МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
АЕРОКОСМІЧНИЙ ФАКУЛЬТЕТ
Кафедра авіаційних двигунів

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач кафедри
д-р техн.наук, проф..
____________ М.С. Кулик
“____” _________ 2020.

ДИПЛОМНА РОБОТА

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ « МАГІСТР »
ЗА ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ
“ ГАЗОТУРБІННІ УСТАНОВКИ І КОМПРЕСОРНІ СТАНЦІЇ ”
(ПОЯСНЮВАЛЬНА ЗАПИСКА)

Тема: Дослідження шляхів удосконалення систем автоматичного керування газотурбінних установок.

Виконав: ____ Насралла Ахмад

Керівник: канд. техн. наук, доцент __________________ Гвоздецький І.І.

Консультанти з окремих розділів пояснювальної записки:

Охорона праці: к.б.н., доцент ________________________Коваленко В.В.

Охорона навколишнього середовища:

канд. техн. наук, доц. ____________________________Черняк Л.М.

Нормоконтролер : ___________________ /_____________________ /

КИЇВ 2020

MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE

NATIONAL AVIATION UNIVERSITY

AEROSPACE FACULTY

AEROENGINES DEPARTMENT

PERMISSION FOR DEFENCE

Head of the Department
Doctor of Sciences (Engineering), prof.
___________ M.S. Kulyk
"_____" ______ 2020

MASTER'S THESIS
ON THE EDUCATIONAL PROFESSIONAL PROGRAM "GAS TURBINE PLANTS AND COMPRESSOR STATIONS"

(EXPLANOTARY NOTE)

Theme: "Research of ways of improvement of automatic control of gas turbine installations"

Performed by: _____________________________________ Nasrallah Ahmad

Supervisor:
Ph.D. (Engineering), prof.______________________________ Gvozdetskyi I.I.

Advisers:

Labor precaution :

Ph.D., Associate Professor______________________________Kovalenko V.V.

Environmental protection :
Ph.D. (Engineering), Assoc. Prof.________________________Chernyak L. M.

Standards Inspector ________________________ /_________________________/

Kyiv 2020

NATIONAL AVIATION UNIVERSITY

Faculty: *Aerospace Faculty*

Department: *Aeroengine department*

Educational degree: *Master*

Specialty: *142 "Power machinery"*

Educational Professional Program: *«Gas Turbine Plants and Compressor Stations»*

APPROVED BY

Head of the Department

__________M. Kulyk

" " ____2019

Graduation Work Assignment

Nasrallah Ahmad

(surname , name and patronic of graduating student)

1. Theme: "Investigations of ways of improvement of automatic control of gas turbine installations"

   Approved by the Rector's order of September 26, 2019 № 2187/ст

2. The project to be performed from 29.10.2019 to 02.02.2020
3. Initial data for the project: Gas turbine plant should be calculated for standard ambient conditions $p_н$ = 101,325 Pa; $T_н$ = 288 K
4. The content of the explanatory note (the list of problems to be considered): Introduction; The brief description of engine designed parameters and substantiation of the main engine working process parameters; Analytical part; Project part and patents research; Special part; Labor precautions; Environmental protection; General conclusion .
5. The list of mandatory graphic materials: power turbine structural scheme, Block diagram of GTP automatic control system. Microsoft office Power Point, AutoCAD should be used to provide graphic support and presentation.

6. Time and Work Schedule

№	Stages of Graduation Project Completion	Stage Completion Dates	Remarks
1.	Literature review of materials concerning theme of diploma work.	15.10. 18-30.10. 19	
2.	Patent review of the problem.	31.10-06.11.19	
3.	Historical review of ACS	07.11-11.19	
4.	Automatic control systems for industrial purposes	12.11-16.11.19	
5.	Modern types of automatic control	17.11-21.11.19	
6.	Integration of ACS of GTP with ACS of CS	22.11-30.11.19	
6.	Labor precaution	15.12.18- 20.12. 19	
7.	Environmental protection	20.12. 18 - 30.12.19	
8.	Arrangement of graphical part of diploma work	14.01. 18 -20.01.20	
9.	Arrangement of the explanatory note	20. 01.19- 25.01.20	

7. Advisers on individual sections

Section	Adviser	Date, Signature	
		Assignment Delivered	Assignment Accepted
Labor precaution	Ph.D., Associate Professor Kovalenko V.V.		
Environmental protection	Ph.D. (Engineering), Assoc. Prof. Chernyak L.M.		

8. Assignment issue date: «_ _» _________ 2020

Diploma work supervisor: __________________ I.I. Gvozdetskyi

(supervisor signature)

Assignment is accepted for execution: _____________ ______Nasrallah Ahmad

(graduate student's signature) (date)

ABSTRACT

The explanatory note of the diploma work “as Turbine Plant for Natural Gas Supercharger Drive with Detailed Development of the Automotive Control System”:

__ pages, __ figures, and __ tables __ references.

Object of research — is the development of integrated automatic control system of gas turbine plant and compressor station, and an assessment of way to improve its effectiveness.

Subject of investigation — automatic control system of modern GTP and its structural elements .

Aim of master’s thesis — is to develop the automatic control system of gas turbine plant and its integration with compressor station’s automatic control and designing control device.

Method of investigation – the thermodynamic and gas dynamic calculation of the engine, patent researches, graphical design of the ACS parts, the special part is devoted to Automatic Control System of the engine.

Practical value of master’s thesis results – obtained results of diploma work can be used by developers of integrated GTP ACS and CS ACS. The results as well can be used in training process in NAU.

GAS TURBINE PLANT, THERMODYNAMIC CALCULATION, GAS DYNAMIC CALCULATION, COMPRESSOR STATION, AUTOMATIC CONTROL SYSTEM, ELECTRONIC CONTROLLER, INTEGRATION

CONTENTS

LIST OF ABBREVIATIONS

ACS – Automatic control system
ECU – electronic control unit
GTU – gas turbine unit
GTP – gas turbine plant
GTE – gas turbine engine
GPU – gas pumping unit
CS – compressor station
ADC – analogue to digital converter
DAC – digital to analogue converter
LPC – low pressure compressor
HPC – high pressure compressor
HPT – high pressure turbine
LPT – low pressure turbine
PT – power turbine
CO – controlled object
SM – servomechanism
FADEC – full authority digital electronic control

$T_н$ – standard temperature
$P_н$ – standard ambient pressure
R – Gas constant
k – Adiabatic index;
η_c^* – Efficiency of compressor stage
$(\frac{b}{t})_{hub}$ – Grid thickness on root radius
α_1 – Angle of gas flow exit of nozzles set.

Other designations and terms are explained in explanatory note parts.

INTRODUCTION

This thesis introduces important concepts in the analysis and improvement of control systems of GTP.

Control theories commonly used today are classical control theory (also called conventional control theory) and modern control theory.

This thesis presents comprehensive treatments of the improvement of control systems based on the conventional control theory and modern control theory of GTP and its integration with a CS control system.

The reader is expected to have fulfilled the following prerequisites:

- Classical and Modern Theories of ACS;
- Design of GTP;
- Electronic Control of GTP;
- Improvement of ACS of GTP Based on Classical Control theory;
- Integration between ACS of GTP and ACS of CS.

This thesis consists of 5 parts or chapters which include information concerning historical aspects and modern development of ACS, thermodynamic and gas dynamic calculation and results of the GTP in addition of a description for the GTE used, detailed ACS of the GTP and integration with CS, ecological aspects of GTPs and finally labor precaution aspects.

Engineering is concerned with understanding and controlling the materials and forces of nature for the benefit of humankind. Control system engineers are concerned with understanding and controlling segments of their environment, often called systems, to provide useful economic products for society. The twin goals of understanding and controlling are complementary because effective systems control requires that the systems be understood and modeled.

Modern ACS of GTP is intended for:

- Automatic creation of signals and features is consistent with the control and control algorithms in all modes of engine operation;

- dosing of gaseous fuel in all modes of operation of the gas turbine drive (GTP) (ignition of the combustion chamber, start-up of the engine, steels and transient modes of operation, limitation of the modes of operation of the engine);
- Protection of the engine from exceeding the limit values of the engine parameters;
- Control of the efficiency of the engine;
- Control and diagnostics of the technical condition of the engine;
- Transmission of the measured parameters of the gas turbine actuator and information on the state of the ACS GTP channel information exchange in the ACS GPA to display it at the workplace of the operator GPA;
- Measurement of GTP vibration parameters;
- Registration of the parameters of the technical state of the GTP;
- Acceptance of commands and signals;
- Transfer of the registered information to the automatic section of accounting and registration of parameters of work and control of the technical state of the GTP.

Modern power plants are complex, large scale systems with a very high degree of automation. The design and operation of these plants is determined by the criteria: economy, availability, safety and, last not least, environmental impact. To achieve these goals the instrumentation and control system must be carefully designed. Today microprocessor based decentralized digital process control systems provide a solid basis for reliable and satisfactory control.

A modern gas turbine plant is characterized by the terms: large scale system, division into subsystems, hierarchical instrumentation and control system. The requirements with respect to control are: optimal economy, maximum reliability and safety, and minimum environmental impact. The solution is achieved by the use of modern ACS. They provide all physical means required. The software, i.e. the concepts and algorithms are also available. So why is there still a large gap between theoretical findings and performance? Not all can be attributed to the conservative management of the utilities. The main problem lies in the fact that obvious, easily comprehensible and provable examples showing that improved control pays are still too few in number. The benefits of improved control are:

- improved efficiency, e.g. by better combustion control, but also by reduction of losses during start-up or cycling, and improved thermodynamic efficiency by higher mean final steam temperature, - longer lifetime of components (especially critical parts like thick-walled headers) due to reduced transient stress, - reduced maintenance on actuators due to smoother control action.

Main attention in the diploma work was paid to integration of developed automatic control system of designed gas turbine plant with automatic control system of compressor station. Such integration can allow improving general characteristics and effectiveness of gas transportation system as whole.

CHAPTER 1
HISTORICAL AND MODERN ASPECTS OF GTP ACS

1.1 Modern state of ACS and ways for their improvement

Automatic control system is an assemble of several automatic devices (AD) which are contracted between each other by their characteristics and which perform such actions on the operating process of GTP that required output characteristic (Parameters) under different ambient condition.

1.1.1 General Approach of Automatic Control in Daily Life

Control systems are an essential part of everyday life in today's society. They control our appliances, our entertainment centers, our cars, and our office environments; they control our industrial processes and our transportation systems; they control our exploration of land, sea, air, and space. Almost all of these applications use digital controllers implemented with computers, microprocessors, or digital electronics. Every electrical, chemical, or mechanical engineering senior or graduate student should therefore be familiar with the basic theory of digital controllers.

CS is to be found in almost every aspect of our daily environment. The human body is, indeed, a very complex and highly perfected adaptive CS. Consider, for example, the human actions required to push an automobile. CS is highly multidisciplinary, with issues and features that are separate from those of other branches of engineering. These issues are various and delicate, and often the most important aspects depend on the seemingly most insignificant details. Historically, the subject has advanced by employing abstraction to extract principles that are potentially applicable to a broad range of applications. Unfortunately, this abstraction often obscures the practical ramifications of important ideas. A more concrete approach to the subject an rejuvenate and reinvigorate education in this exciting and important area of technology. Wiener suggested that the most promising techniques for studying both systems are information theory and CS theory. CS process as that found in physical, biological, and social systems. Likewise, in the human body, a number of CS control temperature, blood pressure, motor reactions, and other conditions. The human body is, indeed, a very complex and highly perfected adaptive CS. Consider, for example, the human actions required to steer an automobile. Let us next look at a CS problem from biology. Parts of the world are being overrun by an increasing population of rats. Here the system consists of the living population of rats and the environmental parameters that affect that population. The natural growth of the rat population is to be controlled to near some desired number, say, and zero. Here the job of the CS engineer is to build a better mouse-trap. CS is to be found in industry, the term automation is very common. Modern industrial plants utilized robots for manufacturing temperature controls, pressure controls, speed controls, position controls, etc. The chemical process control field is an area where automations have played an important role. The philosophical position of the discipline of CS theory within the framework of metaphysics, CS theory is a teleological science. That is, the concepts of CS involve ideas such as purpose, goal-seeking and ideal or desirable norms. Another philosophical aspect of CS theory is that it avoids the concepts of energy but, instead, deals with the phenomenon of information in physical systems. In this sense CS theory deals with the inverse problem of dynamical systems. Because CS is so evident in both nature and humanity, it is impossible to determine when CS was first intentionally used. Newton, Gould, and Kaiser' cite the use of feedback in water clocks built by the Arabs as early as the beginning of the Christian era, but their next references is not dated until 1750. In the year of 1788 by Watt's invention of the fly-ball governor for regulation of the steam engine. In the early 1960s a new CS design method referred to as modern CS theory appeared. This theory is highly mathematical in nature and almost completely oriented to the time domain. Elementary conventional linear system and subsystem modeling (again using computer tools) and approaches to loop design: a comparison of traditional and "intelligent" techniques; thinking of self-tuning and adaptive. Because plans are the yardstick against which manager devise controls, the first step in the CS process logically would be to establish plans. On the other hand, since plans very in detail and complexity, and since managers cannot usually watch everything, special standards are established. Standards are, by definition, simply criterion of performance. Although such measurement is not always practicable, the measurement of performance against standards should ideally be done on a forward-looking basis so that deviations may be detected in advance of their occurrence and avoided by appropriate actions. The alert, forward-looking manager can sometimes predict probable departures form standards. In the absence of such ability, however, deviations should be disclosed as early as possible. Standards should reflect the various positions in an organization structure. If performance is measured accordingly, it is easier to correct deviations. Managers know exactly where, in the assignment of individual or group duties, the corrective measure must be applied. Correction of deviations is the point at which control can be seen as a part of the whole system of management and can be related to the other managerial functions. Managers may correct deviations by redrawing their plans or by modifying their goals. CS applications have social contact not only in developed countries but also in developing countries.

A new work force plan without denying the existing of CS is established by retooling the work forces, thus the challenges of social impacts could be answers wisely and would be bright opportunities to improve human principles of living.

1.1.2 Appointment of GTP automatic control

The whole history of development of gas turbine plants that are used compressor stations as drive for natural gas superchargers is associated with continuous improvement in their increased reliability, supply, and fuel efficiency. Thus, such parameters as reliability and fuel efficiency depend on the specific fuel consumption, specific power and their performance.

Providing the necessary operational characteristics of GTP is associated with a certain method of working process controlling. Intervention in the flow of working process of GTP enables to establish operating mode that will be most advantageous in terms of technical requirements. Under the operation mode gas turbine means a certain set of parameters of working process of engine and the external conditions under which it operates. The external conditions include temperature and pressure of air (p_{H}^*, T_{H}^*). Depending on the set of parameters of working process and external conditions GTP power, specific fuel consumption, mechanical load and temperature details will also have a certain value.

To maintain the desired mode at specific external conditions and change it in the desired direction in engine design provides automatic control system, which has a special control device, and you can use to influence the parameters of the working process i.e. control the engine.

1.1.3 Problems which solved by the automatic control system

The main problems which systems of automatic control of GTP can solve include the following:

1) Run the GTP under different operating conditions (in diverse seasons).

2) Shifting and support operating modes of GTP in accordance with the selected control law.

3) Providing acceptable acceleration performance of GTP injectivity.

4) Supporting the operation of individual units of GTP (axial compressor, combustor, turbine and others).

5) Limitation of limited parameters of working process of GTP to care for parts and components from overloads.

6) Providing a diversity of blocking, which guarantee reliability and reliability of gas compressor units.

1.1.4 Hydro mechanical control systems

Nowadays, mostly is used ACS of GTP owing the fact that at the performance of definite number problems of automatic control may be provided simply and constantly. They may provide high accuracy static control: $\overline{\Delta n}_{\text{ст}} = \pm(0{,}3 \div 0{,}5)\ \%$; $\Delta T_{\text{г}}^{*} = \pm 5\ ^{\circ}\text{C}$.

However, current necessities, which are represented to ACS of GTP, already exceed possibilities of hydro mechanical systems.

These necessities can't be provided due to the following disadvantages:

– hydro mechanical systems are badly suited to unite in whole one electric system control of gas compressor station;

– practically impossible to duplicate and automatic control devices idleness, which affects on the reliability of system;

– Difficult to monitor maintenance of automatic devices, that are a part of automatic control and its maintenance.

Due to these disadvantages hydro mechanical systems lose their positions in favor of electrical systems.

1.1.5 Electric control system

Electric control systems are increasingly applied in a number of serial GTP (D-336, DN-80, DN-71, NK-16ST etc.). They have great perspectives of application in connection with the automatic system functions expansion and number of inherent advantages. Advantages of electrical systems are follows:

– allow to realize a program to manage at any complication that can't afford hydro mechanical systems;

– gives wide possibility to duplicate and reservation of automatic devices and elements of system control;

– can provide high static accuracy of control:

$$- \overline{\Delta n_{\text{ст}}} = \pm 0{,}2\% ;\ \Delta T_{\text{г}}^{*} = \pm 3 \div 5\ ^{\circ}\text{C}.$$

– easier control, you can provide continuous control of technical state of automatic devices with automatic switching on backup system;

– are tractable to calculation and modeling;

– provides easier standardization and unification of joints and elements;

However, on the way of electrical system using, there are certain difficulties, connected with disadvantages of these systems. Consider such disadvantages of electrical systems:

- difficult to create reliable sensors of primary signals, which convert changing of initial parameters in electrical signals;
- necessity of severe stabilization of power supply (needed constant frequency current);
- Not enough supply of reliability at operational conditions of GTP (high and low temperatures of external air, vibration and etc.).

The last disadvantage is eliminated by placing the equipment not on engines, but in some separate places or in sections with forced climate, and also by producing equipment on solid integrated schemes.

1.1.6 Pneumatic system control

Having approximately the same properties as the electrical systems, pneumatic systems become competitive. Besides, in number of cases they have advantages on electrical systems:

- sensors of converting initial signals are less complicated;
- More reliable in difficult conditions of GTP exploitation.

However, pneumatic systems controls have their own disadvantages:

- inclination to clogging by sand and dust;
- Formation of condensate in system and its freezing and other disadvantages.

Comparative estimation of ACS, which is used now on GTP series, shows that hydro mechanical systems, despite its own exploitation reliability and simplicity, has limited possibilities in according with more difficult problems, which are set for ACS. Accordance with this, they partially lose their positions before combined electro-hydro-pneumatic or electro-hydro-mechanical systems.

1.1.7 Electronic Engine Control (EEC)

Mechanical control systems when integrated with newer turbine engines suffered from the inherent limitations of tuning and adjustment beyond their corporeal defined limits. The electronic software based control thus offers distinct advantages, such as: Ease of adjustments of transient schedules/limiter schedules/Magnitude changes and slope changes in schedules/Changes in control logics. All these could be accomplished by changes of software build of the embedded controller in the electronic system. Based on the redundancy management architecture, safe operation even with one lane nonoperational could be demonstrated. At the start of the gas turbine era, there had been only one control variable, namely, fuel flow. With advances in gas turbine cycles and technologies, the need for a greater number of control variables had slowly evolved over the decades. The introduction of digital electronics progressively enlarged the role, importance, and functions of the engine control system as well as its interfaces with the other engine components and the airframe. The radical Technological shift led to a functional shift as Digital electronics is a fast moving technology. This high rate of advance enabled the embodiment in the control system of a large and increasing number of functionalities. The digital control system became the brain of the engine. In addition, digital control systems potentialities created new sets of technological imbalances between the control system and the engine power system. Although digital control systems interacted with, in fact, controlled a higher and enlarging number of engine components, these interdependencies were governed by the so called interface software. Due to this software component, digital control systems were not application-specific, and hardware and software modules could be reused in different applications. Digital control systems therefore exhibited predictable product systemic interdependencies, since such interdependencies were managed by the interface software

1.1.8 Full Authority Digital Electronic Control (FADEC)

Full authority digital engine control (FADEC) is a system consisting of a digital computer, called an electronic engine controller (EEC) or engine control unit (ECU) and its related accessories that control all aspects of aircraft engine performance. FADECs have been produced for both piston and jet engines. Proper full authority digital engine controls have no form of manual override available, placing full authority over the operating parameters of the engine in the hands of the computer. If a total FADEC failure occurs, the engine fails. If the engine is controlled digitally and electronically but allows for manual override, it is considered solely an EEC or ECU. An EEC, though a component of a FADEC, is not by itself FADEC. When standing alone, the EEC makes all of the decisions until the pilot wishes to intervene. FADEC works by receiving multiple input variables of the current flight condition including air density, throttle lever position, engine temperatures, engine pressures, and many other parameters. The inputs are received by the EEC and analyzed up to 70 times per second. Engine operating parameters such as fuel flow, stator vane position, bleed valve position, and others are computed from this data and applied as appropriate. FADEC also controls engine starting and restarting. The FADEC's basic purpose is to provide optimum engine efficiency for a given flight condition. FADEC not only provides for efficient engine operation, it also allows the manufacturer to program engine limitations and receive engine health and maintenance reports. For example, to avoid exceeding a certain engine temperature, the FADEC can be programmed to automatically take the necessary measures without pilot intervention. With the operation of the engines so heavily relying on automation, safety is a great concern. Redundancy is provided in the form of two or more, separate identical channels.

1.1.9 Hydromechanical/Electronic Fuel Control

The addition of the electronic control to the basic hydromechanical fuel control was the next step in the development of turbine engine fuel controls. Generally, this type of system used a remotely located EEC to adjust the fuel flow. The basic function of the engine fuel system is to pressurize the fuel, meter fuel flow, and deliver atomized fuel to the combustion section of the engine. Fuel flow is controlled by a hydromechanical fuel control assembly, which contains a fuel shutoff section and a fuel metering section.

This fuel control unit is sometimes mounted on the vane fuel pump assembly. It provides the power lever connection and the fuel shutoff function. The unit provides mechanical overspeed protection for the gas generator spool during normal (automatic mode) engine operation. In automatic mode, the EEC is in control of metering the fuel. In manual mode, the hydromechanical control takes over.

During normal engine operation, a remotely mounted electronic fuel control unit (EFCU) (same as an EEC) performs the functions of thrust setting, speed governing and acceleration, and deceleration limiting through EFCU outputs to the fuel control assembly in response to power lever inputs. In the event of electrical or EFCU failure, or at the option of the pilot, the fuel control assembly functions in manual mode to allow engine operation at reduced power under control of the hydromechanical portion of the controller only.

1.1.10 Intelligent Life Extending Control

With the desire to reduce engine operating cost, the industry is interested in developing technologies that will allow the engine and its components to operate (remain on wing) longer, thus increasing the time between engine overhauls. How the engine is controlled has a significant impact on the life of the components. Typically, the propulsion system control design engineer attempts to get the maximum performance out of the system while maintaining safe operation. Recent studies have shown that small changes in engine operating parameters, such as turbine inlet temperature, can have a significant impact on the damage accrued by engine components while having little to no effect on engine performance. GRC developed the concept of Life Extending Control where the engine control system is designed to achieve the desired performance while minimizing the damage accrued in engine components, hence maximizing the usable engine life.

1.1.11 Current Research

Future turbine engines require more efficient consumption of energy, which is hindered by the added weight of the current turbine engine control systems. Currently research in advanced engine control technologies to replace the electronic Control system currently used by turbine engines is being undertaken. The intent was to investigate a solution which reduces energy consumption and increases efficiency of turbine engine operations. Active component control approaches such as active combustion control and active flow control for compression systems, and distributed engine control architecture are critical enabling technologies to meet the challenging goals of reducing aircraft engine emissions. Integrated control of inlet and engine systems is key for achieving safety and performance goals of high speed propulsion system. Intelligent propulsion control and diagnostics can significantly increase safety and improve operational reliability of space launch systems. All these are under study by various groups and individuals to improve turbine engine controls.

1.2 Gas Turbine Power Plant Modern Control

Along with advances in system component technologies, modern state-of-the-art power plant control systems are being developed by incorporating such advanced technologies as extensive digitization of high-speed control circuits, interconnection with other equipment over open interfaces, and a repertory of diverse multiplexed systems[6]. Based on that the theory of control was developed and deployed a wide range of leading-edge power plant control systems including gas turbine control systems, steam turbine control systems, and generator excitation control systems.

1.2.1 System configuration

Figure 1.1 shows the system configuration of the system used for a combined cycle power generation facility using gas turbines. The system consists of a plant system, control system, man-machine interface, and remote monitoring system (i-Monitor).

Main units of equipment include the following:

Plant Control Station (PCS)

The PCS is installed in individual plants to be controlled, i.e., each gas turbine plant or a plant using steam turbines and common auxiliary equipment. The PCS's installed in a multiple of plants this way communicate with each other to take general control of plant operations.

Operators & Engineers Station (OES)

The OES generates control commands to the PCS, monitors plant conditions, and performs the tasks related to system maintenance management. Some OES's are equipped with the engineering tools used to compile a control logic program operating on the PCS and make settings, including a change of parameters.

Remote I/O (RIO) panel

The remote I/O panel connects objects to be controlled to the PCS via optical fibers, and controls these remote objects with high speed and reliability.

Gateway (GW)

The PCS uses the gateway to communicate with external control devices, such as the GT generator control panel, ST control panel, etc.

Site communication equipment

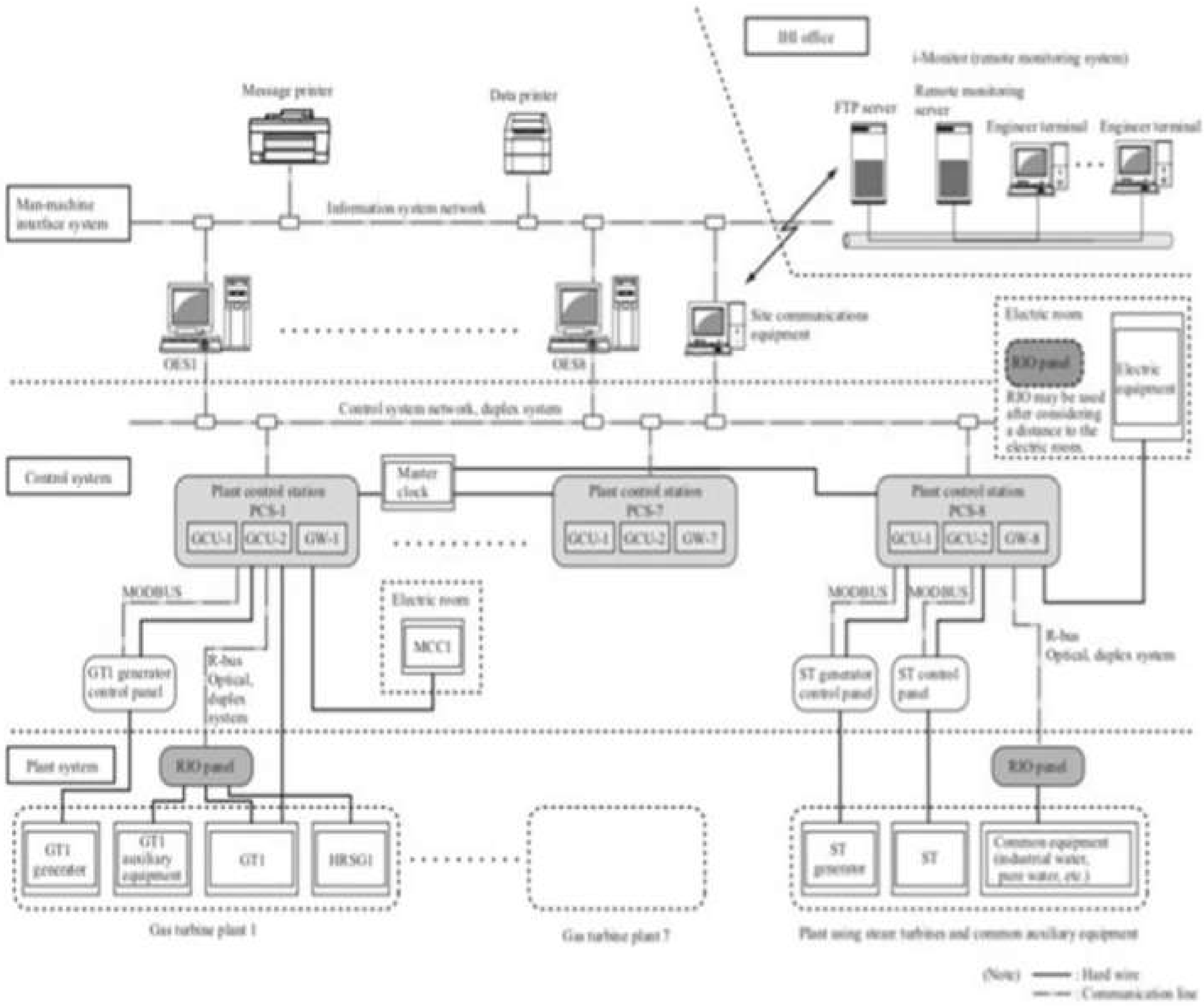

Figure 1.1 Control system configurations of gas turbine power plants

The site communication equipment collects data from the OES, and transfers it to i-Monitor.

1.2.2 Functions

Main functions are as follows:

Plant control function

The PCS receives analog data, digital data, RIO data, or data that is collected by another PCS, performs control operations on the received data according to a control logic, and outputs the results of control operations to control plant operations. In addition, command values specifying the energy to be generated are given to each plant such that the total energy generated by all plants agrees with a specified target value of generated energy.

Plant monitor and alarm functions

To monitor the conditions of plants, monitor functions are provided, including the display of various trend graphs, graphically presented system diagrams, etc. Data to be monitored are divided into some groups according to uses. Data to be collected can be registered by group.

To support the operator in doubt about a specific operation to be performed, an electronic operation manual can be retrieved from a system diagram and brought up on the screen. An annunciator function for displaying plant alarms or events, as well as a self- diagnostic function for detecting an abnormality in the PCS, are also provided.

Engineering functions

For designed ACS to operate, the following three tasks must be performed by using a special engineering tool: creating a control logic program, making a data collection condition setting and other various settings, and registering data in each PCS. Figure 1.2 shows the special engineering tool. The tool provides a function of checking the consistency between the contents of various settings to prevent setting errors from occurring due to human mistakes and to increase the system reliability.

How a created control logic program is working can be displayed online on a block diagram so that operations being performed according to the control logic program can be easily monitored. In addition, input or output data can be cleared or fixed to a value of choice during monitoring to allow system conditioning work to be carried out efficiently.

Online switching function

Set conditions and control logics must be changeable without stopping the operations of a plant. The CSI-III has a function of changing logical-block parameters used by a control logic program during the PCS control operations. In addition to this function, the system has an additional function of switching between control logic programs and set conditions, including the conditions for plant data collection during the PCS control operations. This online switching function is implemented using an engineering tool. Before switching is executed, PCS's are brought into a synchronized state and the consistency between conditions of all PCS's is checked so that a total plant system operates in a consistent, coordinated manner even in a situation where switching cannot be executed for some PCS's.

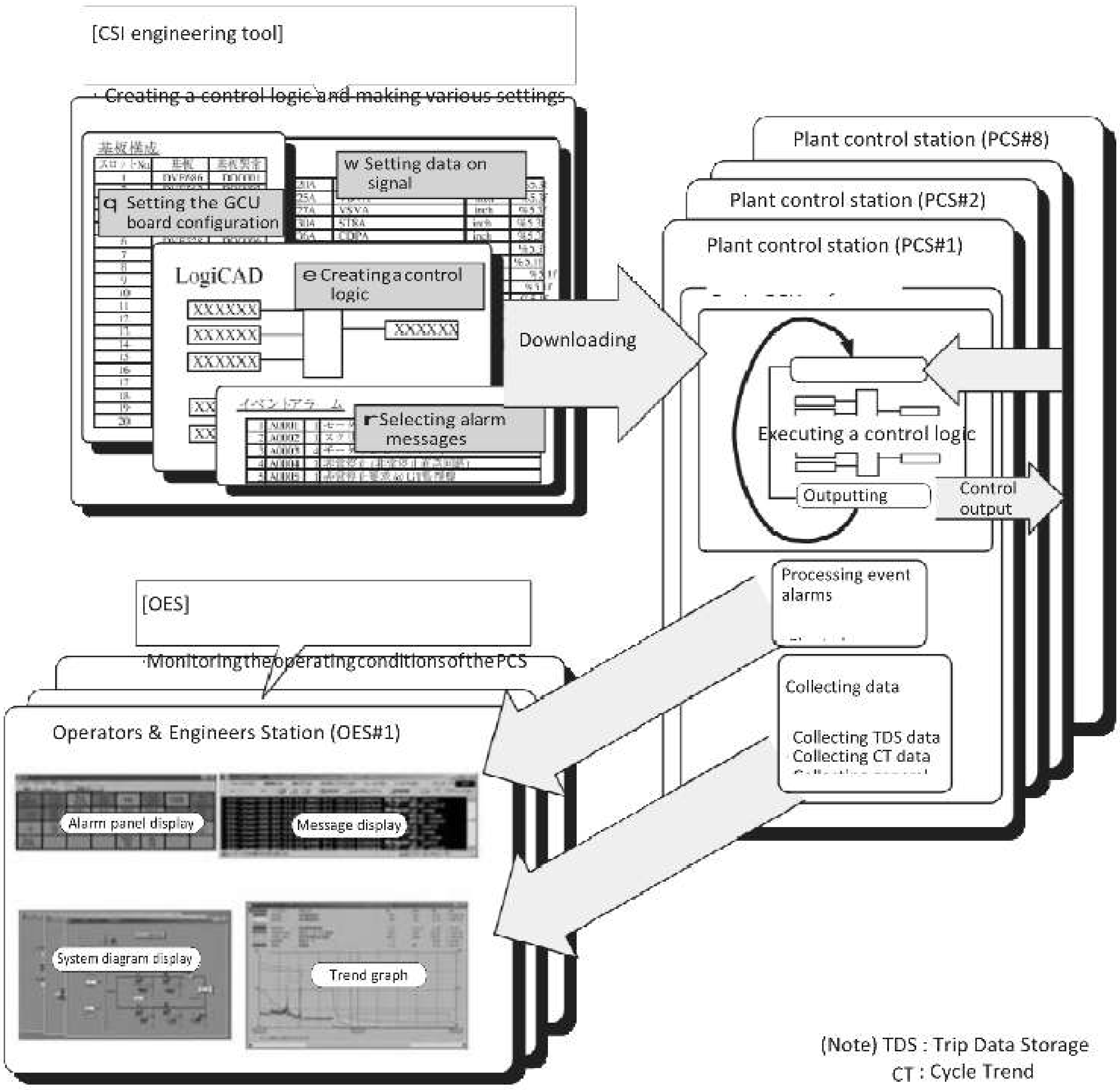

Figure 1.2 Engineering tools

Remote monitoring function

Data sent through a public circuit is published in the in-house LAN, and various data including data on plant conditions can be viewed on the screens of engineers' terminals; the screen is equivalent to the OES screen. This helps expedite maintenance work. In addition, data can be externally transferred, for example, to a customer's server.

1.2.3 Features

The main features of the CSI-III+ are as follows.

High-speed control operation performance

Considering that gas turbines must be controlled in a short control cycle, the the system must be designed with high-speed control operation cycles, i.e., the shortest cycle of 10 ms, the same as with the CSI-III, and 20, 40, 80 and 160 ms–a total of five cycles. Multiple control operations can be performed at these control cycles simultaneously. This enables an optimum control cycle to be selected by considering the conditions of each installation to be controlled and related control conditions so that loads can be leveled off.

In data used for each operation cycle, some data are shared by multiple operation cycles. Before the start of control operations in each operation cycle, the data identification process is executed, i.e., all data that one operation cycle requires are acquired from data used in other operation cycles and the acquired data is retained so that data consistency can be maintained until control operations are completed.

Other than data to be used in the current operation (table of values to be used in the current operation), data on the results of the previous operation performed (table of values used in the previous operation) is made available to each operation cycle. If data used in another operation cycle is to be acquired, the table of values used in the previous operation performed in that operation cycle is referenced. Upon completion of the operation in one operation cycle, the contents in the table of values used in the current operation are copied to the table of values used in the previous operation.

Creating a control logic by using a simple picture language

A control logic edit tool (LogiCAD), one of engineering tools, is provided so that a control logic program can be created easily without the need for special knowledge of software development. LogiCAD has a library of logical blocks. After you select appropriate logical blocks from the library, you paste them onto a sheet and connect them by signal wires. This way, you can visually create a control logic in the form of a block diagram.

To allow an enormous number of control logics used in one plant to be organized efficiently, groups of control logics are defined as macros so that they can be reused in multiple places within the control logic. In addition, it is possible to import control logic sheets from other plants and use them. Each control logic sheet is hierarchically presented to make it easier to check a large number of control logics and do editing work. Figure 1.3 shows the control logic edit tool (LogiCAD).

Before a created control logic is transferred to a PCS, its consistency is checked by LogiCAD so that inconsistencies due to human mistakes can be prevented from being included in the control logic.

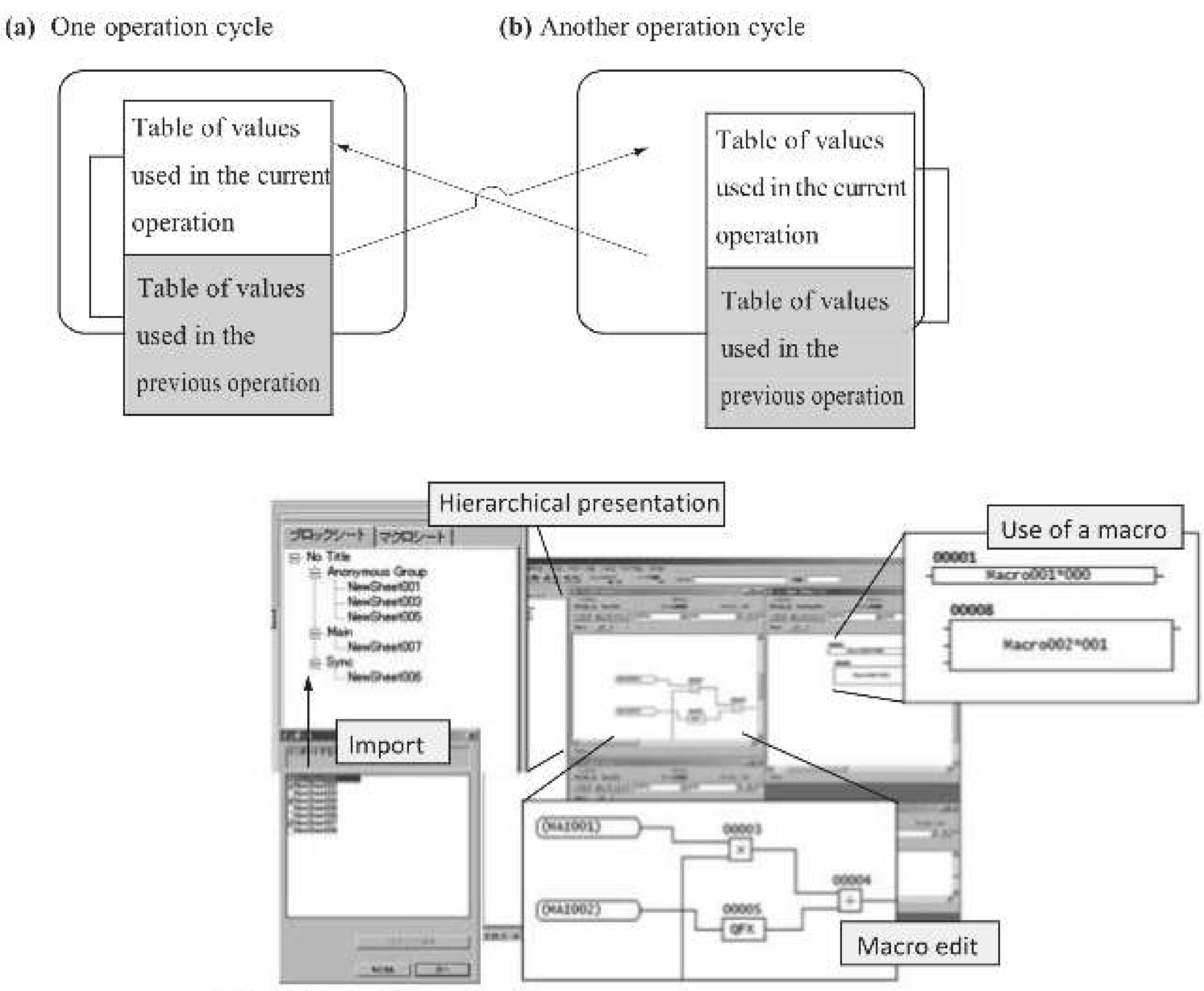

Fig. 3 Data identification

Figure 1.3 Control logic editor (LogiCAD)

Achieving a high degree of reliability by using a dual redundant system

Control unit designed as a dual system since the PCS controls the operations of a plant, it must be able to operate with a high degree of reliability. To achieve a high degree of reliability, the PCS was designed as a dual system in which two control operation units (GCU), each having the same configuration, are used.In this dual system, one GCU operates as a main unit; it performs control operations and controls the operations of a plant based on the results of control operations. The other GCU operates as a sub unit; it performs only control operations at all times.

If an abnormality occurs in the main unit, the active channel selector externally installed detects it and immediately switches from the main unit to the sub unit so that control operations can be continued.

Since the main and sub units perform control operations asynchronously, there is the possibility that a control command value calculated by the main unit may be different from that by the sub unit. To avoid a situation where a difference occurs between the values given by these two units, the main unit transfers its data to the sub unit via a communication board called a Dual Port Memory (DPM), and the sub unit overwrites its own data with the transferred data. Data generated by both systems can be synchronized this way. Figure 1.4 shows how data is synchronized.

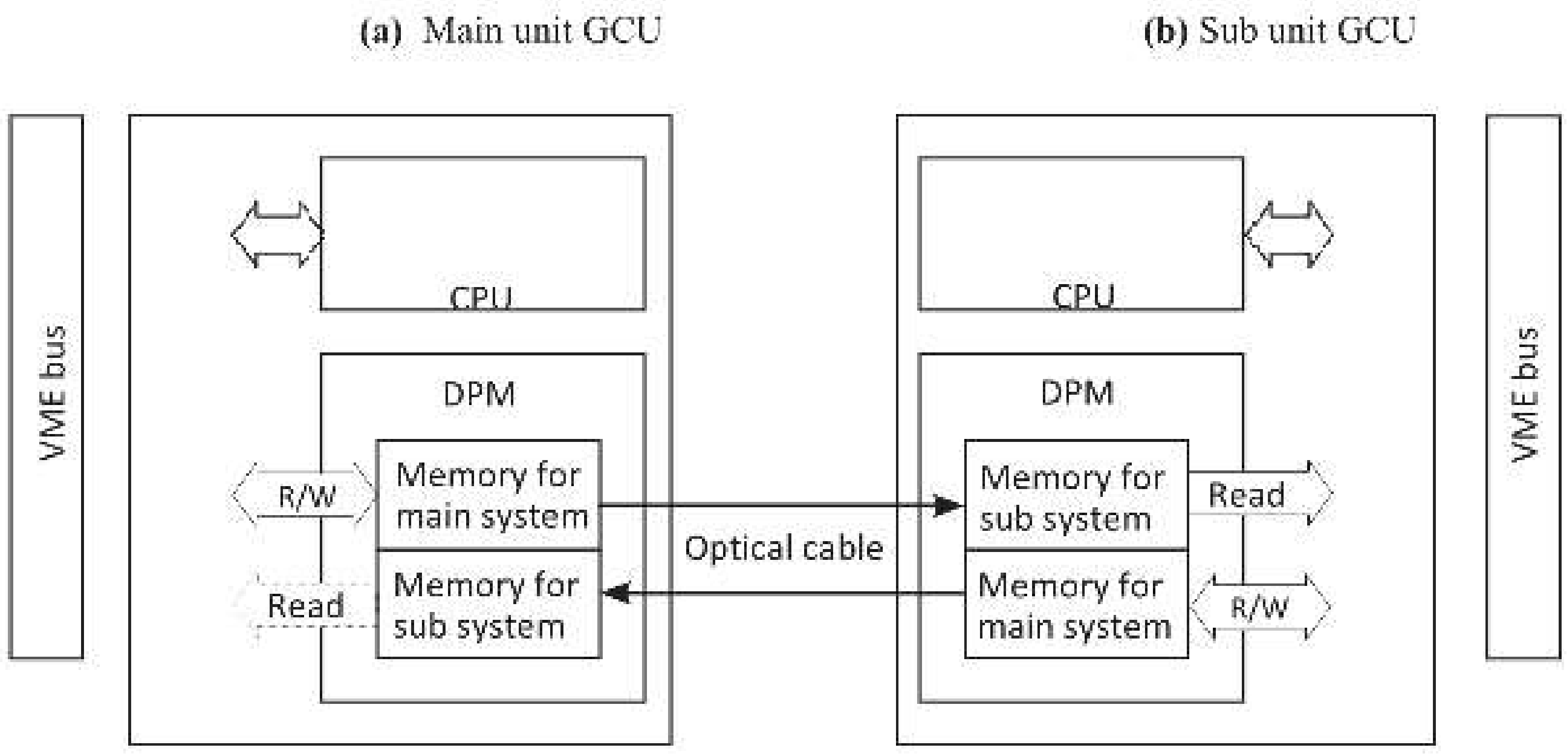

Figure 1.4 Synchronized data

So, the other GCU operates as a sub unit; it performs only control operations at all times.

1.3 Compressor Station Control

1.3.1 Control Strategy

The compressor control strategy must incorporate the following criteria:

- Compressor discharge pressure must be below the maximum allowable operating pressure (MAOP) of the station discharge piping to avoid damage.
- Station discharge pressure must be below the MAOP for the

pipeline to avoid damage and to ensure the pipeline is operating within the acceptable limits approved by the regulatory agency.

- Station suction pressure must be above the minimum allowable operating pressure to meet contractual requirements.
- Driver power must be kept within acceptable limits to avoid tripping of the driver.
- The maximum station discharge temperature should be below the pre- defined temperature limit to protect pipe coating, so coolers are installed downstream of compressor discharge.

Similar to a pump station, the main control loop (via the station control system) for a compressor station will typically be based on discharge pressure control or flow control. These loops will adjust unit speed to maintain the control loop set point and will employ overrides to limit unit speed based on a secondary condition such as minimum suction pressure.

1.3.2 Turbine Unit Control

The turbine unit vendor typically provides the local unit control system. This system handles all of the controls associated with start-up sequencing, shutdown sequencing, and normal operation.

The unit control system interfaces to the station ESD and the station control system. The station control system provides start, stop and operating set points to the unit control system. It receives analogue signal information from the unit controller instrumentation that monitors conditions in the unit such as bearing temperatures, vibration and internal temperature of the turbine, lube oil temperature, etc. These signals are also sent to a condition monitoring system if it exists.

The unit control system monitors and controls the turbine, the compressor and various auxiliary equipment, such as the:

- Starter
- Lube system

- Seal system
- Surge control system
- Bleed valves and inlet guide vanes
- Air inlet system
- Unit fire and gas monitoring

In addition to the standard monitoring of bearing temperatures and internal temperatures of the turbine, it monitors the ambient temperature. The exhaust temperature is usually limited to a maximum set point, based on ambient temperature. An ambient temperature bias may be required to ensure that a maximum horsepower rating is not exceeded in cooler ambient temperatures. A backup shutdown trip is provided in case the temperature limit function fails to respond adequately.

Complex temperature control is also carried out during unit start-up. The temperature control loop overrides the speed control loop in order to ensure that safe operating temperatures are not exceeded during this period. Vibration monitoring is used to stop the machine when a high vibration level on any bearing is detected.

Once normal operating conditions are reached, the maximum speed of the gas turbine is regulated to ensure the temperature limit is not exceeded. Backup mechanical and electronic over-speed devices are usually installed on most machines. Under-speed limits and annunciation may be provided for the turbine and compressor. Turbine under-speed causes a shutdown.

1.3.3 Compressor Unit Control

The compressor described below is coupled directly to a power turbine. The power turbine is not mechanically coupled to the gas generator turbine. The compressor is capable of operating under a specific set of speed and pipeline conditions. A plot of these conditions and the appropriate operating range is provided in a wheel map as shown in Figure 1.5. This may be used by the operator when manually operating the compressor, or integrated into the control system algorithms and logic to enable automatic control.

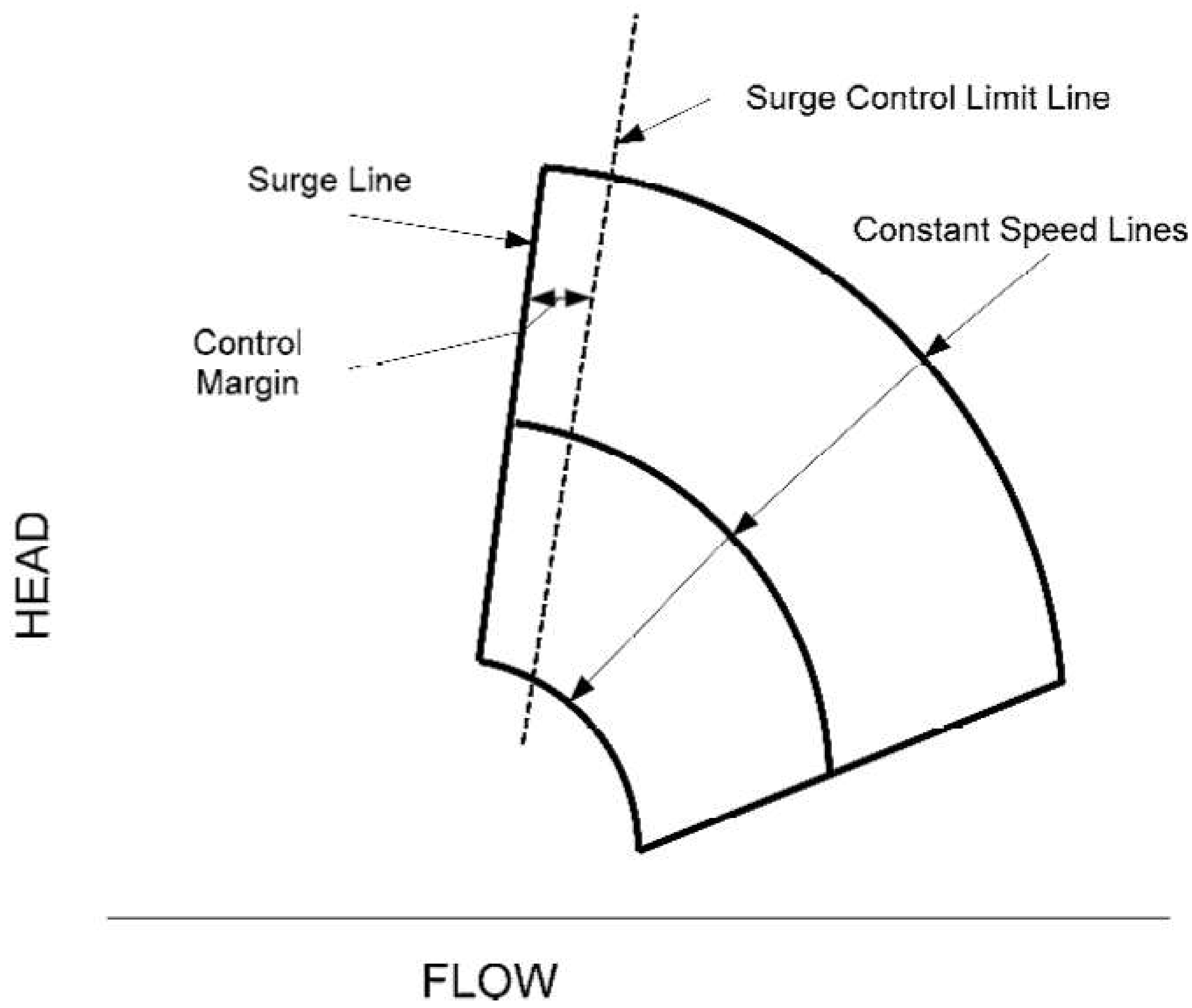

Figure 1.5 - Compressor Wheel Map

There are some special conditions that the station controls need to monitor for:

Choke Operation

A choke condition occurs when there is a low discharge head and a high flow. The compressor is attempting to pump more gas than can enter into the compressor suction. Control of the head developed becomes difficult. If this condition is prolonged, it can be detrimental to the machine. The station control system is responsible for automatically correcting this situation or shutting down the unit. The operators must try to prevent this condition from developing by establishing suitable operating conditions.

Surge Control

A surge condition occurs when there is a high head and low flow and can be very damaging to the compressor. Surge occurs when the head differential between the compressor discharge and suction is greater than the head that the compressor is capable of developing at any given speed. This means that at a given flow the existing compressor head is greater than the head that the machine can develop and flow reversal can occur. Surge cycles can continue until the compressor is destroyed, unless pipeline conditions change or corrective action is taken.

The function of a surge control system is to prevent surges by providing a controlled recycling loop around the compressor. The unit recycle valve opening will be set by the surge controller. As the unit approaches the surge line, the recycle valve will open. This decreases the unit discharge pressure and increases the flow through the compressor (but not through the station), which moves the compressor's operating point away from surge. Typically, the surge control system is comprised of a surge controller, a recycle control valve and the required flow and head measurements. The specific set of head and flow conditions at the surge boundary is called the surge line. All devices in the surge control loop must have very fast response times.

Operating in a recycle condition is extremely inefficient since a percentage of the flow through the compressor (and hence a portion of the energy used in the compressor) is being recycled. Surge control should be augmented by features in the station controls, which can request an increase in speed whenever the unit is approaching the surge line or is in recycle. This increases the speed of the compressor and the flow, thus moving away from the surge line without having to open the unit recycle valve.

Simple surge controllers usually use a 10% safety margin for the surge control line (110% of midrange flow). More sophisticated controllers are available that can compensate for varying suction pressure and temperature, and can maintain protection at a 5% margin. This allows more turndown of the compressor without requiring recycle, and therefore makes for more efficient operation at lower throughput flows.

Some compressors come supplied with their own self-contained surge systems in order to maximize both operational flexibility and safety, and to minimize unit interactions.

However, some designs use the distributed features of a networked architecture to allow the surge control to be located in a separate module, while still being part of the control system. This avoids having an interface between two devices of different manufacture. A third option is to have the surge control function as part of the station control.

3.4 Cyber security of electronic control

Cyber-Physical systems are electronic control systems that control physical processes and machines such as, motors and valves, in an industrial plant using Information and Communication Technologies (ICT) [16]. They can be thought of as the central nervous system of a plant that enable monitoring and control of all operations of a plant. The advances in computing power and network transmission speeds, coupled with a decrease in hardware cost, have enabled new applications of ICT in industrial settings to improve efficiency of the underlying physical processes. The resulting displacement of traditional analog and mechanical devices with complex, software-intensive Industrial Control Systems (ICS), has inadvertently intertwined the architecture of physical processes with cyberspace; thus, exposing them to new threat vectors and vulnerabilities. ICSs monitor and control industrial processes across a wide spectrum of industries; from critical infrastructures such as electric grids, nuclear power plants, gas and water distribution pipelines and oil refineries to standalone cogeneration power plants and Building Management Systems (BMS) in hospitals, universities, malls and commercial buildings. Despite the diversity of scale and application across industries, their system architecture is fairly identical. Typically, these control systems rely on sensors, limit switches and metering devices to acquire data from controlled processes, which is then fed back to Programmable Logic Controllers (PLC) in conjunction with some kind of a Supervisory Control and Data Acquisition (SCADA) system, to control the physical processes through actuators, motors and valves. While security (of data) has been a primary concern for traditional Information Technology (IT) systems since their inception, it is a rather recent phenomenon for ICSs; the traditional top priority for ICS being the reliability and availability of physical devices. This lack of urgency or attention to security risks exposes ICS to potential cyberattacks that can cause actual physical damage or disruption of critical infrastructure or services.

The 2009 Stuxnet cyber attack that partially destroyed a third of the centrifuges at a uranium enrichment facility in Natanz, Iran, demonstrated the unprecedented capabilities of such attacks on ICS, ushering a new era in cyber warfare. Current approaches to examining cybersecurity of cyber-physical systems are often based on analysis of ICT protocols or network configurations; they undertake a narrow technical view that is biased by information security concerns. In reality, security (and by extension cybersecurity), like safety, is an emergent property of a system where the interactions of simple components produce complex behaviors which cannot be predicted by linearly analyzing the individual components in isolation. Instead, a top-down, systems thinking approach is required that examines not only the components on their own but also holistically considers the functional interactions between components, people and management as a whole. System Theoretic Accident Model & Processes (STAMP) is an accident causality model originally developed to address safety of complex systems. The actual method based on the STAMP accident model is called System Theoretic Process Analysis (STPA). Young and Levenson adapted the STPA method to security; the new method is called STPA-Sec. The key idea that distinguishes STPA-Sec from other hazard and vulnerability analysis methods is that it is assumed, right at the onset of the analysis, that the control system has already been compromised; the analysis then starts with identification of high-level, worst-case loss scenarios for the system. It then systematically attempts to identify what control actions throughout the hierarchical functional control structure would move the system into a hazardous state, which under worst case environmental conditions could be exploited to result in a loss scenario.

Finally, new requirements are derived from the analysis that prescribes new constraints that would prevent the system from entering an unsafe/unsecure state that could result in a loss.

1.5 Conclusion

Every day, we want to be sure that we are prepared for anything that life is going to throw at us. It is all part of having a contingency plan. Having control system monitoring and continuous improvement tools in place will allow our systems to be properly integrated. It can also ensure there is communication across all subsystems to ensure complete reliability.

Automatic control systems were first developed over two thousand years ago. The first feedback control device on record is thought to be the ancient Ktesibios's water clock in Alexandria, Egypt around the third century B.C.E. It kept time by regulating the water level in a vessel and, therefore, the water flow from that vessel. Which indicate the important role of control system in all aspects of a human being life.

Modern GTP and CS require more efficient consumption of energy, and increases efficiency of power plant, for this purpose scientist during the past years performed plans and research on the ways and structures of improving these types of power plants which we illustrated some of its aspects in this part.

CHAPTER 2

DESIGNING GAS TURBINE PLANT CALCULATION AND DESCRIPTION OF STRUCTURE

2.1 Thermodynamic calculation

The aim of thermodynamic calculation is to determine the parameters of the working fluid flow in specific sections of the installation and power density, specific fuel consumption, the main gas turbine efficiency. For a given power and found specific air flow capacity is determined to install. The results of thermodynamic calculations used in the following gas-dynamic calculation to determine the geometric parameters of the engine [1], [3].

The necessary data for thermodynamic calculation are: gas temperature at the outlet of the combustion chamber Tg* compressor pressure ratio π_k^*, turbine power N_e.

the calculation is performed according to the ambient conditions:

$p_н$ = 101,325 Pa; $T_н$ = 288 K.

Initial data for thermodynamic and gas dynamic calculations:

H=0;

M_H=0 ($p^*_{h.p.}$=p_0=101.3 kPa, $T^*_{h.p.}$=T_0=288 K)

Tg*= 1380 K;

π_k^*= 18;

η^*_k= 0.98;

k= 1.4;

k_g= 1.33;

R= 287 J/kg*K;

$R_г$= 288 J/kg*K;

N_e= 10000 kW;

H_u= 43000 kJ.

2.1.1 Calculation of low pressure compressor working body

Parameters of air in the station B-B(at the entrance to the GTP)

$$p_B^* = \sigma_{BX}^* \, p^*_H = 0.99*101325=100312 \text{ Pa};$$

$$Tg^* = T_0 = 288 \text{ K}$$

Where $\sigma_B = 0.99$ - Coefficient of regeneration of full pressure in air intake.

The definition of what is consumed to compress 1 kg of air in the compressor and options for air-to station K-K(at the outlet of the compressor)

$$P_{LPC}^* = p_B^* * \pi^*_{LPC} = 100312*5.67=568770 \text{ Pa}$$

$$T_{LPC}^* = T_B^* + \frac{L_K}{\frac{k \cdot R}{k-1}} = 510 \text{ K}$$

when $\eta_{LPC}^* = 0.84$;

$$L_{LPC} = \frac{k}{k-1} \times R \times (T_{LPC}^* - T_B^*) = \frac{1.4}{0.4}*287*(510-288)=221000 \text{ J/kg}$$

Where $k = 1{,}41$, $R = 288$ J/(kg·K); $\eta^*_{с.к} = 0{,}84$ – efficiency of stage of compressor .

2.1.2 Determination of high pressure compressor

Temperature and air pressure at the outlet of the compressor calculated as follows:

$$p_{BBT}^* = \sigma_{ПД}^* \times p^*_{LPC} = 0.99*568770=563100 \text{ Pa};$$

$$p_K^* = p_{BBT}^* \times \pi^*_{HPC} = 563100*3.17=1785000 \text{ Pa};$$

$$T_K^* = 750 \text{ K};$$

$$L_{LPC} = L_{HPC} = 221000 \text{ J/kg};$$

2.1.3. High pressure turbine:

The pressure at the outlet of the combustion chamber:

$$p_H^* = 1713600 \text{ Pa};$$

$$T_{HPT}^* = T_H^* - \frac{L_{HPC}}{\frac{1.33}{0.33} \times R_Г \times (1 - g_{ОХЛ} - g_{ВІДБ}) \times (1 + g_П) \times \eta_{mвт}};$$

$$T_{HPT}^* = 1020 \text{ K};$$

$g_{cool} = 0.035$;

where $g_{cooling}$ – the relative cost of air shown at the outlet of the compressor for cooling turbine parts; g_s=0.02 - relative air flow that is selected for the technological needs of GTP; η_{mc}=0.99 – mechanical efficiency turbocharger compressor.

Size $g_{cooling}$ established depending on the temperature at the outlet of the combustion chamber and the chosen method of cooling.

$$\Pi_{HPT}^{*}=\left[\frac{\eta_{TBT}^{*}}{\eta_{TBT}^{*}-(1-\frac{T_{TBT}^{*}}{T_{\Gamma}^{*}})}\right]^{\frac{1.33}{0.33}}=2.2$$

$$p_{HPT}^{*}=\frac{p_H^{*}}{\pi_{TBT}^{*}}=778900 \text{ Pa}$$

2.1.4. Determination of low pressure turbine

$$T_{LPT}^{*}=1020\text{-}200=820 \text{ K}$$

$$\pi_{LPT}^{*}=2.46;$$

$$p_{LPT}^{*}=\frac{p_{HPT}^{*}}{p_{THTLPT}^{*}}=\frac{778900}{2.46}=316600\ Pa;$$

2.1.5. Determination of power turbine

Determination of the expansion of gas in the power turbine and gas parameters at the exit from it:

$$L_e=\frac{\kappa_г}{\kappa_г-1}\times R_г\times T_{TK}^{*}\times\left[1-\left(\frac{1}{\pi_{TBЛ}^{*}}\right)^{\frac{0.33}{1.33}}\right]\times\eta_{TBЛ}^{*};$$

$$L_e=205000 \text{ j/kg}$$

Where efficiency power turbine $\eta^{*}_{c.т}$ = 0,9 in the transition channel; σ_g = 0,99 pressure loss coefficient.

$$\pi_{TBЛ}^{*}=\frac{p_{TK}^{*}}{p_T^{*}}=\frac{316600}{111460}=2.85;$$

$$p_T^{*}=1.1\times p_H=1.1\times 101325=111460\ Pa;$$

The gas temperature at the outlet of the turbine:

$$T_T^* = T_{TK}^* - \frac{L_e}{\frac{1.33}{0.33}\times 288} = 820 - \frac{205000}{\frac{1.33}{0.33}\times 288} = 640\ K;$$

Setting the value of the reduced rate within λ_T = 0,625 determine the velocity of the gas at the outlet of the turbine, static temperature and pressure:

$$p_T^* = p_{TK}^* \times [1 - \frac{1 - \frac{T_T^*}{T_{TK}^*}}{\eta_{TB\Pi}^*}]^{\frac{1.33}{0.33}};$$

P*= 123316 Pa

2.1.6. Calculation of basic parameters of gas turbine Output device

C_C= 270 m/s

where φ=0.99;

$$T_C^* = T_T^* - \frac{C_C}{\frac{1.33}{0.33}\times R_\Gamma} = 640 - \frac{270^2}{\frac{1.33}{0.33}\times 288} = 577K;$$

Nominal hourly flow of gas consumption (Nm3 / h) for the current density of the gas

$$\rho_C = \frac{p_H}{R_\Gamma \times T_C} = \frac{101325}{288\times 577} = 0.6;$$

$$N_{EKB} = N_e + {}^{1}/_{\beta}\,(C_C - V) = 10500 + {}^{1}/_{15} \times 270 = 10518\ kW;$$

$$C_C = \frac{G_\Pi}{N_{EKB}} = \frac{2082}{10518} = 0.2\ Kg/(kW * h);$$

$$G_\Pi = 3600\times g_f \times G_B \times (1 - g_{OXЛ} - g_{BIДБ}) = 3600 \times 0.017 \times 36 \times (1 - 0.035 - 0.02) = 2082\ kg/hour;$$

For a given air flow capacity of the installation of a compressor is determined by the expression:

$$G_B = \frac{N_e}{L_e} = \frac{10500\times 10^3}{205000} = 51.3\ \text{Kg/s}.$$

2.2. Gas-dynamic calculation of gas turbine plant

Table 1.1 – Results of thermodynamic and gas-dynamic calculation

Table 1.1

Elements of GTP	G, kg/s	N, kW	Section	c, m/s	P^*, kPa	T^*, K	D, m	D_{sl}, m	h_{bl}, m
LPC	46.7	1033.7	In	180	100.3	288	0.638	0.255	0.184
			Out	180	568.8	510	-	0.435	0.105
HPC	46.7	1033.7	In	180	563.1	510	0.5	0.71	0.105
			Out	100	1785	750	0.5	0.646	0.027
HPT	34.6	8037.115	In	230	1713	1380	0.64	0.6	0.04
			Out	270	778.9	1020	0.64	0.6	0.04
LPT	81.54	8037.115	In	230	778.9	1020	0.672	0.528	0.072
			Out	270	316.6	820	0.672	0.528	0.072
PT	68.49	10516.5	In	147	316.6	820	0.672	0.528	0.072
			Out	350	123.3	640	0.735	1.21	0.17

2.2. Description of the structure

This engine is used as a driver of superchargers, gas-pumping, gas-lifting and other industrial units. The engines can be successfully operated in various climatic zones within the ambient temperature range of -60°C to +50°C at altitudes up to 2000 m above sea level [2].

Main advantages:

High efficiency;

Stability of parameters;

Low maintenance costs;

Repairability without engine removal from the industrial unit;

Reliability and trouble-free operation;

Levels of pollutant emissions in accordance with GOST 29328-92;

Level of acoustic performance in accordance with GOST 12.1.003-83;

Controllability.

As we can understand from the information above, this engine is suitable for terrestrial use and it has been chosen for the diploma work.

2.2.1. Design of the engine

Gas turbine engine D -336 is three shaft with axial thirteen compressor's stages , intermediate casing annular chamber , double stages turbine compressor and double stages free turbine and an output device.

The engine is divided into 9 main modules that can be removed or replaced on the engine. This helped to ensure its operational updates need to replacement part and elements in the operation condition.

The engine is equipped with means early detection of problems (equipment's control vibration, pressure differential signaling on oil filters, chips detector, thermo chips signaling the minimum oil pressure, temperature entering inlet).

In case the details of the engine have designated holes for inspection following details:

-Rotors blades at all levels of the LPT

-Rotating Blades at all level HPC

-External and internal wall of flame tube

-Operating injectors

-HPT blades

Engine-Rotating Blades HPT

-Rotating Blade LPT

Fuel is cleaned, drained natural gas GOS 28875-90. The size of the mechanical particles on the gas is no more than 40 microns.

Gas pressure at the inlet of the engine at start up and on all modes MPa …….. 2.35.

The gas temperature at the inlet, K …. 288… 333.

Lubrication system

1) Types…………………….. closed , circulating under pressure

2) Type of oil ……………. Tp 22 c

3) Oil YPM -10 TU 38.101.1299-90

VNII NP 38.101.1299-90

3) Subtly oil filter at the inlet of the engine

4) Pumping oil through the engine at rate power mode when oil temperature at the inlet 333… 338 k 1 / min

5) The average hourly fuel oil (kg /h)…..0.

2.2.2. Engine characteristics

Power output of the turbine shaft power at work in the nominal mode 6300 kw at air temperature at the inlet of the engine + 15 C and atmospheric pressure 760 millimeters of mercury. At the same time the engine reach max rotor speed hp (n = 13400 rpm). When the engine with the max rotor speed of HP with the decrease of in the ambient temperature PT power increase. At the temperature t =-1 C power is 7560 KW value is greater than 1.2 the nominal.

Nominal and minimum operating mode (power shaft CT – CT with the pressure 760 mm of mercury include 6300 and 3000 Kw, respectively) can be obtained by exposure rotor speed W for given algorithm.

2.2.3. Compressor

Compressor –axial two- rotors consists of a supersonic compressor low pressure LPC and subsonic high pressure compressor HPC and connected to the input device spacer.

LCP : six stages consists of a front housing , a rotor and stator include housing guide vane GV ring and valve working HPC: consists of seven stages of an input ,guide vane IGV rotor and stator and valve by pass air .

2.2.4. Combustion chamber

The combustion chamber is annular type, consists of a body outside, with a rectifiable cone machine, flame tube, a fuel nozzles, 2 fuel collector, an igniter flare type fuel manifold with fuel supplying pipes .to the combustion chamber a channel gas injector

2.2.5. Engine turbine

The turbine engine – axial , jet four stage the turbine consists of single stage high pressure , single - stage turbine of low pressure , two stage free turbine FT

The rotor HPC and rotor HPT rotor from a high pressure (HP rotor) . LPT rotor and the rotor of the LPT from law pressure

HPT rotor support LPT, is the rear rotor support HP and LP are roller bearings FT – ball and roller bearing. All are cooled and lubricated with oil under pressure to prevent heating of the bearing by the hot gases of oil insulated cavity radial mechanical contact seal. Support turbine rotor has a device for damping rotor, resulting in the engine – oil dampers support the rotor.

2.2.6. Output device

An output device is formed by running the motor part of the body support free turbine and exhaust devices connecting flow part of the engine exhaust gas pumping shaft

2.2.7. Drive shaft

The drive shaft is design to transmit torque for supercharger to the free turbine, with the drive shaft misalignment and compensate for distortion of the rotor shaft of the turbine and compressor. The hub has no axial location on the turbine shaft to compensate for thermal expansion of part of shaft.

2.2.8. Oil system.

The engine lubrication system

- circulating, under pressure. Ensures a constant supply of oil to the friction surfaces of the bearings of the supports of the rotors, seals, bearings, rotors, rotating parts Central drive, upper gearbox and limiter frequency of rotation of the FT and its drive to lubricate and cool them.

In the engine lubrication system controlled by pressure and the oil temperature at the inlet to the engine.

The engine applied to the detectors of the early detection of lubrication systems, parts and components, washed by the oil.

Alarm signal in ACS when the following limiting parameters:

- Minimum oil pressure at the inlet of the engine;
- clogging of the filter of thin clearing oils;
- The emergence of ferromagnetic particles or temperature in pipelines pumping oil from the cavity:

  Bearing LPC;

  Bearings of the turbines HP and LP;

  Bearings of the free turbine;
- the emergence of a ferromagnetic chip in the pipeline pumping oil from the top of the box, Central drive, supports the HPC and the bottom of the box.

In the engine lubrication system includes the following main units:

- The oil tank installed on SBS;
- Unit coolers installed on SBS;
- Oil aggregate consisting of pressure pump, four efflux pumps, non-return and pressure control valves, fine filter, oil bypass valve and signaling device of pressure drop, the valve of release of air. On oil aggregate mounted receiver system measuring the oil temperature at the inlet of the engine: the air
- purge drum with the strainer of the oil;
- Chip detector;
- Thermal chip detector for presence of ferromagnetic particles and heating of oil in pipelines pumping oil from the supports of the rotors;
- Safety filters oil nozzles;
- Safety filters, lift pump;
- Pipelines, channels and nozzles, oil-drain valve.

The venting system of the engine includes:

- Centrifugal breather;
- Pipelines and channels system venting.

The oil from the oil tank flows by gravity into pressurizing pump oil aggregate, where under pressure is supplied to the fine filter. The oil pressure on the inlet of the engine is maintained within the specified limits of the reducing valve. The oil, after passing a fine filter, external piping is supplied to the support LPC, turbine supports and control devices for oil pressure, and to a support LPC, Central drive and box top drives - by channels formed in the intermediate housing. The remaining parts and components are lubricated by splashing.

The oil from the bearing cavity LPC is pumped by the pump from the cavity of the bearings of the HPT and LPT - pump, and from the cavity of the bearings of the free turbine - pump.

On the way to the bilge pumps oil bathes thermal chip detector and filtered safety filters pumps.

Pumped the oil from the above-mentioned cavity is drained into the sump of the lower gearbox. Here is gravity drained the oil from the cavity of the upper gearbox, HPC bearing and Central drive in internal cavities of the ribs of the intermediate housing.

From the sump in the bottom of the box drives all of the oil, passing chip detector and safety filter, pumped out the main pump and the channel in the bottom box of drives is sent to a Central air-purge drum. Separated in the air-purge drum from the air the oil is supplied for cooling to the unit coolers.

The cooled oil returns to the oil tank.

The oil pressure at the inlet to the engine measured by the pressure transducer, and the minimum pressure is recorded with help of the indicator.

Drain oil from the lubrication system through the faucets found:

- On the tray bottom gearbox;
- The oil tank;
- Unit coolers;
- Through drain boxes located on oil aggregate and the air-purge drum.

Venting all oil cavities is necessary to ensure normal operation of the lubrication systems and seals. The oil cavity of the bearing LPC and bearings of the turbines are prompted in the cavity of the upper gearbox on the outside pipelines. The Central actuator and the lower gearbox is connected to the upper cavity of the gearbox through the channels in the ribs of the intermediate housing. The air-oil mixture from the upper gearbox gets in the centrifugal the prompter, where the detachable oil is drained external pipe in the sump of the lower gearbox, and the purified air is discharged into the exhaust device.

2.4. Basic Parameters of engine similar to projected GTU

Table 1.2 – Basic parameters of engine similar to projected GTU

Table 1.2

GTU	Temperature T_g	N_{en} kW	π_c	N_e kW(Kg/s)	C Kg(kW.hour)	η_{ef}
AI-336-1/2	1280	6300	16	197	0,321	0,31
AI-336-1/2-8	1365	8000	17,5	224	0.315	0,32
AI-336-1/2-10	1373	10000	21,3	240	0.298	0,34

2.5 Conclusion

In gas-dynamic and thermodynamic calculations we determined the parameters of the gas at various stages of compression, as well as their main design parameters (number of stages, geometrical dimensions).

During the calculation of thermodynamic cycles, gas turbines, we found the parameters of a working body in characteristic cross-sections, as well as key energy and economic characteristics. In gas-dynamic calculation GTU we have also found geometrical dimensions and output data of projected GTP namely: N_{sp}=10513 kW/kg*s; C_{sp}=0.2 kg/(kW*h); the values of these output parameters correspond modern level of GTP development.

In this part also we illustrated a description of the engine used in the following GTP.

CHAPTER 3 DEVELOPMENT OF DESIGNED GTP ACS INTEGRATED WITH CS ACS

3.1 Tasks of GTP ACS

The automatic control system is intended for:

- Automatic generation of signals and features is consistent with the control and control algorithms in all modes of engine operation;
- Dosing of gaseous fuel in all modes of operation of the gas turbine drive (GTP) (ignition of the combustion chamber, start-up of the engine, steels and transient modes of operation, limitation of the modes of operation of the engine);
- Protection of the engine from exceeding the limit values of the engine parameters;
- Control of the efficiency of the engine;
- Control and diagnostics of the technical condition of the engine;
- transmission of the measured parameters of the gas turbine actuator and information on the state of the ACS GTP channel information exchange in the ACS GPA to display it at the workplace of the operator GPU;
- Measurement of GTP vibration parameters;
- Registration of the parameters of the technical state of the GTP;
- Acceptance of commands and signals;
- Transfer of the registered information to the automatic module of accounting and registration of parameters of work and control of the technical state of the GTP.

3.2 System requirements

The GTP automatic control system shall meet the following essential requirements:

- Interaction with sensors, signaling devices and actuators mounted on the GTP and in the GPU unit;
- Exchange of information between the ACS GTP and the upper level system of the ACS GPU;
- Implementation of control and regulation laws with established static and dynamic errors;

- Resistance to external disturbances;
- Indicators of reliability of performance of the basic functions of control and management are required;
- Appearance and design must meet the modern requirements of technical aesthetics, ergonomics and engineering psychology

3.3 ACS of GTP with designed engine as controlled object.

As prototype for our designed GTP we choose D-336 engine.

Designed engine is 3-shaft (3-spools) engine which is used for different GTP with power of 4 Mw-10Mw with high gas temperature level in range of 1171K, 1365K, 1373K, and pressure ratio 12,73 to 21.33.

Gaseous fuel from fuel preparation system is given to cutout valve of main fuel supply subsystem and to throttling valve of starting subsystem.

Fuel pressure preparation system is maintained in constant level at the range 2.32 MPa, gaseous fuel temperature in this preparation system is kept up to the range +15 to +40 °C and purity of filtration equals to 40 mcm.

After cutout valve fuel comes in gas butcher where it is metered according to the control system commands and after this is directed to the fuel nozzles, starting fuel pressure after the throttle, before electromagnetic valve of starting fuel is maintained within the limits ± 0.245 MPa.

3.3.1 Functions performed by the ACS and its composition

The automatic control and check system is the main unit of the gas turbine plant control system.

The designed ACS system operates on signals from sensors and signaling devices located on the installation itself, as well as in the GPU (Gas Pumping Unit) compartment, ensures the operation of the installation according to the needs of the GPU technological process and at the same time performs the protective functions of the installation in case of reaching limit values of parameters.

The system is structurally designed placed as a separate unit located in the compartment of the GPU:

Designed ACS performs the following functions:

- Receives and converts analog parameters and signals from sensors and alarms located on the installation;
- Issues information after processing in the automated control system (ACS) of the GPU;
- generates control signals when the installation is started;
- ensures the implementation of transitional modes;
- provides maintenance of the established modes;
- limits the maximum mode of operation of the installation;
- protects the installation from exceeding the maximum allowable parameter values;
- exchanges signals from the ACS GPU;
- Controls the tightness of the shut-off valve;
- controls the efficiency of the gas dispenser DG-336;
- generates and issues signals for normal and emergency stops installation
- protects starter SV-36G;
- calculates the turbine rotor run-off time
- controls the efficiency of the lubrication and shuffling system;
- controls the performance of sensors and alarms;
- Exercises self control.

3.3.2 The main element in the ACS is the Electronic Controller of GTP

Electronic controller receives signals from:

- Sensor for measuring air temperature in the atmosphere Tn;
- Sensor for measuring air pressure in the atmosphere of pH;
- Sensor for measuring the temperature of the oil in the tank TMb;
- The sensor for measuring the air pressure at the inlet to the installation RP;
- three DTA-10 sensors measuring the rotation speeds of nw, nt, nst high and low pressure rotors and power turbine;
- Temperature measurement systems for the low pressure turbine Tg;
- Sensor type PZ19-02 measurement of pressure per kW rkwt;
- Signaling device of MSTV-2,1 of the minimum gas pressure before the starter rcv;
- The sensor of measurement of pressure difference on the oil filter of thin clearing rmf;

- Sensor type P319-03 measurement of gas pressure before the fuel injectors;
- Sensor measurement of oil pressure at the inlet of the PM installation;
- The P-109 sensor for measuring the oil temperature at the entrance to the Tm installation;
- SS-36 shaving signaling devices;
- TCS-36 thermal signaling devices;
- signaling device of fuel gas leakage type CCK;
- signaling devices of the MSTV-2,1 type of position of air bypass valves after CST and KVT;
- Vibration measurement systems;
- OG-336 CT limiter.

The electronic control controller signals to:

- Emergency damper and starter system;
- Ignition unit;
- Starter valve;
- stop valve;
- Fuel gas dispenser.

Starting, cold scrolling, emergency and normal stopping, control of the operating modes of the installation is carried out by the corresponding signals coming from the ERC. Signaling and display of signals is carried out by the respective electronic devices.

Rotary speed sensor DTA-10 produces electrical voltage pulses, the frequency of which is proportional to the rotation speed of the respective rotors. Each inductor of the corresponding rotor is mounted: for the BT rotor - three sensors; for NT rotor - two sensors; five sensors for the PT rotor; for the starter rotor there are two sensors. The sensors are mounted inside the stator of the installation and work together with the inductors mounted on the respective rotors; the starter sensor is mounted in the internal cavity of the starter and works with the inductor mounted on the starter turbine rotor. The temperature of the oil is measured by the P-109 sensor. The principle of operation of the sensor is based on changes in the electrical resistance of the heat-sensitive element depending on the temperature of the oil. Oil pressure is measured by the pressure transducer type P319-01, which converts the value of the excess pressure to a uniform electrical signal. Valve Control Automatic Valves (ACC) 407.6 and 4017.12 are designed for automatic control of valves mounted on LPCT and HPC. As an impulse and working body, they use the air extracted from the HPC.

Automatic control systems also receive a signal from the speed limiter of the rotor of the power turbine (PT) type OG-336 mounted on the box of actuators ST. The OG-336 limiter consists of housing, a centrifugal sensor cover, a lever system, a pusher and a micro switch.

When the speed limit (9400 ± 150 rpm) is reached, the centrifugal sensor overrides the spring tension and closes the contacts of the microswitch through the pusher and lever system, causing the SAKK-336 to signal a stop of the installation.

The designed ACS introduces signals from the rotary vibration control system. The system consists of piezoelectric sensors installed in the front and rear suspension planes and pre-treatment and indication units installed in the GPA compartment. The level of vibration velocity higher than 45 mm / s is considered to be high and higher than 60 mm/s is threatening.

The signals coming to the electronic control controller from the listed sensors give a command to control the stopcock and fuel dispenser.

The block diagram of ACChS-336 is given in the following figure:

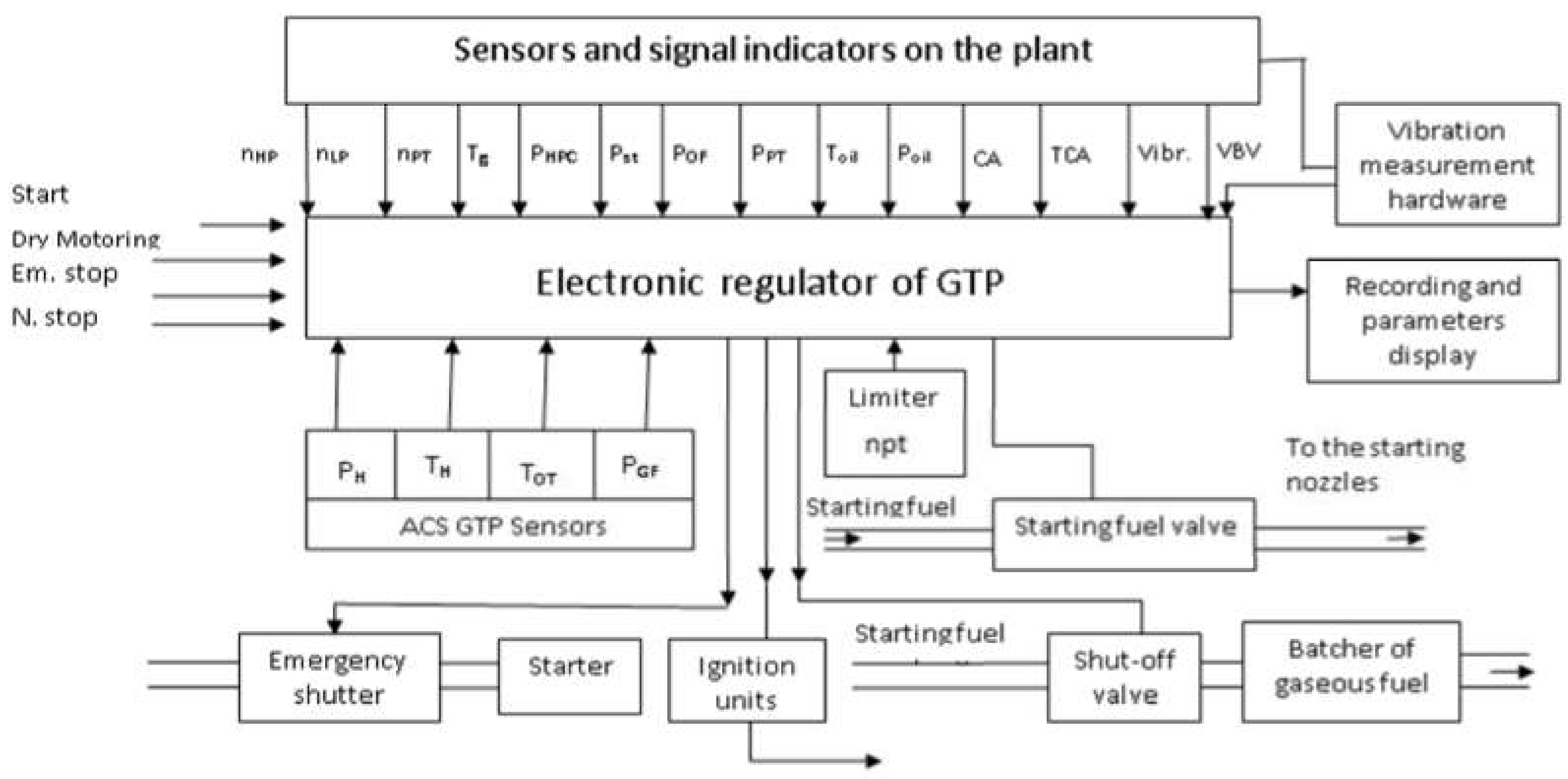

Figure 3.1 – Block diagram of designed ACS

3.3.3 Control law at maximal operating mode

Controlling factor (CF);

As Controlling factor is fuel flow rate G_f number of CF is one (Z_{CF}=1) ;

CP (Controlled parameter) is one parameter of $n_{pt} = n_{pt}$ max

CP _ (Zcp=Zcf)

CLmax: $n_{pt} = n_{pt}$ max=constant

n_{HP} max = limit ; To prevent damaging turbine blades

n_{LP} max = limit ; To prevent vibration

T_g * max = limit ; To prevent explosion

If any limitation is reached the GTP power is reduced.

This control law is the most suitable for GTP which operates at the annular middle temperature is in the range between 288k and 310k (like Ukraine).

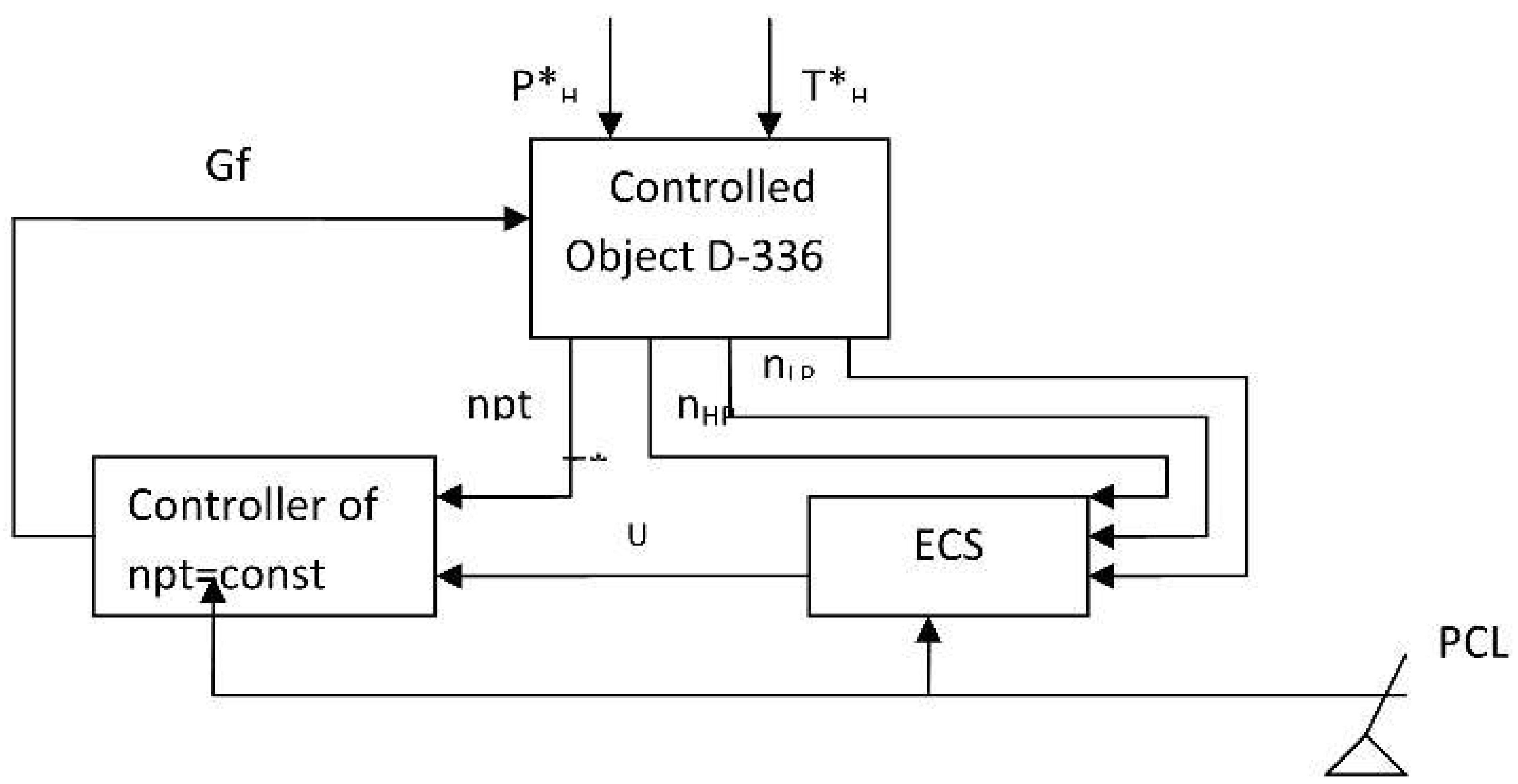

Figure 3.2 – Simplified block diagram ACS of electronic control

Basic controlled value is a value npt . It is measured and compared in a regulator with a size which is specified by position of TCL. Differences between two indicated values causes the change of control factor - fuel flow rate G_f.

Other controlled values (T^*_g, n_{hp}, n_{lp}) are regulated on a restrictive diagram. Originally these controlled values are entered in the special device, executed as electronic control system (ECS). Here takes place their comparing with the values, which is set by the system of setting even so setting of T^*_g is variable and depends on position of TCL, and setting of n_{HP} and n_{lp} is constant on all of the modes of operations of engine, ECS provides the choice of parameter on which a controlling is conducted: on the steady modes it is chosen one controlled parameter from the 3 which provides the minimal delivery of fuel.

At exceeding any of the three indicated parameters of tuning value on the steady mode a signal from ECS is entered to the regulator and decreasing of delivery of fuel takes place to stabilize the value of the controlled parameter which is chosen by ECS. Thus, naturally, value of npt is not under control and actual value of npt will be less in comparison with value which was indicated at certain position of PCL.

3.4 Servo motor

A servo motor is a rotary actuator or motor that allows for a precise control in terms of angular position, acceleration and velocity, capabilities that a regular motor does not have. It makes use of a regular motor and pairs it with a sensor for position feedback. The controller is the most sophisticated part of the servo motor, as it is specifically designed for the purpose.

Advantages and limitations of servo motors

Servo Advantages

For applications where high speed and high torque is needed, servo motors shine. Stepper motors peak around speeds of 2,000 RPM, while servo motors are available many times faster. Servo motors also maintain their torque rating at high speed, up to 90% of the rated torque is available from a servo at high speed. Servo motors are also more efficient than stepper motors with efficiencies between 80-90%. A servo motor can supply roughly twice their rated torque for short periods, providing a well of capacity to draw from when needed. In addition, servo motors are quite, available in AC and DC drive, and do not vibrate or suffer from resonance issues.

Servo Limitations

Servo motors are capable of delivering more power than stepper motors, but do require much more complex drive circuitry and positional feedback for accurate positioning. Servo motors are also much more expensive than stepper motors and are often harder to find. Servo motors often require gear boxes, especially for lower speed operation. The requirement for a gearbox and position encoder make servo motor designs more mechanically complex and increase the maintenance requirements for the system. To top it all off, servo motors are more expensive than stepper motors before adding on the cost of a position encoder.

3.5 Results of Patents research

3.5.1 Actuator Device for Use in a Gas Turbine Engine Fuel Control

Inventors: BLOOM JOSEPH LOUIS

Application Number: 05/376437

Publication Date: 01/21/1975

Filing Date: 07/05/1973

Assignee: LUCAS AEROSPACE LIMITED

Primary Class: 192/48.5

Other Classes: 192/89.21, 192/93A

International Classes: *F02C9/26*; *F02C9/00*; (IPC1-7): F16D47/02

Field of Search: 74/625 192

An actuator device in accordance with the invention comprises first and second angularly movable input members and an angularly movable output member, dog means for interconnecting the second input member and the output member, resilient means arranged to disengage said dog means, means actuable by the first input member for interengaging the dog means when the first input member is in any position within one part of its range of movement and permitting disengagement of said dog means when the first input member is in any position within another part of its range of movement, and coupling means for connecting the first input member to the output member under the action of said resilient member when the second input member is within said other part of its range of movement, the arrangement being such that initial engagement of said coupling means can only be effected when the first input member is in a position within said other part of its range of movement corresponding to the position for the time being of the out- put member and said dog means is fully disengaged only when said coupling means is engaged.

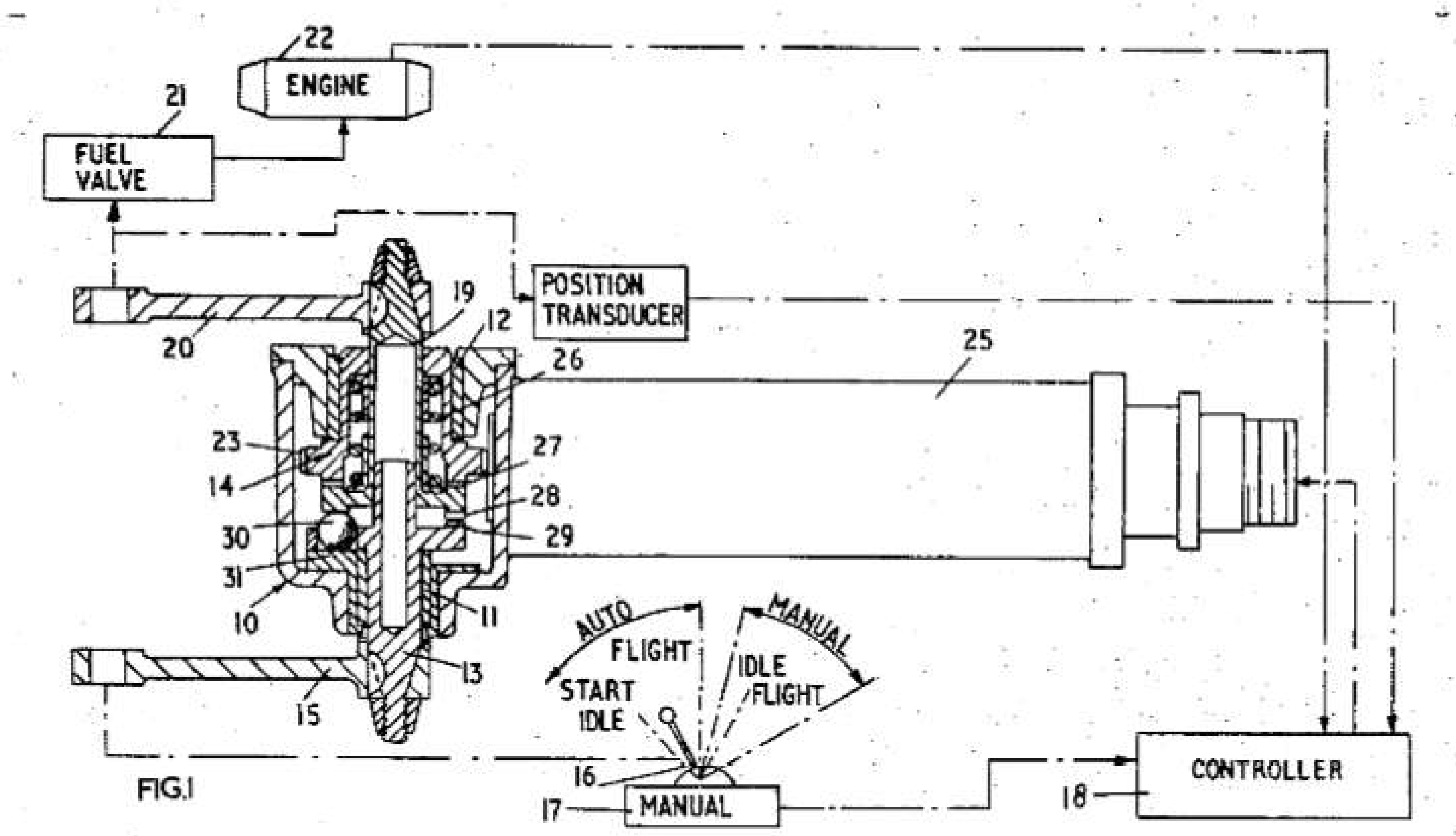

Figure 3.3 – diagrammatic illustration of a fuel system including actuator

This invention relates to an actuator device for use in a gas turbine engine fuel control. An actuator device in accordance with the invention comprises first and second angularly movable input members and an angularly movable output member, dog means for interconnecting the second input member and the output member, resilient means arranged to disengage said dog means, means actuable by the first input member for interengaging the dog means when the first input member is in any position within one part of its range of movement and permitting disengagement of said dog means when the first input member is in any position within another part of its range of movement, and coupling means for connecting the first input member to the output member under the action of said resilient member when the second input member is within said other part of its range of movement, the arrangement being such that initial engagement of said coupling means can only be effected when the first input member is in a position within said other part of its range of movement corresponding to the position for the time being of the output member and said dog means is fully disengaged only when said coupling means is engaged. In the accompanying drawings:

Figure 3.3 is a somewhat diagrammatic illustration of a fuel system including an example of an actuator device n accordance with the invention, the actuator device being shown in section.

The actuator device shown has a body 10 having aligned bearings 11 and 12, supporting first and second angularly movable inptH members 13 and 14 respectively. First input member has an arm 15 thereon which is mechanically coupled to a manual control lever 16 which also actuates an electrical control device 17 for supplying a "desired speed" signal to an electronic con- trailer 18. The lever 16 has a gate (not shown) associated with it to divide its range of movement into two parts for automatic and manual control respectively.

The gate may take any conventional form such that some additional operation, such as a lateral displacement of the lever, is required to move the lever 16 from one part of its range of movement to the other.

The second input member 14 has an axial through bore through which an output member 19 extends, such output member being angularly movable about the common axis of the input members 13, 14 and also axially displaceable. An arm 20 is provided on the out- put member 19 and this is connected in use to a fuel valve 21 which controls the supply of fuel to the engine 22.

The second input member 14 has worm-wheel teeth 23 which engage a worm 24 driven by an electric servo motor unit 25 including a reduction gear train and a tacho-generator speed control. This servomotor unit 25 is driven by pulses supplied by the controller 18.

A spring 26 acts on the output member 19 and urges this axially towards the first input member 13, tending to disengage dog means 27 provided on the second input member 14 and the member 19 and to engage coupling means in the form of a single dog 28 on the output member 19 and a coacting single slot 29 in the first input member 13. For causing the dog means 27 to be engaged a ball 30 is contained in a bore in the first input member 14 and is interposed between the output member 19 and a fixed face cam 31 provided on the body 10. This cam 31 is arranged so that the ball 30 dis- places the output member 19 to engage the dog means 27 whenever the lever 16, and hence the input member 13, is in the automatic part of its range of movement, the coupling means then being disengaged, and to permit movement of the output member 19 under the influence of the spring 26 when-ever the lever 16 is in the manual part of its range of movement.

In this latter condition the coupling means can only be fully engaged when the slot 29 is aligned with the dog 28, i.e. when the input member 13 occupies a particular position corresponding to. the position for the time being of the output member. When the input member 13 does not occupy this particular position the dog 28 can ride over the face of the input member 13, preventing the member 19 from completing its full axial movement under the influence of the spring 26. The dog means 22 is arranged so that it is not fully disengaged when the dog 28 is riding on the surface of the member 13.

In use for normal flight the required speed of the engine is selected by placing the lever 16 in any desired position within the automatic part of its range of movement. The electronic controller 18 then monitors the engine running and drives the second input member 14 to a position such that the fuel delivered to the engine is sufficient for the engine to run at the required speed. In the event of an electronic failure the pilot will be warned by a suitable failure warning (not shown), the motor 25 is denergised. The wormwheel 23 is thereby locked against rotation, and the output member 19 cannot therefore be turned until the dog means 27 has been fully disengaged. The pilot can assume manual control of the engine by moving the lever 16 into the manual part of its range of movement .and then gradually moving it forwards until it occupies a position corresponding to that in which the output member 19 is locked. The coupling means 28, 29, then becomes fully engaged and the dog means 27 is fully disengaged and the control of the output member 19 is then directly dependent on movement of the lever 16. I claim:

1. An actuator device for use in a gas turbine engine fuel control, comprising in combination: a body, first and second input members mounted on the body for independent angular movement relative thereto and directly connected to separate control devices, an angular movable output member mounted. on the body . for angular movement relative thereto and also axial movement relative thereto, dog means on said output member and said second input member for providing a driving connection there

between, resilient means acting on said output member so as to tend to urge the out- put member in a direction to disengage said dog means, means actuable by said first input member for interengaging said dog mens whenever the first input member is in any position within one part of its range of movement relative to the body and permitting disengagement of said dog means whenever the first input member is in any position within another part of its range of movement relative to the body and coupling means for connecting the first input member to the output mem- ber under the action of said resilient member when the first input member is within said other part of its range of movement, said coupling means being operative for preventing axial movement of the output member under the action of said resilient means sufficient to fully disengage the dog means except when said first input member is brought into a position with said other part of its range of movement corresponding to the si-multaneously position of the output member.

2. An actuator device as claimed in claim I in which the output member and the input member are discs and said coupling means comprises a slot in one member and a projection on the other so that engagement of the projection with any part of said one member other than said slot prevents sufficient movement of said output to disengage said dog means.

3. An actuator device as claimed in claim 2 in which the means actuable by the first input member com-prises a ball in a hole in the first input member engaged between a face cam on the body of the device and the output member.

4. An actuator device as claimed in claim 3 in which the second input member is in the form of a wormwheel engaged by a worm rotatable mounted on the body.

5. An actuator device as claimed in claim 4 further comprising an electric motor for driving the worm.

6. An actuator device as claimed in claim 1 in which the second input member is in the form of a wormwheel engaged by a worm rotatable mounted on the body.

7. An actuator device as claimed in claim 6 further comprising an electric motor for driving the worm.

8. An actuator device as claimed in claim 1 in which the means actuable by the first 'input member com-prises a ball in a hole in the first input member engaged between a face cam on the body of the device and the output member.

9. An actuator device comprising, in combination a body, co-axial first and second rotary input members journalled in said body and conductive to separate con-trol devices, a rotary output member journalled in said second input member, dog means on the output mem-ber and the second input member for drivingly inter-connecting such members, a spring acting between the second input member and the output member to tend to disengage the dog means, a face cam fixed in the body, a cam follower rotatable with the first input member and disposed between the cam and the second input member so as to control the engagement of said dog means in accordance with the angular position of the first input member, a dog on the output member, a planar face on the first input directed towards said dog and formed with a single slot to receive said dog when the first input member is in a specific angular position relative to the output member, the cam being shaped so that over one portion of the range of move-ment of the first input member the cam follower causes interengagement of the dog means and over another portion of such range of movement the cam follower does not prevent disengagement of the dog means, such disengagement being prevented by the engagement of the dog with said planar face until the first input mem-ber is moved into its specific angular position relative of the output member whereupon the dog enters the slot to provide a driving connection between the first input member and the output member, and a worm and wheel drive arrangement for the second input member.

3.5.2 Patent # 2

ICON 2000 electric actuator

Inventors: Biffi Italia s.r.l.

Given the fact that the existing equipment within the natural gas compressor station does not allow for the automated regulation of the gas pressure, it was considered as necessary to implement a new automation solution to solve this problem. One of the main problems that needed to be solved was which component to use as execution element for the automation (control) system, or more precisely on what type of valve to fit it. The compressor systems comprise two main types of valves – slide valves and spherical shutter valves. However, the automation system cannot be fitted directly on a spherical shutter valve, because this type of valve is not designed to work in an intermediate position, as this would subject the valve's sphere to intensive corrosion, which in turn would lead to a deteriorated surface and to leaks. Therefore, the automation system is fitted on a slide valve that is better suited for this type of operation. The main elements of the implemented automation system are as follows:

- A BIFFI ICON 2000 electric actuator fitted on the slide valve (figure 3) and a programmable automation and monitoring panel that will be installed in the control room of the natural gas compressor station;

Figure 3.4 – BIFFI ICON 2000 electric actuator fitted onto a disassembled valve.

- A process computer equipped with a power source, input-output and communication modules and with clips for electrical connections;
- HMI (human machine interface) operation panel with an adequate display.
- Automatic circuit breaker for overload and short-circuit protection for the general power circuit and for the power circuit of the controlled valve.

Also, in order to provide for the automated regulation of the gas pressure, it is necessary to install some pressure transducers, each of which will transmit to the automated regulation system a signal of 4-20 mA, proportional to the value of the pressure in the measuring point:

- A pressure transducer for the aspiration part of the compressor, installed ahead of the regulation valve, with a measurement range of 0-60 bar – PT1;
- A pressure transducer for the aspiration part of the compressor, installed below the regulation valve, with a measurement range of 0-60 bar – PT2;
- A pressure transducer for the exhaust part of the compressor, with a measurement range of 0-100 bar – PT3.

All three transducers will provide the regulation system (the automation panel) with the real time values of the three pressures, values that represent the input for the calculation of the control parameter of the regulation system, parameter that will be also sent through an unified 4-20 mA current signal to the electrical actuator BIFFI ICON2000 (figure 4), fitted on the slide valve.

Figure 3.5 – Electric actuator BIFFI ICON 2000

The electric actuator BIFFI ICON 2000 has following characteristics:

- Power supply: either 3 phases from 208 V to 690 V at 50/60 Hz or 1 phase from 110 V to 240 V at 50/60 Hz
- Torque output: From 30 to 57,000 Nm - Speed range: From 12 to 173 RPM at 50/60 Hz

- Work temperature range: -20°C to +85°C
- Non-intrusive configuration;
- User-friendly push-button panel for operation, setting and diagnostics;
- Bluetooth™ wireless connectivity;
- Advanced maintenance data and alarm reports;
- Valve condition monitoring;
- Configurable 'data logger' function for maintenance and diagnostic programs in recorder or event modes;
- Customized numeric and graphic displays with 8 language options;
- Single enhanced terminal block;
- Digital contactless torque and position sensing;
- Watertight and explosion proof PDAs available;
- Suitable for use in SIL 2 applications.

Also, the automation panel will be connected to the spherical shutter valve that can be controlled manually from the HMI part of the automation panel, should this become necessary during the compression process. Each of the two valves can be controlled manually only after introducing a user-specific password and any of these maneuvers will be automatically stored and included in a report that can be visualized later on the HMI display. Also, all essential information from the regulation process can be remotely visualized by means of mobile devices connected through GPRS to the process controller. In order to ensure the system's cybernetic security there will be used a GSM data card with fixed IP and the access to the information provided by the controlled will require the usage of user names and of the corresponding passwords. It will not be possible to issue a command for the modification of the valves' position by GPRS communication, since this connection will be dedicated exclusively to the reading of data from the regulated process. The only possibility for controlling the valves or for cancelling the controlled pressure will be by means of the HMI installed on the frontal panel of the automation system or by using the buttons of the local panels for the operation of the electric actuators BIFFI ICON 2000 fitted on the slide valve and on the spherical shutter valve. In turn, the controller will communicate with a remote process computer by GPRS for the transfer of acquired data and for acquiring the targeted values of the regulated process variables. In order to visualize the parameters, the prescription of the regulated process variables and the control of the execution elements connected to the controller, independently from the process computer, there will be used a 15" touch screen installed on the front panel of the automation block. This panel will allow the operation of the two valves, the monitoring of the regulation process from the compressors' aspiration part, as well as the visualization of data on mobile devices by means of GPRS connections. As can be seen in figure 5, the HMI display allows the visualization of the three pressure values in both analogical and digital form, as well as the position of the valve (100% open). The visualization of the functioning parameters and of the valves' position allows a parameterization of the control function. By means of the HMI, the operator can supervise all process parameters and can compare the values of the various displayed parameters, so that he can then make quick decisions function of the indicated pressure value. The situation presented in figure 5 in terms of the displayed values requires some further discussion. The value of the set pressure is higher than that of the pressure registered ahead of the control valve (PT1). In this situation, it can be assumed that the controller will be unable to bring the pressure to the targeted value, as even in the case in which the valve is 100% open, the pressure ahead of the valve can be at most equal to that behind the valve. This is a particular case for which the control system has to be programmed in such a manner that it alerts the operator if the value is too high.

3.6 Calculation of the Diameters of the controlled unit

Initial data for calculation was obtained from the thermo and gas dynamic calculations

Data: Power of GTP N_e= 10 MW;

Pressure after fuel preparation unit (FPU) is P=2.5 MPa;

Specific fuel consumption is C_{sp}=0.238 Kg/kW.h

Fuel gas speed in control unit is c= 40m/s

Minimal diameter of metering needle is d= 0.02 m

Gas consumption: $G_g= C_{sp}*N_e= 0.238*10^4=2390$ m^3/h => 0.66 m^3/s

Density: $\rho = \frac{1}{V}$

PV=RT, where R of natural gas= 518

$V = RT/P = 518*289/25000000 = 0.0617$ m^2

$\rho = \frac{1}{V} = \frac{1}{0.0617} = 16.2$ Kg/m^3

Finding the maximum area of the flowing ring in the metering needle:

$F= \pi (D^2-d^2)/4,$

Where D is outer/maximal diameter of metering needle

$G_g= \rho*C_s*F$

⇨ $F=G_g/\rho*c= 0.66/(16.2*40)=$ 0.01 m^2

$D^2= (4F+\pi d^2)/\pi= (4*0.01+ \pi 0.02)/\pi=$ 0.02

⇨ $D= 0.14$ m

3.7 Explanation of actuator operation

The figure below shows the electric actuator which has the role of controlling the metering needle (controlled unit) by signalization of its position for moving to the left or right side.

As we can see in the figure, the gas fuel flows from the pipelines into the fuel preparation unit where the pressure of the natural gas is reduced to approximately 2.5 MPa, and then the gas fuel continues its way through the inlet tube and further to the burners (in combustion chamber).

Amount of fuel depends on the area of the circle ring path between the set and metering needle, if the needle moves to the right side this area is increased, which means an increase in the amount of fuel gas going to the burners. If the metering needle moves to the left side the area is decreased which means a decrease in the amount of fuel going to the burners. The movement of the metering needle is achieved due to the electric actuator force. The metering needle carry on an additional fragment which close entirely the area of gas fuel flowing in cases of complete or emergency shutdown of GTP.

In addition the figure shows the feedback device connected to the electronic controller, this device transmit signal about the stats of controlled factor (gas fuel flow rate G_f).

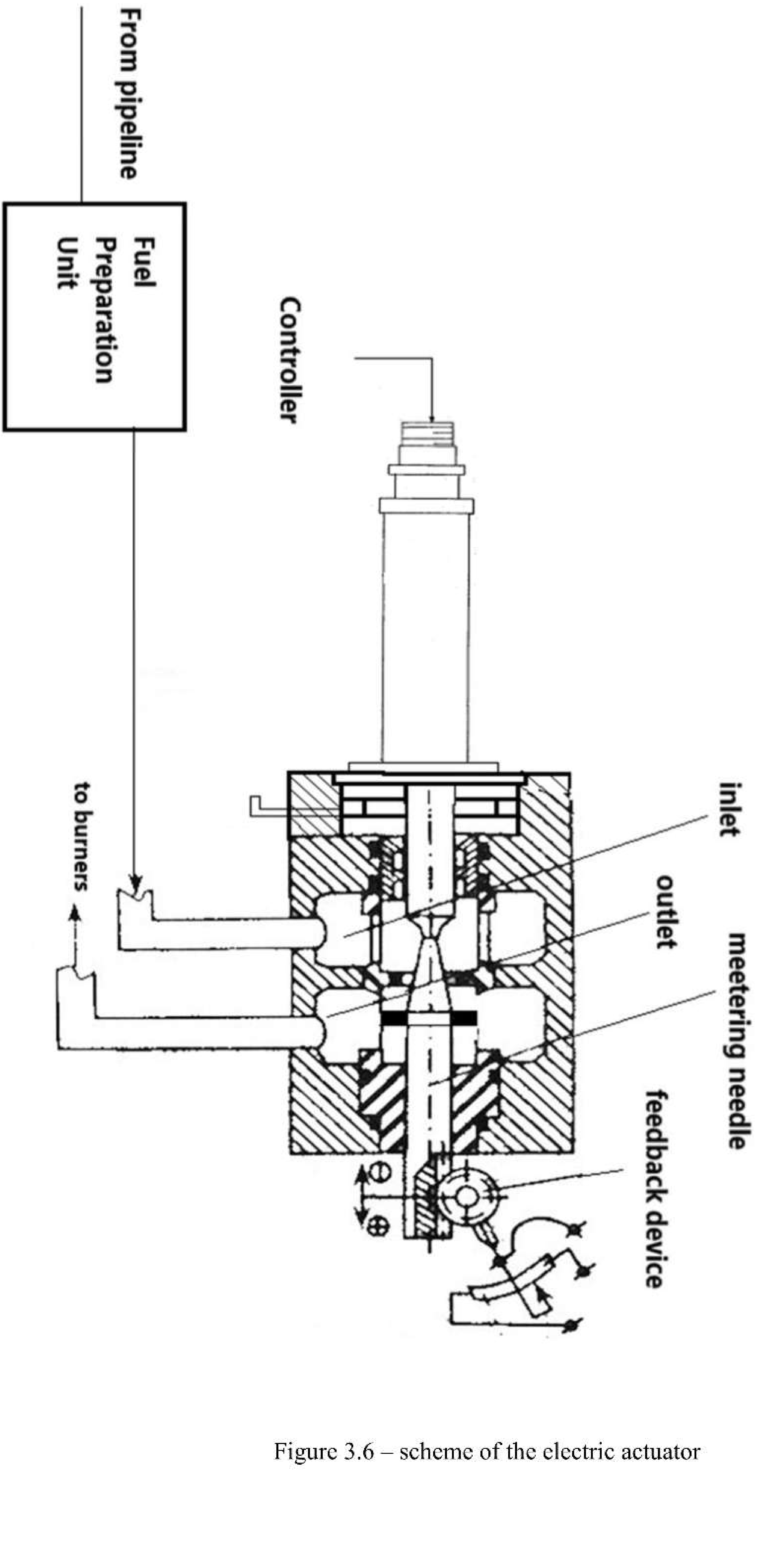

Figure 3.6 – scheme of the electric actuator

3.8 Integrated electronic control system

The figure 3.7 shows the block diagram of the integrated automatic control system between the ACS of GTP and the ACS of CS.

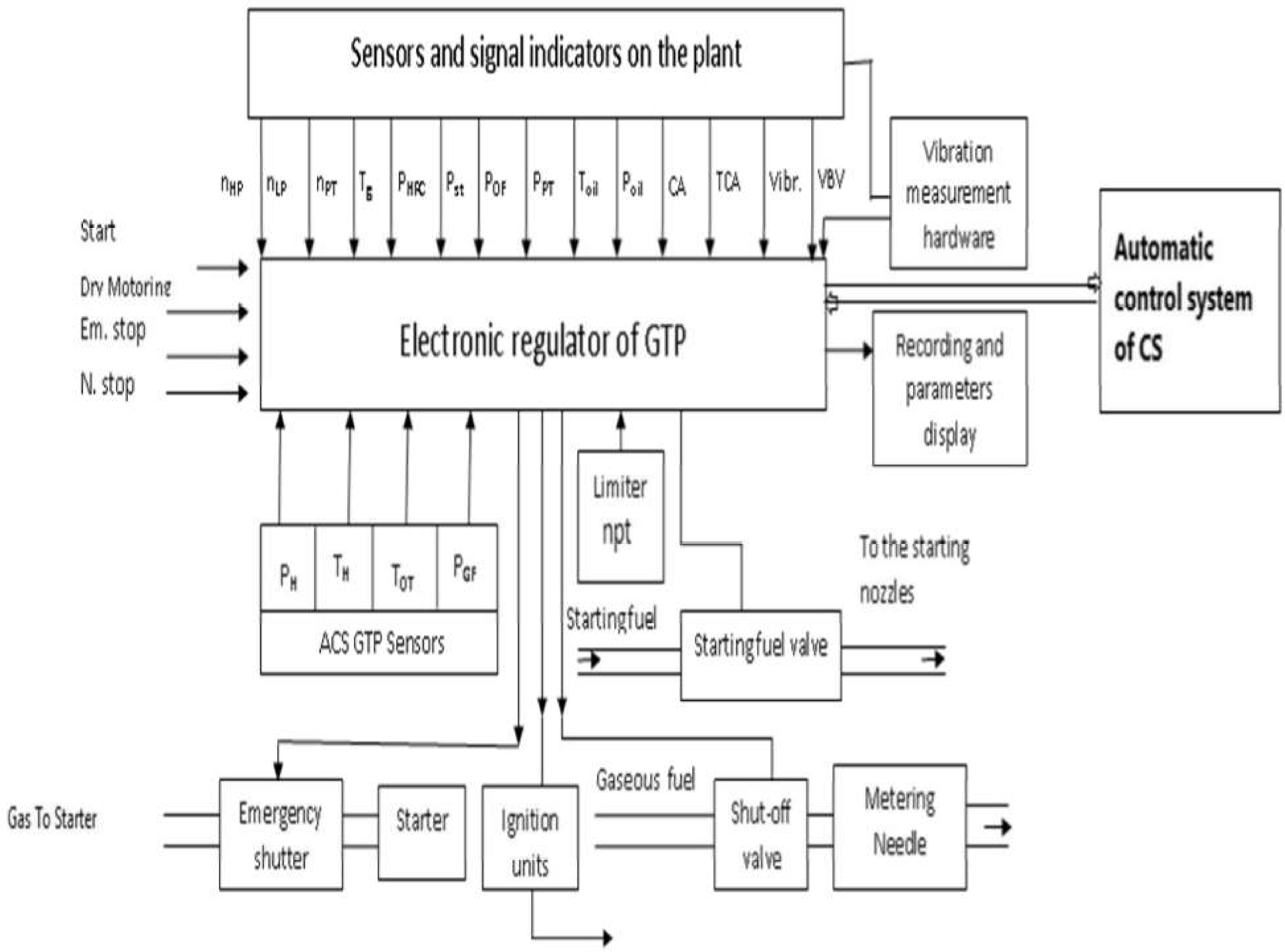

Figure 3.7 – Block diagram of the integrated automatic control system

This system consists of different devices which are agreed between each other and perform actions on the operating process of the GTP by regulating the fuel flow rate G_f. The integrated ACS consists of sensors and signal indicators on the plant, electronic regulator and different hydro-mechanical devices.

The electronic regulator or controller is connected with the ACS of CS.

The input signals directed to the main electronic regulator are:

Rotational speed of the three rotors

Gas temperature – T_g

Pressure before the turbine starter – P_{st}

Oil filter pressure difference – P_{of}

Pressure before power turbine – P_{pt}

Oil pressure – P_{oil}

Oil temperature – T_{oil}

Air temperature – T_{air}

Chip enunciator – C_{at}

Thermo-chip enunciator – TCA

Vibration signal – V_{ibr}

Variable bleed valve – VBV

IPS – Input signals to GTP ACS

OTP – Output signals from GTP ACS

3.9 Conclusion

As we can see and understand from the demonstration before, the use of electric actuator assure a great improvement in the operation of the engine as more suitable and smooth fuel variation and affects positively on the efficiency and power of the GTP and makes the operation more accurate.

The integration between GTP ACS and CS ACS in modern engineering aspect is indeed an important jump which has benefits illustrated by reducing the human factor error due the connect control room or dispatch station.

CHAPTER 4

ENVIRONMENTAL IMPACTS OF POWER PLANTS

4.1 How a Power Plant Might Cause Impacts

A power plant can influence the environment by its construction and by its operation. These effects, or impacts, can be either temporary or permanent. A power plant and its auxiliary components (e.g. natural gas pipelines, water intakes and discharge, coal delivery and storage systems, new transmission lines and waste disposal sites) take up space on the soil and in the air, use water resources, and, in many cases, emit pollutants into the air. The plant's footprint on the ground eliminates opportunities for others to purchase or use the land. It can also affect the existing or future uses of adjoining and nearby land parcels. A coal-fired plant includes some relatively tall buildings and high exhaust stacks. The plant's height may result in safety concerns for aircraft or visual impacts for local landowners. If the land to be used for the power plant is a "Greenfield", an undeveloped parcel with mostly vegetation (crops, pasture, or old-field vegetation), there would be impacts on land use, soils, and wildlife present on the site.

Fossil fuel-fired and biomass-fired plants burn fuels to make either hot air or steam needed to spin power turbines generating electricity. Nuclear power plants use the nuclear fission reaction to create steam to do the same. The burning of fuel creates exhaust gases and other by-products, including air pollutants. The use of water to make steam requires large quantities of water from nearby rivers or lakes, or from local underground water aquifers and it must be purified. In some cases, water must be discharged from the plant after it has been used. The amount of used water discharged, the discharge water's temperature, and the concentration of pollutants in the water are all factors to be considered.

A variety of solid wastes can be produced, and these must be handled. The combustion of coal creates ash as a solid waste. Nuclear power plants create spent nuclear fuel rods and low-level radioactive wastes.

Power plants that use water to create steam or for cooling must often filter and purify the water before discharging to surface waters. The filtered solids are a by-product that must be disposed appropriately.

The water used for cooling is often run through cooling towers to reduce the heat. The air that's warmed by the water in the cooling tower goes into the atmosphere carrying great quantities of water as vapor, in some cases millions of gallons per day. That lost water vapor, obtained locally, represents significant water consumption by the power plant.

Some aspects of the construction and operation of a power plant can have unsettling effects on the community in which the power plant is built. Construction of the power plant, while very organized, can be viewed by surrounding landowners and other citizens as ugly and chaotic and might have an effect on community aesthetics or business. Costs for community services such as police, fire protection, emergency medical service, and traffic control can increase. Additional requirements might be placed on the municipal water supply or wastewater treatment capacity, or on solid-waste management systems. Coal-fired power plants require an efficient, reliable and long- term means of coal delivery, usually by rail or barge. Nearby road or rail traffic might be complicated or burdened by construction traffic and the delivery of materials, particularly large items. Noise levels in neighborhoods might increase during construction, and power plant operation also creates noise and vibration. The cooling towers of an operating power plant can also create fog and rime ice. Air space issues and compatibility with local land use must be considered in light of the space the power plant occupies and the way it operates.

There also can be positive effects on the community such as jobs for local residents and purchases of locally-produced goods and services creating additional income streams for the area. Local tax revenue or state shared revenue for the local municipalities would increase. And, of course, the electricity produced by the plant could replace out-of-state power purchases whose prices might be more volatile and unreliable. The operation of the plant also could help stabilize the local electric transmission grid so that power is more efficiently and reliably moved from one place to another.

There could also be impacts from the construction of auxiliary or ancillary facilities such as power plant support systems and infrastructures, rail lines, roads, natural gas lines, water or steam lines, and electric transmission lines. Water, steam, and natural gas are transported by pipelines. Pipelines often require the digging of trenches that may impact residential yards, roads, farm fields, woodlands, or wetlands. Natural gas and electric transmission line impacts are discussed in other PSC brochures.

4.2 Public Information and Input in Power Plant Development

The general public should have access to information about the siting of a power plant and the potential impacts that could occur before construction is authorized by the PSC. People in the area often have information that could affect the power plant developer's sitting efforts, the design of the proposed plant, and the ultimate decisions made by the Commission.

A developer might obtain public input by:

- Soliciting input through a periodic newsletter.
- Soliciting responses in personal letters sent to local governments, regional planners, and landowners.
- Holding information meetings to respond to questions, solicit comments, or hand out questionnaires.

With access to the developer's power plant siting criteria, members of the public can think more seriously and meaningfully about the plant. They can:

- Compare sites.
- Understand why particular sites are being examined for a proposal.
- Discuss which environmental factors appear to be of importance in the project.
- Potentially influence the company's siting decisions before it submits a construction application to the PSC.

The public can also provide input during the PSC review of the power plant proposal. There is often discussion about "mitigation." Mitigation involves methods to reduce impacts or to compensate for the impacts in some way so that the adverse effect is lessened. Development of mitigation measures might affect the project review's outcome. Methods for impact mitigation should be considered throughout the regulatory review process.

4.3 Natural Resources Impacts

4.3.1 Air

Operating power plants that burn coal, oil, or natural gas emit air pollutants into the atmosphere requiring the plant be fitted with pollution control equipment to reduce emissions. Many of these power plant air pollutants have been identified and are regulated by federal and state environmental regulatory agencies.

Public exposure to air emissions (air pollution) from a power plant is regulated by the U.S. Environmental Protection Agency (EPA) primarily through two sets of standards:

- The National Ambient Air Quality Standards (NAAQS) for major, "criteria," air pollutants including sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon monoxide (CO), ozone (O_3), particulate matter ($PM_{2.5}$ or PM_{10}), and lead (Pb).
- The National Emissions Standards for Hazardous Air Pollutants (NESHAP) for hazardous elements like mercury (Hg) or cadmium (Cd) and compounds like acetaldehyde (CH_3CHO) or hydrochloric acid (H_2SO_4), all often mentioned simply as HAPs.

The Wisconsin DNR is charged with enforcing the NAAQS for criteria pollutants and NESHAP for HAPs. The Wisconsin DNR air pollution control permit program has permits for two kinds of scenarios: new and existing facilities. For a proposed new power plant, the objective is to ensure through a "construction permit" and "air dispersion modeling" that the plant can meet air pollution standards before it is built and operating. Existing plants receive operation permits that set emission limits and establish monitoring and reporting requirements.

SO_2 has been a cause of acid precipitation, commonly known as "acid rain," which can damage vegetation and acidify lakes. Species vulnerable to acidic conditions have trouble reproducing and, in some cases, die. NOX and volatile organic compounds (VOCs) are components of ozone formation. Ozone is a principal component of smog and can result in respiratory health and other environmental effects. Particulate matter (PM) includes dust and smaller particles with a maximum particle diameter of 10 microns (PM10). It takes 1,000 microns to equal 1 millimeter. In addition to PM10 emission standards, there are federal standards for PM2.5, extremely small particles with a diameter between 2.5 and 10 microns. Small particulates have been shown to cause respiratory problems because they can penetrate deeper into the lungs than the larger particulates. The DNR has been monitoring PM2.5 statewide since 1999. Only a relatively small amount of fine particulates are directly emitted from combustion sources. A more significant concern is the NOX and SO2 emissions from power plants that burn coal or natural gas. These compounds are part of a complex chemical reaction in the atmosphere that creates nitrate- and sulfate-based fine particulates. Most of the DNR's efforts to reduce fine particulate pollution are based on year-round control of NOX and SO2 contaminants.

Mercury (Hg) is naturally present in small quantities in the environment. Human activities have greatly increased the concentration of this pollutant in the air and water. Coal-fired power plants are the biggest category of mercury emitters. Mercury is very volatile and can travel around the world in the atmosphere, repeatedly being deposited and re-emitted into the atmosphere. Mercury is deposited in lakes and rivers by rain, snow and surface runoff. While mercury is a pollutant with global consequences, the local impacts of mercury emissions from power plants also remain a serious concern. Once deposited in waterways, bacteria can convert mercury into methyl mercury that can be easily absorbed by fish and other organisms. Eating contaminated fish is the primary pathway for human exposure to mercury. Ingested mercury can damage the nervous system, especially in children and fetuses. Currently, most Wisconsin lakes and streams have DNR fish consumption "safe-eating" guidelines for mercury (http://dnr.wi.gov/topic/fishing/consumption). Some Wisconsin lakes and streams or stream segments have fish consumption "special advice" because of higher levels of mercury in certain sport fish which can be found on the DNR website. Both the fish consumption guidelines and the special advice contain recommendations regarding avoiding or limiting consumption of certain sport fish, especially women of child bearing years, nursing mothers and children under the age of 15.

Mercury emission control from fossil fuel-burning power plants is improving. It may be possible to reach a 70 to 90-plus percent reduction in mercury emissions using certain combinations of control technologies. While the toxic risk of direct inhalation of mercury from power plant emissions is low, both the DNR[1] and EPA[2] are regulating mercury emissions from coal-fired power plants to reduce the build up (bioaccumulation) of mercury in the environment.

It is also important to know about the presence of sensitive environmental resources in the area that would be affected by the power plant's emissions. For example, the plant should be located far from any designated wilderness such as national forests whose ecology, public use and enjoyment could be adversely affected by air pollution.

Federal emissions standards are based on health effects research. In an effort to minimize pollutants released to the air, best-achieving emission control technologies are often made a requirement for plant operation. Even though a power plant's emissions are required to meet air emission standards, more sensitive individuals might not be adequately protected. When air pollution levels increase in an area, more vulnerable individuals like the elderly, the sick, and the very young might experience problems.

4.3.2 Global Climate

The planet's ability to retain solar heat is dependent on concentrations of "greenhouse gases" (GHGs) that are in the atmosphere. GHGs are gases in the atmosphere that trap heat, like greenhouse glass, and help keep the planet warm enough for life to survive. The three main human- influenced GHGs are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Power plants fueled by fossil fuels like coal or natural gas produce large amounts of CO_2. Since the beginning of the industrial revolution when large-scale consumption of fossil fuels began, atmospheric concentrations of CO_2 have increased over 30 percent. About half of that increase has occurred since 1970, and the rate of increase has grown since 2000. Scientists believe that increases in GHG concentrations have contributed to additional warming of the planet, and continued increases in concentrations are expected to cause further warming and a variety of global climate changes in the near future.

Increasing amounts of CO_2 and other greenhouse gases in the atmosphere appear to be having substantial impacts on the environment and human health in a variety of places on the planet already. These impacts could include rising sea levels, melting of glaciers and polar ice caps, altered ocean currents, climate alteration and wider ranges for insect-borne diseases of humans and crops. In Wisconsin, some impacts include, or could include, warmer and drier summer weather, increased frequencies of severe storms, lower water levels in the Great Lakes and inland lakes and streams, increased average water temperatures, changes in local ecosystems and species populations, changes in the farm landscape because of effects on crop productivity, increased forest fires, reduced snow and ice cover in winter, and increased heat stress and mortality among people in summer.

At this time, GHGs have been determined to be air pollutants by the U.S. Supreme Court. As such, they are subject to DNR air permit. The U.S. Environmental Protection Agency (EPA) is currently developing separate sets of rules for regulating greenhouse gases in existing power plants and in future, new power plants.[3]

There has been a growing world-wide consensus agreeing with the Intergovernmental Panel on Climate Change (IPCC) that GHG emissions must be reduced. How to do it is still a matter of debate. One method might involve capturing CO_2 at the exhaust stack and depositing it in underground geologic formations. Current research is investigating where such geologic formations might be and how to offset the high cost of this method. It appears that there are no such formations practicable in Wisconsin. Another method being considered is the planting of forests to take up CO_2 and bind the carbon, offsetting increases in CO_2 emissions. However, it is not likely that enough trees could be planted to significantly reduce GHG levels in the atmosphere, certainly not in time to avoid climate change. A third way to reduce GHG emissions would be to reduce fossil fuel-fired power plant generation with increased industrial, commercial and residential energy efficiency (or conservation) and by generation of electricity using renewable resources such as wind power, solar power, or possibly short-term closed-loop biomass power plant systems. With conservation and renewable resources for energy, methods are also being researched looking for ways to extract CO_2 from the atmosphere. The practicality, feasibility and prudence of all of these methods are being investigated.

4.3.3 Water Quantity

Many power plants use water from lakes, rivers, municipal water utilities, or groundwater aquifers. Surface water is often used for plant cooling, and groundwater is often used for plant processes.

Cooling towers are often utilized to condense the steam produced in power plant operation, moving the heat by contact in the towers with either air or a separate water supply. The large water-cooling towers evaporate large quantities of water into the atmosphere. The evaporated water is lost to local stream flow or the local groundwater aquifer. Decreased stream base flow can adversely affect stream morphology, habitat, aquatic plant and animal communities and species, and promote growth of algae and nuisance or invasive aquatic plants. Lakes can be similarly affected. The DNR is authorized to regulate consumptive water use in power plants.

If the water used to make steam for steam turbines or to cool the steam for reuse in the system, water is often drawn from groundwater aquifers. The pumping of large quantities of groundwater creates a "cone of depression" around the well, lowering water levels in the aquifer for some distance from the well. This could affect the productivity of municipal and other nearby wells, and could affect the viability of groundwater-dependent resources in the area, such as lakes, wetlands, springs, and streams.

Power plants replace water permeable soils and sub-soils with impermeable surfaces such as rooftops, concrete pads, and parking lots. The increased impermeable surface area reduces the area where water can infiltrate into the ground to recharge the aquifers and groundwater supplies. Where it is captured, its energy must be dissipated so that it can soak into the aquifer below. If it is instead rerouted to surface waters, the water lost could also have adverse effects on local aquifers that support wetlands, springs, and stream base-flow, and it could have adverse effects on the power plant's groundwater supply.

The DNR monitors water consumption of large power plants and can put permit conditions on a plant's use of surface water so that the surface water and biological diversity are protected in periods of hot weather and naturally low water levels. It also has a permit process for high-capacity wells, to regulate the withdrawal and consumption of water from the aquifers that supply local municipal wells. Non-municipal well productivity is not protected by this permit process.

4.3.4 Water Quality

Power plants must discharge or dispose of process water someplace. Discharge locations range from streams or lakes to local municipal sewer systems that eventually discharge into streams or lakes. To handle the discharge, surface waters or sewer treatment systems must be able to absorb water that has been altered by the addition of heat, acids, or salts. Larger water bodies or streams might be able to accept more of this altered water because of their size and volume or because they have water containing solutes that can buffer the added chemicals, or they might not. Their ability to do this would have to be modeled and calculated.

Pollution and pollutants discharged to surface water from power plants can result in adverse water quality effects. Some power plants use "once-through cooling." In once-through cooling, cooling water is drawn from the lake or river and used to condense the steam for recycling through the plant. The water used for cooling picks up heat from the steam and is then returned to the lake or river at a warmer temperature. Impacts of this technology could include the warming of the lake or river near the discharge point, potentially affecting temperature-sensitive plants, fish, microbial activities, or chemical and physical reactions in the water. Even with cooling towers instead of once- through cooling, discharged process water that is warmer than ambient water temperatures can alter the local fishery composition, aquatic macro invertebrate (bugs) communities, and aquatic plant communities. Surface water pollutants can be taken up by aquatic species resulting in diseases and fish contamination.

Power plant discharge water must be cleaned, filtered, and processed before being discharged. It must be relatively neutral and carry as little heat or newly-dissolved materials as possible. Some minute amount of pollutants, such as mercury, may remain in the power plant discharge water even after treatment. The DNR regulates discharges into state waters through Wisconsin Pollution Discharge Elimination System (WPDES) permits. Through these permits, dissolved or suspended materials and heat from power plants are limited and monitored. For a description of the WPDES program, go to the DNR web site: http://dnr.wi.gov/topic/wastewater.

Construction of an electric power plant will expose large areas of bare ground. Left unmanaged, soil and any attached nutrients or pollutants can be washed from construction sites into nearby lakes, streams and wetlands during storm events or spring thaws. Use of erosion control best management practices can limit the amount of sediment and pollutants that would otherwise be washed offsite.
A construction site erosion control plan would minimize soil erosion, sedimentation, and transport of pollutants from the construction site during and after storm events.

A power plant site presents challenges from uncontrolled stormwater runoff after it is constructed. Water running off rooftops, parking lots, coal piles and other sources can carry a variety of pollutants to surface water. DNR stormwater requirements include development and implementation of a stormwater management plan whose purpose is to minimize pollutants and excess storm water from leaving the site. The power plant design must minimize soil erosion, sedimentation, and transport of pollutants during storms.
The DNR regulates construction site and post construction storm water runoff quantities and quality through its permitting processes

(http://dnr.wi.gov/topic/stormwater).

Air pollutants emitted from power plants can also adversely affect surface waters. Air deposition of nitrogen compounds can lead to or accelerate Lake Eutrophication. This can result in large algae blooms that can deplete oxygen levels in waters killing aquatic organisms. Acid deposition caused power plant emitted airborne pollutants is also a problem in water bodies that are naturally more acidic. Many lakes in northern Wisconsin are in this category. Acid deposition can cause a decline in aquatic plants and microorganisms, affecting fish species populations and diversity. Mercury also can be deposited from the atmosphere. Excess mercury deposited in certain types of lakes has become methyl mercury and led to fish consumption advisories.

4.3.5 Wetlands

Wetlands occur in many different forms and serve vital functions. These functions include storing runoff, regenerating groundwater, filtering sediments and pollutants, serving as spawning areas for some fish species, and providing habitat for wildlife. Power plants with a large construction footprint often require the filling or draining of some wetlands. Even if a wetland is not filled or drained, construction activities near wetlands can damage wetlands in several ways. For example:

- Heavy machinery can crush wetland vegetation, especially that growing on cassocks.
- Wetland soils, especially very peaty soils, can be easily compacted, increasing runoff, and reducing the wetland's water holding capacity.
- The construction of power plant access roads through wetlands can change the quantity or direction of water flow, causing permanent damage to wetland soils and vegetation.

These, and other impacts of power plants, can severely affect wetlands functional values. Some examples of impacts are loss of wetland plant species, decline in species diversity, loss of habitat needed by animal species to survive, a spread of invasive species, and alteration of the wetland hydrologic regime.

Generally, sites with no wetlands or no potential for adverse wetland effects are preferred for power plant construction. Sites with high quality wetlands or large wetlands are less desirable because of the potential adverse impact on a wetland and its functional values.

Potential adverse impacts to wetlands should be avoided. The DNR and the U.S. Army Corps of Engineers both regulate activities affecting wetlands through their permit processes (http://dnr.wi.gov/topic/Waterways/construction/wetlands.html).

4.3.6 Land and Soil

Different power plant types and designs have a wide range of land requirements. Coal-fired power plants need land not only for boilers and turbines but also for rail lines, coal storage piles, and ash landfills. Nuclear power plants may need specific areas for specialized dry cask storage of spent fuel rods. Natural gas-fired plants generally need less space than coal or nuclear plants, but need a large natural gas supply line and sometimes a large tank of oil for backup fuel. If a plant produces steam and the steam is sold to other industries nearby (cogeneration), a large steam line would have to be installed and extended out of the power plant boundary to the steam user. If a proposed power plant is expected to be expanded in the future, the land area must be large enough to accommodate the additional facilities.

Power plants proposed on sites where they are locally perceived to be “out of place” might seek to purchase additional land as a buffer. The surrounding buffer land would prevent new neighbors from locating too near the plant. This buffer could minimize visual and noise effects by increasing distances to nearby homes. Wisconsin’s nuclear power plants have large acreages to buffer between the plants and the surrounding communities. Buffer land might also be needed to increase power plant distance from biologically important natural communities. Additional buffer land would increase the land area needed for the power plant project. Since buffer land would be maintained as a “natural” buffer, the impact on that particular acreage of land could be quite positive, as a conserving impact.

If the plant is built on land that is not level, extensive earth-moving and digging activities may be necessary. Soil erosion and sedimentation into nearby waters or wetlands is a risk. Soil would need to be redistributed or transported to another location and properly managed. For commercial facilities, the DNR regulates erosion at construction sites by requiring an approved soil erosion control plan if construction activities will exceed one acre (see the water quality discussion above).

4.3.7 Vegetation

Vegetation impacts can be of two basic kinds:

- Direct impacts of vegetation removal or damage during construction.
- Indirect impacts on vegetation from air pollution or surface water impacts caused by the power plant.

The vegetation communities at any site depend largely on: (1) soil quality and fertility, (2) relative elevations and slopes, (3) moisture availability, (4) solar radiation, and (5) the degree and type of disturbance in the area. A new power plant could affect the vegetation communities by eliminating them or by altering one or more of these five factors, which could weaken the communities (for example, by shading them or by redirecting runoff away so that a vegetative community receives less water.)

Removing or weakening the vegetation on a power plant site could have an effect on the vegetation communities in the surrounding landscape. If the affected vegetation is rare, unique or locally important, the loss of its contribution to the seed or gene pool might have an effect on the surrounding vegetation communities. There could be adverse effects on the insects, wildlife or other organisms that depend on the vegetation as a source of food for insects, wildlife, or other organisms. Non-native plant species introduced or promoted by construction disturbance could spread and encroach into other nearby natural plant communities.

Power plants emit air pollutants and water vapor as fog into the atmosphere that could affect the growth and survival of certain vegetation communities. Some pollutants are toxins or promote diseases that damage or kill plants. Conversely, the pollutants could provide nutrients to the plants, like fertilizer from the air. Fog from cooling towers could change the moisture regime so that some plants have a competitive advantage over others from differences in the ability to utilize the moisture or to resist fungal disease.

Vegetation in surface waters could also be affected, or lost, by construction of water intake or discharge facilities, by the removal of water (intake) for power plant processes, or by the nature of waste water discharged by the power plant into the water body.

3.4.8 Wildlife

Impacts to vegetation could create a chain of wildlife impacts. Impacts on local or migrating wildlife could occur when their habitat and source of food is removed or damaged. The food source could be the vegetation itself or bugs, animals, birds, or organisms that rely on the vegetation for food.

Nesting and den areas would be destroyed.

Construction of a new power plant could displace certain species of wildlife and attract other species. Loss of habitat for prairie or woodland species could occur, and habitat for "edge species" and "generalists" could be created. Edge species and generalists can thrive or survive on the habitat created by the construction disturbance or the new buildings and landscaping. Species that relied specifically on the original natural habitat might not survive or might need to leave the area.

Migratory species that depended on the original local habitat for resting, feeding, or reproduction would have to find new places for these activities. Birds could also be killed outright by striking tall power plant structures or new power lines.

Fish, mussels, and other aquatic life in surface water bodies and streams could also be affected by power plant construction or operation, particularly the construction and operation of water intake or discharge facilities, or the dredging of barge unloading areas. Fish and other aquatic organisms could get drawn into water intake systems. Coal pile and coal dust runoff could cause problems if acids and dissolved toxic metals are deposited in surface water. Loss of feeding, resting, or reproductive habitat could harm a river or lake species' ability to survive.

4.3.9 Protected Species

A number of species of plants, birds, mammals, reptiles, insects, crustaceans, and fish are listed with the U.S. Fish and Wildlife Service or the DNR as "endangered" or "threatened" species. These species have small populations that are particularly vulnerable to habitat disturbance or destruction. Species and natural communities listed as endangered and threatened are actively tracked by the DNR

Wisconsin also lists "special concern" species. These are species about which some problem of abundance or distribution is suspected but not yet proved. The main purpose of this list is to focus attention on certain species before they become threatened or endangered. Most are actively tracked.

If a local population of a listed species would be reduced or lost, that would constitute a "taking" under the law, and the power plant developer would need to abide by the agency's regulatory requirements to avoid or reduce the adverse effects on that species. The power plant developer must consult with DNR Endangered Resources staff as part of its regulatory application development processes, and it must follow DNR direction to:

- Determine if any protected species or species of special concern are present.
- Protect those species during the construction and operation of the power plant.

4.3.10 Historical and Archaeological Sites

Historic buildings, burial grounds, archeological sites, cultural areas, and Native American sacred areas are all considered "historic properties" by the Wisconsin Historical Society (WHS) and are treated as sensitive and vulnerable resources.

Under the national and state Historic Preservation Acts, the federal and state governments try to protect historic and archeological sites, and also identify cultural areas and Native American sacred places as protected resources. These resources are important and increasingly rare tools for learning about the past. Some also have religious significance. Power plant construction can damage these resources wherever soils are disturbed or where heavy equipment is used, by:

- Digging them out.
- Breaking or crushing them.
- Mixing them in the sub-soil so that the ability to date them is lost.

- Exposing them to erosion or the elements by uprooting trees and clearing the land.
- Making the sites more accessible to vandals.

The WHS has the primary responsibility in Wisconsin for protecting archeological and historic resources. It manages a database that contains records of known "historic properties" in the state. This inventory must be searched for any historic, archeological, or cultural sites that might be affected by a construction project. If any are found, the PSC must consult with the WHS and follow (or have the developer follow) its recommendations to avoid, reduce, or mitigate impacts.

Depending on the situation, surveys by qualified archeologists might be required to clarify the location, geographical spread, and significance of the resources. If there is a federal interest in the project, the appropriate federal agency must consult with WHS under the National Historic Preservation Act. This federal law is more stringent and may require field archeological survey work to determine if there are any yet-unknown resources that could be affected.

Sometimes no historic or archeological resources are discovered in the database but an archeological site is encountered during the actual construction. If this happens, the project developer must stop construction at that site and notify the WHS and PSC. Then, the project must follow the WHS recommendations for managing or minimizing the potential impacts to the archeological site.

4.4 Conclusion

Power Plant affects environmental segments of the surrounding region very badly. Large amount of SOx, NOx & SPM are generated which damage the environment and are highly responsible for deterioration of health of human beings, animal kingdom as well as plants. Emission of SPM & RSPM disperse over 25 Kms radius land and cause respiratory and related ailments to human beings and animal kingdom. SPM gets deposited on the plants which affect photosynthesis. Due to penetration of pollutants inside the plants through leaves & branches, imbalance of minerals, micro and major nutrients in the plants take place which affect the plant growth severely.

CHAPTER 5
LABOUR PRECAUTIONS

5.1 Methodology of Safety in Control centers and Control room

Automation of processes has been increasingly advance in GTP, accelerating the pace of the technological innovations, the insist for better quality and accuracy, and the increasing complexity of processes, to require less field operators and more qualified operators at rooms and / or control centers, and therefore greater ergonomics and human factors demands.

The present study considers the workplace as a whole, including monitors and related equipment needed for the worker to make operational decisions that allow the operation of the process plants. Principles of ergonomics and safety were considered for design of control centers and for updating the current facilities. This study developed a guide that addresses the needs of today's control centers, a space with more functionality and comfort for the operators, due to their well being affect the decision making process. The operator's actions depend on the optimal workplace and, any mistake decision can have a direct impact on the integrity of people, environment and company assets. The study took into account the physical condition of the furniture and fixtures included but not limited to location, orientation, distribution, organization and space, anthropometric measures of workstations, lighting conditions, noise and temperature, safety, ventilation and conditions for the ergonomic design of the human-machine interface.

The approach followed for the development of the guide was based on the "User-centered design" concept. Therefore users and their needs have been taking in account in all the project phases, through participatory ergonomics activities like personal interviews, focus groups, and on site surveys. The present study is the result of a two phases process: diagnostic and a guideline development. The diagnostic phase included a questionnaire modified from the ergonomics rating strategy Déparis and Sobane developed by Jacques Malchaire, (2004) and a structured interview with the control room operators, included the human and technical needs that were addressed. The study used a checklist designed and adapted from: A Guide to the Ergonomics of

Manufacturing (Martin Helander, 2005). This list was filled out simultaneously with the interview, by another team member. While the interview, several aspects of the operators activities were documented and reported, including a photographic record of the entire workspace. Subsequently, the qualitative information from the interviews, the quantitative checklist and the photographic record information were confronted to analyze and diagnose any sub standard situations and activities undertaken in the current control centers.

The next step was the statistical analysis of the data using standard tools and a Fuzzy Inference System for automatic estimation of discomfort based on different entry criteria and rules.

Based on the findings of diagnostic phase, the development phase was conducted. This includes the construction of an integrated guide to ergonomic criteria and requirements for design and implementation of control rooms and control centers, taking into account current regulations and national and international standards.

The following diagram of figure 5.1 shows a summary of the items covered in the guide:

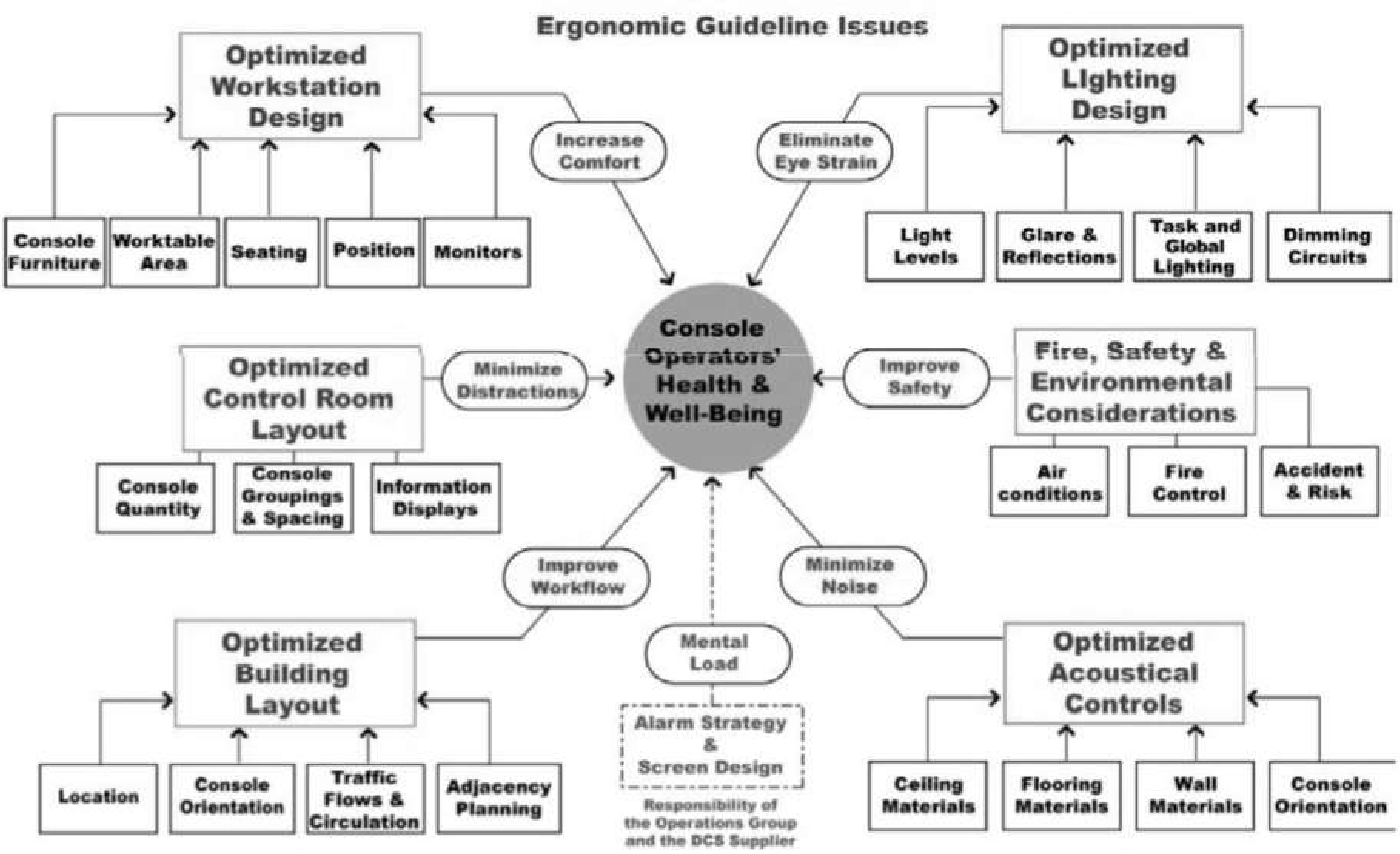

Figure 5.1 – summary of the items covered

5.2 Considerations of location for safety.

5.2.1 Location of the control Center

The control center location depends on the process that would be carried on. Accordingly, here are included some general parameters for the building location. The location of the control center should be the first consideration to take into account when designing a safe and planned control center. The study identified the desirability of planning the location of the center on the outskirts of the process plant to provide an escape route as safe as possible. A separation of 20 to 30 meters at least between hazardous areas and the center or control room is recommended, however it should be a blast study and control the building should not be hit by a wave with a pressure higher than 1.0 PSI, a graphic representation is shown in Figure 5.2.

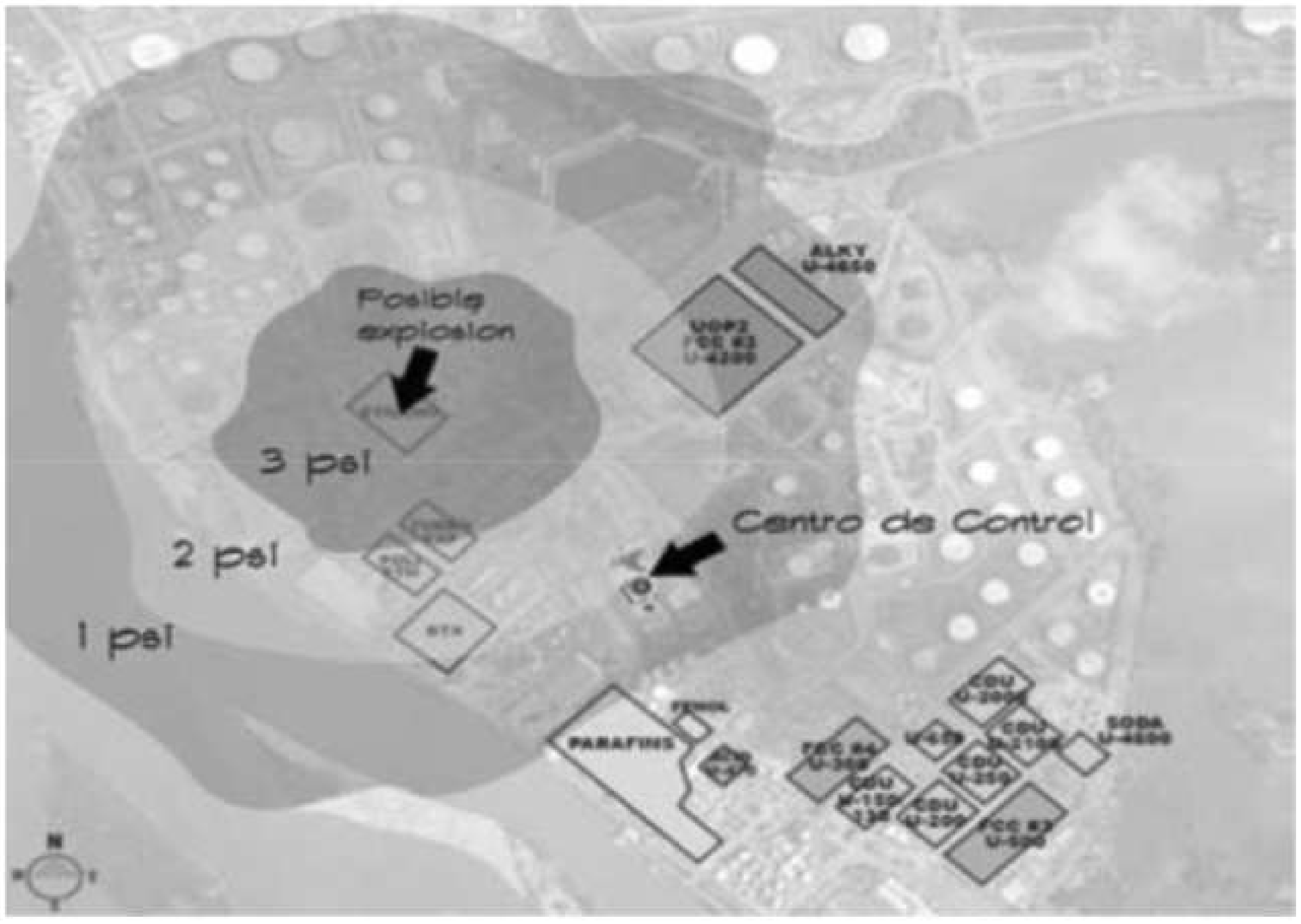

Figure 5.2 – Location of the control Center

Structures near the center of control that are at risk of falling, should be avoided when making the planning of the control room location, and the roof of the building where the operators are placed on should not be supportive of machinery or heavy equipment.

The construction of the control room should take into account the existence of chemicals and toxic atmospheres. It is advisable to avoid placing the centers or control rooms adjacent to buildings containing machinery generating noise and vibration. When it is inescapable to locate the control center in the area of influence of a possible explosion, it should be assessed and compensated for the increased risk involved in this decision with other security measures such as use of firewalls or additional safety equipment.

5.2.2 Fire Control

regardless of the low rate of occurrence of fire events in the control rooms, the risks continue to increase as computers require more power and generate more heat, the uninterruptible power systems and storage batteries, generate an additional risk. As shown in Figure 5.3.

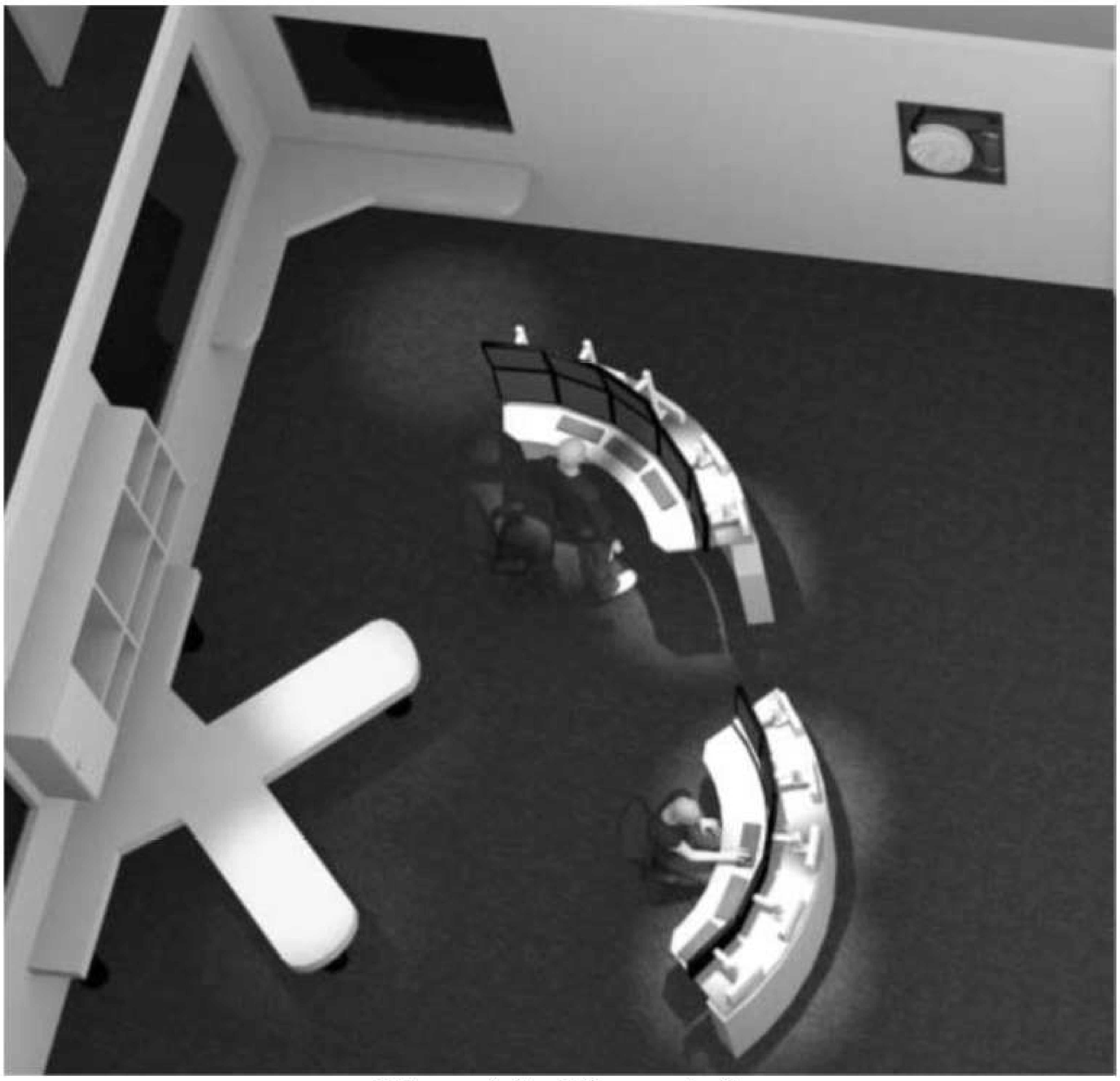

Figure 5.3 – Fire control

It is for this reason that there should be a fire control room in all buildings and should not be used as storage rooms. The fire control rooms should have sufficient space to accommodate the (s) pump (s) counter-fire hoses, fire control panel, etc. and must have enough space to carry out maintenance and testing. In addition to the fire control systems referred to the control center, it must be defined how long to hold the walls of the room, which houses critical electronic equipment, as well as the time required to operate in emergency conditions and ensure routes evacuation.

The use of access controls should be performed unrestricted areas where it is necessary to register people entering and verifying whether they are authorized to enter premises.

Control access should include:

- Main entrance (after the lock): Access to supervisors center operators and control engineers.
- Entrance to the control room: Access to the control room operators and supervisors.
- Engineering or technical Room: Access to control engineers and technicians.

Personal identification cards are one of the methods used for access control, thanks to technologies that can be integrated as bar codes, magnetic stripe, proximity cards and smart cards. During the study identified the desirability of using biometric systems as systems of control and accuracy for the registration of staff as it eliminates the possibility that a person made through other registration records giving your card or key.

5.3 Conditions of orientation and spatial distribution

5.3.1 Console Orientation

All operators must develop a mental map of the site, units, locations and process flow. The "cognitive map" of the operators is an important criterion in the orientation of the consoles in the control room, and the plant.

The consoles should be oriented so that the operator is facing the process to facilitate decision making and avoid errors of location. Operators should be avoided with the process control their backs. The consoles don't need to physically see the process, only to have their consoles aimed.

The operator's consoles must be oriented in the flow of the process. From left to right which is the first process, then the process or part of the process that follows the operation, and so on.

5.3.2 Circulation and traffic flow

Inside of the control room, the flow of personnel should be in front of the operator's console, not behind them to avoid distractions and discomfort. In the analysis of circulation, movement and flow of personnel, it should be taken into account the entrances, the exits of the control room and the location of consoles so that seek to "see" directly to the doors. Also it should be taken into account the considerations previously mentioned of access control to prevent flow of personnel that do not have to do with the operation. Figure 5.4

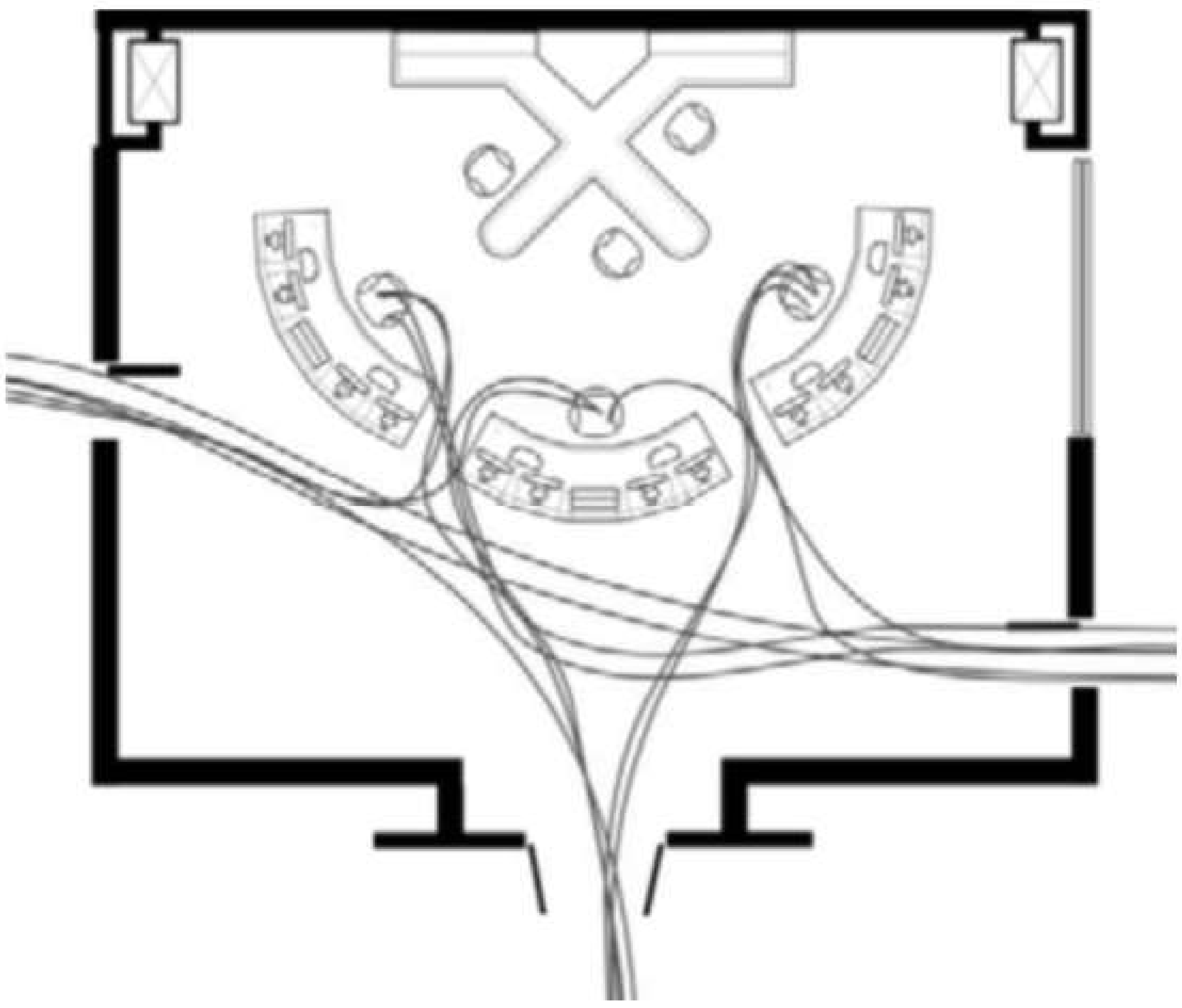

Figure 5.4 – Circulation and traffic flow

5.3.3 Proximity planning

By locating corridors around the control room eliminates the need for anyone other than traffic operation inside the control room, so this is recommended. Locate the restrooms services, the supervisor's room, the documentation room and the coffee room immediately next to the control room without direct access from these rooms from inside the control room reducing long stretches of travel for the operators.

The coffee room should be adjoining the control room and can be communicated through a polarized acoustic window according to the recommendations in this document, allowing observing the process, but not in the opposite direction.

The technical room, for electronic and mechanical equipment must be at one end of the building, as far as possible away from the control room. It is desirable to have at least two entrances / exits. (Main entrance and, at least 1 emergency exit). The main entrance should have lock structure.

Include storage room and / or room to the concierge in order not to have items stored in the control room. For control centers medium and large it can be placed a training station with a console-like features that can be operated by trainees. Consideration should be given office space and a conference room and separate meetings of the control room.

The area of permits and administrative activities related to the operation should not be within the control room, but must be communicated through a window in the hallway, or control room supervisor's office for processing through permits it. We recommend installing a waiting room at the permits window.

5.3.4 Lighting Conditions

Taking into account the different activities carried out by staff within the control room, work continuously for 24 hours and various visual abilities of the operators, the lighting design must consider the following aspects:

_ Provide adequate lighting for reading documents and operating keyboards or keypads, should improve the readability of information on active and passive displays, self-illuminated equipment such as CCTV, VDT, generators and light alarm process status.

_ The single fluorescent lighting is not adequate for the visual comfort of the operators.

_ Reflections should be avoided, whatever its source, for example lighting, reflections by the difference in luminance over the visual field. The qualification of lighting installations can be determined using the limits specified in ISO / IEC 8995.

_ Objects must be removed behind the consoles that can generate unwanted reflections as tables or shelves with glass.

_ Avoiding the use of light bulbs or fluorescent lamps that create reflections in the peripheral visual field.

_ The fixtures should be located so that eliminates reflections of light bulbs or fluorescent lamps that create reflections in the peripheral visual field. Avoid light falling directly on screen. The layout, angles and location of these shadows can prevent darkness cover part of the screen generation discomfort.

_ Rooms throughout the building must be equipped with permanent emergency lighting.

_ The organization of the lighting should be appropriate for the visual demands of the tasks carried out in the work environment and must consider the demands of a normal and emergency work as well as considerations of the effects of natural and artificial light.

_ You must use 500 to 700 lx in the computer and work area, with the possibility of regulating the amount of lighting in each workplace. These levels should be reviewed to operators of 12- hour shifts sitting in front of the screens.

_ When you specify lighting levels, those levels should be maintained during the life of the luminaries.

_ Lighting systems must consider future changes in equipment, physical distribution, and teamwork. The options to rearrange the lights should be considered in light of this document.

_ Adjust light levels to optimize the rate of brightness between the different visual fields to be addressed by the operator, including screens, adjacent areas to the edge of the screen, the keyboard, and work surfaces.

_ Rates of brightness between the screens and the adjacent environment (surfaces and notebook, etc.) must not be greater than 1:3, a contrast ratio of 1:10 is acceptable between the screen and the areas illuminated remote, so, if it measures 70 lx in or around the screen, the border areas and the keyboard should not exceed 210 lx and other areas in the visual field operator should not exceed 700 lx.

_ Once you have established adequate lighting levels for the consoles, then consideration should be given supplementary lighting in different areas of the control room. Whenever the selected luminary's type does not cause any glare or reflections may be from any manufacturer.

_ It was found that the combined illumination from fluorescent lamps (with parabolic lighting) and additional lights down, they are an effective solution for adding light in or around the control room. In addition, these fixtures should provide enough light for cleaning and maintenance activities, also with regulators so that the lighting level can be reduced in the normal operation of the room.

Reflection ranges of the interior surfaces must be (ISO-8995 "Lighting of indoor workplaces")

• Ceiling: 0.6 to 0.9

• Walls: 0.3 to 0.8

• Floor: 0.1 to 0.5

_ The physical layout of the console determines lighting requirements, therefore, the orientation of the consoles should be considered in determining lighting needs and location of lamps on the top of the equipment.

_ The adjustable task lighting should be given the conditions and different characteristics of each operator, also noting that stations have self illuminated devices.

_ The operator task lighting should not interfere with the illumination of other different workstation. Figure 5.5

Figure 5.5 – lighting

_ Should consider the different visual demands associated with the perception of the data presented on a screen. As is the case of reading of texts and graphics analysis, screen-based information is not, for example, reading texts in drawings, watching screens on the walls that may be present in the same workplace.

_ The required number of fixtures of lamps from 100 to 150 Watt should be designed to provide

25 to 200 lx (adjustable) to produce an appropriate coating beam in the general area of the control room; this condition does not apply to specific lighting in the office work.

_ The required number of light fixtures from 100 to 150 Watt should be designed to provide 25 to

200 lx (adjustable) to produce an appropriate coating beam in the general area of the room, this condition does not apply to specific lighting in the workplace.

_ The distribution of the luminaries of 4 to 6 uniform lighting over the console can be combined with the 2x2 fluorescent lights to achieve optimal levels of illumination.

_ It should be considered the radius of curvature of the consoles to effectively place the lights and shadows to avoid uncomfortable or inadequate brightness.

_ It should be considered lighting levels taking into account the need for legibility of the documents in the rear console, the night monitoring of the process and maintenance activities including cleaning.

_ Where possible, lighting systems should use different light sources, both natural and artificial. The location of any window, lattice or lighting fixtures should minimize the potential for generating and discomfort glare from direct light and must take into account the conditions of ventilation and location of the control center before using any natural light sources.

_ The general lighting of the room must operate with optimum quality 7x24 hours.

_ In the event of emergency power failure, lighting must exist to allow staff to continue the operation or if appropriate, develop emergency procedures.

_ The minimum duration of the emergency lighting should be one hour.

_ In rooms where critical activities are developed, emergency lighting should be 100 lx at a height of 0.76 m above the floor.

5.3.5 Acoustic Conditions

The key to the success of a control room is solving the problems of acoustics, which are produced by the presence of people and equipment. One of the concerns of the operators is the noise, defined as unwanted sound. There are several ways to control noise in the air (sound generated from the speech, radio noise, alarms, etc.) In a control room, the strategies being considered to absorb noise, lower energy transmitted in the medium are:

_ Sound deadening on the floor mat using refinery finishes appropriate for the harsh environment.

_ Absorb sound with paneled walls and finishes

_ People working inside the room should be kept separate from the noisy equipment such as air conditioning; some of these teams should be isolated in a special room with noise-absorbing materials. See figure 5.6 for a recommended set up.

_ The average noise level inside the control room should be up to 55 db. The acceptable range for that level is 45 to 50 db.

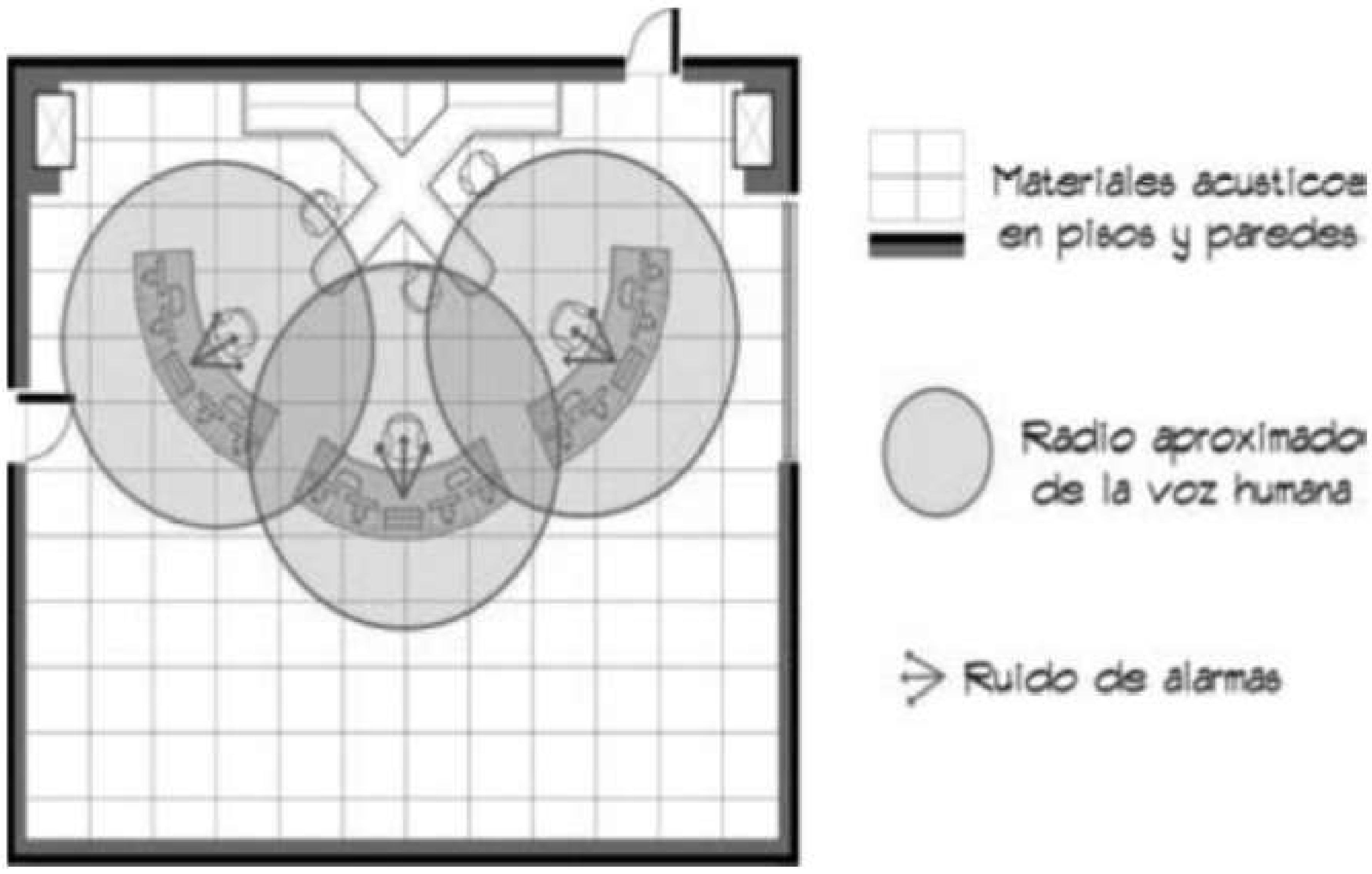

Figure 5.6 – Isolation system

_ Absorb sound in the ceiling, using noise reduction systems, placing the console to direct the sound to the vicinity using acoustic finishes and other sound reduction materials.

_ Since the noise wave has a direction, It should be discussed the generation of noise both equipment and people to properly locate the workstations in order to decrease the noise discomfort. This uses radio charts with the voice and direction of the sound of alarms, Figure 5.6.

_ Absorb sound in the ceiling, using noise reduction systems, placing the console to direct the sound to the vicinity using acoustic finishes and other sound shocking materials.

_ Since the noise wave has a direction, you should discuss this generation of noise both equipment and people to properly locate the workstations in order to decrease the discomfort generated. This uses radio charts with the voice and direction of the sound of alarms, Figure 5.6.

_ The provision of equipment set out, allows the noise generated in the operation, travel through the air directly into the walls made of materials capable of absorbing it. The ceiling and the floor will not allow sound waves propagate in such a way that disturbs other operators.

5.3.6 Conditions for the design of control room

_ There are several basic configurations of control rooms here as examples of common minimum standards needed to ensure adequate and appropriate space for workstations.

_ The grouping of the bays should be arched to have controls and displays at the same distance.

_ The outer radius of the arc location of the consoles is defined according to the same settings. When you have 2 consoles arc radius must be at least 440 cm, for 3 consoles minimum radius of 480 cm and 4 radio consoles at least 600 cm. In the case of 6 operators, referred to two alignments that combine previously described configurations, where you can check the corresponding arc radius for the location of the consoles.

_ The minimum distance between consoles is 100 cm.

_ The minimum distance between consoles and the back wall is 160 cm.

_ The minimum distance between consoles and the side walls is 180 cm.

_ Cabinet is recommended console 4 or 5 bays 1 operator, Figure 5.7.

_ The furniture should be designed for functional work environment. The design must ensure sufficient rest so that the operator feels comfortable in your workstation.

_The work surface should be adjustable in height and adjustable to users' anthropometric dimensions of the spaces, but above all adjustable to allow normal operation both standing and sitting. Adapted to the workers in Colombia

_ The minimum distance between consoles is 100 cm.

_ The minimum distance between consoles and the back wall is 160 cm.

_ The minimum distance between consoles and the side walls is 180 cm.

_ A cabinet is recommended for a console of 4 or 5 bays and 1 operator, Figure 5.7.

_ The furniture should be designed for functional work environment. The design must ensure sufficient rest so that the operator feels comfortable in your workstation

_ The work surface should be adjustable in height and adjustable to users' anthropometric dimensions of the spaces, but above all adjustable to allow normal operation both standing and sitting

_ Sliding doors are recommended in the lower pane of the console, which ensure easy, comfortable, open cable trays that allow screens to run without interruption.

_ The furniture should allow the assembly of flat
screens to hide including accessories and cables.

_ It is recommended to use flexible modular structures, or standard modules, that allow be adding or relocating as necessary.

_ The furniture should be kept clean, preferably laminated fabric for easy cleanup.

_ The cabinet of the console should offer the possibility of holding at least 6 screens, with expansion capability up to 10 screens including CCTV monitor each location of the console.

_ The function of a seat well designed for users with visual display of data is to provide a stable and comfortable, allowing movement and tasks.

It is recommended for workstations that require standing and sitting and using combinations adjustable to suit the end user. The concept of adaptation is related to key design parameters such as:

• Adjustment the seat lumbar area.
• Adjustable arm rests.
• Support for lower back.

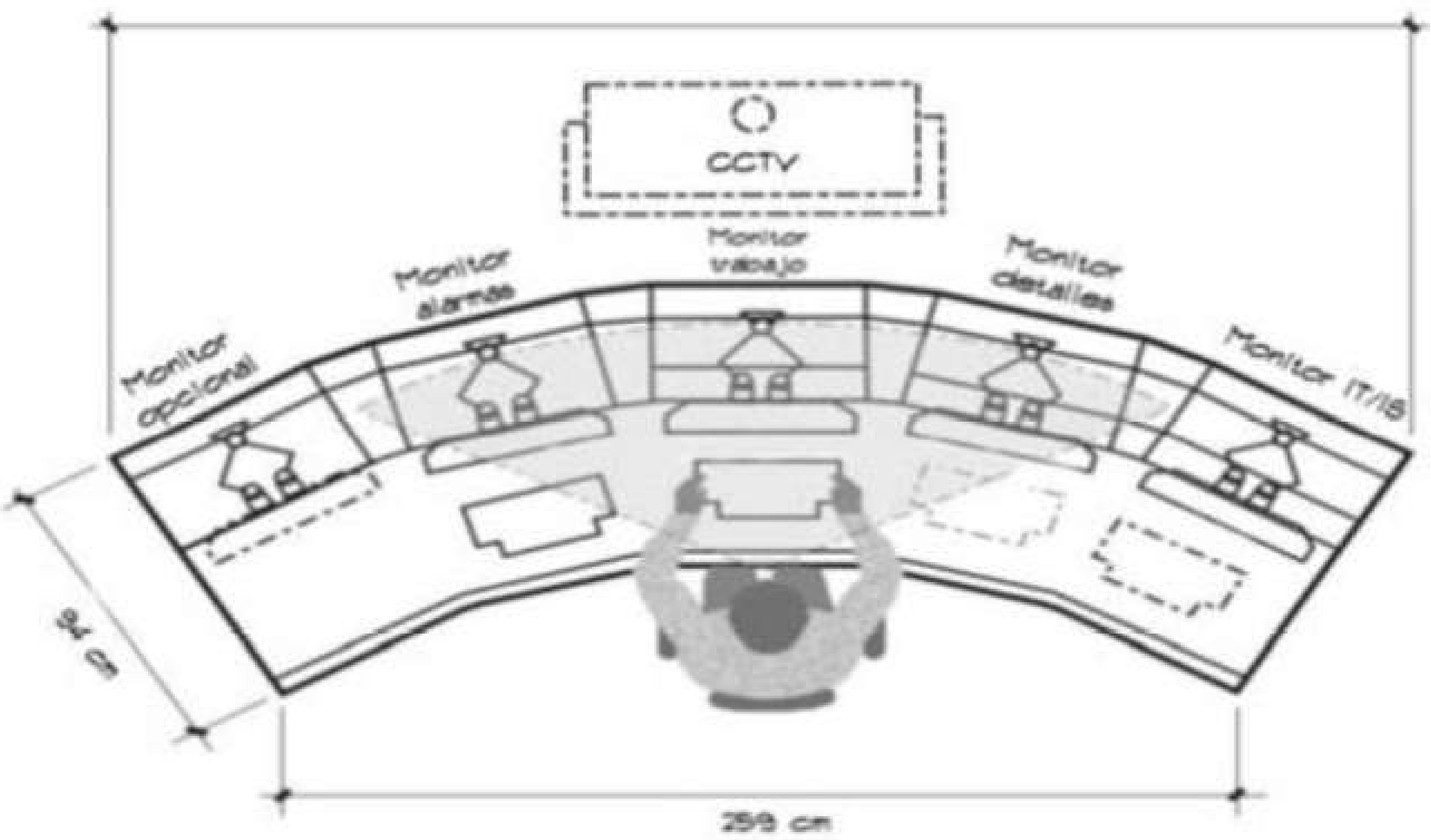

Figure 5.7 – Cabinet for consol

_ The chair should prevent the spine compression, the highest seat of adapting the user will take the following parameters, for the workers in Colombia:

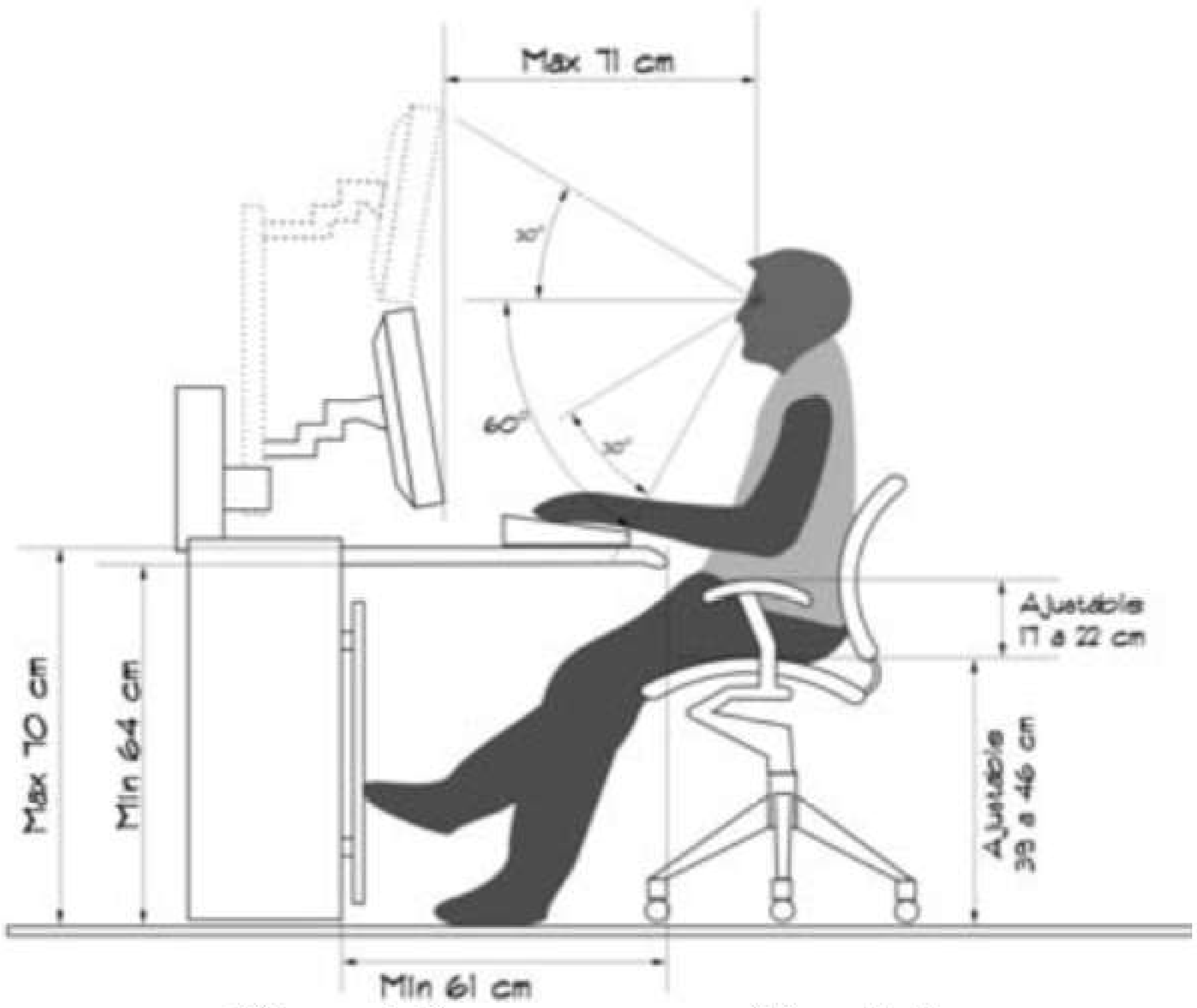

Figure 5.8 – parameters of the chair

_ The considerations presented above for the safe and ergonomic design of control centers, are visibly appreciated renders the following prototype, as shown in figure 5.9:

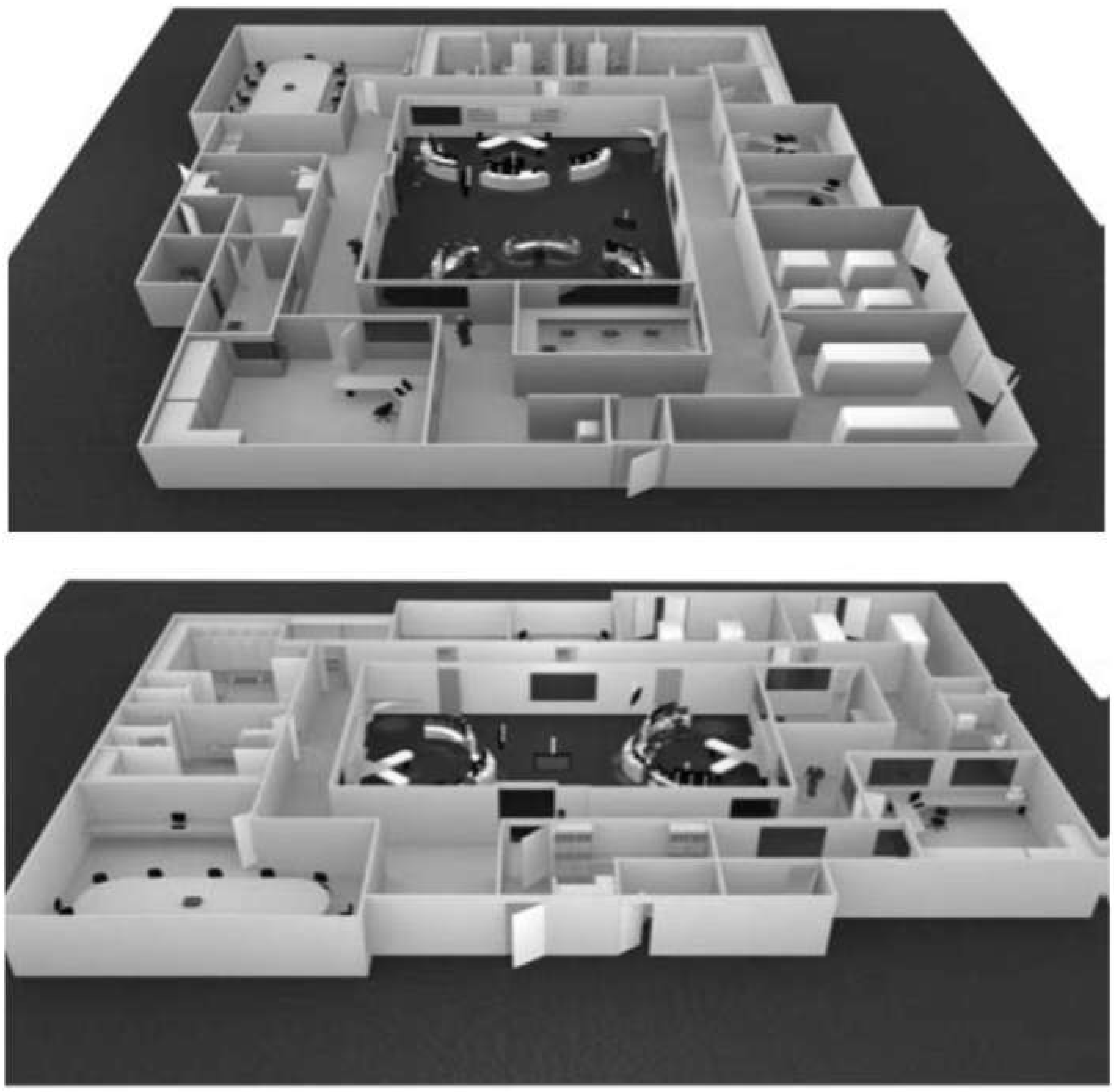

Figure 5.9 – prototype of control centers

5.4 Conclusions

This part reflects as main result the "Ergonomic Aspects for the Design of Control Centers" which presents graphically and concrete recommendations and conditions in terms of:

_ Location and safety

_ Air and ventilation

_ Guidance, distribution and spaces

_ Lighting

_ Acoustics

_ Design of control room

_ Furniture Workstation

_ Ergonomic man-machine interface

Criteria were proposed ergonomic and safety requirements related to ergonomic architectural design elements, work stations, physical environment and distribution of elements of active and passive safety, applicable to control room built in the future.

Were defined minimum, desirable and ideal in terms of position or changes in posture and movement in the control room, that have been studied and that these serve to be replicated to other projects of new control rooms.

This part proposed a new contribution in literature with an ergonomic guide specializing in the design needed to make suitable implementations in areas and work stations (including furniture) in control rooms to be built in the future, in operations of transport, production, refinery and industrial processes, seeking to obtain ergonomic standards and safety requirements for the design, distribution and adequacy of control rooms that tend to work efficiently, comfortably and with the improved security.

GENERAL CONCLUSIONS

The task for the master's thesis has been solved by introducing an improved and integrated ACS between GTP and CS.

1– Having control system monitoring and continuous improvement tools in place will allow our systems to be properly integrated. It can also ensure there is communication across all subsystems to ensure complete reliability.

Modern GTP and CS require more efficient consumption of energy, and increases efficiency of power plant. For this purpose in diploma work 2 ways were used: integration of gas turbine plant ACS and CS automatic control and improvement of control device and actuator of ACS of GTP.

2 – In gas-dynamic and thermodynamic calculations we determined the parameters of the gas at various stages of compression, as well as their main design parameters (number of stages, geometrical dimensions).

During the calculation of thermodynamic cycles, gas turbines, we found the parameters of a working body in characteristic cross-sections, as well as key energy and economic characteristics. In gas-dynamic calculation GTU we have also found geometrical dimensions and output data of projected GTP namely: $N_{sp}= 10513$ kW/(kg*s); $C_{sp}= 0.238$ kg/(kW*h); the values of these output parameters correspond modern level of GTP development.

We illustrated a description of the prototype engine used in the following GTP.

3 – The use of electric actuator assure a great improvement in the operation of the engine as more suitable and smooth fuel variation and affects positively on the efficiency and power of the GTP and makes the operation more accurate.

The integration between GTP ACS and CS ACS in modern engineering aspect is indeed an important jump which has benefits illustrated by reducing the human factor error due the connect control room or dispatch station.

4 – The results of this thesis can be used for improving the performance of modern electronic control systems related to GTP and CS control.

5 – Power Plant affects environmental segments of the surrounding region very badly. Large amount of SOx, NOx & SPM are generated which damage the environment and are highly responsible for deterioration of health of human beings, animal kingdom as well as plants. Emission of SPM & RSPM separate over 25 Kms radius land and cause respiratory and related ailments to human beings and animal kingdom. SPM gets deposited on the plants which affect photosynthesis. Due to dispersion of pollutants inside the plants through leaves & branches, imbalance of minerals, micro and major nutrients in the plants take place which affect the plant growth severely. Spreading & deposition of SPM on soil disturb the soil strata thereby the fertile and forest land becomes less productive. Because of continuous & long lasting emission of SOx & NOx, which are the principal pollutants emitted from a coal based power plant, structures & buildings get exaggerated due to corrosive reactions.

6 – Main result the "Ergonomic Aspects for the Design of Control Centers" which presents graphically and concrete recommendations and conditions in terms of:

– Location and safety
– Air and ventilation
– Guidance, distribution and spaces
– Lighting
– Acoustics
– Design of control room
– Furniture Workstation
– Ergonomic man-machine interface

Criteria were proposed ergonomic and safety requirements related to ergonomic architectural design elements, work stations, physical environment and distribution of elements of active and passive safety, applicable to any control room is built in the future.

REFERENCES

1. Л.Д. Гай, В.О. Конєв, М.С. Кулик, та ін. Термодинамічний та газодинамічний розрахунки компресорів та газотурбінних установок.- НАУ, 2002.-60с.
2. Конструкция и прочностьавиационныхдвигателей: Методическиеуказания по выполнению РГР «Расчет на прочностьрабочей лопатки турбины ГТД» и домашнегозадания «Расчет напрочность вала турбины».- К.:УТУГА, 1994.- 36 с.
3. Конструкция и прочностьавиационныхдвигателей: Методическиеуказания по выполнениюдомашнегозадания «Расчетмасляной, топливной и пусковой систем ГТД». / Сост.: А.Н.Ветров, А.А.Иваненко, Н.А. Ковешников и др. - К.: КИИГА, 1988.-20 с.
4. Modern Control Engineering, Fifth Edition,/ Author: Katsuhiko Ogata, book 2010- 894 pages
5. Pipeline System Automation and Control,/ Author: Mike S. Yoon C. Bruce Warren Steve Adam, Book: 2007- 427 pages
6. https://www.ihi.co.jp/var/ezwebin_site/storage/original/application/d55cc802f03d027fe5d8a325213f3b2b.pdf
7. https://pdfs.semanticscholar.org/c059/cacb3133ce23546a2b9a9ca885030d4e5ad1.pdf
8. http://www.ijcttjournal.org/IJCTT-V23P127.pdf
9. http://www.freepatentsonline.com/ACTUATOR%20DEVICE%20FOR%20USE%20IN%20A%20GAS%20TURBINE%20FUEL%20CONTROL.pdf
10. https://www.ccn-cert.cni.es/publico/InfraestructurasCriticaspublico/Guide%20to%20Industrial%20Control%20.pdf
11. http://www.ece.mtu.edu/faculty/shiyan/EE4262Spring17/DigitalControlTextBook.pdf

12.https://www.uni-obuda.hu/journal/Andoga_Fozo_Madarasz_12.pdf

13.http://www.freepatentsonline.com/APPARATUS%20FOR%20ACTUATING%20AND%20GOVERNING%20PARTS%20OF%20GAS%20TURBINES%20AND%20OTHER%20MOTIVE%20POWER%20DEVICES.pdf

14.http://dl.icdst.org/pdfs/files/4fd6e5ae41a6b686d1f9bbb20de891f7.pdf

15.http://elesy.com/engineering/solutions/midstream-gas/compressor-station-automation-system.aspx

16. https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-82r2.pdf