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Department of Electronics

Final Year Project Report Presented in Partial Fulfilment of the Requirements for the Degree of

MASTER

In Electrical and Electronics Engineering

Option: **Power Engineering**

Title:

Electrical Installation Design and Study for the Wastewater Treatment Plant (WWTP) of BBA

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Abstract

The aim of this thesis is to provide a clear, practical and step by-step electrical installation design study of the wastewater treatment plant (WWTP) of Bordj Bou Arrerij (BBA), according to national and international Standards. The first chapter presents the methodology to be used, and refers to all chapters of the thesis according to the different steps of the study.

The project will constitute a high qualified training for real electrical engineering project in order to blend in a professional environment.

Dedication

This study is wholeheartedly dedicated to our beloved ***parents*** *and* ***my family members****, who have been my source of inspiration***,** *whose affection, love, encouragement and prays of day and night make me able to get such success and honor.*

To all my ***friends****,* ***relatives****,* ***mentor****,* ***teachers****,* ***classmates*** *from primary school to my last year of university.*

And to all with whom I spent wonderful moments.

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In the name of Allah, the Most Gracious and the Most Merciful Alhamdulillah, all praises to Allah for the strengths and His blessing in completing this project.

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Last but not least, we are infinitely grateful to our family members, particularly our parents for their patience, unwavering support, continuous encouragement, and belief in us throughout our whole life. We would have never made it this far without them beside us every step of the way.

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Institute of Electrical and Electronic Engineering

Oussama OUALI **Samir FRIAS**

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General introduction

Planning and design are the key activities which, together with management, allow any engineering project to be taken from the initial concept stage through to successful implementation.

Power engineers are concerned with the application of proven techniques and procedures to the solution of practical engineering problems. They exercise Technical Responsibility and are competent to exercise creative abilities and skills in areas technology. In order to acquire and assert these qualities, we opted in this thesis in electrical engineering to be indulged in the professional environment of the engineer which is the design and study office, by obtaining a design project of electrical installation for a wastewater treatment plant (WWTP) located in BORDJ BOU ARRERIDJ.

In this project, the design study has been carried out to provide the facility by an optimal and efficient electrical system. This study is based on methods and standards of design, calculation and selection of electrical equipment and protection systems according to common national and international standards (IEC, BS, NF, AS, NZS…). These calculations and selections are also performed with the convenient computer softwares.

This report is fundamentally organized in five chapters; the first chapter will present generalities about the project and project management and the role of engineer. The second chapter will be devoted to the methods of calculation and sizing of energy sources which is in our case MV/LV power transformer, whereas the third chapter deals with cables (sizing and selection) and protection devices, while the fourth chapter presents the landscape lighting design of the facility, and finally the fifth chapter consists the grounding system design.

CHAPTER I : PROJECT ORGANIZATION

I.1 Introduction:

In this Chapter we will represent our project, and give an overview of the work we have to do.
First we will define the engineer role, and then we will talk about the wastewater treatment plant (WWTP) BORDJ BOU ARRERIJ where the design study is going to be conducted for.

We will also talk in this chapter about the general philosophy of electrical design, which it will allow us to better understand the specifications, and therefore have more details on the design of installation, subject of this thesis.

I.2 Engineer job overview:

Electrical Design Engineers are professionals who have the ability to apply engineering principles, physics and materials science for the analysis, design, installation and maintenance of electrical systems.

Electrical Design Engineers create solutions, which can range from small component designs to large-scale systems. More commonly you would be working on security, alarm systems, lighting and HV, MV, and LV systems.

Electrical Design Engineers have the opportunity to work on all stages of a system, from the early research, development and design all the way through to the installation and final commissioning.

I.2.1 Engineer's skills:

According to British Standard for Professional Engineering Competence (UK-SPEC), Engineers are able to demonstrate:

- The theoretical knowledge to solve problems in developed technologies using well proven analytical techniques, this includes:
  Engage in formal learning. Learn new engineering theories and techniques in the workplace, at seminars, etc. Broaden your knowledge of engineering codes, standards and specifications. Manage/contribute to market research, and product and process research and development. Involvement with cross disciplinary working. Conduct statistically sound appraisal of data. Use evidence from best practice to improve effectiveness. Apply root cause analysis.

- Successful application of their knowledge to deliver engineering projects or services using established technologies and methods, this includes:
  Contribute to the marketing of and tendering for new engineering products, processes and systems. Contribute to the specification and procurement of new engineering products, processes and systems. Develop decommissioning processes. Set targets, and draft programs and action plans. Schedule activities. Contribute to theoretical and applied research. Manage/Contribute to value engineering and whole life costing. Work in design teams. Draft specifications. Find and evaluate

information from a variety of sources, including online. Develop and test options. Identify resources and costs of options. Produce detailed designs. Be aware of IP constraints and opportunities.

- Responsibility for project and financial planning and management together with some responsibility for leading and developing other professional staff, this includes:
  Manage/contribute to project planning activities. Produce and implement procurement plans. Contribute to project risk assessments. Collaborate with key stakeholders. Plan programs and delivery of tasks. Identify resources and costs. Prepare and agree contracts/work orders Manage/contribute to project operations. Manage the balance between quality, cost and time. Manage contingency processes. Contribute to the management of project funding, payments and recovery. Satisfy legal and statutory obligations. Manage tasks within identified financial, commercial and regulatory constraints.

- Effective interpersonal skills in communicating technical matters, for example:
  Reports, letters, emails, drawings, specifications and working papers (eg meeting minutes, planning documents, correspondence) in a variety of formats. Engaging or interacting with professional networks. Presentations, records of discussions and their outcomes

- Commitment to professional engineering values, this includes:
  Contribute to the affairs of your institution. Work with a variety of conditions of contract. Undertake formal health and safety training. Work with health and safety legislation and best practice. Carry out safety audits. Identify and minimize hazards. Assess and control risks. Deliver health and safety briefings and inductions.[1]

I.3 Project description:

The wastewater treatment plant station (WWTP) is located in the Wilaya of BORDJ BOU ARRERIJ along the national road number 45 (N45)

Figure I.1 :Satellite view of wastewater treatment plant of BBA

The objective of this project is to design an electrical system to feed all electrical equipment of the facility in a safe and efficient way based on national and international standards and using convenient softwares.

I.3.1 Wastewater treatment process:

Treatment of the wastewater generally involves three stages, called primary, secondary and tertiary treatment.

- *Primary treatment* consists of temporarily holding the sewage in a quiescent basin where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface. The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment. Some sewage treatment plants that are connected to a combined sewer system have a bypass arrangement after the primary treatment unit. This means that during very heavy rainfall events, the secondary and tertiary treatment systems can be bypassed to protect them from hydraulic overloading, and the mixture of sewage and stormwater only receives primary treatment.
- *Secondary treatment* removes dissolved and suspended biological matter. Secondary treatment is typically performed by indigenous, water-borne micro-organisms in a managed habitat. Secondary treatment may require a separation process to remove the micro-organisms from the treated water prior to discharge or tertiary treatment.
- *Tertiary treatment* is sometimes defined as anything more than primary and secondary treatment in order to allow ejection into a highly sensitive or fragile ecosystem (estuaries, low-flow rivers, coral reefs...). Treated water is sometimes disinfected chemically or physically (for example, by lagoons and microfiltration) prior to discharge into a stream, river, bay, lagoon or wetland, or it can be used for the irrigation of a golf course, greenway or park. If it is sufficiently clean, it can also be used for groundwater recharge or agricultural purposes.

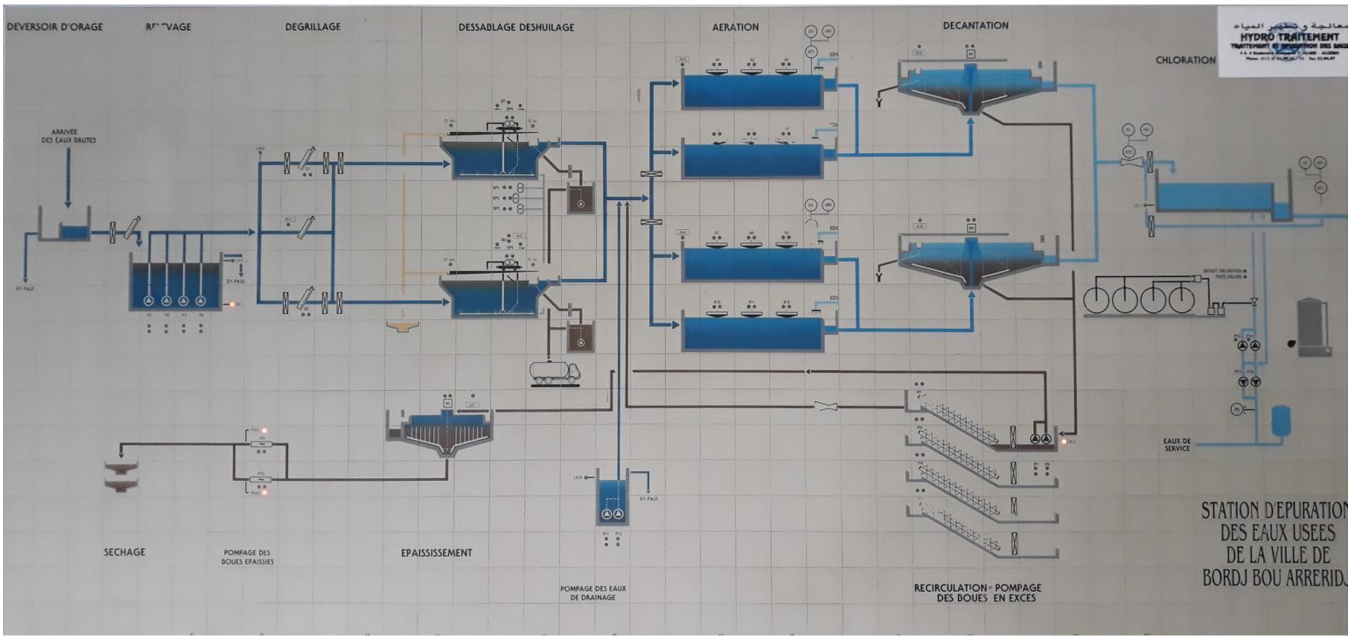


Figure I.2: Simplified process flow diagram

Figure I.3 :photos taken in WWTP of BBA

I.4 Rules and statutory regulations

Range of low-voltage extends from 0 V to 1000 V in a.c. and from 0 V to 1500 V in d.c. One of the first decisions is the selection of type of current between the alternative current which corresponds to the most common type of current throughout the world and the direct current. Then designers have to select the most appropriate rated voltage within these ranges of voltages. When connected to a LV public network, the type of current and the rated voltage are already selected and imposed by the Utility. Compliance with national regulations is then the second priority of the designers of electrical installation. Regulations may be based on national or international standards such as the IEC 60364 series.

Selection of equipment complying with national or international product standards and appropriate verification of the completed installation is a powerful mean for providing a safe installation with the expected quality. Defining and complying with the verification and testing of the electrical installation at its completion as well as periodic time will guarantee the safety and the quality of this installation all along its life cycle. Conformity of equipment according to the appropriate product standards used within the installation is also of prime importance for the level of safety and quality.

Environmental conditions will become more and more stringent and will need to be considered at the design stage of the installation. This may include national or regional regulations considering the material used in the equipment as well as the dismantling of the installation at its end of life.[3]

I.5 Project Design Electrical Philosophy:

This part describes the general requirements for the design engineering and of electrical installations to be provided for WWTP electrical installation project.

I.5.1 Power Source:

Main Feed: the electrical energy in our facility comes from an indoor MV/LV private substation located inside the facility and consists of two power transformers. The substation is connected to the public MV grid.

I.5.2 Eligible Voltage Drop:

The maximum allowable voltage drop on the cables in the case of private MV/LV substation supplied from a public distribution MV system, expressed in percent (%):

- lighting circuit 6%
- other uses (heating and power) 8% [3]

I.5.3 Protective Devices

All protective equipment will be designed and applied to the electric power systems to detect abnormal and intolerable conditions and to initiate appropriate corrective actions.

I.5.4 Electrical Equipment

I.5.4.1 Low Voltage Equipment:

Distribution switchboards, including the main LV switchboard (MLVS), are critical to the dependability of an electrical installation. They must comply with well-defined standards governing the design and construction of LV switchgear assemblies

The distribution switchboard enclosure provides dual protection:

- Protection of switchgear, indicating instruments, relays, fusegear, etc. against mechanical impacts, vibrations and other external influences likely to interfere with operational integrity (EMI, dust, moisture, vermin, etc.)

- The protection of human life against the possibility of direct and indirect electric shock.

Low voltage switchboard will be designed, selected and manufactured in accordance with applicable IEC standards.[3]

I.5.5 Cables Installation

I.5.5.1 Installing Cables above the Ground:

The cables will be installed mainly on hot dip galvanized steel ladder type trays.

Cable trays will be installed without a detachable cover for proper ventilation, except when:

- Mechanical damage to the cables may occur during plant maintenance.
- A spill of oil or chemicals may occur.

The cable trays will be designed to withstand the effects of wind on paths loaded with cables.
The cables used for control over cable trays can be laid in bundles over several layers as long as the thermal factor does not affect the capacity of the cables.

I.5.5.2 Installing Cables Underground:

The cables will be passed underground using concrete trenches in the areas where mechanical damage to the cables may occur during plant maintenance, or when the cables are designed to pass through the roads and landscape areas of the facility.

I.5.5.3 Conductor marking:

Conductor identification must always respect the following three rules:

- Rule 1:
  - The double color green and yellow is strictly reserved for the PE and PEN protection conductors
- Rule 2:
  - When a circuit comprises a neutral conductor, it must be light blue or marked "1" for cables with more than five conductors
  - When a circuit does not have a neutral conductor, the light blue conductor may be used as a phase conductor if it is part of a cable with more than one conductor
- Rule 3: Phase conductors may be any color except:
  - Green and yellow
  - Green
  - Yellow
  - Light blue (see rule 2).[3]

I.5.5.4 Cable specification:

Once the correct cable has been determined, it can be described in a cable specification. Cable specifications generally start with the conductor and progress radially through the insulation and coverings. The following is a check list that can be used in preparing a cable specification:

- Number of conductors in cable, and phase identification required
- Conductor size (AWG, kcmil) and material
- Insulation (rubber, polyvinyl chloride, XLPE, EPR, etc.)
- Voltage rating, and whether system requires 100%, 133%, or 173% insulation level
- Shielding system, required on cable systems rated 8 kV and above and may be required on systems rated 2001-8000 V
- Outer finishes
- Installation approvals required (for use in cable tray, direct burial, messenger supported, wet location, exposure to sunlight or oil, etc.)
- Applicable UL listing
- Test voltage and partial-discharge voltage
- Ground-fault-current value and time duration
- Cable accessories, if any, to be supplied by cable manufacturer [4]

I.5.6 Lighting design:

In our project we are going to design a lighting system for the outdoor Wastewater treatment plant, including parking, facility roads, and the places where the main treatment processes are located. We are going to use simple cross and double cross luminaire poles for the parking and roads, and projectors for the Aeration tanks. According to **EN 12464-2** (October 2007) the required illuminance for parking areas is 20 lx.[5]

I.5.7 Earthing system

The role of the entrepreneur is to plan for the design study, financial tasks, installation and connection of the earthing system. This network will consist mainly of buried loops connected to earth electrodes on which all structures and electric equipment are connected.

The entrepreneur will have to do all the necessary works to obtain an earth resistance between 1Ω and 5 Ω According to IEEE Std 142-2007 standards.[6]

All electric metallic masses, accessible or not, will be connected to the earth circuit:

- Cable trays
- Electric cables screens
- Electrical panels
- All lighting devices
- Electrical appliance with metal frame

I.6 Software used in this project:

Before getting into the design, we give a brief description about the software used in this project.

I.6.1 AutoCAD:

Figure I.4: AutoCAD logo

AutoCAD is a commercial computer-aided design (CAD) and drafting software application. Developed and marketed by Autodesk. It is used in industry, by architects, project managers, engineers, graphic designers, city planners and other professionals. It allows in particular to make projections and therefore to represent 3D objects.

The files produced by AutoCAD have the extension DWG and are organized in layers which allow the user to control the display as well as certain properties.

I.6.2 CANECO:

Figure I.5: CANECO BT logo

Caneco BT is software for automated calculations, sizing, and diagrams of low voltage electrical installations. It all the specific requirements in electrical engineering, including:

- Calculation and sizing
- Schematics
- Automated cabinet layout
- Costing of materials to design and operate complete projects.

I.6.3 DIALUX EVO:

Figure I.6: DIALUX EVO logo

DIALux is the leading software for lighting design, available free of charge in 25 languages. Plan, calculate and visualize light for indoor and outdoor areas. From entire buildings and individual rooms to parking spaces or street lighting. Create a unique atmosphere with real products of our DIALux partners › and convince with an individual lighting project.

I.6.4 CYMgrd:

Figure I.7: CYMgrd logo

CYMGRD assists engineers to design grounding facilities for substations and buildings. The program can be used to perform soil resistivity measurement interpretations, elevation of ground potential rise and danger point evaluation within any area of interest.

CYMGRD can also determine the equivalent resistance of ground grids of arbitrary shapes that are composed of ground conductors, rods and arcs since it employs matrix techniques for resolving the current distribution to ground.

CYMGRD calculates surface voltage and touch voltage potential gradients at any point of interest within the area of investigation.

CHAPTER II : ELECTRICAL SOURCE STUDY

II.1 Introduction:

This chapter will deal with the steps that must be followed to size the electrical energy sources (Transformers) based on national and international standards; starting by the single line diagram SLD, establishing the load schedule, and then sizing the transformers.

This system consists of two transformers; one is working in continuous mode and the other one remains as standby.

II.2 Single line diagram SLD:

II.2.1 Definition:

According to NF X 50-106-2 standards, single line diagram is a diagram represents the configuration of the electrical networks, including those of automatisms, serving the different parts of the system and showing their mutual relations and the means used for this purpose. [7]

The key single-line diagram should show the sources of power e.g. generators, utility intakes, the main switchboard and the interconnections to the subsidiary or secondary switchboards. It should also show important equipment such as power transformers, busbars, busbar section circuit breakers, incoming and interconnecting circuit breakers, large items of equipment such as high voltage induction motors, series reactors for fault current limitation, and connections to old or existing equipment if these are relevant and the main earthing arrangements. [8]

II.2.2 SLD Representation of our system:

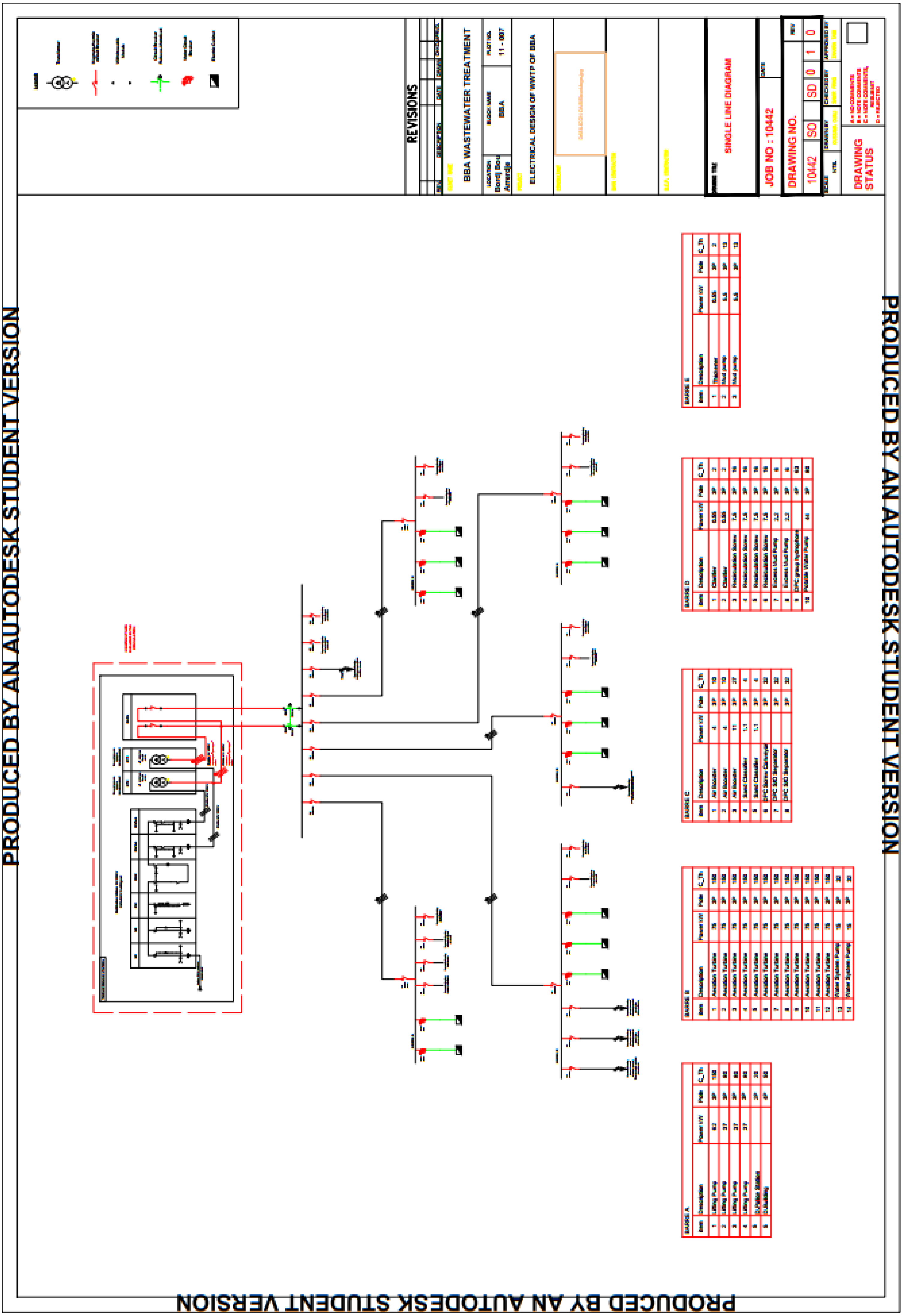


Figure II.1: Single Line Diagram of the system

II.3 Load Schedule:

II.3.1 Definition:

The electrical load schedule is an estimate of the instantaneous electrical loads operating in a facility, in terms of active, reactive and apparent power (measured in kW, kVAR and kVA respectively). The load schedule is usually categorised by switchboard or occasionally by sub-facility / area.

II.3.2 Calculation Methodology:

There are no standards governing load schedules and therefore this calculation is based on generally accepted industry practice. [9]

Collecting the list of loads and load parameters are one of the earliest tasks for the engineer who is designing a power system of a facility. Then the loads are classified based on three parameters, the first criterion is the voltage, and the second parameter is based on the load duty such that there are three types of loads; continuous, intermittent and standby loads, applying diversity factors of 1, 0.5, 0.1 respectively. And finally depending on the criticality of the load, depending on whether it is a normal load, an essential load or a critical load.[8]

These information are used to estimate the total plant running load (TPRL) and the total plant peak load (TPPL) taking into account all possible future extensions of the installation, the safety margin, and the power-factor correction, if justified.

Transformers are selected among the range of standard transformer ratings available.[3]

II.3.3 Calculation Steps:

II.3.3.1 Step 1: Collect list of loads:

The first step is to gather a list of all the electrical loads that will be supplied by the power system affected by the load schedule. There are generally two types of loads that need to be collected:

- **Process loads** are the loads that are directly relevant to the facility. In factories and industrial plants, process loads are the motors, heaters, compressors, conveyors, etc. that form the main business of the plant.
- **Non-process loads** are the auxiliary loads that are necessary to run the facility, e.g. lighting, HVAC, utility systems (power and water), DCS/PLC control systems, fire safety systems, etc.[9]

II.3.3.2 Step 2: Collect electrical load parameters:

A number of electrical load parameters are necessary to construct the load schedule:

- **Rated power:** is the full load or nameplate rating of the load and represents the maximum continuous power output of the load.[9]
  In our project, the rated power of all equipment is available.

- **Efficiency** accounts for the losses incurred when converting electrical energy to mechanical energy (or whatever type of energy the load outputs). Some of the electrical power drawn by the load is lost, usually in the form of heat to the ambient environment.
  most of the equipment's efficiency of our project are given in the datasheets of the equipment, Where information regarding efficiencies is not available, then estimates of between 0.8 and 1 can be used (typically 0.85 or 0.9 is used when efficiencies are unknown).
- **Power factor** of the load is necessary to determine the reactive components of the load schedule. Normally the load power factor at full load is used, but the power factor at the duty point can also be used for increased accuracy. Where power factors are not readily available, then estimates can be used (typically 0.85 for motor loads >7.5kW, 1.0 for heater loads and 0.8 for all other loads). [9]
- **Utilization factor (ku):** All individual loads are not necessarily operating at full rated nominal power. In normal operating conditions the power consumption of a load is sometimes less than that indicated as its nominal power rating, a fairly common occurrence that justifies the application of an utilization factor (ku) in the estimation of realistic values. This factor must be applied to each individual load, with particular attention to electric motors, which are very rarely operated at full load. [3]
  In our case the absorbed powers of some loads are given in their data-sheet, so (ku) can be calculated by dividing the absorbed power over the rated power of individual loads. Where (ku) is unknown, the following estimation is done:
  In industrial installation this factor may be estimated on an average at 0.75
  for motors. For incandescent-lighting loads, the factor always equals 1. For socket-outlet circuits, the factors depend entirely on the type of appliances being supplied from the sockets concerned. [3]
- **Diversity factor (ks):** It is a matter of common experience that the simultaneous operation of all installed loads of a given installation never occurs in practice, i.e. there is always some degree of diversity and this fact is taken into account for estimating purposes by the use of a factor (ks). The determination of ks factors is the responsibility of the designer, since it requires a detailed knowledge of the installation and the conditions in which the individual circuits are to be exploited. For this reason, it is not possible to give precise values for general application. [3]
  In our project, we are applying a diversity factor of 1.0, 0.5, and 0.1, for continuous, intermittent, and standby loads respectively. [8]
- **Absorbed power** is the expected power that will be drawn by the load. Most loads will not operate at its rated capacity, but at a lower point.[9]
  Some absorbed powers are given in the datasheet of equipment. When the absorbed power is not given, it can be estimated as follows: $P_{abs} = P_n \times k_u$

  where: P_{abs} is the absorbed active power

P_n is the rated power

k_u is the utilization factor and it is taken 0.75 as previously shown.

II.3.3.3 Step 3: Classify the loads:

Once the loads have been identified, it is needed to classify them accordingly:

- **Voltage level:**
  taking into account the voltage level and which switchboard the loads are located is one of the major consideration, large loads may need to be on MV or HV switchboards depending on the size of the load and how many voltage levels are available. [9]
  All the loads of our project are of LV level.
- **Load duty:**

  Loads are classified according to their duty as continuous, intermittent and standby loads:
  **Continuous loads* are those that normally operate continuously over a 24 hour period.
  **Intermittent loads* only operate for a fraction of a 24 hour period
  **Standby loads* are those that are on standby or rarely operate under normal conditions.

  We can determine the duty of the load based on its operation philosophy which is demonstrated here for some exciting loads of the facility:

  ***Lifting Pumps (A-LP):** we have four lifting pumps that are used to pump the wastewater to the Trash-Rake machine. But at most three of them may run simultaneously, the other one is remained as Standby.
  The operation sequence of three pumps is based on the wastewater level:
  - LSLL: very low level: Trigger an alarm.
  - LSL: low level: Stop pumps one and two.
  - LSH1: high level: Run pump one and stop pump three.
  - LSH2: high level: Run pomp two.
  - LSH3: high level: Run pump three.
  - LSHH: very high level: Trigger an alarm.

  Accordingly, one pump is set as a continuous load, two pumps as intermittent loads and the last one as standby load.

  ***Two Vertical Trash Rakes (C-DPCSC): -** Automatic timer mode- the trash rake selected for this mode, is governed by a programmable timer (running time and stopping time), therefore, one is selected to be continuous load and the other as intermittent load.

  ***Screw conveyer (C-DPCSC):** The screw conveyor is used to transport and compact the rejects transmitted by the trash rakes and unload them on transportable skip. The operation of the conveyor is associated with that of the trash rakes. Since we have at least one trash rake is set to be a continuous load, therefore the screw conveyor is also set as continuous load.

***Aeration Turbine (B-AT):** The 12 aerators T1 / T12 are distributed over two identical aeration tanks: T1 / T6 in tank N ° 1, and T7 / T12 in tank N ° 2
The description below concerns the aeration tank N ° 1, then the same description is forwarded to tank N ° 2.

Automatic mode based on oxygen measurement: The operation of each group of 06 aerators depends on the oxygen values measured in the aeration tank (OXIT 1 sensor and transmitter for tank 1 and OXIT 2 for tank 2) and acts on the 06 aerators of the basin concerned.

The objective is to keep the measured oxygen value between OXSL1 and OXSH1
where: -OXSL 1: low oxygen threshold
-OXSH 1: high oxygen threshold

Taking into account the ventilation capacity installed when the 6 machines are in operation the oxygen level must rise and reach the high threshold.

- If the measurement is <OXSL1: start-up of the aerator T1 and then if after a time t1 (in mn adjustable by the supervisor) the measurement remains <OXSL1: activation of the aerator T4.

- If after time t1, the measurement remains <OXSL1: switching ON the aerator T5, then T2, T3 and T6 with the same time interval t1.

Normally after starting the 06 aerators the oxygen value must exceed OXSL1

- If the measurement is> OXSH1: turn OFF the aerator T1. Then if after a time t2 (in min adjustable on the supervisor) the measurement remains> OXSH1: turn OFF the T4 aerator.
- If after time t2, the measurement remains >OXSH1: switch OFF the aerator T5, then T2, T3 and T6 with the same time interval t2.

Based on this operation mode, we set four aerators as continuous loads, and the remaining eight as intermittent loads. [10]

- **Load criticality:**

In general terms there are three ways of considering a load or group of loads and these may be cast in the form of questions.

Firstly*; will the loss of power jeopardize safety of personnel or cause serious damage within the plant? These loads can be called **'vital' loads.

Secondly;* will the loss of power cause degradation or loss of the manufactured product? These loads can be called the **'essential' loads.

Thirdly;* does the loss have no effect on safety or production? These can be called the **'non-essential' loads. [8]

II.3.3.4 Step 4: Calculate consumed load

The consumed power is the quantity of electrical power that the load is expected to consume. For each load we calculate the consumed active and reactive loading, derived as follows:

$$P_a = \frac{P_{abs}}{\eta}$$

$$Q_a = P_a \sqrt{\frac{1}{(\cos\phi)^2} - 1}$$

Where: P_a is the consumed active power
Q_a is the consumed reactive power
P_{abs} is the absorbed active power
η is the load efficiency in pu
$\cos\phi$ is the load power factor in pu [9]

II.3.3.5 Step 5: Calculate operating and peak load:

The total load can be considered in two forms, the total plant operating load (OL) and the total plant peak load (PL).

- **Operating load:** is the expected load during normal operation and it is the sum of the total continuous load and the intermittent load multiplied by its diversity factor (in our design it is taken 1 for continuous loads and 0.5 for intermittent loads)

$$OL = 1.0 * \sum L_c + 0.5 * \sum L_i$$

Where: OL is the operating load (kW or kVAR)
$\sum L_c$ is the sum of the continuous load (kW or kVAR)
$\sum L_i$ is the sum of intermittent load (kW or kVAR)

- **Peak load:** The peak load is the expected maximum load during normal operation. Peak loading is typically infrequent and of short duration, occurring when standby loads (with a diversity factor of 0.1) are operated.

$$PL = 1.0 * \sum L_c + 0.5 * \sum L_i + 0.1 * \sum L_s$$

Where: PL is the Peak load (kW or kVAR)
$\sum L_c$ is the sum of the continuous load (kW or kVAR)
$\sum L_i$ is the sum of intermittent load (kW or kVAR)
$\sum L_s$ is the sum of standby load (kW or kVAR) [9] [8]

During the detail design phase of the project the load schedules will be modified and additional loads will inevitably be added. At least **10%** extra load should be added to the first estimate. [8]

II.3.3.6 Step6: Calculating Transformer size:

The over sizing of a transformer results in:

- Excessive investment
- Un necessarily high no-load losses
- Lower on-load losses.

Under sizing a transformer causes:

- On long-term overload, serious consequences for the transformer, owing to the premature ageing of the windings insulation, and in extreme cases, resulting in failure of insulation and loss of the transformer.
- A reduced efficiency when fully loaded. [3]

Calculating the transformer size:

The highest efficiency of the transformer is attained in the range 50 % - 70 % of the full load, [3]

$$P_r = \frac{1.1 * PL}{0.70}$$

Where: P_r is recommended transformer size when 70% loading (KVA)
$(1.1 * PL)$ is the peak load with 10% extra load (KVA)

All the project data and calculations are done using Microsoft Excel program. The results of our study are shown in the load schedule in the table below (or see annex A):

NO	TAG NO.	DESCRIPTION	VOLTAGE (V)	ABSORBED LOAD (kW)	MOTOR or EQUIPMENT RATING / LOAD (kW)	Utilization FACTOR (ku) (DECIM.)	EFFICIENCY AT LOAD FACTOR (DECIM.)	POWER FACTOR (DECIM.)	DUTY	CONSUMED LOAD					
										CONTINUOUS		INTERMITTENT		STANDBY	
										kW	kVAR	kW	kVAR	kW	kVAR
		Main Distribution Board													
1	M-EL-001	Exterior Lighting	230	7.30			0.85	0.95	I			8.59	2.82		
2	M-UPSC-002	UPC+Control circuit	230	2.20			0.85	0.96	C	2.59	0.75				
		BARRE-A													
3	A-LP-001	Ebara 300DRD565T6AG Lifting Pump	400	57.20	65.00	0.88	0.95	0.86	C	60.21	35.73				
4	A-LP-002	Lifting Pump	400	32.56	37.00	0.88	0.95	0.86	C	34.27	20.34				
5	A-LP-003	Lifting Pump	400	32.56	37.00	0.88	0.95	0.86	I			34.27	20.34		
6	A-LP-004	Lifting Pump	400	32.56	37.00	0.88	0.95	0.86	I			34.27	20.34		
7	A-PS-005	Police Station	230	3.52	4.00	0.88	0.95	0.80	I			3.71	2.78		
8	A-Bl-006	Buildings	230	8.80	11.00	0.80	0.85	0.80	I			10.35	7.76		
9	A-UPSC-007	UPC+Control circuit	230	1.00	1.30	0.77	0.85	0.96	C	1.18	0.34				
		BARRE-B													
10	B-WSP-001	Ebara 150DMLF515T4BG Water System Pump	400	13.65	15.00	0.91	0.93	0.84	C	14.68	9.48				
11	B-WSP-002	Ebara 150DMLF515T4BG Water System Pump	400	13.65	15.00	0.91	0.93	0.84	S					14.68	9.48
12	B-AT-003	Sereco TASC070 Aeration Turbine	400	53.25	75.00	0.71	0.95	0.90	C	56.05	27.15				
13	B-AT-004	Sereco TASC070 Aeration Turbine	400	53.25	75.00	0.71	0.95	0.90	C	56.05	27.15				
14	B-AT-005	Sereco TASC070 Aeration Turbine	400	53.25	75.00	0.71	0.95	0.90	C	56.05	27.15				
15	B-AT-006	Sereco TASC070 Aeration Turbine	400	53.25	75.00	0.71	0.95	0.90	C	56.05	27.15				
16	B-AT-007	Sereco TASC070 Aeration Turbine	400	53.25	75.00	0.71	0.95	0.90	I			56.05	27.15		
17	B-AT-008	Sereco TASC070 Aeration Turbine	400	53.25	75.00	0.71	0.95	0.90	I			56.05	27.15		
18	B-AT-009	Sereco TASC070 Aeration Turbine	400	53.25	75.00	0.71	0.95	0.90	I			56.05	27.15		
19	B-AT-010	Sereco TASC070 Aeration Turbine	400	53.25	75.00	0.71	0.95	0.90	I			56.05	27.15		
20	B-AT-011	Sereco TASC070 Aeration Turbine	400	53.25	75.00	0.71	0.95	0.90	I			56.05	27.15		
21	B-AT-012	Sereco TASC070 Aeration Turbine	400	53.25	75.00	0.71	0.95	0.90	I			56.05	27.15		
22	B-AT-013	Sereco TASC070 Aeration Turbine	400	53.25	75.00	0.71	0.95	0.90	I			56.05	27.15		
23	B-AT-014	Sereco TASC070 Aeration Turbine	400	53.25	75.00	0.71	0.95	0.90	I			56.05	27.15		
24	B-UPSC-015	UPC+Control circuit	230	1.00	1.30	0.77	0.85	0.96	C	1.18	0.34				
		BARRE-C													
25	C-DPCSC-001	Sereco GVC Vertical Trash Rake panel							C	0.95	0.79	0.25	0.25		
26	C-DPSOS-002	Sereco PDRA Sand Oil Separator							C	4.08	3.09				
27	C-DPSOS-003	Sereco PDRA Sand Oil Separator							C	4.08	3.09				
28	C-SC-004	Sereco ES200 Sand Classifier	400	0.70	1.10	0.64	0.85	0.78	C	0.83	0.66				
29	C-SC-005	Sereco ES200 Sand Classifier	400	0.70	1.10	0.64	0.85	0.78	C	0.83	0.66				
30	C-AB-006	Sereco Air Booster (Souffelante)	400	4.13	5.50	0.75	0.85	0.80	C	4.85	3.64				
31	C-AB-007	Sereco Air Booster (Souffelante)	400	4.13	5.50	0.75	0.85	0.80	C	4.85	3.64				
32	C-AB-008	Air Booster	400	8.25	11.00	0.75	0.85	0.85	S					9.71	6.02
33	C-UPSC-009	UPC+Control circuit	230	1.00	1.30	0.77	0.85	0.96	C	1.18	0.34				
		BARRE-D													
34	D-Cl-001	Sereco PRTP Clarifier	400	0.41	0.55	0.74	0.75	0.73	C	0.54	0.51				
35	D-Cl-002	Sereco PRTP Clarifier	400	0.41	0.55	0.74	0.75	0.73	C	0.54	0.51				
36	D-RS-003	Recirculation Screw	400	5.63	7.50	0.75	0.85	0.85	I			6.62	4.10		
37	D-RS-004	Recirculation Screw	400	5.63	7.50	0.75	0.85	0.85	I			6.62	4.10		
38	D-RS-005	Recirculation Screw	400	5.63	7.50	0.75	0.85	0.85	I			6.62	4.10		
39	D-RS-006	Recirculation Screw	400	5.63	7.50	0.75	0.85	0.85	I			6.62	4.10		
40	D-EMP-007	Excess Mud Pump	400	1.65	2.20	0.75	0.85	0.80	C	1.94	1.46				
41	D-EMP-008	Excess Mud Pump	400	1.65	2.20	0.75	0.85	0.80	I			1.94	1.46		
42	D-GH-009	Group Hydrophore Panel	400	8.25	11.00	0.75	0.85	0.85		9.71	6.02	19.41	12.03	10.35	6.42
43	D-PWP-010	Potable Water Pumping Unit	400	33.00	44.00	0.75	0.85	0.80	I			38.82	29.12		

NO	TAG NO.	DESCRIPTION	VOLTAGE (V)	ABSORBED LOAD (kW)	MOTOR or EQUIPMENT RATING / LOAD (kW)	Utilization FACTOR (ku) (DECIM.)	EFFICIENCY AT LOAD FACTOR (DECIM.)	POWER FACTOR (DECIM.)	DUTY	CONSUMED LOAD CONTINUOUS kW	CONTINUOUS kVAR	INTERMITTENT kW	INTERMITTENT kVAR	STANDBY kW	STANDBY kVAR
44	D-UPSC-011	UPC+Control circuit	230	1.69	2.20	0.77	0.85	0.96	C	1.99	0.58				
		BARRE-E													
45	E-Th-001	Sereco PRTP Thickener	400	0.41	0.55	0.74	0.75	0.73	C	0.54	0.51				
46	E-MP-002	Mud Pump	400	4.13	5.50	0.75	0.85	0.80	C	4.85	3.64				
47	E-MP-003	Mud Pump	400	4.13	5.50	0.75	0.85	0.80	S					4.85	3.64
48	E-UPSC-004	UPC+Control circuit	230	6.93	9.00	0.77	0.85	0.96	C	18.75	5.47				
###															
									TOTAL	398.84	210.19	626.51	330.48	39.59	25.56
									Diversity Factor (ks) %	100.00%		50.00%		10.00%	

	KW	KVAR	KVA	cosø	Amp	Volts
Operating Load (OL)	712.10	375.43	805.00	0.88	1161.9	400
Peak Load (PL)	716.05	377.98	809.69	0.88	1168.7	400
Operating Load with 10% growth factor	783.30	412.97	885.50	0.88	1278.1	400
Peak Load with 10% growth factor	787.66	415.78	890.66	0.88	1285.6	400
recommended transformer size when 70% loading (Pr)	1125.2	593.973	1272.4	0.88	1836.5	400
70%						

NO	TAG NO.	DESCRIPTION	DIVERSITY FACTOR (%)	ABSORBED LOAD (kW)	MOTOR or EQUIPMENT RATING / LOAD (kW)	LOAD FACTOR (DECIM.)	EFFICIENCY AT LOAD FACTOR (DECIM.)	POWER FACTOR (DECIM.)	DUTY	CONSUMED LOAD CONTINUOUS kW	CONTINUOUS kVAr	INTERMITTENT kW	INTERMITTENT kVAr	STANDBY kW	STANDBY kVAr
25	C-DPCSC-001	Sereco GVC Vertical Trash Rake	400	0.17	0.37	0.75	0.67	0.71	C	0.25	0.25				
		Sereco GVC Vertical Trash Rake	400	0.17	0.37	0.75	0.67	0.71	I			0.25	0.25		
		Sereco CTGC200 Srew Conveyor Trash Rake	400	0.59	1.50	0.39	0.85	0.79	C	0.69	0.54				

		kW	kVAr	kW	kVAr	kW	kVAr
TOTAL		0.95	0.79	0.25	0.25		
kVA		1.23		0.36			

Table II.1 : Load List

NO	TAG NO.	DESCRIPTION	DIVERSITY FACTOR (%)	ABSORBED LOAD (kW)	MOTOR or EQUIPMENT RATING / LOAD (kW)	LOAD FACTOR (DECIM.)	EFFICIENCY AT LOAD FACTOR (DECIM.)	POWER FACTOR (DECIM.)	DUTY	CONSUMED LOAD					
										CONTINUOUS		INTERMITTENT		STANDBY	
										kW	kVAr	kW	kVAr	kW	kVAr
26	C-DPSOS-001	Air Booster	400	3.00	4.00	0.75	0.85	0.80	C	3.53	2.65				
		Side Cart	400	0.09	0.18	0.50	0.58	0.61	C	0.16	0.20				
		Scraper lifting	400	0.11	0.37	0.30	0.67	0.71	C	0.16	0.16				
		Control Panel		0.20	0.60	0.33	0.85	0.95	C	0.24	0.08				

		kW	kVAr	kW	kVAr	kW	kVAr
TOTAL		4.08	3.09				
kVA		5.12					

NO	TAG NO.	DESCRIPTION	DIVERSITY FACTOR (%)	ABSORBED LOAD (kW)	MOTOR or EQUIPMENT RATING / LOAD (kW)	LOAD FACTOR (DECIM.)	EFFICIENCY AT LOAD FACTOR (DECIM.)	POWER FACTOR (DECIM.)	DUTY	CONSUMED LOAD					
										CONTINUOUS		INTERMITTENT		STANDBY	
										kW	kVAr	kW	kVAr	kW	kVAr
42	D-GH-009	Group Hydrophore	400	8.25	11.00	0.75	0.85	0.85	C	9.71	6.02				
		Group Hydrophore	400	8.25	11.00	0.75	0.85	0.85	I			9.71	6.02		
		Group Hydrophore		8.25	11.00	0.75	0.85	0.85	I			9.71	6.02		
		Group Hydrophore	400	8.80	11.00	0.80	0.85	0.85	S					10.35	6.42

		kW	kVAr	kW	kVAr	kW	kVAr
TOTAL		9.71	6.02	19.41	12.03	10.35	6.42
kVA		11.42		22.84		12	

Table II.1: Load list

II.4 Choice of MV/LV transformer:

There are two basic types of distribution transformer:

- Dry type (cast resin encapsulated) transformer
- Liquid filled (oil-immersed) transformer. [3]

To supply power to the load centers and main loads in industrial plants, dry-type transformers according to DIN EN 60076-11 (VDE 0532-76-11): 2005-04 [11.1] or IEC 60076-11: 2004-05 [11.2] are preferred.[11]

To select cast-resin transformers, the following electrical quantities must be determined:

- rated voltage U_{rT} (primary and secondary side),
- impedance voltage at rated current u_{rZ},
- connection symbol,
- rated power S_{rT}. [11]

II.4.1 Rated voltage U_{rT}

It is important to note that the rated voltage of the transformer on the secondary side has values that are 5 % higher than the nominal system voltage of the LV level. This largely compensates for the internal voltage drops of the transformer when a load is applied. Distribution transformers can also be adapted to the prevailing system conditions using taps. [11]

The tapping range is stated as 5% positive or negative of the nominal system voltage U_{nN}

II.4.2 Impedance voltage at rated current urZ

The impedance voltage at rated current is the voltage that is applied to the primary winding of the transformer when the rated current IrT is flowing in the short-circuited secondary winding. It is expressed as a percentage of the primary-side rated voltage.

The impedance voltage at rated current u_{rZ} must always be used as the standardized calculation value for the short-circuit stress of the electrical equipment.
It is also a measure of how “voltage stiff“ the distribution transformer is. If the impedance voltage at rated current is small, the transformer is “voltage stiff“; if it is large, the transformer is not “voltage stiff“.

Table 1 Standard impedance voltages at rated current in the power range of GEAFOL cast-resin transformers that is relevant to industrial applications:

S_{rT} in kVA	250		315		400		500		630		800		1,000		1,250	1,600	2,000	2,500
u_{rz} in %	4	6	4	6	4	6	4	6	4	6	4	6	4	6	6	6	6	6

Table II.2: Standard impedance voltages at rated current [11]

II.4.3 Connection symbol

The connection symbols indicates how the two windings of a transformer are connected and by what factor of 30° the pointer of the lower voltage side trails that of the higher voltage side with terminal designation coordinate in the counterclockwise direction.

The preferred connection groups are Yy0, Dy5, Yd5, Yz5 and Dyn5. [12]

II.4.4 Rated power *S*rT

For transformer ratings under 10MVA, IEC 60076-1 suggest preferred values based on the R10 series: 10, 12.5, 16, 20, 25, 31.5, 40, 50, 63, 80, 100, and multiples of 10_n. For example, the preferred transformer sizes from 500kVA to 4000kVA are: 500, 630, 800, 1000, 1250, 1600, 2000, 2500, 3150, and 4000.[13]

II.5 Conclusion

Based on all previous results and standards, our transformers have the following specifications:

- Type: dry-type transformers
- Rated voltage (V): 11kV/0.42kV
- Rated power (SrT): 1600kVA
- Impedance voltage at rated current (urZ): 6%
- Vector group: Dyn5

CHAPTER III : CABLES AND PROTECTION

III.1 Cables sizing and selection:

III.1.1 Introduction:

Cable sizing methods do differ across international standards (e.g. IEC, NEC, BS, etc) and some standards emphasize certain things over others. However the general principles underlying any cable sizing calculation do not change. In this article, a general methodology for sizing cables is first presented and then the specific international standards are introduced.

III.1.1.1 Description

Single core or multicore cables with copper or aluminum conductor, insulated, either armored or none armored and sheathed.

III.1.1.2 Construction:

Conductor: Plain circular, compacted or shaper, copper or aluminum conductor.

Insulation: XLPE; cross linked polyethylene or PVC; Polyvinyl chloride.

Armour: aluminium or galvanized steel, wire or tape.

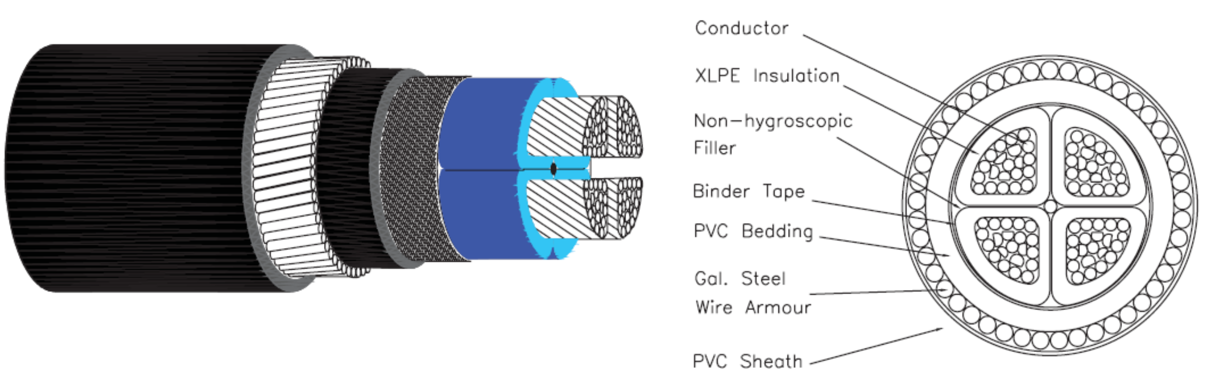


Figure III.1: construction of an armoured power cable with XLPE isolation

III.1.2 Why do the calculation?

The proper sizing of an electrical (load bearing) cable is important to ensure that the cable can:

- Operate continuously under full load without being damaged.
- Withstand the worst short circuits currents flowing through the cable.
- Provide the load with a suitable voltage (and avoid excessive voltage drop).
- (optional) Ensure operation of protective devices during an earth fault.

III.1.3 General Methodology

Sizing Cable sizing methods follow the unchanged basic step process. Firstly, it's vital to gather data about the cables, installation surroundings, and the load that it will carry. In addition, it's crucial to find the current carrying capacity (A, ampere) and voltage drop per ampere meter (mV/A/m) of the cable [14]. The current carrying capacity of a cable is the maximum current that can flow continuously through a cable without damaging the cable's insulation and other components [15]. Short circuit temperature rise and earth fault loop impedance are significant factors to verify the cable size.

Each conductors and cables except superconductor have some amount of resistance. This resistance is directly proportional to the length and inversely proportional to the diameter of the conductor.

Laws of resistance: $$R = \rho \left(\frac{L}{a}\right)$$ [14]

Voltage drop occurs in every conductor as the current flows through it. According to Institute of Electrical and Electronics Engineers (IEEE) rule B-23, at any point between a power supply terminal and installation, voltage drop should not increase above 2.5% of provided (supply) voltage [16].

The cable should withstand the temperature and heat emission with using good insulation materials such as conductors, and bedding.

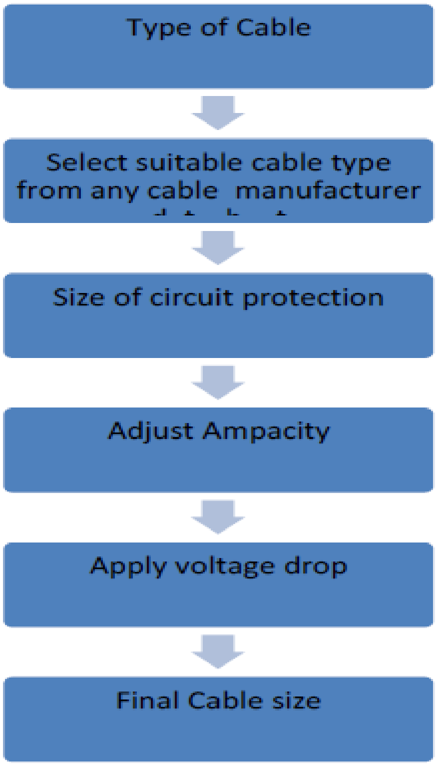


Figure III.2: Flow chart shows the steps to determine the cable sizing.

III.1.4. Cable Layout:

Cable layout plays an important role in electrical installation work as it transmits information on the connection of various appliances and equipment to the power grid. It shows how electrical cables are interconnected and can also show where devices and components can be connected to the system. The information on the drawings provides the complete design or layout of the electrical installation and also helps to assemble the various equipment.

From the site schemes and electrical power generation equipment layout cable paths are drawn using AUTOCAD.

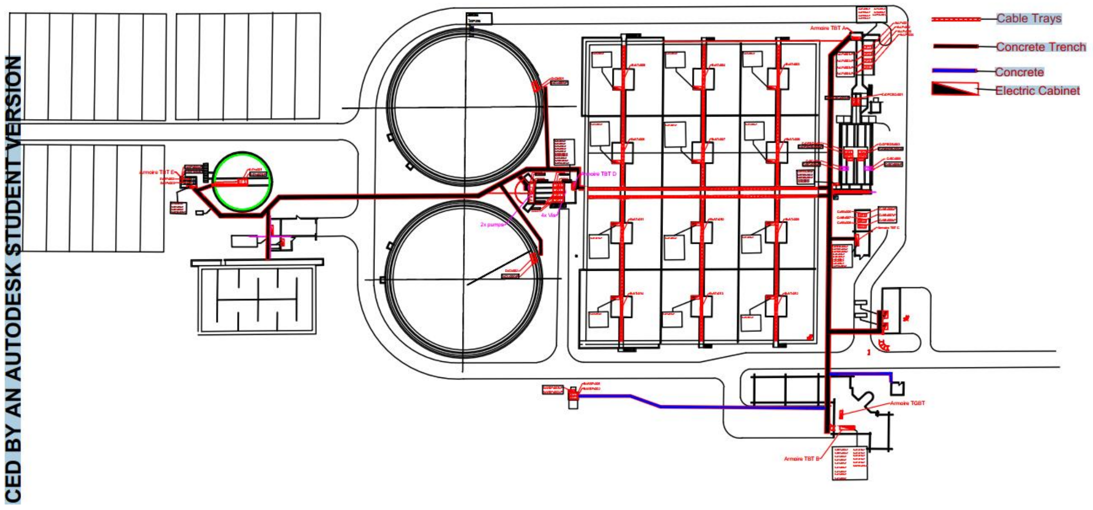


Figure III.3: Cable layout shows in detail the cable routing and installation

III.1.4 Data Gathering:

The first step is to collate the relevant information that is required to perform the sizing calculation. Typically, we will need to obtain the following data:

III.1.4.1 Load Details:

The characteristics of the load that the cable will supply, which includes:

- Load type: motor or feeder.
- Three phase, single phase or DC.
- System / source voltage.
- Full load current (A) - or calculate this if the load is defined in terms of power (kW) .
- Full load power factor (pu) .
- Locked rotor or load starting current (A).
- Starting power factor (pu) .
- Distance / length of cable run from source to load - this length should be as close as possible to the actual route of the cable and include enough contingency for vertical drops / rises and termination of the cable tails.

III.1.4.2 Cable Construction:

The basic characteristics of the cable's physical construction, which includes:

- Conductor material - normally copper or Aluminum .
- Conductor shape - e.g. circular or shaped.
- Conductor type - e.g. stranded or solid.
- Conductor surface coating - e.g. plain (no coating), tinned, silver or nickel.
- Insulation type - e.g. PVC, XLPE, EPR.
- Number of cores - single core or multicore (e.g. 2C, 3C or 4C) .

III.1.4.3 Installation Conditions

How the cable will be installed, which includes:

- Above ground or underground
- Installation / arrangement - e.g. for underground cables, is it directly buried or buried in conduit.
- For above ground cables, is it installed on cable tray / ladder, against a wall, in air, etc.
- Ambient or soil temperature of the installation site.
- Cable bunching, i.e. the number of cables that are bunched together.
- Cable spacing, i.e. whether cables are installed touching or spaced.
- Soil thermal resistivity (for underground cables) .
- Depth of laying (for underground cables) .

III.1.4.4 Correction Factors Of Cable

International standards and cable manufacturers will provide derating factors for a range of installation conditions, for example ambient or soil temperature, grouping or bunching of cables, and soil thermal resistivity. The installed current rating is calculated by multiplying the base current rating with each of the derating factors.

$$I_c = I_b \times k_d \quad \ldots\ldots\ldots\ldots[15]$$

Where:

I_c is the installed current rating (A).

I_b is the base current rating (A).

K_d are the product of all the derating factors.

Upstream protective device circuit breaker is not required to protect the cable against overloads. As a result, cables need only to be sized to cater for the full load current of the motor [18].

$$Il \leq Ic < Ip \ldots\ldots\ldots [16]$$

Where Il is the full load current (A), Ip is the protective device rating (A) Ic is the installed cable current rating(A).Cable Impedances is a function of the cable size (cross-sectional area) and the length of the cable.

Most cable manufacturers will quote a cable's resistance and reactance in Ω/km.

Impedances for low voltage AC single core and multicore cables can be used in the absence of any other data [19].

III.1.5 Continuous Current Carrying Capability

The ampacity of a cable quoted from the manufacturer is based on a specific set of installation conditions. When a cable is installed in a different set of conditions the cable must be derated appropriately.

$$IT \geq InC \ldots\ldots [22] \qquad C = C1 * C2 * C * C4 * C5$$

- IT Current currying capacity
- In Base current rating
- C1 ground Temperature factor (Direct buried cables only)
- C2 Ambient Temperature factor (Cables run on tray only)
- C3 Depth of Lay factor (Direct buried cables only)
- C4 Grouping factor
- C5 Thermal Resistivity of the ground factor (Direct buried cables only)

The values from each one of these factors, where applicable, are then multiplied together to give an overall rating factor for the cable. In our case the factors are obtained from CEI 60364-5-52 standard.

III.1.6 Voltage Drop:

III.1.6.1 AC three phase system:

$$V_{3\theta} = \frac{\sqrt{3}\, I\, (R_c\, Cos\, \theta + X_c\, Sin\, \theta)\, L}{1000} \qquad \ldots\ldots\ldots\ldots\ldots\ldots [20]$$

Where V3ø is the three phase voltage drop (V), I is the nominal full load or starting current as applicable (A), Rc is the ac resistance of the cable (Ω/km), Xc is the ac reactance of the cable (Ω/km) cos ø is the load power factor (pu) L is the length of the cable (m) [20].

III.1.6.2 AC single phase system:

Voltage Drop = 21 (R Cos θ + X Sin θ) L ……………[21]

It is standards to indicate maximum permissible voltage drops, which is the maximum voltage drop that is permissible across a cable. If the cable exceeds this voltage drop, then a bigger cable size should be preferred.

Greatest voltage drops across a cable are specified because load consumers will have an input voltage tolerance range. If the voltage at the electrical device is lower than its rated minimum voltage, then the appliance may not work appropriately [21].

It may be more precise to calculate the maximum length of a cable for a particular conductor size given a maximum permissible voltage drop 5% of nominal voltage at full load rather than the voltage drop itself. To construct tables showing the maximum lengths corresponding to different cable sizes in order to speed up the selection of similar type cables.

III.2 Protection:

III.2.1 Overload Protection

For protection against overload, protective devices must be provided to break any overload current flowing in the conductors before such a current could cause a temperature rise detrimental to insulation, joints, terminations and surroundings of the cables and busbars. When assigning protective devices for the protection of cables and lines against overload, the dimensioning and tripping rules must be followed on the basis of (IEC 60 364, Part 43) standard.

• Conditions of the dimensioning rule to be met:

a) non-adjustable protective devices (e.g. fuses, miniature circuit-breakers (MCBs))

$I_{load} \leq In \leq Iperm$ …………[11].

b) adjustable protective devices (e.g. circuit-breakers (ACBs, MCCBs))

$I_{load} \leq IR \leq Iperm$…………[11].

• Condition of the tripping rule to be met:

$I2 \leq 1.45 \cdot Iperm$…………[11].

Where:

I_{load} : load current of the cable or circuit.

In :nominal current of the non-adjustable protective device.

Iperm : permissible current-carrying capacity of the cable.

IR : setting value of the protective device (inverse-time-delay overload release L).

I2 : current that causes tripping of the protection device under conditions defined in the device standards (conventional tripping or fusing current).

III.2.2 Short Circuit Protection:

Protection against short circuit must be ensured by the protective device disconnecting the short-circuit current before the permissible short-circuit temperature of the cable is reached [11]. To ensure short-circuit protection, the following condition must be met:

$$k^2 \cdot A_n^2 \geq I^2_k \cdot t_k \text{.....................[11].}$$

A_n : nominal conductor cross-sectional area in mm2

I_k :effective short-circuit current (RMS value) in A

t_k :short-circuit duration in sec.

k :material-related value of the cable type.

III.3 Calculation Using Software:

CANECO is a Design Software provides a quick and immediate interface to use all the support services.

The main functionalities of the program are:

- Drawing single-line electric diagrams key diagram of the auxiliary circuits.
- Calculating line current and voltage drops and short-circuit currents.
- Dimensioning low and medium voltage cables.
- Dimensioning switching and protection devices.
- Setting and coordinating protection devices.
- Verifying cable protection.
- Printing single-line diagrams and project documentation·

For the simulation, when a new project is opened the Power supply details can be entered as well as the selectin calculation methods and standards and types of cables and circuit breakers and other specifications and options can be set.

III.3.1 Power source settings:

Starting by setting the power source and all the related factors

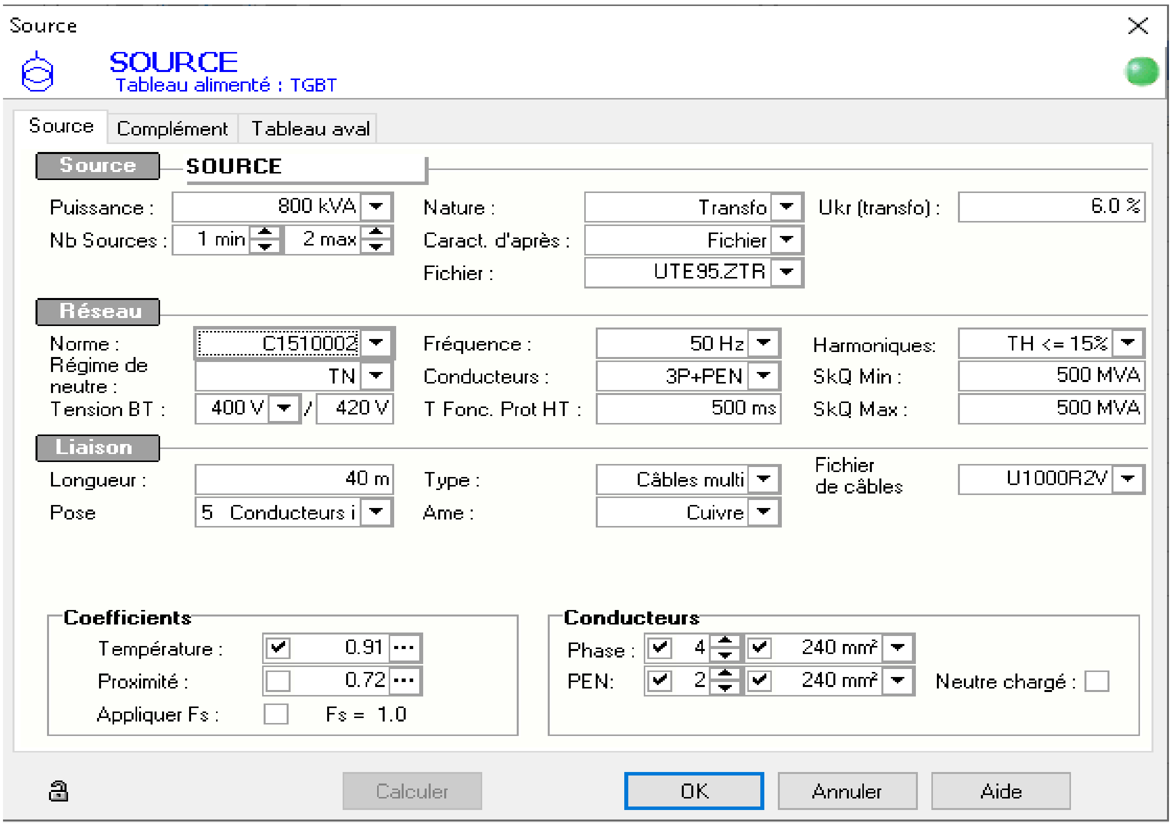


Figure III.4: Power source properties of the main panel

III.3.2 Main panel settings:

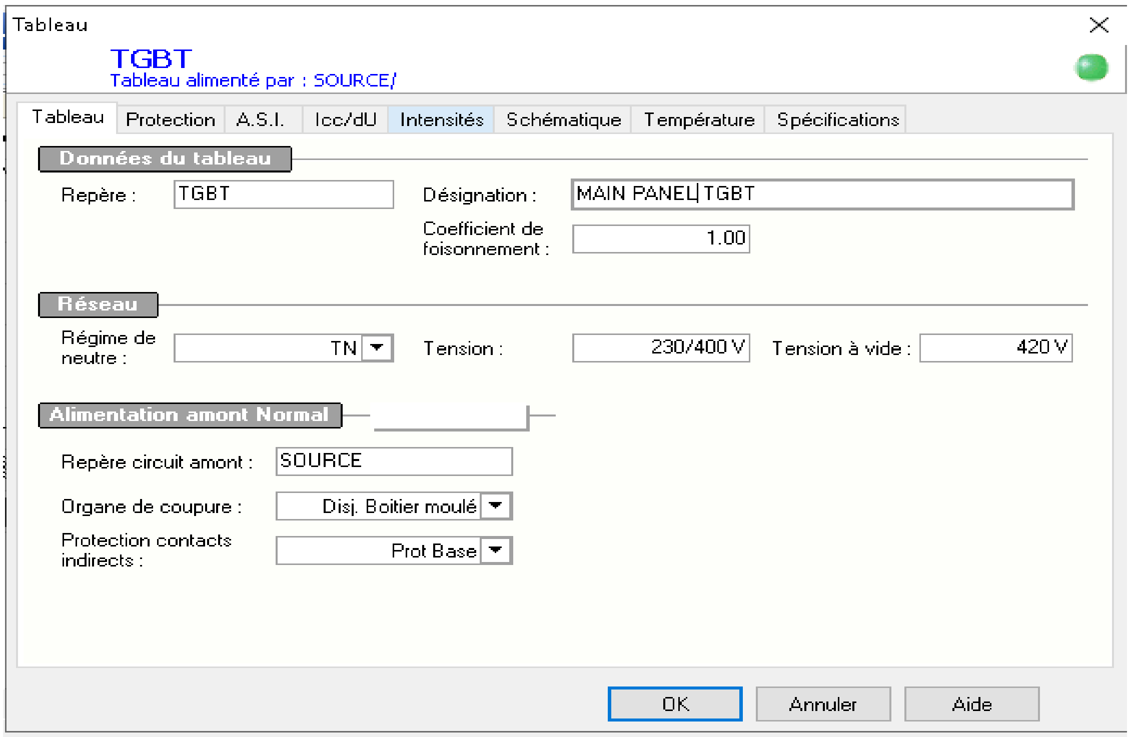


Figure III.5: Main panel properties

III.3.3 Distribution panels settings:

There are 5 distribution panels feeds from the main TGBT panel:

- BARRE A
- BARRE B
- BARRE C
- BARRE D
- BARRE E
- LIGHTING PANEL
- UPS AND CONTROL CIRCUIT PANEL

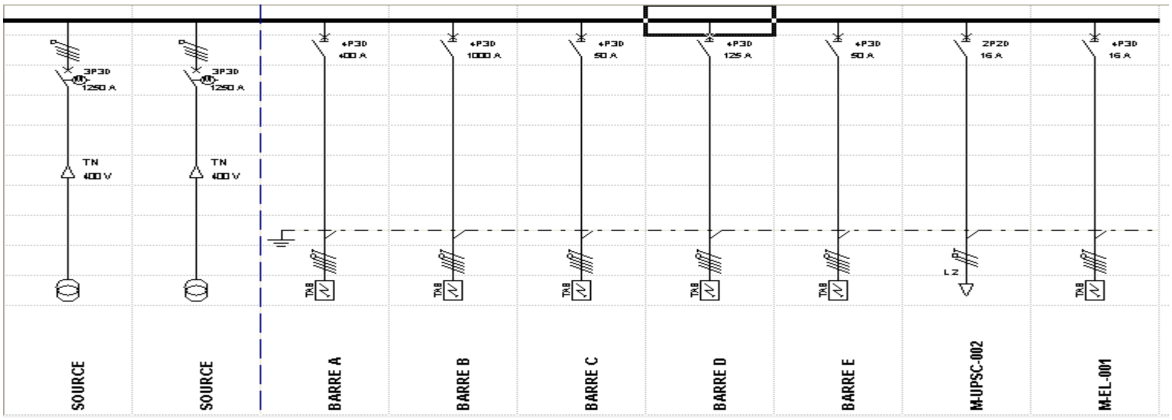


Figure III.6: Distribution panels

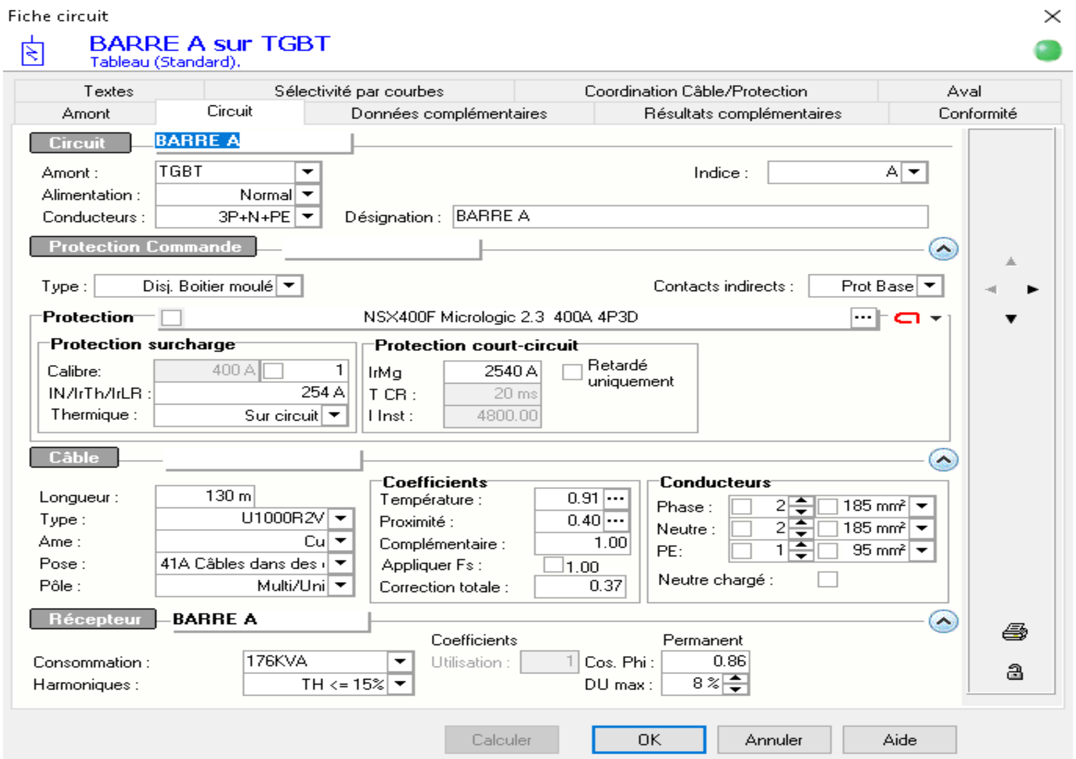


Figure III.7: Example of BARRE A settings

III.3.4 Loads settings:

After the settings of all the distribution panels, then each load must be set and attached to its panel

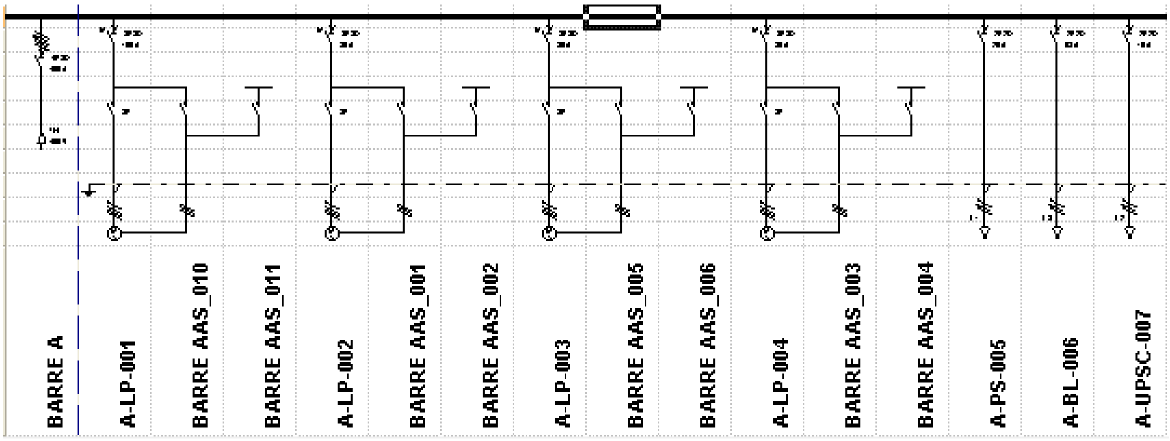


Figure III.8: All the loads of BARRE A

III.3.4 Simulation results:

III.3.4.1 Cables schedule :

Amont	Repère	Désignation	Longueur	Type de câble	Ame	Câble	Neutre
TGBT	BARRE A	BARRE A	130 m	U1000R2V	Cu	2X3X(1X185)	2X(1X185)
TGBT	BARRE B	BARRE A	12 m	U1000R2V	Cu	3X3X(1X500)	3X(1X500)
TGBT	BARRE C	BARRE C	70 m	U1000R2V	Cu	5G35	
TGBT	BARRE D	BARRE D	158 m	U1000R2V	Cu	3X(1X150)	1X150
TGBT	BARRE E	BARRE E	300 m	U1000R2V	Cu	4X50+G35	
TGBT	M-UPSC-002	UPC+Control circuit	10 m	U1000R2V	Cu	3G2.5	
TGBT	M-EL-001	DEPARTURE FEEDING LIGHTING PANEL	6 m	U1000R2V	Cu	5G2.5	
BARRE A	A-LP-001	LIFTING PUMP 1	6 m	U1000R2V	Cu	4G35	
BARRE A	A-LP-002	LIFTING PUMP 2	8 m	U1000R2V	Cu	4G16	
BARRE A	A-LP-003	LIFTING PUMP 3	10 m	U1000R2V	Cu	4G16	
BARRE A	A-LP-004	LIFTING PUMP 4	12 m	U1000R2V	Cu	4G16	
BARRE A	A-PS-005	POLICE STATION	135 m	U1000R2V	Cu	3G16	
BARRE A	A-BL-006	BUILDINGS	115 m	U1000R2V	Cu	3G25	
BARRE A	A-UPSC-007	UPC+Control circuit	138 m	U1000R2V	Cu	3G10	
BARRE B	B-AT-003	Aeration Turbine 1	134 m	U1000R2V	Cu	3X(1X150)	
BARRE B	B-AT-004	Aeration Turbine 2	159 m	U1000R2V	Cu	3X(1X150)	
BARRE B	B-AT-005	Aeration Turbine 3	182 m	U1000R2V	Cu	3X(1X150)	
BARRE B	B-AT-006	Aeration Turbine 4	112 m	U1000R2V	Cu	3X(1X150)	
BARRE B	B-AT-007	Aeration Turbine 5	135 m	U1000R2V	Cu	3X(1X150)	
BARRE B	B-AT-008	Aeration Turbine 6	159 m	U1000R2V	Cu	3X(1X150)	
BARRE B	B-AT-009	Aeration Turbine 7	109 m	U1000R2V	Cu	3X(1X150)	
BARRE B	B-AT-010	Aeration Turbine 8	132 m	U1000R2V	Cu	3X(1X150)	
BARRE B	B-AT-011	Aeration Turbine 9	157 m	U1000R2V	Cu	3X(1X150)	
BARRE B	B-AT-012	Aeration Turbine 10	132 m	U1000R2V	Cu	3X(1X150)	
BARRE B	B-AT-013	Aeration Turbine 11	156 m	U1000R2V	Cu	3X(1X150)	
BARRE B	B-AT-014	Aeration Turbine 12	180 m	U1000R2V	Cu	3X(1X150)	
BARRE B	B-WSP-001	SYSTEM PUMP 1	89 m	U1000R2V	Cu	4G10	
BARRE B	B-WSP-002	SYSTEM PUMP 2	90 m	U1000R2V	Cu	4G10	
BARRE B	B-UPSC-015	UPC+Control circuit	33 m	U1000R2V	Cu	3G2.5	
BARRE C	C-AB-006	AIR BOOSTER 1	10 m	U1000R2V	Cu	4G2.5	
BARRE C	C-AB-007	AIR BOOSTER 2	8 m	U1000R2V	Cu	4G2.5	
BARRE C	C-AB-008	AIR BOOSTER 3	6 m	U1000R2V	Cu	4G2.5	
BARRE C	C-SC-004	SAND CLASSIFIER 1	35 m	U1000R2V	Cu	4G2.5	
BARRE C	C-SC-005	SAND CLASSIFIER 2	45 m	U1000R2V	Cu	4G2.5	
BARRE C	C-DPSOS-002	DEPARTURE FEEDING PANEL OF SO SEPARATOR 1	30 m	U1000R2V	Cu	5G6	
BARRE C	C-DPSOS-003	DEPARTURE FEEDING PANEL OF SO SEPARATOR 2	42 m	U1000R2V	Cu	5G25	

Amont	Repère	Désignation	Longueur	Type de câble	Ame	Câble	Neutre
BARRE C	C-DPCSC-001	DEPARTURE FEEDING PANEL OF SCREW CONVEYOR	61 m	U1000R2V	Cu	5G25	
BARRE C	C-UPSC-009	UPC+Control circuit	60 m	U1000R2V	Cu	3G4	
BARRE D	D-RS-003	RECIRCULATION SCREW 1	5 m	U1000R2V	Cu	4G2.5	
BARRE D	D-RS-004	RECIRCULATION SCREW 2	7 m	U1000R2V	Cu	4G2.5	
BARRE D	D-RS-005	RECIRCULATION SCREW 3	8 m	U1000R2V	Cu	4G2.5	
BARRE D	BARRE DM006	RECIRCULATION SCREW 4	10 m	U1000R2V	Cu	4G2.5	
BARRE D	D-EMP-007	EXCESS MUD PUMP 1	34 m	U1000R2V	Cu	4G2.5	
BARRE D	D-EMP-008	EXCESS MUD PUMP 2	38 m	U1000R2V	Cu	4G2.5	
BARRE D	D-CL-001	Sereco PRTP Clarifier 1	47 m	U1000R2V	Cu	4G2.5	
BARRE D	D-CL-002	Sereco PRTP Clarifier 2	63 m	U1000R2V	Cu	4G2.5	
BARRE D	D-UPSC-011	UPC+Control circuit	153 m	U1000R2V	Cu	3G10	
BARRE E	E-MP-002	MUD PUMP 1	4 m	U1000R2V	Cu	4G2.5	
BARRE E	E-MP-003	MUD PUMP 2	3 m	U1000R2V	Cu	4G2.5	
BARRE E	E-TH-001	THICKNER	20 m	U1000R2V	Cu	4G2.5	
BARRE E	E-UPSC-004	UPC+Control circuit	290 m	U1000R2V	Cu	3G25	
M-EL-001	ECL01	LIGHTING CIRCUIT 1	610 m	U1000R2V	Cu	3G35	
M-EL-001	ECL02	LIGHTING CIRCUIT 1	479 m	U1000R2V	Cu	3G25	
M-EL-001	ECL03	LIGHTING CIRCUIT 3	608 m	U1000R2V	Cu	3G25	

Table III.1: Cables schedule

III.3.4.2 Circuit Breakers schedule:

Repère	Type Protection	IB	Bloc de coupure	Bloc déclencheur	Bloc différentiel	Calibre	IrTh / IN	IZ	IrMg / IN	IInstant	Tempo	IInstantOnOff	Ir Mg Max
BARRE A	Disj. Boitier moul	254.00 A	NSX400F	Micrologic 2.3		400 A	254.00	271.83 A	2540.0	4800.00	20 ms		3667 A
BARRE B	Disj. Boitier moul	824.20 A	NS1000N	Micrologic 2.0		1000 A	825.00	846.17 A	8250.0	0.00	20 ms		11170 A
BARRE C	Disj. Boitier moul	44.70 A	NSX100F	TM50D		50 A	45.00	48.01 A	500.0	0.00			1824 A
BARRE D	Disj. Boitier moul	112.70 A	NSX160F	TM125D		125 A	112.70	119.22 A	1250.0	0.00			1678 A
BARRE E	Disj. Boitier moul	42.30 A	NSX100F	TM50D		50 A	43.00	60.00 A	500.0	0.00			536 A
M-UPSC-002	Disj. Boitier moul	5.86 A	NSX100F	TM16D		16 A	11.20	13.25 A	190.0	0.00			973 A
M-EL-001	Disj. Boitier moul	11.70 A	NSX100F	TM16D		16 A	11.70	20.71 A	190.0	0.00			1575 A
A-LP-001	Disjonct. Mot	109.10 A	NSX160F	Micrologic 2.2M		150 A	110.00	108.11 A	1430.0	2250.00	20 ms		3104 A
A-LP-002	Disjonct. Mot	68.40 A	NSX100F	Micrologic 6.2EM		80 A	69.00	68.56 A	897.0	1200.00	20 ms		2551 A
A-LP-003	Disjonct. Mot	68.40 A	NSX100F	Micrologic 6.2EM		80 A	69.00	68.56 A	897.0	1200.00	20 ms		2383 A
A-LP-004	Disjonct. Mot	68.40 A	NSX100F	Micrologic 6.2EM		80 A	69.00	68.56 A	897.0	1200.00	20 ms		2234 A
A-PS-005	Disj. Boitier moul	21.70 A	NSX100F	TM25D		25 A	21.70	62.52 A	300.0	0.00			426 A
A-BL-006	Disj. Boitier moul	59.50 A	NSX100F	TM63D		63 A	59.50	110.53 A	500.0	0.00			710 A
A-UPSC-007	Disj. Boitier moul	5.86 A	NSX100F	TM16D		16 A	11.20	46.65 A	190.0	0.00			273 A
B-AT-003	Disjonct. Mot	115.40 A	NSX160F	Micrologic 2.2M		150 A	116.00	119.22 A	1508.0	2250.00	20 ms		1999 A
B-AT-004	Disjonct. Mot	115.40 A	NSX160F	Micrologic 2.2M		150 A	116.00	119.22 A	1508.0	2250.00	20 ms		1721 A
B-AT-005	Disjonct. Mot	115.40 A	NSX160F	Micrologic 2.2M		150 A	116.00	119.22 A	1508.0	2250.00	20 ms		1526 A
B-AT-006	Disjonct. Mot	115.40 A	NSX160F	Micrologic 2.2M		150 A	116.00	119.22 A	1508.0	2250.00	20 ms		2327 A
B-AT-007	Disjonct. Mot	115.40 A	NSX160F	Micrologic 2.2M		150 A	116.00	119.22 A	1508.0	2250.00	20 ms		1986 A
B-AT-008	Disjonct. Mot	115.40 A	NSX160F	Micrologic 2.2M		150 A	116.00	119.22 A	1508.0	2250.00	20 ms		1721 A
B-AT-009	Disjonct. Mot	115.40 A	NSX160F	Micrologic 2.2M		150 A	116.00	119.22 A	1508.0	2250.00	20 ms		2381 A
B-AT-010	Disjonct. Mot	115.40 A	NSX160F	Micrologic 2.2M		150 A	116.00	119.22 A	1508.0	2250.00	20 ms		2025 A
B-AT-011	Disjonct. Mot	115.40 A	NSX160F	Micrologic 2.2M		150 A	116.00	119.22 A	1508.0	2250.00	20 ms		1741 A
B-AT-012	Disjonct. Mot	115.40 A	NSX160F	Micrologic 2.2M		150 A	116.00	119.22 A	1508.0	2250.00	20 ms		2025 A
B-AT-013	Disjonct. Mot	115.40 A	NSX160F	Micrologic 2.2M		150 A	116.00	119.22 A	1508.0	2250.00	20 ms		1750 A
B-AT-014	Disjonct. Mot	115.40 A	NSX160F	Micrologic 2.2M		150 A	116.00	119.22 A	1508.0	2250.00	20 ms		1541 A
B-WSP-001	Disjonct. Mot	29.90 A	NS100N	STR22ME		40 A	30.00	37.53 A	390.0	600.00			445 A
B-WSP-002	Disjonct. Mot	29.90 A	NS100N	STR22ME		40 A	30.00	37.53 A	390.0	600.00			441 A
B-UPSC-015	Disj. Boitier moul	5.86 A	NSX100F	TM16D		16 A	11.20	24.84 A	190.0	0.00			303 A
C-AB-005	Disjonct. Mot	10.90 A	P25M			14 A	11.00	22.14 A	168.0	0.00			656 A
C-AB-007	Disjonct. Mot	10.90 A	P25M			14 A	11.00	22.14 A	168.0	0.00			753 A
C-AB-008	Disjonct. Mot	20.90 A	P25M			23 A	21.00	22.14 A	276.0	0.00			883 A
C-SC-004	Disjonct. Mot	2.37 A	P25M			2.5 A	2.40	9.23 A	30.0	0.00			251 A
C-SC-005	Disjonct. Mot	2.37 A	P25M			2.5 A	2.40	9.23 A	30.0	0.00			201 A
C-DPSOS-002	Disj. Boitier moul	32.00 A	NSX100F	TM32D		32 A	32.00	39.13 A	400.0	0.00			564 A
C-DPSOS-003	Disj. Boitier moul	32.00 A	NSX100F	TM32D		32 A	32.00	38.90 A	400.0	0.00			1041 A
C-DPCSC-001	Disj. Boitier moul	32.00 A	NSX100F	TM32D		32 A	32.00	38.90 A	400.0	0.00			871 A
C-UPSC-009	Disj. Boitier moul	5.86 A	NSX100F	TM16D		16 A	11.20	14.65 A	190.0	0.00			236 A
D-RS-003	Disjonct. Mot	13.90 A	P25M			14 A	14.00	20.99 A	168.0	0.00			932 A
D-RS-004	Disjonct. Mot	13.90 A	P25M			14 A	14.00	20.99 A	168.0	0.00			789 A
D-RS-005	Disjonct. Mot	13.90 A	P25M			14 A	14.00	20.99 A	168.0	0.00			733 A
BARRE DM006	Disjonct. Mot	13.90 A	P25M			14 A	14.00	20.99 A	168.0	0.00			641 A
D-EMP-007	Disjonct. Mot	4.45 A	P25M			6.3 A	4.50	12.69 A	75.6	0.00			255 A
D-EMP-008	Disjonct. Mot	4.45 A	P25M			6.3 A	4.50	12.69 A	75.6	0.00			232 A
D-CL-001	Disjonct. Mot	1.56 A	P25M			1.6 A	1.60	12.69 A	19.2	0.00			192 A
D-CL-002	Disjonct. Mot	1.56 A	P25M			1.6 A	1.60	12.69 A	19.2	0.00			147 A
D-UPSC-011	Disj. Boitier moul	5.86 A	NSX100F	TM16D		16 A	11.20	25.92 A	190.0	0.00			230 A
E-MP-002	Disjonct. Mot	10.90 A	P25M			14 A	11.00	23.58 A	168.0	0.00			443 A
E-MP-003	Disjonct. Mot	10.90 A	P25M			14 A	11.00	23.58 A	168.0	0.00			464 A
E-TH-001	Disjonct. Mot	1.56 A	P25M			1.6 A	1.60	18.69 A	19.2	0.00			261 A
E-UPSC-004	Disj. Boitier moul	5.86 A	NSX100F	TM16D		16 A	11.20	44.21 A	190.0	0.00			211 A
ECL01	Disjonct. C	12.80 A	DT40			16 A		126.61 A	140.0	0.00			
ECL02	Disjonct. C	11.30 A	DT40			16 A		97.80 A	140.0	0.00			
ECL03	Disjonct. C	10.60 A	C60L			16 A		97.80 A	130.0	0.00			

Table III.2: Circuit Breakers schedule

III.4 Parameters and constraints

Ic: Installed current rating (A)

Ib: Base current rating (A)

Kd: Product of all the derating factors

Il: Full load current (A)

Ip: Protective device rating (A)

Cc: Circuit buried in the ground

Ca: Ambient temperature

Cs: Soil resistivity

Cd: Depth of burial

Ci: Thermal Insulation

It: The value of current for ingle circuit at ambient temperature

Cf: Semi-enclosed fuse to BS 3036

Cg: For grouping

V3ø: Three phase voltage drop (V)

I: current (A)

Rc: AC resistance of the cable (Ω/km)

Xc: AC reactance of the cable (Ω/km)

cos ø: Load power factor (pu)

L: Length of the cable (m)

A: Short circuit temperature rise

k: Cable material properties

III.5 Conclusion:

In this chapter the standards were used for dimensioning the cables that feed the installation using the calculation notes with the cable layout design, then the protection for all installations was selected based on the equipment rated current and the cable current.

For further confirmation and making sure the calculations were reliable caneco software was used, and the output results were satisfyingly.

CHAPTER IV : LIGHTING SYSTEM DESIGN

IV.1 Introduction:

Lighting represents 15% of the quantity of electricity consumed in industry and 40% in buildings [3]. Good lighting design is often the most overlooked aspect of lighting efficiency, and vice versa.

A lighting installation cannot be efficient AND attractive, without careful consideration of all the aspects of lighting design. This includes choice of lamps, control gear and luminaire, along with luminaire placement, use of day lighting and intelligent control such as motion detectors and automatic dimming. [23]

IV.2 Lighting design process

To achieve the best overall outcome in a lighting installation, it is important to avoid the tendency of rushing straight into luminaire selection before determining more broadly what is required from the system. The use of a structured design process helps to avoid this. The key steps in the design process are:

1. Identify the requirements
2. Determine the method of lighting
3. Select the lighting equipment
4. Calculate the lighting parameters and adjust the design as required
5. Determine the control system.
6. Check that the fittings to be installed are those that the design was based on
7. Inspect the installation upon completion and, if possible, a few months after occupation, to determine what worked and what didn't. This is the only way to build up experience to apply to future designs

The four initial stages are considered in more detail in the following sections [23]

IV.2.1 Identifying the requirements:

This involves gaining a full understanding of what the lighting installation is intended to achieve. This includes the:

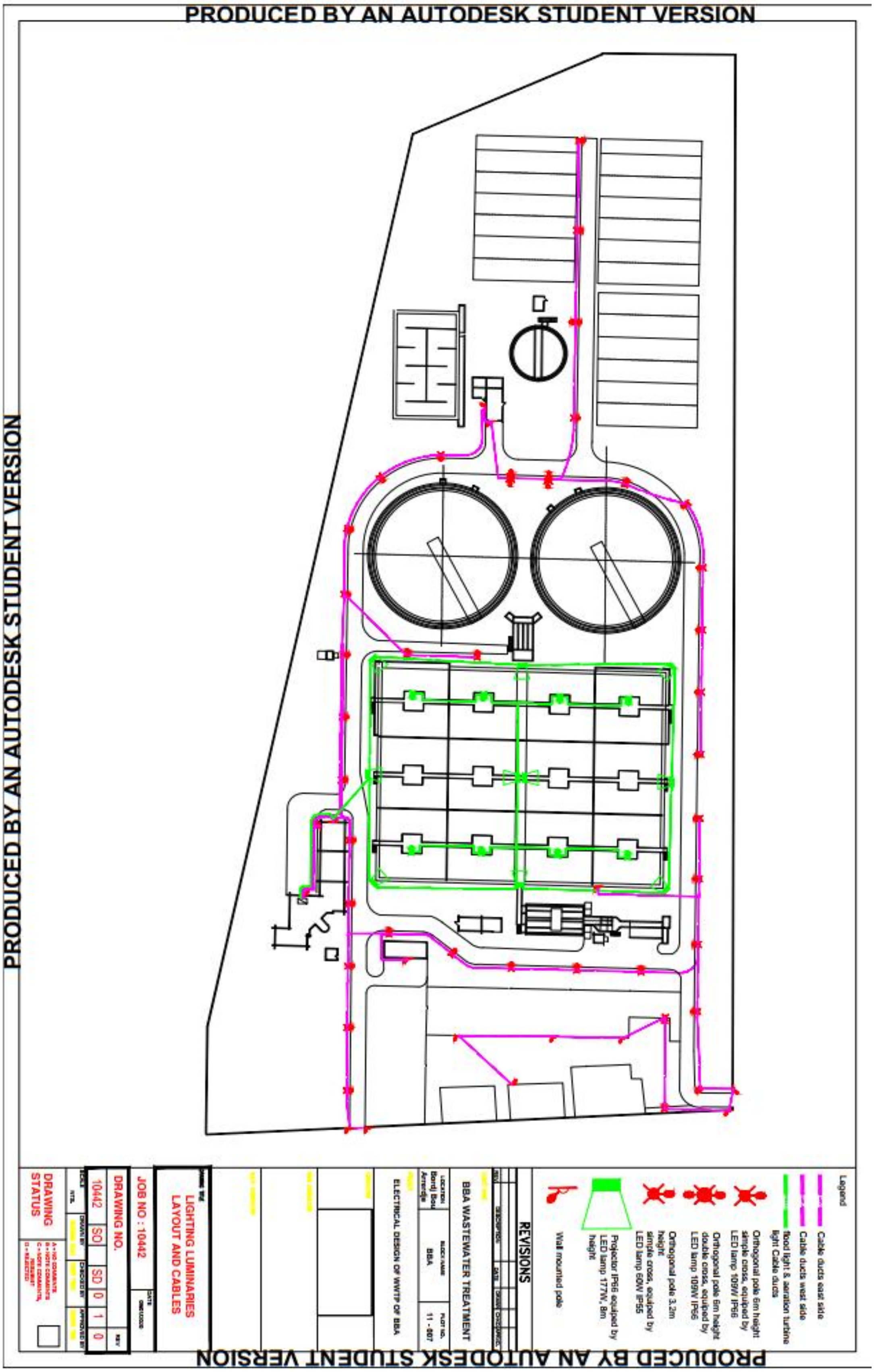
- Task Requirements: Illuminance & Glare
- Mood of the space
- Relation to shape of space
- Things to be emphasised
- Things to hide
- Direction of light
- Interaction of daylight [23]

In our project we are going to design a lighting system for the outdoor Wastewater treatment plant, including parking, facility roads, and the places where the main treatment processes are located. We are going to use simple cross and double cross luminaire poles for the parking and roads, and projectors for the Aeration tanks.

According to **EN 12464-2** (October 2007) the required illuminance for parking areas is **20lx**. [5]

The AutoCAD file below shows how luminaires and projectors are distributed as well as the lighting cables' ways

Figure IV.1: luminaires and cable layout



IV.2.2 Determine the method of lighting

At this stage, consideration is given to how the light is to be delivered, e.g. will it be recessed, surface mounted, direct or indirect, or will up-lighting be used, and its primary characteristics, e.g. will it be prismatic, low brightness or mellow light. Consideration should be given at this stage to the use of daylight to minimise the need for artificial light. [23]

The bright, uniform illumination of LED lighting diminishes shadows and improves visibility, helping people feel safer and more comfortable, without forgetting energy saving which is one of the most important characteristics of LED lamps. In our project, 6m height simple cross or double cross poles equipped with LED lamps are distributed all over the facility as shown before. The flood light luminaires are also equipped with LED lamps and mounted on an 8m height poles.

IV.2.3 Select the lighting equipment

Once the method of lighting has been selected, the most appropriate light source can then be chosen followed by the luminaire. The following attributes should be studied when choosing the light source:

- Light output (lumens)
- Total input wattage
- Efficacy (lumens per Watt)
- Lifetime
- Physical size
- Surface brightness / glare
- Colour characteristics
- Electrical characteristics
- Requirement for control gear
- Compatibility with existing electrical system
- Suitability for the operating environment [23]

IV.2.4 Calculate the lighting parameters

There are a wide range of manual computation methods for the calculation of different lighting aspects. These include complex methods for calculating the illuminance from a wide variety of shapes of luminous objects. The majority of these have now been superseded by computer programs. One of these programs is the DIALUX EVO software.

DIALUX EVO allows the engineers to draw the 3D model of the project, calculate the lighting parameters and select the appropriate lighting equipment.[23]

Basic parameters used in lighting:

Luminous flux – Luminous intensity – Illuminance – Luminance

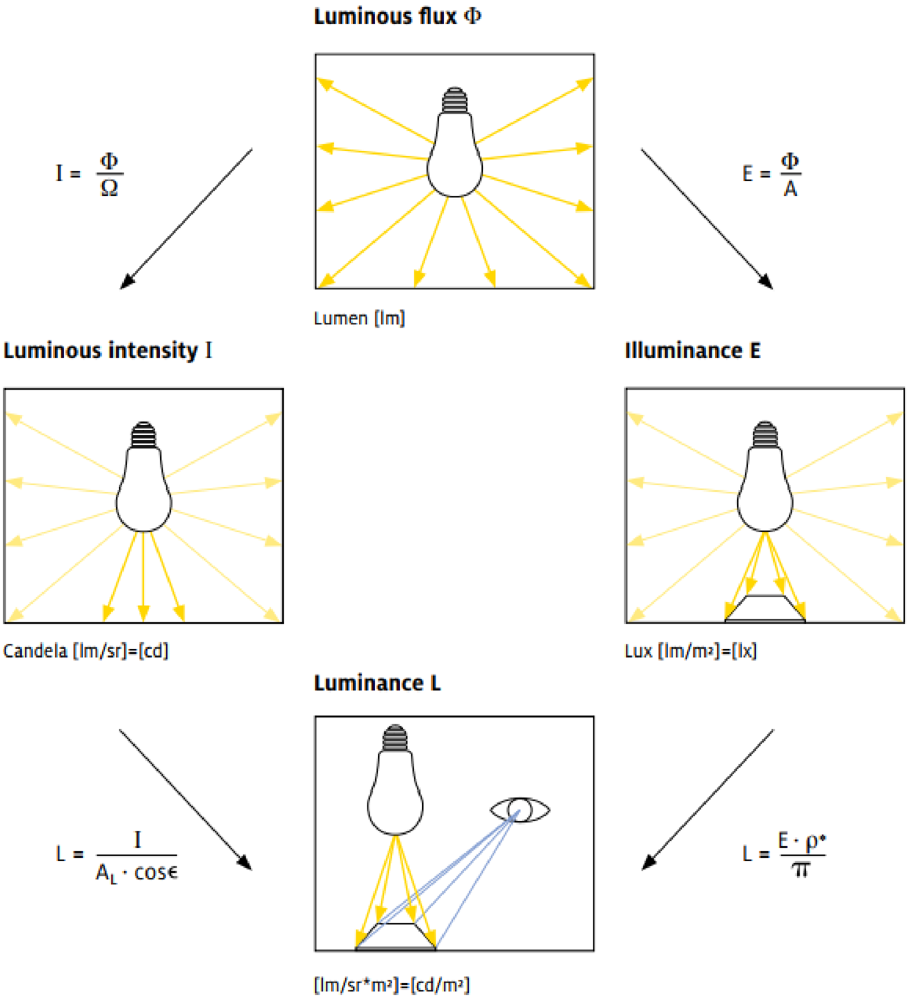


Figure IV.2: Basic lighting parameters

Ω = solid angle into which luminous flux is emitted

A = area hit by luminous flux

$A_L . \cos \in$ = visible areas of light source

ρ = reflectance of area

π = 3.14

* = for diffuse surface areas [24]

- **Luminous flux**: The *luminous flux* describes the quantity of light emitted by a light source. The *luminous efficiency* is the ratio of the luminous flux to the electrical power consumed (lm/W). It is a measure of a light source’s economic efficiency.
  Abbreviation: Φ Phi Unit: lm Lumen
- **Luminous intensity:** The *luminous intensity* describes the quantity of light that is radiated in a particular direction. This is a useful measurement for directive

lighting elements such as reflectors. It is represented by the *luminous intensity distribution curve* (LDC).
Abbreviation: I Unit: cd Candela

- **Illuminance:** *Illuminance* describes the quantity of luminous flux falling on a surface. Relevant standards specify the required illuminance (Parking Areas illuminance is 20 lx according to **EN 12464-2** (October 2007) standards).
  Abbreviation: E Unit: lx Lux
- **Luminance:** *Luminance* is the only basic lighting parameter that is perceived by the eye. It describes on the one hand a light source's impression of brightness, and on the other, a surface and therefore depends to a large extent on the degree of reflection (colour and surface).
  Abbreviation: L Unit: cd/m2 [24]

IV.3 Calculation and design using DIALUX EVO software

IV.3.1 Drawing 3D model of the station

First step is to import the AutoCAD file of the station layout to DIALUX EVO software, and then we start using the software tools to get the 3D model of the station. The drawing is shown in the figure below:

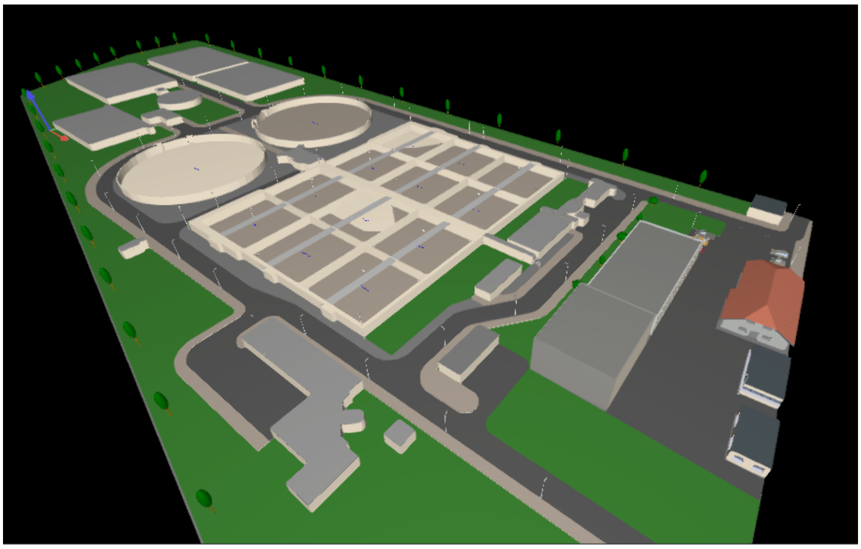


Figure IV.3: 3D model of the station

IV.3.2 Luminaire layout plan

The next step is to set up the luminaires all over the staion, the numbers from 1 to 64 on the figure below show how the luminaires are distributed on the station

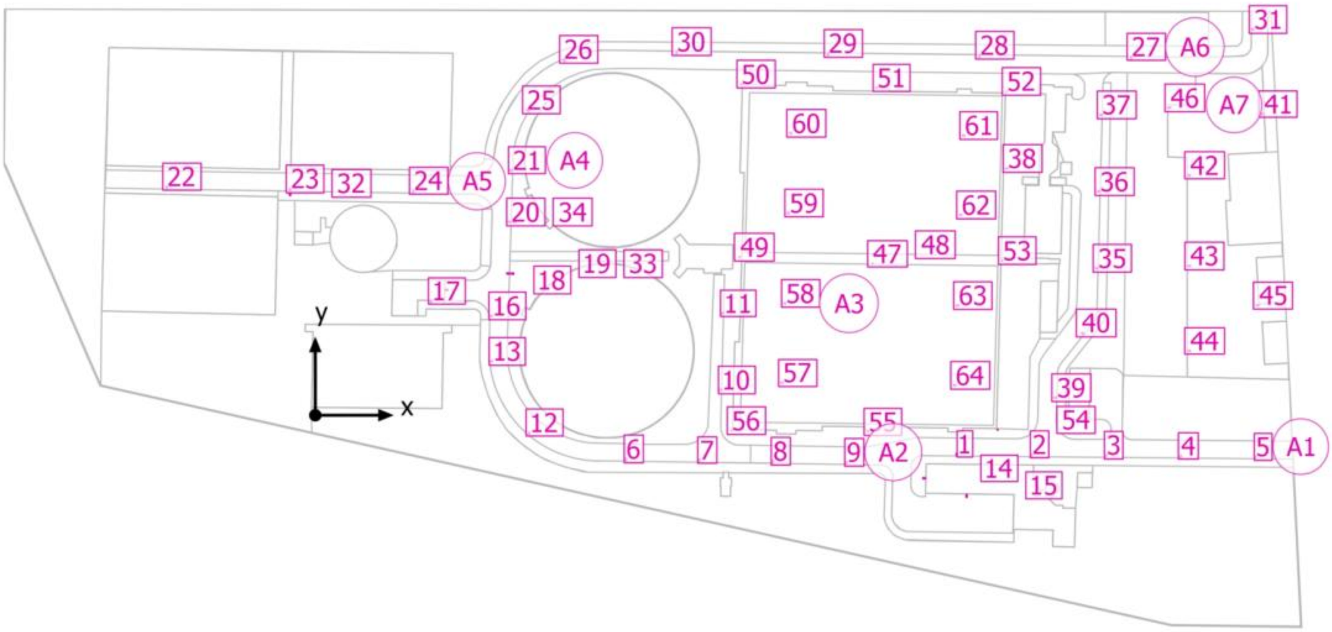


Figure IV.4: luminaire layout plan

IV.3.3 Luminaire list:

Φ_{total}	P_{total}	Luminous efficacy
719742 lm	7264.0 W	99.1 lm/W

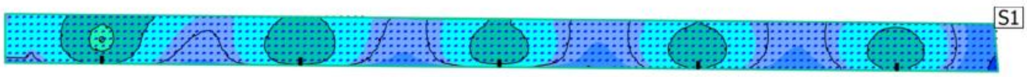
pcs.	Manufacturer	Article No.	Article name	P	Φ	Luminous efficacy	Index
10	APPLETON	AMLHL1W G7	AREAMASTER LED 24000 LUMENS NEMA 7X 6 CLEAR GLASS 3000 CCT	177.0 W	19753 lm	111.6 lm/W	
8	DW_WINDSO R	MOR L LED B	Monaro	60.0 W	4867 lm	81.1 lm/W	
46	WEEF	661-6355	VFL540-SE-LD-48/96 [S60.4K]	109.0 W	10506 lm	96.4 lm/W	

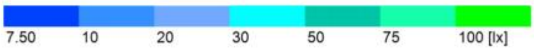
Table IV.1: Luminaire list

IV.3.4 Calculation surfaces:

Dialux evo allows the user to specify the surfaces that are assigned to be lighten. A minimum illuminance of 20lx (to **EN 12464-2** (October 2007) standards) should be provided on the specified surfaces by the installed luminaires, otherwise we should add or remove luminaires to reach the preferred value. After drawing the calculation surfaces and run the calculation, we can get the average value of the illuminance ($\bar{E}$) as well as the ISOLUX diagram which represents the illuminance distribution all over the specified surfaces.

Calculated surface (S1):





Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 2 Perpendicular illuminance Height: 0.100 m	38.6 lx	8.78 lx	80.5 lx	0.23	0.11	S1

Figure IV.5: ISOLUX diagram of surface (S1)

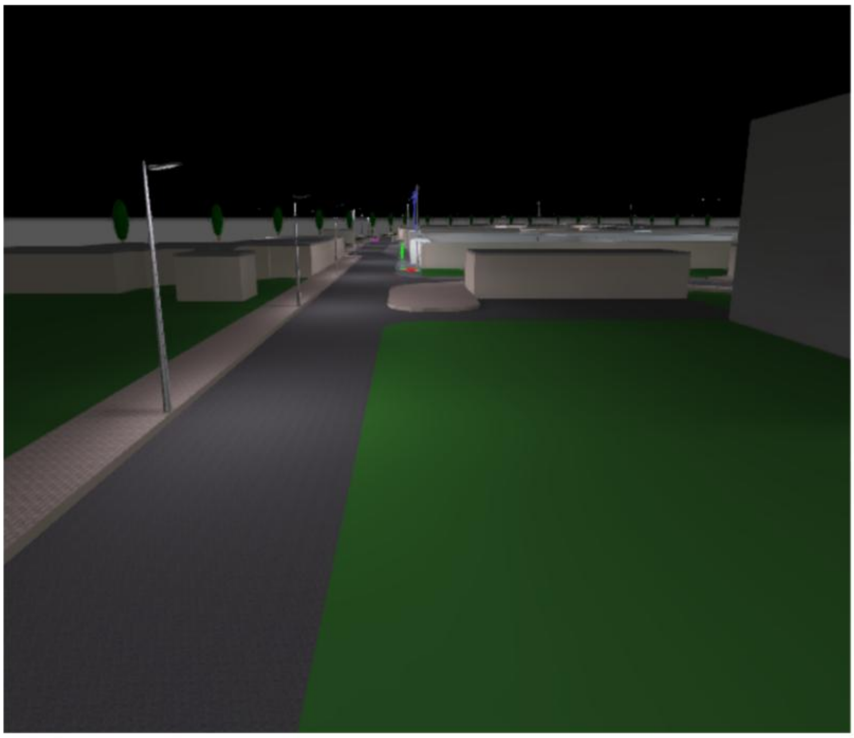


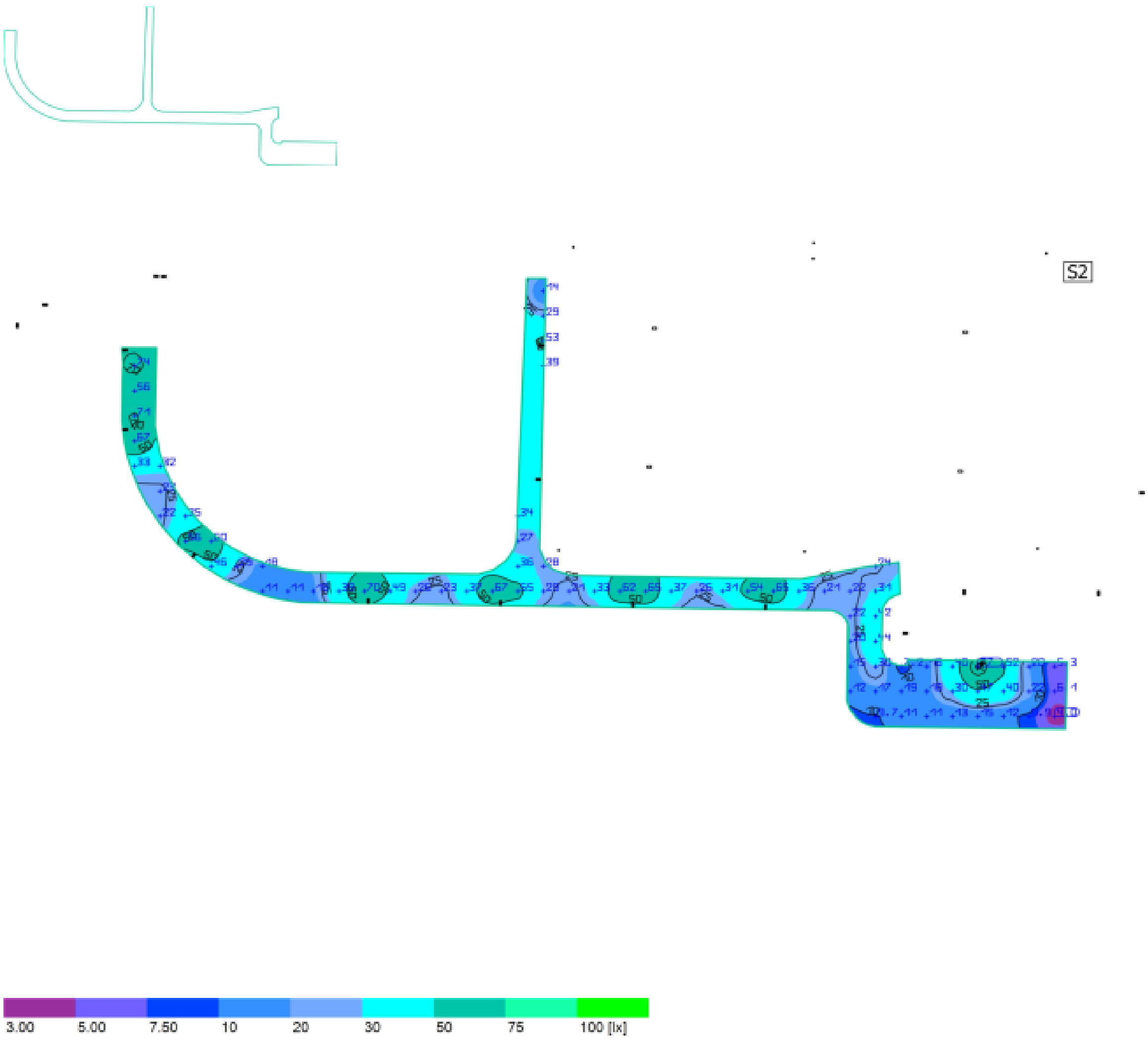
Figure IV.6 : Side view of surface (S1)

The mounting height of the luminaires is 6m, it cannot be controlled because the project construction is provided with 6m height poles.

We can notice from the ISOLUX diagram that the minimum illuminance values is 8.78lx located between the luminaires, however the maximum value is 80.5lx located exactly under the luminaires. The average value (Ē) is slightly bigger than the standard value, this is because if we remove one luminaires, the average illuminance becomes very low and we lose the visibility.

The same remarks have been forwarded to other surfaces.

Calculated surface (S2):



Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 3 Perpendicular illuminance Height: 0.100 m	32.5 lx	3.95 lx	76.8 lx	0.12	0.051	S2

Figure IV.7: ISOLUX diagram of surface (S2)

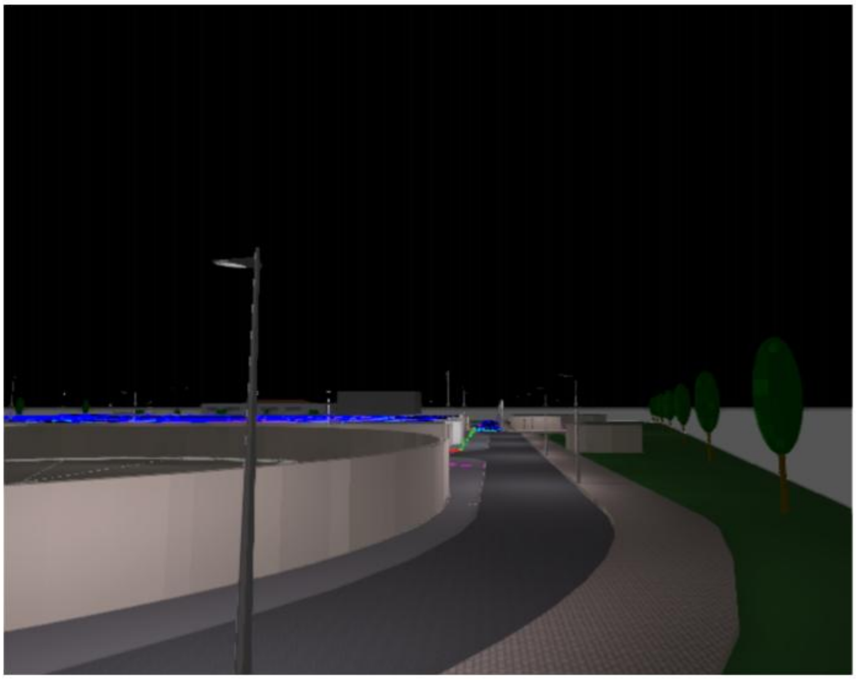
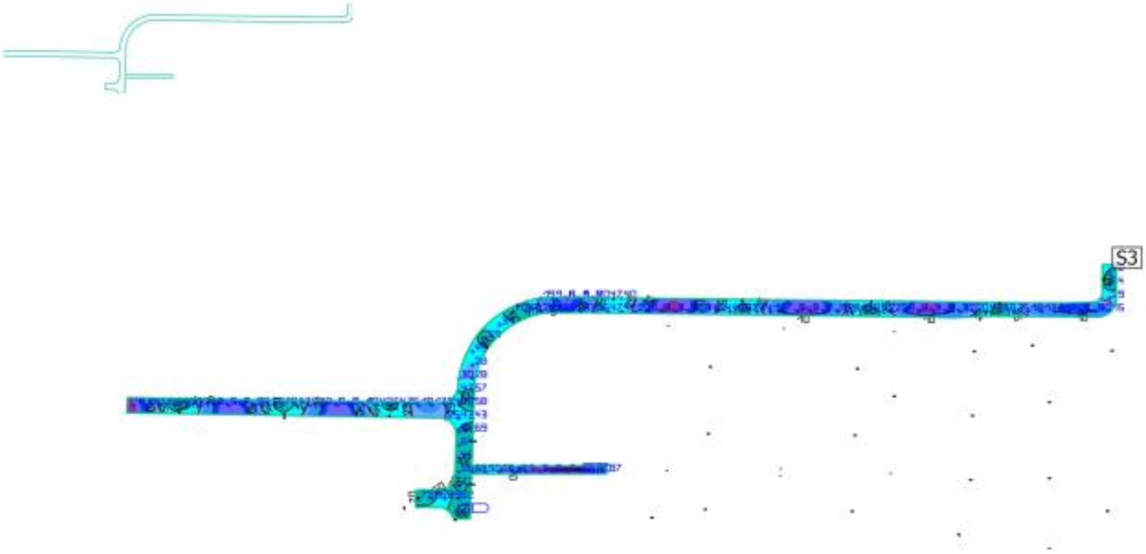


Figure IV.8: Side view of surface (S2)

Calculated surface (S3):



Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 4 Perpendicular illuminance Height: 0.300 m	29.6 lx	0.59 lx	78.4 lx	0.020	0.008	S3

Figure IV.9: ISOLUX diagram of surface (S3)

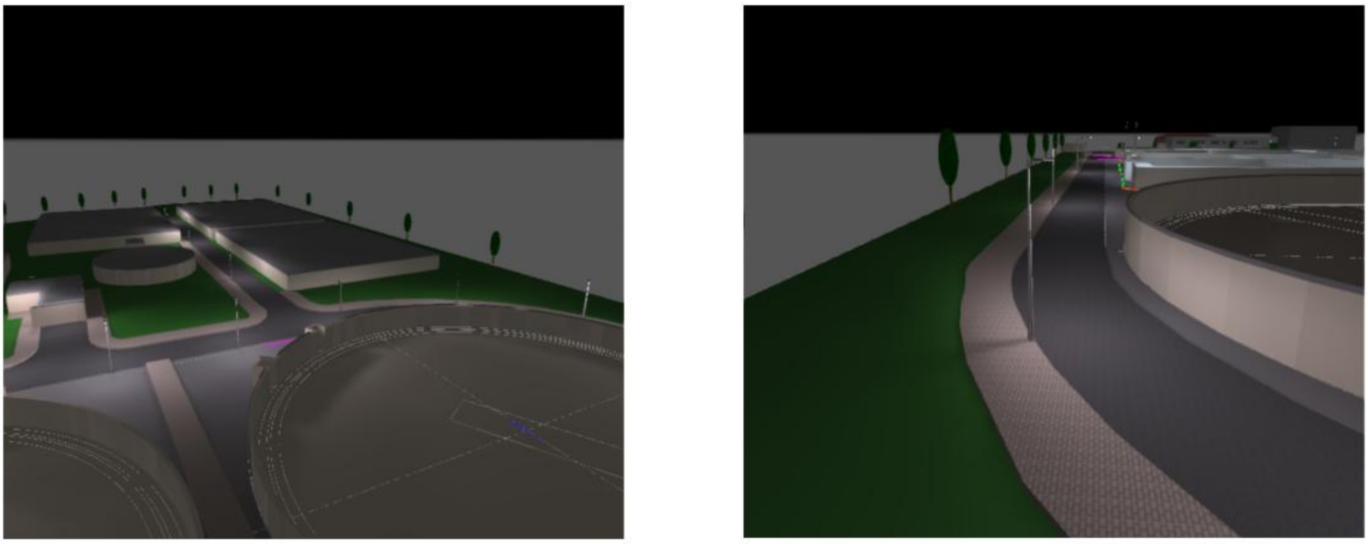
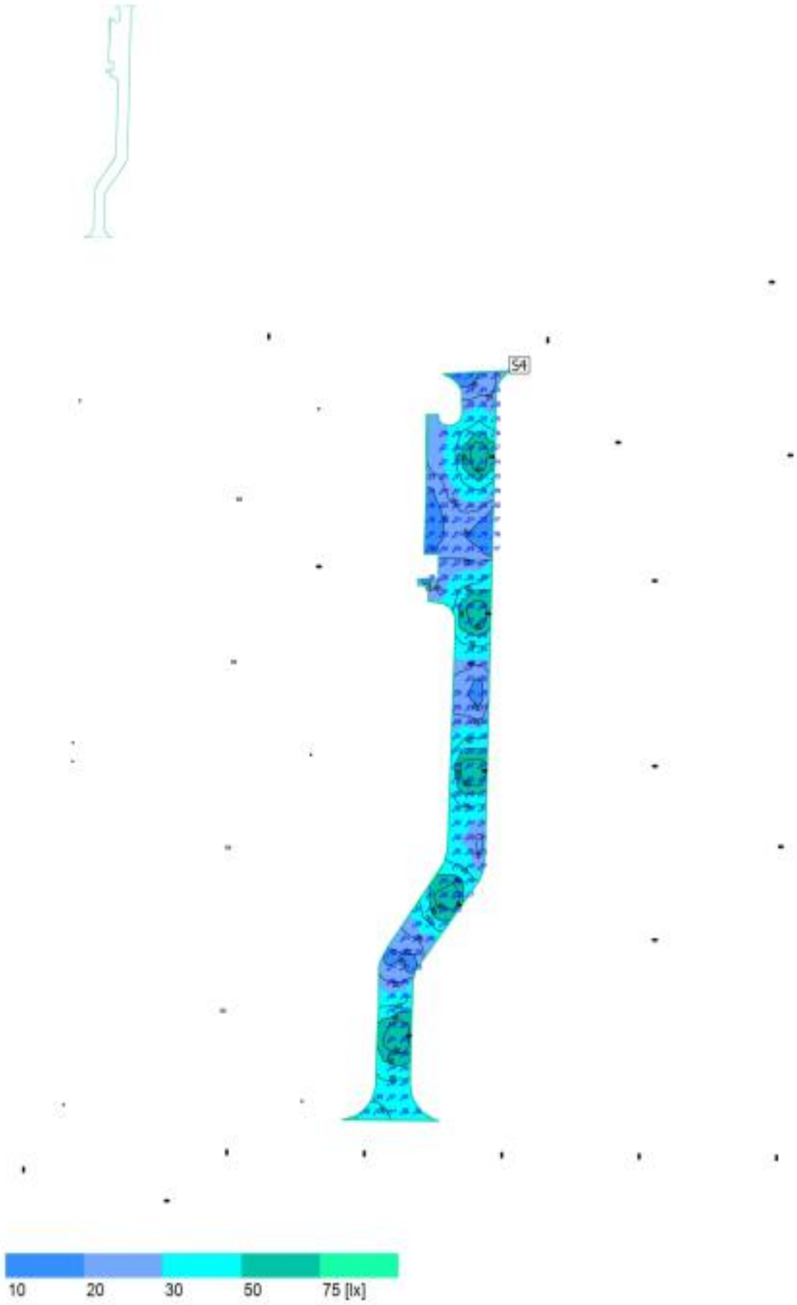


Figure IV.10 : Side view of surface (S3)

Calculated surface (S4):



Properties	$\bar{E}$	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 5 Perpendicular illuminance Height: 0.100 m	35.4 lx	10.4 lx	69.9 lx	0.29	0.15	S4

Figure IV.11: ISOLUX diagram of surface (S4)

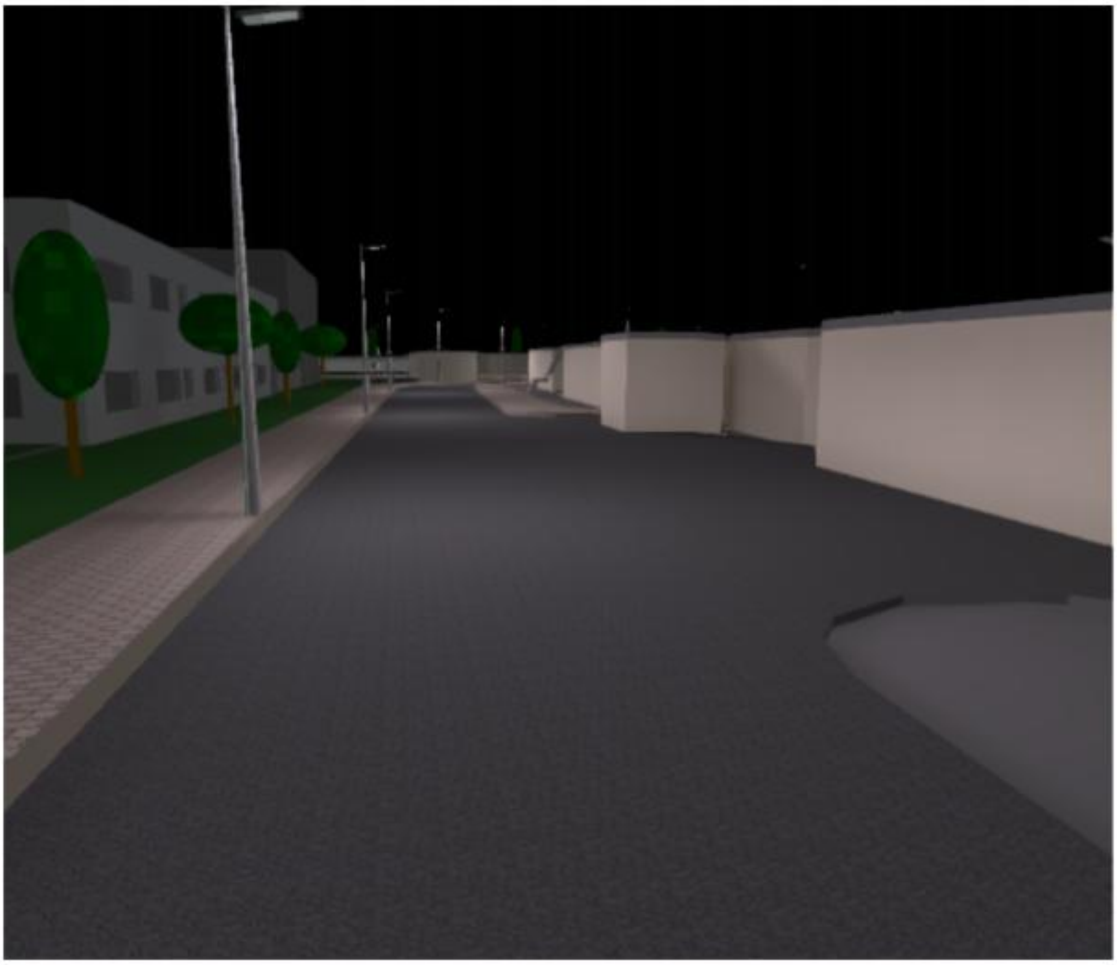
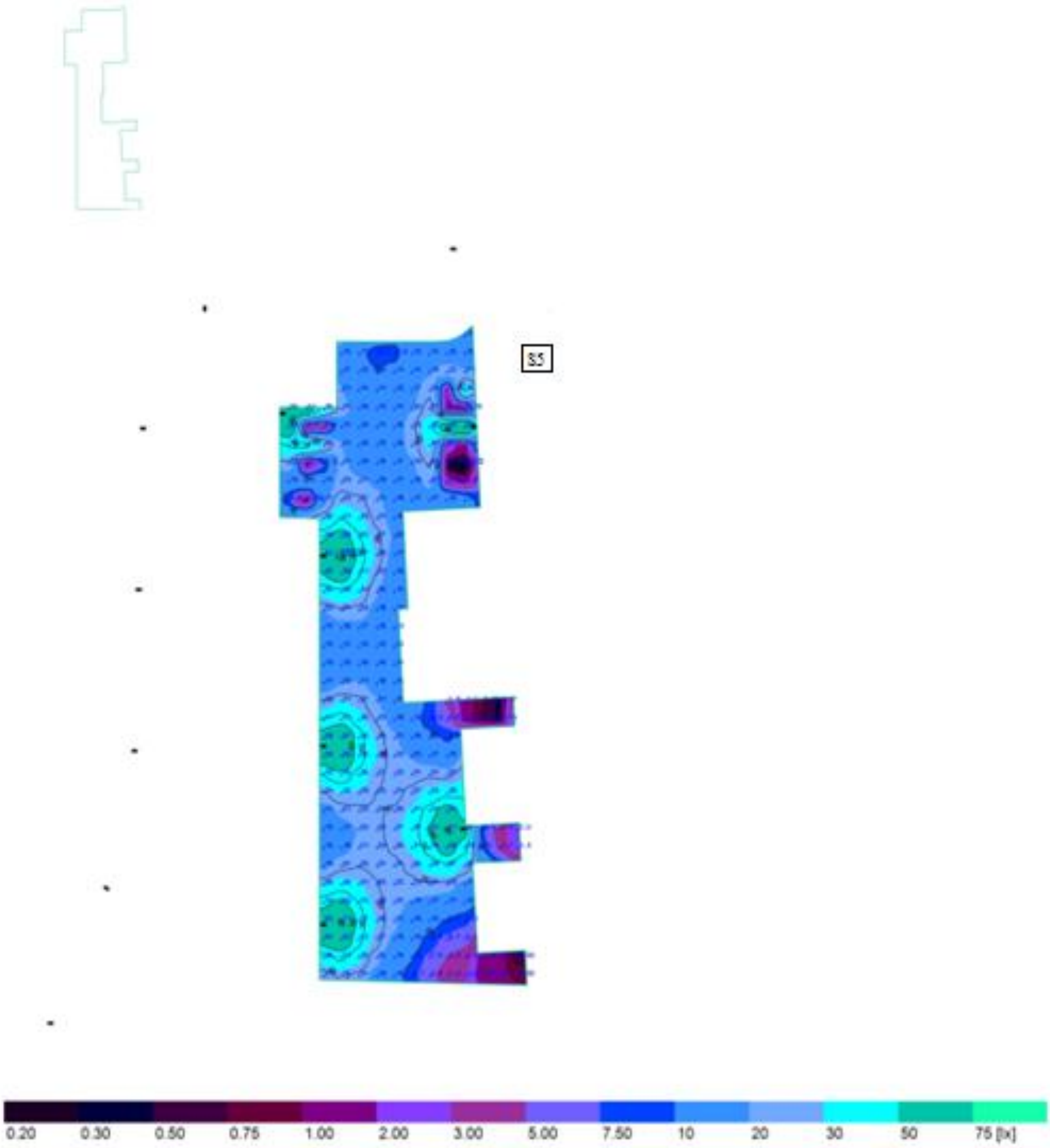


Figure IV.12: Side view of surface (S4)

Calculated surface (S5):

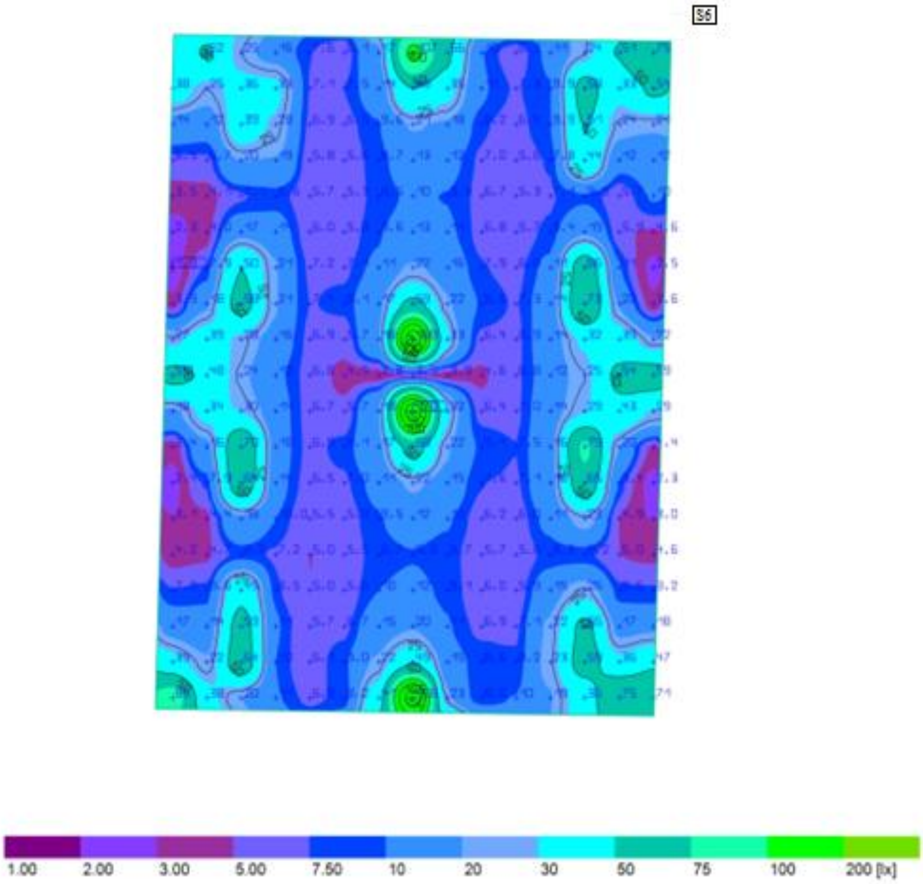


Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 6 Perpendicular illuminance Height: 0.100 m	22.9 lx	0.10 lx	71.7 lx	0.004	0.001	S5

Figure IV.13: ISOLUX diagram of surface (S5)

Figure IV.14 : Side views of surface (S5)

Calculated surface (S6):



Properties	Ē	E_{min}	E_{max}	g_1	g_2	Index
Calculation surface 7 Perpendicular illuminance Height: 2.800 m	20.3 lx	1.93 lx	170 lx	0.095	0.011	S6

Figure IV.15: ISOLUX diagram of surface (S6)

This surface is where the 12 aeration turbines are located. It is already known that this turbines need to be accessed by the technicians, so providing good illuminance in this area is very important. We can notice from the ISOLUX diagram that the walking roads are well illuminated (the green colours; about 50lx to 70lx), whereas, the blue and purple colours represent weak illuminance (3lx to 10lx) because there is no walking roads there.

We have used floodlights luminaires of 8m height poles surrounding the surface, and simple cross luminaires of 3.2m height located at each aeration turbine.

The following views represent how the surface is look like:

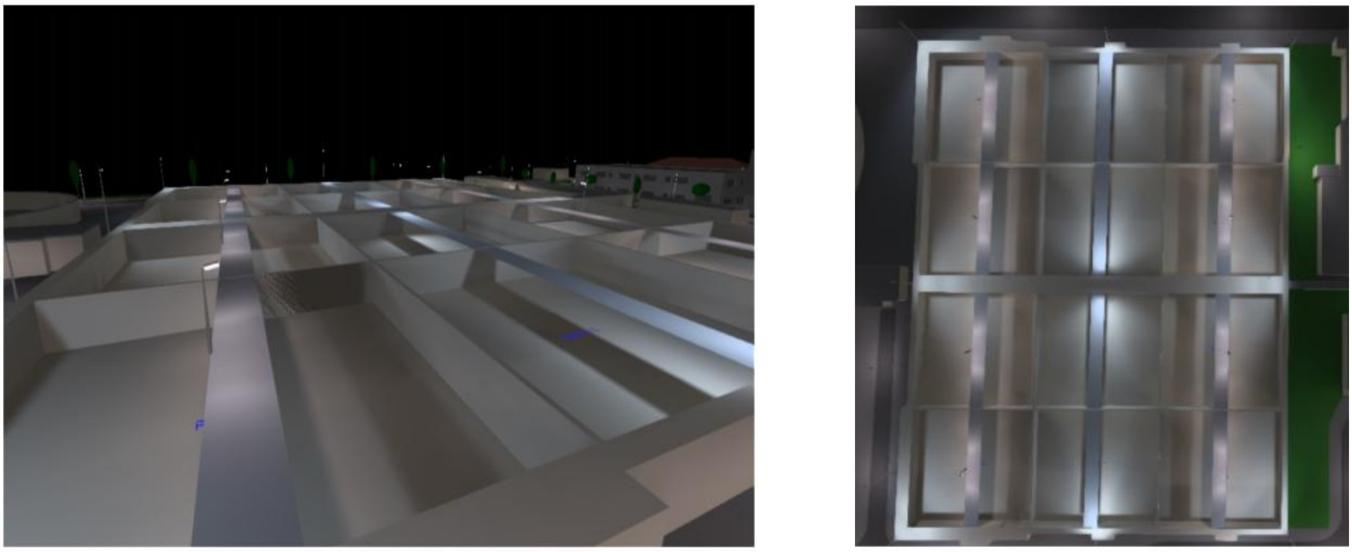


Figure IV.16: Side views of surface (S6)

IV.4 Conclusion:

The lighting design procedures have been done with the help of DIALUX EVO software, where we drew the 3D model of the station, installed the appropriate luminaires, run the calculation and obtaining the preferable result.

The night view of the overall station is shown below:

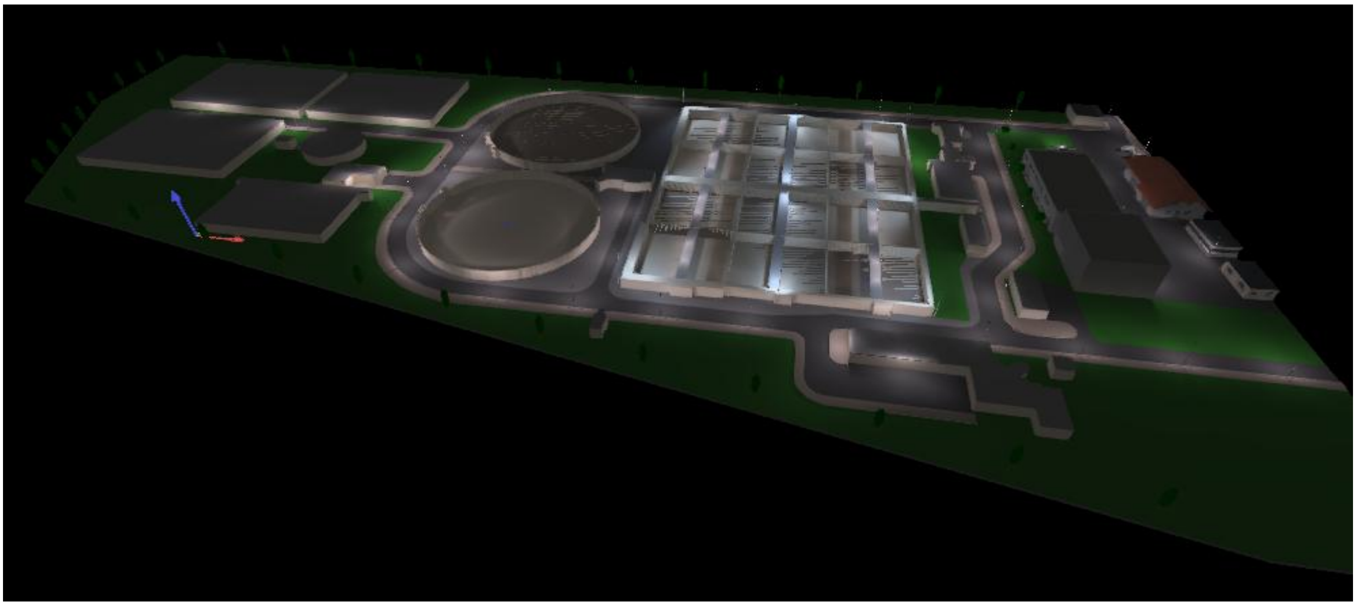


Figure IV.17: Night view of the overall station

CHAPTER V : EARTHING SYSTEM DESIGN

V.1 Introduction:

The earthing system in a plant / facility is very important for a few reasons, all of which are related to either the protection of people and equipment and/or the optimal operation of the electrical system. These include:

- Equipotential bonding of conductive objects (e.g. metallic equipment, buildings, piping etc) to the earthing system prevents the presence of dangerous voltages between objects (and earth).
- The earthing system provides a low resistance return path for earth faults within the plant, which protects both personnel and equipment
- For earth faults with return paths to offsite generation sources, a low resistance earthing grid relative to remote earth prevents dangerous ground potential rises (touch and step potentials)
- The earthing system provides a low resistance path (relative to remote earth) for voltage transients such as lightning and surges / overvoltages
- Equipotential bonding helps prevent electrostatic buildup and discharge, which can cause sparks with enough energy to ignite flammable atmospheres
- The earthing system provides a reference potential for electronic circuits and helps reduce electrical noise for electronic, instrumentation and communication systems [9]

V.2 Selection criteria for the TT, TN and IT systems

Selection does not depend on safety criteria. The three systems are equivalent in terms of protection of persons if all installation and operating rules are correctly followed.

The selection criteria for the best system(s) depend on the regulatory requirements, the required continuity of service, operating conditions and the types of network and loads. [3]

Table below shows in details Comparison of system earthing arrangements:

	TT	TN-S	TN-C	IT1[a]	IT2[b]	Comments
Electrical characteristics						
Fault current	-	- -	- -	+	- -	Only the IT system offers virtually negligible first-fault currents
Fault voltage	-	-	-	+	-	In the IT system, the touch voltage is very low for the first fault, but is considerable for the second
Touch voltage	+/- -	-	-	+	-	In the TT system, the touch voltage is very low if system is equipotential, otherwise it is high
Protection						
Protection of persons against indirect contact	+	+	+	+	+	All SEAs (system earthing arrangement) are equivalent, if the rules are followed
Protection of persons with emergency generating sets	+	-	-	+	-	Systems where protection is ensured by RCDs are not sensitive to a change in the internal impedance of the source
Protection against fire (with an RCD)	+	+	Not allowed	+	+	All SEAs in which RCDs can be used are equivalent. The TN-C system is forbidden on premises where there is a risk of fire
Overvoltages						
Continuous overvoltage	+	+	+	-	+	A phase-to-earth overvoltage is continuous in the IT system if there is a first insulation fault
Transient overvoltage	+	-	-	+	-	Systems with high fault currents may cause transient overvoltages
Overvoltage if transformer breakdown (primary/secondary)	-	+	+	+	+	In the TT system, there is a voltage imbalance between the different earth electrodes. The other systems are interconnected to a single earth electrode
Electromagnetic compatibility						
Immunity to nearby lightning strikes	-	+	+	+	+	In the TT system, there may be voltage imbalances between the earth electrodes. In the TT system, there is a significant current loop between the two separate earth electrodes
Immunity to lightning strikes on MV lines	-	-	-	-	-	All SEAs are equivalent when a MV line takes a direct lightning strike
Continuous emission of an electromagnetic field	+	+	-	+	+	Connection of the PEN to the metal structures of the building is conducive to the continuous generation of electromagnetic fields
Transient non-equipotentiality of the PE	+	-	-	+	-	The PE is no longer equipotential if there is a high fault current
Continuity of service						
Interruption for first fault	-	-	-	+	+	Only the IT system avoids tripping for the first insulation fault
Voltage dip during insulation fault	+	-	-	+	-	The TN-S, TNC and IT (2nd fault) systems generate high fault currents which may cause phase voltage dips
Installation						
Special devices	-	+	+	-	-	The TT system requires the use of RCDs. The IT system requires the use of IMDs
Number of earth electrodes	-	+	+	-/+	-/+	The TT system requires two distinct earth electrodes. The IT system offers a choice between one or two earth electrodes
Number of cables	-	-	+	-	-	Only the TN-C system offers, in certain cases, a reduction in the number of cables
Maintenance						
Cost of repairs	-	- -	- -	-	- -	The cost of repairs depends on the damage caused by the amplitude of the fault currents
Installation damage	+	-	-	++	-	Systems causing high fault currents require a check on the installation after clearing the fault

Table V.1: Comparison of earthing arrangements [4]

TN-C Earthing system type:

In the TN-C earthing system (which is the chosen system in our project) the source is earthed as for the TT system. In the installation side, all exposed and extraneous-conductive-parts are connected to the neutral conductor where the neutral conductor is also used as a protective conductor and is referred to as a PEN (**P**rotective **E**arth and **N**eutral) conductor. This system is not permitted for conductors of less than 10 mm2 or for portable equipment.

The PEN conductor must therefore be connected to a number of earth electrodes in the installation.

Caution: In the TN-C system, the “protective conductor” function has priority over the “neutral function”. In particular, a PEN conductor must always be connected to the earthing terminal of a load and a jumper is used to connect this terminal to the neutral terminal. [3]

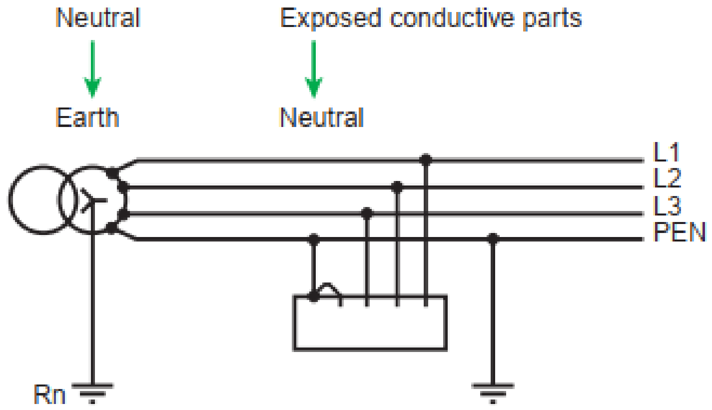


Figure V.1: TN-C system [3]

V.3 Sizing criterion

According to IEEE Std 142-2007 standards, Resistances in the 1 ohm to 5 ohm range are generally found suitable for earth protection in industrial plant substations and buildings and large commercial installations. [6]

V.4 Why do the calculation?

The grounding calculation aids in the proper design of the grounding system. Using the results of this calculation, we can:

- Determine the minimum size of the grounding conductors required for the main earth grid
- Ensure that the grounding design is appropriate to prevent dangerous step and touch potentials (if this is necessary) [9]

V.5 Prerequisites:

The following information is required / desirable before starting the calculation:

- Earthing loop layout
- Maximum earth fault current into the grounding grid
- Maximum fault clearing time [25]

V.5.1 Earthing loop layout

By using AutoCAD software, we drew the earthing loop of the system. The loop passes through all principle electric cabinet including the main distribution board.

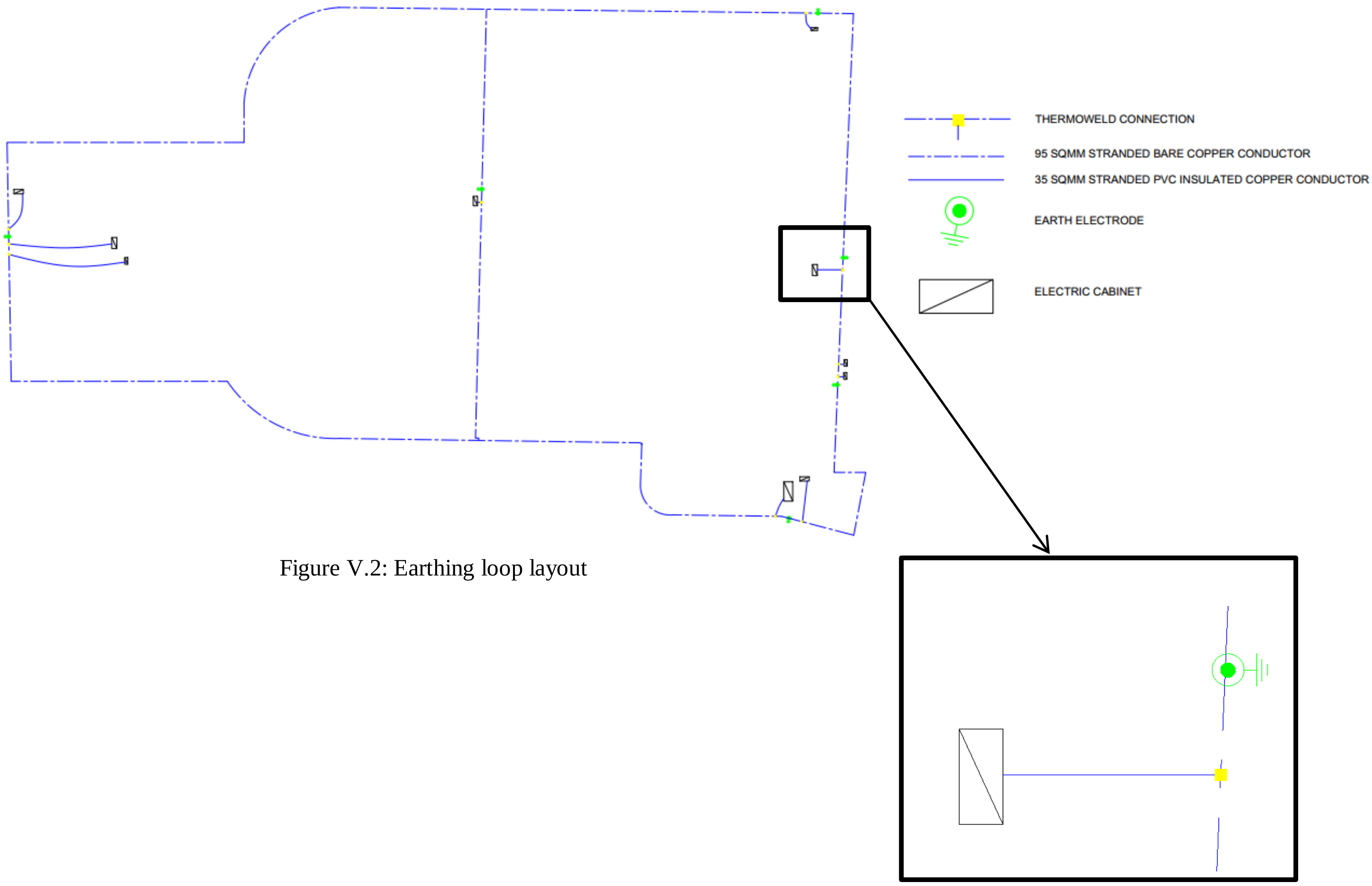


Figure V.2: Earthing loop layout

V.5.2 Short-circuit current at the secondary terminals of a MV/LV distribution transformer

Knowing the levels of 3-phase symmetrical short-circuit currents (Isc) at different points in an installation is an essential feature of its design

In a simplified approach, the impedance of the MV system is assumed to be negligibly small, so that :

$$I_{sc} = \frac{I_n \times 100}{U_{sc}} \quad \text{Where: } I_n = \frac{S \times 10^3}{U_{20}\sqrt{3}}$$

S = kVA rating of the transformer
U_{20} = phase-to-phase secondary volts on open circuit
In = nominal current in amps
Isc = short-circuit fault current in amps
Usc = short-circuit impedance voltage of the transformer in %.

Typical values of Usc for distribution transformers are given in the figure below

Transformer rating (kVA)	Usc in %	
	Oil-immersed	Cast-resin dry type
50 to 750	4	6
800 to 3200	6	6

Table V.2: Typical values of Usc for different KVA ratings of transformers with MV windings ≤20kV [3]

$$I_n = \frac{1250 \times 10^3}{400 \times \sqrt{3}} = 1804.22\ A$$

$$I_{sc} = \frac{1804.22 \times 100}{6} = 30.07\ KA$$

V.5.3 Maximum fault clearing time

The table below shows the maximum fault clearing time depends on the voltage level of the system

Rated voltages and maximum cut-off times for TN systems

Voltage U_0 in V	Cut-off time in s
230	0.4
400	0.2
> 400	0.1

Table V.3: maximum fault clearing [12]

V.6 Measurement of soil resistivity

The resistance to the earth of any earth electrode may be determined by the resistivity of the surrounding soil. Resistivity depends upon the soil structure, strata, rock formation.

The resistivity can change with:

- depth;
- temperature;
- moisture content; and
- can vary from place to place.

The design of the grounding installation may be started with knowledge of the soilresistivity. For example, for a simple installation the type and number of earth electrodes may be estimated and the separation needed of HV and LV earths may be determined. For grid substations sample measurements should be taken at many locations around the site and at various electrode depths.

Soil resistivity – Wenner test:

In a technique developed by Dr Frank Wenner of the U.S. Bureau of Standards (now NIST); it was demonstrated that provided the electrode depth (b) is small with respect to the spacing (a). The average soil resistivity ρ to a depth a in Ω.cm may be found from:

$$\rho = 2\,\pi\,a\,R$$

Where: π is the constant 3.1416;
a is the distance between the electrodes in cm; and
R (V/A) is the reading obtained from the Earth tester in ohms (Ω).

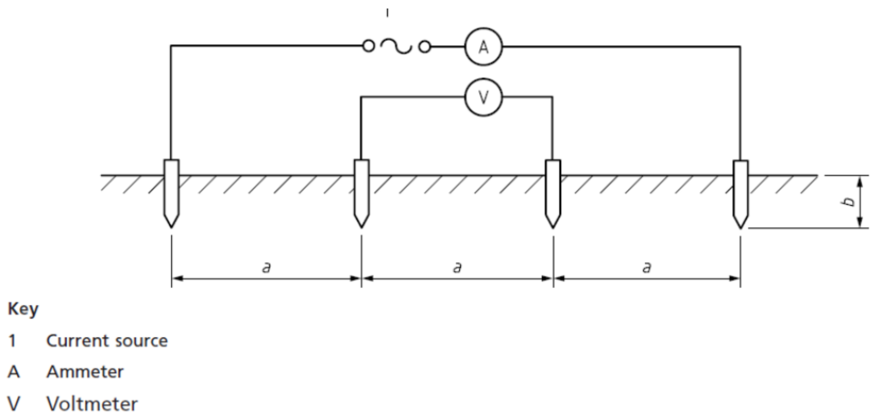


Figure V.3: Wenner test configuration

V.7 Ground Conductor Size

The required conductor size can be calculated using the Adiabatic method based on the following equation: [3]

$$S = \frac{\sqrt{I^2 .t}}{k}$$

Where: S - [mm²] PEN Conductor cross sectional area
I - [A] rms fault current.
t - [sec] Fault current duration (considered as 0.2 sec)
K – Material Constant from Table A.54 of IEC60364-4-54 (K = 143 for copper) [3]

$$S = \frac{\sqrt{30070^2 \times 0.2}}{143} = 94.04\ mm^2$$

The most appropriate standardized cable cross section is 95 mm^2

V.8 Single ground Rod Resistances

Based on the resistivity of the ground the resistance of earth rods of various depths can be calculated, Using Section 9.5.3 of BS7430-2011: [25]

$$R_{rod} = \frac{\rho}{2\pi L}[\ln\left(\frac{8L}{d}\right) - 1]$$

Where: ρ - [Ωm] Ground resistivity

L - [m] Length of rod

d - [m] Diameter of rod = 20mm

V.9 Multiple ground Rod Resistances

Using the single earth rod resistances in Section V.8 (Above), the values of groups of earth rods can be calculated.

Section 9.5.4 of BS7430-2011 allows the resistance of a group of earth rods connected in a straight line to be calculated using the equations:[25]

$$R_{t-rod} = \frac{1}{n}\frac{\rho}{2\pi L}\left[ln\left(\frac{8L}{d}\right) - 1 + \frac{L}{S}ln\left(\frac{1.78n}{2.718}\right)\right]$$

Where: ρ is the resistivity of soil, in ohm metres (Ωm);

L is the length of the electrode, in metres (m);

n is the number of rods;

s is the spacing between the rods, in metres (m).

V.10 Ground Conductor Resistances

Using the cross-section area of the main earth conductor in Section V.7 (Above), the resistance of the earth conductor can be calculated.

Section 9.5.5 of BS7430-2011 allows the resistance of round earth conductor to be calculated using the equations:[25]

$$R_{cond} = \frac{\rho}{2\pi L}ln\left(\frac{L^2}{1.85hd}\right)$$

Where: ρ is the resistivity of soil, in ohm metres (Ω.m);

L is the length of the main earth conductor, in metres (m);

h is the depth of the main earth conductor, in metres (m);

d is the diameter of the main earth conductor, in metres (m).

When two or more strips in straight lengths, each of length L in metres (m) and a separation distance s meters are laid parallel to each other, the combined resistance may be calculated from the following equation:

$$R_{n-cond} = F.R_{cond}$$

Where: Rn is the resistance of n conductors in parallel, in ohms (Ω)

R_{cond} is the resistance of a single strip of length L, calculated from the preceding $\boldsymbol{R_{cond}}$ equation, in ohms (Ω).

F has the following values:

$$\text{For Three lengths, } F_3 = 0.33 + \left[0.071\ \left(\frac{s}{L}\right)\right]^{-0.408}$$

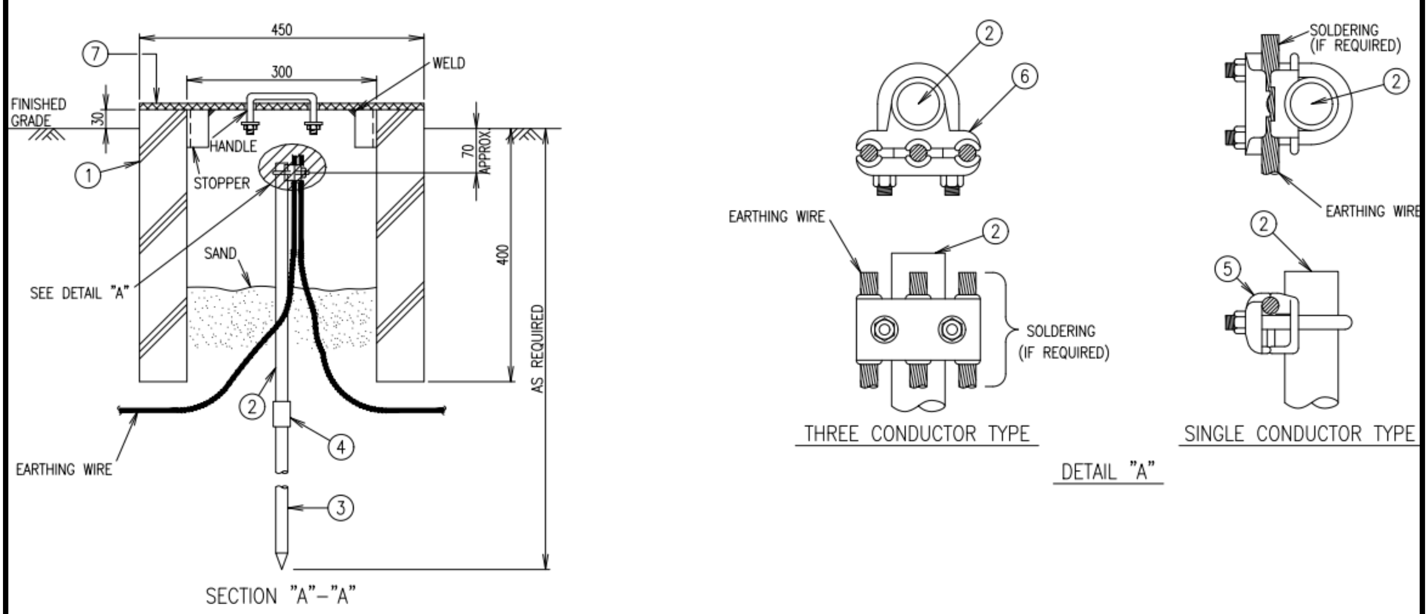
$$\text{For Two lengths, } F_2 = 0.5 + \left[0.078\ \left(\frac{s}{L}\right)\right]^{-0.307}$$

V.11 Total resistance of the grounding network:

The total resistance of the grounding network is calculated considering the earth conductor running in parallel with the earth rods' resistance.

$$\frac{1}{R} = \frac{1}{R_{t-rod}} + \frac{1}{R_{n-cond1}} + \frac{1}{R_{n-cond2}} + \cdots$$

This resistance can be reduced by encasing the earth rods in low resistivity materials as quested in BS 7430 (2011) section 9.5.7 [25]



NO.	MATERIAL NO. OR SYMBOL	DESCRIPTION OR SPECIFICATION
1	401J	CONCRETE INSPECTION PIT (SQUARE TYPE)
2	401A-A	COPPER ROD DRIVING SIDE, 3/4"ø 1800L
3	401A-A	COPPER ROD COUPLING SIDE, 3/4"ø 1800L
4	401B-A	COUPLING FOR COPPER ROD
5	116A-A	EARTH CLAMP FOR SINGLE CONDUCTOR
6	116A-B	EARTH CLAMP FOR THREE CONDUCTOR
7	401H	INSPECTION PIT COVER (STEEL PLATE 5t) WITH STOPPER (L-50x50x5tx50L) AND HANDLE

Figure V.4: Electrode – earthing cable connection and some earthing details

V.12 Calculation Via software:

Since the earthing loop in our case is not uniform, preceding the manual calculation is very difficult. CYMGrd 6.3 software based on IEEE-std 80 is used to get the grounding network resistance.

- First the structure layout is imported from AutoCAD in (.dwg) format
- Details of the earth conductor and rods including cross section diameter and electrode length are entered.
- Soil parameters and grid parameters are also entered to the software

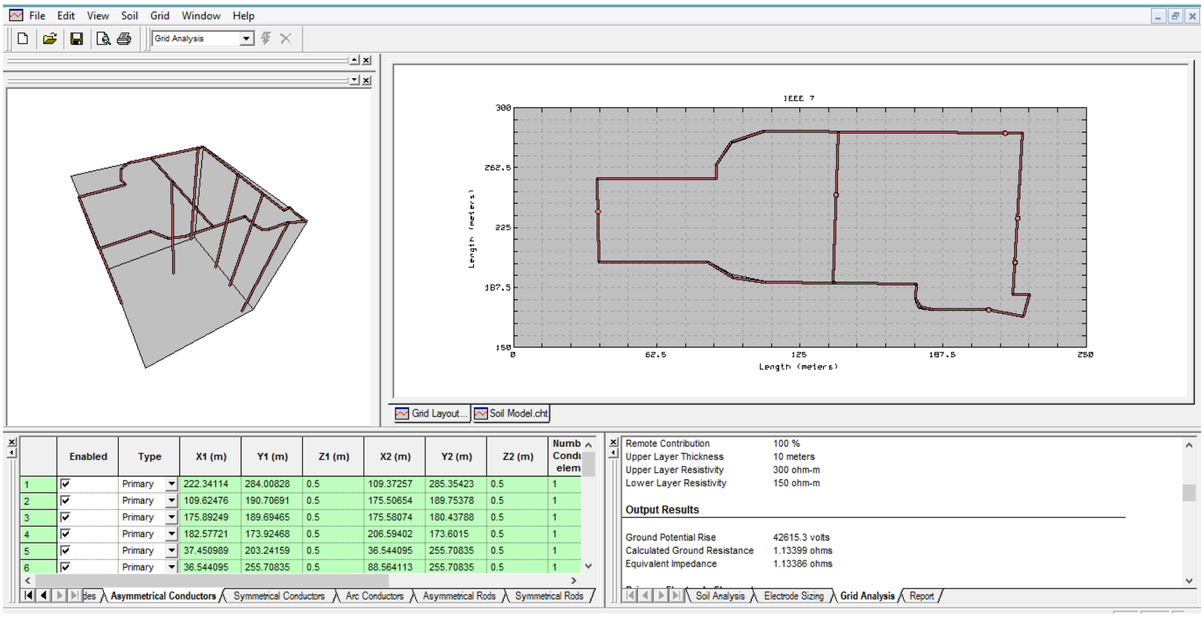


Figure V.5: Earthing layout on CYMGRD software

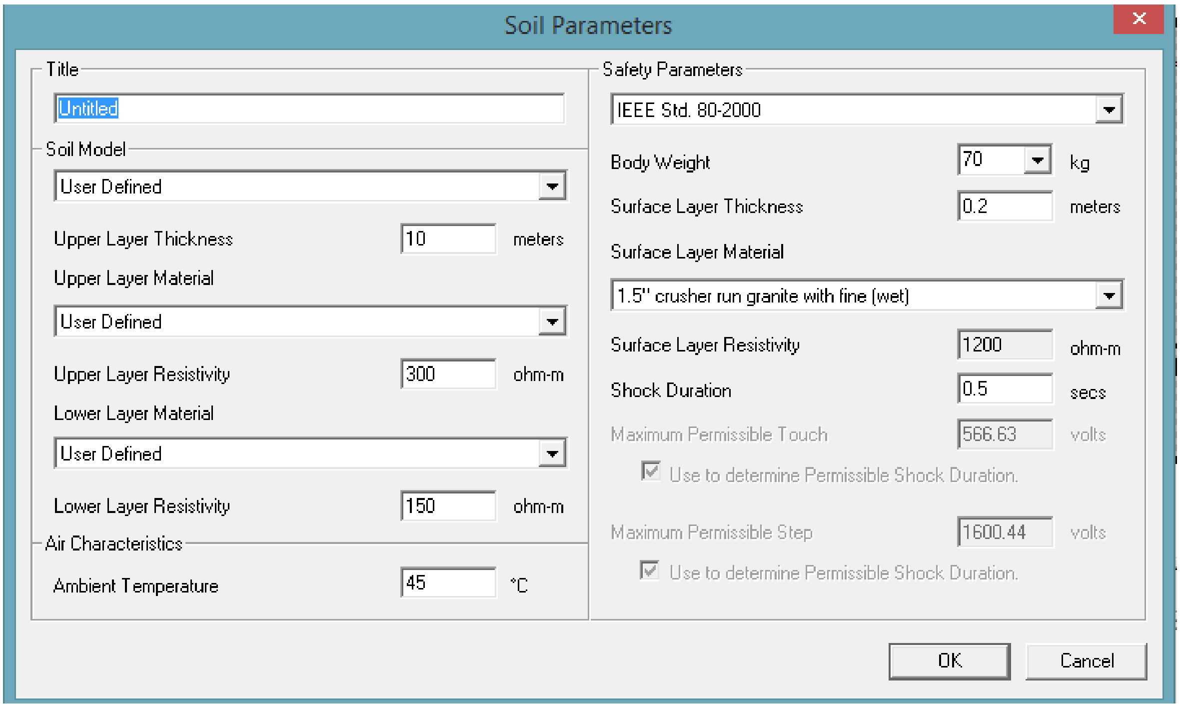


Figure V.6: soil parameters

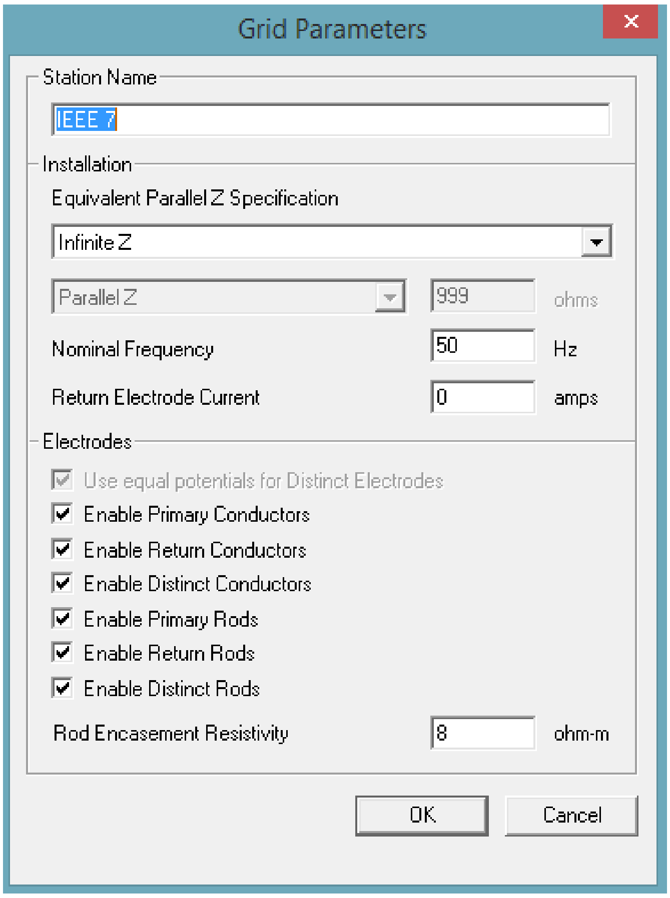


Figure V.7: Grid parameters

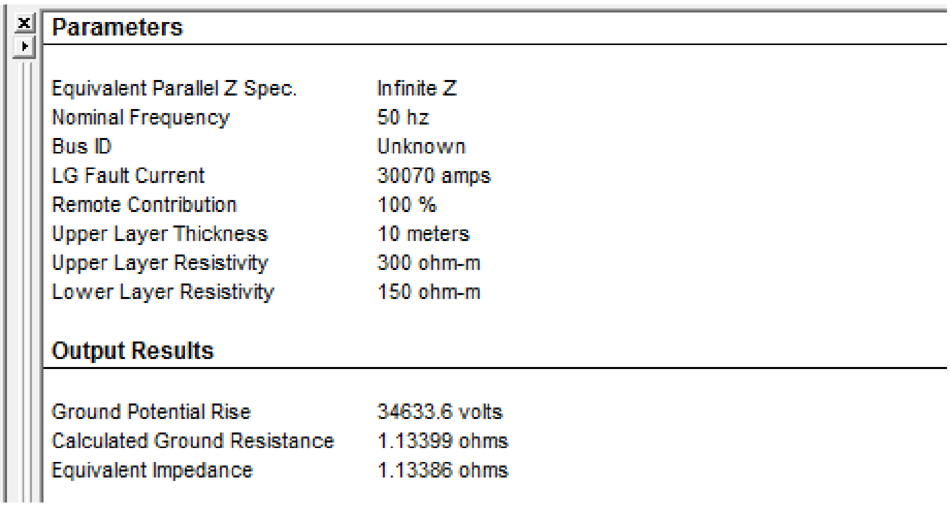


Figure V.8: Output results of the CYMGRD softawre

V.13 Conclution:

We notice that the resultant ground resistance is 1.13ohms which is very acceptable.

This result is obtained by using a copper earthing cable of 11mm cross section diameter (as calculated in section V.7), and earthing electrodes of 4m length and 20mm cross section diameter

General Conclusion

The objective of this project is to design an electrical system for the wastewater treatment plant (WWTP) of Bordj Bou Arrerij (BBA). The project study is considered to be under the responsibility of ELKINDI Engineering office. The study has been started from the basic documents provided by the stakeholders, these documents consists of the general layout of the facility –representing electric cabinets and machines location-, machines' datasheets, and equipment operating sequence.

The design started first by sizing the electrical source, this step includes drawing single line diagram, calculation of the load demands of the facility and choosing the appropriate transformers. Second, protection equipment and cables sizing and layout are established with the help of CANECO and AutoCAD software. Third, a landscape lighting design is done to provide the facility by an efficient and optimal lighting system. In this step we have learned the different lighting parameters and representations and how DIALUX EVO software is very helpful in lighting design. Finally, we designed a TN-C earthing system for WWTP, this system has a non-uniform loop that is why proceeding manual calculation is very difficult, but using CYMGRD software allows us to establish the design.

By the completion of this project the following achievements have been gained:

- Learning to undertake a real-life project by interacting with the engineering office
- Learning electrical design steps
- Learning how to apply national and international standards in electrical design
- Mastering several computer design software such as AUTOCAD, CANECO, DIALUX EVO and CYMGRD
- Enriching theoretical capacities in the field of technical operations.

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