CHAPTER ONE

INTRODUCTION

1.1Background:

The Rosaries Dam is about 500 kilometers south – east of Khartoum. It site on the Blue Nile, the part of the river that flow out of Ethiopia to meet the White Nile in Khartoum. Almost half of Sudan's power output is supplied by the less than 280MW hydroelectric plant that is found at the dam.

Hydropower is a renewable resource that has many advantages over other sources of electrical power. Hydropower plants have very low operating and maintenance costs because they consume no fossil or nuclear fuel and do not involve high temperature processes [1].

In Rosaries hydro power using the reaction turbine (axial flow turbine) Kaplan, the Kaplan principle applies to all units that have their runner blade angle and wicket gate opening coordinated for extending the range of optimal performance. Although the patent for the Kaplan turbine did not involve head, the Kaplan turbine adjustable runner blades are coordinated automatically with operating adjustable wicket gates to obtain the most efficient operation under varying head, flow, or load conditions. This principal can be using in any configuration.[1]

A governor adjusts the water flow to maintain the generating unit's speed and the system frequency. Also, it maintains a balance between the water input to the turbine and the power requirements of the system. In Rosaries station use the digital governor.

A digitally controlled governor can control speed, unit output, flow, water level, or any system parameter that can be sensed by a transducer, switches, or contacts. The digital governor's main advantage is its versatility and the case with which changes can be made. It also enables easy interfacing with other computer systems.

Digital governor can perform many additional control functions not done previously by mechanical and analog governors. Functions that digital governors can provide include:

- Speed and power control.
- Generator control: Some digital governors include voltage and reactive power Volt Ampere Reactive (VAR) control.
- Pond control: There are many different control requirements for headwater control or tail water control.
- Flow Control: Water supply requirements or environmental concerns may dictate minimum flows.
- Turbine Creep Detection: Using zero velocity speed sensors and software logic, digital governors can detect turbine creep.
- Control Sequencing: Governors using relays typically do control sequencing of governor start up, braking, and shutdown. Digital control expands the sequencing capabilities and allows ease of changes for such applications as sequencing of multiple units or unit start or stop based on time to control ponding, irrigation, or scenic water flow requirements.

1.2 Importance of the Study:

This research studies the dynamic behavior of volumetric pumps, hydraulic flow and schemes of the speed governing system from Rosaries hydroelectric power plant machines (from unit one to unit seven). It is motivated for the need to update this system, optimization of operation times and reduction of wear and casualty in the pressurization subsystem components. The present text has the objective to propose improvement measures looking to reduce the power resources consumption within the electric motors of the pressurization pumps of the speed governor in these seven power plants.

1.3 Problem Statement:

It possible to safe energy by using the analysis of hydraulic system in a Rosaries hydropower plant and to reach the stability of the system. And reduce the leakage of oil from all units?

1.4 Objectives:

- Reduce the operation time of pumps, by reducing oil leakage losses.
- Calculation of the energy savings.
- Modification of the system.

1.5 Methodology:

The procedure to be followed in this research is as follows:

- Estimate the power losses due to working pump with unloaded.
- Estimate the actual pump working with loaded.
- Determine the time spent for the gear pump working without loaded.
- To avoid overloading the power distribution system.
- To avoid unnecessary wear and tear on equipment by reducing starting torque.
- Estimate the leakage of oil in all units.

1.6 Thesis Structure Outline:

The following provides an outline of this thesis.

In chapter one description the Rosaries dam background, importance of the study, problem statement, objectives, methodology and thesis structure outline.

In Chapter two discussed the Kaplan turbine that used in Rosaries hydro power station on details, and discussed to the Pro-control system used in station to control the operation, and discussed the governor on general and that used on the Rosaries hydro power station.

Chapter three presents the theoretical analysis of the governor system and the equation that used in calculation of saving power and oil leakage in units.

Chapter four presents discussed the calculation of the results.

Chapter five concludes the thesis and recommendation.

CHAPTER TWO

Literature Review

2.1 Kaplan Turbines:

In Al Rosaries power station The Kaplan Turbine is a reaction type feathering propeller where both the kinetic and pressure energy in the water are converted into mechanical work in the runner. The main feature of Kaplan Turbine is the simultaneous adjustability of its runner blade and guide vane opening to match the fluctuation of the load. Adjustability is controlled by governor and cam actions. This coordinated opening results in better load operation over a wide range of load when compared with other reaction turbine [2]. After the inlet the flow makes a right angle turn and enters the runner in an axial direction. The advantage of the runner blades and guide vanes being adjustable is that the range of head which the turbine can work at is flexible [3], The Kaplan turbine main components shown in Figure (2.1), which are:-

2.1.1 Draft Tube:

A well design draft tube recovers a large portion of the kinetic energy in the discharged water from the Runner by de-accelerating its velocity to the outlet Tail Race with minimum loss.

2.1.2 Spiral Casing:

This is provided in reaction turbines to distribute water uniformly through gates into the runner. (24 gates in Rosaries power plant)

2.1.3 Guide Vanes:

These regulate the quantity and direction of the water to the runner. The regulating ring mounted on the top cover is rotated by one or two or more hydraulic servomotors, through the connecting rods. (Unit 1 to 4 has two servomotors and units 5 to 7 have four servomotors).

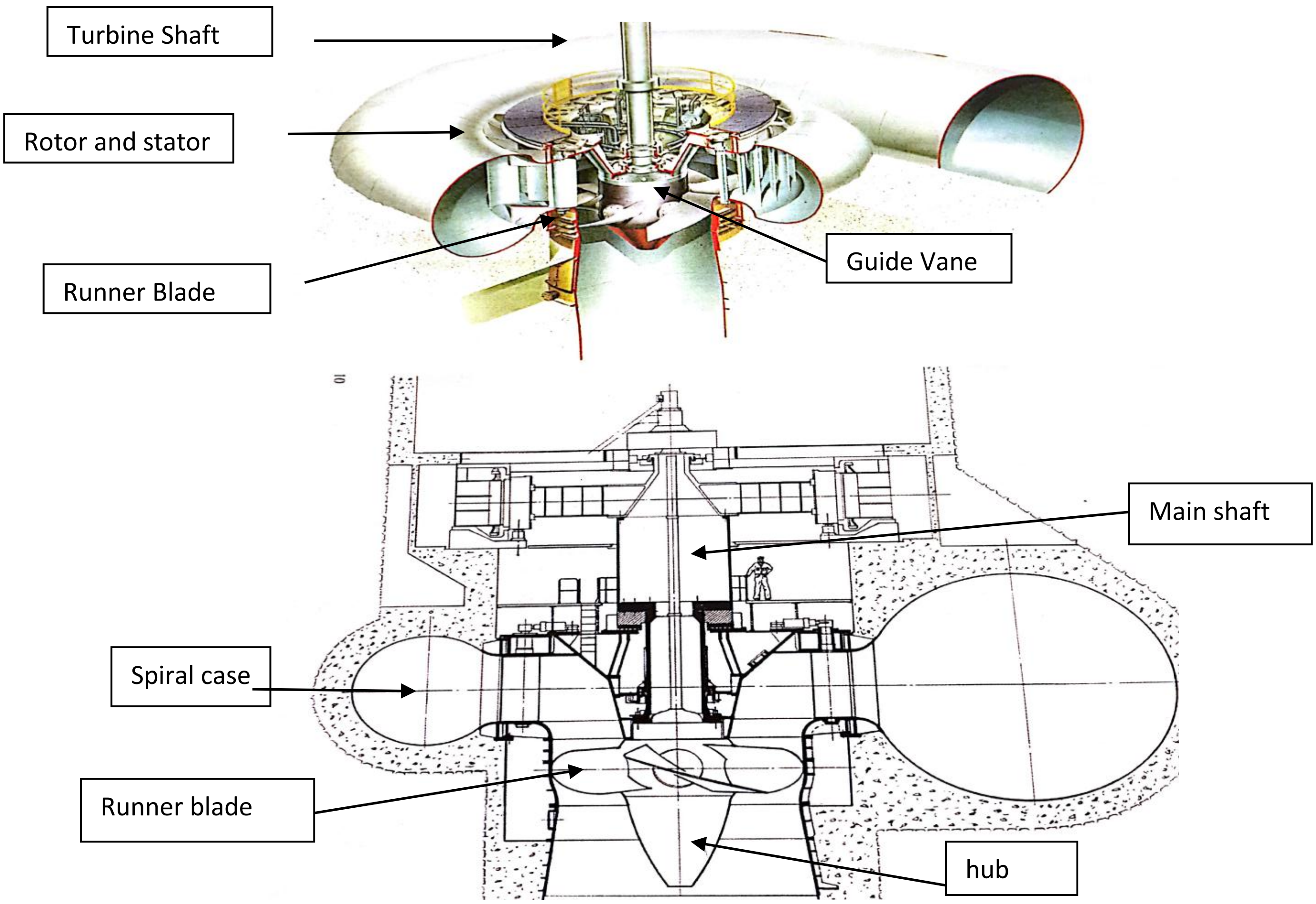

Figure (2.1): Turbine Main Component

2.1.4 Main Shaft:

The shaft is coupled to the runner through keys or fitted bolts at the lower end and through fitted bolts to the generator shaft at the coupling end.

2.2 Construction of Kaplan Turbines:

The runner has only a six radial blades oriented on the hub and without an outer rim. The water flows axially through the runner blades have a slight curvature and cause relatively low flow losses. This allows for higher flow velocities without great loss of efficiency. Accordingly the runner diameter becomes relatively small and the rotational speed more than two times higher than for a Francis turbine for the corresponding head and discharge. In this way the generator dimensions as well become comparatively smaller and cheaper. The comparatively high efficiencies at partial loads and the ability of overloading is obtained by a coordinated regulation of the guide vanes and the runner blades to obtain optimal efficiency for all operations [3].

A vertical section through a Kaplan unit is shown on Figure (2.2) from the upstream basin the water flows into the scroll casing (1). The water flows from the scroll casing through the stay ring (2), the guide apparatus (3), the runner and the draft tube (4) into the tail water basin. The generator (5) is arranged above the turbine, and in most cases above the highest level of the tail water. The axial thrust bearing (6) is loaded with axial forces from all the rotating parts. In many cases this bearing is arranged upon the upper turbine cover, which then has to carry all the axial forces [3].

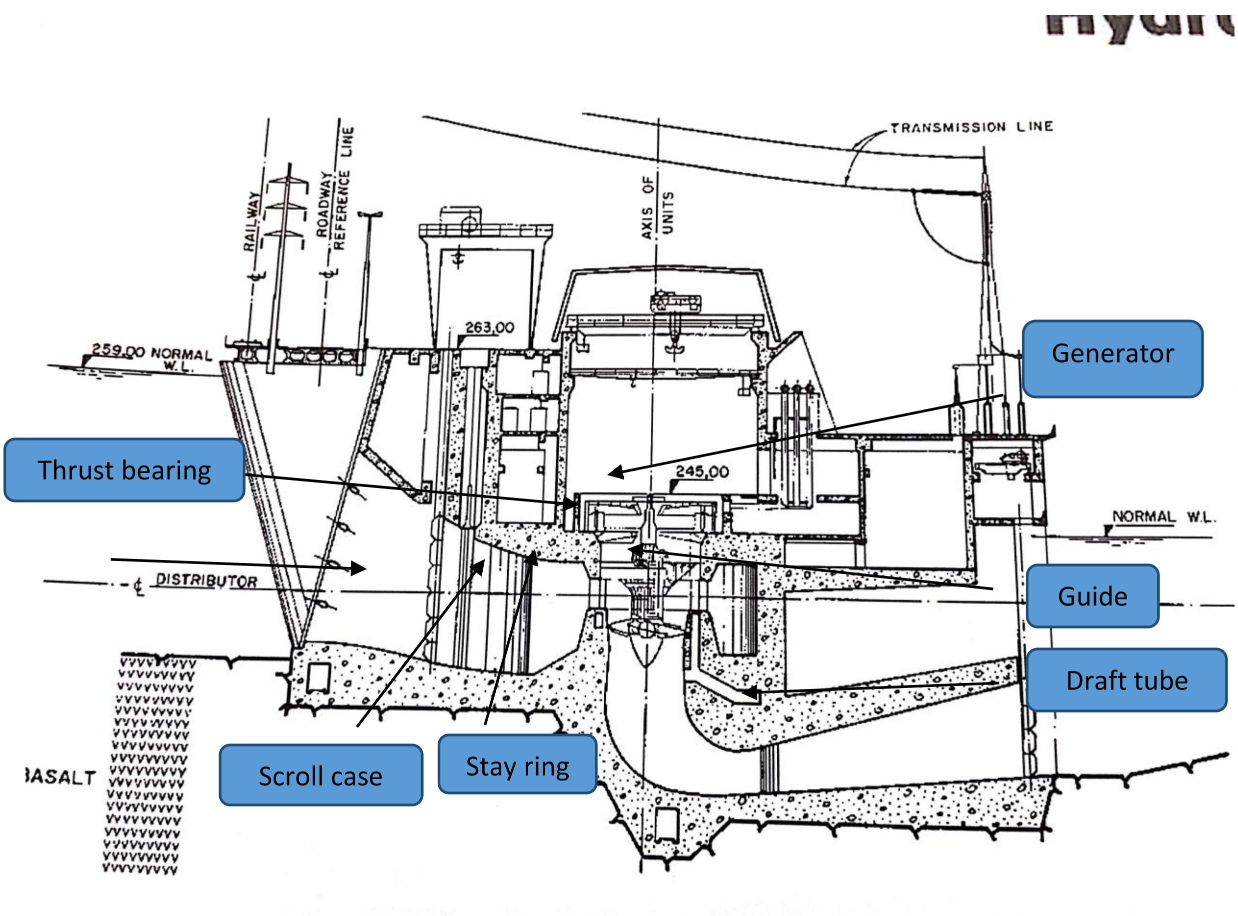

Figure (2.2): Vertical Section of a Kaplan Turbine plant (RHPS)

2.3 The Guide Vane Cascade:

In the sense of operation a regulating ring rotates the guide vanes through the same angles simultaneously when adjustments follow changes of the turbine load. The vane design is purposely to obtain optimal hydraulic flow conditions, and they are given a smooth surface finish.

2.4 Runner Blade Servomotor:

An example of a servomotor motion of the runner blades is shown schematically on Figure (2.3). The servomotor may consist of a moving cylinder and a fixed piston integrated with the hub. The conversion from axial piston movement to rotating blade movement is carried out by a link and lever construction. The hub is completely filled with oil to provide reliable lubrication of moving parts. The oil pressure inside the hub is kept higher than the outside water pressure to prevent water penetration into the oil.

2.4.1 Regulating Mechanism of the Runner Blades:

An example of the regulating system of the runner blade slope is shown on Figure (2.3). The slope of the runner blades (1a) are adjusted by the rotary motion activated by the force from the piston (11a) through the rod (17). The cylindrical extension of the upper end of the turbine shaft (9) serves as a servomotor cylinder (11) whereas the lower flange of the generator shaft serves as cover. The rod (17) moves in the two bearings (20). The oil supply to the servomotor (11) is entered at the upper end of the generator shaft (10). The oil is conveyed to the respective sides of the servomotor through two coaxial pipes (22 and 23) inside the hollow generator shaft. The inner tube (22) conveys oil to and from the lower side of the piston (11a), whereas the annular opening between the pipes (22) and (23) conveys oil to and from the piston top side. The oil is supplied through the entrance arrangement (12) with the two chambers (12a) and (12b) at the top of the unit.

2.4.2 Cooperation of Regulating the Guide Vanes and the Runner Blades:

The turbine governor operates directly on servomotor which executes the movement of the turbine blades shown on Figure 2.6. The movement of the servomotor trigs and controls the slope adjustment of the runner vanes. This is carried out by a rod and lever transfer from the servomotor to the cam which is turned according to the movement of the servomotor piston. In this way the spool valve is moved out of the neutral position and the servomotor piston is then put to movement by the oil pressure supply. The spool valve receives pressure oil either directly from the oil pump or from the accumulator which is energized by an oil pump.

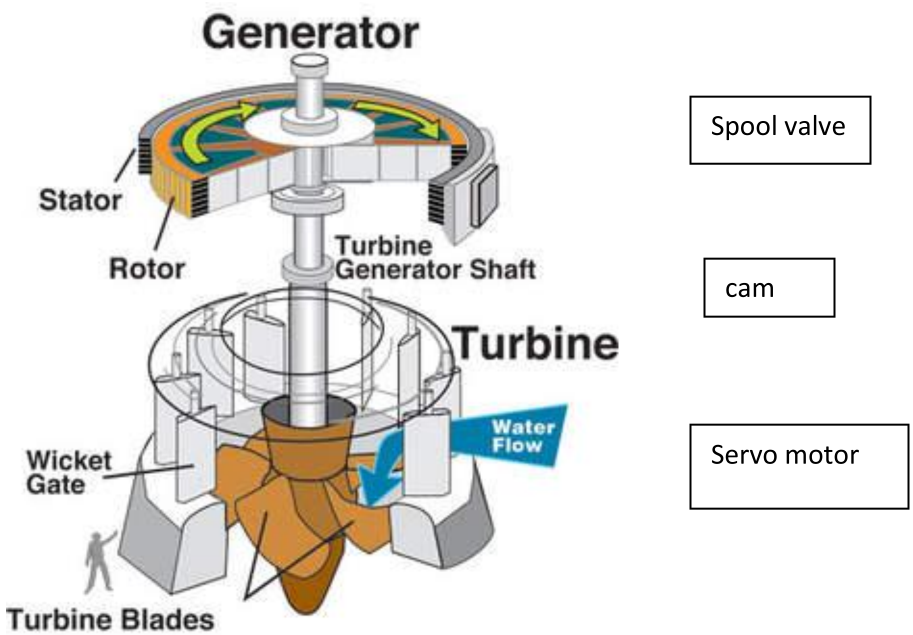

Figure (2.3): Regulating Mechanism of Kaplan Turbine Guide Vanes

2.5 Dual Control of Kaplan Turbines:

Optimal efficiencies of Kaplan turbines are obtained by optimal combination of the functions of the guide vane cascade control and the runner blade control. The combination of the two control functions may be carried out either by mechanical-hydraulic or by electro hydraulic operation [3]. A mechanical-hydraulic combination unit is integrated in the runner blade control system and consists of:

- main valve
- feedback mechanism
- combination control function curve
- pipe connections to the oil supply unit

The combination control function is to:

- Distribute oil for operation of the runner blades via the main valve Governors.

- position the runner blades according to the control function which is governed by the guide vane control

- Feedback of the spool position in the main valve

2.6 Governors for Hydraulic Turbines:

The primary speed/load control function involves feeding back speed error to control the gate position. In order to ensure satisfactory and stable parallel operation, the governor is provided with droop characteristics. The purpose of the droop is to ensure suitable load sharing between generating units [4].

2.7 Governing Principles:

Turbine governors are equipment for the control and adjustment of the turbine power output and evening out deviations between power and the grid load as fast as possible.

The turbine governors have to comply with two major purposes:

- To keep the rotational speed stable and constant of the turbine-generator unit at any grid load and prevailing condition in the water conduit.
- At load rejections or emergency stops the turbine admissions have to be closed down according to acceptable limits of the rotational speed rise of the unit and the pressure rise in the water conduit.

  Alterations of the grid load cause deviations between turbine power output and the load.

  For a load decrease the excess power accelerates the rotating masses of the unit according to a higher rotational speed [3].

The governor function for a turbine with water conduit is shown in the block diagram on figure (2.4).The input reference signal is compared feedback signal. By a momentary change in the load a deviation between the generator power output and the load occurs. This deviation causes the unit inertia masses either to accelerate or to decelerate. The output of this process is the speed, which again is compared with the reference [3].

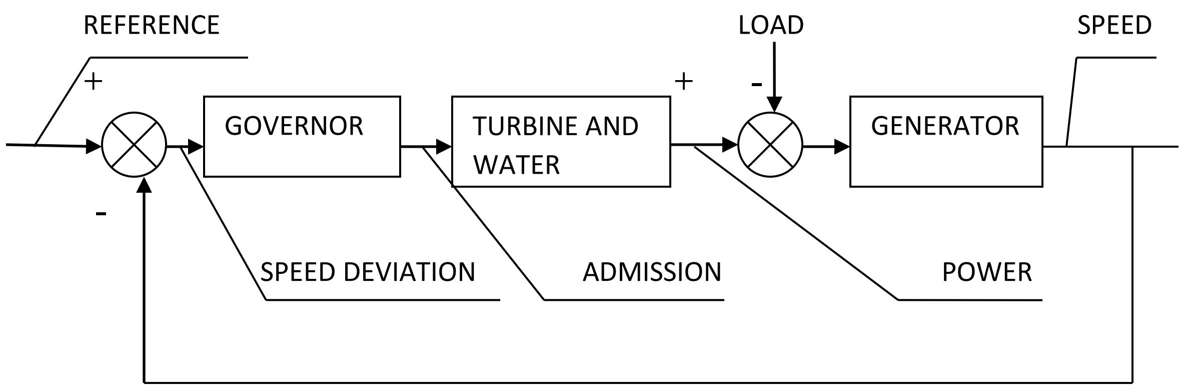

Figure (2.4) Block Diagram of A Turbine Closed Loop System

2.8 Isochronous Governor:

The adjective isochronous means constant speed, an isochronous governor adjusts the turbine gate to bring the frequency back to the nominal or scheduled value Figure (2.5). Shows the schematic of such a speed-governor system. The measured speed r is compared with reference speed $\omega 0$. The error signal (equal to the speed deviation) is amplified and integrated to produce a control signal ΔY which actuates the gate of the hydraulic turbine.

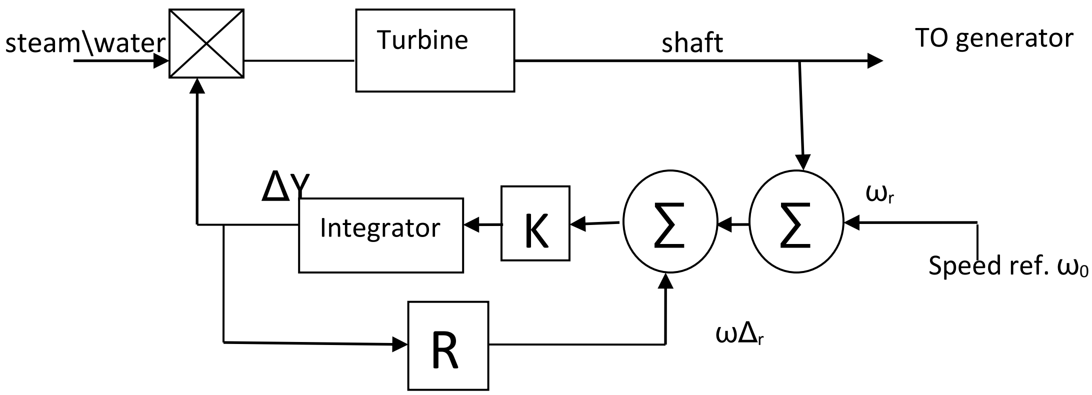

Figure (2.5) Schematic of an Isochronous Governor

2.9 Percent Speed Regulation or Droop:

The value of determines the steady-state speed versus load characteristics of the generating unit as shown in Figure (2.6). The ratio of speed deviation (ωr) or frequency deviation(Δf) to change in gate position(ΔY)or power output(ΔP)is equal to R. The parameter R is referred to as speed regulation or droop. It can be expressed in percent as

$$\textbf{Percent R} = \frac{\textbf{Percents peed or frequency change}}{\textbf{Percent power output change}} * 100\%$$

$$= \frac{\boldsymbol{\omega_{NL}} - \boldsymbol{\omega_{FL}}}{\boldsymbol{\omega_0}} * 100\% \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2.1)$$

Where

ω_{NL} = steady-state speed at no load.

ω_{FL} = steady-state speed at full load.

ω_0 = normal speed.

For example, a 5% droop or regulation means that a frequency deviation of 5% causes a 100% change in gate position or power output.

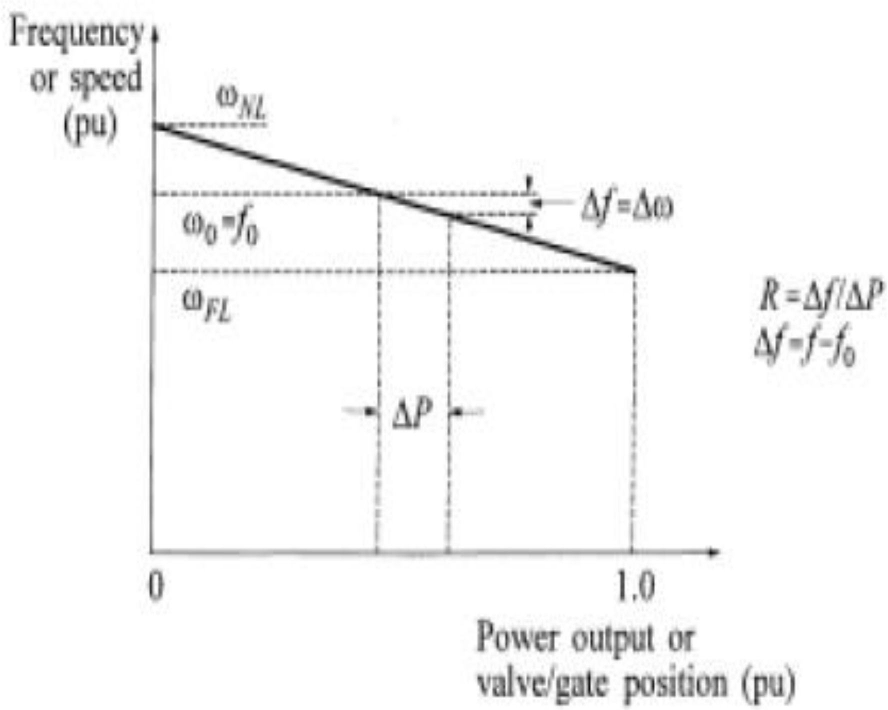

Figure (2.6) Ideal Steady-State Characteristics of a Governor with Speed Droop

2.10 Control of Generating Unit Power Output:

The relationship between speed and load can be adjusted by changing an input shown as load reference set point in Figure (2.6).

In practice the adjustment of load reference set point is accomplished by operating the speed-changer motor. The effect of this adjustment is depicted in Figure (2.7). Which shows a family of different characteristics for different speed changer motor settings. The characteristics shown are for governor associated with a 50 Hz system.

These characteristics are shown the load reference settings, A, B and C. At 50Hz, characteristics A. results in zero power output, B result in 50% power output and C results in 100% power output, thus, the power output of the generating unit at a given speed may be adjusting the load reference set point. This can be adjusted to any desired value by adjusting the load reference set point. This can be obtained through actuation of the speed-changer motor, for each setting, the speed-load characteristic has a 4% droop, that is, speed changer of 4 %(2Hz) causes a 100% change in power output.

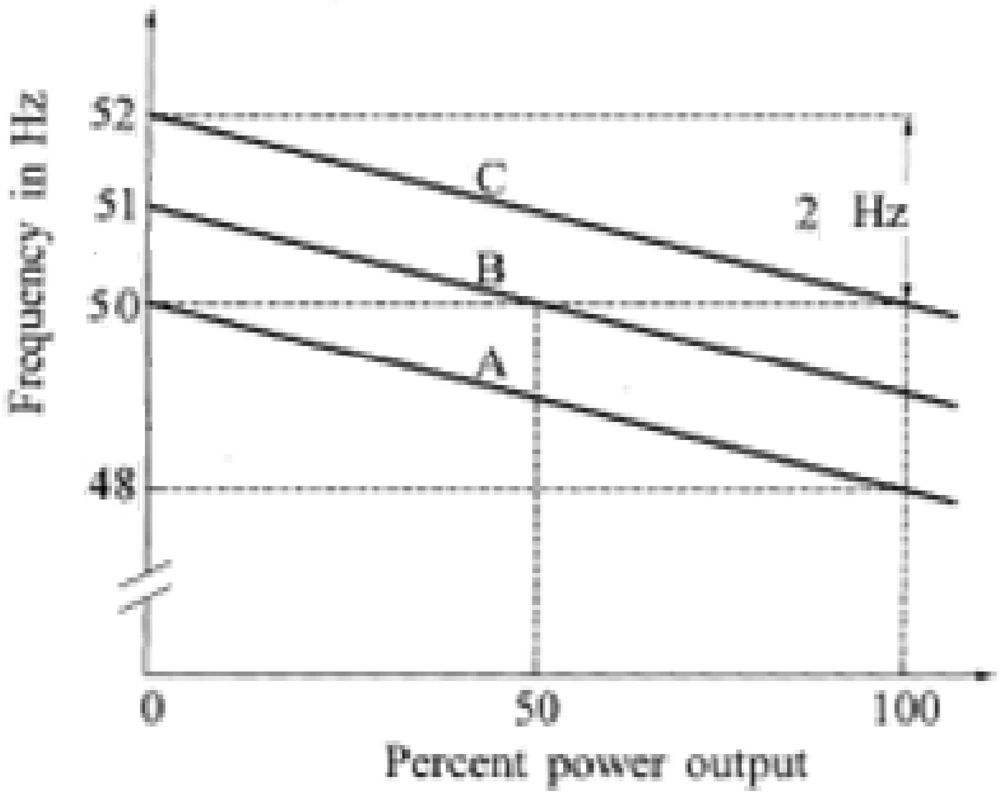

Figure (2.7) Effect of Speed-Changer Setting on Governor Characteristics

When two or more generating units are operating in parallel, the speed-droop characteristic (corresponding to a load reference setting) of each unit merely establishes the proportion of the load picked up by the unit when a sudden change in system load occurs. The output of each unit at any given system frequency can be varied only by changing its load reference, which in effect moves the speed-droop characteristics up and down.

When a generating unit is feeding an isolated load, the adjustment of the speed changer changes the unit speed. However, when the unit is synchronized to power system, the speed-changer adjustment changes the system power output; it only has amino effect on system frequency, depending on the size of the unit relative to that of the total system generation.

2.11 Distributed Control Systems:

2.11.1 Control Systems- Brief Background:

A control system is a collection of components working together under the direction of some machine intelligence.

In a modern control system, electronic intelligence controls some physical process. Control systems are the “automatic” in such things as automatic pilot and automatic washer. Because the machine itself is making the routine decisions, the human operator is freed to do other things. In many cases, machine intelligence is better than direct human control because it can react faster or slower (keep track of long-term slow changes), respond more precisely, and maintain an accurate log of the system’s performance. [5]. every control system has (at least) a controller and an actuator (also called a final control element). Shown in the block diagram in Figure (2.8). The controller is the intelligence of the system and is usually electronic. The input to the controller is called the set point, which is a signal representing the desired system output. The actuator is an

Electromechanical device that takes the signal from the controller and converts it in to some kind of physical action. Examples of typical actuators would be an electric motor, an electrically controlled valve, or a heating element. The last block in Figure (2.8). Is labeled process and has an output labeled controlled variable. The process block represents the physical process being affected by the actuator, and the controlled variable is the measurable result of that process [6].

2.11.2 Analogue and Digital Control Systems:

In an analog control system**,** the controller consists of traditional analog devices and Circuits, that is, linear amplifiers. The first control systems were analog because it was the only available technology. In the analog control system, any change in either set point or feedback is sensed immediately, and the amplifiers adjust their output (to the actuator) accordingly. In a digital control system, the controller uses a digital circuit. In most cases, this circuit is actually a computer, usually microprocessor- or microcontroller-based. The computer executes a program that repeats over-and-over (each repetition is called an iteration or scan). The program instructs the computer to read the set point and sensor data and then use these numbers to calculate the controller output (which is sent to the actuator). The program then loops back to the beginning and starts over again [6].

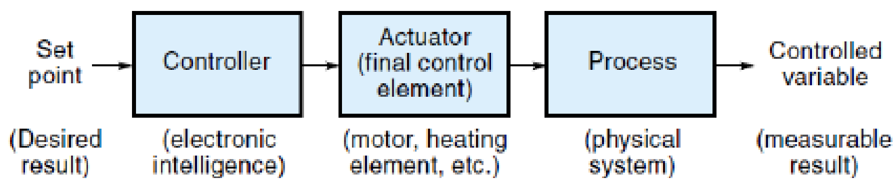

Figure (2.8): A block Diagram of a Control System

2.12 Pro-control Control System:

2.12.1 Pro-control P13 power plant control system:

Pro-control P13 is a complete DCS software and hardware collection produced by ABB and can be installed in fossil power plants, gas turbine and combined cycle power plants, hydro power plants, nuclear power plants, waste to energy plants, industrial plants and AC and DC high voltage distribution. Generally, the key functions of pro-control fall in to: -

- Plant management
- Operations
- Control and input/output
- Engineering

2.12.2 Plant Management:

Reduced time to decision making and action is critical for improving the availability and productivity of the plant. This is accomplished by improving three main aspects

2.12.3 Information Management:

Information management functions are inherent to the system 800xA.Historical process and business data is collected from disparate sources and stored securely. It involves Intuitive Presentation Flexible report generation and distribution and secure historical data storage and access.

2.12.4 Plant Performance:

Optimax is integrated with the Procontrol P13 system. This permits fast and simple extension of the proven Procontrol P13 functionality. ABB's Optimax range of products provides solutions covering early detection of calibration problems to avoid unnecessary trips and improve their predictive maintenance.

2.12.5 Plant Level Optimization:

- Reporting
- Analysis tools
- Enterprise level optimization

2.12.6 Operations:

Industrial IT 800xA Process Portal System Interface extends beyond the realm of process control to provide rapid and consistent access to field devices, asset optimization tools, information management systems, safety systems, and applications. It provides accurate and timely information that is critical for making the right decisions. This is accomplished by presenting relevant information including access to distributed information so as to achieve quick response to plant conditions.

2.12.7 Control and Input/output:

The Pro-control P13 Control and I/O Devices are designed for maximal robustness allowing very high plant operation availability and quality of the control tasks. It is composed of multiprocessor control modules, this includes

- Input modules
- Output modules
- Local bus modules
- Interplant modules
- Processing modules

2.12.8 POS 30 (Process Operator Station):

The POS30 operator station available for PROCONTROL P has proven to be the ideal tool for controlling, supervising, monitoring, analyzing and optimizing the power plant process. It is a consistent and uniform user interface for the whole plant, even if the plant is subdivided into different locations. Scalable system performance and flexible hardware and network expandability enables POS30 installations to grow up from the smallest single user configuration to the largest enterprise-wide full scope system to keep up with the user's growth requirements.

The functionality of POS30 is characterized by

- Unrestricted plant control and data access from any POS30 display station.
- Provision of a complete set of displays which are necessary for efficient control as e.g. mimics, trends, sequence of events and characteristics.
- Support of the operator in case of abnormal plant conditions by fast access to relevant displays and efficient navigation among displays.
- High resolution graphics and windowing; support of workplace concepts; multi-screening; mouse as preferred pointing device.

- Consistent and uniform color scheme, adaptable by authorized users.
- Basic process and plant management functions: data recording, calculations, counting of operating time, switch cycles, impulses and quantities and a broad range of reporting facilities.
- System security ensured by personal user accounts with password profiles.
- System diagnosis with summary status information.
- Client/server architecture based on industrial PCs, running Linux, a powerful and free portable operating system.

The POS30 system consists of three main components:

1. OMS:

The Operation and Monitoring Services (OMS) is the basic component of POS30. It provides the functionality for all process control requirements.

2. RCR:

The Recording Calculation and Reporting Services (RCR) is an option covering the process and plant management functionality.

3. XTC:

The (XTC) Data Interface provides facilities to Integrate 3rd party (DCS) and (PLC) system e .g. via (OPC), to communicate with plant.

Management and optimization systems and to enable multifaceted remote access features.

2.13 The Control System Description:

The pro-control control system Figure (2.9). has different modes of operation. When the generating unit is isolated from the grid (isochronous) the system works as a speed/frequency controller (depicted as frequency controller in the figure) control system. When connected to the grid, it works as a load controller (depicted as active power controller in Figure (2.9).

Level and Flow controllers are used to limit output power through selection logic. This is needed when water flow or level is too insufficient to reach the required output power values.

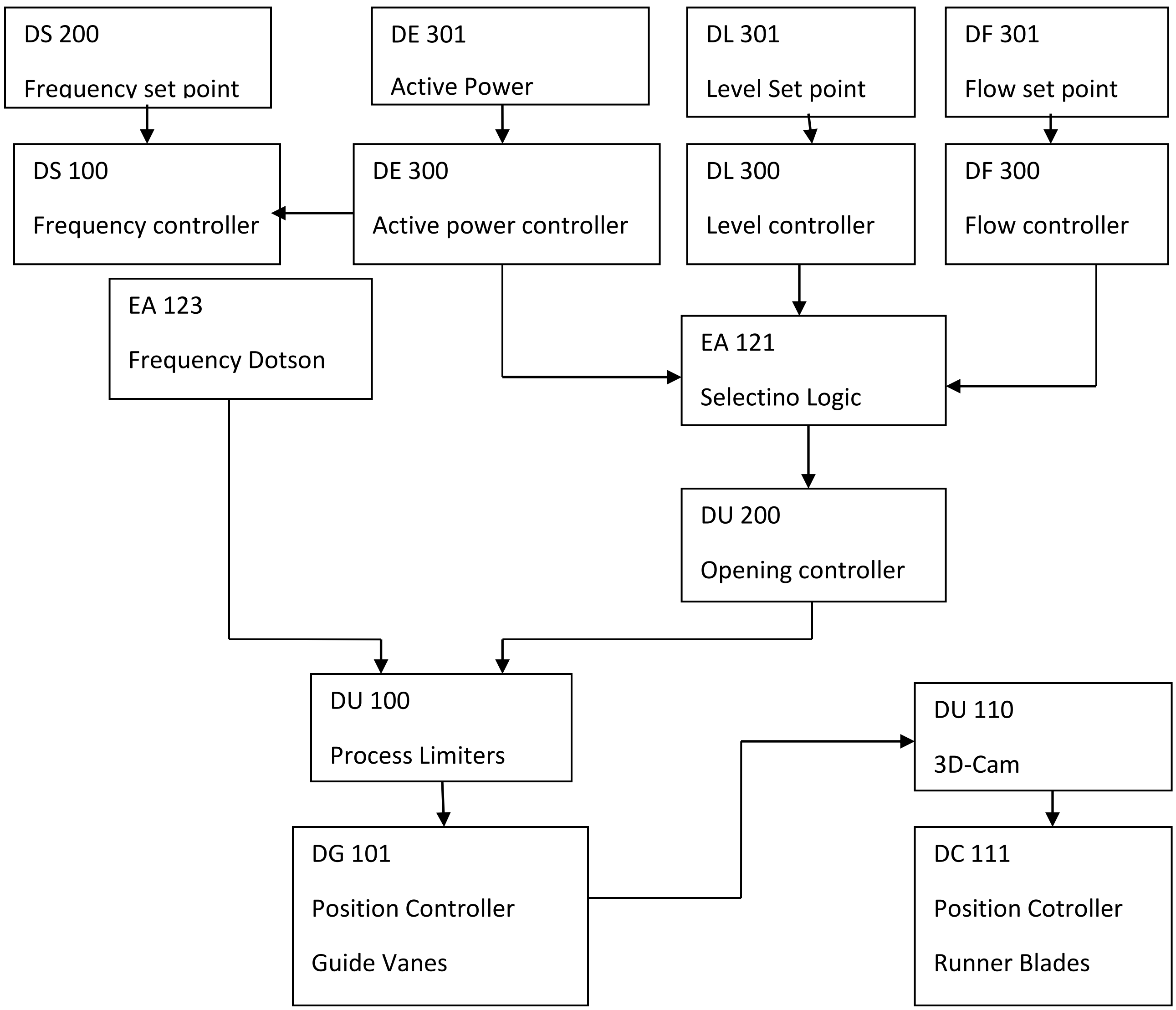

Figure (2.9) Pro-control Control Diagram

2.13.1 Functional Description of Pro-control:

2.13.2 Positioning Control:

When operating in the upper load range the guide vane as well as the runner may be limited depending on the head. This is done to prevent the turbine from leaving the optimized cam control. The limiting functions limit the set point of the wicket gate and the runner via the minimum selection.

The runner is operated off cam when it reopened or when the flush, stop and/or surge controls are in operation as well as during stopping of the unit. In these cases the positioning circuit has a defined set point.

During quick shut downs or load rejections the stop control closes the guide vane at full orifice speed until the turbine stops supplying power. From this point on, it starts closing slowly. As soon as the actual speed exceeds the speed set point, the runner is controlled at adjustable opening, this means it is governed from the "off" cam control. As soon as the actual speed falls below speed set limit, it is released again for on cam control.

The runner set point position is calculated via the head dependent came from the guide vane set point position and the head signal. The three-dimensional cam is defined with freely adjustable parameters.

The position control function includes also an opening limiter that can be adjusted between -5 and 105%. The actual value of the opening limiter limits the opening of the guide vane and the runner via a minimum selection. The load limiting functionality acts on the minimum selection and limits the output power to a predefined upper limit.

2.13.3 Speed Control:

The speed controller set point is adjustable between 90 and 110%. The set point ramp is readjusted automatically to 100% during the start command and after synchronization. The no load opening is compensated automatically in the speed controller to allow favorable synchronization for all operation points. The frequency dead band becomes effective during parallel operation. The dead band limit is freely adjustable.

The PID-type speed controller determines the set point for the wicket gate servomotor position by calculating the difference between the set point and actual speed value. The permanent speed droop determines the influence of the frequency changes on the controller output (isolated network operation).

According to the mode of operation the wicket gate set point signals, calculated by the speed, opening, or water level controller are connected through the selecting logic. The speed controller output does not follow the other controller outputs

2.13.4 Opening Control:

The opening set point is adjustable between -5 and 105%. The operation mode opening control may only be selected when the unit operates in parallel. During all other operation modes the opening set point follows the actual guide vane opening. Thus, bump less transfer between modes is possible at all times. If there are frequency deviations from the rated value, the frequency compensation value is determined by the frequency opening droop.

2.13.5 Water Level and Flow Control:

The set point of the water level controller is a predefined parameter. The operation mode water level control may only be selected when the unit operates in parallel. When activating water level mode, the set point starts from actual level and comes through a gradient limiter to a preset value. This results in minimum disturbance of actual flow and water level.

If the value of the flow set point is less than the water level, the water flow is used in calculation of limits. Otherwise it is water level (minimum selection).

2.13.6 Contained Logic:

The operation mode selection (control of the speed, opening, water level, etc.) ensues according to the most plausible option at a given time. When a fault occurs, the system switches to another feasible operation (e.g. opening control) or shuts down the unit. Internal isolated network detection monitors the frequency deviations in relation to the rated value of 50 Hz = 100%. When either the upper or lower limit value (beyond the speed range) is reached, the message "isolated network (internal detection)" appears provided that there is no "isolated network (external detection)" input. The mode "isolated network detected" prevails as long as the speed remains beyond the required speed range or as long as there is an "isolated network (external detection)” input. Usually, when operating in the isolated network mode a switch to speed control ensues and the isolated network parameters are selected.

2.14 Governors and Governors Type:

The governor uses either mechanical or electronic feedback to sense the speed of the turbine. Proportional or directional valves controlled by the governor operate cylinders that open and close wicket gates or needle valves to adjust the flow of water to the turbine in order to maintain constant turbine speed.

Three types of governors for speed and power control of hydraulic turbines are [5]

1. Mechanical governor.
2. Analogue electronic governor.
3. Digital electronic governor.

2.14.1 Mechanical Governor:

Mechanical governor were universally used in hydro generation up to 1965 or so. In these governors, a synchronous motor run by a shaft permanent generator senses the speed and fly balls fixed to the sleeves control the pressure oil system for servo motor control. Speed sensing and control section are physically linked to the mechanical hydraulic actuator Performance, adjustment of signals for stable operations i.e. permanent speed droop, temporary speed droop and dashpot 7 to 14 time by adjusting mechanical linkages.

A simple but classic example of a turbine governor is shown schematically in Figure (2.10).

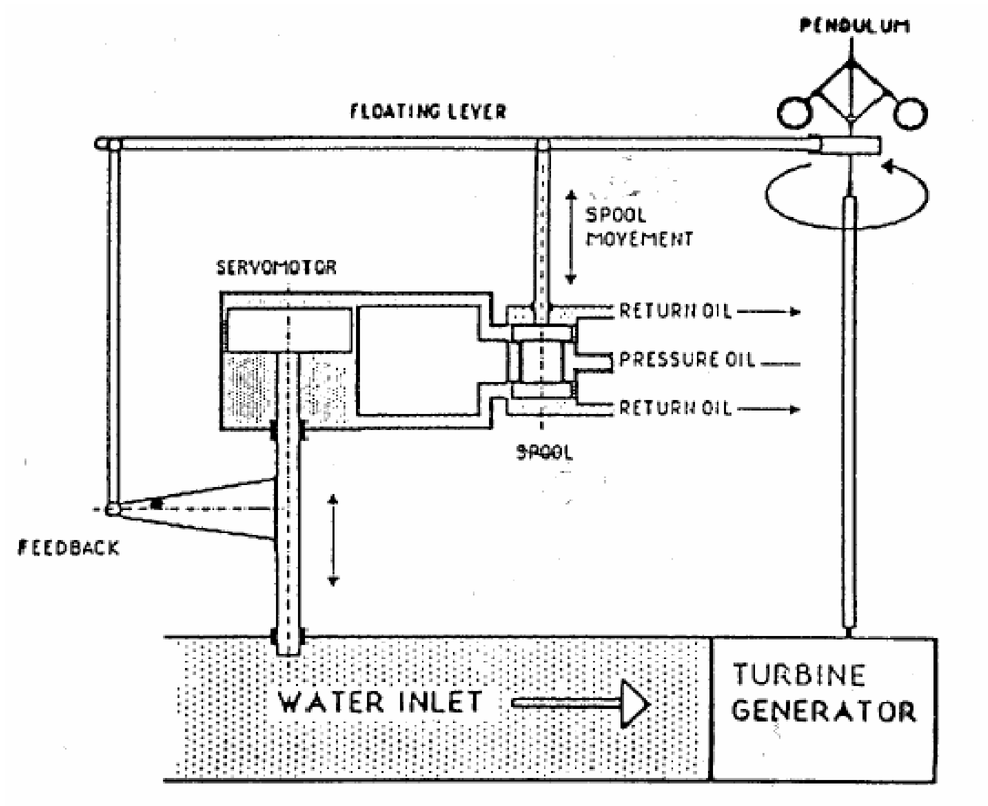

Figure (2.10) Hydraulic Governor with Direct Acting Pendulum

This is a governor with a belt driven centrifugal pendulum. For explaining the governor actions it is chosen to start at a moment of stable equilibrium between power and load. In this condition the control valve is closed by the spool, which is in the neutral position.

When a decrease in the grid load occurs, the rotational speed starts increasing the pendulum sleeve and the connected end of the floating lever moves upwards. The lever moves the spool accordingly upward out of the neutral position and opens the hydraulic conduits to the servomotor.

High-pressure oil flows to the piston topside. The piston moves downwards and reduces the gate opening and the turbine power. At the moment when the power is equal to the load, the rotational speed culminates as indicated on Figure (2.11). [4].

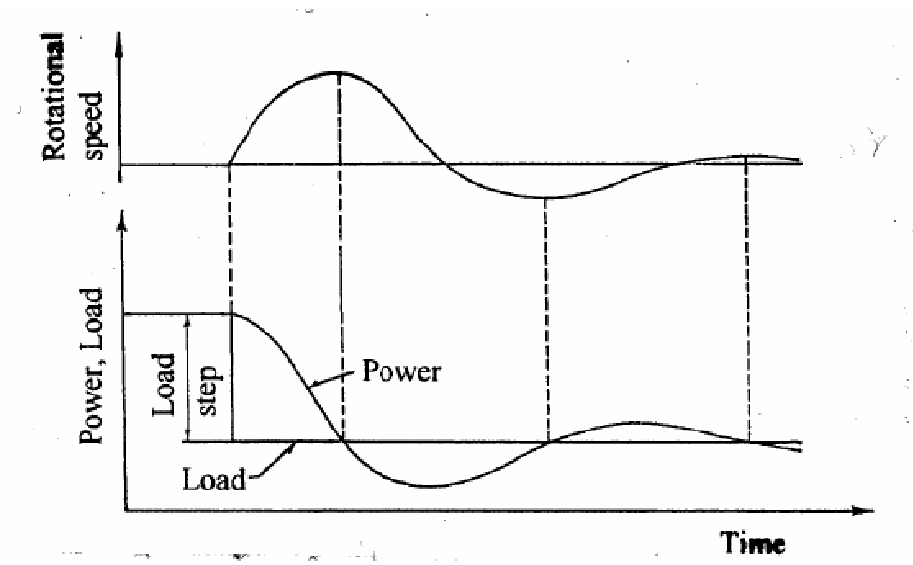

Figure (2.11): Time Response of Power Output and Rotational Speed after A load Reduction

At this moment however, the spool valve is still open. The piston movement continues and the power output decreases even more. Consequently the speed decreases and the pendulum sleeve and the spool are moving downwards again.

During this movement the spool valve passes the neutral position and opens then for high-pressure oil flow to the opposite side of the piston. The piston movement is thereby returned and the power output increasing. Next time the rotational speed culminates the power again is equal to the load and therefore a succeeding swing in the speed and power output take place as previously described. As Figure (2.11). indicates, the swings are strongly damped because of the feedback system. This feedback is arranged by a linkage connection between the servomotor rod and the end of the floating lever that is opposite to the sleeve as shown on the Figure (2.10). When the piston moves in the closing direction, the floating lever moves the spool accordingly in the same direction towards the neutral position. In this way a stable control process is obtained.

2.14.2 Analogue Electronic Governor:

In electronic governor's hydraulic actuators, speed sensing is done by speed signal generators (SSG). The signal is converted to proportional voltage signal and amplified in a magnetic amplifier. Electronic hydraulic transducer converts proportional signal to release proportional pressure oil for servomotor operation. Feedback control is obtained by mechanical linkages. Control linkages are mostly mechanical.

2.14.3 Digital Electronic Governor:

Speed sensing and processing is digital. PID digital speed control can be combined with unit and plant control functions. All linkages are electric. Speed sensing is done by a digital signal, like proximity switches. Feedback control or restoring mechanisms (position of wicket gate servomotor) is by electric signals.

2.14.4 Digital Electro Hydraulic Control System (DEH):

This system uses a digital controller, which is interfaced with the turbine valve actuators through analogue hybrid section. The digital control system offers considerable flexibility since the control functions can be implemented through software.

The normal speed control function is set to provide the standard 4%-5% regulation. The response of the governor is very fast, the time constant being on the order of 0.03s. Programmable dead band may be provided to prevent governor response to small frequency variations

Owners considering using an electronic governor should evaluate the need for additional spare parts (such as printed circuit boards) and the need for additional skills and training for maintenance personnel. This may be a particular concern for plants located in remote areas.

The governor may be packaged in various arrangements. Three configurations are common: the gate-shaft type governor; actuator-type governor; and the cabinet type governor.

Rosaries Power Generation Station is an important part of power generation in Sudan. The station consists of seven vertical turbines. These turbines work under water head of 29m height. These seven turbines are directly connected to seven electric generators, the generated power of each is 40MW, working under voltage of 11KV. The power generated from 7 Units is 280 MW.

In the past governors were mechanical, developed from the centrifugal pendulum governor designed by James Watt in the seventeenth century. Governors used droop control or speed regulation to control output power.

The control and protection systems in hydropower stations have advanced dramatically in recent years. In the first half of the twentieth century, small hydropower plants were using hardwired relays for semi-automatic operation of the turbine auxiliaries, and mechanical governor for speed control. With the development in computer technology, computers are now widely used in hydropower stations for various controls.

The governing in Rosaries digital, provided by ABB under their PROOCONTOL P system, the aim of digital governing systems is to provide efficient control, as well as added functions, implemented for different situations, for example considering change in water flow or water level in output power.

PROCONTROL P adds further positive aspects; the process operator software provided, POS 30 offers wide range of power plant management and statistical collection.

2.15 The Main Functions of The Governing System:

- Control of the turbine start-up and shutdown sequences.
- Synchronization of the turbine with grid.
- Control of the active power supplied by the generation to an interconnected network.
- Control of network frequency on an isolated electrical network.
- Production of the unit against over speed in case of load rejection.
- Control of advanced sequences.

The speed governor system operating in Rosaries power station has great proportions, with a medium volume of hydraulic fluid, and requires safe and quick actuation. Due to the complexity of the system, it is possible to rearrange it in subsystems, so the circuits become more didactic to analyze. The major subsystems are the pressurization unity, accumulators, valves and control devices for servomotors, actuators (servomotors) and the air auxiliary system. Other essential mechanism for the safe operation of the speed governor is the over speed sensor valve (actuated by the over speed device mounted on the shaft), the control valve for the wicket gate closing time and the servomotor hydraulic lock.

CHAPTER THREE

METHODOLOGY AND TOOLS

3.1 Theoretical Analysis:

One common way to generate electric energy is the rotation of a synchronous machine, which is responsible to convert the mechanical energy from the driver and requires constant speed to produce an acceptable range of frequency for the consumers[7].The drivers for these generators are usually turbines, whether they uses water or others as source of energy. Therefore, these machines are susceptible to deviation in the electric load, caused by the demand on the electric system and require a speed governor to control the frequency generated. This work studies the speed governor for Kaplan turbines, which actuates in the section of water entrance in order to promote its control. The wicket gate controls the water flow variation in hydro Kaplan turbines. The gate is a set of moving vanes that closes or opens, promoting the reduction or increase of the area, respectively, in the inlet of the turbine. A group of the rods connected to the regulation ring drives the wicket gate, also called distributor. This ring is moved by the servomotors of the hydraulic responsible for the speed control [8]. The speed governor system operating in Rosaries has great proportions, with a medium volume of hydraulic fluid, and requires safe and quick actuation. Due to the complexity of the system, it is possible to rearrange it in subsystems, so the circuit becomes more didactic to analyze.

The major subsystems are the pressurization unity, accumulators, valves and control devices for servomotors, actuators (servomotors) and the air auxiliary system. Others essential mechanism for the safe operation of the speed governor is the over speed sensor valve (actuated by the over speed device mounted on the shaft), the control valve for the wicket gate closing time and the servomotor hydraulic lock.

In figure (3.1) are shown some system components mentioned. The servomotor figure (3.1a) is the actuator that promotes wicket gate movement and is located at 46m above sea level (elevation 46). The electric motors of the pressurization pumps of the speed governor are shown in figure (3.1b), the pumps are installed inside the sump tank figure (3.1d) as well as the other hydraulic components responsible for the speed governor's hydraulic logic. The accumulator's figure (3.1c) and the sump tank are located at the elevation 48. The intermittence valve in figure (3.1e) is the hydraulic component responsible for directing the discharge of the pump, controlling the intermittent work of pressurization. In the same picture figure (3.1e) is shown the pressure detector valve, responsible to open or close the intermittence valve accordingly to the pressure in the accumulators.

Figure (3.1a) Servomotor

Figure (3.1b) Pressurization Pumps Drivers

Figure (3.1c) Accumulators

Figure (3.1d) Sump Tank

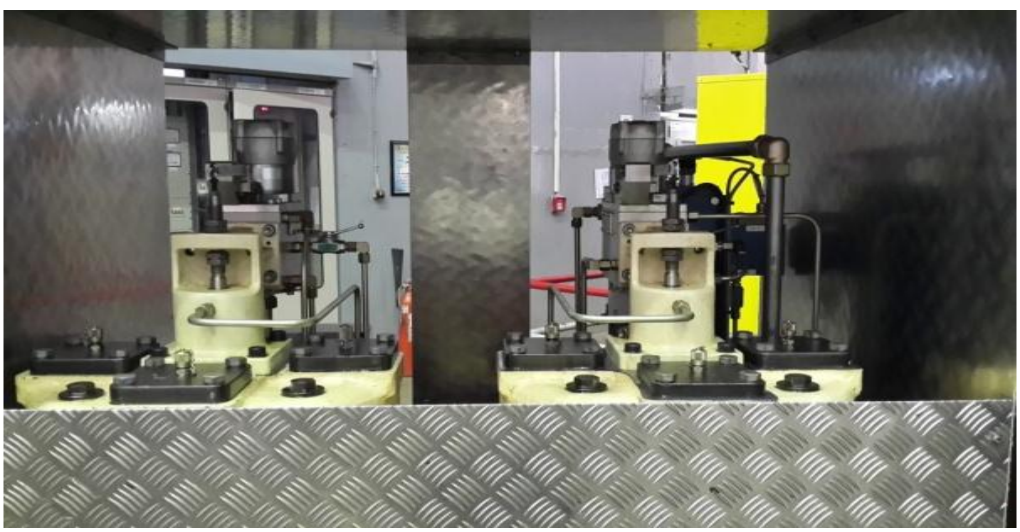

Figure (3.1e) Intermittence Valve and Pressure Detector Valve

Figure (3.1) Component of the Speed Governor System

3.2 Hydraulic Acumulators:

It is important to describe hydraulic accumulators, because the pressure transducer installed on this tank provides the measures used to estimate the pressurization intermission time in this article. In addition, the pumps have this intermittent work rate due to the existence of the air oil pressure vessel, which makes possible the operation of the system. In a simple hydraulic system, the designer specifies the pressurization pumps accordingly with the maximum capacity of the actuators. This causes an over specification of these pumps , which will require a high power electric motor to drive the pump and, consequently, a high cost with motor starters and cabling and to make the system more economical and reliable it's inserted in its logic of work a hydraulic accumulator, that reduces the pump requirements [9]. It becomes more critical when the system has a large size and works with actuation in short periods, which is the case of a speed governor system. There are hydraulic systems that require a constant and close range of work pressure that needs to be maintained for a long period of time. It's hard to keep a hydraulic circuit pressurized, due to the internal or external leakage of its component that causes pressure drops. That is the case of the speed governor and, besides the leakage; it requires a large amount of fluid for a short period of time during the actuation and supply the leakages of the system's components. Accumulators have the function to absorb the shocks caused by the instantaneous pressure that may occur due to sudden flow stoppage. They can either compensate the effect of thermal expansion or contraction which depends on the system's operational condition [10].

In Rosaries, the speed governor system has gas pressurized accumulator called air-oil tank, responsible for those functions described above. The pressure in this accumulator is constantly monitored by the supervisory system and controls the operational regime of the pumps. In other words, the device that senses the accumulator pressure is a spring adjusted to put the pump in full load when the pressure in the air-oil tank reaches 3.5 MPa. This device is called pressure detector valve, and it is a exclusively mechanical component, susceptible to deviations in the adjustment, variation in the system's pressure, mechanical wear and clearances. When this valve actuate its discharge oil pressure in intermittence valve. This valve controls the discharge of the pump, redirecting the flow to the main pressurized line or to the heat exchangers to promote recirculation of the fluid. Due to safety there are alarms linked to the pressure inside the tank and alarms activated by the tanks level sensor. This sensor consists of a set of level switches that send a electrical signal to the supervisory system when the level of oil inside the tank reaches specific limits.

3.3 Volumetric Pumps:

As the hydraulic accumulator it is important to describe the operation principle of volumetric pumps. Understanding the pumps operation, it is possible to infer the influence of changes in pressurization time interval and it is important to select another pump compatible with the fluid characteristics, which is capable to deliver the necessary flow at the system's working pressure. To obtain the necessary pressure in hydraulic systems, positive displacement pumps are used, which differently of the centrifugal pumps supply energy to the fluid due to the volume, reduction. The resultant fluid pressure depends on the restrictions applied to the flow on the downstream piping to the pump [13]. Due to the pressure rise caused by the shutoff of these pumps it is necessary to install safety devices and construct a robust pipeline [11]. It is important to know the operating conditions to select a pump. Some of these conditions are the discharge pressure, speed expected range, temperature, noise level, characteristics of the motor drive, flow rate and viscosity of the discharged fluid [12]. Screw pumps have some advantages, like a wide range of flows and pressure, also a high range of liquids and viscosities low internal velocities, some designs are tolerable for entrained air and other gases, cause low churning, low foaming, operate with low mechanical vibration, noise and the flow is pulsation-free [13]. These characteristics are enhanced accordingly to the design of the rotors. The pumps can be constructed with single or multiple rotors, where the multiple rotors type can be subdivided in timed or untimed design. The timed pumps generally refers to a pump with two rotors synchronized by timing gears, so the drive is connected to one screw and the other one has its movement engaged by the pair of gears, that can be assembled inside the pump housing or in a special casing that avoid contact with the pumped fluid. Untimed type of screw has rotors with mating-thread forms, so the driving force is transmitted continuously between the rotors. Generally it refers to pumps constructed with three rotors; one is driven rotor that meshes with the others two screws called idlers. The housing provides support for the axial loads [13]. The pressurization pump operating in the speed governor of Rosaries consists of multiple screw untimed rotor, which is similar to the description above, a power and two lateral rotors. The screws have a helical thread that promotes close fitting and engagement of the movement. The mating between the rotors is necessary to promote the flow through the pump. This flow is axial through the pumping elements unlike the other rotary pumps [13]. For further results it is necessary to evaluate the necessary theoretical power to drive the pump rotor (W_t) and the pump displacement (S_d). These operating parameters can be calculated with the Equation (3.1) and (3.2). (Q_t) represents the theoretical flow through pump, (N_b) is the pump rotor speed, g is the gravitational acceleration, ρ is the specific mass of the pumped fluid and (H_p) stands for the monomeric elevation of the pump. Equation (3.2) can be simplified to the product of (ΔP), which is the provided differential pressure by the pump in P_a, with the theoretical flow (Q_t) ,

$$Q_t = S_d * N_b \ldots\ldots\ldots\ldots\ldots S_d = \frac{Q_t}{N_b} \qquad (3.1)$$

$$W_t = \rho Q_t g H_P = Q_t \Delta P \qquad (3.2)$$

These equations can be applied to different positive fixed displacement equipment, either it is a vane, gear, lobe or screw pump, The differences between these types of rotor is the geometry used to calculate theirs displacement per revolution .

3.4 Induction Motors:

In this section, the emphasis given to the study of motor drives will be needed to explain the behavior of currents and starting torque for induction motors. This is important because the proposed improvement, which this work suggests, causesa significant fall in energy consumption, because the number of pressurization cycles will be reduced, as well as the total time working in full load of the electric motor for the pressurization of the oil. For the use in the next results, it is important to estimate the output power of a induction motor, in the same way as it is necessary to know the angular speed of the driver motor. Equation 3 & 4 returns the electric power(W_{el}), and the motor speed (N_m) respectively, where $V_l$is the line voltage, $I_l$is the line current and cosφ represents the induction motor power factor In equation 4 f represents the electric tension frequency and P is the motor poles number.

$$W_{el} = \sqrt{3} V_i I_i \cos\varphi \qquad \text{[W]} \qquad (3.3)$$

$$N_m = 120 * f/P \qquad \text{[RPM]} \qquad (3.4)$$

Most of pump drives in industrial environment are three phased induction motors, this equipment presents low cost when compared to other motors, it is easy to control, robust and efficient. Induction motors are composed essentially of a rotor and stator. The stator is connected to the electric grid and electromagnetically induces currents flux in the rotor [14].

The interest in this study is the curves obtained for the motor torque and current, from the start of the motor to the steady operation. This is critical for the speed governor's; the start current can reach 3 to 4 times the normal operation current. Also, when two pumps need to drive simultaneously, the electrical panel has an over current that shuts down the source of the motors and causes trip on the generating unit.

To develop this article it was necessary to identify the variables involved with the pressurization pumps operation. The study started with the interpretation of the hydraulic schemes available on the technical library of dam. These diagrams lead the author to comprehend the redundant assemble used to pressurize the oil. It was verified that these pumps cannot stay too out of operation and the housing of the electric motor should always be heated. The heating is necessary due to bearings lubrication, if the housing has its heating off, the grease gets too thick and there is no possibility of starting the engine.

After this previous study and the orientation of professional responsible for the maintenance engineering, the author identified the pressure in the hydraulic accumulator as the variable of interest, associating the intermittent behavior of the pressurization pumps with the oil level lowering in the tank. As mentioned above the hydraulic accumulator is responsible to supply the system internal leakage and this leakage is different in all generating units that imply different intermission times between pressurizations. This occurs due to the difference of the clearances in the hydraulic system's inherent components that may appear with different operational conditions for the equipment.

The data collected on the supervisory system represents the level in the air-oil accumulator of the speed governor system. These data behaves as shown on Figure (3.2a) and Figure (3.2b). This diagram refers to the pressure inside the tank, acquired in all generating units as a safety alarm trigger. The Figure 3.2 shows the difference that can exist between the intermission time in the generating units, that means different wears and lifetime of the main pressurization pumps

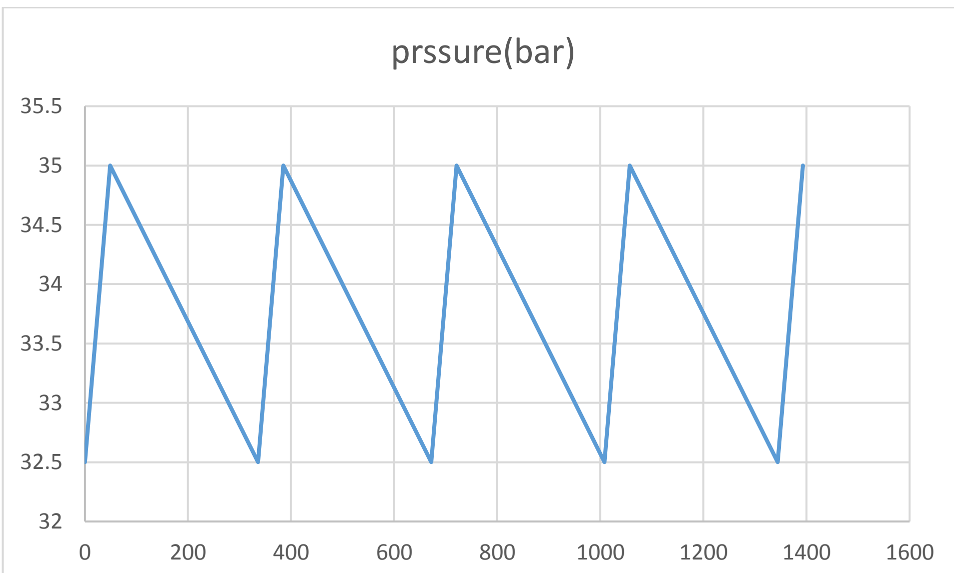

Figure (3.2a) Pressure Diagram Measured in Unit (5)

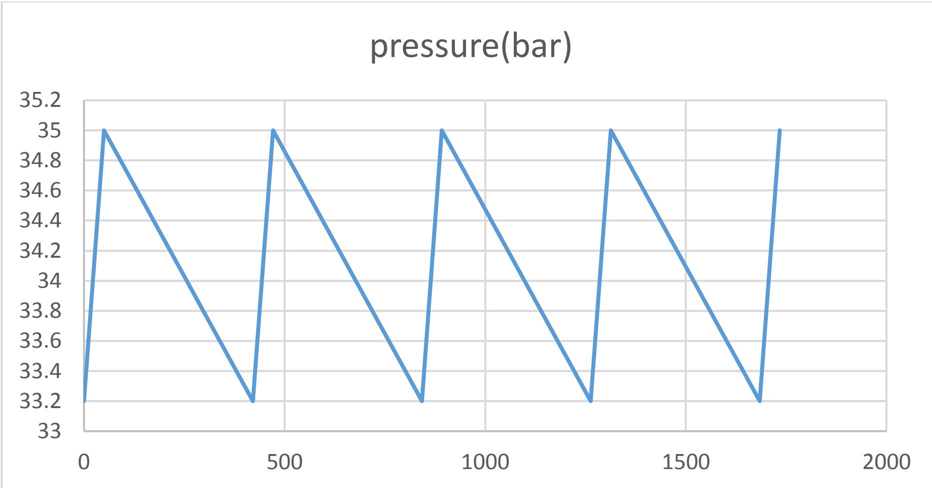

Figure (3.2b) Pressure Diagram Measured in Unit (2)

Figure (3.2): Behavior of the Oil Level in Two Different Generating Units. (5and2)

To obtain the leakage flow of each generating unit, it was necessary to measure the oil level on the generating unit .With the resultant measures of the sensor. The author was able to correlate the pressure collected by the supervisory system with the oil level variation inside the accumulator tank appear in Figure 3.3 and figure 3.4 (a) and (b). This leads to the possibility of estimate the leakage flow that leaves the tank steady state operation.

Fig (3.3) The Oil Level Sensor Inside the Accumulator

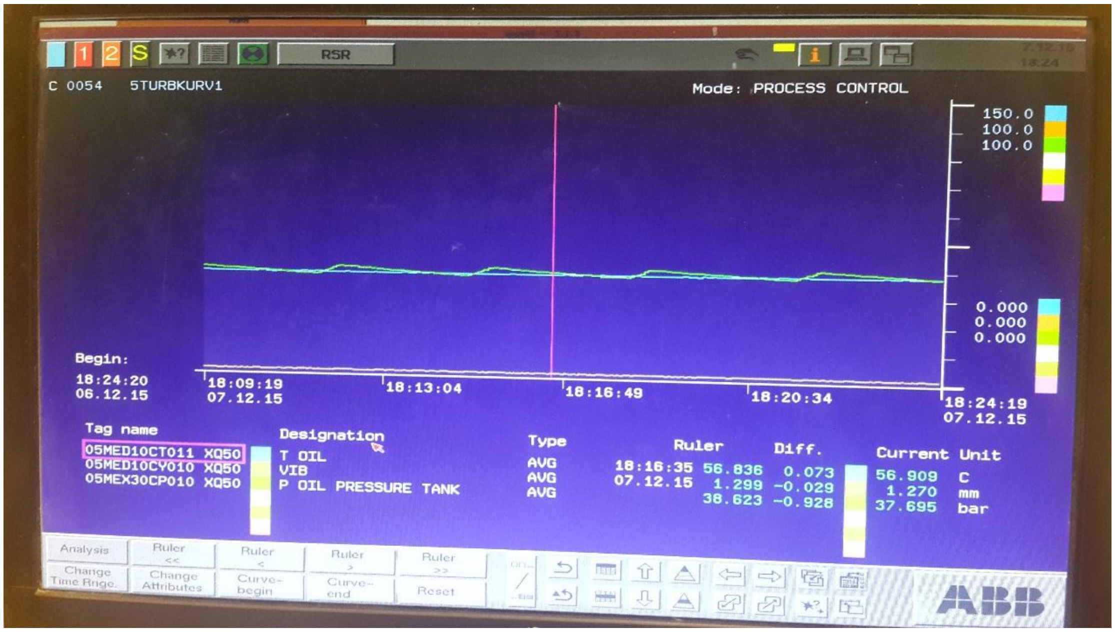

Figure (3.4a) The Pressure Chart of Unit 5

Figure (3.4b) The Pressure Chart of Unit 4

Figure (3.4) Pressure Diagram for Units (4and 5)

To apply statistical treatment in the data collected on the supervisory system, it was implemented an algorithm in Matlab®. The algorithm consists in comparing near points in the data vector to determine the position of the maximum and minimum points. This way the pressurization intermission time can be estimate by subtracting the minimum and the maximum points, although this is not valid for the pressurization time. The pressurization time varies within 43 to 59 seconds and the minimum sampling time of the supervisory system. Due to the pressure behavior inside the tank or the sensor dynamic, the measuring error is not acceptable with this sampling time. So, the pressurization time can be accepting the results for the intermission times, the author has established a maximum standard deviation of 9%. The first results were computed with 10 seconds between measuring points, during two days of operating time. The calculus obtained in some generating units was heavily dispersed and a finer study was necessary. After tests with 2 and 5 seconds sampling time, during constant output power of the generating unit, the standard deviation was acceptable in all results, as shown on the next section.

The main results of the algorithm consists in the intermission times for all generating units in minutes, the standard deviation, the oil volume reduction between pressurization, and the leakage flow of the hydraulic accumulator. As explained due to hydraulic system's similarity between all generating units.

This evaluated result is necessary to develop the proper equipment selection. The main purpose of this article is to determine a steady state pump, accordingly to the criteria established in the standards IEEE Std 125 and IEEE Std 1207. This pump is also called by makeup pump or pony pump, and has the function to supply the hydraulic system's oil leakages during regular operation of larger generating units.

CHAPTER FOUR

RESULTS AND DISCUSSIN

4.1 Introduction

The methodology explained on the previous section leads to the results in Table (4.1). The computed results was evaluated with 5 seconds sampling time on Oct 14th from15h 00min to 22h 00min , the data used to estimate the UG 7's intermission time refers to Nov 14th from 15h 00min to 22h 00min. The unit's output power in this period was above 85%. This period of the year is been chosen because the highest or maximum load, the deviation for the measures was acceptable in all generating units. The servomotor displacement during normal operation of the generating unit has high influence in the time between the pressurizations, which can lead to inconsistent analysis. The global analysis presented in the Tab. 1, makes possible to determine equipment to operate in all units. Accordingly to IEEE Std 1207, the makeup pump helps reduce the number of start/stop cycles of the lead pump when the servomotors are at constant operating position. Generally, the makeup pump should be able to provide two times the oil consumption during steady-state conditions. The excess can be diverted to a kidney loop filtering system, which also helps maintain the oil cleanliness level. The whole idea of this design is to provide common equipment, capable to supply the demanded flow, which can either improve the oil quality or reduce the number of pressurizations of the lead pump. The major direct impact of this

Table (4.1): Results Obtained for the Intermission Times in all Generating Units.

UNITS	Intermittent Time(min)	Standard Deviation (Min)	Percent Deviaton (%)	Volume Leakage (m^3)	leakage flow (l/min)
U1	5.24	0.356	6.79	0.61	116.41
U2	6.19	0.405	6.54	0.52	84.00
U3	4.78	0.327	6.84	0.51	106.69
U4	4.69	0.316	6.84	0.55	117.27
U5	5.87	0.481	8.19	o.49	83.48
U6	5.81	0.346	5.96	0.50	86.06
U7	4.75	0.466	9.81	0.44	92.63

Installation is the energy it can results for the system. The main pump drivers are 45 KW motors. This motor has a high energy demand and elevated start currents. From data collected on the maintenance registers and using the equation 2 it is possible to estimate the energy savings potential as given in Table (4.2).

Table (4.2): Energy Saving Potential

UNITS	Energy Consumed without Load[KWh]	Energy Consumed with Load[KWh]	Energy Savings Potential[%]
01	1129	646	57.2
02	1335	646	48.4
03	1031	646	62.7
04	1011	646	63.9
05	1266	646	51.0
06	1253	646	51.6
07	1024	646	63.0

The division on the Table (4.2). Appears due to in the operational parameters of 50 Hz driver.

Computing the global energy savings potential, it leads to 8049 KWh, economies and to 8977265 KWh annual economies.

This value is theoretical, it may be reduce with the makeup pump installation, for instance, but it is a very high potential for every common industrial environment. The energy saving is only the direct impact of this modernization.

The major gain for the maintenance staff is the cost reduction, low amount of spare parts 0f lead pumps required and improvement of the oil's quality. Consequently, this leads to great reliability and uptime on the generating units.

Therefore, based on the results evaluated and in catalogues from manufacturers it is possible to choose one equipment capable to operate in the described conditions.

4.2 Hydraulic Pump Selection:

Applying equation (3.1) and (3.2) to determine the value of maximum drive power for the units

Minimum pump displacement=$\frac{\mathbf{117.27*1000}}{\mathbf{3600}} = \mathbf{32.58\ cm^3}$

$$\boldsymbol{W_t = \frac{117.27 * 40}{60} = 7818\ w}$$

The maximum drive power should be fixed in 10^3 W

Then new $\boldsymbol{Q_t = \frac{10^3*10*60}{40}}$**= 150** $\boldsymbol{L/min}$

Table 1 gives the maximum leakage flow of 117.27Lpm, which will be assumed as the theoretical flow Q_t . Evaluating the maximum driver speed, given by Eq. 4 results in 3600 RPM, which leads to a minimum pump displacement of 32.58cm^3 . Equation 2 returns a minimum driver power 7818 W, with operating pressure of 4.0 MPa and the same theoretical flow. The reference flow accordingly to the standard is the twice of the demanded by the hydraulic system. However, as the flow of generating unit 2 is not quite representative, the maximum driver power should be fixed in 10 kw. This is necessary to attend the purpose to design a small and economic system. This way, the maximum theoretical flow given by Equation (3.2) using the same pressure as before is 150L/min.

Based on the previous criteria searching in manufacturers catalogues, looking for the equipment which best suits those functions. The rotor pump that will be used is the gear type. Gear pump is a viable option due to its simplicity of use and maintenance, it is capable to supply the demanded flow and pressure, it is efficient, resistant to cavitation and compact. Second reliable technical data was found on parker Hannifin's catalogue, which leads to a pump with a fixed displacement of 36.50 cm^3, that can provides maximum theoretical output flow of 126.97 L/min. The information obtained in the catalogue is essential to plot the characteristics curves of the gear pump, shown on Figure (4.1). The design selected to operate in this project is the H90 gear pump, which can supply oil up to 10.3 MPa pressure.

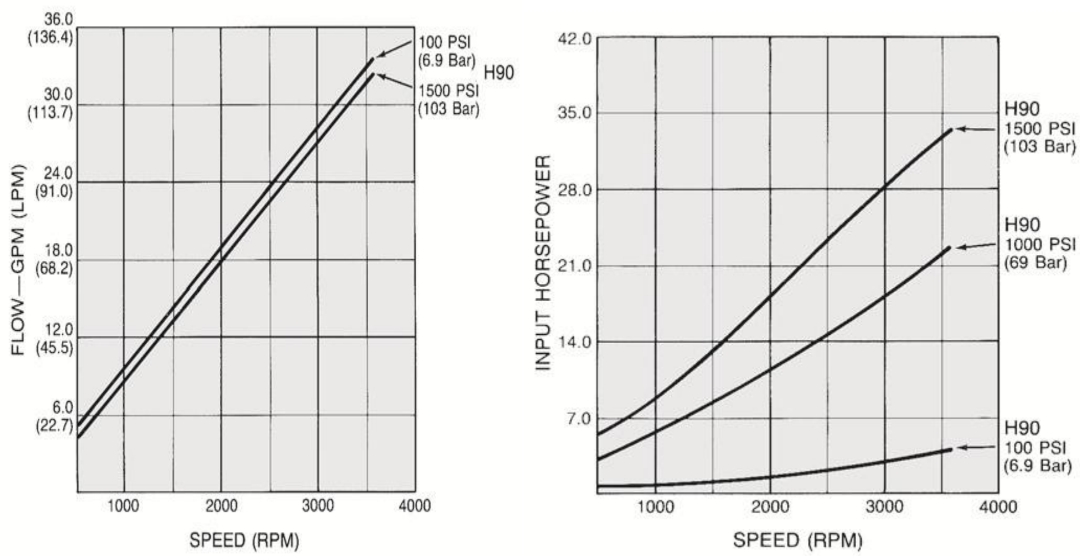

Figure (4.1) Characteristic Curves of the Gear Pump

Figure (4.1). shows that the input power increases with the flow, in this graphic it is possible to see the theoretical and the real power for pressurization at 4MPa, which is an amount given by the catalogue close to speed governor's operating pressure. It is possible to estimate the pump efficiency evaluating the theoretical and the real power ratio. As shown on Figure (4.1). a medium value obtained for the efficiency is about 89%.

It is possible to evaluate the internal leakage of this pump to the given pressure and speed, comparing the flow given by the catalogue and the theoretical flow. The internal leakage of this pump empirically measured in bench tests applied to the equipment and behaves as a curve dependent both on pressure discharge and driver speed. The driver torque value depends on the working pressure, which is a limitation to map its behavior. A constant operating pressure implies in a constant driver torque, that makes the power directly proportional to the pump's rotation.

Table (4.3). shows the mean value of the steady state leakage, the flow reference accordingly to the standard, the respective necessary power to drive the pump and the nominal rotation, applying the mean efficiency evaluated above. The values in red represents the units where is not possible to follow the normative recommendations to the hydraulic design. These occurrences do not discredit the design proposition, even though it is not possible to achieve the required flow, the number of pumping cycles will be decreased or even eliminated it in some cases, Another design restriction that must be respected accordingly to manufacturer is the minimum suction height, which is necessary to keep the flow pressure on the pump's entrance above 254 mmHg at 1800 RPM and 127 mmHg at 3600 RPM.

Table (4.3): Operating Parameters of each Generating Unit to Selected Pumps

Generator units	Mean flow [L/min]	Normative Flow [L/min]	Required Power [KW]	Driver Speed [RPM]
Unit 1	116.41	232.82	15.44	3450
Unit 2	84.00	168.00	11.73	2970
Unit 3	106.69	213.38	15.44	3450
Unit 4	117.27	234.54	15.44	3450
Unit 5	83.48	166.96	11.73	2970
Unit 6	86.06	172.12	11.70	2970
Unit 7	92.63	185.26	15.44	3450

With the results described above, it is possible to note that these pumps cover the necessary flow at the system pressure, with a low power driver. Furthermore the efficiency is acceptable and it is possible to control the delivered flow rate by changing the speed of the pump driver the benefits of these changes in the hydraulic circuit consist in reducing significantly the power consumption from the electrical motors used on the main pumps extend the main pressurization pumps life which implies in reducing the costs and decreasing maintenance down time. Adapting this pump can be an alternative to achieve those goals by extending or eliminating the pressurization intermission time.

4.3 Hydraulic Design and General Description:

To the proper operating of the hydraulic circuit it is necessary to specify components as pressure line filter, recirculating filter, control valve to change the flow direction manometers in the upstream and downstream line of the pump, flow-meter, check valves, relief valves, cabling and electric panel to connect the induction motor and the directional valve. Also it is necessary to control the actuation of the directional valve using the pressure inside the accumulator tank.

This control system should change the directional valve position whenever the pressure inside the accumulator reaches 3.2 MPa to avoid the main pump pressurization the pressure detector sensor should be adjusted to close the intermittence valves below 3MPa in this configuration the main pump would be responsible to maintain the temperature of the speed governor's oil while the makeup pump provide the system's leakage during steady state operation.

Figure (4.2). Shows the hydraulic scheme of the makeup pump. When the pressure inside the accumulator reaches 3.2MPa the directional valve is on the position shown on Figure (4.2). Discharging filtered oil to the accumulator tank. When the pressure reaches 4.0MPa the directional valve changes the flow direction to the recirculating filter. The pressure line filter is a non-bypass filter to avoid entrance of unfiltered oil in the main hydraulic circuit. Both filters have a switch that remotely indicates its obstruction or malfunction. All the components should have good manufacturing quality long lifetime and market continuity. This design concept can substantively improve the oil's quality if implemented with the necessary adjustment to make the system better.

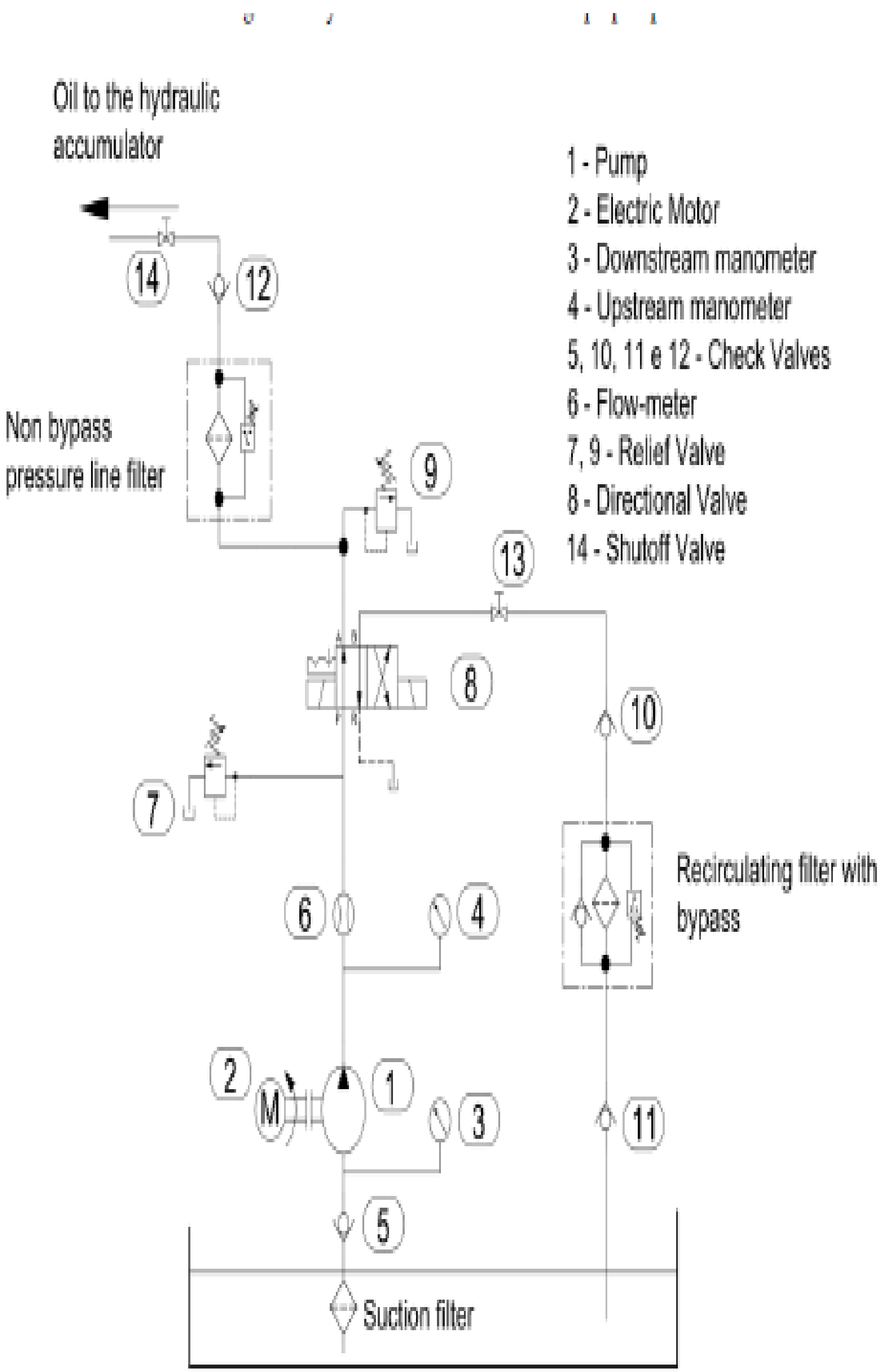

Figure (4.2) Hydraulic schemes for the makeup pump

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions:

This results show that there is a possibility of reducing significantly the power consumption, leading to a more efficient system and rising the time of recirculation on the heat exchangers, ensuring that overheating do not occurs in the oil. The speed governor for energy generation this equipment depends on hydraulic systems to developed actuating power and this article discusses one possible main to improve the system quality.

Table (4.2) shown that the energy saving potential in the power station for all units, the power consumption before the study in the maximum load is 12571 KWh, this amount of power reducing after the study to 4522 KWh, that means the ratio of saving is 56.2%.

Figure (4.1) shown that the hydraulic scheme of the makeup pump, if the pressure inside the accumulator tank is lower the directional valve is open to filtered oil to the accumulator tank when the pressure reach maximum the directional change the flow direction to the recirculating filter, this design concept can substantively improve the oil's quality if implemented with the necessary adjustment to make the system better.

5.2 Recommendation:

- Study the use of motor soft starter device, speed drive device or star-delta-star for all motor that use to drive governor pump for start-stop. In load and unload time. This device use with AC, electrical motor to temporarily reduce the load and torque in the power train. Avoid pressure surge, smoothly started, stability of the power supply and reduce the transient voltage drops that may affect other loads.
- Study and redesign of the drainage pumps system that use to retain the excessive oil from the servo-motors of guide vane and the gate to the main tank for reduce the lot of leakage oil.

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