Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria dell'Energia

Relazione per la prova finale
«Study and Preliminary Project of the Electrical System for a CHP Plant»

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Foreword.

- **International bid for the implementation of 3,7 MWe Biomass Cogeneration Plant on turn-key basis**.
- **Development of the plant preliminary engineering with specific regard to the Electrical System**

Main charateristics and scope.

- **A biomass power plant generating at least 3.5 gross MWe.**
- **All the process auxiliaries necessary for the power plant operation (water treatment, compressed air, biomass storage and feeding system, etc.).**
- **A 2 tph (tons per hour) (11 Bar; 280°C) steam bleed-feeding line to a nearby industrial plant and condensate return line.**
- **An electrical system able to provide about 2 MWe to the nearby industrial plant and interconnecting with public network to discharge the power surplus or operate the industrial plant in case of maintenance/failure/stop of the cogeneration plant**.

Purpose and role.

- **To participate in the electrical design of the plant and to calculate the optimal section of the main electrical energy transmitting lines of the plant. The most suitable section is calculated by finding the smallest one that respects the parameters of max. voltage drop and thermic regime. This will be object of the section "main cable line sizing"**.

DESIGN FLOW CHART AND RESPONSIBILITY MATRIX

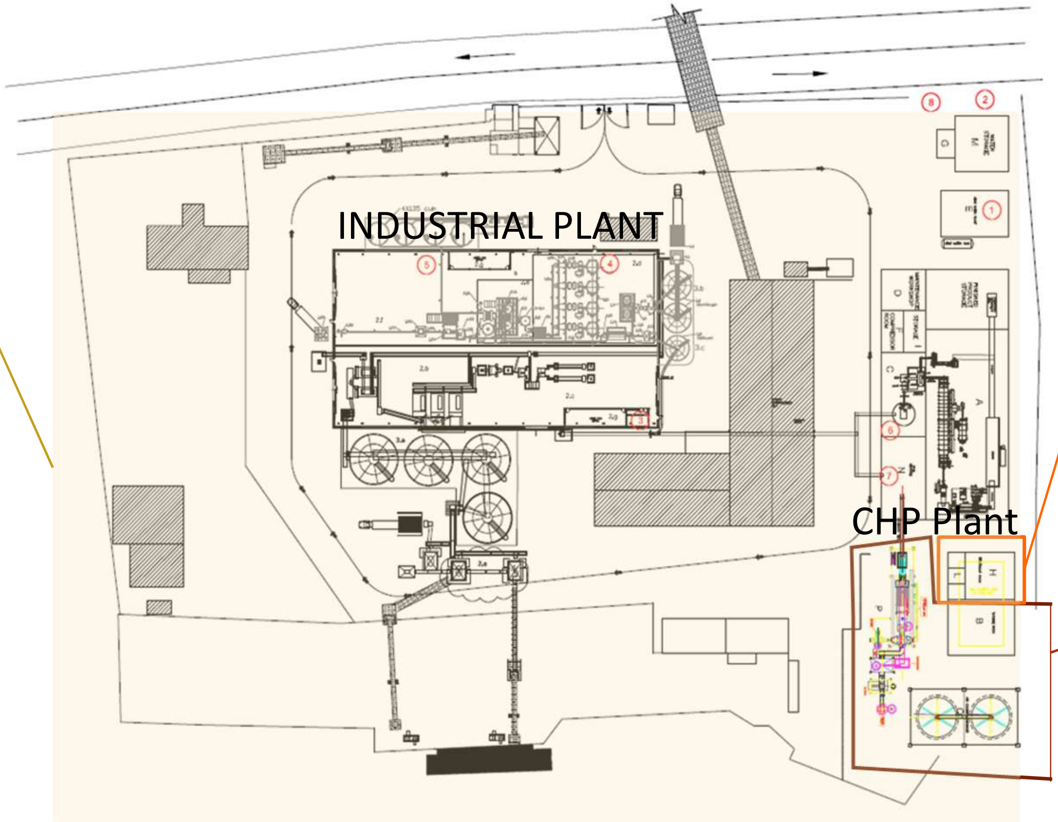
ACTIVITY	RESPONSIBLE PARTY
Analisys of Project Technical Requirements and Scope of Works	All Partners
Responsability Matrix	All Partners
Steam Cycle and Turbogenerator Performances	Turbogenerator Supplier
Heat and Mass Balance and Combustion System Definition	Boiler Designer/Manufacturer
Offer Technical Specifications Turbogenerator	Turbogenerator Supplier
Offer Technical Specifications Boiler and Combustion System	Boiler Designer/Manufacturer
Main Process Packages Requirements for: Power,Process Water,WWT,Compressed Air,Cooling,etc	Turbogenerator and Boiler Manufacturer
General assembly Drawings and System Layouts for Main Process Packages	Turbogenerator and Boiler Manufacturer

ACTIVITY	RESPONSIBLE PARTY
Concept Design and Enquiry Specification of Plant Auxiliary Systems:PWT,WWT,Comp Air, Cooling,	LEADER ENGINEERING
Enquiries for Aux Systems to Specialised Vendors	LEADER ENGINEERING
Calculations of Total Plant Requirements for Electrical System and Sub Systems	LEADER ENGINEERING
Electrical Single Line Diagram	LEADER ENGINEERING
Enquiry Specifications and Enquiries to Specialised Vendors for Main Electrical Equipment	LEADER ENGINEERING
Plant Layout	LEADER ENGINEERING
Main Cable and Pipe Routing	LEADER ENGINEERING
Main Cable and Pipe Sizing and Costing	LEAD ENG /VENDORS

PLANT LAYOUT DESCRIPTION

Auxiliary systems.

- Water pumping system.
- Water storage system.
- Demineralized water production unit.
- Compressed air system.
- Fire detection and fire fighting system.



Electrical building.

- Medium and low voltage switchgears.
- Transformers.
- System control room.
- Interconnecting Cable Ways.

Design Criteria: close to Turbine Building.

Cogeneration plant units.

- Steam generator.
- Turbogenerator.
- Air-cooler-condenser.

Design Criteria: close to ACC to minimize pump work and "continuous losses".

PLANT FUNCTIONAL DESCRIPTION

Steam generator and groundnut plant.

- GN shells production.
- GN shells stored and transferred to steam generator.
- GN shells burned and the steam produced is used in the steam cycle.

Continuous mode.

- Steam cycle produces 3,7 MW at 6.6 kV-50Hz with an STG.
- Power directed to switchgear for co-gen plant and process plant usage.
- Redundant power stepped-up to 33kV and directed to national power grid.

Start-up mode and grid failure.

- Start-up power drawn from 33kV grid.
- Stepped down to be available to 6.6kV bus and 400v bus.
- STG synchronized at 6.6 kV 50 Hz
- In case of grid failure, the STG unit will run in island mode. After grid repairing, STG back to normal operation.

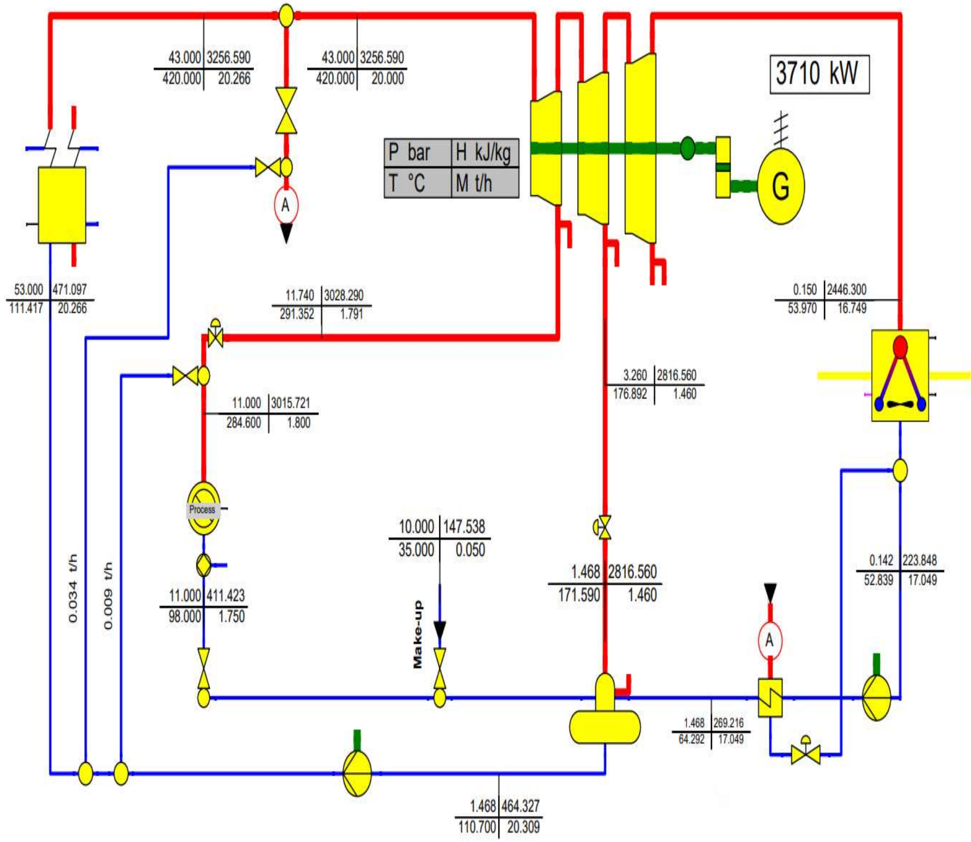
PROJECT CONSTRAINTS
- **Environmental Conditions**
- **Water Availability**

STEAM CONDENSING ALTERNATIVES

A. Basic Solution with ACC Cooling Condensing System

B. Optional Solution with WCC (Water Cooled Condenser) Cooling Condensing System with Air Cooler

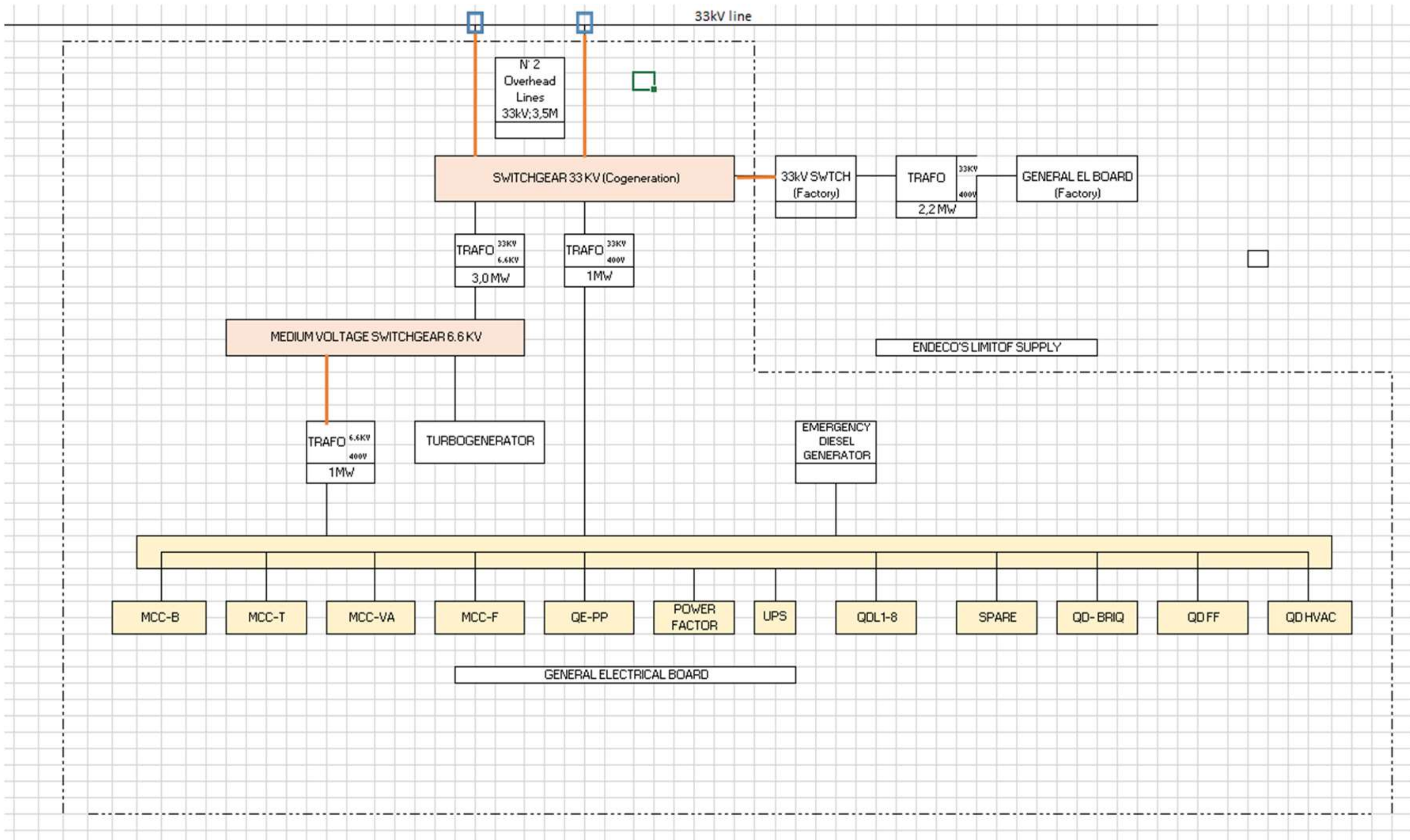
ACC ADVANTAGES
- **Reduction of the turbine back pressure from 0.235 ata down to 0.15 ata which results in power generation of 3710 kW (160kW higher than WCC option)**
- **Reduction of Auxiliary Power Consumption of about 250kW associated to lower absorbed power by fans and water recirculation pumps**
- **ACC Solution is less expensive**
- **Lower net specific consumption and lower specific investment cost (US$/kW)**



ELECTRICAL SYSTEM PRELIMINARY DESIGN(1)

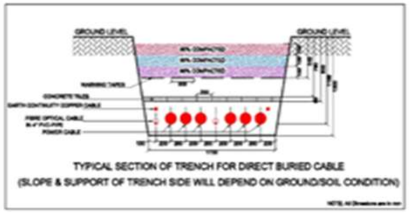
SCHEMATIC SINGLE LINE DIAGRAM

- It shows the functional connection among electrical components
- It is designed to allow plant operation in: island mode, network mode, emergency mode, start up and shut down mode



SIGNLE LINE BLOCK DIAGRAM

Project Main Cable Lines Types

Type fo Connection	Adopted Connection	Length	Sample
33kV Main In-Outcoming Line	Overhead	200m	
33kV Factory Connection	Underground	200m	
Medium Voltage Transformer Connection from/to SwitchBoard	Cable Tray-Trench	20-50m	

IDENTIFICATION OF THE ELETRICAL REQUIREMENTS FOR THE VARIOUS PLANT SECTIONS

- **CHECK DESIGN BASIS FOR ALL PLANT SECTIONS**
- **COLLECTION ALL ELECTRICAL DATA OF PLANT SUBSYSTEMS**
- **TABULATION ANALISYS AND ELABORATION OF COLLECTED DATA**
- **(Note: Tables below show examples of the executed work)**

MCC STEAM CYCLE

Item	supply	total	in operation	each	total	each	total in operation
FEEDWATER PUMPS	MCC-VA	2	1	60,00	120,00	54,00	54,00
CONDENSATE TO DEAERATOR PUMPS	MCC-VA	2	1	10,00	20,00	9,00	9,00
CLOSED COOLING CIRCUIT - COOLING WATER CIRCUIT PUMPS	MCC-VA	2	2	15,00	30,00	12,00	24,00
AIR COOLED CONDENSER (ACC) FANS	MCC-VA	7	6	11,73	82,11	10,56	63,34
AIR COOLER PROCESS	MCC-VA	5	4	11,73	58,65	10,56	42,23
VACUUM TANK - EXTRACTION PUMPS	MCC-VA	2	1	2,20	4,40	1,87	1,87
THERMAL CYCLE MAKE UP - UT DEMI WATER PUMPS	MCC-VA	2	1	5,00	10,00	3,50	3,50
CONDENSATE PIT - TURBINE AREA DRAIN LIFT SUMP PUMP	MCC-VA	1	1	1,10	1,10	0,94	0,94
CHEMICALS DOSING SYSTEM FOR COOLING CIRCUIT	MCC-VA	1	1	2,20	2,20	1,87	1,87
TOTALS		24			328,46		200,75

MCC STEAM TURBINE UNIT

Item	supply	P&ID	total	in operation	each	total	each	total in operation
LUBE OIL PUMP ELECTRIC MOTOR	MCC-T	Turbina	2	1	5,50	11,00	4,68	4,68
AUXILIARY OIL PUMP ELECTRIC MOTOR	MCC-T	Turbina	2	1	5,50	11,00	4,68	4,68
MAIN CONTROL OIL PUMP	MCC-T	Turbina	1	1	5,50	5,50	4,68	4,68
MAIN CONTROL OIL PUMP	MCC-T	Turbina	1	0	5,50	5,50	4,68	0,00
TURBINE OIL ELECTRIC HEATER	MCC-T	Turbina	3	3	3,00	9,00	3,00	9,00
OIL MIST SEPARATOR FAN ELECTRIC MOTOR	MCC-T	Turbina	1	1	1,00	1,00	0,85	0,85
OIL TANK HEATER	MCC-T	Turbina	4	4	3,00	12,00	3,00	12,00
ELECTRIC TURNING GEAR	MCC-T	Turbina	1	0	7,50	7,50	6,38	0,00
WATER RING PUMP	MCC-T	Turbina	2	1	11,00	22,00	9,35	9,35
GENERATOR STANDSTILL HEATER	MCC-T	Turbina	1	1	3,60	3,60	3,06	3,06
CONDENSATE EXTRACTION PUMPS	MCC-T	Turbina	2	1	15,00	30,00	13,50	13,50
TOTAL			20			118,10		61,79

UPS DESIGN DATA

Item	supply	total	in operation	each	total	each	total in operation
COMBUSTION SYSTEM AND STEAM GENERATOR							
HYDRAULIC UNIT CONTROL PANEL	UPS	1	1	1,50	1,50	1,05	1,05
COMBUSTION CONTROL PANEL	UPS	1	1	2,00	2,00	1,40	1,40
START-UP DIESEL OIL BURNERS - DIESEL PUMP (BMS)	UPS	1	0	1,50	1,50	1,28	0,00
DIESEL OIL BURNERS - LOCAL CONTROL PANEL	UPS	1	1	1,00	1,00	0,80	0,80
BOILER BUNDLES CLEANING SYSTEM - LOCAL CONTROL PANEL	UPS	1	1	2,00	2,00	1,60	1,60
TOTAL COMBUSTION SYSTEM AND STEAM GENERATOR		5	4		8		5
TURBOGENERATOR AND THERMAL CYCLE							
CONTROL OIL EMERGENCY PUMP ELECTRIC MOTOR	UPS	1	0	3,00	3,00	2,55	0,00
TURBINE CONTROL PANEL	UPS	1	1	3,00	3,00	2,40	2,40
GENERATOR CONTROL/SYNCHRONIZATION PANELS	UPS	1	1	4,00	4,00	3,20	3,20
GENERATOR STAR-POINT PANEL	UPS	1	1	1,50	1,50	1,20	1,20
TOTAL TURBOGENERATOR AND THERMAL CYCLE		4	3		12		7

ELECTRICAL SYSTEM PRELIMINARY DESIGN(4)

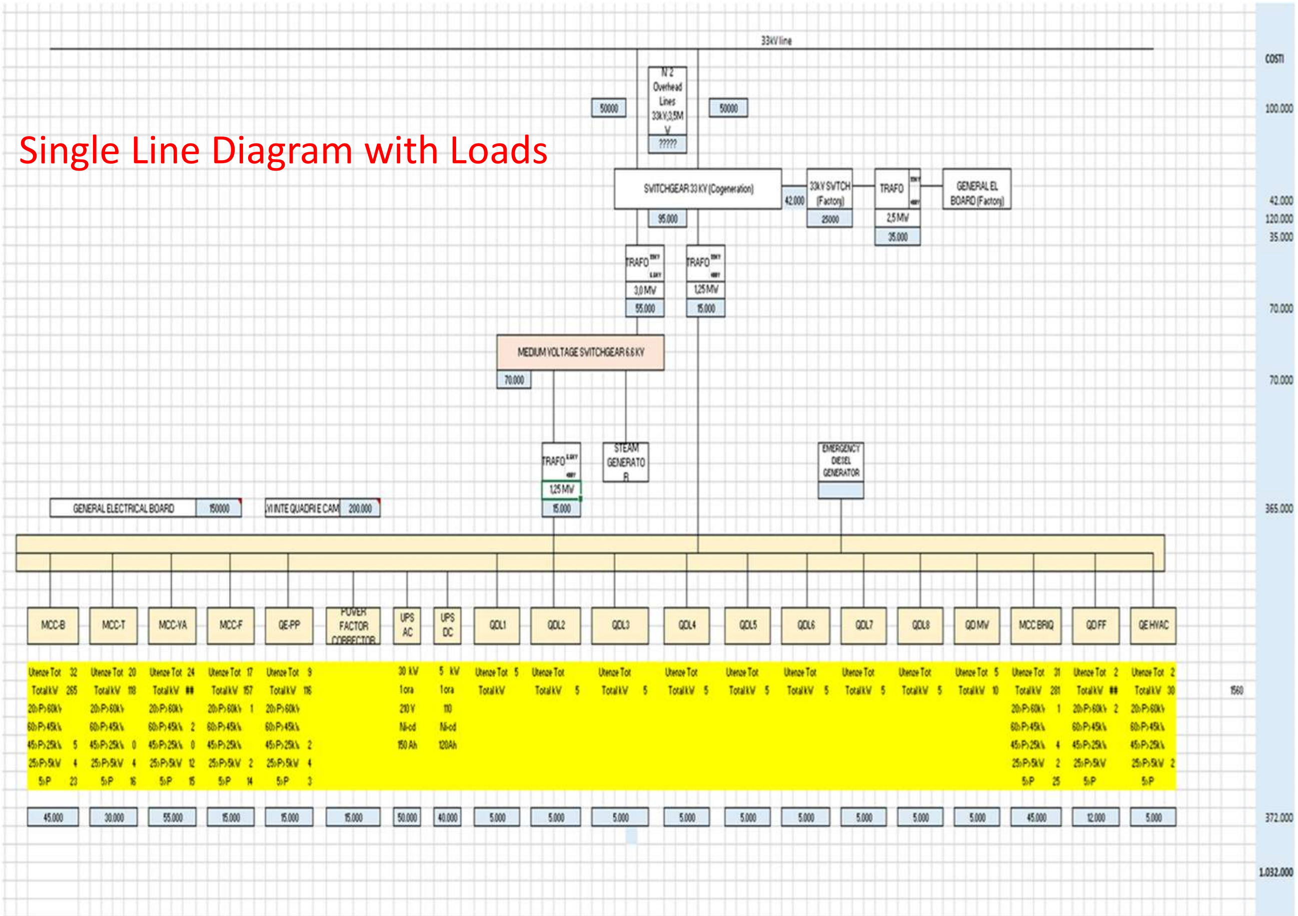
ANALISYS and ELABORATION of ELECTRICAL DATA

- Consolidation of SLD structure
- Transformer sizing
- Preliminary configuration and sizing of electrical switchboards
- Main cable line sizing
- Preliminary cost estimation

COST ESTIMATION METHODS

- Cost data base of similar project
- Specific new enquiries

Single Line Diagram with Loads



MAIN CABLE SIZING CRITERIA

Voltage drop.

- Proportional to the fixed line length and inversely proportional to the line section.
- Acceptable voltage drop below the 0.1%.

Thermic regime.

- Analysis divided **between** continuous regime and adiabatic regime.
- Continuous regime influenced by pose and insulation (influence on the thermic interaction and life span of the conductor).
- Adiabatic regime analysis to foresee the conductor withstanding in the case of a short circuit of the system.

MAIN CABLE LINE SIZING METHOD(1)

Starting variables.

- Un-Nominal voltage
- |S|-Apparent power module
- L- Line length
- Cosphi-Power factor
- Isc- Short circuit current

Voltage drop.

- Calculate load current $\underline{I}_L$.
- Find line parameters: Kilometre resistance and kilometre reactance.
- Use industrial voltage drop formula and compare result with the acceptable value.

Thermic regime.

- Divided between *adiabatic* and *continuous.*
- *Continuous:* Compare cable tabulated ampacity with $|\underline{I}_L|$ multiplied with corrective factors when needed.
- *Adiabatic:* Calculation of the max current density bearable by the insulation, multiplied by the analysed section, and compared with Isc.

MAIN CABLE LINE SIZING CALCULATIONS DIFFERENCES (2)

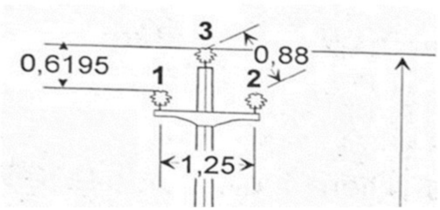
- Calculations change depending on the type of the line
- Main Differences between insulated cables and overhead cables

VOLTAGE DROP

$\Delta U = r\_\theta * I_{L\text{-}A} + X\__{E} * I_{L\text{-}R}$ [v]

- **Insulated cables:** the values of r_θ and Xe are tabulated by the vendors, or the norms
- **Overhead line:** the parameter $X\__{E}$ depends on how conductors are distributed

Ex:



THERMIC REGIME

- **Continuous:** considered in all cases. Section verified by comparing cable ampacity [A], adjusted with corrective factors, with the load current I_L [A]
- **Adiabatic:** considered only in insulated cables. Section verified as follows:

$$G = k\sqrt{\frac{\theta max - \theta es}{\Delta t}} \quad [A/mm^2]$$

Current density is then multiplied for the section and compared with the short circuit current

RESULTS

	Acceptable voltage drop[V]	Load current [A]	Voltage drop [V]	Ampacity [A]	Max Isc current [kA]	Section of choice [mm^2]
Overhead line	19,052	118,094	7,93 ✓	348 ✓	/	120
Underground line	19,052	43,74	2,25 ✓	239,7 ✓	18,214 <25 × 36,428 >25 ✓	240
Line on tray	3,81	109,34	1,25 ✓	227,715 ✓	18,214 <25 × 36,428 >25 ✓	240

CONCLUSIONS

Academic.

-- New knowledge on steam generators and ACC

-- Real life practical experience with the engineering knowledge acquired in university

Experiences acquired.

Working on this project has been a great occasion of self-challenge and growth as a future engineer.

Both academic and work-field new knowledge and experiences.

Work field.

-- Know-how on the design method of complex projects

-- Experience with an engineering team