires and Cables	130
13.	Paint	35
14.	Stand wood	150
15.	Total	6495

1.6 Timing diagram

Table (1.2): Time Line of the Project:

Tasks \ Weeks	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Literature Review and Problem Statement	■	■	■	■											
Proposing Methodology				■	■	■									
Component's Survey and Cost Estimation, Selection							■	■	■						
Reporting First Chapters									■	■	■				
Design of system Parts									■	■	■	■			
Typing the Report						■	■	■	■	■	■	■	■	■	
Report Submission														■	■

Table (1.3): Time Line 2 of the Project:

Task \ Weeks	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Starting Implementation of the Mechanical Design	■	■	■	■	■	■									
Purchasing the Components			■	■	■	■	■	■	■						
Assembly the Electrical and Mechanical Parts							■	■	■	■					
Testing and Calibration										■	■	■			
Typing the Final Report													■	■	
Report Submission and Preparing the Project Presentation															■

Chapter Two

Theoretical Background

Introduction

In this chapter an overall description will be content over, the SCADA system and its components, Pumps, VFDs ,& Measurement devices.

2.1 SCADA:

SCADA is a type of industrial control system (ICS),computer controlled system monitors and controls industrial processes that exist in the physical world[7] . SCADA systems historically distinguish themselves from other ICS (Integrated computer solution) systems by being large scale processes that can include multiple sites (among) large distances, These processes include industrial, infrastructure, and facility-based processes, as Industrial processes include those of manufacturing, production, power generation, fabrication, and refining, and may run in continuous, batch, repetitive, or discrete modes[7]. Infrastructure processes may be public or private, and include water treatment and distribution, wastewater collection and treatment, oil and gas pipelines, electrical power transmission and distribution, wind farms, civil defense siren systems, and large communication systems[7].

SCADA stands for Supervisory Control and Data Acquisition. As the name indicates, it is not a full control system, but rather focuses on the supervisory level. It is a software package installed on networked computing platforms, like personal computers (PCs) or small dedicated devices which are hardened for industrial environments . SCADA provides a high level layer on top of the Programmable Logic Controllers (PLCs) layer which is positioned over the plant hardware devices. Thus, we have a functionally modular platform in which there are three layers interacting with each other in a hierarchical manner as sketched in Figure (2.1) & Figure (2.2)

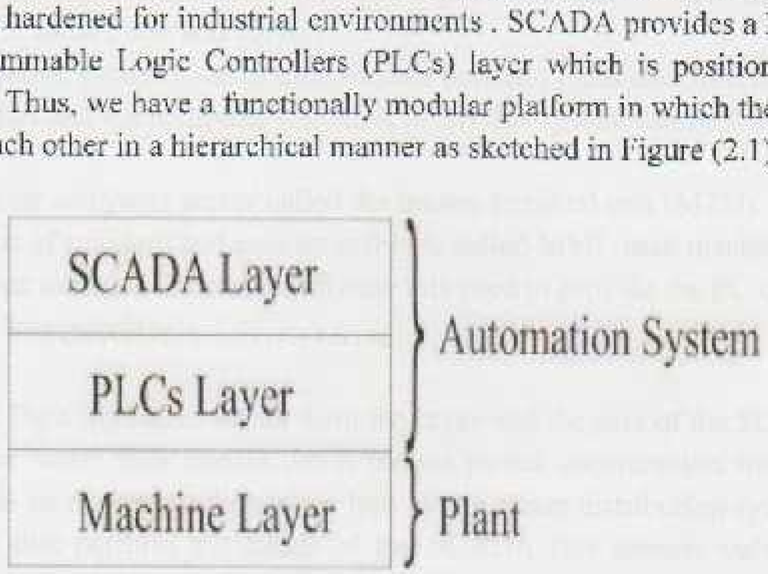


Figure 2.1: Functional decomposition of an automation system[8]

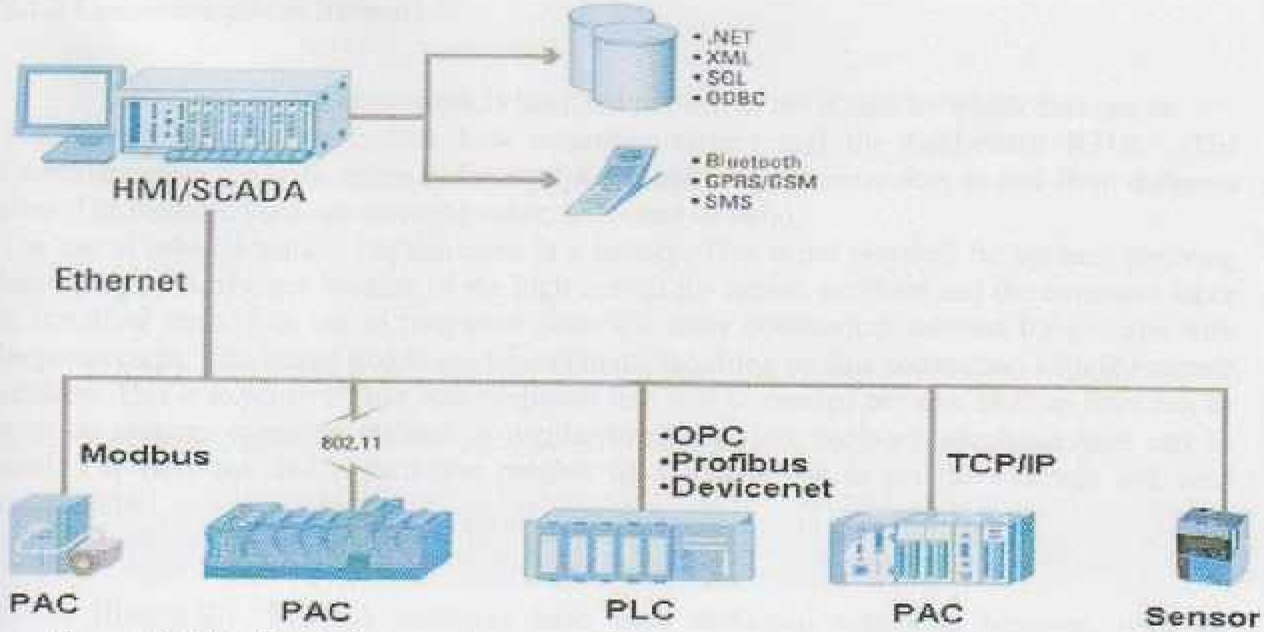


Figure 2.2: This block diagram shows a typical open architecture HMI/SCADA system[8]

2.1.1 SCADA Components:

The major components of SCADA system are as follows:

1) RTUs (Remote Terminal Unit) or PLCs which interface to field sensing devices and local control switch box and valve.
2) Communication system used to transfer data between Field data interface (FDI) and control unites and the computer (SCADA hoist) this system can be Radio, WIFI ,or Ethernet .
3) A central host computer server called the master terminal unit (MTU).
4) A collection of standard and custom software called MMI (man machine interface) or HMI (human machine interface) software this used to provide the PC contains SCADA , FDI (field data interface)

FDI (Field Data Interface) which form the (eyes and the ears of the SCADA) the devices that interfaced like water flow meters ,level meters power consumption meters ,and pressure meters that can tell an experienced operator how will a water distribution system is performing ,Other equipment that perform the hands of the SCADA like electric valves ,actuators ,and motor control .

2.1.2 Communications Network [9]

The communications network is intended to provide the means by which data can be Transferred between the central host computer servers and the field-based RTUs . The Communication Network refers to the equipment needed to transfer data to and from different sites. The medium used can either be cable, telephone or radio.
The use of cable is usually implemented in a factory. This is not practical for systems covering large geographical areas because of the high cost of the cables, conduits and the extensive labor in installing them. The use of telephone lines is a more economical solution for systems with large coverage. The leased line is used for systems requiring on-line connection with the remote stations. This is expensive since one telephone line will be needed per site. Dial-up lines can be used on systems requiring updates at regular intervals. Here ordinary telephone lines can be used. The host can dial a particular number of a remote site to get the readings and send commands.

Historically, SCADA networks have been dedicated networks; however, with the Increased deployment of office LANs and WANs as a solution for interoffice computer Networking, there exists the possibility to integrate SCADA LANs into everyday office Computer networks.

2.1.3 RTUs (Remote Terminal Units) [10]

Are preciously used to convert electronic signal revived from device into the language used to transmit the data over a communication, Field data communication system ,This intended to provide the means by which data can be transferred between the central host computer and the field based RTU, Bandwidth an important property of a communication Chanel .Figure (2.3) RTU unit.

Figure 2.3: RTU UNIT[10]

2.1.4 The Central host computer

The computer process the information received from and sent to the RTU sites and presents it to human operators in a form that the operators can work with.
Note that: SCADA vendors offer proprietary hardware depending system that was largely incompatible with other vendors. To avoid SCADA project fails the following project phase must achieved: Software defined, designed, written, checked & tested.

2.1.5 Data acquisition mechanism:

Data acquisition at first accomplished by the RTU scanning the field data interface devices connected to the RTU . The time perform this task is called the scanning interval which near tow seconds and the PC scan the RTU sometimes RTU send the data to PC without pulling by PC this mechanism is called unsolicited messaging.

Handling of data during SCADA failure:

1) Storing the data in the RTU and then resenting the data when pulled from PC. In times of failure the capacity of the RTU is used to archive data until a backup central host is brought online or the original system has recovered.
2) System redundancy. Such as dual communication system .Dual RTU or dual PC.

2.1.6 Operator Workstations and Software Components

Operator workstations are most often computer terminals that are networked with the SCADA central host computer. The central host computer acts as a server for the SCADA application, and the operator terminals are clients that request and send information to the central host computer based on the request and action of the operators [11].

.

2.1.7 Software products typically used within a SCADA system are as follows[12]:

1) Central host computer operating system: Software used to control the central host computer hardware.
2) Operator terminal operating system: Software used to control the central host computer hardware.
3) Central host computer application: Software that handles the transmittal and reception of data to and from the RTUs and the central host.
4) Operator terminal application: Application that enables users to access information available on the central host computer application.
5) Communications protocol drivers: Software that is usually based within the central host and the RTUs.
6) Communications network management software: Software required to control the communications network and to allow the communications networks themselves to be monitored for performance and failures.
7) RTU automation software: Software that allows engineering staff to configure and maintain the application housed within the RTUs (or PLCs).

2.2 PLC (Programmable Logic Controller)

2.2.1 What is a PLC?

Figure 2.4 Typical PLC

A PLC (i.e. Programmable Logic Controller) is a device that invented to replace the necessary sequential relay circuits for machine control. The PLC works by looking at its inputs and depending upon their state turning on/off its outputs as shown in figure (2.4). The user enters a program, usually via software, that gives the desired results.

PLCs are used in many "real world" applications. If there is industry present, chances are good that there is a plc present. If you are involved in machining, packaging, material handling, automated assembly or countless other industries you are probably already using them. If you are not, you are wasting money and time. Almost any application that needs some type of electrical control has a need for a plc[13].

2.2.2 PLC Application

It can be used for large spectrum of applications such as shown in Figure (2.6) (motor, pump, actuator…etc)

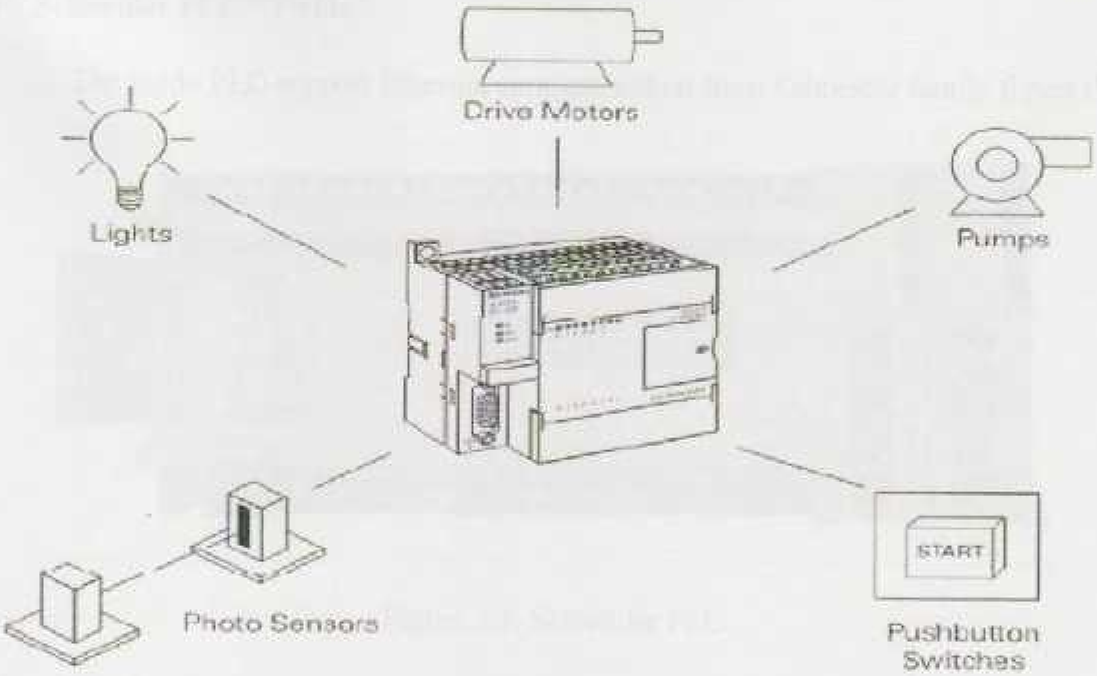


Figure 2.5 : PLC application

2.2.3 PLC component

The following figure shows a parts of PLC

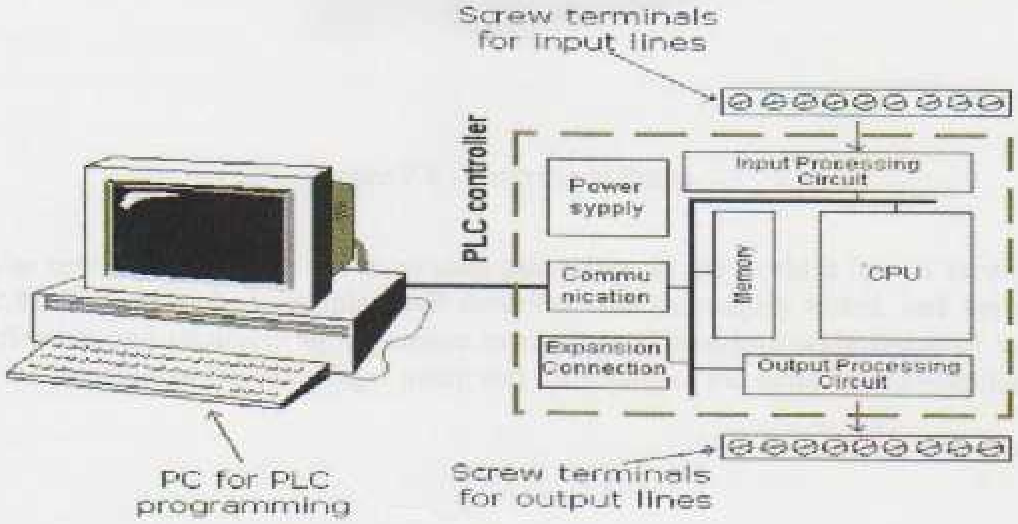


Figure 2.6 : PLC system overview

2.2.4 Schneider PLC "Twido"

The twido PLC support Ethernet communication from Schneider family figure (2.7) .

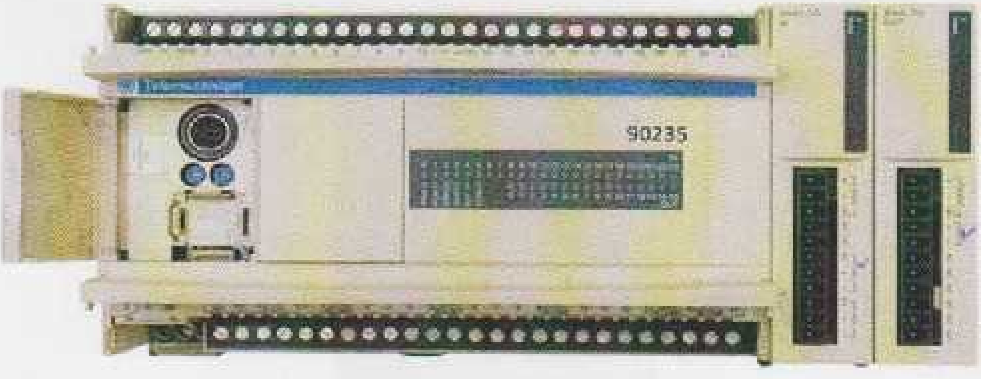


Figure 2.7: Schneider PLC

2.3 Centrifugal Pump

Figure 2.8 : Centrifugal Pump

The centrifugal pump is the most used pump type in the world it has an view given in Figure (2.8). The principle is simple, well described and thoroughly tested, and the pump is robust, effective and relatively in expensive to produce. There is a wide range of variations based on the principle of the centrifugal pump and consisting of the same basic hydraulic parts.

2.4 VFD (Variable Frequency Drive)

Is a converter that converts a fixed ac input voltage and frequency to a controlled variable voltage and frequency to operate a motor at required speed shown in figure (2.9) .

Figure 2.9: Inverter

2.4.1 Parts of inverters :

1) An input converter to rectify ac power to dc power ,it is normally called the source
2) An energy forced device which separate the input from the output and allows each to operate independently from the other it is usually called the line filter
3) A dc to ac inverter in the output stage it is called inverter ,if generates the desired ac output voltage and frequency .

2.4.2 Advantages of VFD :

1) Produce variable speed process speed which applied in cutting machine conveyor .
2) Compressor and pumps many applications requires them to operate at part load conventional Constant speed motors and control valves have been used for these applications, this alternative is more expensive and cause flow induced vibration and cavitations in the system, The motor operates at full load continuously regardless of the flow required.
3) Motor starting ,due to the high current and torque at starting the power supply is also affected adversely due to voltage dips ,a much smaller VSD (rated at few percent of the motor),can be used to increase the speed of the motors gently.

2.5 Pressure Measurement Device

Figure 2.10 : Pressure Transducers

The analog pressure sensor range (0-1&6bar) used to send signal (4-20mA) to the PLC depend on discharge situation as shown in figure (2.10).

2.6 Liquid Level Control Relay

Figure 2.11 : liquid level control relay

Three electrodes are connected to the "T","B" and "E" terminals.
When the liquid level reaches the upper level electrode (T) then the relay energizes its contacts to turn off the pump.
When the liquid level reaches the bottom level electrode (B) then the relay de-energizes its contact and turns the pump on.
Sensitivity (impedance between electrodes) can be adjusted in the range of 5-100 KW using the knob on the front side of the relay.

Chapter Three

System design

3.1 Introduction

In this chapter we want to introduce, pumping design and the benefits from the project like the annually money saving after implement this project ,but we want to draw your attention. this idea is implemented on a case study since its seems to be like actual appliances in many pumping systems, like irrigation regimes , water pumping stations and municipalities. etc.

3.2 Block diagram

The figure (3.1) illustrates the block diagram for our project.

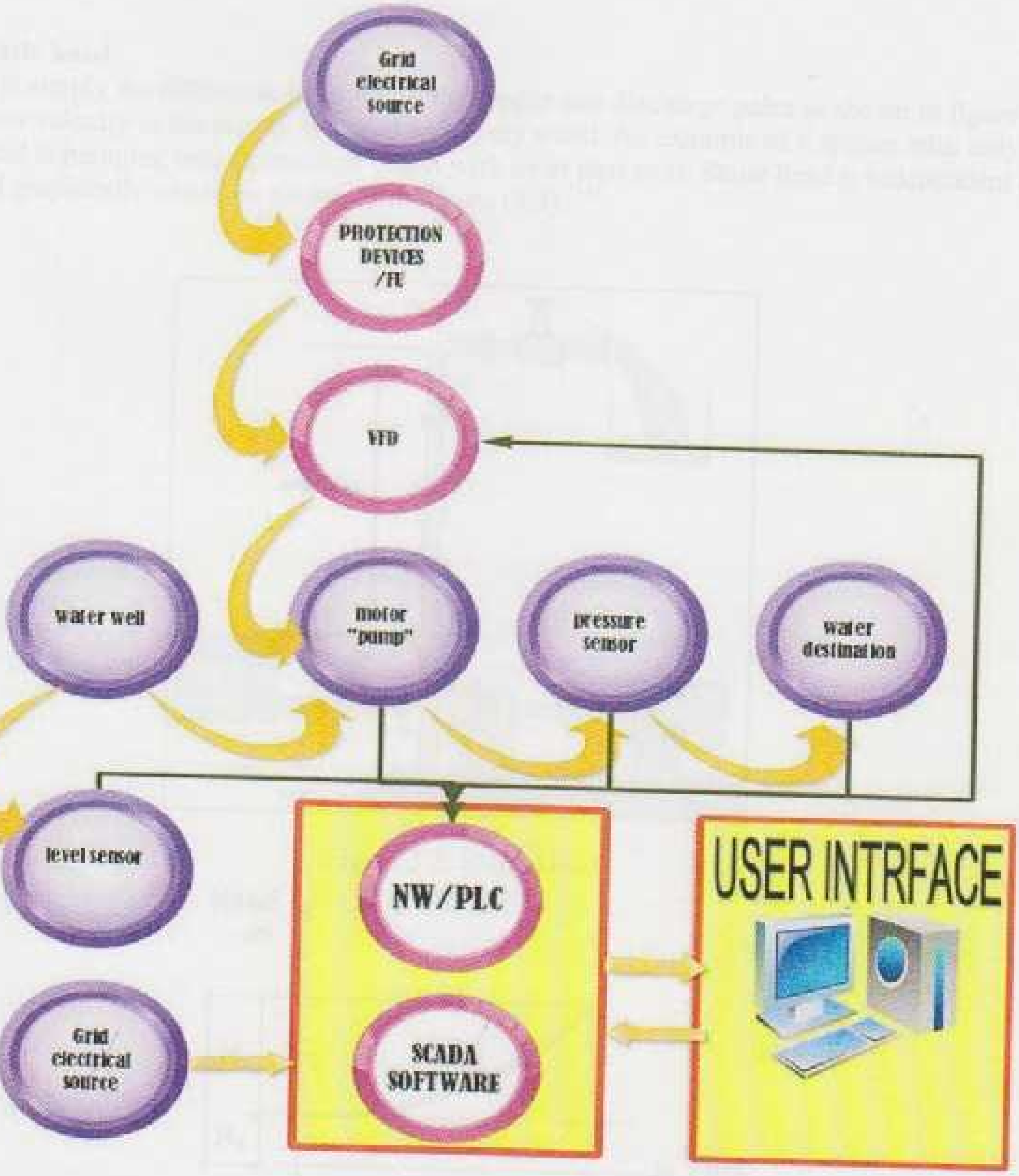


Figure 3.1: General block diagram

Note: In this chapter we did the calculations for big project to illustrate a clear result for the main aim of the project and the implement of this idea we will do it in a small practical project. It's worth to note that this calculations is done for a main station pump in Anbta village in Tulkarem and we received it's data from Eng. Mohammed Demeri from IC Systems Co. Palestine - Ramallah, Alnoor Building .

3.3 Pumping system

In a pumping system, the objective, in most cases, is either to transfer a liquid from a source to a required destination. A pressure is needed to make the liquid flow at the required rate and this must overcome head 'losses' in the system. Losses are of two types: static and friction head. [14]

3.3.1 Static head

Is simply the difference in height of the supply and discharge point as shown in figure (3.2), flow velocity in the pipe is assumed to be very small. An example of a system with only static head is pumping into a pressured vessel with short pipe runs. Static head is independent of flow and graphically would be shown as in Figure (3.3).[14]

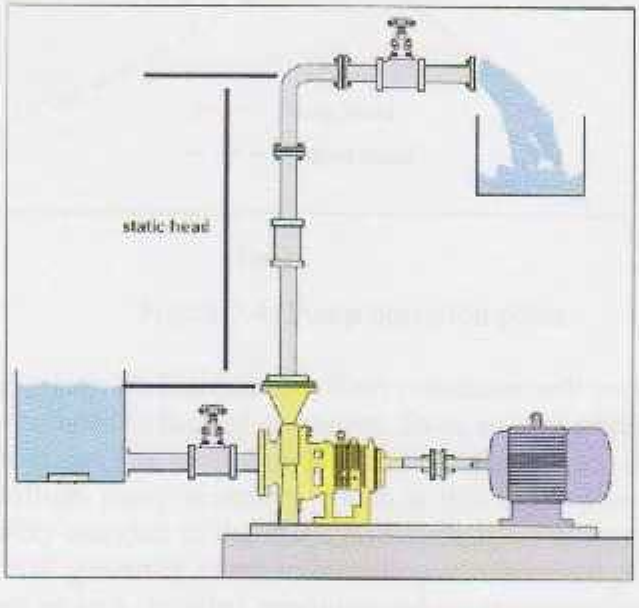


Figure 3.2: Static Head

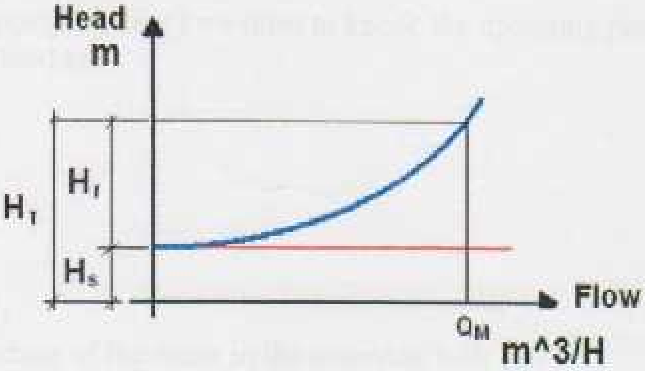


Figure 3.3: Static Head vs. Flow

3.3.2 Friction Head (Dynamic Head Loss)[14]

Dynamic head loss is the friction loss on the liquid being moved, in pipes, valves and equipment in the system. Friction tables are universally available for various pipe fittings and valves. In case of fittings, friction is stated as an equivalent length of pipe of the same size. The friction losses are proportional to the square of the flow rate.

3.3.3 Pump operating point[15]

When a pump is installed in a system the effect can be illustrated graphically by superimposing pump and system curves. The operating point will always be where the two curves intersect as shown in Figure(3.4).

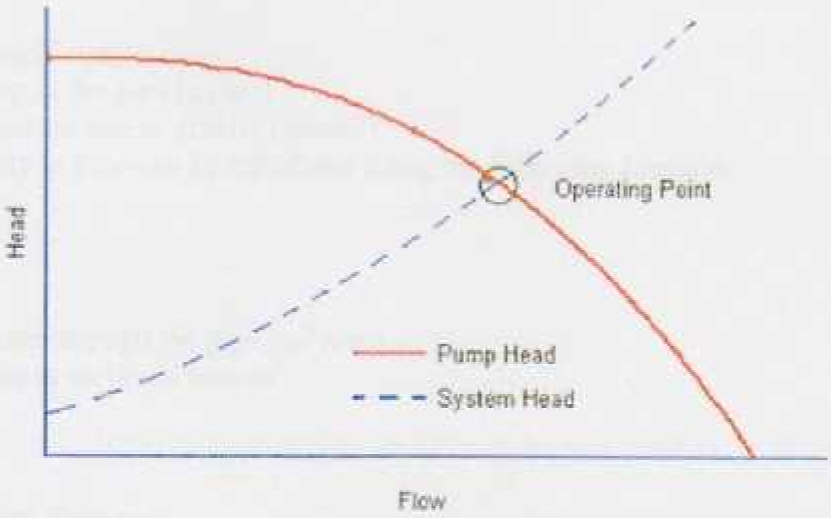


Figure 3.4: Pump operation point

For a centrifugal pump, an increasing system resistance will reduce the flow, eventually to zero, but the maximum head is limited as shown. Even so, this condition is only acceptable for a short period without causing problems. An error in the system curve calculation is also likely to lead to a centrifugal pump selection, which is less than optimal for the actual system head losses. Adding safety margins to the calculated system curve to ensure that a sufficiently large pump is selected will generally result in installing an oversized pump, which will operate at an excessive flow rate or in a throttled condition, which increases energy usage and reduces pump life.

For the above system (pump system) we must to know the operating pressure or the total system head, Ht , is defined as:

$$Ht = H_s + H_d + P_{rt} - P_{res} \quad (3.1)$$

Where:

H_s = Static head (m)

H_d = Dynamic head (m)

P_{rt} = Pressure on the surface of the water in the receiving tank (m)

P_{res} = Pressure on the surface of the water in the reservoir (m)

Although the atmospheric pressure changes with height, the change in pressure that occurs over the pumping height is often so small that it can be considered negligible.

In this example, the change in pressure over the elevation from the reservoir to the receiving tank is not that significant and hence is negligible.

$P_{rt} - P_{res} = 0$ (3.2)

Therefore, equation (3.1) becomes:

$H_t = H_s + H_d$ (3.3)

The dynamic head is generated as a result of friction within the system. The dynamic head is calculated using the basic Darcy Weisbach equation given by:

$$H_D = \frac{KV^2}{2g} \quad (3.4)$$

where

K = loss coefficient

v = velocity in the pipe (m/sec)

g = acceleration due to gravity (m/sec^2)

The velocity in pipe can be calculated using the following formula:

$$V = \frac{Q}{A} \quad (3.5)$$

where

Q = flow rate through the pipe (m^3 /sec)

A = pipe cross sectional area m^2

$$A = \frac{\pi D^2}{4} \quad (3.6)$$

D= pipelines diameter

The loss coefficient K include tow parameters:

$K = K_{fittings} + K_{pipe}$ (3.7)

K fittings is associated with the fittings used in the pipe works of the system to pump the water from reservoir to the discharge point.

Values can be obtained from standard tables and a total K fittings value can be calculated by adding all the K fittings values for each individual fitting within the system.

K pipe is associated with the straight lengths of pipe used within the system and is defined as:

$$K\,pipe = \frac{FL}{D} \quad (3.8)$$

Where

F = friction coefficient

L = pipe length (m)

D = pipe diameter (m)

The friction coefficient f can be found using modified version of the Colebrook White equation:

$$F = \frac{0.25}{\left[\log\left\{\frac{K}{3.7*D} + \frac{5.74}{Re^{0.9}}\right\}\right]^2} \quad (3.9)$$

Where

k = Roughness factor (m)

Re = Reynolds number

The pipe roughness factor k is a standard value obtained from standard tables and is based upon the material of the pipe, including any internal coatings, and the internal condition of the pipeline i.e. good, normal or poor.

Reynolds number is a dimensionless quantity associated with the smoothness of flow of a fluid and relating to the energy absorbed within the fluid as it moves. For any flow in pipe, Reynolds number can be calculated using the following formula:

$$Re=\frac{VD}{v} \tag{3.10}$$

Where

υ = Kinematic viscosity (m^2 /s)

3.4 Factors Affecting Pump Performance

3.4.1 Matching Pump and System Head-flow Characteristics

Centrifugal pumps are characterized by the relationship between the flow rate (Q) they produce and the pressure (H) at which the flow is delivered. Pump efficiency varies with flow and pressure, and it is highest at one particular flow rate.[15]

3.4.2 Effect of over sizing the pump

When a single pump is required to operate over a range of flow rates and pressures, standard procedure is to design the pump to meet the greatest output demand of both flow and pressure. For this reason, pumps are often oversized and they will be operating inefficiently over a range of duties. This common situation presents an opportunity to reduce energy requirements by using control methods such as a variable speed drive. Most existing systems requiring a control method use bypass lines, throttling valves, multiple pumps, or pump speed adjustments. Figures (3.5) till (3.7) illustrate common control methods including variable speed and the potential energy savings . Often, changing the pump's speed is the most efficient method of control. When a pump's speed is reduced, less energy is used by the pump's power unit and therefore less energy needs to be dissipated or bypassed.[15]

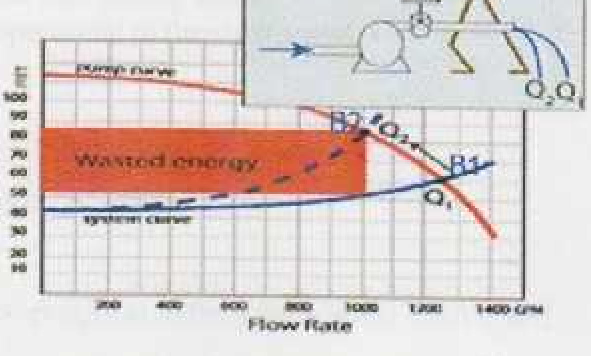


Figure 3.5: Throttling the flow[16]

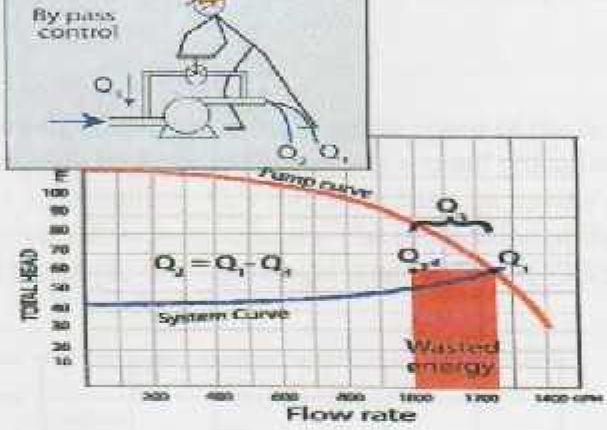


Figure 3.6: Bypass control energy use [16]

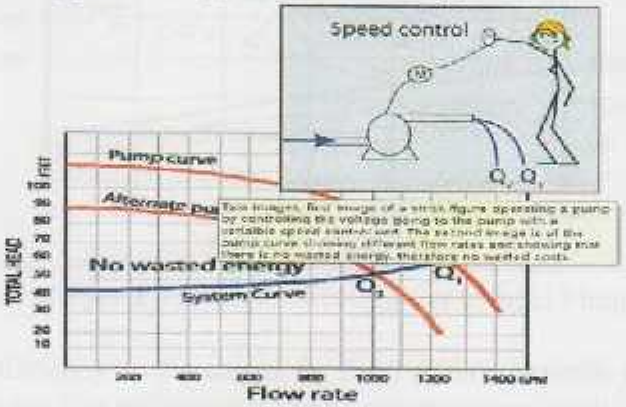


Figure 3.7: Variable speed control [16]

3.4.3Effect of speed variation [17]

As stated above, a centrifugal pump is a dynamic device with the head generated from a rotating impeller. Therefore a relationship between impeller peripheral velocity and generated head . Peripheral velocity is directly related to shaft rotational speed, for a fixed impeller diameter and so varying the rotational speed has a direct effect on the performance of the pump. All the parameters will change if the speed is varied and it is important to have an appreciation of how these parameters vary in order to safely control a pump at different speeds. The equations relating rotodynamic pump performance parameters of flow, head and power absorbed, to speed are known as the Affinity Laws:

First affinity law : flow is proportional to the shaft speed

$$\frac{Q_1}{Q_2} = \frac{N_1}{N_2} \qquad (3.11)$$

Where
Q – flow through the pipe (m^3/sec)
N = shaft speed (rpm)

Second affinity low: head is proportional to the square of the shaft speed

$$\frac{H_1}{H_2} = \frac{N_1^2}{N_2^2} \qquad (3.12a)$$

Where: H is the discharging head (m)

Third Affinity law: power is proportional to the cube of the shaft speed

$$\frac{P_1}{P_2} = \frac{N_1^3}{N_2^3} \qquad (3.12b)$$

Where : P is the power in (watt)

As can be seen from the above laws, doubling the speed of the centrifugal pump will increase the power consumption by 8 times. Conversely a small reduction in speed will result in drastic reduction in power consumption. This forms the basis for energy conservation in centrifugal pumps with varying flow requirements. The implication of this can be better understood as shown in an example of a centrifugal pump in Figure (3.8) below.

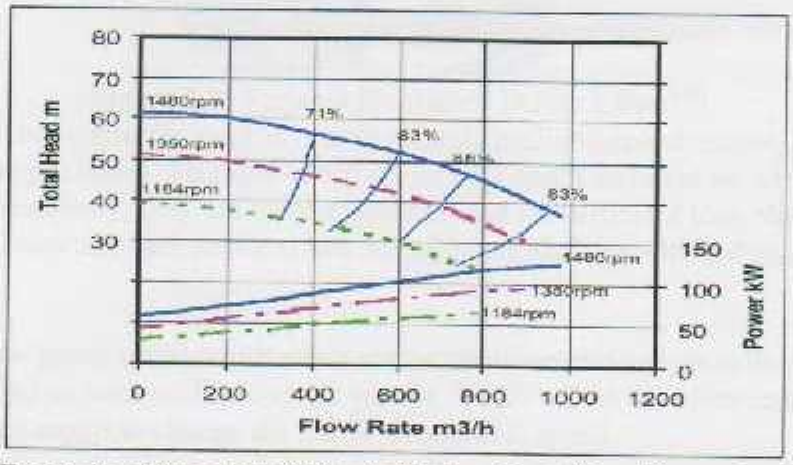


Figure 3.8: Example of Speed Variation Effecting Centrifugal Pump Performance [16]

Points of equal efficiency on the curves for the 3 different speeds are joined to make the iso-efficiency lines, showing that efficiency remains constant over small changes of speed providing the pump continues to operate at the same position related to its best efficiency point (BEP).

The affinity laws give a good approximation of how pump performance curves change with speed but in order to obtain the actual performance of the pump in a system, the system curve also has to be taken into calculations.

Once the flows and pressures are known, the pump's horsepower can be determined for a given efficiency using the power equations shown below.

$$P = \frac{QH}{3960 \times \eta} \qquad (3.13)$$

$$KW = \frac{P \times 0.746 \times KW/HP}{\eta\, motor} \qquad (3.14)$$

3.5 Meeting variable flow reduction

In contrast, pump speed adjustments provide the most efficient means of controlling pump flow. By reducing pump speed, less energy is imparted to the fluid and less energy needs to be throttled or bypassed. There are two primary methods of reducing pump speed: multiple-speed pump motors and variable frequency drives (VFDs). Figure (3.9)

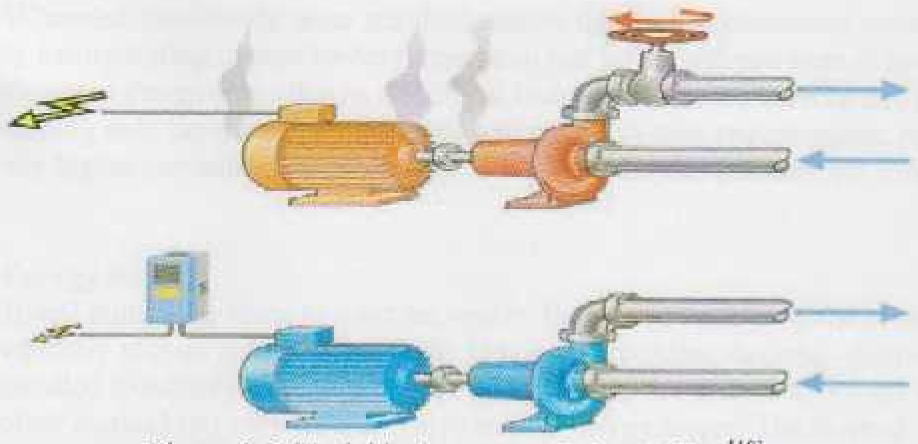


Figure 3.9: Variable Frequency Drives Effect[18]

Although both directly control pump output, multiple-speed motors and VFDs serve entirely separate applications. Multiple-speed motors contain a different set of windings for each motor speed; consequently, they are more expensive and less efficient than single speed motors. Multiple speed motors also lack subtle speed changing capabilities within discrete speeds.

VFDs allow pump speed adjustments over a continuous range, avoiding the need to jump from speed to speed as with multiple-speed pumps. VFDs adjust the electrical frequency of the power supplied to a motor to change the motor's rotational speed.

For many systems, VFDs offer a means to improve pump operating efficiency despite changes in operating conditions. When a VFD slows a pump, its head/flow and brake horsepower (BHP) curves drop down and to the left and its efficiency curve shifts to the left. This efficiency response provides an essential cost advantage; by keeping the operating efficiency as high as possible across variations in the system's flow demand, the energy and maintenance costs of the pump can be significantly reduced.

Another system benefit of VFDs is a soft start capability. During startup, most motors experience in-rush currents that are 5 - 6 times higher than normal operating currents. This high current fades when the motor spins up to normal speed. VFDs allow the motor to be started with a lower startup current (usually only about 1.5 times the normal operating current). This reduces wear on the motor and its controller [17]

3.6 Why do we need to use VFD?

Primary function of a VFD in aquatic applications is to realize energy savings. By controlling speed of a pump rather than controlling flow through use of throttling valves, energy savings can be substantial. By way of example, a speed reduction of 20% can yield energy savings of 50%.[17]

3.6.1 Adjustable Speed Drives

Available in many different types, adjustable speed drives offer optimum method for matching pump flow rates to system requirements. Adjustable frequency drive (inverter) is most commonly used. It converts standard plant power (230 or 460 V, 50 Hz) to adjustable voltage and frequency to power AC motor. The frequency applied to AC motor determines motor speed.

The AC motors are usually same standard motors that can be connected across AC power line. By incorporating bypass starters, operation can be maintained even if inverter should fail. Adjustable speed drives also offer an additional benefit - increased bearing and pump seal life. By maintaining only pressure needed in pump to satisfy system requirements, pump is not subjected to any higher pressures than necessary. Therefore, the components last longer.[15]

3.6.2 Pump Energy Savings

Centrifugal pumps are sized to meet maximum flow rate required by the system. System conditions frequently require reducing flow rate. However, throttling devices - dampers and valves - are installed to adjust pump output. Throttling devices are effective, but not energy efficient. Another method can vary flow and also reduce energy losses. The method: adjust pump impeller speeds so units deliver required flow.

Centrifugal pump operation is defined by two independent curves. One is the pump curve, which is solely a function of pump characteristics. The other is system curve, which depends on size of pipe, length of pipe, number and location of elbows, etc. The intersection of these two curves is called natural operating point, because pump pressure matches system losses.[14]

3.6.3 Additional Benefits of VFDs [17]

In addition to energy savings and better process control, VFDs can provide other benefits:

1) A VFD may be used for control of process temperature, pressure or flow without use of a separate controller. Suitable sensors and electronics are used to interface driven equipment with VFD.
2) Maintenance costs can be lowered, since lower operating speeds result in longer life for bearings and motors.
3) Eliminating throttling valves and dampers also does away with maintaining these devices and all associated controls.
4) A soft starter for motor is no longer required.
5) Controlled ramp-up speed in a liquid system can eliminate water hammer problems.
6) Ability of a VFD to limit torque to a user-selected level can protect driven equipment that cannot tolerate excessive torque.

3.6.4 Internal Configuration

VFDs contain three primary sections:

1) Rectifier Circuit - consists of diodes, SCRs, or insulated gate bipolar transistors. These devices convert AC line power to direct current.
2) DC Bus - consists of capacitors that filter and store the DC charge.
3) Inverter - consists of high-voltage, high-power transistors that convert DC power to a variable-frequency, variable-voltage AC output delivered to load.

3.6.5 Basic Configuration

This configuration the least expensive option of the two major types shown in figure (3.10) . It features a basic drive connected between the line and the load. Speed control is generally operator initiated either through a front panel keypad or speed potentiometer.

Functionality and features on this type of drive are generally limited. It should be noted that an external disconnect is required and that this type of.

One major issue with this type of drive is that being the sole load driving component, a failure of the drive will bring the entire system down until the drive is removed from service for repair or replacement.

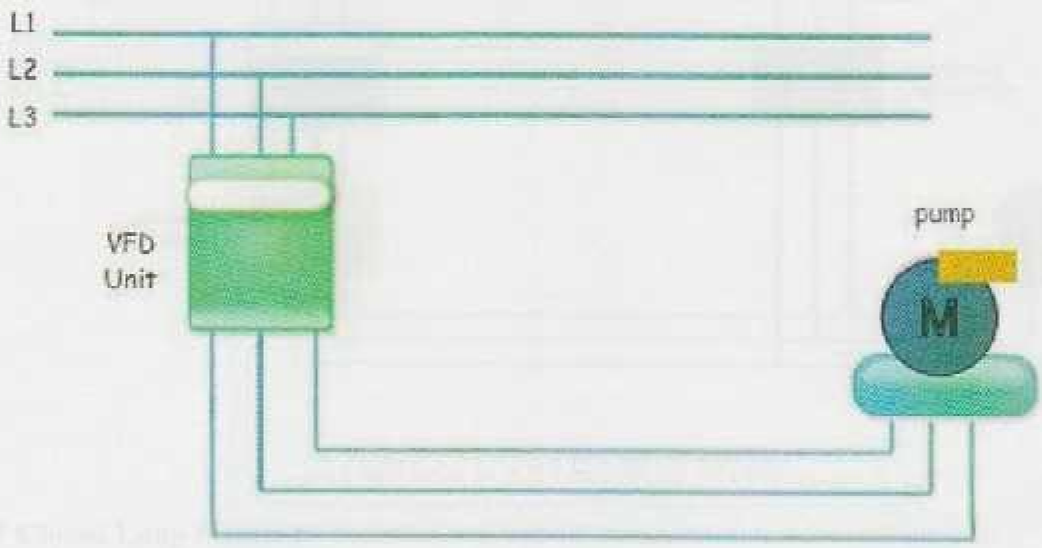


Figure 3.10: VFD basic configurations

3.6.6 Two Contactor Bypass

This configuration is a step up from basic . It generally features a secondary enclosure with additional control circuitry and two contactors which can bypass drive circuitry allowing manual control of load through conventional across the line motor starter control in many cases. It should be noted that while the output sections of the drive are isolated from the load, the drive input sections are not and that failure of input section components may still prevent manual system operation. This type of drive may or may not include a service disconnect and additional load protection Figure (3.11).

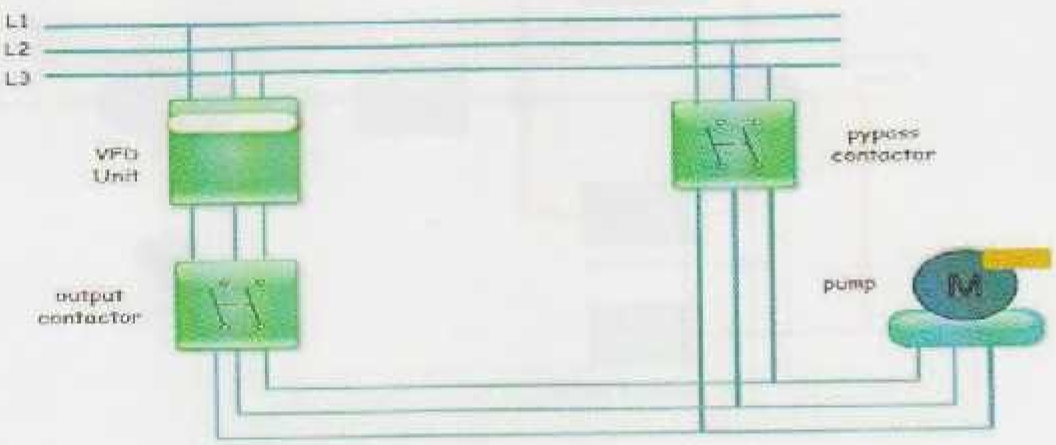


Figure 3.11: Two contactor bypass

3.6.7 Closed Loop Control

Closed loop or integrated control employs a feedback signal to the drive allowing the drive to compensate for filter loading conditions, valve sequencing, and other downstream conditions that may affect system flow rates. The feedback element in aquatic systems is typically via the use of a flow sensor placed in the pump discharge line figure (3.12) or the return line to the pool or water feature. This configuration virtually eliminates operator error and routine adjustment system. Figure (3.13)

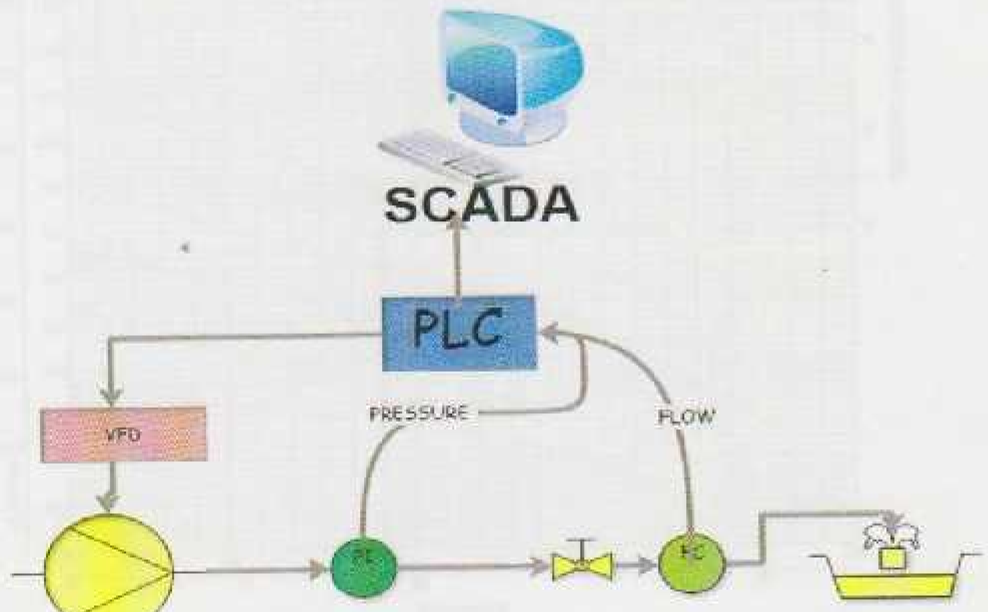


Figure 3.12: Interconnection diagram

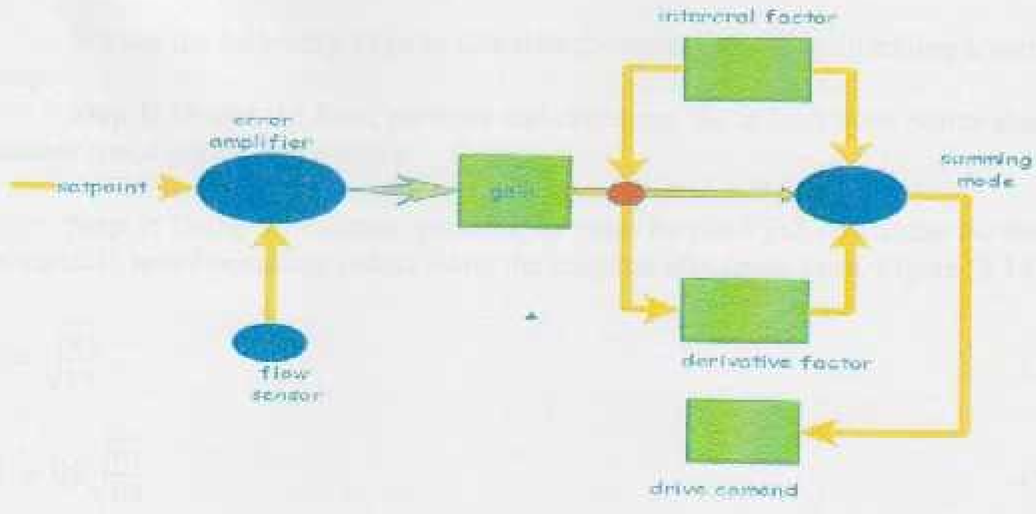


Figure 3.13: Close loop control

3.7 Case Study:

A 100 HP pump is used to pump water from a well up to a civilians area. The system is capable of pumping up to 500 GPM, but the existing flow averages around 300 GPM most of the time. In this project we are planning to install a variable frequency drive (VFD) on the pump motor to control the supply pressure. The system pressure simply follows the 100 HP pump curve shown in Figure (3.14) Controls on the VFD will limit the maximum pressure to 700 feet of head.

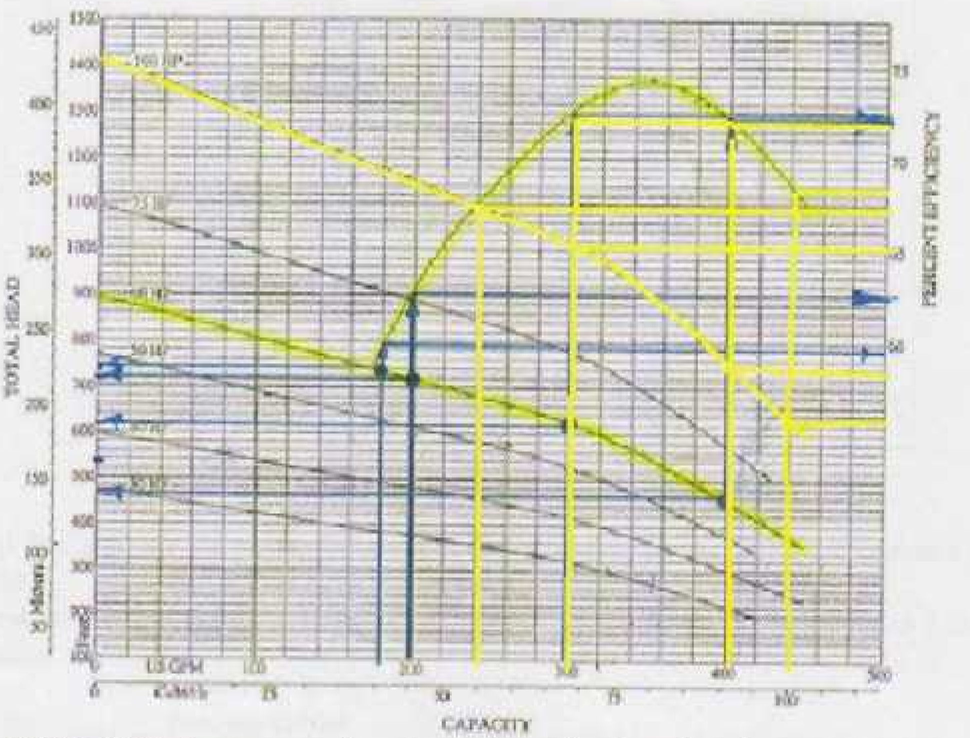


Figure 3.14: Pump curve for case study with selected performance points

3.7.1 Steps to Calculate Irrigation Pump VFD Saving

We use the following steps to calculate the energy saved by installing a variable speed pump.

Step 1: Obtain the flow, pressure and efficiency for at least three points along the pump's constant speed performance curve.

Step 2: Using the constant pressure set point for the VFD, determine the flow for each of the variable speed operating points along the constant efficiency lines. Figure (3.15)

$$\frac{Q1}{Q2} = \sqrt{\frac{H1}{H2}} \qquad (3.15)$$

$$Q1 = Q2\sqrt{\frac{H1}{H2}} \qquad (3.16)$$

$$\text{Flow with VFD} = \text{flow at constant speed}\sqrt{\frac{\text{constant pressure head}}{\text{Head at constant speed}}} \qquad (3.17)$$

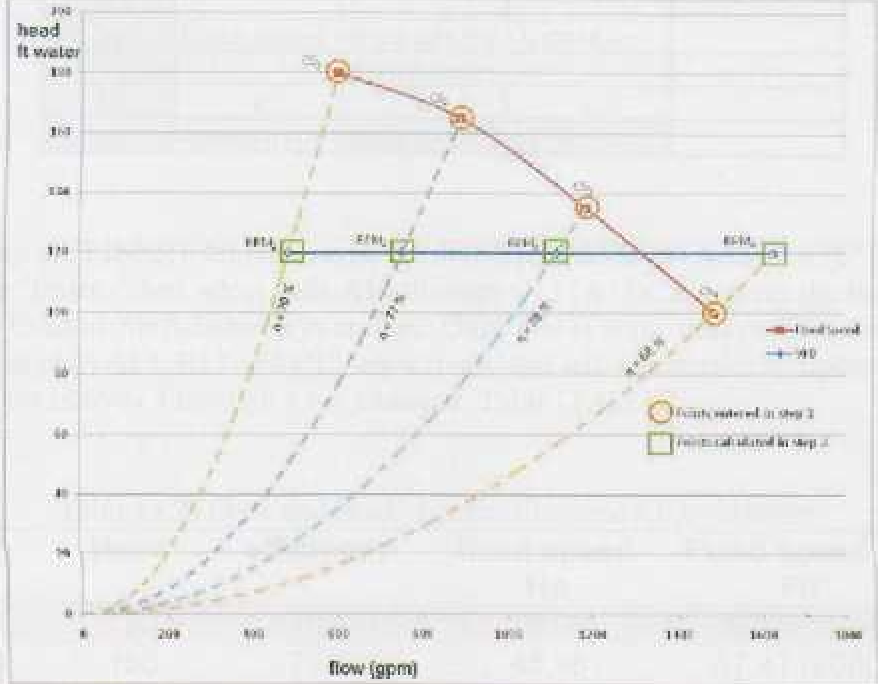


Figure 3.15: Flow vs. Pressure Curve w/ Constant Eff. Lines

Step 3: Calculate the power for each of the operating points along the constant speed and variable

speed lines using the flow, head and efficiency values found in Steps 1 and 2 using the equation below

$$P = \frac{QH}{3960 \times \eta} \quad KW = \frac{P \times 0.746 \times KW/HP}{\eta\ motor}$$

Step 4: Determine the coefficients a, b and c(on table 3.1) that define the horsepower of the constant speed and variable speed pump as a function of the flow rate Q (Gallons per minute). Note that the coefficients a,b and c may be found by plotting the four points on a scatter plot in Excel and then showing the trend line and formula for a second order polynomial that goes through these points. Another option is to use Excel's "LINEST" function to automatically calculate the variables. The LINEST function can calculate the coefficients for up to a third order polynomial. Although LINEST is an obscure function in Excel that is very poorly documented or explained, it proves very useful at describing functions that follow A parabolic pattern. Table (3.1)

Table (3.1) Excel sheet table

	A	B	C	D
1	From Pump Curve			Fixed
2	Flow	Head	Efficiency	Speed HP
3	400	460	73%	64.09
4	300	620	72%	65.24
5	200	720	63%	58.18
6	180	740	60%	56.53
7				
8	Fixed Speed HP = (A3*B3)/(3960*C3)			
9				
10	Fixed Speed HP = a GPM^2 + b GPM + c			
11	Coefficients			
12	a	b	c	
13	=LINEST($D$3:$D$3,$A$3:$A$6^{1,2})			

To apply the LINEST function, type "=LINEST($D$3:$D$3,$A$3:$A$6^{1,2})" into cell A13, press "Enter, "then select cells A13 through C13 (A13:C13), press the function key F2, and then press Control-Shift-Enter keys at once. Once this is done, the coefficients a, b and c will be shown in cells A13, B13 and C13respectively and will automatically update as the flows and horse powers in rows 3 through 4 are changed. Table (3.1),(3.2)

Table (3.2) Flow and head changes illustrate a,b,c variables

Flow	Head	efficiency	fixed speed Hp	Fixed speed HP Fit*
600	180	70%	38.96	39.19719343
890	165	77%	48.16	47.47125809
1190	135	78%	52.01	52.68772806
1490	96	66%	54.73	54.50463133
a	b	c		
-1.9E-05	0.056672	11.99305777		

Fixed speed HP= $(flow \times head) \div (3960 \times eff)$

Fixed speed HP Fit*= $aGPM^2$ + bGPM + C

Table (3.3) Varying Speed Effect

Flow	Head	efficiency	fixed Head VFD Hp	Fixed Head VFD HP Fit*
490	120	70%	21.21	21.52457694
759	120	77%	29.87	29.16478912
1122	120	78%	43.59	44.09028794
1666	120	66%	76.49	76.38453535
A	B	C		
2.01E-5	0.003274	15.08967953		

Fixed Head VFD HP = $(flow \times head) \div (3960 \times eff)$
Fixed Head VFD HP Fit = $aGPM^2 + \text{bGPM} + C$

Step 5: Use the horsepower formulas from Step 4 to determine the energy savings at each of the flow conditions of the pump

$$KW = \frac{P \times 0.746 \times KW/HP}{\eta \text{ motor}}$$

When the head vs. flow curve for different speeds is known, the following steps can be used to calculate theoretical energy savings when installing a VFD on a pumping system.

Now we want to apply the previous steps on the actual pump

Step 1: Determine the flow (Q), head (H) and efficiency (η) for three or more points along the constant speed pump curve. Table (3.4).

Table (3.4) Flow, head, efficiency changes

Flow	Head	Efficiency	fixed speed Hp	Fixed speed HP Fit by a,b,c
440	620	68%	101.31	97.92693589
400	740	73%	102.39	108.3092449
300	1020	72%	107.32	102.8162275
240	840	67%	75.98	77.9555324

Fixed speed HP Fit=a GPM^2+b GPM +c

Step 2: Use the affinity law $Q1 = Q2 \times \sqrt{\frac{H1}{H2}}$ and constant efficiency lines to define the flow rates and efficiencies through the variable speed pump running at different speeds to maintain a constant pressure.

Flow with VFD= flow with constant speed × $\sqrt{\frac{\text{constant pressure head}}{\text{head at constant speed}}}$

Step 3: Determine the horsepower of the constant speed and variable speed pump for each of the flows and efficiencies found in Steps 1 and 2 using the formula.

$$P = \frac{QH}{3960 \times \eta}$$

Step 4: Using the process described in Step 3, determine the polynomial coefficients a, b and c that define the variable speed pump's horsepower at different flow rates and a constant discharge pressure. Table (3.5)

Table (3.5)Variable speed pump's horsepower at different flow rates and a constant discharge pressure.

Flow	Head	efficiency	fixed Head VFD Hp	Pump RPM	Fixed Head VFD HP Fit*
497.8	700	68%	129.40	2100	129.5067565
371.99	700	73%	90.08	1900	89.7245732
237.64	700	72%	58.34	1780	59.32544334
209.49	700	67%	55.27	1700	54.53740732
a	B	c			
0.00034	0.01551	36.1158514			

The maximum speed of the variable speed pump is typically limited to the speed of the constant Speed pump, (figure 3.16) so the actual HP of the variable speed pump may not reach the values shown in the table above.

The speed of the variable speed pump is determined using the relationship $\frac{N1}{N2} = \frac{Q1}{Q2}$.

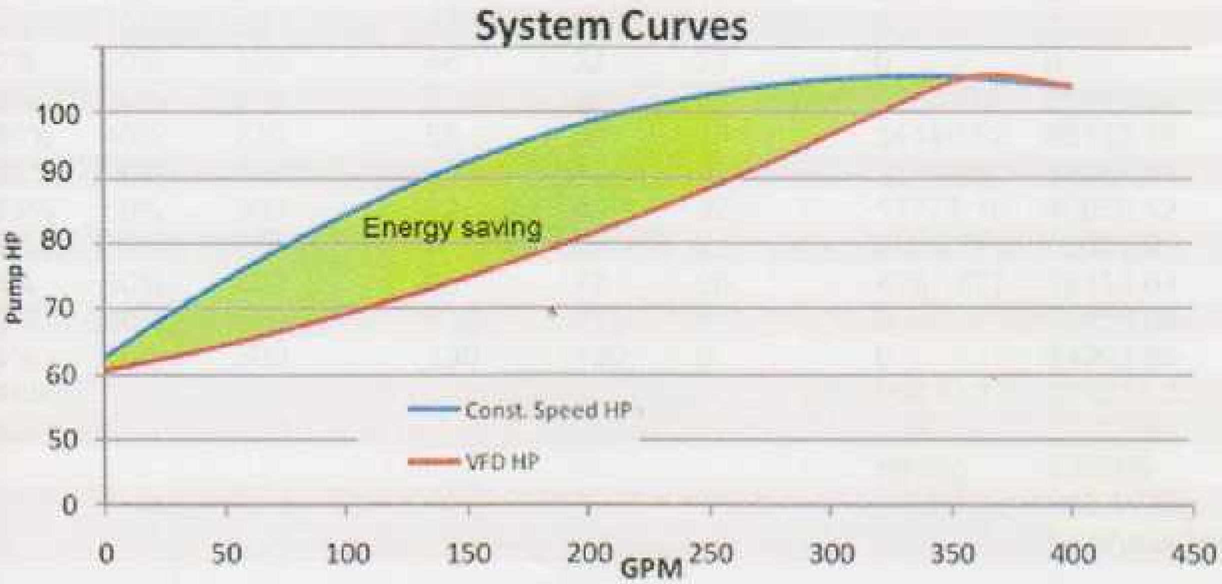


Figure 3.16: VFD system curve VS constant speed curve

Step 5: Estimate the percentage of time that the pump operates at various flow rates. Note that there may be a percentage of time when the pump is OFF, which is different than when the pump is running with little or no flow. Table (3.6)

Table (3.6) The percentage of time that the pump operates at various flow rates

%Time	0%	0%	0%	0%	0%	5%	40%	30%	10%	5%	5%	5%	100%
Of design %flow	off	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	Total
Flow rate	0	0	50	100	200	230	240	300	350	400	450	500	GPM

Step 6: For each of the flow rates identified in Step 5, calculate the horsepower for the constant speed and variable speed pump using the coefficients and formulas found in Steps 4. Then calculate the annual energy savings using the formula:

$$KWh_{saving} = \frac{(HP_{constant\ speed} - HP_{VFD})\left(\frac{Hrs}{Yr} @ \text{flow}\right)(0.746\frac{KW}{HP})}{\eta\ \text{motor}}$$

The annual energy saving shown in table (3.7) .

Table (3.7) energy saving calculation

Time %	% design flow	design flow.GPM	Fixed speed HP	Fixed Head w/ VFD HP	Fixed Head HP Savings	Fixed Head Kwh Savings	Fixed Kwh
0%	0%	0	36	35	1	0	0
0%	0%	0	38	34	4	0	0
0%	10%	50	41	20	21	0	0
0%	20%	100.	46	22	24	0	0
5%	30%	200	53	30	23	4280.785	9850.354
40%	40%	230	58	35	23	34140.52	86123.16
20%	50%	240	60	31	29	21363.53	44384.41
15%	60%	300	72	40	32	17772.15	40050.42
5%	70%	350	84	63	21	3885.708	15581.8
5%	80%	400	98	72	26	4767.677	18134.64
5%	90%	450	113	113	0	0	21008.66
5%	100%	500	130	130	0	0	24203.85
100 %						86210.37	259337.3
						saving	33.24%
							862.1 Kwh/year/HP

3.7.2 Money saving calculation:

from the calculation the total power saving = 86210 KWh/Year

The cost of KWh= 0.7 NIS

Total money saving =86210×0.6=51726 NIS/Year

VFD, 100HP, 142A, 460V, 3 Ph In, 3 Ph Out used (Grainger Item #12T631)

Price : **$10,066.00**(40264NIS)

Payback Period = Initial Investment / Annual Cash Flow = 40264NIS / 51726 = 0.77 years.

3.8 practical module calculation

We use the following steps to calculate the energy saved by installing a variable speed pump in small module.

Step 1: Determine the flow (Q), head (H) and efficiency (η) for three or more points along the constant speed pump curve Figure (3.19) . Table (3.8) .

Table 3.8 Flow, head, efficiency changes

Flow	Head	efficiency	fixed speed Hp	fixed speed HP*
18.5	34	54%	0.29	0.293565
15.9	36	56%	0.26	0.259816
13.2	38	54%	0.23	0.232869
10.6	40	50%	0.21	0.214722
a	b	c		
0.000566	-0.00649	0.219945774		

Step 2: Using the constant pressure set point for the VFD, determine the flow for each of the variable speed operating points along the constant efficiency lines. Figure (3.17) the value shown in table (3.9) .

$$\frac{Q1}{Q2} = \sqrt{\frac{H1}{H2}} \tag{3.15}$$

$$Q1 = Q2\sqrt{\frac{H1}{H2}} \tag{3.16}$$

$$\text{Flow with VFD} = \text{flow at constant speed} \sqrt{\frac{\text{constant pressure head}}{\text{Head at constant speed}}} \tag{3.17}$$

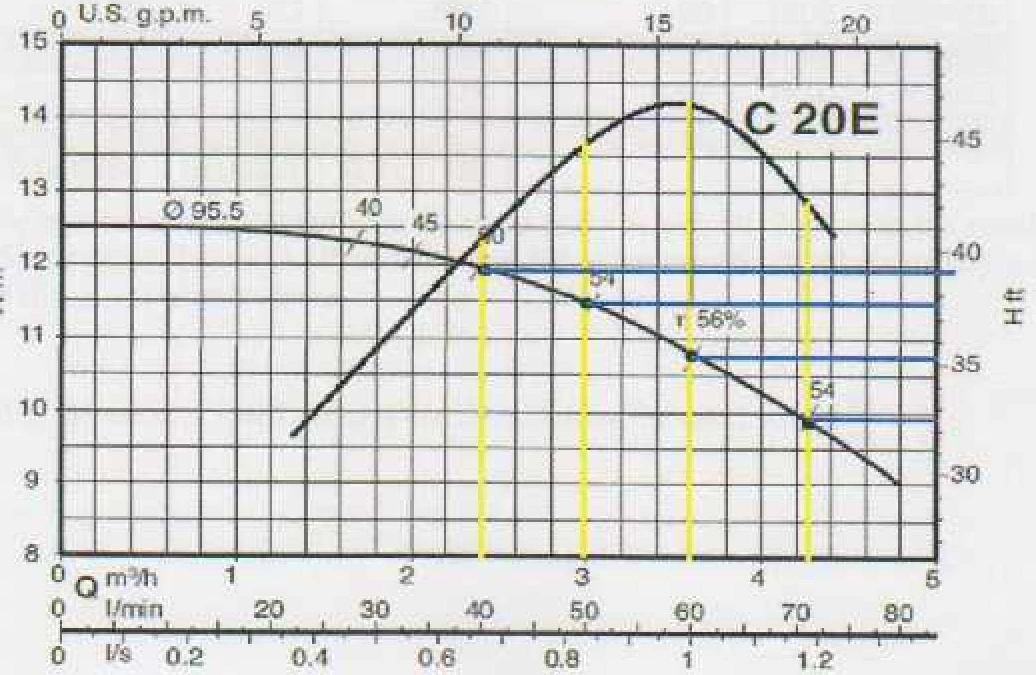


Figure: 3.17 Pump curve for project with selected performance points

Table (3.9) flow at variable speed operating point

flow	head	efficiency	constant pressure flow
18.5	34	54%	11.43942
15.9	36	56%	9.554711
13.2	38	54%	7.720649
10.6	40	50%	6.04293

Step 3: Determine the horsepower of the constant speed and variable speed pump for each of the flows and efficiencies found in Steps 1 and 2 using the formula.

$$P = \frac{QH}{3960 \times \eta} \quad (3.19)$$

Step 4: Using the process described in Step 3, determine the polynomial coefficients a, b and c that define the variable speed pump's horsepower at different flow rates and a constant discharge pressure. Table (3.10)

Table (3.10)Variable speed pump's horsepower at different flow rates and a constant discharge pressure.

Flow	Head	efficiency	fixed speed Hp	Pump rpm	fixed speed HP*
11.43	22	54%	0.12	2200	0.117359
9.55	22	56%	0.09	1800	0.095466
7.72	22	54%	0.08	1640	0.078666
6	22	50%	0.07	1570	0.066933
A	b	c			
0.000664	-0.00229	0.0567794			

The maximum speed of the variable speed pump is typically limited to the speed of the constant Speed pump, Figure (3.18) so the actual HP of the variable speed pump may not reach the values shown in the table above.

The speed of the variable speed pump is determined using the relationship $\frac{N1}{N2} = \frac{Q1}{Q2}$.

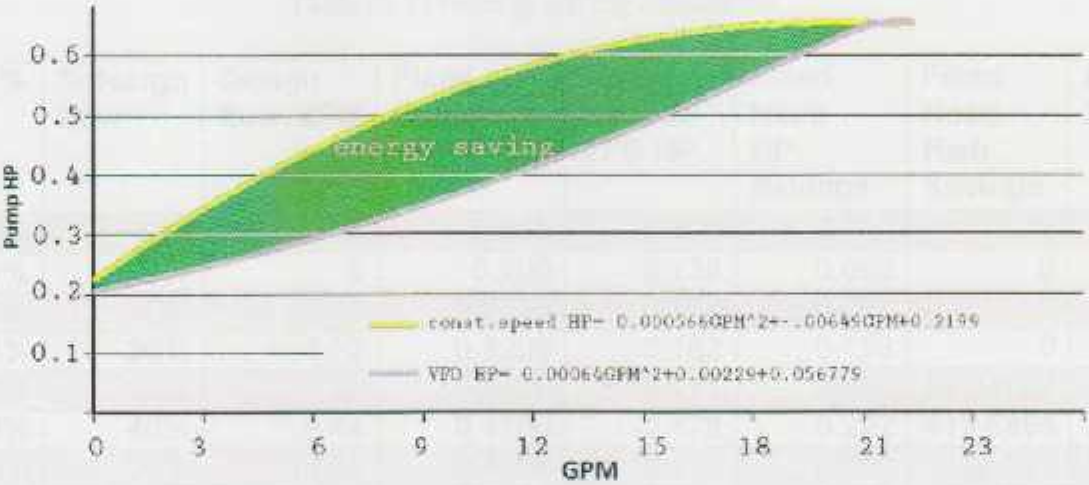


Figure 3.20: VFD system curve VS constant speed curve

Step 5: Estimate the percentage of time that the pump operates at various flow rates. Note that there may be a percentage of time when the pump is OFF, which is different than when the pump is running with little or no flow. Table (3.11)

Table (3.11) The percentage of time that the pump operates at various flow rates

%Time	0%	0%	0%	0%	0%	5%	40%	30%	10%	5%	5%	5%	100%
% Of design flow	**off**	**0%**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**100%**	**Total**
Flow rate	**0**	**0**	**6**	**8**	**11**	**12.5**	**13**	**14**	**16**	**16.8**	**17.8**	**19**	**GPM**

Step 6: For each of the flow rates identified in Step 5, calculate the horsepower for the constant speed and variable speed pump using the coefficients and formulas found in Steps 4. Then calculate the annual energy savings using the formula:

$$KWh_{saving} = \frac{(HP_{constant\ speed} - HP_{VFD})\left(\frac{Hrs}{Yr} @ \text{flow}\right)\left(0.746\frac{KW}{HP}\right)}{\eta\ \text{motor}} \qquad (3.20)$$

The annual energy saving shown in Table (3.12).

Table (3.12) energy saving calculation

Time %	%design flow	design flow.GPM	Fixed Speed HP	Fixed Head w/ VFD HP	Fixed Head HP Savings	Fixed Head Kwh Savings	Fixed Kwh
0%	0%	0	0.000	0.000	0.000	0	0
0%	0%	0	0.200	0.138	0.062	0	0
0%	10%	2.11	0.2300	0.138	0.092	0	0
0%	20%	4.22	0.3200	0.162	0.158	0	0
5%	30%	6.33	0.3400	0.171	0.169	29.84887	63.12177
40%	40%	8.44	0.4700	0.178	0.292	412.5856	698.0525
20%	50%	10.55	0.4900	0.210	0.280	197.815	363.8785
15%	60%	12.66	0.5000	0.232	0.268	142.0029	278.4784
5%	70%	14.77	0.5200	0.287	0.233	41.15259	96.53918
5%	80%	16.88	0.5300	0.310	0.220	38.85652	98.3957
5%	90%	18.99	0.5500	0.370	0.180	31.7917	102.1088
5%	100%	21.1	0.5700	0.400	0.170	30.02549	105.8218
						924.0787	1806.397
100%						saving	51.00%

Money saving calculation

from the calculation the total power saving = 924.1 KWh/Year.
The cost of KWh= 0.7 NIS.
Total money saving =924.1×0.7=647 NIS/Year.
Initial investment = 4000 NIS.
Payback Period = Initial Investment / Annual Cash Flow = 4000NIS / 647 = 6 years.

3.9 Summery

We conclude from the previous calculations that it's viable to apply this project on a big stations like irrigation stations and the stations in big cities

To deliver a clear idea for our project, in the next chapter we well discuses SCADA system, and we describe tow case study about SCADA system benefit.

3.10 Electrical circuit

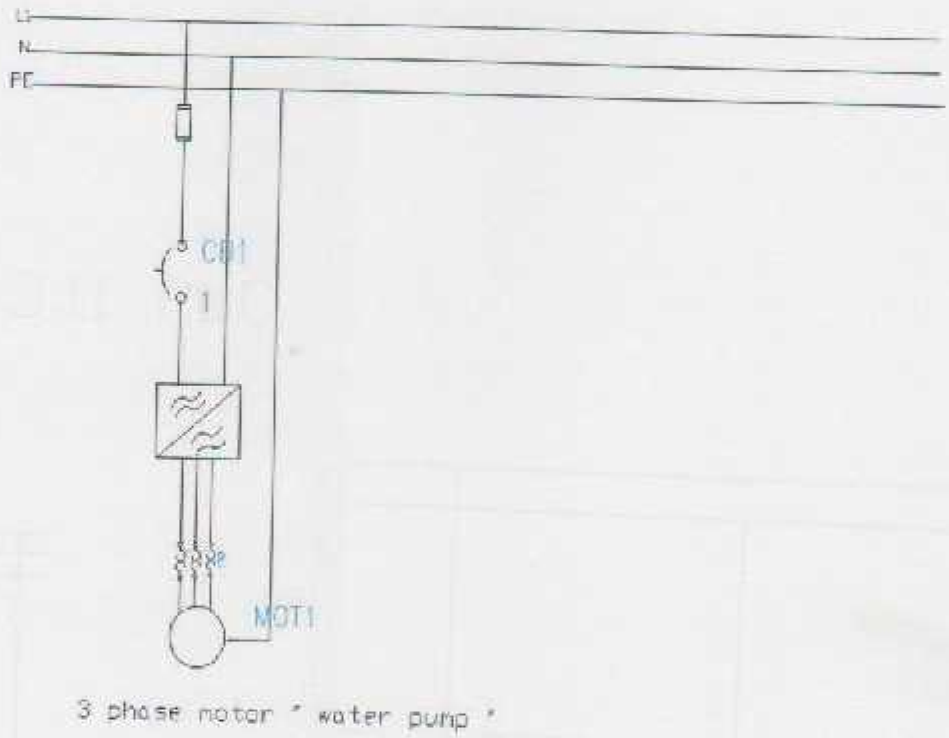
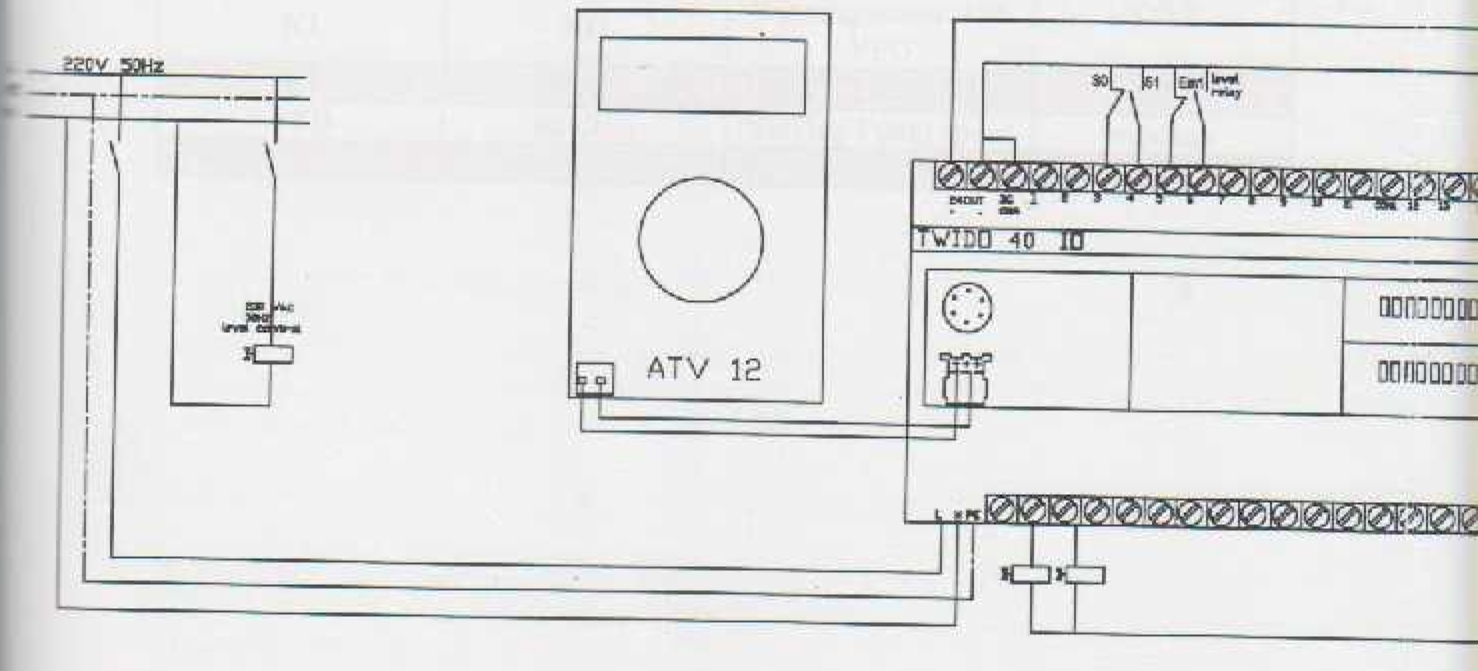
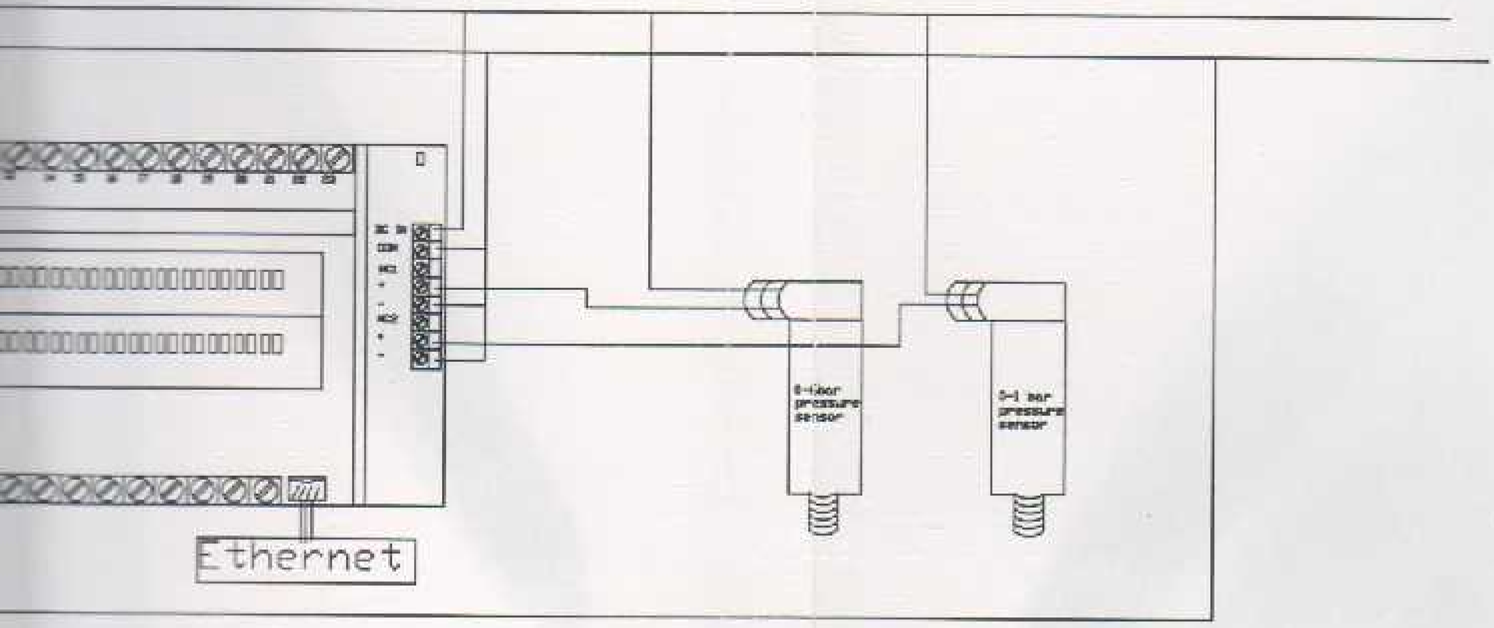


Figure 3.19: electrical circuit

3.11 PLC Connection.




0-4bar pressure sensor
0-1 bar pressure sensor
Ethernet

The PLC allocation table shown in table(3.13).

Table (3.13) Allocation table of PLC

Symbol	State	description	Address
EM	NC	Emergency switch	I0.2
OL	NC	Over load switch	I0.3
S0	NC	Stop motor	I0.4
S1	NO	Start motor	I0.5
Level relay	NC	Turn the pump off when the discharge tank is full	I0.6
PS1	Analog input	Pressure sensor	IW0.1
PS2	Analog input	Pressure sensor (level)	IW1.0
K1	NO	Running motor with VFD	Q0.2
R1	NO	FAN, Running signal	Q0.3
VFD	modbus	Varying Pump speed	modbus

Chapter Four

SCADA SYSTEM

4.1 Introduction

Supervisory Control and Data Acquisition (SCADA) solutions provide a base for more reliable operation of water systems and significant operating and financial benefits, both, which are important to utility management. They provide means for increased productivity, reducing the number of failure events. System parameters, which are communicated via wireless data network present true conditions, and commands sent from SCADA Centrals to remote sites that are aimed to achieve optimal, reliable and safe operation[19].

Figure (4.1) below outlines the "shop floor to top floor" interaction involving operation and control of remote site and information flow to management and company finance. In order to implement such solutions, SCADA systems shall allow for seam less network communications from any Remote Terminal Unit (RTU) to any RTU and from any RTU[20] to the SCADA computer.

Figure 4.1: Information flow to management

SCADA systems help achieve optimal system operation by adding new features to the system such as pump operation sequencing, electric energy consumption , efficiency monitoring, historical scenarios analysis, web access, SMS phone, etc.

4.1.1 SCADA operation benefits

On the top of these operating benefits, utilities may achieve reduction of their electric power bill, more convenient work for their maintenance teams, more effective and faster handling of critical events, reducing indirect costs contributed by communicating , etc[19].

4.1.2 Field Sites Operation

Efficient monitoring of water distribution networks has long been a challenge for management, even in countries with well-developed infrastructure and good operating practices. The principles involving such solution lead to the use of SCADA systems combined with wireless communication and RTUs or PLC, which perform the monitoring and control functions as specifically required for each site [20].

4.1.3 Reservoir Monitoring Devices:

Water level in reservoirs is usually monitored via tow status sensors and one analog sensor. The purpose of the tow status sensors (maximum level and minimum level) is obvious, and the information provided by the analog sensor may help monitoring the rate of change and the actual level in between the extremes indicated by the status level switches. The information provided by these sensors is processed by the RTU or PLC and the calculated results provide the following inputs to the SCADA control center[20]:

1) Actual level which can be below or above the planned level for that time.
2) Rate of change (above normal) as expected for the time of the day.
3) Reservoir overflows condition (causing loss of potable water).

4.1.4 Pressure and Flow Monitoring Devices:

Pressure sensors are usually installed next to valves and are aimed to provide input to Pressure Reduction Valves (PRV), which are controlled by the RTU or PLC , and flow meter to varying the speed of the pump to meet the varying in demand [23].

Benefits:

1) Maintaining stable pressure help optimizing the flow rate .
2) Minimize leaks through non repaired pipe breaks.
3) Reduce misuse of water due to high pressure.
4) Allow reducing the pressure as needed.
5) Record flow and pressure data in each section.

4.1.5 Pumping Stations Control[23]:

SCADA RTUs or PLC perform monitoring and control of pumping stations and measures electricity consumption. Controlling the pumping station operation and measurement of the power consumption allows:

1) Early warning on an overloaded pump which may cause malfunction.
2) Detection of a faulty or inefficient pump (damaged membrane).
3) Periodic pump sequencing, aimed to minimize wearing out of a pump.

4) Optimal pumping cycles as per electricity Time of Use rates.
5) Monitoring the operating hours (of pumps) in between maintenance.
6) Monitoring of electric power outage at pumping stations.

4.1.6 Water Quality &Contamination Detection:

Nowadays water utilities are obliged to test and confirm the high quality of potable water. This requires constant monitoring of the water quality parameters by SCADA RTUs installed in remote installations which are configured to report to the control center when an event takes place.

Benefits: Measurement of the water quality allows performing emergency shutdown, thus providing enhanced security for the public[25].

1) Early detection of water contamination by fault (wrong chemical treatment).
2) Prevention of risk to public resulting from a terror action.

4.1.7 Managing Remote Sites

Properly engineered SCADA systems shall allow for seamless communications between all RTUs and from any RTU to the SCADA Master Control Center (MCC). [24].

4.1.8 Instant Data Communication[23]:

This function is highly important as the operator must be updated as soon as possible on every event happening at remote sites, and must have the ability to send commands which may have to be implemented right away.

Benefits: Having a reliable communication solution in place provides:

1) Remote monitoring and control of pumping stations, valves and reservoirs.
2) Immediate alert to the operator on any changes or alarm conditions.

4.2 Accumulated Data:

Provides opportunity for analyzing the collected historical data in the database of the SCADA computer . This allows better planning of installation expansions, performing post event analysis and estimating expected water consumption (weekends, holidays, etc.).

4.3 System Health Monitoring[25]:

Water is considered a top critical utility supply to the public and also for agriculture. Consequently, municipalities are obliged to provide a high level of service, which can only be achieved by implementing SCADA solutions that provide communication coverage to all field-installed equipment.

1) Constant water level monitoring in reservoirs.
2) Monitoring the operating efficiency of each pump.
3) The monitoring of electric power supply to pumping stations.
4) Leak detection along main pipes resulted from bursts.

4.4 Web Access:

Water utilities are now seeking new ways to introduce improvements, which may reduce their operating and maintenance costs. With the introduction of advanced wireless access solutions, utilities may obtain valuable real time information from anywhere and anytime. Figure 4.2 below illustrates details of a SCADA system screen, showing the key electric parameters and accumulated flow parameters[26].

4.5 Management and Finance

Management decision to integrate and operate a SCADA system is aimed to improve their operation via better collaboration between the of computer hardware, instrumentation and sensors, electric control panels, power monitoring devices, software programming, data communication, equipment and infrastructure, consulting fees, and system installation and commissioning. Appropriate selection of these components may help achieving the system goals and expedite the Return on Investment (RoI). The following considerations apply to implementing such SCADA solution:

4.6 Electricity Bill Saving:

Statistics show that cost of their electric bill represents a significant portion of water utilities annual expenditure. Therefore, saving on the electricity bill is an important task and challenge

1) Using SCADA solutions monitoring and recording the actual flow from and calculating the forecasted demand for the upcoming hours.
2) Pumping the water to the reservoirs using the most suitable pumps
3) Negotiating reduced cost of electricity supply with the electric utility and pay for the electricity based on time of Use.
4) Monitoring the operating efficiency of each pump (cubic liters/kWh) and activating only the healthy pumps.

4.6.1 Reduced Cost of Maintenance:

Operating maintenance is probably the second largest expenditure factor considered by electric utilities. These include the cost of all repairs (damages and preventive maintenance) and the cost of spare parts purchasing and storing in warehouses. The overall figure can be broken down into several segments referring to the installed system:

1) Monitoring of pumping stations helps prevent major pump malfunctions.
2) Monitoring pipe pressure fluctuations help preventing pipe bursts.
3) Remote monitoring minimizes the needs of traveling to remote sites.
4) Remote control allows activating emergency shutdown in case of trouble.
5) Computerized control allows more effective control on stock of spare parts.

4.7 Human Machine Interface (HMI) for SCADA[30]:

The computer hardware is considered the "heart & soul" of the system. The reason is that people consider the computer as "main thing" that makes the system working. Figure (4.4)

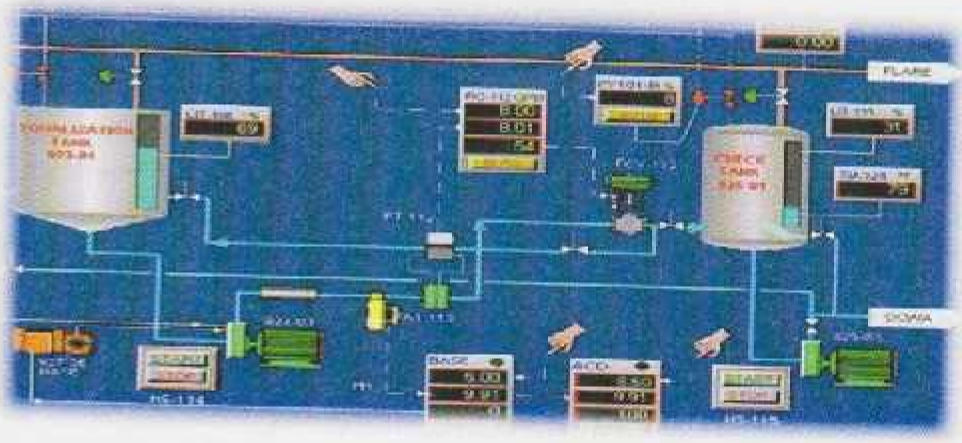


Figure 4.2 : HMI for SCADA

Other important concerns refer to operator training. Therefore selecting a software type having a convenient and comprehensive HMI is as important as selecting the one with the most advanced features.

1) Use of friendly software and HMI minimize need for lengthy training.
2) Simple to understand HMI minimizes human errors and avoids large problems.

4.8 Demand Prediction:

Planning of a water system and system expansions are based on the assumption of growth in both population and demand. The obvious objective is that the system's capacity must cope with peak demand. Pressure reducers, are calibrated to maintain a consistent supply during normal hours, but they must have remote control on order to cope with the peak demands as well. Demand prediction based on accumulated data helps achieving:

1) Steady supply and stable pressure to end user customers.
2) Optimally filled reservoirs achieved with maximal saving of electric power.
3) Optimally operating pumping stations and planned pumps' sequencing.

4.9 Water Saving and Losses Reduction[28]:

Improperly managed water networks might result in increased cost, insufficient supply of potable water, frequent travel to remote sites, unsatisfied customers and more. Such problem s might be caused not only by operating a poorly maintained infrastructure but also by excessive use or misuse of water. Aimed to minimize these problems, water utilities are required to introduce improvements by operating their system based on real time data communicated from remote sites to the SCADA control center:

1) Maintaining stable water flow pressure in central locations along the pipeline.
2) Calculating sum-check of water flow along the water pipe for loss detection.
3) Reducing pressure during non-busy hours along damaged/leaky pipes.

4.10 Reduced Cost of Damages:

System failures may practically happen anytime and anywhere. However, by early detection, experienced SCADA operators can reduce the time from the event occurrence to the start of implementing corrective action. Using the analyzed data, they can help improve operating reliability, reducing operating costs and modernizing the water distribution network[28]:

1) Replace inefficiently operating water pumps ahead of the failure.
2) Immediately act when a corrosion process along pipe is detected.
3) Prevent small problems to convert to big ones via RTU or PLc and communications.

4.10.1 Investment Considerations and Calculations

The annual cost is typically composed of three main components:

1) Capital cost. This calculation is based on the interest rate of the capital, initially invested in the system, and also includes future investments in improvements and upgrades.
2) Annual depreciation. This cost is related to the equipment, which was purchased to run the system.
3) Operating costs. Mane power, training of operators, field transportation, maintenance costs, etc.
4) Supply Reliability. This factor combines both financial and operating benefits and is as important as the purely financial factors. It leads to saving of water and boosting customer satisfaction.

4.10.2 SCADA Cost Contributors

Integrating and operating a SCADA system involve the use of computer hardware, instrumentation and sensors, electrical control panels, software programming, data communication, equipment and infrastructure, consulting fees, and system installation and commissioning. Careful selection of these components may help making the system expandable, upgradeable and also affordable [27].

1) Hardware Instrumentation. Although investment in computer hardware is not the most critical neither the expensive part, it is considered the "heart & soul" of the system.
2) Computer Operating System and Application Program.
3) Communication Infrastructure. The data communication data network used for the SCADA can be viewed as the "nerves" of the system.
4) Field Instrumentation. These devices are often provided "built-in" with the equipment to be monitored or controlled.
5) System Installation and Commissioning
6) System Maintenance Costs.
7) Operators and Technicians: In order to operate these systems, utilities must employ well trained operators who work probably .
8) Other Cost Factors: Field installations as well and sensors must be tested and calibrated periodically.

4.10.3 VFD and SCAD Are they worth while investments?

now we start to study two system to show that are they worthwhile investment or not

1) Delano-Earlimart Irrigation District

Delano-Earlimart Irrigation District (DEID) is located on the east side of the San Joaquin Valley near the town of Delano-California. The district obtains water from the Friant Kern Canal. Approximately one third of the district is uphill from the Friant Kern Canal and the remainder of the district is downhill. Water is pumped from the Friant Kern Canal in both directions, uphill and downhill. A majority of the pumping serves the uphill users. Downhill pumping provides service to water users near the Friant Kern Canal. For the remainder of the downhill section of the district, water flows by gravity to service water users[30].

Figure 4.3: DEID turnout from the Friant Kern Canal that services an uphill section of the district.

The district currently has 14 variable frequency drives (VFDs) and a supervisory control and data acquisition (SCADA) system in place that allows remote and automatic monitoring and control of all district pump stations and reservoirs. Before this current system was in place, district personnel would manually stage pumps in a pump station to maintain a water level in a standpipe near the pump station. Excess water would be bypassed back to the original source. District personnel would have to physically monitor the reservoirs and pump stations 24 hours a day, 7 days a week.

Benefits

1) Increased level of service
2) Reduced downtime
3) Reduced pump wear
4) Reduction in staff size
5) Reduced vehicle wear
6) Reduced stress on management and field personnel

Capital Costs vs. Annual Savings (the actual calculation for this project)

Annual Savings

Vehicle wear =$2,208

Field Personnel=$74,880

Management and Office Personnel= $11,360

Pump wear=$6,667

Total Annual Savings=$95,115

Total Capital Cost to District = $447,041

Simple Payback (Years) =4.7

With the VFDs and SCADA system, the pumps automatically match a set point in the standpipe just upstream of the pumps. A computer in the district office monitors and collects data from the pump stations. The pumps can also be controlled from the district office. Alarms within the SCADA system ring district personnel pagers, indicating a problem. Using Pc Anywhere, district operations managers can monitor and make changes in pumping operations from their home computers during nights and weekends.

The results from the SCADA system and the VFD installations have been positive. The increased level of service the district has been able to achieve is one of the most important results. District personnel and farmers now have complete confidence that water will be available when it is ordered and that it will be delivered at a relatively constant rate. Previously, they did not have this confidence because of the unpredictability associated with the old system. The district has been able to reduce inefficiencies and downtime by analyzing system data with SCADA.

Analyzing the number of times pumps are turned on and off, the number of hours each pump is running, and the flow rates delivered has helped indicate problems in the pump, motor or control program, or if someone is taking water when they were not scheduled too. Running hours on motors can be balanced on the district's large pump stations by changing the rotation (when the motors are turned on, relative to the other motors) of the non-VFD motors in the pump station. The SCADA system also allows the district personnel to quickly troubleshoot farmer complaints, such as not receiving the proper flow rate.

2) Sausalito Irrigation District

Sausalito Irrigation District (SID) is located near Porterville, California in the Central SanJoaquin Valley. The district water supply is pumped and gravity fed from the Friant Kern Canal.SID has installed four VFDs but has not installed a SCADA system at this time. The VFDs were installed on pump stations that pump water from the Friant Kern Canal into pressurized pipelines that distribute water throughout the district. SID installed the VFDs so that[30]:

1) Water did not have to be bypassed back to the source, wasting energy.
2) Field personnel did not have to continuously monitor and change the pump in configuration throughout the day and night.

The VFDs have solved these problems at their respective pump station since installation. The VFD automatically matches supply with demand so that the bypass is no longer necessary and field personnel do not have to continually monitor each station. This has improved the level of service provided to water users by increasing the flexibility they have in water deliveries.

The water ordering procedures are still the same, with the exception that on Sundays and part of Saturdays the water user is allowed to operate his or her own turnout. The district has installed 1 to 2 figure 4.6

Figure 4.4: Two variable frequency drives at pump station CID.

Benefits

Increased level of service.

1) Energy savings.
2) Field personnel have Sundays and part of Saturdays off.
3) Reduced stress on management and field personnel.
4) Reduced vehicle wear.

Capital Costs vs. Annual Savings

Annual Savings

Energy Savings from 3 VFDs = $19,900

Vehicle wear = $720

Field Personnel= $9,360

Total Annual Savings = $29,970

Total Capital Cost to District = $62,720

Simple Payback (Years) = 2.1

With the addition of the VFDs, the district has experienced significant energy savings. This is attributed to the reduction in pumped water that is bypassed. The district also attributes some of the energy savings to the past operation of the pump stations. If a relatively low flow was demanded and the water user was near the pump station, the district would at times operate a pump at a lower head than was designed. This caused the pump to operate less efficiently than normal.

VFDs have the potential to save energy. The amount of energy saved will depend on the current operation of the pumping system as well as the future operation. It is difficult to predict exactly how much savings, if any, will occur however, there are many other benefits from VFDs and SCADA. We are in a new day and age, where irrigation water delivery is shifting from an art to an industrial process. Pressures from increasing energy costs and environmental issues are

Chapter Five

Implementation

Implementation:

In chapter three we explained VFD with pumping system calculation in case study and in our module. From that result we started implementing the project practically not just theoretically. In this chapter we will explain the implementation process, providing photos of the project in different viewpoint, and the target from every part.

5.1 Implementation Process:

5.1.1 The Body:

First part that we worked on , is the body of the project as shown in figure (5.1), where this body will hold all parts of the project .

Figure 5.1: The Body of the module

5.1.2 Main Tank

The main tank in our project (200L) act as water source and shown in figure (5.2) .

Figure 5.2: Main Tank

5.1.3 Discharge Tank

The water discharge on the small tank which shown in the figure(5.3)

Figure 5.3: Discharge Tank

5.1.4 Pump

Three phase centrifugal pump fixed under the main tank , and the discharge line out from the outlet shown in figure (5.4)

Figure 5.4: Three Phase Pump

... in the traditional ... the flow without any change in ... used to increase the flow without any change ... pend on the consumers request as shown in figure (5.5) .

Figure 5.5: Manual Valve

5.1.4 Pump

Three phase centrifugal pump fixed under the main tank , and the discharge line out from the outlet shown in figure (5.4)

Figure 5.4: Three Phase Pump

5.1.5 Manual Valve

It is used to control the flow amount in, the tradintional way by close it to reduce the flow or open it when we need to increase the flow without any change in the motor speed, by depend on the consumers request as shown in figure (5.5) .

Figure 5.5: Manual Valve

5.1.6 Level Sensor

The pressure sensor shown in figure (5.6) used to measure the water level of the tank, the relation between the pressure and level is linear relation ,the sensor's analog output (4-20mA) 4mA represent the bottom level of the tank also (1mA ⟶ 0.8 Meter).
The level in pumping system considered as important signal so the signal of the level sensor is monitoring by SCADA .

Figure 5.6: Level Sensor

5.1.7 Pressure Sensor:

The pressure sensor on the discharge line shown in figure (5.7) used to send the signal to PLC at manual control mode, and this signal used to measure the power loss in the system when the valve is shutting down to reduce the flow by depend on the consumers request .

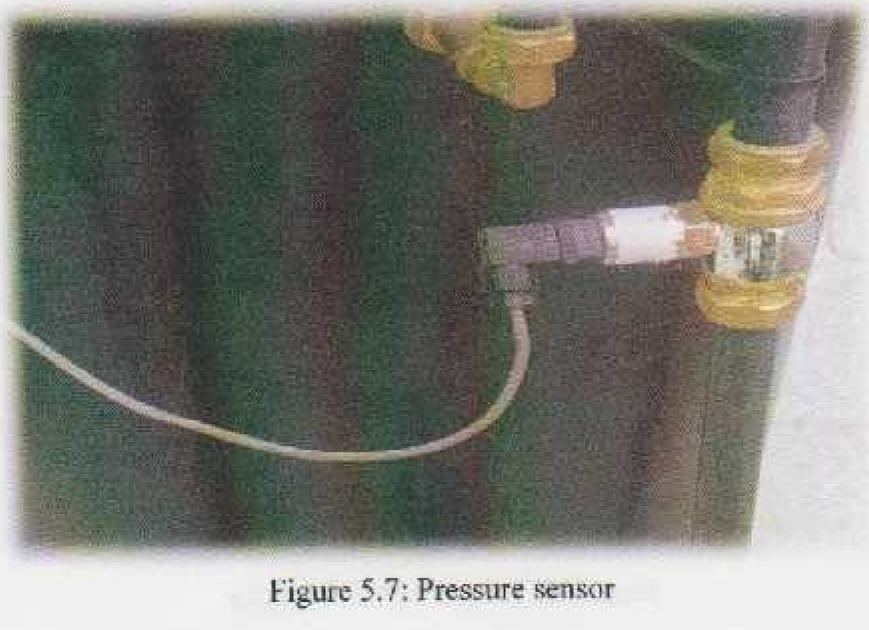


Figure 5.7: Pressure sensor

5.1.8 Liquid level relay:

This relay (in the red rectangle) shown in figure (5.8) used to send signal to PLC at state:

1- when the discharge tank is full.
2- when it's empty the relay .

Figure 5.8: Level relay

5.1.9 Modbus VFD Control :

The VFD connect whit PLC by modbus comminication method shown in figure(5.9), it's allows us to deal with prameter by SCADA screen .

5.1.10 Electrical Panel

The electrical panel contains the control circuit and power circuit and it is protection as shown in figure (5.10) .

Figure 5.10: Electrical Panel .

5.1.11 Ventilation Fan :

The VFD should ventilate and we use fan for that as shown in figure (5.11).

Figure 5.11 Ventilation Fan.

5.2 Final Shape Of The Project

The final shape of the project shown in figure (5.12-5.15)

Figure 5.12 Final Shape Of The Project

Figure 5.13 The Final Shape Of The Project

Figure 5.14 final shape of the project

Figure 5.15 final shape of the project

5.3 SCADA Monitoring software :

This screen shown in figure represntes the screen used to control as run or stop the all system and explan the nessecary field data like the flow ,max speed and motor power at full load

Software security :

- The security in SCADA system is necessary and we implemented that in this project to make reliability system.
- To assign to the system you must have a valid user name supported by a valid password.

The figure (5.16) shown the security screen when the program turned on

Figure 5.16 : Software Password

Starting screen :

The screen shown in figure (5.17) appear after sucsses sign in .

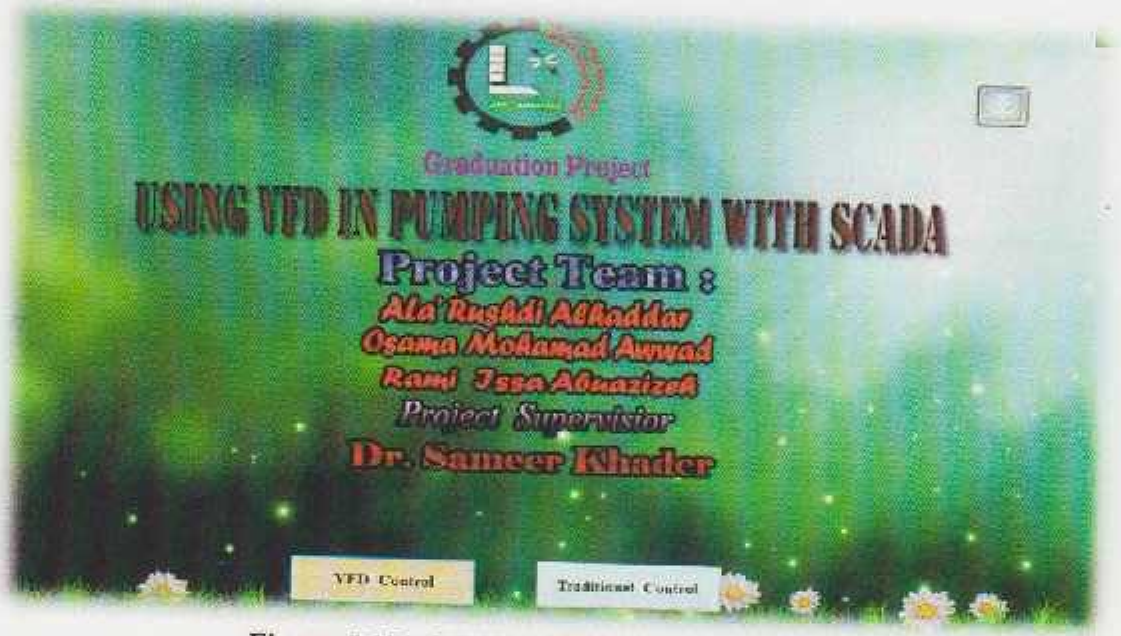


Figure 5.17 : SCADA/HMI Starting Screen .

VFD Control screen:

The screen shown in figure (5.18) appear when the user press VFD control in main screen and the control will be VFD control , the screen allaw the user to enter the flow value which is less than the max value , then the speed will decrease based this value by first affinty law relation , in this screen the operator can turn the system on and off and monitoring the power drop after the speed reduce and the power saving, and the water level in the tank.

Figure 5.18 VFD Monitoring Screen

Traditional control :

The screen shown in figure (5.19) appear when the user press Traditional control in main screen and the control will be traditional by manual valve, the screen allow the user to monitor the value of , pressure after the valve close to reduce the flow , and the value of the power loss by this way by apply affinty law (2^{nd} and 3^{rd}), and also the operator can turn the system on and off, and the water level in the tank.

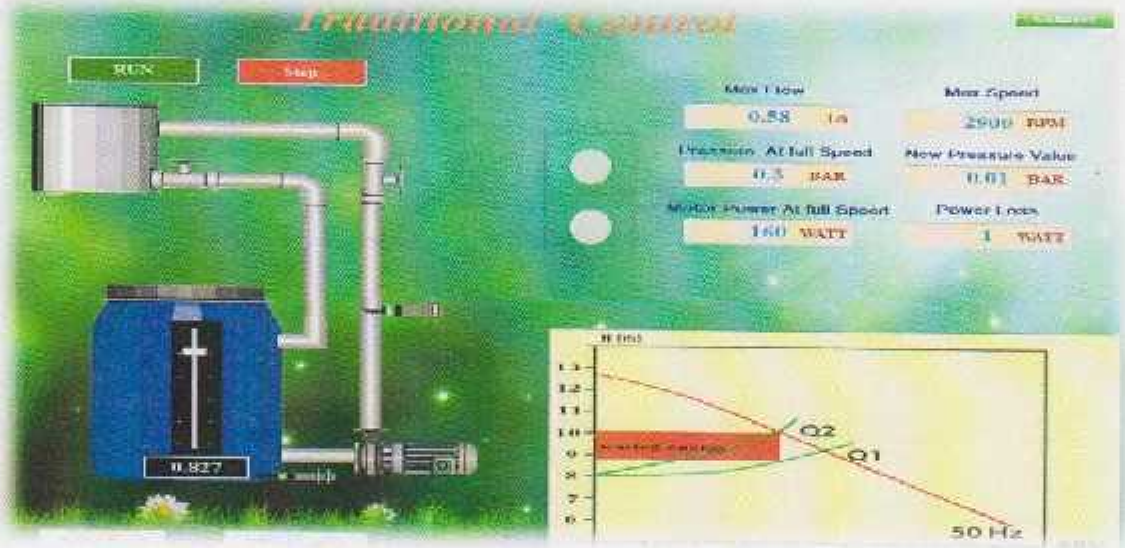


Figure : 5.19 Traditional control screen.

5.4 Obstacles and solutions:

We encountered several obstacles during the implementation phase. They are:

1- Flow value

The max flow value calculated after the Implementation by using definit volum of the discharge tank to aviod using flow meter with analog output value because it's high cost(1500 Euro) .

2- Discharge tank

We use level liquid relay to stop the motor when the tank is full because it's full rapidly .

3- SCADA software

The scada software it's high expensive and it's used for large application and not for modular and small project so thate we use local scada software to relase the idea .

4- Commincation device

To avoid use RTU and spicial comminaction device we use ethernet PLC that provide the same function of RTU and it's commnication .

Chapter six

"Conclusion and Recommendation"

6.1 Conclusion

6.2 Recommendation

6.1 Conclusion:

In this section we will illustrate the main concluded points that resulted from applying and the project also it is present the main aims that we are achieved from the project we can summary the conclusion in points :

1- The team work of the project put the aims of the project and studied the theoretical part of the project (theoretical and laws) the team proved that the theoretical method can be executed in real word ad they can be applicable
2- From used the VFD we achieved the main idea (saving energy and pumping system)
3- In the project we measured the flow amount after the implementation By calculating the size of the tank mathematically in specific case instead the flow sensor which is highly expensive and we get acceptable result in the flow meter is used in large project like irrigation system and municipalities
4- In this project we used a pressure sensor in order to measure the main tank water level it gain to mention that the resolution in this sensor is 0.0001 bar
5- SCADA system is implemented in this project to reduce primitive manner monitoring
6- The Ethernet telecommunication system is applied in this project to get a fast data transfer .

6.2 Recommendation:

Finally it is good to mention some recommendation that can contribute to the provision of enhancements to the project , could have been done , but there was no plenty of time ,and not have the enough financial support .we summarized the recommendation in the following points

1- Implement this idea in all pumping system that classified under varying flow demand .
2- Using flow in pumping system to accurate amount of flow in open pumping system .
3- GPRS communication to control the system in the far areas.
4- To make a more secure system it is viable to design and implement rules for access control and sharing of date like implement firewalls and special people can access to the program .

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Appendix

(Data sheet)

Centrifugal pumps:

09/2012

C Centrifugal Pumps
with open impeller

calpeda

Construction

Close-coupled centrifugal pumps with open impeller.
Free-flow impeller (vortex or recessed impeller) for type C 16/1E.

C: version with pump casing and lantern bracket in cast iron.
B-C: version with pump casing and lantern bracket in bronze (the pumps are supplied fully painted).

Applications

For moderately dirty liquids or emulsions.
For industry and agriculture.

Operating conditions

Liquid temperature from -10 °C to +90 °C.
Ambient temperature up to 40 °C.
Total suction lift up to 6 m.
Maximum permissible working pressure: 6 bar.
Maximum size of solids: 4 mm.
Continuous duty.

Motor

2-pole induction motor, 50 Hz (n ≈ 2900 rpm).
C: three-phase 230/400 V ± 10%.
CM: single-phase 230 V ± 10%, with thermal protector. Capacitor inside the terminal box.
Insulation class F.
Protection IP 54.
Classification scheme IE2 for three-phase motors from 0,75 kW.
Constructed in accordance with: EN 60034-1; EN 60034-30; EN 60335-1, EN 60335-2-41.

Special features on request

- Other voltages.
- Frequency 60 Hz (as per 60 Hz data sheet).
- Protection IP 55.
- Special mechanical seal.
- Higher or lower liquid or ambient temperatures.
- Motor suitable operation with frequency converter.

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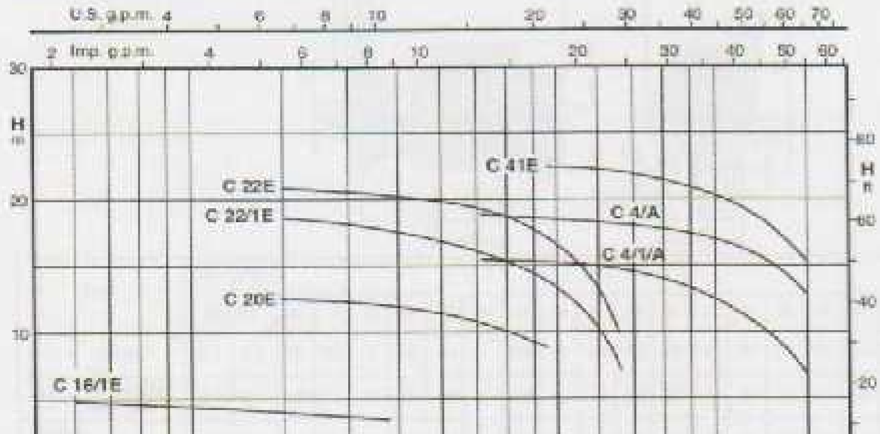
Materials

Component	C	B-C
Pump casing	Cast iron GJL 200 EN 1561	Bronze G-Cu Sn 10 EN 1982
Lantern bracket	Cast iron GJL 200 EN 1561	Bronze G-Cu Sn 10 EN 1982
Impeller	Brass P-Cu Zn 40 Pb 2 UNI 5705	
Shaft	Chrome steel 1.4104 EN 10088 (AISI 430)	Cr-Ni-Mo steel 1.4401 EN 10088 (AISI 316)
	Chrome-nickel steel 1.4305 EN 10088 (AISI 303) for C 41	
Mechanical seal	Carbon - Ceramic - NBR	

Coverage chart n ≈ 2900 rpm



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C Centrifugal Pumps
with open impeller

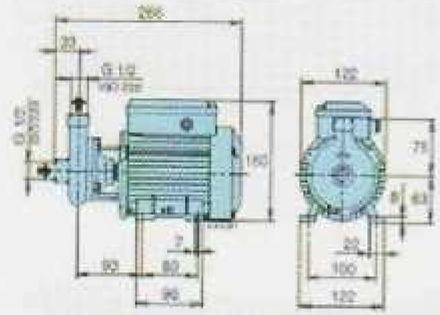
calpeda

Performance n ≈ 2900 rpm

3~	230V A	400V A	1~	230V A	P_1 kW	P_2 kW	P_2 HP	Q m³/h	0,6	0,9	1,2	1,5	1,8	2,4	3	3,6	4,8	6	6,6	8,4	9,6	10,8	12	13,2	15
								l/min	10	15	20	25	30	40	50	60	80	100	110	140	160	180	200	220	250
C 16/1E B-C 16/1E	1,7	1	CM 16/1E B-CM 16/1E	1,2	0,16	0,15	0,2	H m	5	4,7	4,4	4,2	4	3,6											
C 20E B-C 20/A	1,9 2,3	1,1 1,3	CM 20E B-CM 20/A	2,5 2,8	0,4	0,37	0,5	H m				12,3	12,2	12	11,5	10,8	9								
C 22/1E B-C 22/1/A	2,4 2,5	1,4 1,3	CM 22/1E B-CM 22/1/A	3 3,6	0,6	0,45	0,6	H m				19	18	17,5	17	16	14	10	7,5						
C 22E B-C 22/A	3	1,7	CM 22E B-CM 22/A	3,5 4,5	0,9	0,55	0,75	H m				20,5	20	20	19	19,5	16,5	14	12						
C 4/1/A	3	1,7	CM 4/1/A	4,8	0,81	0,55	0,75	H m								15,8	15,4	15,2	15	14	13,1	12	10,8	9,5	7
C 4/A B-C 41/1E	3,7 3,3	2,2 1,9	CM 4/A B-CM 41/1E	5,7 5,8	1,2	0,75	1	H m								19	18,8	18,5	18,3	17,7	17,4	16,8	16	15	13
C 41E B-C 41E	4,7	2,7	CM 41E B-CM 41E	7,4	1,6	1,1	1,5	H m									22,4	22,3	22,2	21,5	21	20,5	19,5	18	15,5

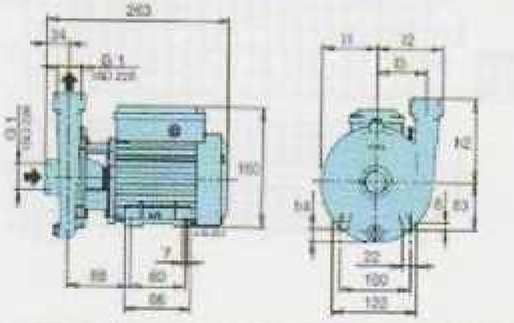
P_1 Maximum power input
P_2 Rated motor power output
B-C, B-CM = Bronze construction
H Total head in m.
ρ = Density 1000 kg/m³
ν = Kinematic viscosity max 20 mm²/sec
Tolerances according to ISO 9906, annex A.

Dimensions and weights

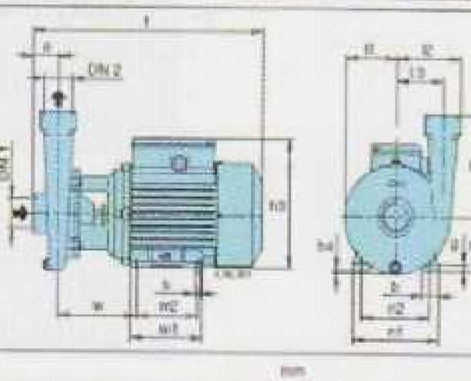


TYPE	kg
C 16/1E	5,2
CM 16/1E	5,2

TYPE	kg
B-C 16/1E	5,6
B-CM 16/1E	5,6



TYPE	mm h2	h4	l1	l2	l3	kg C	kg CM
C 20E	90	5	67	82	60	6,6	6,8
C 22/1E - C 22E	110	17	77	94	71	8 - 8,5	8 - 8,5



TYPE		DN1 ISO 228	DN2 ISO 228	a	f	h1	h2	h3	h4	m1	m2	n1	n2	b	s	l1	l2	l3	w	[illegible]	kg C	kg CM	kg B-C	kg B-CM
–	B-C 20/A	G 1	G 1	35	303	71	90	162	–	106	90	134	112	22	7	70	84	60	105	10	–	–	8,1	8,1
– –	B-C 22/1/A B-C 22/A	G 1	G 1	35	303	71	110	182	9	106	90	134	112	22	7	81	93	71	106	10	–	–	9,3 9,6	10,3 10,6
C 4/1/A C 4/A	– –	G 1¼	G 1¼	43	304	71	160	182	18	106	90	134	112	22	7	86	108	78	100	10	10,8 11,8	11,6 12,8	– –	– –
– C 41E	B-C 41/1E B-C 41E	G 1¼	G 1¼	43	360	80	180	208	9	125	100	155	125	30	9,5	86	108	78	132	10	– 18,5	– 19,3	18,3 19,2	17,9 20,1

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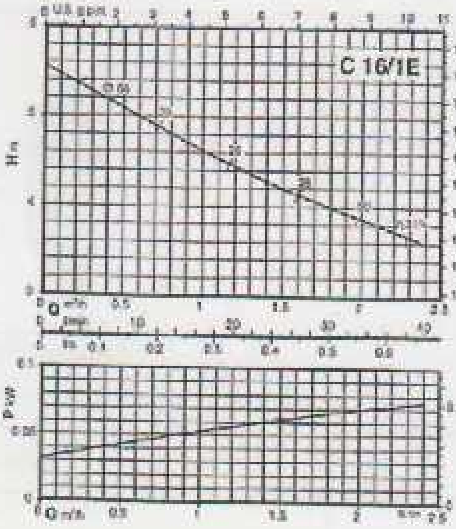
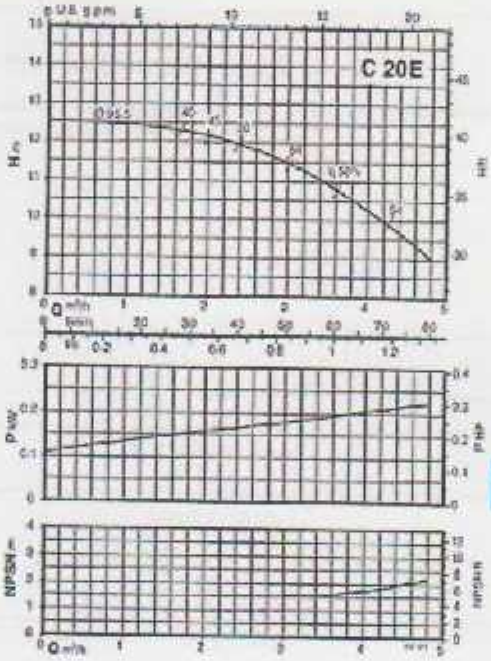
Characteristic curves n ≈ 2900 rpm





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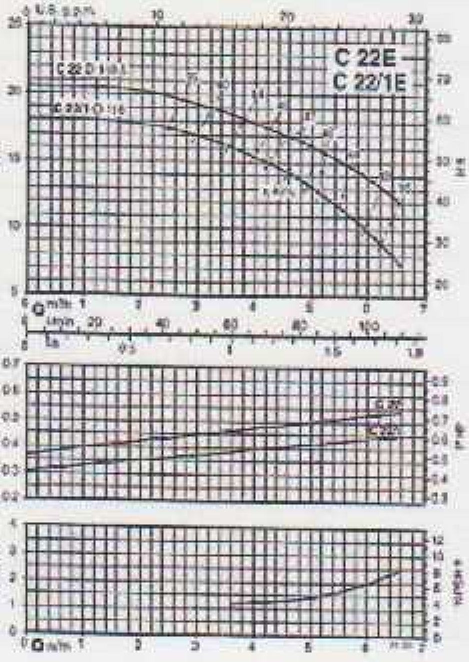

Pressure sensor:

Telemecanique Sensors
1875 Founders Drive
Dayton, OH 45420-1017
Toll Free: (800) 435-2121 • Phone: (937) 252-2121 • Fax: (937) 259-5830
E-Mail: hydepark@us.schneider-electric.com • Web site: www.sasensors.com

Item # XMLG001D21, IEC OsiSense Electronic Pressure Sensor - XMLG

List Price QUOTE

IEC OsiSense Electronic Pressure Sensor - XMLG

XMLG, rated 0 to 14.5 psi, stainless steel with M12 Electrical Connector, 4 - 20 mA Analog output, and G 1/14A (BSP Male) Fluid connection, 22.8mm diameter, sold individually

SPECIFICATIONS

Pressure Range	0 - 14.5 psi (0 to 1 bar)
Output	Analog, 4 - 20 mA
Electrical Connection	M12
Differential	n/a
Fluid Connection	G 1/4A (BSP male)
Enclosure Rating	IP65, IP67 conforms to IEC/EN 60529, NEMA 4
Actuator Type	Ceramic Cell
Fluid Characteristics	Hydraulic Oils, air, fresh water, sea water, corrosive fluids
Max Allowable Pressure	39.1 psi
Rated Supply Voltage	12 / 24 V
Voltage Limits	8 - 33 V
Current Consumption	< 20 mA
Ambient Air Temperature for Operation	5 to 185°F (-15 to +85°C)
Materials in contact w/fluid	Ceramic Al2O3, SS AISI 303, Viton® FPM, PPS

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Vibration Resistance	20 gn (9 - 2000 Hz) conforming to IEC 60068-2-6
Shock Resistance	25 gn (half sine wave 11 ms) conforms to IEC 60068-2-27)
Output Response Time	< 2 ms
Drift	±
Repeat Accuracy	±0.1% of the measuring range
RoHS	Yes
Weight	.21 lb
Certifications	UL / CSA / CE

Level liquid controller:

ke – SKR

LIQUID LEVEL CONTROL RELAY

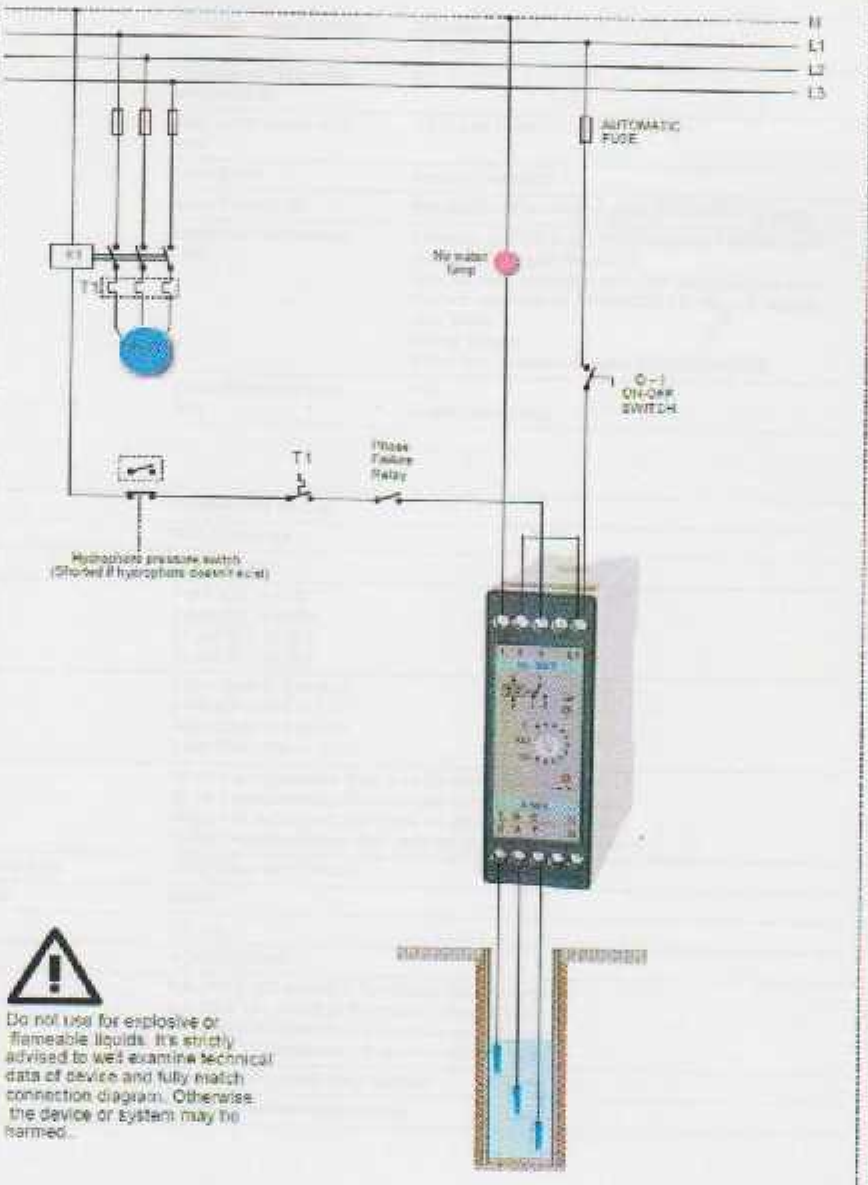
► 5 – 100 KΩ Sensitivity Adj.

KAEL

General :

Three electrodes are connected to the "T","B" and "E" terminals.
When the liquid level reaches the upper level electrode (T) then the relay energizes its contacts to turn on the pump.
When the liquid level reaches the bottom level electrode (B) then the relay de-energizes its contact and turns the pump off.
Sensitivity (impedance between electrodes) can be adjusted in the range of 5-100 KΩ using the knob on the front side of the relay.

- the upper level electrode : Top (T)
- the bottom level electrode : Bottom (B)
- the earth electrode : Earth (E)



TECHNICAL DATA:

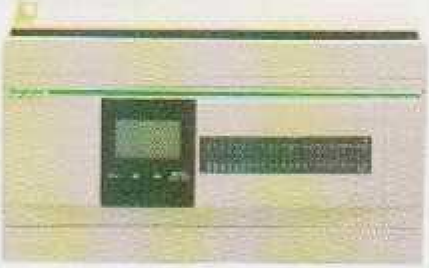
Operational Voltage (Un)	
L1 – N terminals	: 220 Vac
Operating Range	: (0.8 – 1.1)x Un (Un nominal voltage)
Frequency	: 50 Hz
Sensitivity	: 5-100 KΩ adjustable
Contact Current	: Max. 5 A / 240 VAC
Power Consumption	: < 4 VA
Device Protection Class	: IP20
Connector Protection Class	: IP00
Ambient Temperature	: -5°C ... +50°C
Connection Type	: To connection rail in electrical panel
Dimensions	: 26x82x60 mm

Do not use for explosive or flameable liquids. It's strictly advised to well examine technical data of device and fully match connection diagram. Otherwise the device or system may be harmed.

Schneider PLC "twido":

Product data sheet
Characteristics

TWDLCAE40DRF
compact PLC base Twido - 100..240 V AC supply - 24 I 24 V DC - 16 O



Main

Range of product	Twido
Product or component type	Compact base controller
Discrete I/O number	40
Discrete input number	24
Discrete input voltage	24 V
Discrete input voltage type	DC
Discrete output number	2 transistor 14 relay
Number of I/O expansion module	7
[Us] rated supply voltage	100...240 V AC
Use of slot	Memory cartridge
Data backed up	Internal RAM external battery TSXPLP01 3 years
Integrated connection type	Ethernet TCP/IP RJ45 10/100 Mbit/s 1 twisted pair transparent ready class A10 Non isolated serial link mini DIN Modbus/character mode master/slave RTU/ASCII RS485 half duplex 38.4 kbit/s Power supply Serial link interface adaptor RS232C/RS485
Complementary function	PID Event processing

Complementary

Concept	Transparent Ready
Discrete input logic	Sink or source
Input voltage limits	20.4...26.4 V
Discrete input current	7 mA I0.2 to I0.5 7 mA I0.8 to I0.23 11 mA I0.0 to I0.1 11 mA I0.5 to I0.7
Input impedance	2100 Ohm I0.0 to I0.1 2100 Ohm I0.6 to I0.7 3400 Ohm I0.2 to I0.5 3400 Ohm I0.8 to I0.23
Filter time	35 µs + programmed filter time for I0.0 to I0.5 at state 1 40 µs + programmed filter time for I0.0 to I0.5 at state 0 40 µs + programmed filter time for I0.6 to I0.23 at state 1 150 µs + programmed filter time for I0.6 to I0.23 at state 0
Insulation between channel and internal logic	1500 Vrms for 1 minute
Insulation resistance between channel	None
Minimum load	0.1 mA
Contact resistance	≤ 30000 µOhm
Load current	2 A 240 V AC resistive 30 cyc/mn relay outputs 2 A 30 V DC resistive 30 cyc/mn relay outputs 2 A 240 V AC inductive 30 cyc/mn relay outputs 2 A 30 V DC inductive 30 cyc/mn relay outputs
Mechanical durability	≥ 20000000 cycles relay outputs
Electrical durability	≥ 100000 cycles relay outputs

Current consumption	5 mA 24 V DC at state 0 90 mA 5 V DC at state 1 128 mA 24 V DC at state 1 128 mA 24 V DC state 1 + input ON 170 mA 5 V DC at state 0 240 mA 5 V DC state 1 + input ON
I/O connection	Non-removable screw terminal block
Input/Output number	≤ 152 removable screw terminal block with I/O expansion module ≤ 208 spring terminal block with I/O expansion module ≤ 264 HE-10 connector with I/O expansion module
Network frequency	50/60 Hz
Supply voltage limits	85...264 V
Network frequency limits	47...63 Hz
Power supply output current	0.4 A 24 V DC sensors
Power supply input current	790 mA
Inrush current	≤ 35 A
Protection type	Power protection internal fuse
Power consumption in VA	65 VA 100 V 77 VA 264 V
Insulation resistance	> 10 MOhm at 500 V, between supply and earth terminals > 10 MOhm at 500 V, between I/O and earth terminals
Program memory	3000 instructions
Exact time for 1 K instruction	1 ms
System overhead	0.5 ms
Memory description	Internal RAM 256 internal bits, no floating, no trigonometrical Internal RAM 3000 internal words, no floating, no trigonometrical Internal RAM 128 timers, no floating, no trigonometrical Internal RAM 128 counters, no floating, no trigonometrical Internal RAM double words, no floating, no trigonometrical Internal RAM floating, trigonometrical
Free slots	1
Realtime clock	With <= 30 s/month 30 days
Port Ethernet	10BASE-T/100BASE-TX
Communication service	BOOTP client Ethernet TCP/IP Modbus messaging Ethernet TCP/IP
Positioning functions	PWM/PLS 2.7 kHz
Counting input number	2 20000 Hz 32 bits 4 5000 Hz 16 bits
Analogue adjustment points	1 point adjustable from 0...1023 1 point adjustable from 0 to 511 points
Marking	CE
Status LED	1 LED green PWR 1 LED green RUN 1 LED red module error (ERR) 1 LED user pilot light (STAT) 1 LED Ethernet status (LAN ST) 1 LED 10 or 100 Mbits rate (LACT) 1 LED per channel green I/O status
Product weight	0.525 kg

Environment

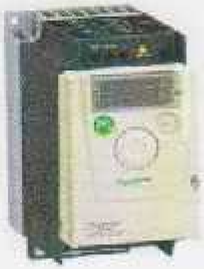
Immunity to microbreaks	10 ms
Dielectric strength	1500 V for 1 minute, between supply and earth terminals 1500 V for 1 minute, between I/O and earth terminals
Product certifications	CSA UL
Ambient air temperature for operation	0...55 °C
Ambient air temperature for storage	-25...70 °C
Relative humidity	30...95 % without condensation
IP degree of protection	IP20
Operating altitude	0...2000 m
Storage altitude	0...3000 m

Altivar 12 "inverter":

Product data sheet
Characteristics

ATV12H075M2

variable speed drive ATV12 - 0.75kW - 1hp - 200..240V - 1ph - with heat sink



Main

Commercial Status	Commercialised
Range of product	Altivar 12
Product or component type	Variable speed drive
Product destination	Asynchronous motors
Product specific application	Simple machine
Assembly style	With heat sink
Component name	ATV12
Quantity per set	Set of 1
EMC filter	Integrated
Built-in fan	Without
Network number of phases	Single phase
[Us] rated supply voltage	200...240 V (- 15...10 %)
Motor power kW	0.75 kW
Motor power hp	1 hp
Communication port protocol	Modbus
Line current	8.5 A at 240 V 10.2 A at 200 V
Speed range	1...20
Transient overtorque	150...170 % of nominal motor torque depending on drive rating and type of motor
Asynchronous motor control profile	Quadratic voltage/frequency ratio Sensorless flux vector control Voltage/Frequency ratio (V/f)
IP degree of protection	IP20 without blanking plate on upper part
Noise level	0 dB

Complementary

Supply frequency	50/60 Hz (+/- 5 %)
Type of connector	1 RJ45 for Modbus on front face
Physical interface	2-wire RS 485 for Modbus
Transmission frame	RTU for Modbus
Transmission rate	38400 bit/s 19200 bit/s 9600 bit/s 4800 bit/s
Number of addresses	1...247 for Modbus
Communication service	Read device identification (43) Read/Write multiple registers (23), messaging: 4/4 words maximum Write multiple registers (16), messaging: 27 words maximum Write single register (06), messaging: 29 words maximum Read holding registers (03), messaging: 29 words maximum
Prospective line Isc	<= 1 kA
Continuous output current	4.2 A at 4 kHz
Maximum transient current	6.3 A for 60 s
Speed drive output frequency	0.5...400 Hz
Nominal switching frequency	4 kHz

Switching frequency	4...16 kHz with derating factor 2...16 kHz adjustable
Braking torque	Upto 70 % of nominal motor torque without braking resistor Upto 150 % of nominal motor torque with braking resistor at high inertia
Motor slip compensation	Adjustable Preset in factory
Electrical connection	L1, L2, L3, U, V, W, PA, PC terminal 3.5 mm² (AWG 12)
Tightening torque	0.8 N.m
Insulation	Electrical between power and control
Supply	Internal supply for logic inputs 24 V DC, voltage limits 20.4...28.8 V 100 mA for overload and short-circuit protection Internal supply for reference potentiometer 5 V DC, voltage limits 4.75...5.25 V 10 mA for overload and short-circuit protection
Analogue input number	1
Analogue input type	AI1 configurable voltage 0...5 V, impedance 30 kOhm AI1 configurable voltage 0...10 V, impedance 30 kOhm AI1 configurable current 0...20 mA, impedance 250 Ohm
Discrete input number	4
Discrete input type	(LI1...LI4) programmable, 24 V, voltage limits 18...30 V
Discrete input logic	Positive logic (source), 0...< 5 V (state 0), > 11 V (state 1) Negative logic (sink), > 16 V (state 0), < 10 V (state 1), input impedance 3.5 kOhm
Sampling duration	< 20 ms, tolerance +/- 1 ms for logic input < 10 ms for analogue input
Linearity error	+/- 0.3 % of maximum value for analogue input
Analogue output number	1
Analogue output type	(AO1) software-configurable current, analogue output range 0...20 mA, output impedance 800 Ohm, analogue output resolution 8 bits (AO1) software-configurable voltage, analogue output range 0...10 V, output impedance 470 Ohm, analogue output resolution 8 bits
Discrete output number	2
Discrete output type	(R1A, R1B, R1C) protected relay output 1 C/O (LO+, LO-) logic output
Minimum switching current	5 mA at 24 V DC for logic relay
Maximum switching current	4 A at 30 V DC resistive load cos phi = 1 L/R = 0 ms for logic relay 3 A at 250 V AC resistive load cos phi = 1 L/R = 0 ms for logic relay 2 A at 30 V DC inductive load cos phi = 0.4 L/R = 7 ms for logic relay 2 A at 250 V AC inductive load cos phi = 0.4 L/R = 7 ms for logic relay
Acceleration and deceleration ramps	Linear from 0 to 999.9 s S U
Braking to standstill	By DC injection, 0.1...30 s
Protection type	Thermal motor protection via the drive by continuous calculation of I²t Against input phase loss in three-phase Short-circuit between motor phases Overheating protection Overcurrent between output phases and earth Line supply undervoltage Line supply overvoltage
Frequency resolution	Display unit 0.1 Hz Analog input converter A/D, 10 bits
Time constant	20 ms, tolerance +/- 1 ms for reference change
Marking	CE
Operating position	Vertical +/- 10 degree
Height	143 mm
Width	72 mm
Depth	131.2 mm
Product weight	0.8 kg