كلية الدراسات العليا

Sudan University of Science and Technology

College of Graduate Studies

جامعة السودان للعلوم والتكنولوجيا

Design and simulation of a control system for a center pivot irrigation device

تصميم ونمذجة نظام تحكم لجهاز ري مركزي محوري

Al thesis submitted in partial fulfillment of the requirement for the degree of Master of Science in mechatronics engineering

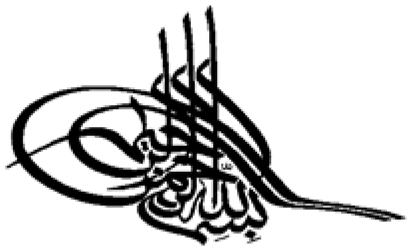
By

Waleed Elhag Elbasheer Babiker

Supervisor

Dr. Abdel Fattah Bilal Abdel Salam

November 2018



قال تعالى: **(إِنَّ فِي خَلْقِ السَّمَاوَاتِ وَالْأَرْضِ وَاخْتِلَافِ اللَّيْلِ وَالنَّهَارِ لَآيَاتٍ لِّأُولِي الْأَلْبَابِ * الَّذِينَ يَذْكُرُونَ اللَّهَ قِيَامًا وَقُعُودًا وَعَلَىٰ جُنُوبِهِمْ وَيَتَفَكَّرُونَ فِي خَلْقِ السَّمَاوَاتِ وَالْأَرْضِ رَبَّنَا مَا خَلَقْتَ هَٰذَا بَاطِلًا سُبْحَانَكَ فَقِنَا عَذَابَ النَّارِ).**

ســورة آل عمـــران

الأيات (190 – 191)

Dedication

To the utmost knowledge lighthouse to our greatest and most honored prophet Mohamed - May peace and grace from Allah be upon him

To the spring that never stops giving, to my mother who weaves my happiness with strings from her merciful heart... to my mother.

To whom he strives to bless comfort and welfare and never stints what he owns to push me in the success way who taught me to promote life stairs wisely and patiently, to my dearest father

To whose love flows in my veins, and my heart always remembers them, to my brothers and sisters.

To those who taught us letters of gold and words of jewel of the utmost and sweetest sentences in the whole knowledge. Who reworded to us their knowledge simply and from their thoughts made a lighthouse guides us through the knowledge and success path, to our honored teachers and professors.

Acknowledgment

I wish to express my thanks and be grateful for the helpful assistance and advice of Dr Abdel Fattah Abdel Salam Bilal

My thanks and appreciation to all the teaching staff of the college of graduate studies Sudan University of science and technology.

My thanks and appreciation to everyone who helped and encouraged my effort.

Abstract

In the agricultural projects that use the center pivot irrigation system, which depends on the groundwater wells as a source of water using turbine pumps, which are actuated by internal combustion engines, the suspension of the center pivot irrigation device on the movement when a malfunction occurs with its continuous flow of water is a big problem and waste water, fuel and time, It also damages some crops that are heavily affected by water,this research studies the design of an automatic clutch system instead of the manual clutch that used to actuate center pivot irrigation pumps, two circuits were designed the first circuit is a hydraulic circuit connected with the hand leaver of clutch and the second circuit is to control of the speed of internal combustion engine and hydraulic circuit, when a malfunction occurs in center pivot irrigation device, the control circuit received a signal from safety circuit and transmitted signal to reduce a speed of internal combustion engine and actuate a hydraulic circuit to unengaged a water pump and then shut down the internal combustion engine and there for ensuring from safety of cultivated crops and not wasting water, time and fuel.

التجريد

في المشاريع الزراعية التي تستخدم نظام الري المحوري والتي تعتمد علي الآبار الجوفيه كمصدر للمياه بإستخدام طلمبات توربينيه والتي تدار بواسطة ماكينات الاحتراق الداخلي تعتبر مشكلة توقف جهاز الري المحوري عن الحركة عند حدوث عطل ما مع إستمراريه تدفق المياه مشكله كبيره وهدر للمياه والوقود والوقت كما يحدث ضرارا لبعض المحاصيل المزروعه التي تتاثر بكثرة المياه ، هذا البحث يدرس تصميم نظام قابض آلي بدلا عن القابض العادي المستخدم في إدارة طلمبات الري المحوري، تم تصميم دائرتين الأولى هيدروليكية توصل مع ذراع القابض والثانيه للتحكم في سرعة ماكينة الاحتراق الداخلي والدائره الهيدروليكية فعند حدوث عطل في جهاز المحوري يتوقف عن الحركة وتصل إشارة لدائرة التحكم حيث يتم تخفيض سرعة الماكينة وتشغيل الدائره الهيدروليكية لإيقاف الماكينة عن العمل تتابعا وبالتالـــي الحفـاظ علي سلامـــة المحاصيـــل الزراعة وعدم هدر الماء والوقت والوقود.

Table of contents

List of Figures

Chapter one
introduction

Chapter one

Introduction

1.1 General Introduction:

The term 'Center pivot irrigation ' as it applies to the area of agriculture can be defined as a self-propelled irrigation system in which a single pipeline supported on towers rotates around a central point. These systems are typically about one-quarter mile long and serve 128 to 132 acre circular fields [1], in global agricultural farms water plants are used instead of using individual wells for each pivot irrigation device and be a source of water from rivers and is the connection between the central station and irrigation devices by pipeline to transport water in certain diameter and certain speed according to the amount of water required , Sudan is using underground wells as a source of water and any pivot device required separated wells and to extract water from this well using a turbine pump, this pump connected with the main machine with a shaft uses a clutch device to connect and disconnect the shaft between special gearbox of pump and machine, this machine also supply electricity to pivot irrigation device connects with a generator to produce electrical energy

1.2 Problem statement:

Pivot irrigation device consists of several towers that contain classic control units to control the rotation of pivot irrigation device and protect it from destruction, if any malfunction in one of the towers occurs, the electrical circuit will be separated from the device by a safety circuit

When unplugging the device if a malfunction occurs during the irrigation process, the device stop moving and a water pump still working because a water pump connected with a machine by a shaft and power take off clutch, this clutch unengaged manually by moving hand leaver of clutch by hand . When this a malfunction occurs without observing, there are some problems will be generated like a damaging cultivated plant , the sinking of cultivated field and there for inability to harvest due to the concentration of water in a specific area of the field or is unable to irrigate the rest of the field. There is also a waste of fuel, as there is no need to use the machine when the pivot irrigation device fails, also the machine consumes 50 liters of fuel per hour

1.3 Research idea:

To solve this problem, it's needed to control the hydraulic system by a microcontroller which receive a signals from the safety circuit in center pivot irrigation system

When a malfunction occurs, center pivot irrigation device stops the movement and send a signal from the safety circuit to a microcontroller to reduce the speed of the machine to ideal speed (600_800 rpm), which enables us to unengaged the pump, then the hydraulic unit separates the pump, and shut down the internal combustion engine

1.4 Objectives:

- The main objective of the project is to design and simulation a control system which uses a microcontroller and a hydraulic unit to convert a clutch from manual to automatic

This is done through:

I. Using microcontroller received a signal from a safety circuit in center pivot irrigation device.

II. A microcontroller transmitted a signal to the computer of internal combustion engine, which will control the speed of the machine when any malfunction in center pivot irrigation device and shut down the machine.

III. Using simulation to represent a control system.

Chapter tow
Literature Review

Chapter tow

Literature Review

2.1 Center Pivot Overview:

The center pivot system consists of one single sprayer or sprinkler pipeline of relatively large diameter, composed of high tensile galvanized light steel or aluminum pipes supported above ground by towers move on wheels, long spans, steel trusses and/or cables (Figure 10.1). One end of the line is connected to a pivot mechanism at the center of the command area; the entire line rotates about the pivot. The application rate of the water emitters varies from lower values near the pivot to higher ones towards the outer end by the use of small and large nozzles along the line accordingly.

The center pivot (CP) is a low/medium pressure fully mechanized automated irrigation system of permanent assemble. It has become very popular in the Near East region in recent years for irrigation of most of field crops, cereals, legumes, forage and vegetables. It is also used for supplementary irrigation for rain fed grain. The cost of each system unit is relatively high and is therefore best suited to large irrigated farms. The area covered can be from 3.5 ha to 60 ha, according to the size of the CP, and the larger the area the lower is the cost of the system per unit area.

Center pivots are well-engineered structures that effectively deliver water to large circular fields each has a main water delivery pipe suspended over the field out of the way of the crops. Sprinklers or spray nozzles can be spaced along that pipe to apply water wherever the pipe is traveling. At each tower, pipe sections are connected with flexible joints that allow the pipe to move through a limited range without twisting or breaking. This flexibility also allows vertical bending that enables pivots to climb moderate hilly slopes.[2]

2.2. Advantages of Center Pivot Systems

Center pivot systems offer many advantages over other irrigation application methods:

- Potential for automated operation, reducing labor costs
- Simplified and predictable water delivery
- Ability to apply to more shallow depths
- Uniform distribution of water
- Increased ability to plan and schedule irrigation applications
- Easier to apply agri-chemicals (chemigation)
- Little annual setup required
- Reliability

2.3. Disadvantages of center pivot systems include:

- Relatively high initial cost
- Relatively high pipe-friction losses
- Circular pattern leaves dry corners and potentially lower yield
- Topographic changes cause potential operating pressure variations
- Can have operational challenges requiring human interventions
- Potential risk for injury if the operator is not familiar with operation

2.4 Structure of Center pivot irrigation device:

Center pivot irrigation device consist into mechanical structure and electrical component

2.4.1 Mechanical Structure:

The Basic and the Center Pivot System is a combination of a Pivot, Span(s), Span Joint(s), Tower(s), and optional End Boom.

2.4.1.1 Pivot:

The Pivot is the device the Center Pivot System rotates around. The Standard Pivot consists of a Center Pivot Bearing Assembly supported by Legs anchored to a concrete base. Water enters the Pivot from either a bottom elbow or pipe at the base of the Pivot. Then it is conveyed upward through the Riser Pipe and Center Pivot Bearing Assembly out to the first Span. The Basic Pivot is further detailed in figure (2-1) [1]

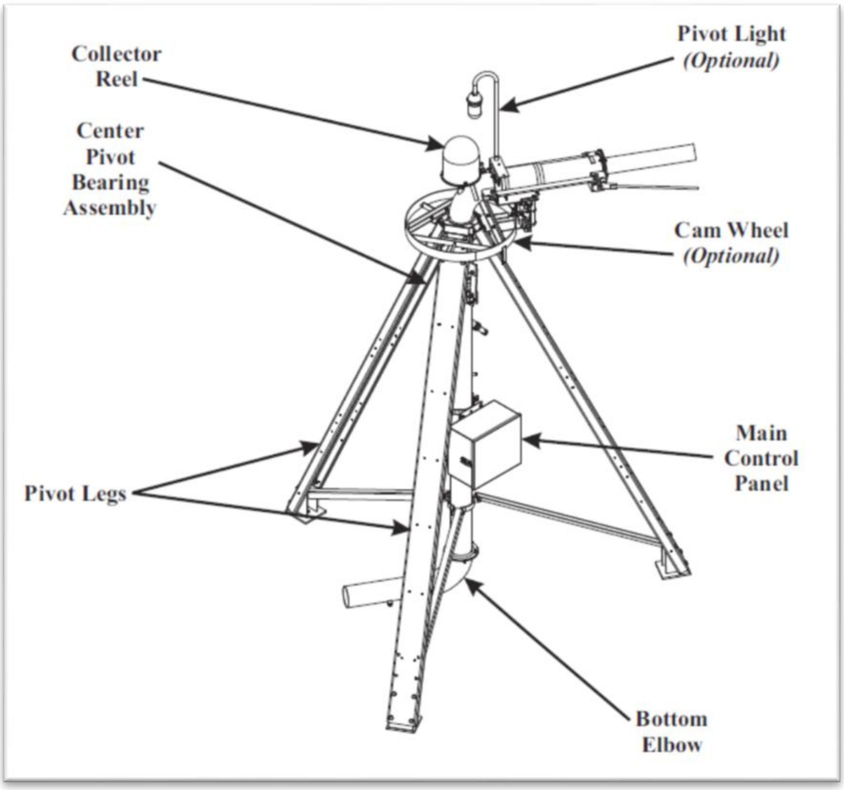


Figure (2-1) pivot component in center pivot device [1]

2.4.1.2 Spans:

After water leaves the Pivot, it travels across the field through a series of suspended pipelines called Spans see figure (2-2). each span Consist of 4-1/2” diameter pipe and lengths from 80’to 194’. To resist corrosion, each System is custom designed with Galvanized Steel Pipe. As indicated below, the Pipe is supported by Galvanized Under trussing which consists of Truss Rods, Span Struts, Truss Braces, and Tower Stiffeners. [1]

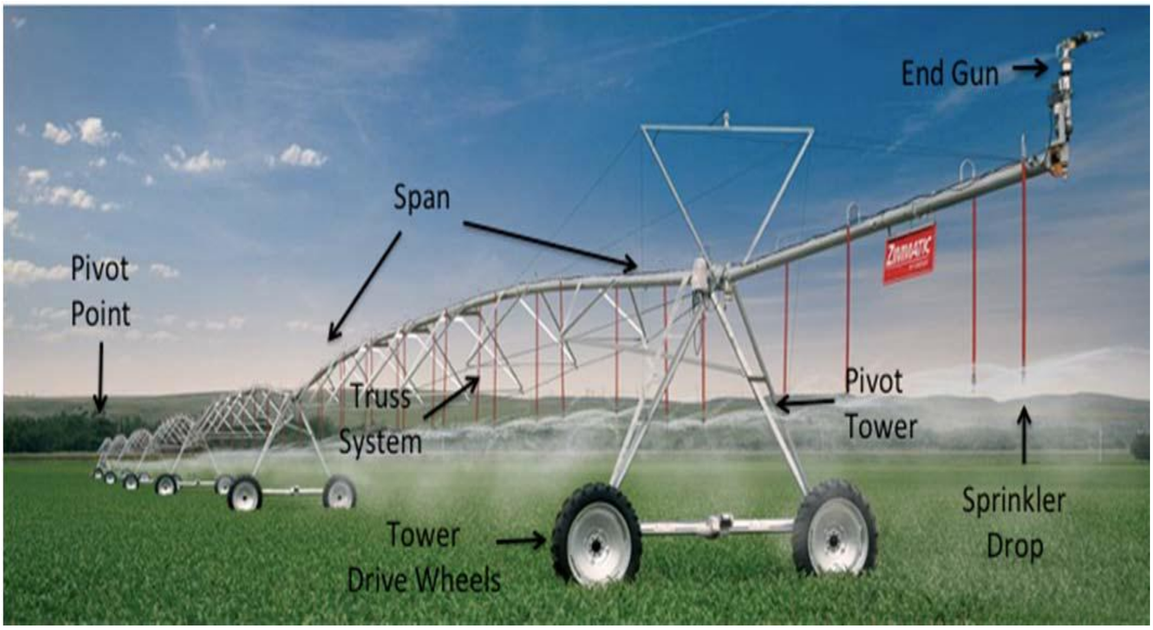


Figure (2-2) span component in center pivot device

2.4.1.3 Span Joints

The Span Internal Flex Joint consists of a Receiver (Tower Top) and Hook. The Hook connects to the Receiver inside a Boot supported by T Bolt Clamps. The Internal Span Flex Joint is a critical part of the flexibility and strength of a pivot System.in the span joint shown in Figure (2-3) the internal flex joint allows unrestricted movement of the span up to 24% differential change in grade. Three axis flexibility with center line rotation reduces structural stress and provides extended boot life by minimizing stress on the boot material. [1]

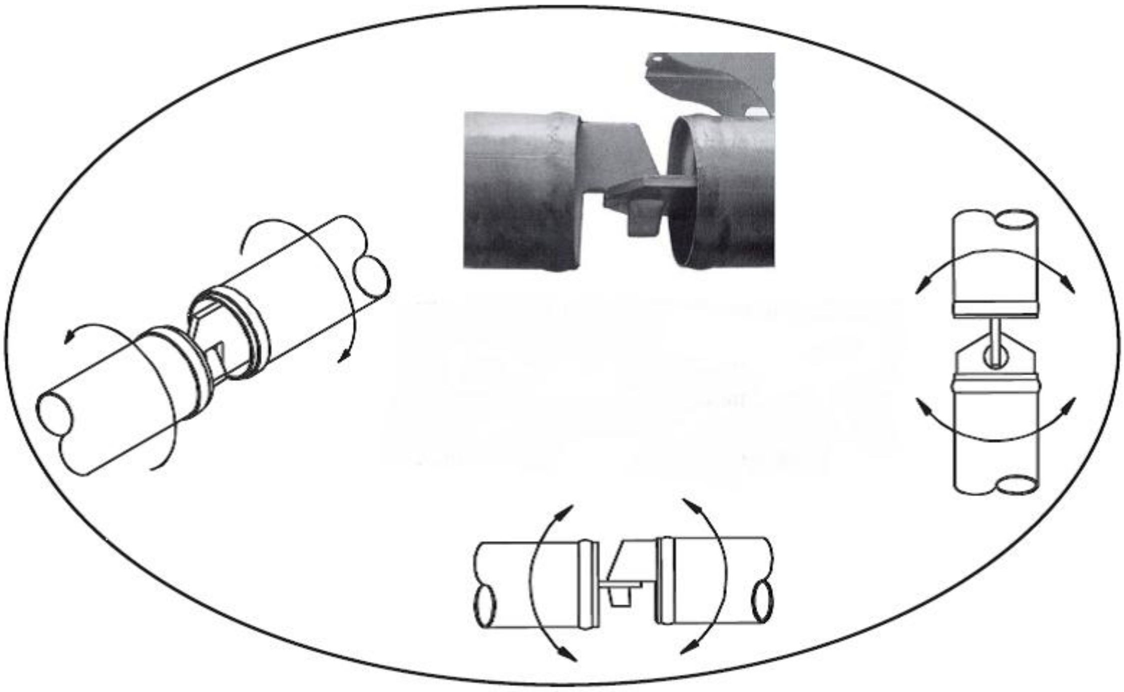


Figure (2-3) span joint [1]

2.4.1.4 Towers

A Tower is attached to the end of each Span. A Tower contains all the necessary components for the movement, alignment, and support of the entire System. The Single-Leg Tower design is durable and flexible. Engineered to absorb stress that would normally be transferred to the pipeline, the Tower design maximizes System Life and reduces component fatigue. The Tower Components are illustrated in figure (2-4). [1]

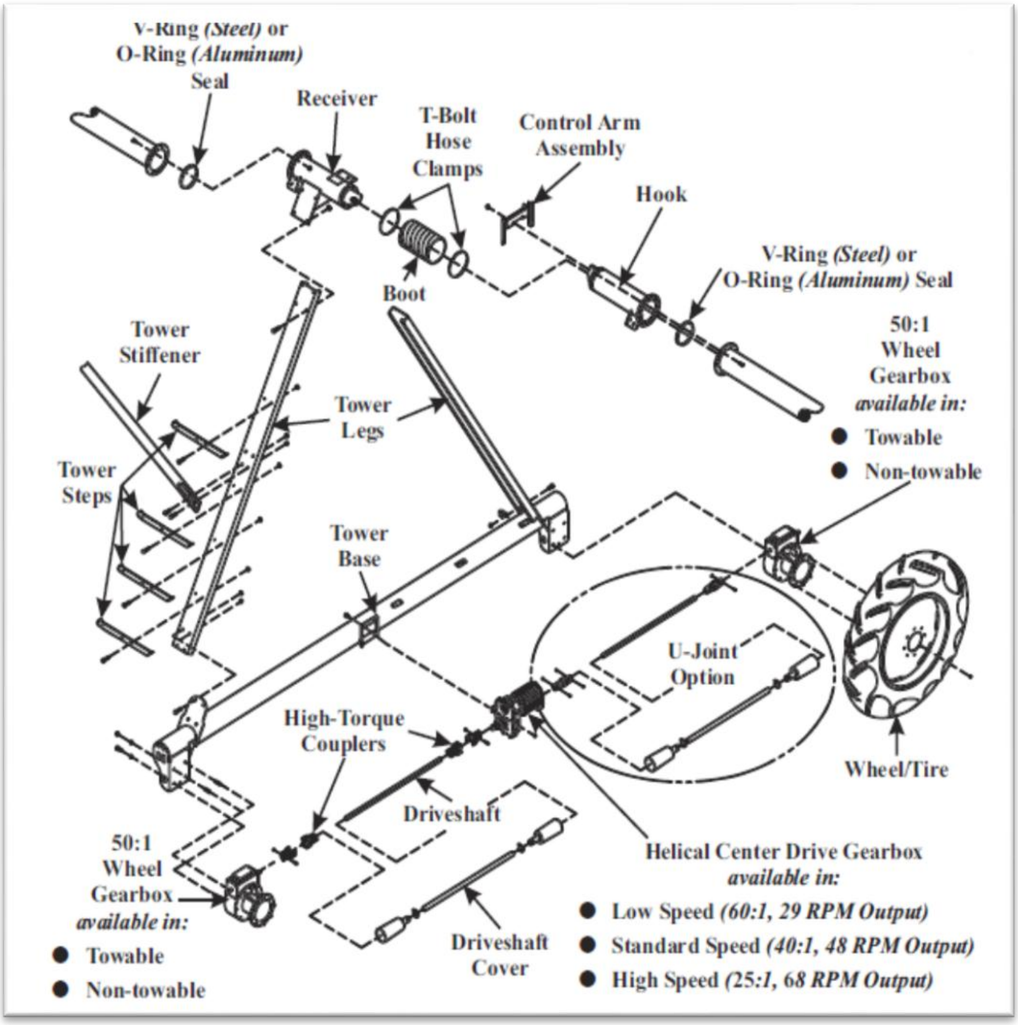


Figure (2-4) tower component [1]

2.4.1.5 End Boom (Optional)

The End Boom is the suspended pipeline beyond the Last Tower see figure (2-5). End Boom lengths vary from 3'to 42'with pipe diameters ranging from 3" to 4-1/2". End Booms can be outfitted with many options including a wide variety of End Guns and Booster Pumps. [1]

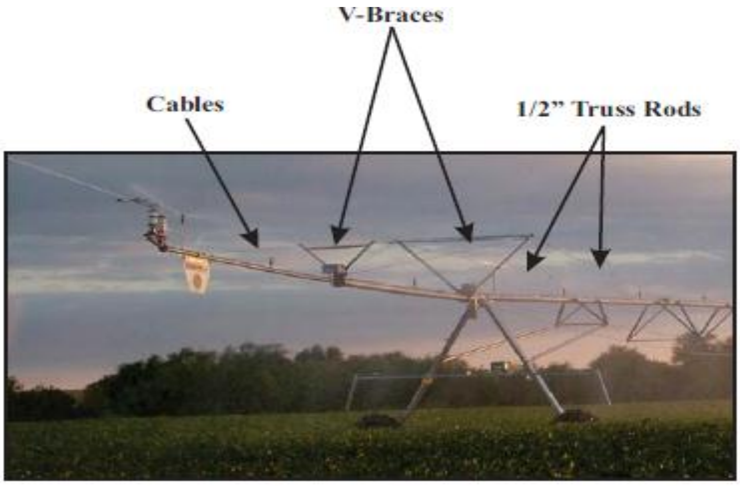


Figure (2-5) end gun boom

2.4.2 Electrical Structure

Center Pivot Electrical Structure is comprised of a Main Control Panel, Collector Reel, Span Cables, and various Control Boxes

2.4.2.1 Main Control Panel

The Main Control Panel is the operations center of the Center Pivot System. Normally, the Main Control Panel is located at the Pivot Center, but it can be remotely mounted at the edge of the field. The Main Control Panel must be supplied with either 480V, 3Phase, or 240V, 1 Phase, AC power from utility power lines, engine-driven generators, or phase convertors. A120VAC Transformer inside the Main Control Panel supplies the 120V Control Power. The Control Panel provides the required control functions for System operation [1].

2.4.2.2 Collector Reel

From the Main Control Panel, the power cable is routed up through a J-Pipe in the Pivot Riser Pipe to the Collector Reel. This device allows the Span Cable to swivel at the Pivot and not wrap around the Pivot. The Collector Reel consists of stacked, insulated brass rings that remain stationary and are separated by insulators see figure (2-6). The brushes of the Collector Reel revolve around the brass rings to provide a continuous electrical circuit without twisting the cable as the System makes revolutions around the field. [1]

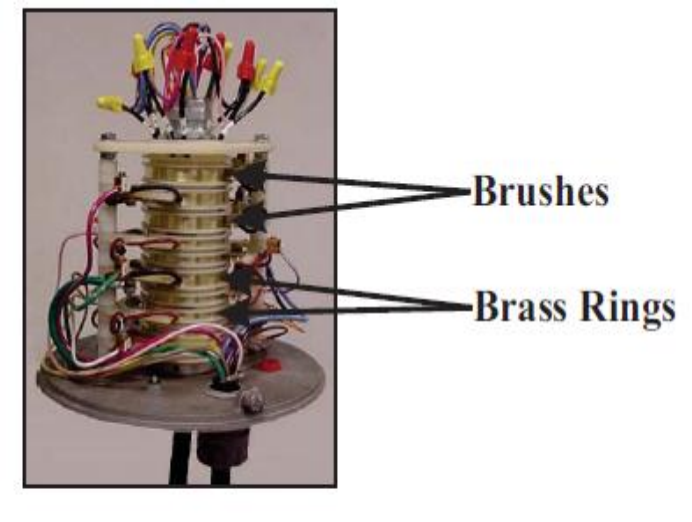


Figure (2-6) collector reel

2.4.2.3 Tower Boxes

The Span Cable leaves the Collector Reel and runs the entire length of the System through the various Tower Boxes. The Span Cable carries 120VACand either 480VACor 240VACto each Tower Box. The 120VAC is the control voltage while the 480VACor 240VACpowers the Center Drives. There are three basic Tower Boxes figure (2-7). The “C” Box is located at the End Tower. The “B” Box is located at the next to last Tower. The “A” Boxes are located on all Intermediate Towers. [1]

A-Box

B-Box

C-Box

Figure (2-7) show three kind of tower box

2.4.2.4 Alignment Circuit

The Alignment Circuit is a parallel circuit that determines when a Tower is to move. The Percent Timer, PAC Timer, controls *(optional)* the End Tower. As the End Tower moves, all the other Towers move to keep “in-line” or maintain alignment with the End Tower. For example, if the Percent Timer, is set at 100%, then the End Tower would run all the time and all the Intermediate Towers will move to keep “in-line” or maintain alignment with the End Tower. However, the slower the System runs, the more water that is applied. Therefore, if the Percent Timer is set at 50%, then the End Tower would only run 30 seconds out of each minute or 50% of the time and all the Intermediate Towers will move to keep “in-line” or maintain alignment with the End Tower.

To maintain alignment with the End Tower, each Intermediate Tower has a Control Yoke fastened to the bottom of the Tower Box and a Control Arm mounted at the joint of the Hook and first Water Pipe on the Span.

Between the Control Yoke and Arm, Control Rods are placed to allow the Yoke to operate as the Hook and Receiver Joint flexes see figure (2-8). The Control Yoke rotates under the Tower Box operating a set of Cams. These Cams operate the Alignment and Safety Micro switches in the Tower Box. When the Control Yoke rotates on the Next to End Tower (caused when the End Tower moves), the Cam activates the Alignment Micro switch. This causes the Tower Contactor to engage and sends 480 VAC power to the Tower Center Drive Motor. The Next to End Tower will run for a period of time until it moves "in-line" with the End Tower. All Towers to the inside of the Next to End Tower will move respectively. As a result, any Tower can be moving at any given time, depending on whether or not the Control Assembly senses movement in the angular difference in relation to the next outer adjacent Span. [3]

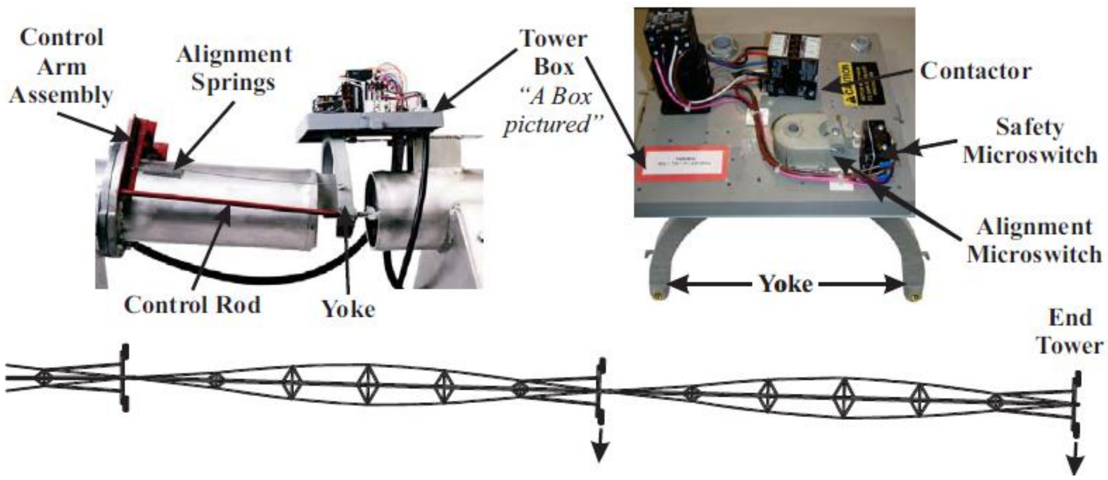


Figure (2-8) alignment circuit [3]

2.4.2.5 Safety Circuit

The Safety Circuit is a series circuit which carries the neutral for the Reversing Contactors in the Main Control Panel. The Safety Circuit travels out to the Last Tower and returns through a series of Tower Box Safety Micro switches see figure (2-9). If for any reason a Tower does not move, or if it runs too far ahead, the Cam will open the Safety Micro switch and cause the System to shut down. In the Next to Last Tower (B-Box), the Safety Circuit runs through the Overwatering Timer. In the event the Next to Last Tower doesn't move for a factory preset 20 minutes, the Over Watering Timer will open the Safety Circuit and shut the System down. Once the Next to Last Tower moves, the Overwatering Timer is reset. [3]

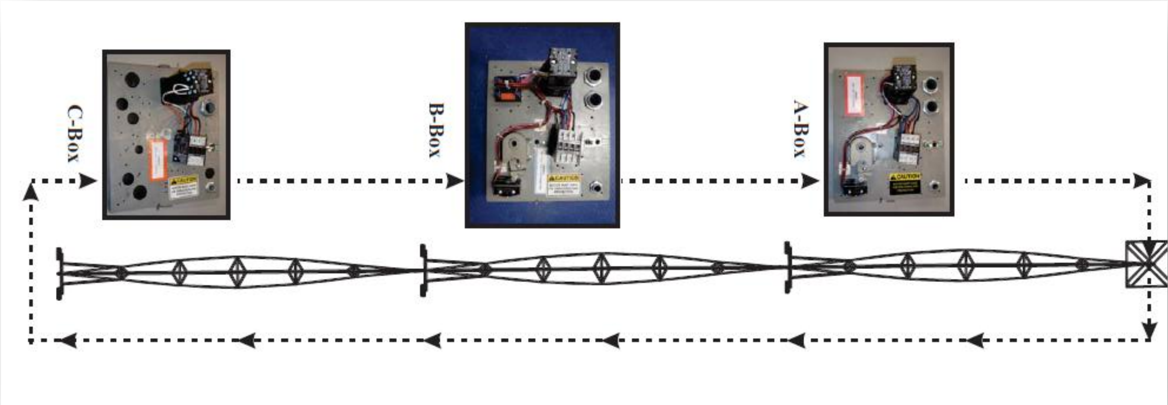


Figure (2-9) safety circuit in center pivot system [3]

2.5 Power units

The power unit on an irrigation system must supply power to lift water and deliver pressure at the desired flow rate to the irrigation delivery system. Common irrigation power units include electric motors and stationary internal combustion engines. The power unit must be matched to the irrigation pump requirements to achieve an efficient operation. An engine or motor that is too small cannot deliver the water at the rate and/or pressure required by the irrigation system. An engine or motor that is too large may be inefficient and have excessive initial and operating costs because of the unused capacity. An irrigation load is relatively constant, so the power unit must be suitable for continuous duty at the design load. Electric motors are designed and rated for continuous loads, while internal combustion engines must either be rated for continuous duty at the design load or be derated from some other horsepower rating to a continuous horsepower rating. [4]

2.6 Manual power take-off clutch:

A **power take-off** (PTO) is a system that comprises of a splined output shaft, designed to be connected and disconnected quickly and easily, and a corresponding input shaft on the application end. The **power take-off** allows devices to draw energy from the engine.

Twin Disc Power Take-Offs are suitable for application to all internal combustion engines with standard SAE flywheel housing dimensions from No. 6 through No. 00. The PTO's contain clutches ranging in size from one plate 6.5" to one plate 14" in two plate size from 11.5" to 18"; and three plate size from 14" to 21". Suitable power take offs are available for use with engines in industrial installations up to 1667 horsepower in duty class II application[7]

A power take-off consist of a complete clutch assembly with shaft and bearings mounted in a cast iron housing that provides for easy engine installation.

PTO's are used as a standard method for transmitting the power of engines in a great variety of industrial applications such as: air compressors, agricultural machinery, pump drives, crushers, road building machinery, cranes and shovels, oil field service, etc.

Twin Disc offers power take-offs for all industrial engines. The ISF line is designed especially for today's high-speed, high-horsepower industrial engines, and presently is offered in two and three clutch plate construction. This multiple-plate, ventilated design assures ample cooling area to withstand heat, and with solid plates these PTO' scan effectively handle the stress of higher engine speeds. The ISF units feature oil lubricated tapered roller bearings that extend lubrication intervals.

Available on most size PTO are sealed pilot bail or roller bearings as optional equipment. These bearings eliminate the lubrication requirement and shaft rifle-drilling normally encountered with standard pilot bearings. Also available, As optional components, are ball bearing throw-out collars and finger springs. Horsepower and torque capacities listed can be increased by the use of sintered-iron clutch plates which are available as optional equipment in the 8" through 21" sizes.

All bearing, shaft and other parts are designed with liberal safety factors to maximize life under normal operating conditions. To avoid overloading the shaft and bearings, use the allowable side pull load data in this bulletin, and calculate the side load. The resultant value should be less than the corresponding maximum value listed for each power take-off.

Actual design torque capacity of the clutches used in power take-offs is in excess of the horsepower rating listed. This permits Twin Disc Power Take-Offs in proper adjustment. To withstand temporary torque over loads. Rated torque can be transmitted while moderately slipping during short periods without permanent damage [7]

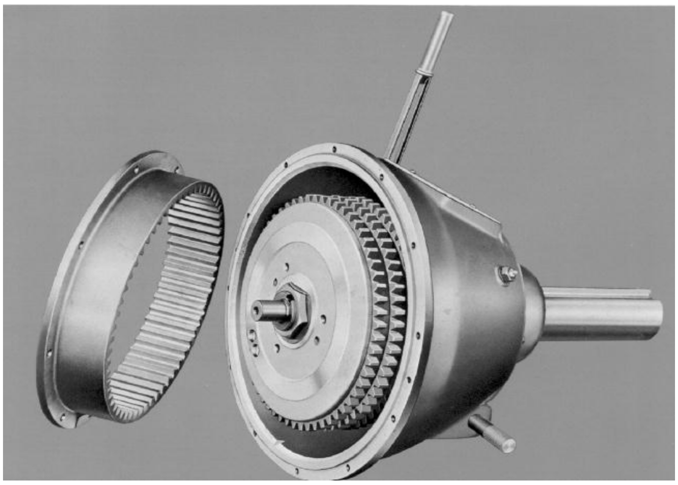


Figure (2.10) Manual power take-off clutch

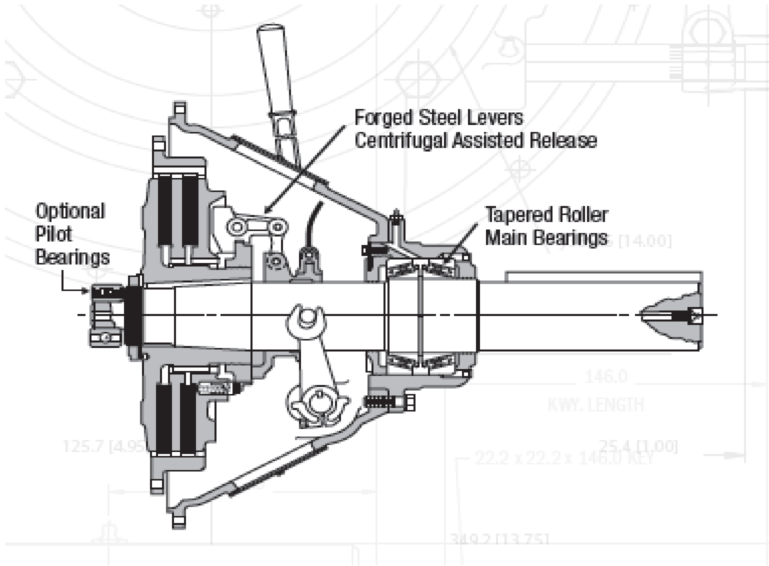


Figure (2.10A) Manual power take-off clutch installation

2.7 Irrigation Water Supply:

Water supplies for irrigation are either surface water sources or wells. Surface water sources include irrigation canals and ditches, streams and rivers, ponds and lakes, and other ditches or lagoons. Surface water does not contribute to increased energy use other than pump siting and pipeline length.

2.8 Pumping plant

Design of the pump system depends on the amount of water desired, the water source, and pressure required for the irrigation system. The pumping plant system includes the pump, power unit and drive component, if needed (Figure 2.11). All components have an energy efficiency associated with them. Correct design and maintenance of the pump and power unit is critical for low cost operation of the irrigation system. [5]

Figure (2.11) Diesel powered turbine pump with right angle drive

2.9 Irrigation pumps:

Pumps commonly used for irrigation systems include horizontal or vertical centrifugal, deep-well line shaft turbine, and submersible. Line shaft turbine and submersible pumps are variations of a centrifugal pump that are designed to be used in wells or wet well installations.

2.9.1 Centrifugal pumps

Centrifugal pumps are used to pump from reservoirs, lakes, streams, and shallow wells. Some models are used as pressure booster pumps within irrigation pipelines or to operate an end gun on center pivots. All centrifugal pumps must be completely filled with water or primed before they will operate. The intake (suction) line, as well as the pump, must be filled with water and free of air. Airtight joints and connections on the intake pipe are essential.

Figures (2.12) show horizontal centrifugal pump installations. The pump has a vertical impeller connected to a horizontal shaft. A vertical centrifugal has a horizontal impeller connected to a vertical shaft. The single impeller is located inside a sealed housing called the volute case.

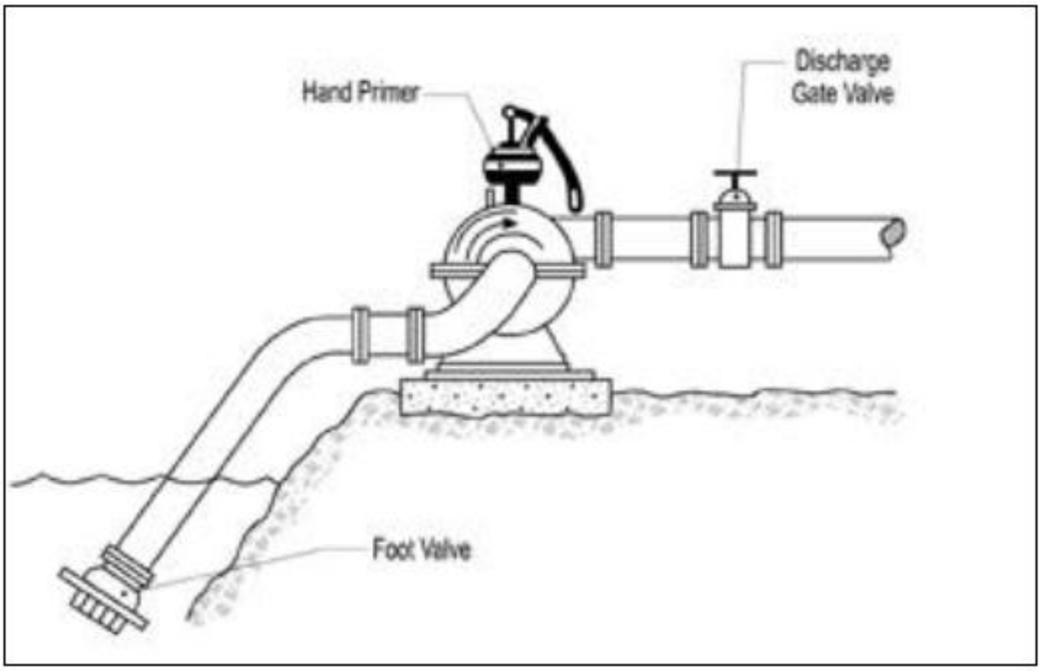


Figure (2.12) Horizontal centrifugal pump installation [6]

Require less maintenance, are easier to install, and are more accessible for inspection and maintenance than a vertical centrifugal. The horizontal pump's impeller shaft is typically powered by direct connection or v-belts to a horizontal electric motor or to a drive shaft of an engine. Vertical centrifugal pumps are powered typically by a vertical electric motor.

Centrifugal pumps are located above the water level. The pump does not suck water into the pump even though "suction" is commonly used to describe how the pump intake operates. Atmospheric pressure moves water into the intake line when the pump creates a negative gauge pressure, therefore, a centrifugal pump can only lift water vertically the equivalent of one atmosphere of pressure which is about 33 feet at sea level. Changes in elevation above sea level and in barometric pressure can reduce the maximum lift. Additionally, pump lift is reduced by friction losses in the intake line and fittings, vapor pressure reduction, and velocity head.

Centrifugal pumps draw water into the impellers after they have been primed. Impeller rotation throws water toward the outside of the impeller by centrifugal force and creates a lower pressure at the center of the impeller. This action develops a partial vacuum near the impeller inlet that causes the water to move into the impeller. Thus, they must not be set any higher than the manufacturer's recommended maximum practical suction lift (MPSL) above the water surface while pumping (also called the total dynamic suction lift, TDSL). MPSL values can vary from less than 10 to about 20 feet.

Operating a centrifugal pump at suction lifts greater than designed, or under conditions of high or fluctuating vacuum pressure, can result in pump damage by cavitation. Cavitation is caused by imploding air bubbles and water vapor that make a distinctive noise (like gravel flowing through the pump). Cavitation erodes the surface of the impeller and can eventually cause it to become deeply pitted.

The maximum suction lift can depend on the pump and the installation of the pump. Manufacturers determine and report the net positive suction head (NPSH) for pumps at sea level on each impeller performance curve. To find the maximum suction lift (head) at which a pump will operate, subtract the NPSH from 33 feet. For a centrifugal pump to operate at its designed efficiency throughout its life, it should be correctly located, have a good foundation, and be properly aligned. Make sure the power unit drive shaft or belt drive rotates in the same direction as the arrows on the pump casing. Be sure the pump aligns with the power unit and piping. Size suction pipes so that water velocity is less than 2 to 3 feet per second (fps). The intake pipe, especially with long intakes and high suction lifts, should have a uniform slope upward from the water source to the pump. Avoid high spots where air can collect and cause the pump to lose prime. Suspend the inlet end of the suction pipe above the bottom of a stream or pond, or lay it in a concrete or metal sump. On horizontal suction lines with a reducer, use the eccentric-type inlet with the straight section on the upper side of the line and the tapered section on the bottom side. Air that enters the suction pipe may cause the pump to lose prime, or the air may become trapped in the impeller, which reduces the output of the pump. If the water level is too low or the suction pipe inlet is not sufficiently submerged in the water, air can enter the suction pipe through a vortex or whirlpool. In shallow water, a mat or float with vertical straightening vanes will reduce the potential for the problems a vortex causes Make any bend in the suction line a long sweep or long radius elbow and place it as far away from the pump as practical. A short elbow at the pump inlet disturbs the water flow and may cause noisy operation, efficiency loss, and heavy end thrusts, particularly with high suction lift. [6]

2.9.2 Turbine pumps:

Deep-well turbine pumps are used in cased wells or where the water surface is below the practical limits of a centrifugal pump (Figure2.12). Turbine pumps also are used with some surface water supplies where the pumps are set in wet wells or sumps. Priming is not a concern because the intake for the turbine pump is continuously under water. Turbine pump efficiencies are comparable to or greater than those of most centrifugal pumps. Turbine pumps give long and dependable service if properly installed and maintained.

A turbine pump includes the bowl assembly, line shaft and pump column assembly, and the discharge head assembly Figure (2.13). The bowl assembly contains an inlet and one or more bowl assemblies or stages with impellers located below the pumping water level in the well. The shaft and column assembly connects the head and bowl assemblies and is positioned inside the well casing. The line shaft carries the power, and the pump column carries the water upward. The line shaft on a turbine may be lubricated by oil or water. An oil-lubricated pump has an enclosed shaft into which oil drips, lubricating the bearings; it keeps sand carried in the water out of the bearings. A water-lubricated pump has an open shaft where the bearings are lubricated by the pumped water. A water-lubricated pump is free of oil and is preferred for a domestic or municipal water supply. The discharge head assembly supports the column and shaft assembly and the bowl assembly in the well. The discharge head includes a port for the water discharge and a mounting platform for an electric motor or a right angle drive to connect a horizontal power shaft from an engine.

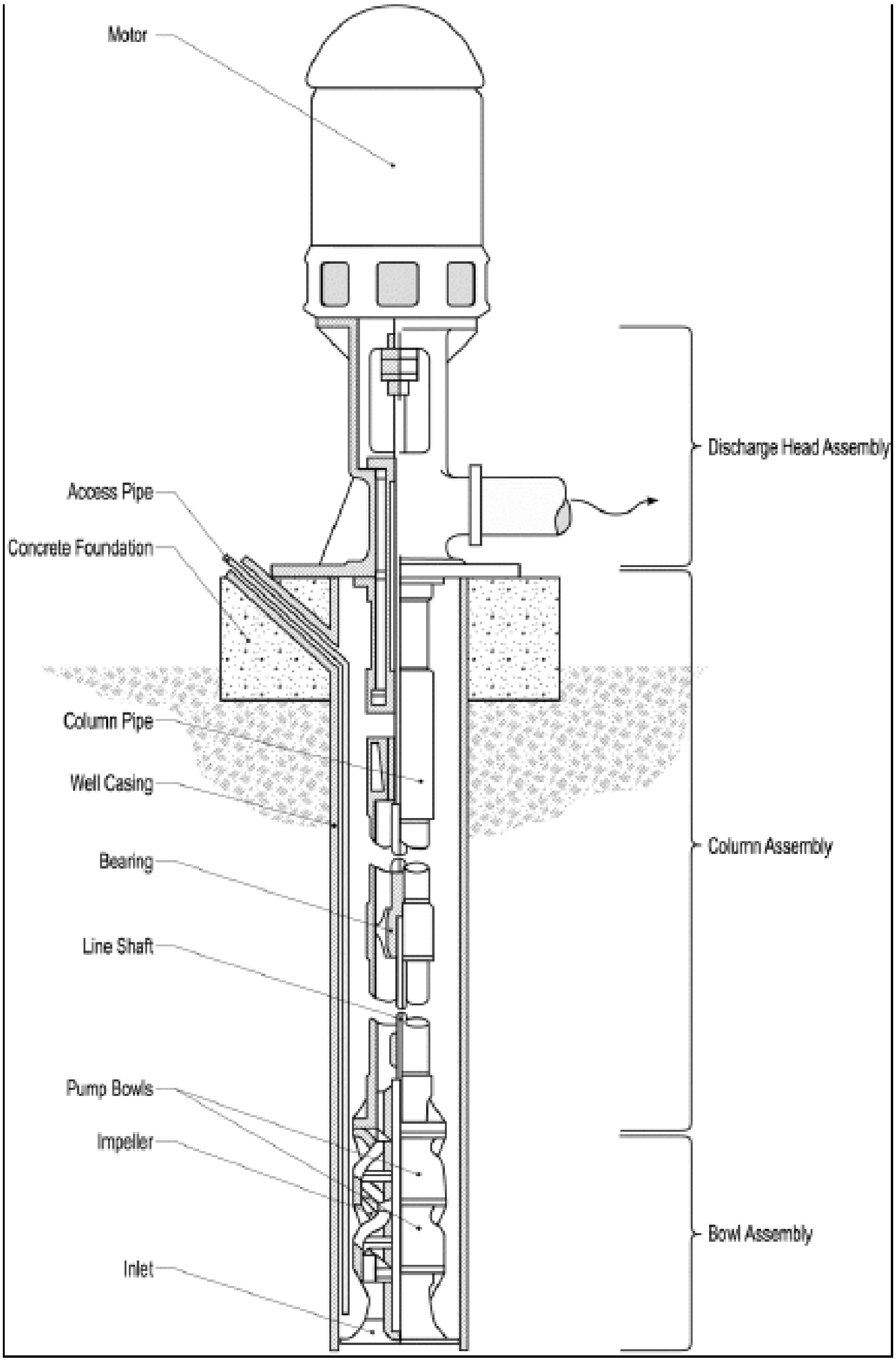


Figure (2.13) Turbine pump cross-section [6]

An oil-lubricated pump has an enclosed shaft into which oil drips, lubricating the bearings; it keeps sand carried in the water out of the bearings. A water-lubricated pump has an open shaft where the bearings

Deep-well turbine pumps must have correct alignment of the well casing, column, pump head, and the power unit. Alignment of the pump in the well casing is most important so that no part of the pump assembly touches the well casing; otherwise vibration will wear holes in the well casing where the two touch. A permanent foundation is required for the discharge head to maintain alignment between the pump, drive, and well casing.

The impeller in a turbine pump operates similarly to an impeller in a centrifugal pump, but because the bowl and impeller diameter is limited in size, each impeller develops less pressure head. To achieve the desired pressure head several impellers are installed in series, one impeller above the other, with each impeller having its own bowl assembly. Each rotating impeller unit raises the operating head for a turbine pump a set amount at a given flow rate. With this stacking or staging of impellers, a three-stage bowl assembly has three impellers attached to a common shaft and develops three times the pressure head of a single-stage pump at that flow rate.

The operating characteristics of a turbine pump, like a centrifugal pump, depend mainly on bowl design, impeller diameter, and speed of rotation. Total head capacity, efficiency, horsepower, and speed are similar to those for centrifugal pumps producing a similar flow rate and head.

Impellers in turbine pumps are either semi-open or enclosed. A semi-open impeller has only the top side of the impeller vanes closed (Figure 2.14). The bottom side runs with a close clearance to the pump bowl assembly, or it may have a special seal. For non-sealed impellers, this clearance is critical and must be adjusted when the pump is installed. Adjustments to the impellers are made by tightening or loosening the adjustment nut at the top of the head assembly. A maladjusted impeller clearance causes inefficient operation if the impellers are set too high. Mechanical damage results from impellers set so low that they touch the bowl assemblies. Adjustment tolerances are not as critical for enclosed impellers. [6]

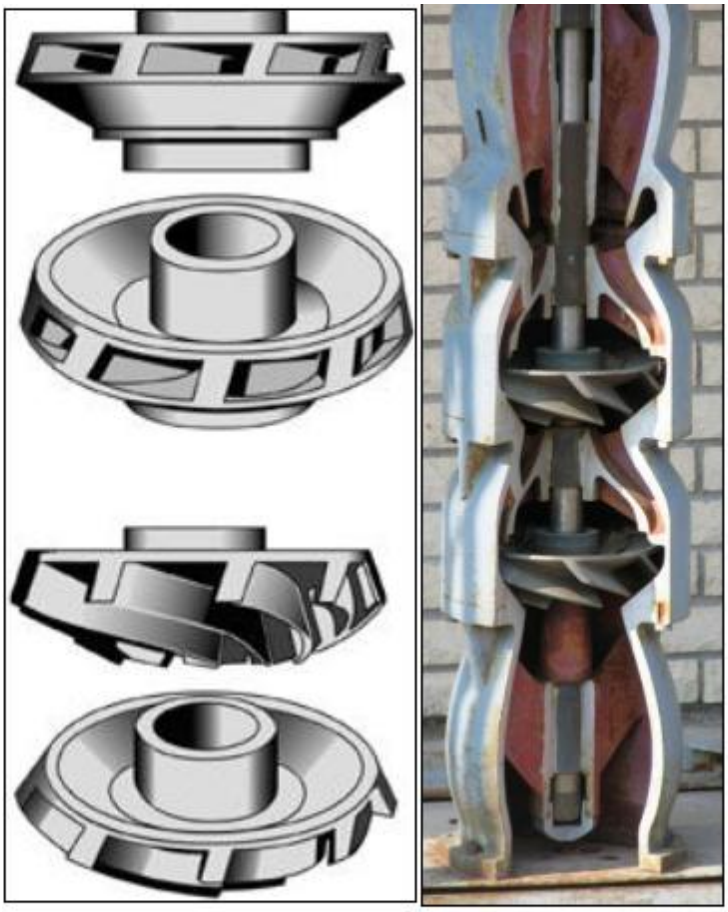


Figure (2.14) Turbine pump impellers and two-stage bowl assembly cross-section **[6]**

2.9.3 Submersible pumps:

A submersible pump is a turbine pump with a submersible electric motor attached to the bottom of the bowl inlet Figure (2.15). Both the pump and motor are suspended in water, which eliminates long line shaft and bearings of deep-well turbines. Operating characteristics are similar to those of deep well turbine pumps.

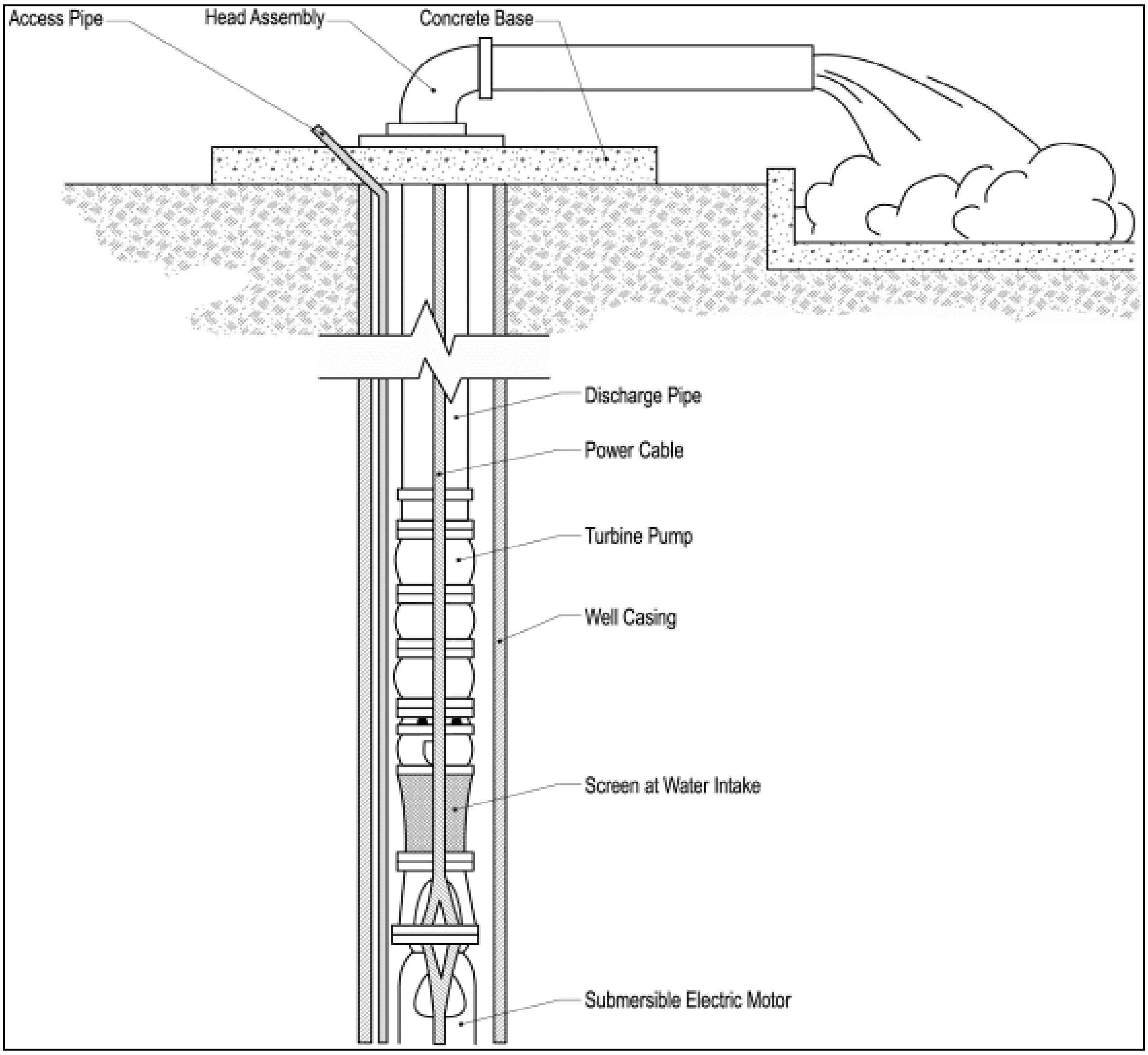


Figure (2.15) Submersible pump installation [6]

The submersible pump has enclosed impellers. A screened water inlet is between the motor and pump. Water must flow past the motor for cooling purposes, and some assemblies contain a shroud to direct intake water past the motor housing.

Submersible motors are small in diameter and are much longer than ordinary motors. Submersible pumps come in a range of capacities for 4-inch wells or larger. Electric wiring for the motors should be sized based on the electrical code. [6]

2.10 Basic hydraulic theory:

The basis for all hydraulic systems is expressed by Pascal's law which states the pressure exerted anywhere upon an enclosed liquid is transmitted undiminished, in all directions, to the interior of the container. This principle allows large forces to be generated with relatively little effort.

The simplest hydraulic circuit consists of a reservoir, pump, relief valve, 3-way directional control valve, single acting cylinder, connectors and lines. This system is used where the cylinder piston is returned by mechanical force. With the control valve in neutral, pump flow passes through the valve and back to the reservoir. With the valve shifted, oil is directed to the piston side of the cylinder, causing the piston to move, extending the rod. If the valve is returned to neutral, the oil is trapped in the cylinder, holding it in a fixed position, while the pump flow is returned to the reservoir. Shifting the valve in the opposite direction permits the oil to pass through the valve back to the reservoir. The relief valve limits the system pressure to a pre-set amount.

A hydraulic system using a double acting cylinder and a 4-way valve differs from the single acting cylinder system in that the cylinder can exert force in both directions. With the control valve in neutral, flow is returned to the reservoir. When shifted in one direction, oil is directed to the piston side of the cylinder, causing the cylinder to extend. Oil from the rod side passes through the valve back to the reservoir. If the valve is shifted to neutral, oil in the cylinder is trapped, holding it in a fixed position. When the valve is shifted in the opposite position, oil is directed to the rod side of the cylinder, causing the cylinder to retract. Oil from the piston side passes through the valve back to the reservoir. Cylinder extend force is a result of the pressure (psi) times the piston area. Retract force is a result of the pressure (psi) times the area difference between the piston minus the rod diameter.

All the systems described above are open center systems due to the oil flowing through the control valve back to tank. Most systems are this type. Closed center systems use control valves with the inlet port blocked and variable displacement pumps. With the control valve in neutral, the pump is “de-stroked” to zero flow. [8]

2.10.1. Hydraulic system component for this design:

- double acting cylinder
- gear pump
- motor drive
- 4/3 solenoid directional control valve
- Pressure relief valve
- reservoir

2.10.1.1 Double acting cylinder:

The most familiar double acting cylinder shown in fig (2.16) is the single rod end. This type of cylinder provides power in both directions, with a pressure port at either end. Single rod end cylinders exert greater forces when extending than when retracting, since the piston area on the blind end is larger than the piston area on the rod end (due to the area covered by the piston rod). [9]

Figure (2.16) show double acting cylinder

2.10.1.2 Gear pump:

The driven gear is coupled to the motor. The idler gear is driven by the rotation of the driven gear. Oil is pulled into the suction port, carried in the gap between the gear teeth figure (2.17), and comes out of the pressure port. Adjustment of the system pressure requires a relief valve in the circuit**. [9]**

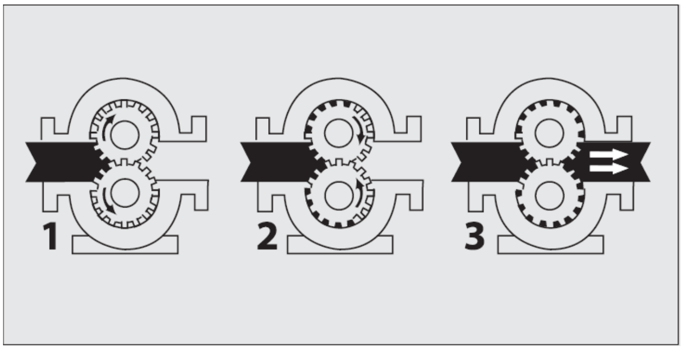


Figure (2.17) flow in gear pump [9]

2.10.1.3 4/3 solenoid directional control valve

A very common way to actuate a spool valve is by using solenoid .illustrated in fig (2.18) as shown, when electric coil (solenoid) is energized, it creates a magnetic force that pulls the armature into the coil .this causes armature to push on the rod to move the spool of the valve

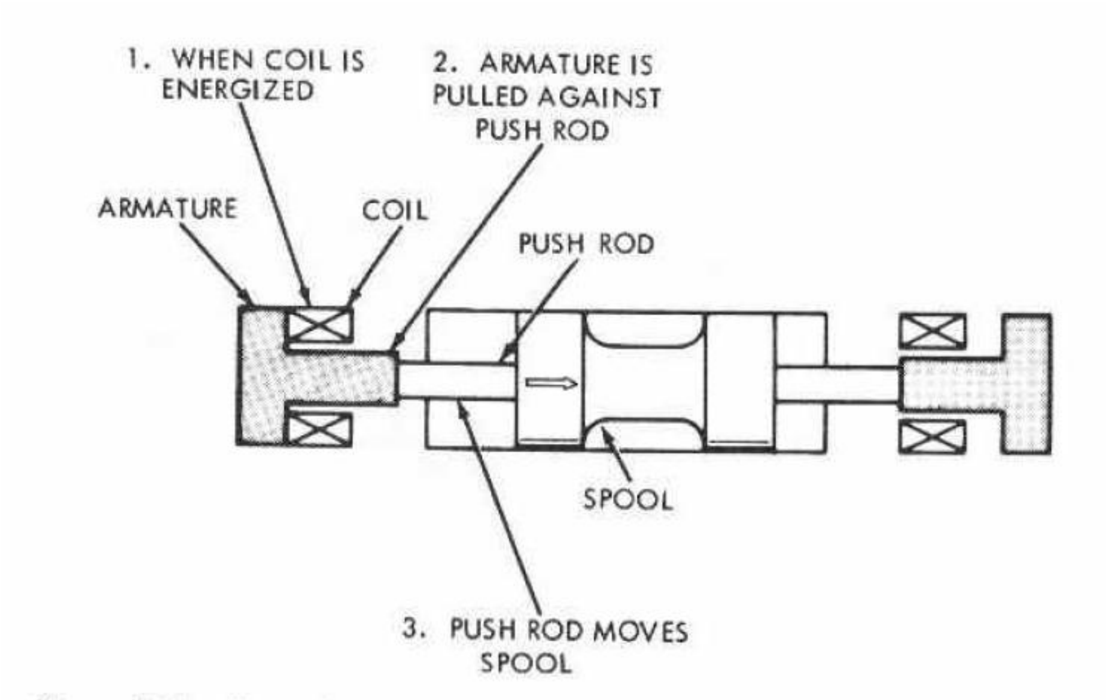


Figure (2.18) show solenoid directional control valve installation **[9]**

The valve has a solenoid at each end of spool .specifically it is a solenoid 4way /3position , spring centered directional control valve and is represented by the graphical symbol in. fig (2.19) notice the symbol used to represent the solenoid at both end of the spool . [9]

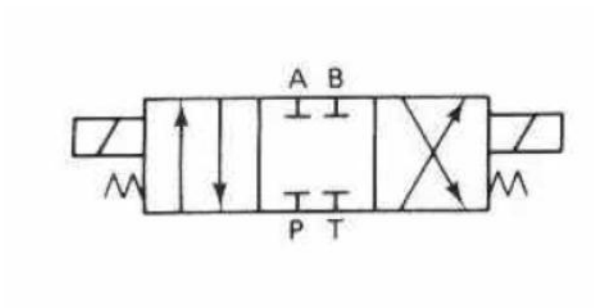


Figure (2.20) show solenoid directional control valve symbol [9]

2.10.1.4 Pressure relief valve

Relief valves are connected with high-pressure and return low pressure lines. They are used to limit the maximum operating pressure in the high-pressure lines. The relief valve consists mainly of a poppet, loaded by a spring see Fig (2.20). The poppet is pushed by the spring to rest against its seat in the valve housing. The spring pre-compression force is adjusted by a spring seat screw or by inserting distance rings.

The poppet is subjected to both the spring and pressure forces. The poppet rests against its seat as long as the pressure force, $FP = PAP$, is less than the spring force, $F_\chi = k_{\chi o}$. The two forces are equal when the pressure reaches the cracking pressure, Pr. For further increases of pressure, the poppet is displaced and the oil flows from the high pressure line, P, to the return line, T. [9]

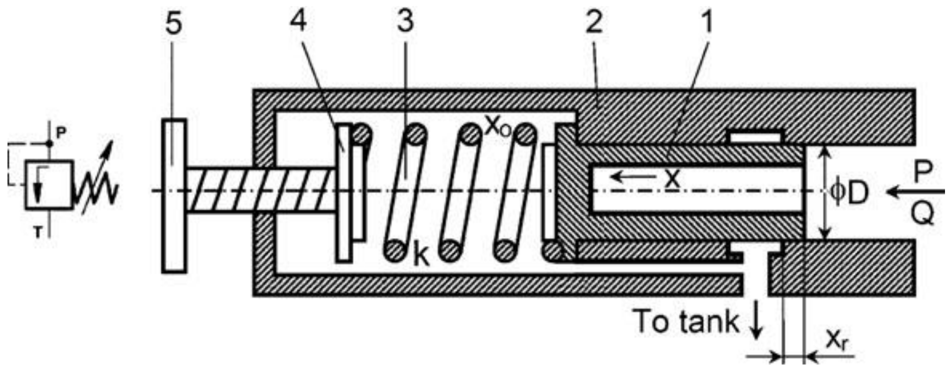


Figure (2.20) show pressure relief valve installation [9]

2.10.1.5 Reservoir Size:

The oil capacity of the reservoir used in a hydraulic power unit (HPU) provides the oil volume required to operate the cylinders and other devices in a system, and also absorbs and radiates the heat produced during the operation of the HPU. Using a small reservoir may result in an overheated system. The guideline for sizing the reservoir is 3 to 4 times the flow rate of the pump (gpm). [9]

2.11 previous studies:

There are some previous studies similar to this research in principle in the use of motors used in the management of water pumps. These studies are limited to the use of a device that changes in the values of the frequency of the electric current, which in turn leads to control the speed of the motor and thus reduces the speed of the water pump, when a malfunction The device of the inverter reducing the speed of the motor so that the control panel to disconnect the electric current from the motor at a low speed without any problem with the pump because the separation of the pump at high speeds lead to some special

Chapter three

Design and simulations

Chapter three

Design and simulation

3.1 preface

The research aims to design a mechanism fig(3.1) that allows to separate the shaft of the water pump from the internal combustion engine by moving hand leaver of the clutch when there malfunction occurs in center pivot irrigation device

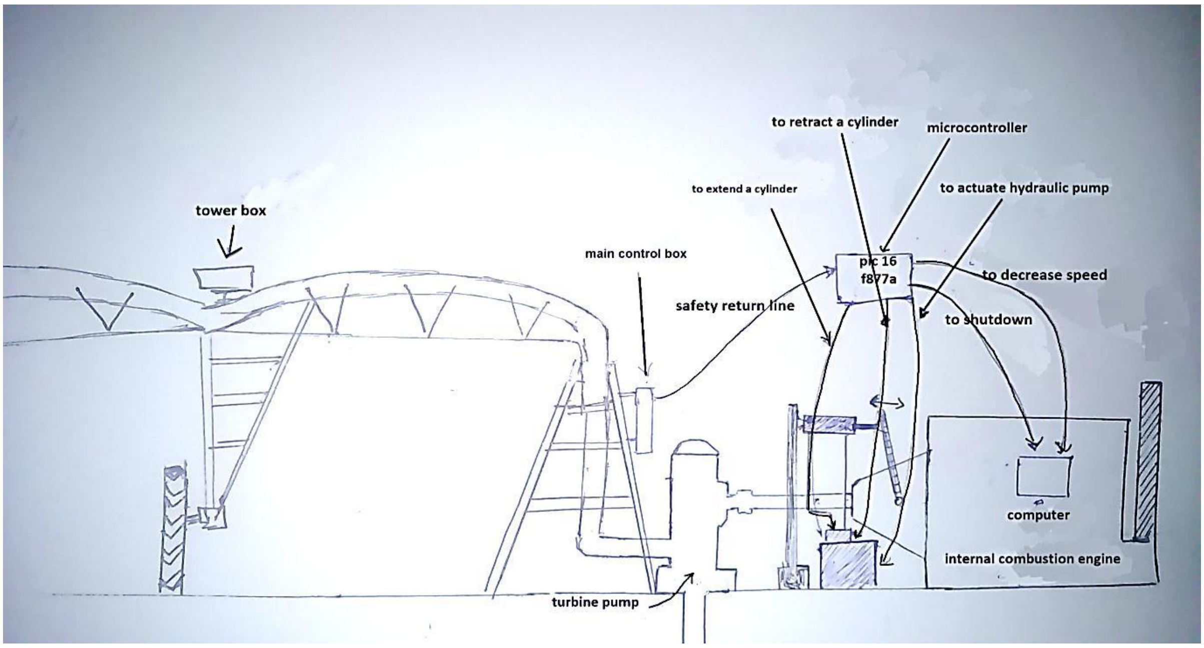


Figure (3.1) illustrate research idea

3.2 design concept:

The design divided into three steps

1. Hydraulic circuit
2. Control system

3. Programming and Interfacing between control unit and hydraulic circuit

3.2.1 Design specification:

In this design:

1. Diameter of cylinder blind is 0.0381 m.
2. Diameter of piston rod is 0.0254 m.
3. The stroke length is 0.15 m.
4. Force needed for extension is 200 N.
5. Force needed for retraction is 120 N

3.2.2 Hydraulic circuit design

In this research we will design a hydraulic cylinder, and (solenoid – pressure – relief) valve and a hydraulic pump selected due to hydraulic cylinder

3.2.2.1 Double acting cylinder:

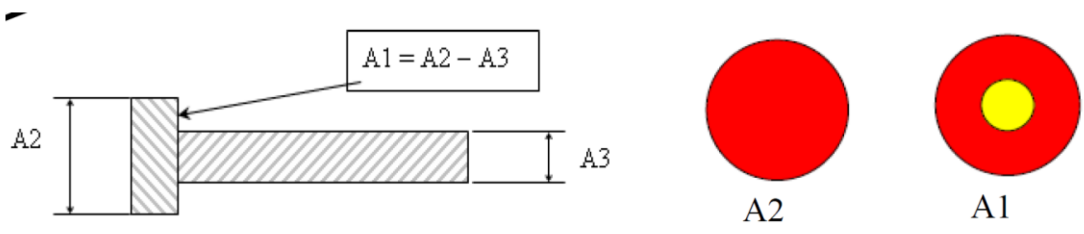


Figure (3.2) blind and rod area in double acting cylinder

Cylinder blind end area (in square meter)

$$A2 = \frac{\pi d^2}{4} = \frac{3.14 \times 0.0381^2}{4} = 0.00114 \ m^2$$

Cylinder rod end area (in square meter)

= Cylinder blind end area _ Cylinder rod area

Cylinder rod area (A3) $=\frac{\pi d^2}{4} = \frac{3.14\times0.0254^2}{4} = 0.00051 \ m^2$

∴ Cylinder rod end area (A2) =0.00114_0.00051= 0.00063 m^2

Pressure and flow rate needed for extend the cylinder:

Pressure = $\frac{force}{blind\ end\ area} = \frac{200}{0.00114}$ =175438.59 N/m^2

Flow rate = $\frac{blind\ end\ area\times stroke\ length}{time\ for\ 1stroke}$

$=\frac{0.00114\times0.15}{2}$ =0.0000855 m^3/s

Pressure and flow rate needed for retract the cylinder:

Pressure = $\frac{force}{rod\ end\ area} = \frac{120}{0.00063}$ =190476.19 N/m^2

Flow rate = $\frac{blind\ end\ area\times stroke\ length}{time\ for\ 1stroke}$

$=\frac{0.00063\times0.15}{2}$ = 0.00004725 m^3/s

Hydraulic power developed by hydraulic cylinder can be found by using:

Power (kW) =input flow (m^3/s) ×pressure (kN/m^2)

= 0.00004725 × 190.47619

=.00899 kW

3.2.2.2 Gear pump:

Power of gear pump =power needed for cylinder +losses

Note: there some Frictional losses in hydraulic pipelines, valves and fitting

3.2.2.3 Motor drive:

In this project vane motor (single face) used to drive a gear pump, the horsepower must be equal or greater than horsepower of gear pump.

3.2.2.4 Control of a Double-Acting Hydraulic Cylinder

The circuit diagram to control double-acting cylinder is shown in Fig (3.3) the control of a double-acting hydraulic cylinder is described as follows:

1. When the 4/3 valve is in its neutral position (tandem design), the cylinder is hydraulically locked and the pump is unloaded back to the tank.

2. When the 4/3 valve is actuated into the flow path, the cylinder is extended against its load as oil flows from port P through port A. Oil in the rod end of the cylinder is free to flow back to the tank through the four-way valve from port B through port T.

3. When the 4/3 valve is actuated into the right-envelope configuration, the cylinder retracts as oil flows from port P through port B. Oil in the blank end is returned to the tank via the flow path from port A to port T.

At the ends of the stroke, there is no system demand for oil. Thus, the pump flow goes through the relief valve at its pressure level setting unless the four-way valve is deactivated.

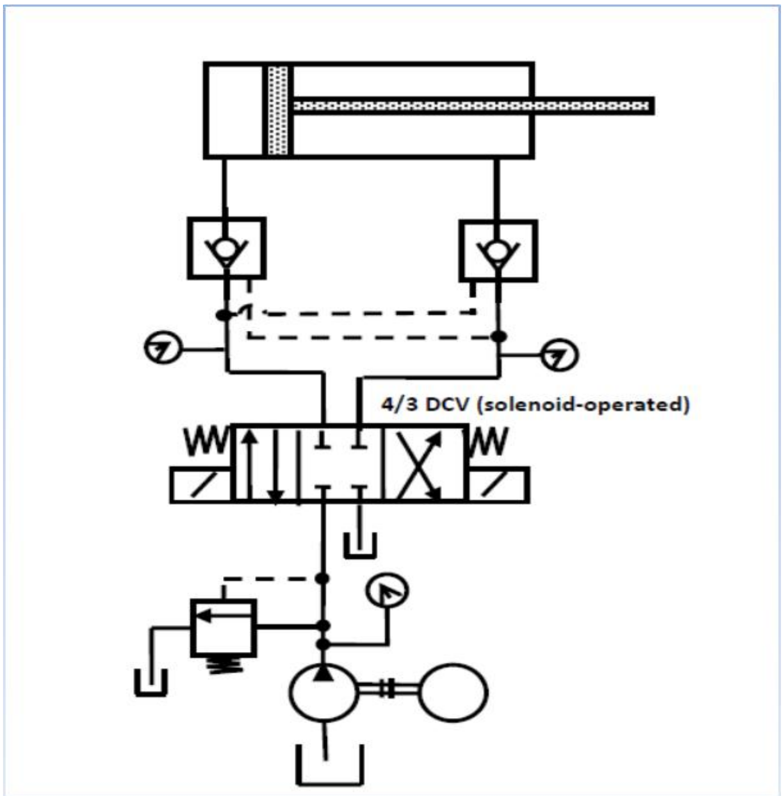


Figure (3.3) show control of double acting cylinder

3.2.3 Control system:

And to do this design must be depends of following steps:

- Take a signal from the center pivot irrigation device when a fault occurs Taken from the safety circuit. The value of this signal is 110 volt
- Enter this signal to Microcontrollers programmed to receive this signal and output three different signals, including:

  1. signal to reduce the speed of the machine for optimum speed Which enables us to separate the pump water without any problems with the pump
  2. signal to the hydraulic circuit used to operate it and separate the pump by moving the clutch arm

3. signal to Turn off the machine

3.2.3.1 Conditions of control signals:

First: The incoming signal for the microcontroller must be within 5 volts, but the signal from the safety circuit in center pivot irrigation device is 110 volts. So it must be reduced to 5 volts or inserted into a relay 110 volt to allow a 5 volt.

second: internal combustion engine operational speed range between (1200_1500) rpm, the speed at which water pumps managed to give the amount of water needed for optimal irrigation, but the perfect speed to disconnect and connect the water pump with internal combustion machine between (600_ 800) RPM. When a malfunction in your center pivot irrigation speed within (1200_1500) rpm, so it must be reduced the speed to the ideal speed to separate the water pump. A computer of the internal combustion engine has two internal point when connected with each other leading to reduce speed of the internal combustion engine to ideal speed (800 rpm).

So the first output signal from a microcontroller must be connected to these points because the first objective of the control circuit designed is to reduce the speed of the internal combustion engine to the ideal speed to separate the water pump

Third: After the reduction of the speed of the machine, a signal transmitted from a microcontrollers to hydraulic circuit to actuate a hydraulic pump and solenoid valve to move a clutch arm to separate a water pump and stop working. This signal is programmed according to time necessary to operate the hydraulic circuit to move the arm of clutch

Fourth: a computer in the internal combustion engine has a push button key to shut down the internal combustion engine so the third signal must be connector with the internal points of this key. When these signals reach the internal points, the machine is shut down

Fifth: it is necessary to add another input signal to the microcontrollers. This signal is manual. When it reaches the microcontroller, a signal is generates from a microcontroller to the hydraulic circuit to operate the hydraulic pump and the other end of the solenoid valve to move the clutch arm and connect the water pump again with the internal combustion engine

3.2.4 Programming and Interfacing:

3.2.4.1 Interfacing:

- In Figure (3-4) a relay (RL4) is normally close take a coil current from safety return line at 120 v to pass current at 5v ,3.1A to a microcontroller
- A signal at RB0 from a microcontroller to a base of switch (Q3) to passing 5V from collector to emitter to actuate a relay (RL1) to operate a solenoid valve to extend a cylinder
- A signal at RB0 from a microcontroller to a base of switch (Q2) to passing 5V from collector to emitter to actuate a relay (RL2)) to operate a solenoid valve to retract a cylinder
- A signal at RB0 from a microcontroller to a base of switch (Q1) to passing 5V from collector to emitter to actuate a relay (RL3)) to operate a motor drive of hydraulic pump
- A signal at (RB3) from a microcontroller to a computer of internal combustion engine to decrease speed
- A signal at (RB4) from a microcontroller to a computer of internal combustion engine to shutdown
- RL1 , RL2 and RL3 is normally open

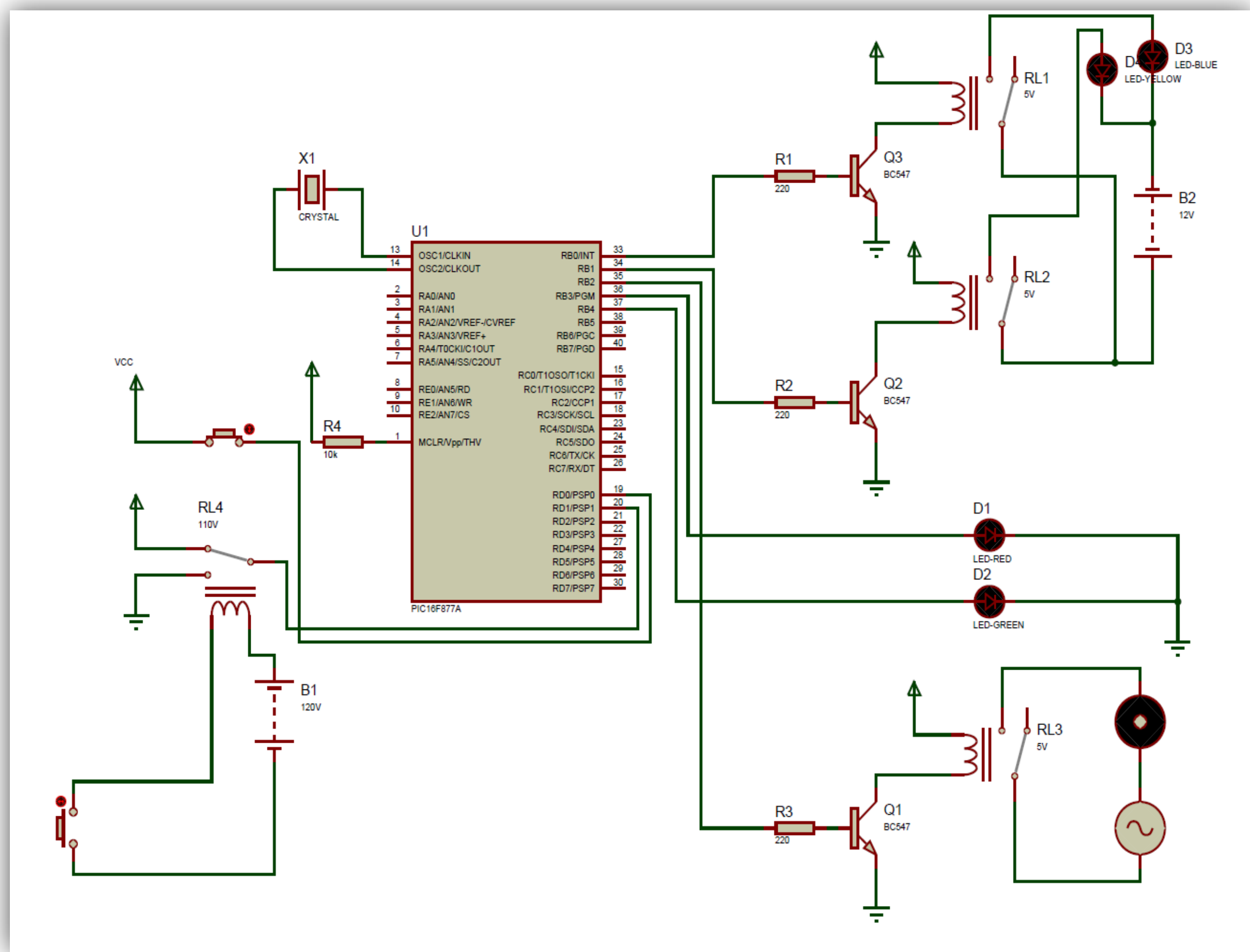


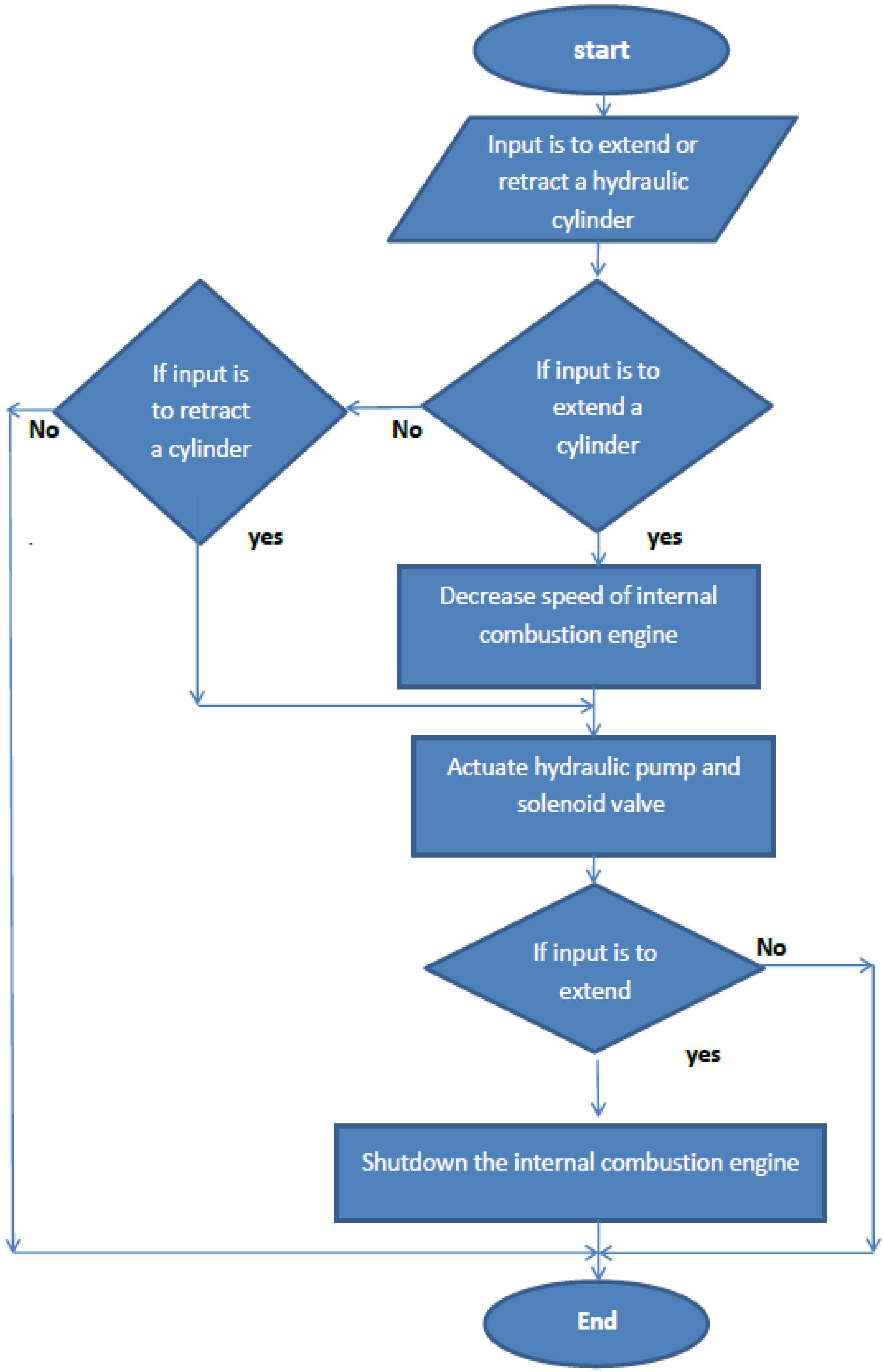
Figure (3-4) interfacing of control system

3.2.4.2 Programing code:

This code is to control of automatic clutch system to engage and unengaged a water pump from internal combustion engine

- A signal at (portd.bin1) as input, this signal receive to microcontroller from safety circuit in center pivot irrigation device to unengaged a water pump by extend a hydraulic cylinder when a malfunction occurs in center pivot irrigation device
- A signal at (portd.bin0) as input this signal receive to microcontroller manually to engage a water pump with internal combustion engine by retract a hydraulic cylinder
- A signal transmitted from (portb.bin4) is to reduce a speed in internal combustion engine to 800 rpm
- A signal from (portb.bin0) is to actuate a solenoid valve to extend a cylinder
- A signal from (portb.bin3) is to actuate a hydraulic pump
- A signal from (port b. bin 1) is to actuate a solenoid valve to retract a cylinder
- A signal from (portb.bin4) is to shut down the internal combustion engine

Flow chart of programming code:



Code:

```
Void main () {

int a=0;

int b=0;

TRISD=255;

PORTD=0;

TRISB=0;

PORTB=0;

delay_ms(2000);

 do {

if((portd.f1==1)&&(a==0)){

a=1;

PORTB.F4=1;

delay_ms(5000);

PORTB.F0=1;

PORTB.F2=1;

PORTB.F4=0;

delay_ms(5000);

PORTB.F0=0;

PORTB.F2=0;
```

```
PORTB.F3=1;

delay_ms(5000);

PORTB.F3=0;

}

if(portd.f1==0){

a=0;

}

if((portd.f0==1)&&(b==0)){

b=1;

PORTB.F1=1;

PORTB.F2=1;

delay_ms(5000);

PORTB.F1=0;

PORTB.F2=0;

}

if(portd.f0==0){

b=0;

}

} while(1);

}
```

Chapter Four

Results and discussion

Chapter Four

Results and discussion

4.1 Discussion of results:

In this research we used hydraulic unit and control system to design automatic clutch which use to unengaged a water pump if a malfunction occur in center pivot irrigation device, we used simulation by proteus program and the expected results in the following:

4.1.1 Normal mode :

In this case, the center pivot irrigation system is in normal mode and we do not need any interference from a microcontroller Fig (4-1), because there is no problem occur in center pivot device and working perfectly

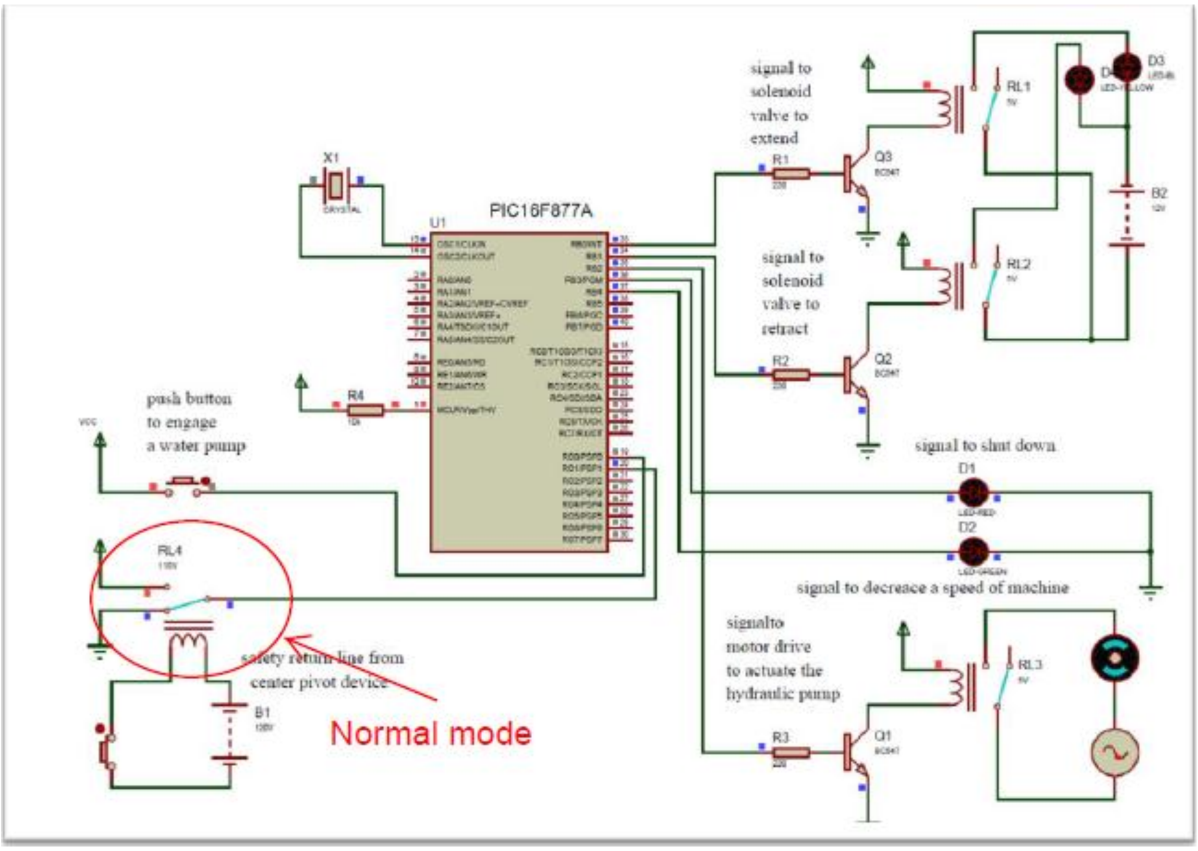


Figure (4-1) normal mode in center pivot irrigation device

4.1.2 Decrease speed of internal combustion engine :

When a malfunction occur in center pivot irrigation device during irrigation process. the return safety line connected with relay (RL4) is become zero volts and thus allows a relay to pass 5 volt to a microcontroller see Figure (4-2), the first output from a microcontroller (RB4) is to decrease a speed of internal combustion engine to 800 RPM, the output receive a computer of internal combustion engine to do this, the green led (D2) present this operation

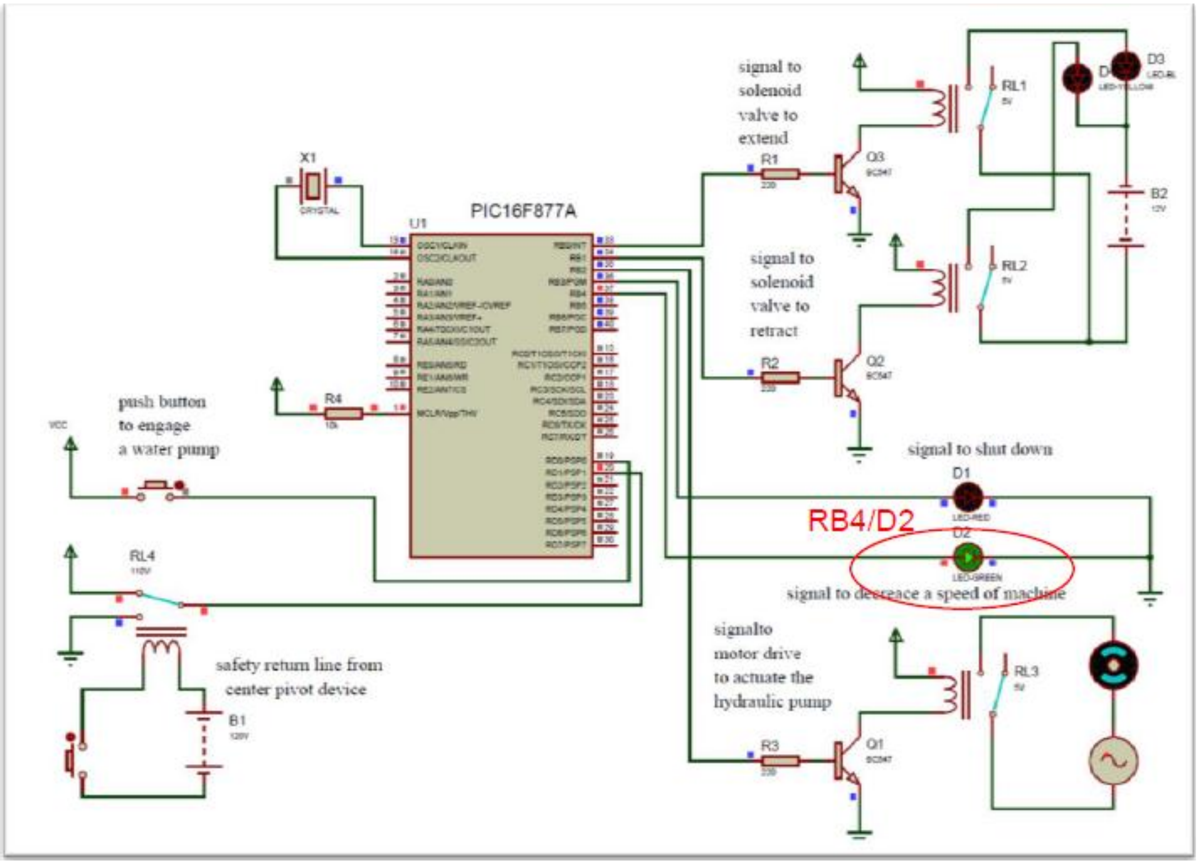


Figure (4-2) illustrate decrease of machine speed

4.1.3Actuate a hydraulic pump and solenoid valve :

After arrival speed of internal combustion engine to the optimum speed (800rpm) to unengaged a water pump, a microcontroller transmitted tow signals figure (4-3) one of these signal (RB2) is to operate motor drive of hydraulic pump and the other signal (RB0) is to actuate solenoid valve (blue led (D3) illustrate this operation) to extend a hydraulic cylinder and unengaged a water pump.

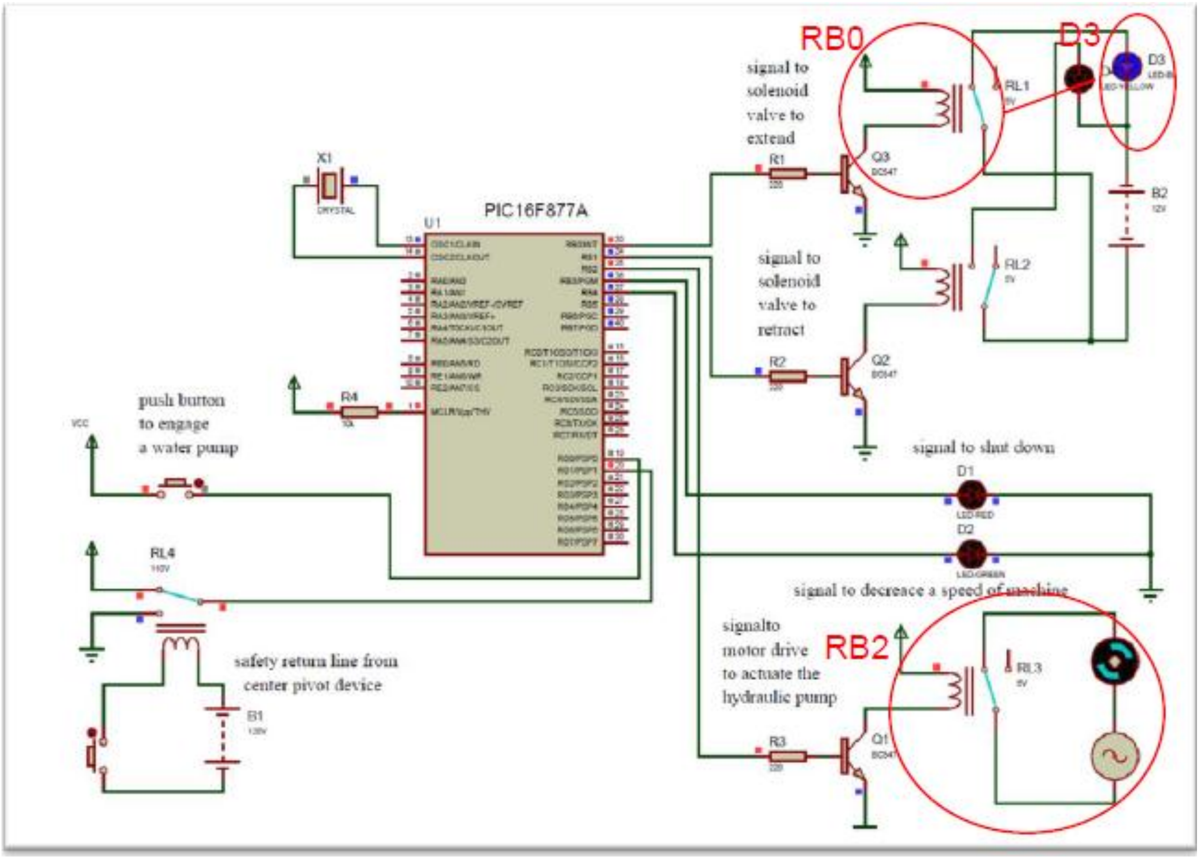


Figure (4-3) illustrate operating of solenoid valve and motor drive of hydraulic pump to extend a cylinder

4.1.4 Shut down the internal combustion engine :

After unengaged a water pump the output signal (RB3) from a microcontroller receive a computer of internal combustion engine to shut down a machine show figure (4-4). This signal, this operation done by connected this signal with shutdown key in a computer of internal combustion engine, red led (D1) illustrate a signal from a microcontroller to machine.

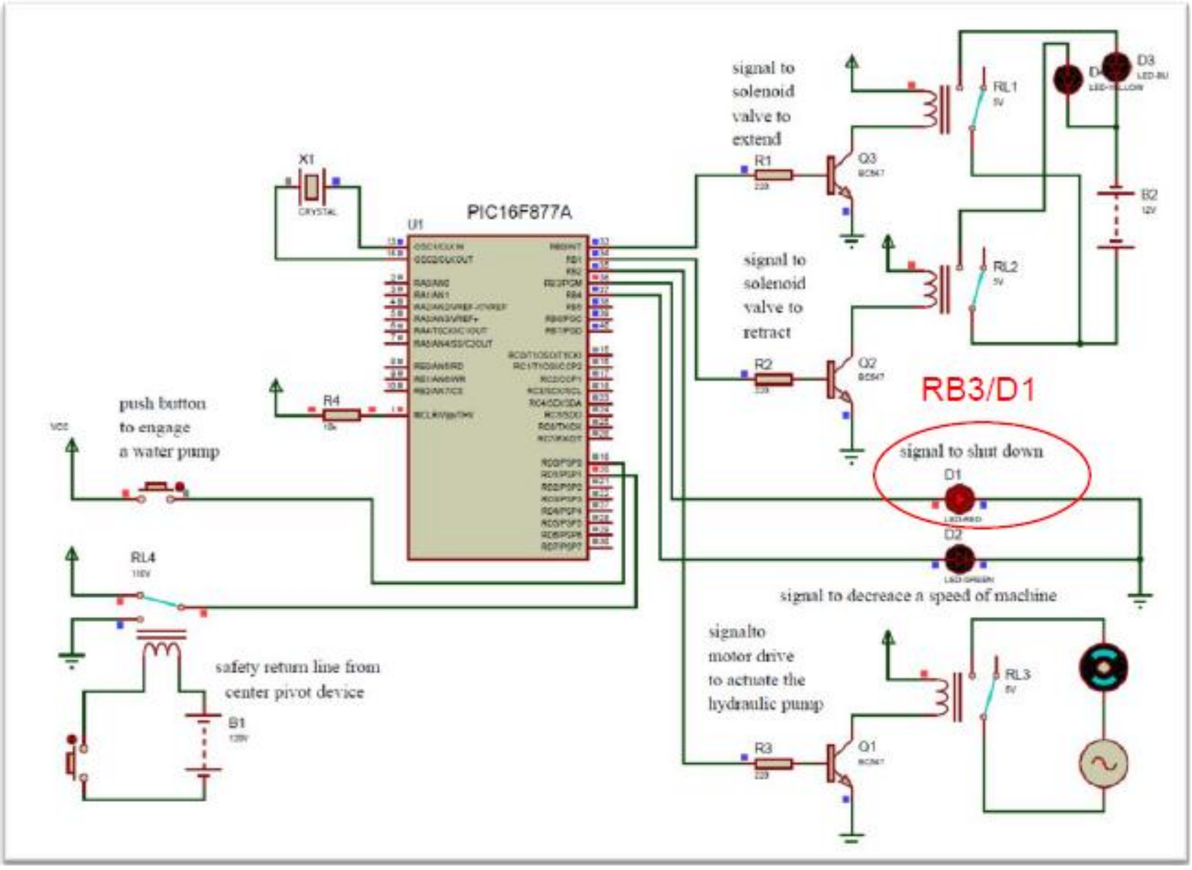


Figure (4-4) show operation of shutdown a machine

4.1.5 **Engage a water pump with internal combustion engine:**

This operation is additional options to engage a water pump by retract a hydraulic cylinder, a microcontroller receive signal manually from push button in (RD0) and transmitted two signals one of these signal is to actuate motor drive of hydraulic pump (RB2) and the second signal (RB1)is to actuate a solenoid valve and there for retract a hydraulic cylinder, the yellow led (D4) illustrate operation of solenoid valve to retract a hydraulic cylinder

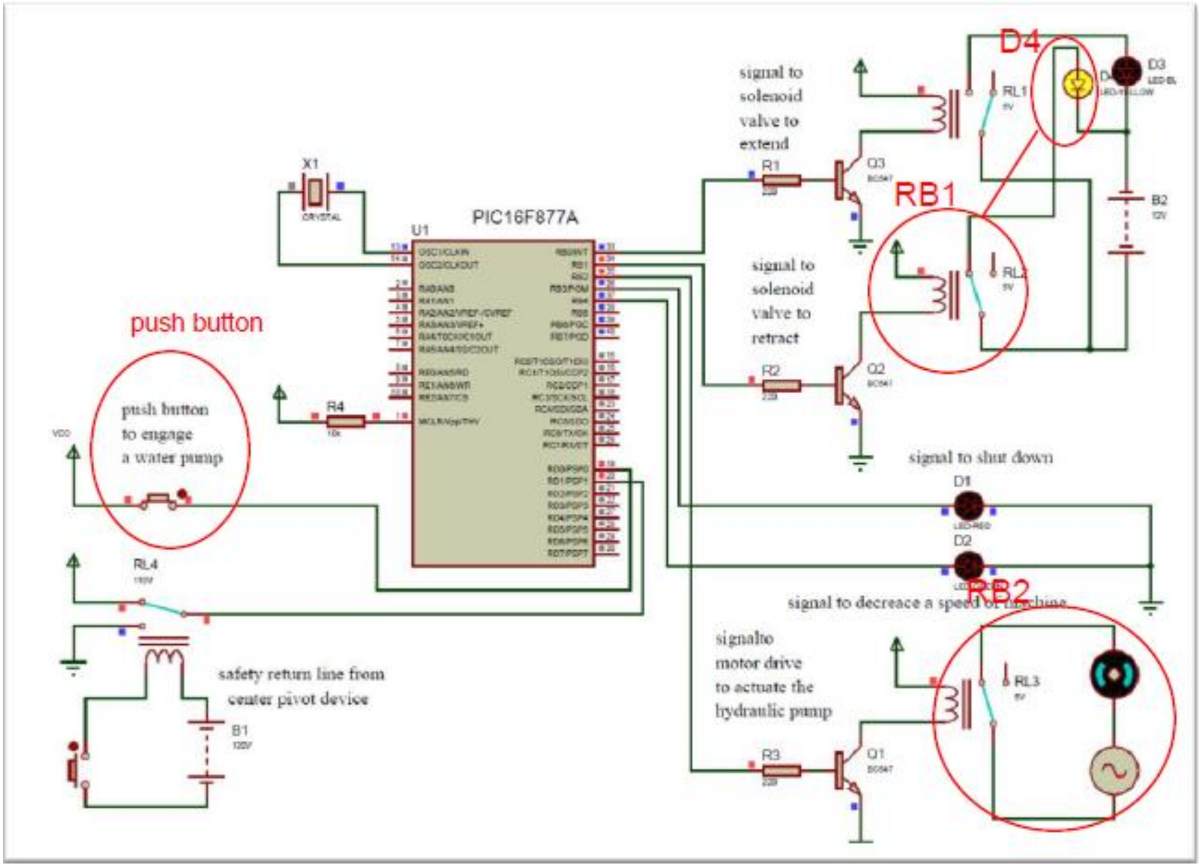


Figure (4-5) illustrate operation of solenoid valve and motor drive of hydraulic pump to retract a cylinder

Chapter Five
Conclusion and Recommendation

Chapter Five

Conclusion and recommendations

5.1 Conclusion:

The following were concluded:

In this research we using a hydraulic unit and control system to design and simulation of an automatic clutch which uses in internal combustion engine for center pivot irrigation device.

when a malfunction occurs in center pivot irrigation device during irrigation process, some problem will be generated, because a water pump unengaged manually by moving hand leaver of clutch by hand, and center pivot device stop motion and stays in one place, this case leading to accumulation of water in this area and resulting of this damage occurs in the cultivated area and there will also be waste of fuel by internal combustion engine.

So the proposal solution of this problem is to convert a manual power take-off clutch to automatic by using control system which uses a hydraulic unit designed for this purpose controlled by a microcontroller to unengaged a water pump when a malfunction occurs in center pivot irrigation device.

A microcontroller linked to the safety circuit of center pivot irrigation device and a computer of an internal combustion engine , if a malfunction occurs in center pivot device the output signals of a microcontroller is to decrease speed of internal combustion engine and actuate a hydraulic unit to unengaged a water pump, then shut down the internal combustion engine.

The expected result in center pivot irrigation process when using this design represented in development of clutch, operate center pivot device without any problems and saving time and money due to the lack of waste of fuel

5.2 Recommendations

1. Use of an automatic clutch in internal combustion engine that operate without a computer to unengaged a water pump when a failure occurs in center pivot irrigation device.
2. Automatic realignment of the center pivot irrigation device when misalignment occur on span towers of center pivot irrigation device.
3. Protection of center pivot irrigation device in the event of air storms by pumping a water automatically.

Reference :

1. Center Pivot System Design. 2000. The Irrigation Association. Falls Church,VA.
2. Center Pivot Irrigation Management Handbook, 2011, University of Nebraska Extension, Lincoln, NE.
3. Wiring and Equipment for Electrically Driven or Controlled Irrigation Machines. ASABE Standard S362. ASABE. St Joseph, MI
4. Farm Irrigation System Evaluation: A Guide for Management. 1978. Utah State University, Logan, UT
5. Design and Operation of Farm Irrigation Systems. 2007. ASABE Monograph.
6. Irrigation Pumping Plant Performance Handbook, 1982, Biological Engineering
   Department, University of Nebraska, Lincoln, NE.
7. Technical Irrigation Pumping Plant Test Procedure Manual, 1982, Cooperative Extension Service, University of Nebraska, Lincoln, NE
8. fluid power engineering , M. Galal Rabie, Ph.D. Professor of Mechanical Engineering, Modern Academy for Engineering and Technology Cairo, Egypt
9. fluid power with applications , fourth edition Anthony Esposito , US
10. USDA-NRCS. 2010. Variable Speed Drive (VSD) for Irrigation Pumping. Engineering Technical Note No. MT-14.