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MÉMOIRE

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Par

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Electrical protections basics in medium voltage network of pelletizing plant TOSYALI-ALGERIA.

Soutenu le 16/08/2022 devant le jury composé de :

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ملخص

يسعى الخبراء في مجال الكهرباء إلى ابتكار تقنيات حماية متطورة، تماشيا مع احتياج العالم المتزايد للطاقات بما في ذلك الطاقة الكهربائية، يتمثل هذا في تطوير الحمايات الكلاسيكية الى رقمية مدعمة بنظام المراقبة المبرمج.

ان نقل القدرة الكهربائية يتطلب دراسة شاملة للخط الناقل من حيث الخواص الفيزيائية كالطول و ابراج النقل و كذا الكهربائية مثل مقاومة و سعة الخط، لضمان النقل في ظروف حسنة و آمنة.

يتم استقبال القدرة الكهربائية بعد النقل في مراكز كهربائيّة مغلقة, تتوفر على جميع الوسائل الفيزيائية و الرقمية للكشف عن الاخطاء و الانذارات بطريقة الية و حصرها.

تعتبر المحولات حلقة الوصل في شبكات النقل و التوزيع، لذا وجب توفير حمايات خاصة فيزيائية كمرحل بوخلرز، و رقمية مبرمجة متمثلة في المرحلات الرقمية التي تستقبل مختلف الاشارات كاشارات دخل , و تتخذ قرارات الاخراج بناءا على البرنامج المدخل من المستخدم.

ان تصميم الشبكات و صيانتها يتطلب معرفة معمقة باهم الحسابات المستخدمة في هذا المجال كحسابات تيارات الحمل و القصر و الهبوط في الجهد، بالإضافة الى قراءة المخططات التي تسهل عملية كشف المستخدم للاعطال و تتبعها.

Summary

Experts in the field of electricity are seeking to innovate advanced protection technologies, in line with the world's growing need for energy, including electrical energy. This is represented by developing classic protections into digital ones supported by a programmed monitoring system.

The transmission of electrical power requires a comprehensive study of the transmission line in terms of physical properties such as length and transmission towers, as well as electrical properties such as resistance and capacity of the line, to ensure transmission in good and safe conditions.

The electrical power is received after transmission in closed electrical centers, which have all the physical and digital means to detect and account for errors and alarms in an automated manner.

Transformers are considered the link in transmission and distribution networks, so special protections must be provided, both physical, such as the Bucholz relay, and programmed digital, represented by digital relays that receive various signals as input signals, and make output decisions based on the program entered by the user.

Designing and maintaining networks requires in-depth knowledge of the most important calculations used in this field, such as calculations of load currents, short circuits, and voltage drops, in addition to reading diagrams that facilitate the user’s detection and tracking of faults.

Résumé

Les experts dans le domaine de l'électricité cherchent à innover en matière de technologies de protection avancées, en phase avec les besoins croissants du monde en énergie, y compris en énergie électrique, en développant les protections classiques en protections numériques soutenues par un système de surveillance programmé.

Le transport d'énergie électrique nécessite une étude approfondie de la ligne de transport en termes de propriétés physiques telles que la longueur et les pylônes de transmission, ainsi que de propriétés électriques telles que la résistance et la capacité de la ligne, pour garantir un transport dans de bonnes conditions et en toute sécurité.

L'énergie électrique est reçue après transmission dans des centres électriques fermés MCC, qui disposent de tous les moyens physiques et numériques pour détecter et comptabiliser les erreurs et les alarmes de manière automatisée.

Les transformateurs sont considérés comme le lien dans les réseaux de transmission et de distribution, c'est pourquoi des protections spéciales doivent être fournies, à la fois physiques, comme le relais Bucholz, et numériques programmées, représentées par des relais numériques qui reçoivent divers signaux comme signaux d'entrée et prennent des décisions de sortie basées sur le programme saisi par l'utilisateur.

Concevoir et entretenir des réseaux nécessite une connaissance approfondie des calculs les plus importants utilisés dans ce domaine, tels que les calculs de courants de charge, de court-circuit et de chutes de tension, en plus de la lecture de schémas qui facilitent la détection et le suivi des défauts par l'utilisateur.

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Thanks

First of all, I want to thank ALLAH the almighty for having me Given the strength, the courage, the will and the patience to complete this Present work.

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All the people who have contributed to my formation be Thank you for all their efforts.

Finally, I am particularly grateful to my parents, my brothers, my sisters, and all my colleagues who spared efforts to support me.

Introduction

There are many protections that accompany the production, transmission and distribution of electrical energy, which are divided into mechanical protections that are manually operated by the operator and automatic protections programmed inside closed electrical centers called switchgear.

The switchgear is a combination of devices responsible for sensitivity, detection, processing and cutting in the abnormal condition of the electrical network.

The power is distributed and the switchgear cells are supplied by means of a bus bar, whose installation methods differ according to the operator, as there are more than six methods of installing bus bars, which gives us an opportunity to ensure the supply of electricity to the network in addition to the SEU3000 in the event of any problem or for the purpose of periodic maintenance

The largest component of the switchgear is the newly designed VCB breaker that receives various disconnection and connection commands from the programmed protection relay, which in turn receives signals and values of current, voltage and tension from the measurement sensors.

One of the most important parts of the network is the transformer, which is a link between high and low voltages, which poses a great danger in the event of any technical problem in it. Therefore, many protections have been provided for the transformer to reduce these risks.

These coasters are divided into what is in the heart of the transformer and what is in the switchgear, which is the protection relay the mastermind of it.

Therefore, all decisions taken in the electrical network in the protection system are responsible for the relay and for their definition and presentation to the operator

Chapter I

The transmission of the electrical power

I.1. Electrical power transmission

Electric power transmission is the bulk transfer of electrical energy from generating power plants to electrical substations. Electricity is transported over long distances at high voltages, this is due to the fact that generating stations are usually situated away from the load centers. Which minimizes the loss of electricity.

The network that transmits and delivers power from the producers to the consumers is called the **transmission system** or “power grid”.

Along of transmission electrical line; voltage value will increase and decrease as per location and utilization and we have:

I.1.1. Primary transmission.

When it is generated at a power station, electrical energy will typically be anywhere between 11kV and 33kV. Before it is sent to distribution centers via transmission lines, it is stepped up using a step up transformer to a voltage level that can be anywhere between 100kV and 700kV or more, depending on the distance that it needs to be transmitted; the longer the distance, the higher the voltage level.

I.1.2. Secondary transmission

When electrical power reaches a receiving station, the voltage is stepped back down to a voltage typically between 33kV and 66kV. It is then sent to transmission lines emerging from this receiving station to electrical substations closer to “load centers” such as cities, villages, and urban areas. This process is known as secondary transmission.

Picture I.1 : Drawing showing the path of electric power from production to exploitation.

I.2. Electrical power level voltage

According to the IEC 38 standard, the voltages in the electrical network are classified into three categories, High Voltage (HV), Medium Voltage (MV) and Low Voltage (LV).

But after that another standard came for update another classification which is using now, it's UTE C18-510 And its giving as following**:(1)**

Table I.1: Voltage level in the case of alternating and continuous voltage.

Voltage range		Nominal voltage value UN in VOLTS	
		Alternative voltage	**Direct voltage**
Very low voltage		**Un ⩽ 50**	**Un ⩽ 120**
Low voltage	**LVA**	**50 ⩽ Un ⩽ 500**	**120 ⩽ Un ⩽ 750**
	LVB	**500 ⩽ Un ⩽ 1000**	**750 ⩽ Un ⩽ 1500**
High voltage	**HVA OR MV**	**1000 ⩽ Un ⩽ 50000**	**1500 ⩽ Un ⩽ 75000**
	HVB	**Un ⩾ 50000**	**Un ⩾ 75000**

I.3. Overhead electrical transmission lines

The main function of electric transmission lines is to transfer electric power from one place to another. The main component of the overhead transmission line is the conductor, while the rest of the parts are auxiliary parts to carry the conductor and isolate it from the ground. In overhead lines, air is used as an insulating medium, but air - like all insulators - breaks its insulation if the voltage exceeds a certain value, and in the case of air it is equal to 30 cm/kV, meaning that if the two voltages reach more than this value, the air will turn into a conductor. Therefore, the purpose of using electrical towers was to keep the conductors at a safe height from the ground, as well as to find a safe distance between them and each other.

Picture I.2 : Overhead transmission line tower with components.

I.4. The Factors affecting the design of electrical towers of transmission lines

The most important of which are:

- The electric voltage used.
- The number of circuits carried by the tower.
- The distance between the towers.
- The climatic factors to which the line is exposed (winds - snow...............).
- The diameters of the conductors and the distance between them.

I.5. Properties of electrical transmission lines

The properties of electric transmission lines are represented in the elements that determine the electrical performance of the lines, where this performance can be expressed in three elements: the material resistance of the line **(R)**, the inductive reactance of the line **(L)**, and the electrical capacitance of the line **(C).**

I.5.1. Physical resistance of the line (Line Resistive)

The resistance of the line conductors is estimated in ohms and depends on the geometry of the line conductors in terms of resistance; and also on the skin effect.

The formula the line resistance can be described as

$$R = \rho \frac{\mathbf{l}}{\mathbf{A}}$$

R = series resistance in **[Ω]**

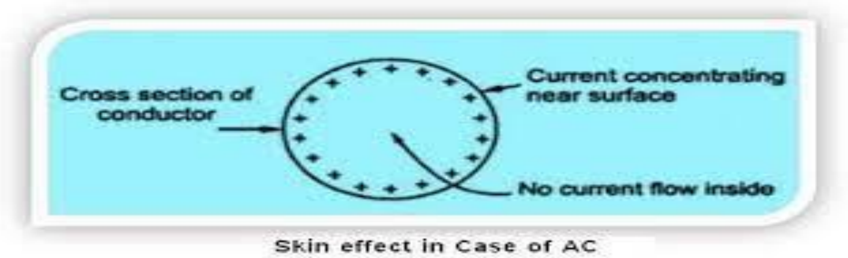
l = length of the conductor in **[m]**

A = cross-sectional area of the conductor in **[mm^2]**

ρ = specific resistance in **[$\Omega \cdot mm^2/m$]**

I.5.2. Skin effect

It is a phenomenon that occurs due to the change in the value of the electric current in the conductor, which produces a variable electric field, which in turn produces an electromotive force outward from inside the conductor, resulting in the current strength being higher in the outer surface and decreasing until it is absent in the center of the conductor. If we conclude that not all of the area Exploited in transport, if the resistance of the conductor rises, on the other hand, we also find that the frequency is individually proportional to this phenomenon, so it is preferable to use frequency links instead of a warm sole.



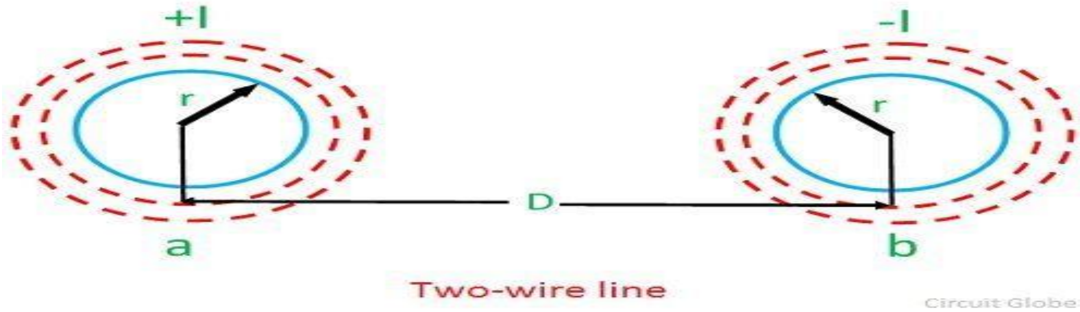
Picture I.3 : An image showing the concentration of alternative current around the conductor.

Picture I.4 : Skin effect as per the change on the frequency.

I.5.3. The inductive reactance of the line

The inductive reactance of the line is the most important characteristic due to its direct and effective effect on the conduction capacitance and the voltage drop of the transmission lines.

Rough faraday’s rule, which states that each current-carrying carrier forms a magnetic field with variable flows and waves, which in turn will affect the side conductors to produce reverse cars affecting the performance of the transmission line, which is known as inductance. The flux linking with the conductor consist of two parts, namely, the internal flux and the external flux. The internal flux is induced due to the current flow in the conductor. The external flux produced around the conductor is due to its own current and the current of the other conductors; Let the current flow in the conductors are opposite in direction so that one becomes return path for the other.



Picture I.5 : The affecting of two lines for each other’s as per distance as called inductance effect

The flux linkages of conductor ‘a’ is given by the formula

$$\lambda a = 2 * 10^{-7}[\, IaIn\frac{1}{Daa} + Ib\frac{1}{Dab} \,]$$

Where

$$Ia = +I$$

$$Ib = -I$$

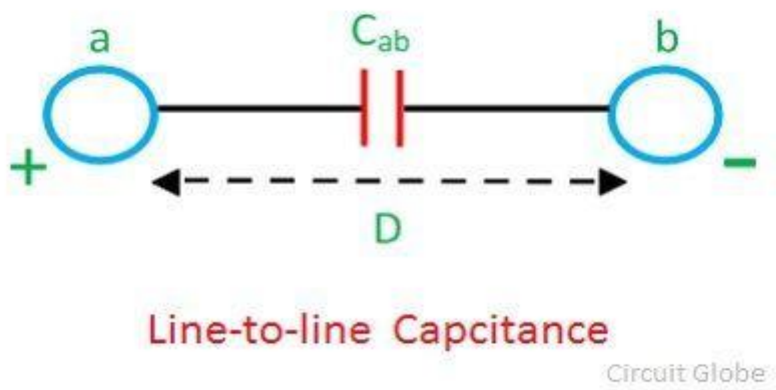
$$Daa = r'$$

$$Dab = D$$

I.5.4. The capacitance of the line (C)

When the potential difference between the conductors is very high, an electric displacement current passes through the insulator between the conductors and the ground, which is represented by air in the overhead lines.

The capacitance of the transmission line along with the conductances forms the shunt admittance. The conductance in the transmission line is because of the leakage over the surface of the conductor. Considered a line consisting of two conductors A and B each of radius r. The distance between the conductors being D shown in the diagram below:-



Picture I.6 : The potential difference between the conductors a and b is.

$$\boldsymbol{Vab} = \frac{\mathbf{1}}{\mathbf{2\pi\varepsilon}}\left[\mathbf{qaIn}\ \frac{\mathbf{Dab}}{\mathbf{Daa}} + \mathbf{qbIn}\ \frac{\mathbf{Dbb}}{\mathbf{Dba}}\right]$$

Where

qa = charge on conductor a.
qb = charge on conductor b.
$\boldsymbol{Vab}$ = potential difference between conductor a and b.
ε = absolute permittivity.

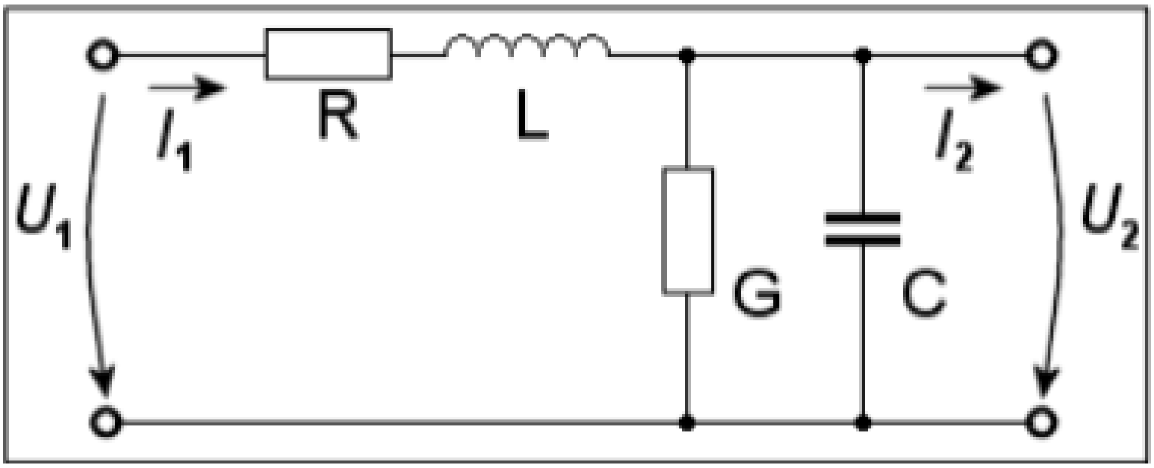
$$\boldsymbol{qa} + \boldsymbol{qb} = \mathbf{0}$$

So That ,

$$\boldsymbol{qa} = -\boldsymbol{qb}$$

$$\boldsymbol{Dab} = \boldsymbol{Dba} = \boldsymbol{D}$$

$$\boldsymbol{Daa} = \boldsymbol{Dbb} = \boldsymbol{r}$$



Picture I.7 : Transmission line element.

I.7. The purpose of increasing voltage during power transmission

The primary reason that power is transmitted at high voltages is to increase efficiency. As electricity is transmitted over long distances, there are inherent energy losses along the way. High voltage transmission minimizes the amount of power lost as electricity flows from one location to the next. How? The higher the voltage, the lower the current. The lower the current, the lower the resistance losses in the conductors. And when resistance losses are low, energy losses are low also. Electrical engineers consider factors such as the power being transmitted and the distance required for transmission when determining the optimal transmission voltage **(2)**.

The reasons for raising the voltage can be summarized in the following points:

- Reducing lost power during transmission of electrical energy.
- Reducing the current value across the transmission lines, which also reduces the voltage drop.
- Reducing the cost of transmission lines and electric power towers, which is an advantage related to reducing the value of the transmitted current that led to the use of fewer conductors, and this lower costs for the price of conductors and the sizes of towers that carry these conductors.
- Increasing the efficiency of the electricity transmission system.

We have

$$p = \sqrt{3}.U.I.\cos phi$$

We will take a simple system with $pf = 1$.

So $p = U.I$

$$I = P/U$$

We remark that there is an inverse relation between current and voltage and for keep power value in KW constant from the production substation until the consumption areas, we have to choose one quantity for increase or decrease for above mentioned causes we must make voltage UP and automatically current will drop. So we get as following:

$$U = R.I$$

And $P = U.I$

We get $P = R.I.I$

So $Pj = R.I\hat{}2$

And because **I** is less so losses are less also we get conclusion that electrical power losses related by current and not by voltage.

I.8. Important protection in HV transmission lines

I.8.1 Protection of distance (impedance protection)

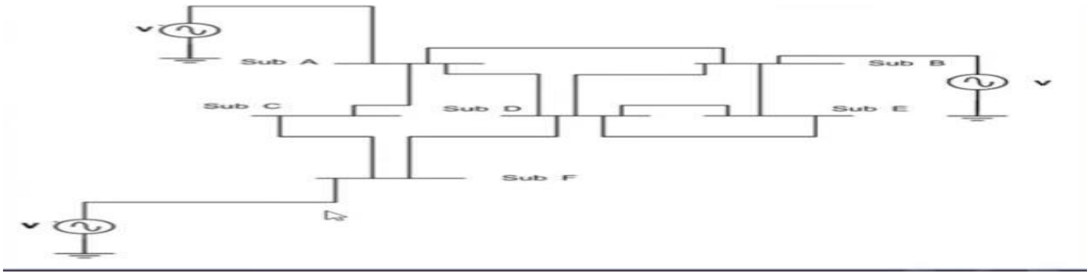
Distance protection relay is the name given to the main protection of the line, whose action depends on the distance of the feeding point to the fault. The time of operation of such protection is a function of the ratio of voltage and current, i.e. impedance.

Distance relays are used for both phase fault and ground fault protection, and they provide higher speed for clearing the fault. It is also independent of changes in the magnitude of the short circuits, current and hence they are not much affected by the change in the generation capacity and the system configuration. **(3)**

1

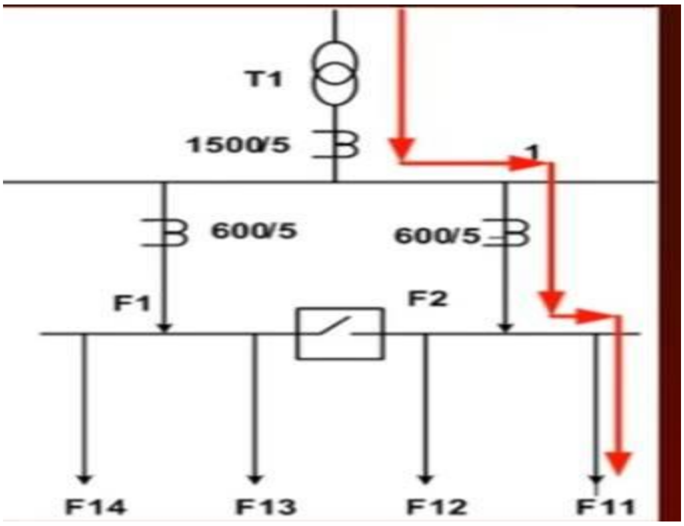
I.8.1.1 operation principle

Suppose we have this electrical network where there are 3 power sources with same voltage level



Picture I.8 : Power grid network single line diagram with many sources

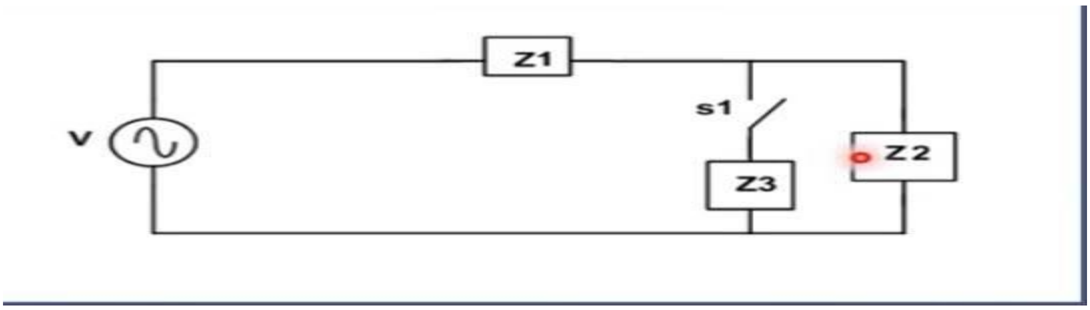
We can not identify the direction of power flow in this case if any source will make power off so will not take over current protection because it using only current with angle for clear the fault because we have only one direction of current like what is showing this picture:



Picture I.9 : Single line diagram with only one source of power.

So we have to pass to the direction protection and look for current measuring by the CT and voltage measurement by the VT for calculate the impedance.

In that network, we have many relays distance protection, it possible that all can see the fault but which one will act it depend to the impedance, that's the electrical selectivity in this type of protection.



Picture I.10 : Simple electrical circuit with its impedances.

Will take this simple example:

We have three impedances:

Z1 = line impedance.

Z2= load impedance.

Z3 = fault impedance.

S1= line switch.

Where:

$$\boldsymbol{Z2 = 100Z1}$$

- Case 1:

Total impedance is **101Z1**

S1 is open:

We can calculate current in pre-fault conditions:

$$\boldsymbol{In = \frac{V}{(100Z1 + Z1)}}$$

$$\boldsymbol{= \frac{V}{101Z1}}$$

- Case 2:

In fault conditions

Suppose if S1 is close now

And we reminder that

$$\boldsymbol{Z2 = 100Z1}$$
$$\boldsymbol{Z3 = 0.1Z1}$$

Because of $\boldsymbol{Z3//Z2}$

So

$$\boldsymbol{Zeq = Zf \approx Z3}$$

So we get

$$: \quad \boldsymbol{If = \frac{V}{(Z1 + Z3)}}$$

$$\boldsymbol{= \frac{V}{(1.1Z1)}}$$

We remakes that

$$\boldsymbol{IF >>>> In}$$

We will change the location of the fault now,

- very near to the power source:

$$Zeq = Z3 = 0.1Z1$$

- In the 50% of the total distance of line.

$$Zeq = Z3 + 0.5Z1 = 0.6Z1$$

So; what we get:

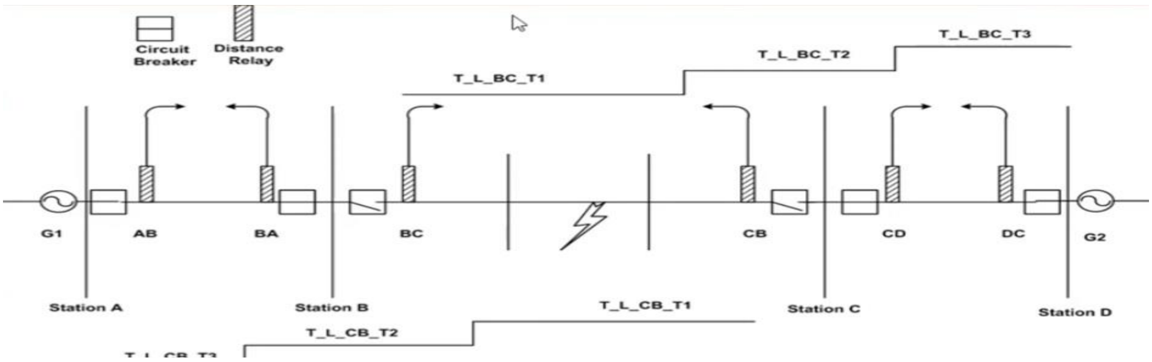
- There is a proportional relation between the length of line and its impedance and the current fault value also.

I.8.1.2 Distance protection zones

A. First example

We have this power linkage, have two power sources G1, G2; and three lines AB/BC/CD.

Each line have two breakers in the frontiers and each line have also two distances relays beside each breakers.



Picture I.11 : Power linkage showing the protection area of each relay.

Suppose we have that fault in the half of line, the fault will be under feeding of both of lines

The Relay who will act only which have a same direction to the fault it mean its direction is forward and auther its direction is reverse

But we have four relay with this option forward so?

Now the selectivity is based on the time delay!!

Relay CB will act first due to the short distance between it and the fault zone and will protect the remaining line, the remaining line will be in normal condition.

- **In case of not tripping**

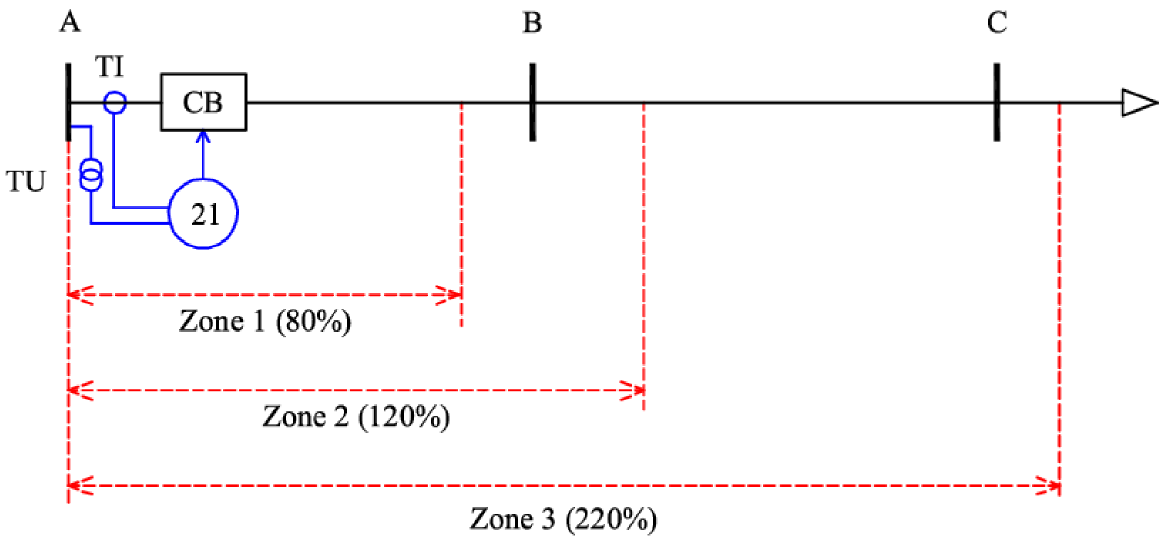
If CB not break due to any technical problem then DC will break after more time delay of CB, and when the time reach it will trip all the line. This protection is not main but called back up protection of auther line (middle line in our case).

Same thing will happen in the auther side of line.

And the series tripping operation while relay failure is depend of an exact programming coordination and communication on the time as per the distance.

I.8.1.3 Distance protection zones

B. Second example



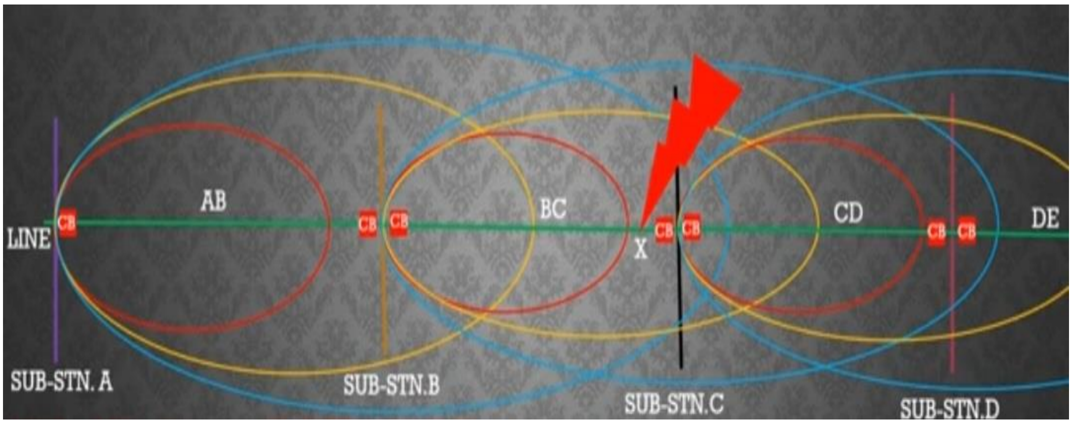
Picture I.12 : Distance protection zones of the transmission line.

The setting on time delay of relay as per zones give the possibility to protect many line on depend of impedance of line in any abnormality status of CB, How?

- Zone 1(T1- 0s): 85% of the distance of line.
- Zone 2 (T2=350ms):120 % of line (full its line plus 20 percent of the auther lime)
- Zone 3(T3=700ms): 200% of line (both lines completely)

If problem happen on its line then it will detect on first priority and instantaneous , if any problem on the breakers so auther relay on the line which is also cover 120° of the line will detect but after more time.

So we get more protection guarantee but in But for different periods of time.



Picture I.13 protection zones access in in four area

The main substation of TOSYALI plant 400KV provide all possible protections for both lines coming from el MAKTAA and from BETIOUA , as it contains a series of automatic and non-automatic mechanical protections at the level of the substation externally ,and many protections cells located inside the closed electrical centers ,after a careful study by the engineers of the Algerian electrical company SONELGAZ and TOSYALI company and the Chinese factory for the different features of the two lines which we talked about previously ,in addition of the needs of the factory as a whole, In order to choose the devices and means necessary for protection and saving without sudden interruptions .

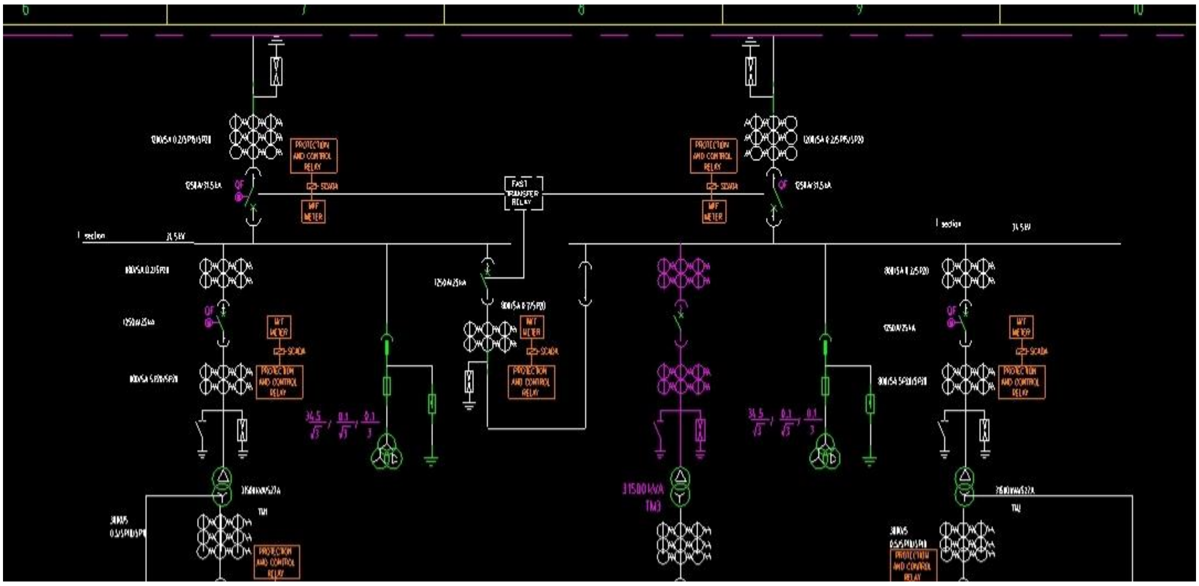
Chapter 02
The reception of the electrical power In the main substation 34.5/6.6KV

II.1. The receiving of power (34.5KV) from the main substation

The substation provide for pellet plant and the new plant beneficiation two lines incomer for feed 3 transformers of 34.5/6.6KV for load of 27000kw for each plant PP and BP . Those two lines will not enter directly to the transformer, it will feed each one bus bar of 34KV size of TMY-3 80*8 who can bear untill1598 A, then this line will enter to the switchgear as following (#1power incoming) and auther line for (#2power incoming)

Those two incoming switch gear are for the protection of the lines which are coming from the substation.

Picture II.1 : Pellet plant substation main power MCC-TOSYALI-



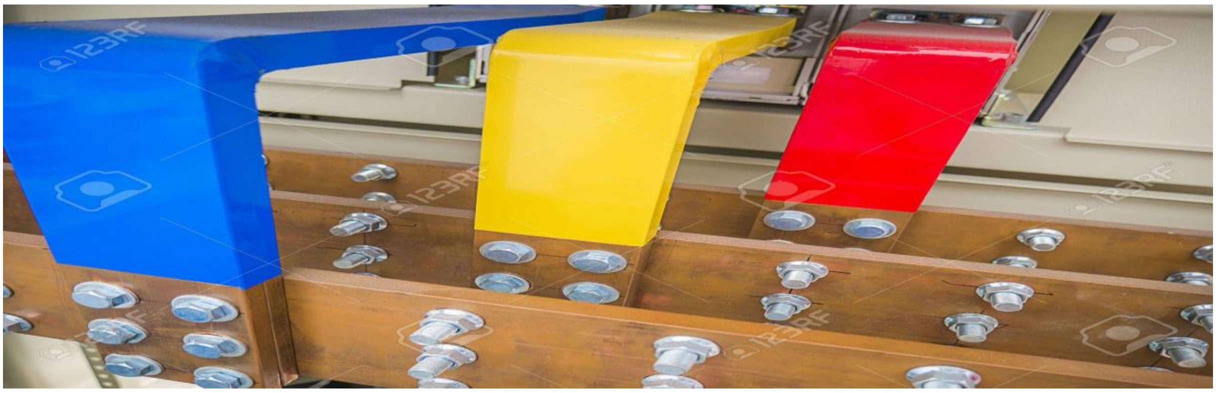
Picture II.2 : Pellet plant substation 34.5/6drawing in autocad-TOSYALI-

II.2. Bus bar and bus coupler switch gear

Between the two Incoming bus bars we have one switch gear of bus coupler added for any abnormality of one from the both lines…

II.2.1. The bus bar arrangements:

An electrical bus bar can be defined as a conductor or groups of conductors which collects electrical power from the incoming feeder and distributes them to outgoing feeder.**(4)**

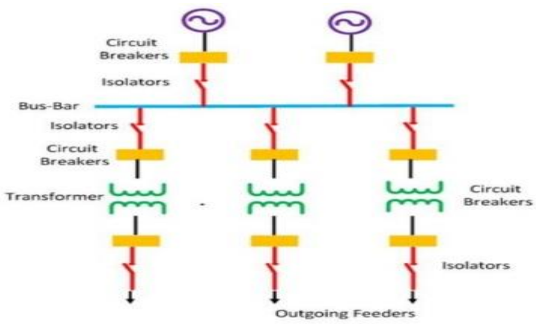


Picture II.3 : Three phase bus bars in electrical panel.

II.2.1.1. Types of Bus Bar arrangements are

a. Single Bus Bar arrangements

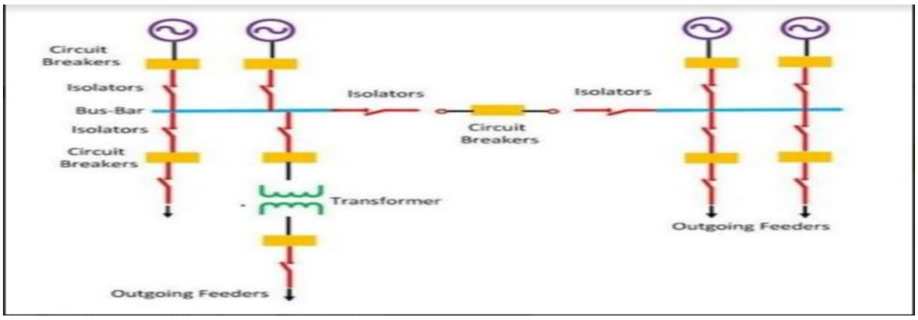
This system has only one bus bar and all the substation equipment like transformer circuit breaker, isolator, and feeder are connects to only this bus bar.



Picture II.4 : A power grid under feeding of one bus bar

b. Sectionalized single bus bar arrangement:

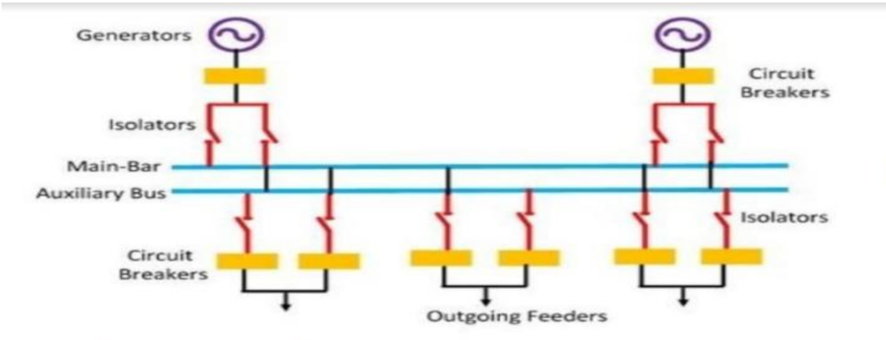
In this bus bar arrangement a circuit breaker and isolator is used to divide the bus bar in two sections. The advantage of using sectionalized bus bar system is that faulty section can be removed without effecting the continuity of the supply.



Picture II.5 : A power network under feeding of one Sectionalized single bus bar.

c. Main and transfer bus bar arrangement

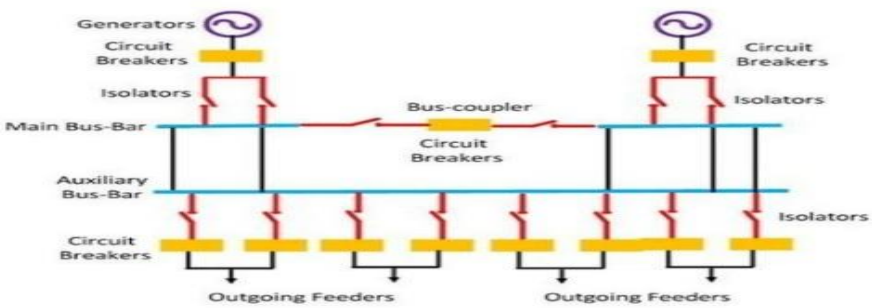
In this type of bus bar arrangement two types of bus bar mainly, auxiliary bus bar and main bus bar used.



Picture II.6 : A power network under feeding of main and transfer bus bar.

d. Sectionalized double bus bar arrangement

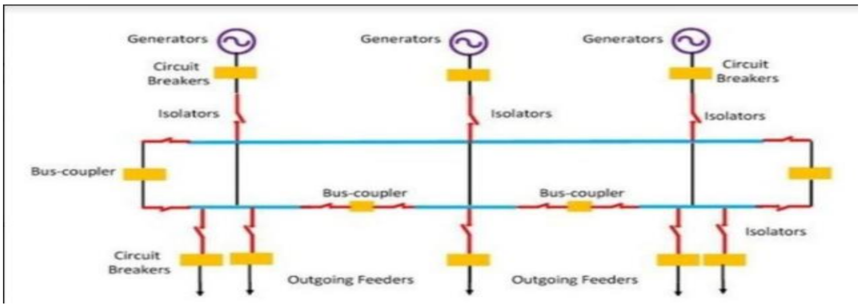
In this type of a bus bar arrangement, a sectionalized main bus bar is used along with the auxiliary bus bar. Any section of the main bus bar can be removed and its load can be transferred to the auxiliary bus bar. One can sectionalize the auxiliary bus bar as well but it would increase the cost because of an additional coupler.



Picture II.7 : A power network under feeding of sectionalized double bus bar.

e. Ring Main Bus bar arrangement

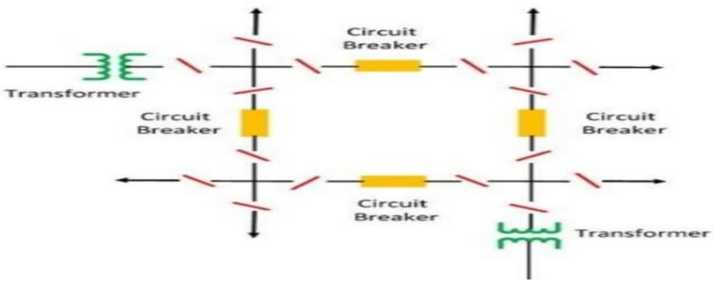
In this type of bus bar arrangement the end of one bus bar is connected with the starting of other bus bar in order to form a ring. Such type of arrangement will provide two path for the supply thus the fault will not affect their working.



Picture II.8 : Power network under feeding of ring main bus bar arrangement.

f. Mesh Arrangement

In this type of arrangement, circuit breaker are installed are installed in form of the mesh formed by the buses. Such arrangement is controlled by four circuit breakers. When fault occurs on any section, two circuit breakers have to be open resulting in the opening of the mesh. Such type of arrangement provide security against bus bar fault.



Picture II.9 : A power network under feeding of mesh Arrangement.

II.2.2. Bus coupler and its purpose

II.2.2.1. Definition

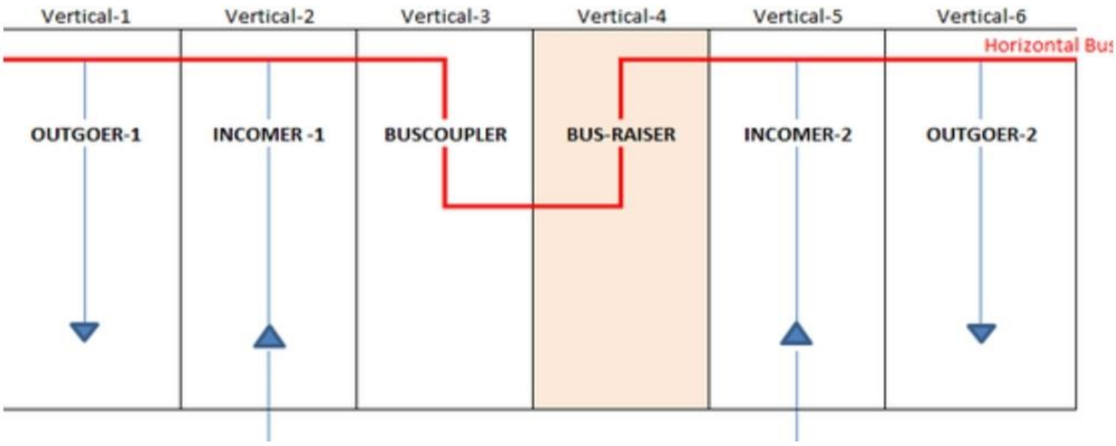
The Bus Coupler, also called Tie Breaker, is a circuit breaker that is similar in specifications to the two feeders that are with it in the station.**(5)**

If you have a secondary station in which feeder No1 feeds Bus bar No1 and feeder No 2 feeds Bus bar No 2, then the Bus Coupler connects between Bus bar 1 and Bus bar 2 in special cases such as ;redundancy, maintenance, operations logic,…

Picture II.10 : Bus coupler switchgear in pellet plant -TOSYALI-ALGERIE

II.2.2.2. Linking principle of the bus coupler cells

As we know that each circuit breaker has 6 poles, three inside from the busbar and three outside to the load ،When following up the parts of an electric station, we notice that all parts have circuit breakers or a space for the Spare circuit breaker, but there is a space with a cover on it on the side of the Bus Coupler either on the right or the left called Bus Riser. In this space, one of the Bus bars exiting cell No. 1 is converted from bottom to the top (entry) and so the Bus Coupler is between the Bus bars.



Picture II.11 : The method of connection in case of bus coupler linking.

II.2.2.3. Protection proprieties on the bus coupler cells

The protection on the Bus Coupler is different from what is on the two feeders because it originally works with one of the two feeders, so there are no relays to increase of current or voltage decrease or Differential and others, but there is a Residual Under Voltage relay and this is connected to one for each Bus bar that works when the voltage decreases to about 15% From the bus bar voltage to allow the bus coupler to be closed.

There is also a Synchrony-verifier Relay to compare between the two feeders and close if there is synchronization to allow the closure of the Bus Coupler and auxiliary relays on the Bus Coupler.

Picture II.12 : Control panel of the bus coupler switchgear in pellet plant 34.5/6.6KV Tosyali -Algerie.

II.3. High speed transfer device ABB SUE 3000

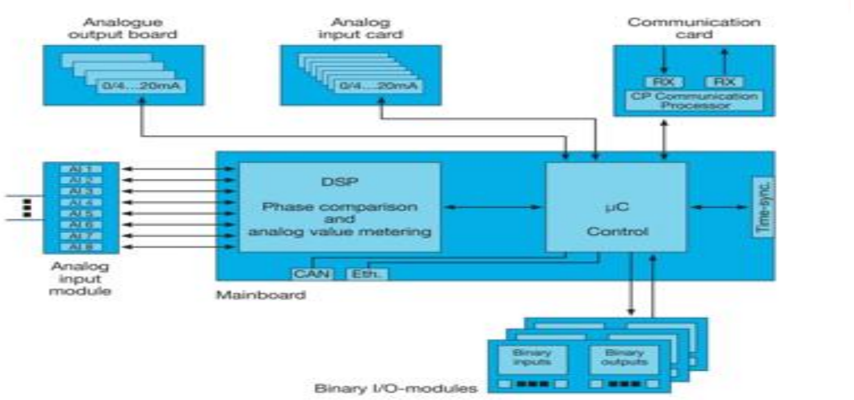
The SUE 3000 High Speed Transfer Device is programmed automatic device for rapid switching between feeders in order to reduce power outage time and ensure continuity of feeding loads; It can be implemented everywhere where a disturbance of the electrical supply would lead to a breakdown in production, which would lead as a result to costs.**(6)**

SUE3000 is set up for different switchgear arrangements, in pellet/beneficiation plant they are using second type of this device; Switchgear configuration with two incoming feeders and one bus bar sectionalized.

Picture II.13 : High speed transfer device ABB SUE 3000 HMI in pellet plant substation .

II.3.1. SUE 3000 internal structure

SUE 3000, as shown in bellow figure, consists of two parts, a Central Unit and a separate Human Machine Interface (HMI). The Central Unit contains the power supply, processor and analog and binary Input and Output (I/O) modules, as well as optional modules for supplementary functions.



Picture II.14 : Hardware SUE 3000 components.

II.3.2. SUE 3000 human machine interface

The HMI Control Unit is a stand-alone unit with its own power supply. It can be installed on the Low Voltage (LV) compartment door or in a dedicated compartment close to the Central Unit. The HMI is normally used to set the parameters of the device and to operate it locally. The HMI is connected to the Central Unit by a shielded, isolated twisted pair according to the RS 485 interface.

Picture II.15 : SUE 3000 High speed transfer device.

II.4. the feed of the three main transformers TM1/TM2/TM3

Picture II.16 : Back side of 34.5KV switchgear in main substation into the transformers in pellet plant 34.5/6.6kv Tosyali-Algerie

As before we mentioned that we have two lines incoming feeds two separated bus bar so we have That incoming one feed one transformer TM1 and incomer two feed two transformer TM2/TM3,For all those transformers there are independent switchgear (protection cell) for provide all the protection possible of the Transformers.

II.5. Electrical switchgear

The apparatus used for **switching, controlling and protecting the electrical circuits** and equipment is known as switchgear**.**

The term ‘switchgear’ is a generic term that includes a wide range of switching devices like circuit breakers, switches, switch fuse units, off-load isolators, HRC fuses, contactors, miniature circuit breakers, ELCBs, GFCIs etc.

It also includes the combination of these switching devices with associated control, measuring, protecting and regulating equipment. The switchgear devices and their assemblies are used in connection with the generation, transmission, distribution, and conversion of electrical energy. **(7)**

Picture II.17 : 2#main transformer electrical switchgear in Pellet substation tosyali-algerie .

II.5.1. The function of a Switchgear

Switchgear has to perform the functions of carrying, making and breaking the normal load current like a switch.

In addition, it has to perform the function of clearing the fault current for which sensing devices like current transformers, potential transformers and various types of relays, depending on the application, are employed.

There also has to be provision for metering, controlling and data, wherein innumerable devices are used for achieving the switching function.

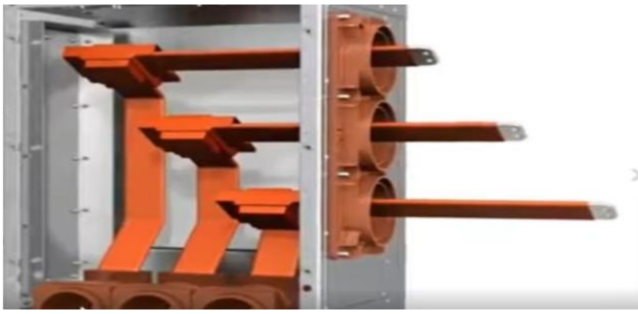
Thus switchgear can include circuit breaker, current transformers, potential transformers, protective relays, measuring instruments, switches, fuses, MCBs, surge arrestors, isolators, and various associated types of equipment. (Related components can be found at electronic components distributor)

II.5.2. Components of Switchgear

Switchgear essentially consists of switching and protecting devices such as switches, fuses, isolators, circuit breakers, protective relays, control panels, lightning arrestors, current transformers, potential transformers, auto reclosures, and various associated equipment.

II.5.2.1. Flower box

it's the link between the main bus bar and the switchgear, represent the input power of the circuit breaker



Picture II.18 : Switch gear flower box.

II.5.2.2. The vacuum circuit breaker VCB

A vacuum circuit breaker, VCB is installed in the medium voltage distribution lines to protect life and load equipment. In case of accidents such as over-current, short circuit, or ground fault current, VCB works by interrupting the circuit through the inner vacuum

Interrupter which is triggered by a signal from the Protection relay ref 615 installed in the circuit.

Vacuum offers the highest insulating strength. So it has far superior arc quenching properties than any other medium (oil in oil CB, SF6 in SF6 circuit breaker).

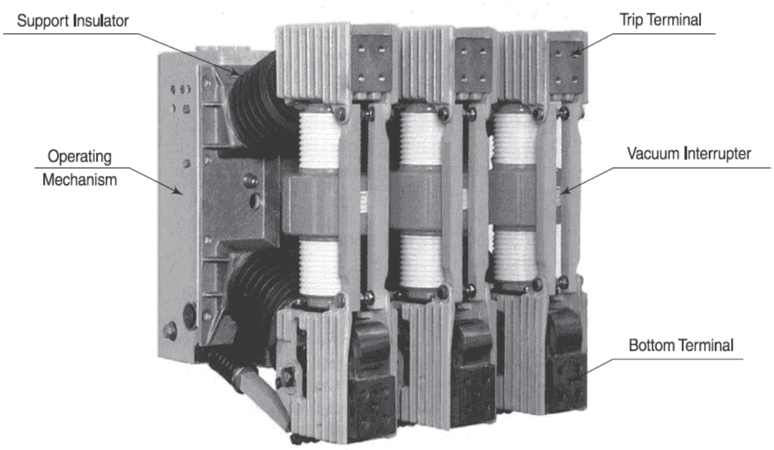
Picture II.19 : A forward picture of one VCB in pellet plant MCC Tosyali-ALGERIE.

II 5.2.2.1 Construction of Vacuum Circuit Breaker

Typical parts of the vacuum circuit breaker are shown in the figure.

It consists of fixed contact, moving contact and arc shield mounted inside a vacuum chamber (vacuum interrupter). It is shown as an insulating vessel in the given figure.

The movable member is connected to the control mechanism by stainless steel bellows. This enables the permanent sealing of the vacuum chamber so as to eliminate the possibility of the leak.



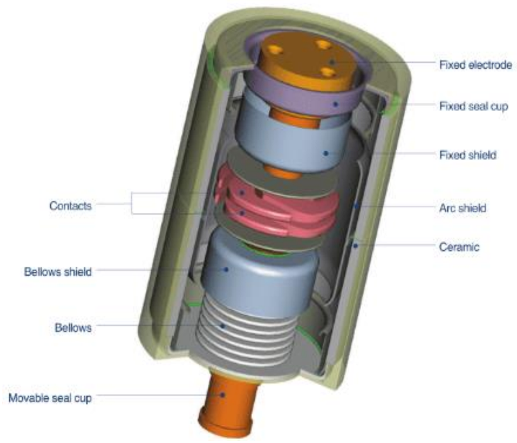
Picture II.20 : Internal components of the vacuum circuit breaker.

A. Vacuum Interrupter

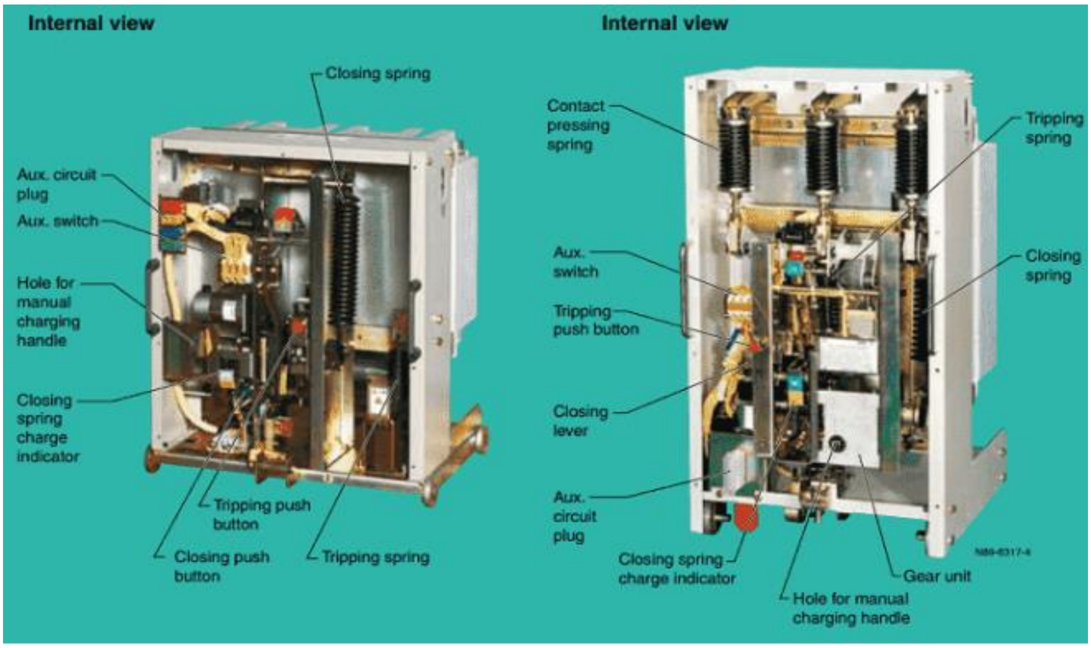
The interruption of arc in a Vacuum Circuit Breaker is carried out by the **vacuum interrupters.**(8)

In principle, a vacuum interrupter has a steel arc chamber in the center and symmetrically arranged ceramic insulators.

Refer the figures below showing the main parts of a typical vacuum interrupter. Modern constructions of this interrupter have a metal shield surrounding the arcing contacts.



Picture II.21 : Cross picture of Vacuum Interrupter.



Picture II.22 : The whole internal components of the VCB

B. Eathling switch

While doing a rack out of the breaker, this switch will close and make the outgoing to the load connected with the earthling link of the plant for guarantee of the safety if any remaining electrical on the load.

This switch have a mechanical interlock with the breaker, if the breaker is in out position and we want to enter it so we cannot while this earthling switch is close.

Picture II.23 : Earthling switch of the vacuum circuit breaker for all three phases**.**

II5.2.2.2 operation of Vacuum Circuit Breaker

The working of Vacuum circuit breakers is briefly explained below :

- When the breaker operates, the moving contact separates from the fixed contact and an arc is struck between the contacts. The production of the arc is due to the ionization of metal ions and depends very much upon the material of contacts.
- The arc is quickly extinguished because the metallic vapors, electrons, and ions produced during arc are diffused in a short time and seized by the surfaces of moving and fixed members and shields.
- Since vacuum has a very fast rate of recovery of dielectric strength, the arc extinction in a vacuum breaker occurs with a short contact separation (say **0.625 cm**).

A. Racking operation of the VCB

Racking a circuit breaker is the act of physically moving a circuit breaker ON or OFF of an electrical bus, thereby physically connecting or disconnecting it from an electrical circuit. The circuit breaker may be moved vertically or horizontally usually by turning a hand cranked screw or a lever. Need to rack circuit breakers in order to safely perform maintenance or repairs to electrical circuits.

- **34.5KV Rack in Procedure**

- Identify the correct Breaker
- Check the breaker is open & spring is fully discharged
- Ensure that breaker control supply is switched off
- Place the breaker in the compartment in test position & insert the breaker control supply plug.
- Rack in the breaker and confirm the breaker status on the display on the control panel.
- Switch on the breaker control supply (MCB)

- **34.5KV Rack out procedures**

- Identify the correct breaker
- Confirm the breaker is open from its control relay.
- Select the breaker in Local mode
- Rack-out the breaker with the compartment door closed
- Switch off the control supply (MCB)

II5.2.3 Instrument Transformers

In a modern power system, the circuits operate at very high voltages and carry current of thousands of amperes. The measuring instruments and protective devices cannot work satisfactorily if mounted directly on the power lines. This difficulty is overcome by installing instrument transformers on the power lines.

The function of these instrument transformers is to transform voltages or currents in the power lines to values which are convenient for the operation of measuring instruments and relays**.(9)**

There are two types of instrument transformers

1. Curent transformer (C.T.)
2. Potential transformer (P.T.)

II5.2.3.1 Advantages of Instrument Transformers

The use of instrument transformers permits the following advantages:

- They isolate the measuring instruments and relays from high-voltage power circuits.

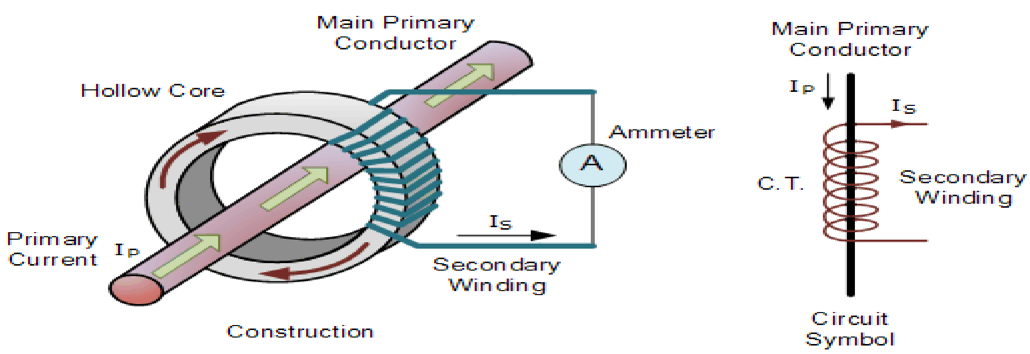
- The leads in the secondary circuits carry relatively small voltages and currents. This permits to use wires of smaller size with minimum insulation.

II5.2.3.2 Current transformer:

The **Current Transformer** (C.T.), is a type of "instrument transformer" that is designed to produce an alternating current in its secondary winding which is proportional to the current being measured in its primary. *Current transformers* reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter.

Current transformers can reduce or "step-down" current levels from thousands of amperes down to a standard output of a known ratio to either 5 Amps or 1 Amp for normal operation.

Picture II.24 : Current transformer measuring instrument.



Picture II.25 : Working principle of the CT

A current transformer, like any other transformer, must satisfy the amp-turn equation and we know from our tutorial on double wound voltage transformers that this turns ratio is equal to:

$$TR = N = \frac{Np}{Ns}$$

$$= \frac{Is}{Ip}$$

From which we get:

$$Is = \left(\frac{Np}{Ns}\right) * Ip$$

The current ratio will sets the turn's ratio and as the primary usually consists of one or two turns whilst the secondary can have several hundred turns, the ratio between the primary and secondary can be quite large.

II.5.2.3.3 Potential transformer

The potential transformer may be defined as an instrument transformer used for the transformation of voltage from a higher value to the lower value. This transformer step down the voltage to a safe limit value which can be easily measured by the ordinary low voltage instrument like a voltmeter, wattmeter and watt-hour meters, etc.

Picture II.26 : Potential transformer measuring circuit.

A. Construction of Potential Transformer

The potential transformer is made with high-quality core operating at low flux density so that the magnetizing current is small. The terminal of the transformer should be designed so that the variation of the voltage ratio with load is minimum and the phase shift between the input and output voltage is also minimum.

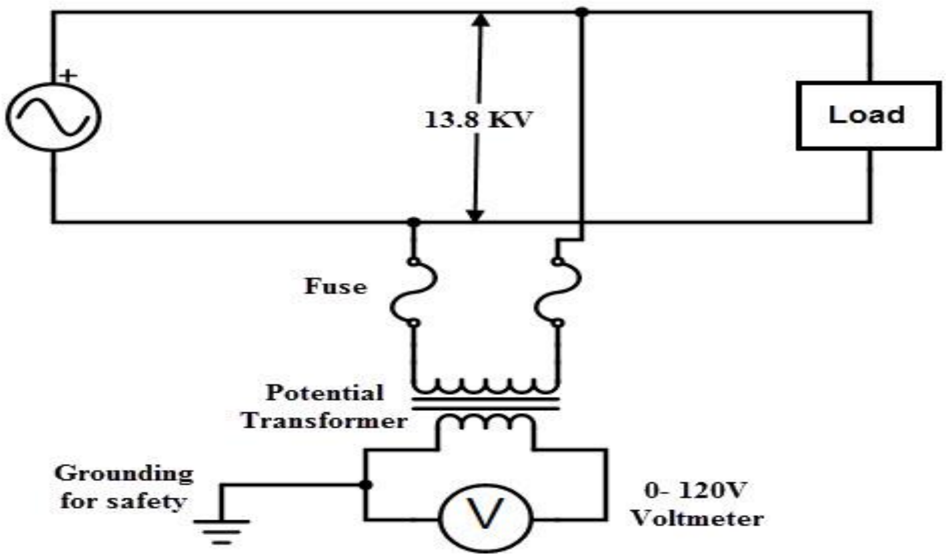
The primary winding has a large number of turns, and the secondary winding has a much small number of turns. For reducing the leakage reactance, the co-axial winding is used in the potential transformer. The insulation cost is also reduced by dividing the primary winding into the sections which reduced the insulation between the layers.

B. Connection of Potential Transformer

The potential transformer is connected in parallel with the circuit. The primary windings of the potential transformer are directly connected to the power circuit whose voltage is to be measured. The secondary terminals of the potential transformer are connected to the measuring instrument like the voltmeter, wattmeter, etc. The secondary windings of the potential transformer are magnetically coupled through the magnetic circuit of the primary windings.

C. Potential Transformer ratio

is the ratio of the primary rated voltage of the PT divided by the secondary rated voltage of the PT. A 480:120V rated PT will have a PT ratio of 4.



Picture II.27 : PT connection in a inside the circuit

Chapter III

Transformer protection

III.1. Numerical protection relay

As the technology developed the protection devices have also undergone many changes from a normal fuse to the circuit breaker. For years we have been using static relays and magnetic relays for protecting an electrical network, now when the microprocessors got evolved the protection devices also got evolved. We previously learned about different types of relays, and Numerical Relay was one of them, so in following study we will focus more on this type of relay.

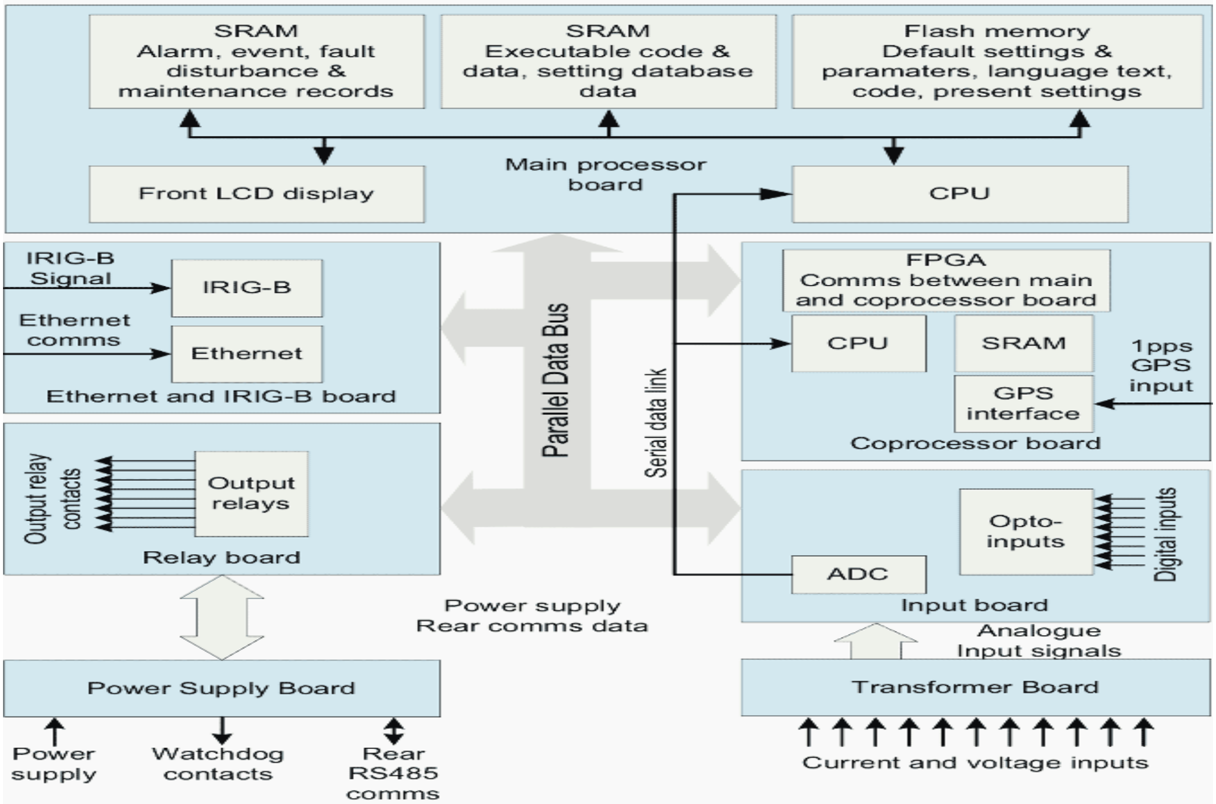
Numeric relays are the evolved form of a static and electromagnetic relay. They are basically a device used for measuring electric parameters in an electrical network and convert them into numerical data which undergoes mathematical and logical analysis to decide on tripping an electrical network.

The main purpose of a numerical relay is to protect the electrical network from unexpected fault currents. Numerical relays are mostly preferred because of their versatile characteristics. A **single Numerical relay can monitor multiple parameters like current, voltage, Frequency, onset time, offset time, etc**. And the same relay can be used for analyzing and monitoring multiple faults such as over current, over fluxing, different current and more**.(10)**

Picture III.1 : Numerical protection relays.

III.1.1. Numerical Relay operation and Hardware Architecture

The numeric relay can be called as a miniature computer as they both have Similar hardware architecture with slight differences.



Picture III.2 : Hardware Architecture of a numerical relay

Their architecture can look confusing but we can just simplify whole architecture into these major categories

- Input Module
- CPU
- Memory
- Multiplexer and Analog to digital converter
- Output module
- Digital input/Communication module

III.1.2. Types of Numerical Relay

The numerical relays are used for various types of protection and they are classified on the basis of characteristics, Logic, Actuation parameter and application. Although they are classified under different conditions their purpose remains the same, to activate the trip system when there is a fault in the electrical network.**(11)**

III.1.2.1. Based on Logic

These classifications are made on the basis of logical operation of the relay

- **Over Current/ Earth Fault**: When excessive current flows through a system it will trip the circuit breaker. Use for transformer and feeder protection.
- **Directional overcurrent**: It is operated when the fault drives the power to flow in a particular direction (Opposite to the specified direction). Used in the protection of Bus bar, Generator, and Transformers.
- **Differential:** The differential relay is set to trip when the phase difference of two or more identical electrical quantities exceeds the specified value. It can Protect Transformers and Generators from localized faults.
- **Under/ Over Voltage**: The voltage in an electric network might drop or rise below or above a fixed value, the circuit is tripped under such conditions.
- **Distance**: This type of relay is operated based on the distance between the impedance of the fault and the position of the relay. They are mostly used in the protection of transmission lines.

III.1.2.2. Based on actuating parameters

- Current relays
- Voltage relays
- Frequency relays
- Power relays Etc.

III.1.2.3. Based on Application

- Primary relay
- Backup relay

If the protection system fails the whole network might get collapsed so they use the backup relay. Doing this will help us protect the system even if the primary relay goes faulty.

III.2. Protection relay REF615 ABB

The REF615 is a dedicated feeder IED perfectly aligned for the feeders protection; The is IED provides non-directional phase and ground overcurrent, thermal overload, phase unbalance and phase discontinuity protection with optional sensitive earth fault (SEF), high impedance fault detection (HIZ), directional phase, ground and neutral overcurrent and phase, ground (residual), positive sequence and negative sequence under voltage and overvoltage protection.

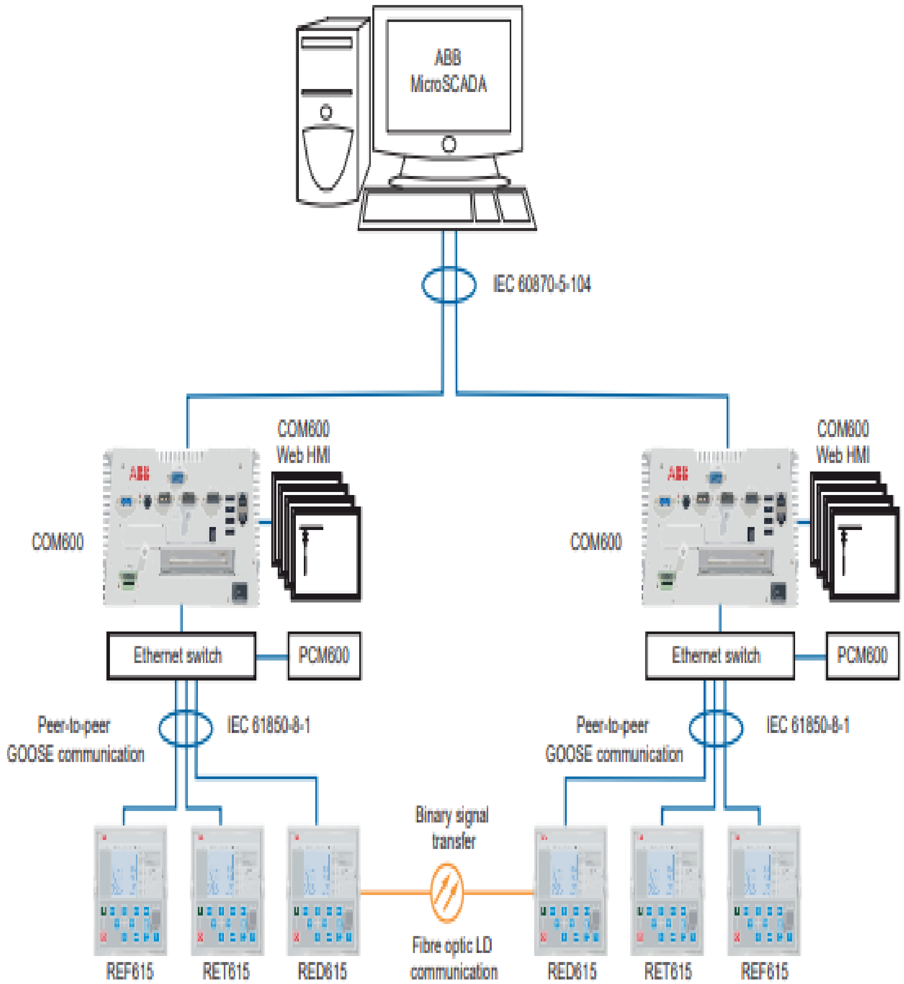
The device was fed either with 220 VAC or 110 DC, and received various data from the measuring devices and followed the program entered to the relay either via HMI or through the PCM 600 program to carry out various logical operations such as tripping or alarming, this relay has a large screen that displays various measurements such as current, Frequency and voltage, it also displays the one-line diagram of the circuit and the position of the breaker in relation to the load or the ground.

Picture III.3: Numerical protection relay REF615 from ABB

III.2.1. Control of the ref615

The cutter is controlled by the relay either locally or by SCADA system through the remote control room.

The relay offers status and control of one or two breakers, depending on the standard configuration selected, with a set of push-buttons on the front panel local human machine interface (LHMI) for opening and closing a breaker. Flexible remote breaker control of select-before-trip (SBO) or direct trip is also available with each of the supported DNP3.0 Level 2+, Modbus and IEC 61850 communication protocols. Interlocking schemes required by the application are configured with the signal matrix tool in PCM600 by the application are configured with the Signal Matrix Tool (SMT) of the REF61.5 user tool PCM600.



Picture III.4 : Communication scheme of the REF615.

III.2.2. Local HMI explain

Picture III.5: operation and monitoring data

1: device in ON conditions.

2: tripping timer start.

3: feeder in TRIP conditions.

4: errors and alarms list.

5: parameters readings display.

6: VCB close command.

7: VCB open command.

8: clear the faults from the relay.

9:REF615 Manu.

10: communication port.

11: local/remote select.

12: Help

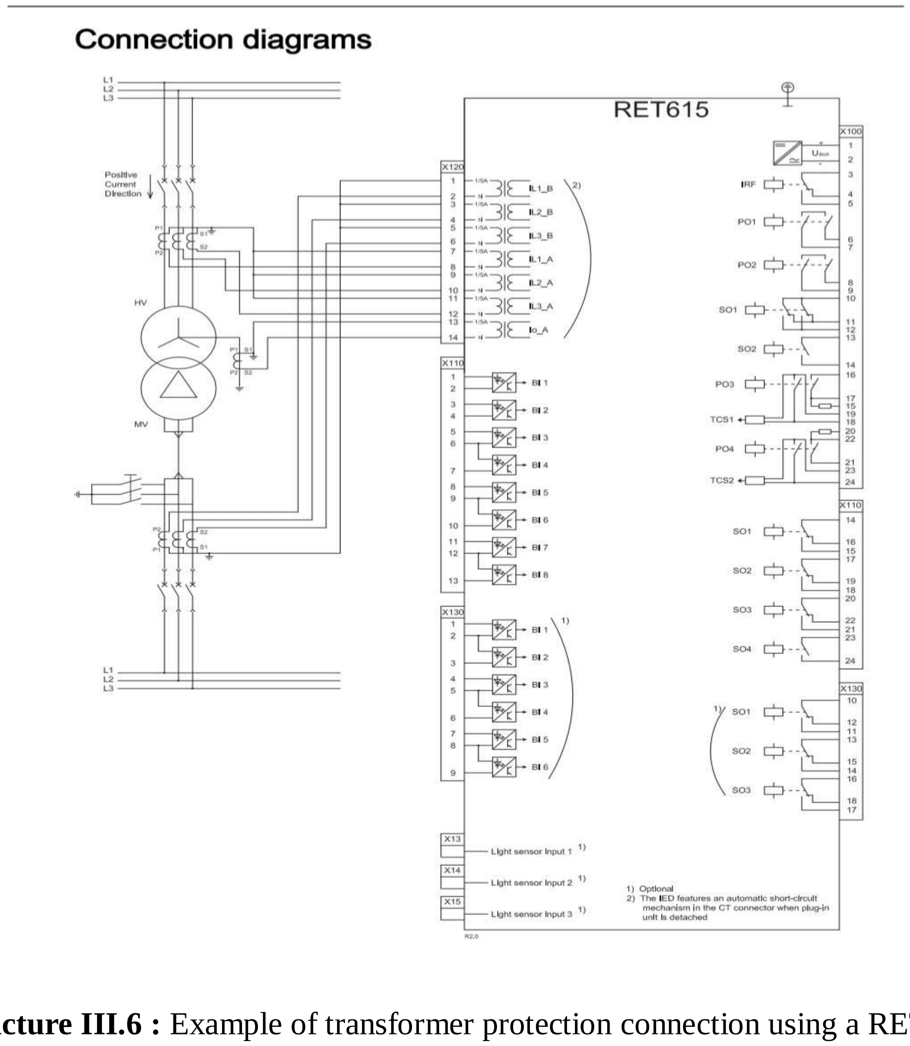
13: return to precedent file

III.3. Protection relay RET615

III.3.1. Definition

RET615 is a dedicated transformer protection and control IED (intelligent electronic device) for power transformers, unit and step-up transformers including power generator-transformer blocks in utility and industry power distribution systems, it's belong to the 615 series.it has been designed to unleash the full potential of the IEC 61850 standard for communication and interoperability between substation automation devices. **(12)**

It provide Differential protection, earth fault protection, transformer overload protection, high/low impedance protection, VCB failure protection, protection against abnormality in oil temperature/gas pressure.



Picture III.6 : Example of transformer protection connection using a RET615 relay.

III.3.2. Components

III.3.2.1. Physical hardware

The IED consists of two main parts: plug-in unit and case. The plug-in unit content depends on the ordered functionality ،further on that there is a display with LCD, keypads, LEDs as author's versions of relays.

Table III.1: Plug-in unit and case of the RET615

Main unit	Slot ID	Content options	
Plug-in unit	-	HMI	Small (4 lines, 16 characters) Large (8 lines, 16 characters)
	X100	Auxiliary power/BO module	48-250 V DC/100-240 V AC; or 24-60 V DC 2 normally-open PO contacts 1 change-over SO contact 1 normally-open SO contact 2 double-pole PO contacts with TCS 1 dedicated internal fault output contact
	X110	BIO module	8 binary inputs 4 signal output contacts
	X120	AI/BI module	6 phase current inputs (1/5A) 1 residual current input (1/5A)
Case	X130	Optional BIO module	6 binary inputs 3 signal output contacts
	X000	Optional communication module	See the technical manual for details about different types of communication modules.

III.3.2.2. Web HMI

The WHMI enables the user to access the IED via a web browser. The supported, web browser version is Internet Explorer 7.0 or later.

WHMI offers several functions:

• Alarm indications and event lists

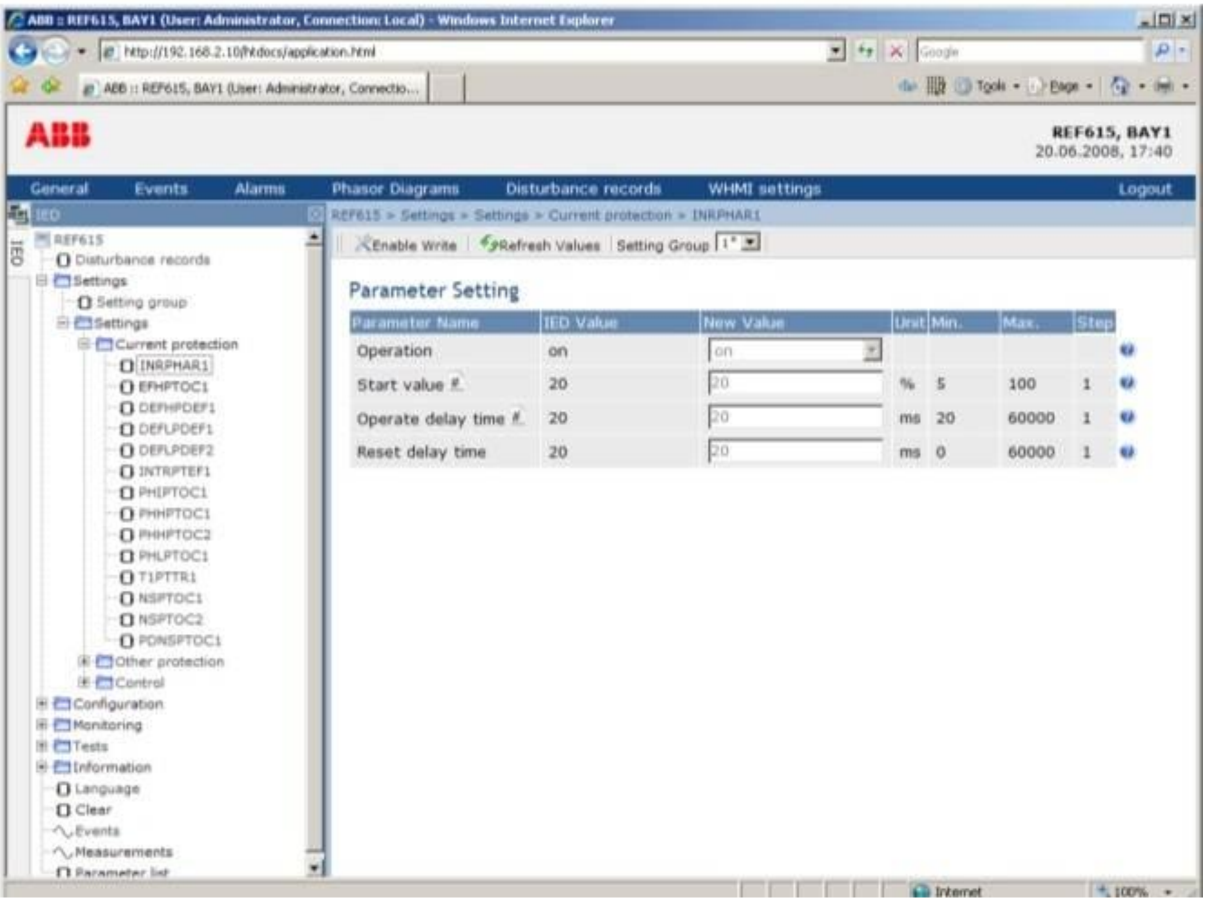
• System supervision

• Parameter setting

•Measurement display

• Disturbance records

• Phasor diagram.



Picture III.7 : Example view of the WHMI.

III. 4 ABB relay communication0

The IED supports a range of communication protocols including IEC 61850, IEC60870-5-103, Modbus® and DNP3. Operational information and controls are Available through these protocols.

All communication connectors, except for the front port connector, are placed on integrated optional communication modules. The IED can be connected to Ethernet based communication systems via the RJ-45 connector (100BASE-TX) or the fibrotic LC connector (100BASE-FX).

III.5Physical protection on the transformer

III.5.1 Temperature Protection

Protection from high oil temperature, which in turn also helps in cooling and in the Low and High voltage coils, and it is treated with the fins on the transformer body, which gains the temperature of the transformer and the RTD sensor is present on it and Avoid explosion or fire

.

III.5.2 Reinforce the insulation between the coils and the iron core of the transformer

The oil also plays the role of insulator between the coils and some of them, and between the coils and the core. The oil surrounds all of these and separates them and increases the insulating strength between them. The oil's insulating coefficient reaches 2.2 (the air insulating coef.ficient is equal to 1), so it approaches the insulating materials in general. It is much better than air.

Picture III.8 : Periodic monitor panel of main transformers 34.5/6.6KV of pellet plant TOSYALI

III5.3. Bushels relay

It is considered one of the most important physical protections for electrical transformers immersed in oil, and its importance lies in the following:

- Protecting the transformer when internal malfunctions and the resulting gases occur.
- Protecting the transformer from low oil level.
- Protecting the transformer from high pressure.

Picture III.9 : Bushels relay.

III.5.3.1 Installation

The Bushels relay is installed on the main oil pipe connecting between the main tank of the transformer and the compensation tank (Conservator tank), this relay consists of an oil chamber with an upper and lower float inside, in addition to an arm connected to the lower float.

III.5.3.2 operation principle

There are several scenarios for making this relay as follows:

a. Issuing a warning signal (Alarm)

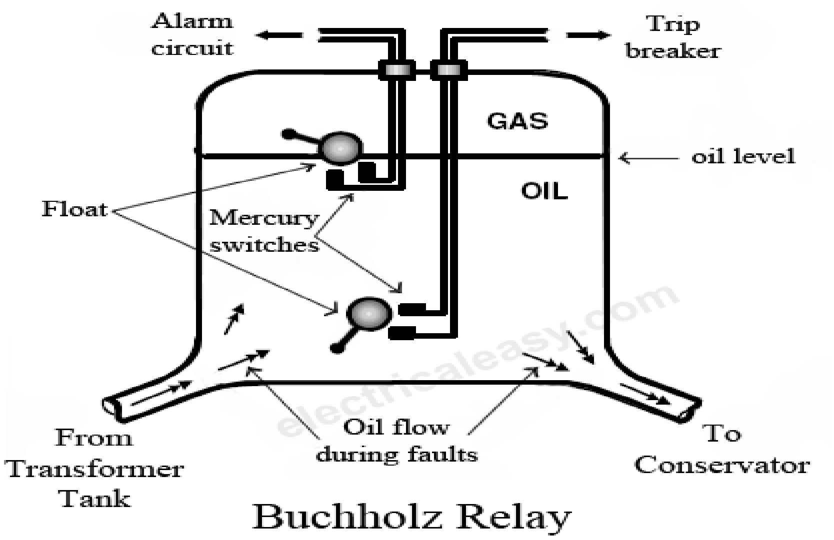
When internal faults occur in the transformer, and as a result of the high temperature, a group of gases is produced that move from the main tank to the compensation tank, passing through the Bushels relay.

b. Issue of a forced dismissal order (Trip) due to low oil level

When the oil level drops, this will cause the lower float of the Bushels relay to go down and issue a forced disconnection command (Trip).

c. Issue a forced dismissal order (Trip) due to high pressure inside the transformer.

In the event of a dangerous malfunction inside the transformer, which leads to an increase in the pressure inside the transformer and the oil transfer from the main tank to the compensation tank (Conservator tank) quickly, which leads to moving the arm connected to the lower float and issuing a forced disconnection order for the transformer (Trip).



Picture III.10: Bushels relay internal structure.

III.5.3.3Protection of the transformer through the ground:

There are many factors for the use of stones in the switch yard while designing several earthling operations in a sub-network, therefore; The main reason for placing gravel in the substation yard is to reduce the ground potential rise (GPR) AKA Step Voltage and Touch Voltage, which can be defined as follows:

Picture III.11 : Floor of HV substation full by stones.

a. Ground Potential Height (GPR)

Whereas, the maximum electrical potential that the substation earthing network can achieve relative to a remote earthing point is assumed to be at the remote earth potential, and this voltage (GPR) is equal to the maximum current of the electrical network multiplied by the resistance of the network itself.

b. Step voltage (Es)

defined as the maximum potential difference present between the feet when a fault current is flowing in the body, a special case of step voltage is Etransferred voltage, where the voltage is transferred into or out of the substation from or to a remote point outside the site substation, and it is usual to observe a distance of one meter between the steel structure and the point on the ground.

c. Definition of touch potential (ET)

It can be defined as the maximum potential difference that exists between an earthed metal structure that can be touched by hand and any point on earth, when a “fault current” flows.

As we know that the step and touch voltage increases during short circuit current and the resistance of stones is much higher compared to other materials which can be found easily and everywhere, that is why stones or pebbles are placed in the substation to reduce

the possibility of stepping and touching potentials in case of maintenance or Work on live equipment.

There are also other reasons:

4 To prevent the growth of weeds that cause fires
5 Water deposition to the ground to reduce the grounding resistance
6 Preventing the accumulation of oils so that there is no slip or fire.
7 Preventing the entry of animals (reptiles, snakes, and mice into the area) because they cause shorts and cut cables.

III.5.3.4 Protection against the moister using silica gel

Air contains a certain amount of moisture content. Therefore, the proper operating mechanism of a fan transformer depends on the moisture content in the air, since the large amount of moisture can cause changes in the dielectric strength of the oil.

Silica gel is used in breather transformers for controlling the level of moisture and prevents it from entering the equipment. They are mainly useful in protecting the transformer oil from the damaging effects of moisture. Silica gel blue crystals and orange beads work effectively in this application. They are manufactured by keeping in mind the requirement of the application as per the industry standards.

Features of Silica Gel

- High adsorption capacity
- Ability to control moisture entry
- High efficiency power
- Highly stable and reliable

Picture III.12: silica gel status before and After use

Picture III.13 : silica gel bottle installation in the transformer before use and after the expiration date

CHAPITRE IV

6.6KV INCOMER DRAWING AND MAIN ELECTRICAL CALCULATION

IV.1. Main electrical calculation

IV.1.1. Power transformer capacity calculation

Power transformers are measured by the apparent power, and the process of selecting a transformer is done according to the loads and the type of transformer required.

Suppose that a unit project in TOSYALI plant contains a special unit that contains the following loads:

Lighting Loads = 100MVA

Maintenance power loads =50MVA

Motors loads =30MVA

HVAC loads =700MVA

Lifts loads =25MVA

UPS loads=40MVA

It mean:

$$\textbf{Total loads} = \sum \textbf{unit loads} = \textbf{945MVA}.$$

Note:

As all loads not operate all the time and note operate with full power at all the time so we can't size the transformer on connected loads but we can sizing the transformer on the total demand load.

$$\textbf{Demande factor} = \frac{\textbf{maximum demand load}}{\textbf{total connected load}}$$

Is the probability that all the equipment's which are belong one type can be in line in the same time.

$$\textbf{diversity factor} = \frac{\textbf{diversity of indivudual max demand}}{\textbf{total max demand}}$$

Can be called also Coincidence factor: is the probability that all equipment from each type can be ON at same time.

We assume the diversity factor depends on the project.

On the project for example we selected

$$\mathbf{DF = 0.8}$$

Total maximum demand load is

$$\mathbf{DF} \quad \times \sum \mathbf{unit\ loads}$$

$$= \mathbf{0.8} \times \mathbf{945} = \mathbf{756\ KVA}.$$

So, we pass to which type transformer

If oil transformer:

Operate at normal operation at 80% of loading capacity.

$$\mathbf{S\ (KVA)} = \frac{\mathbf{756}}{\mathbf{0.8}}$$

= 945KVA

And from standard of transformer we can find 1000KVA

If dry transformer:

Operate at normal operation at 100% of loading capacity.

$$\mathbf{S\ (KVA)} = \frac{\mathbf{756}}{\mathbf{1}}$$

= 756KVA

From standard we can find 800KVA transformer.

We have also to take care about extension loads, that is the spare loads,

It’s equal to 25%, from the each type of loads...

IV.1.2. Voltage drop calculation

Voltage drop is the difference of potential existing between two poles of any load which should not cross 5 % from the rating voltage of load which is mentioned on its name plate

In case of Voltage drop, load will take huge current because of the decreasing of the voltage as per power law :

$$\mathbf{P = \sqrt{3} * U * I * COS\ PHI.}$$

$$\mathbf{I = \frac{P}{\sqrt{3} * U * COS\ PHI.}}$$

There is a reverse relation between current and voltage, if any one from them Increase, so auther will decrease.

IV.1.2.1. At any point from the cable way

We have two methods of voltage drop calculation

A. Ohms law

$$\mathbf{Vd = Zt * Ir}$$

Where:

Zt: Cable impedance

Ir: rated current

B. From the Factor from cable name plate

$$\mathbf{Vd = (mv/A/m)/10\text{^} - 3 * Ir * L}$$

Where:

$(\mathbf{mv/A/m})$: From cable characteristique.

Ir: rated current

L: cable length

$$\mathbf{Vd}\ \% = \left(\frac{\mathbf{Vd}}{\mathbf{Vr}}\right) * \mathbf{100}$$

IV.1.2.2. Voltage drop calculation at transformer LV side

$$\mathbf{VD = Z\% * Vs}$$

We have

Vs: secondary voltage

Z%: short circuit reactance (taken from the data sheet)

We have transformer of TRX (34.5/6.6kv) and its SC reactance is 4%.

$$\mathbf{VD = Z\% * Vs}$$
$$\mathbf{= 0.04 * 6600 = 264V}$$

SO the voltage at secondary side will be as following

$$\mathbf{6600\text{-}264 = 6336V}$$

IV.1.3. Short circuit current value calculation

Electrical faults usually occur due to breakdown of the insulating media between live conductors or between a live conductors and earth.

And we have:

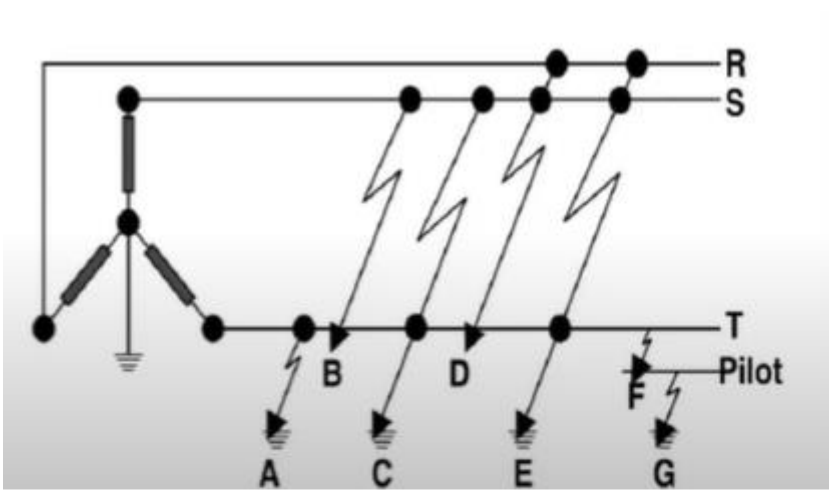
Symmetrical faults:

3ph's, 3PH-G.

Asymmetrical faults

PH-PH, PH-G, PH-PH-G

Danger one is when 3PH connected together or with ground, in this case current will increase quickly and reach a very high value and may provoke a huge damage.



Picture IV.1 : Different status of the short circuit.

IV.1.3.1. Short-circuit electrical energy

$$\mathbf{E} = \mathbf{Isc^{\wedge}2} \times \mathbf{T}$$

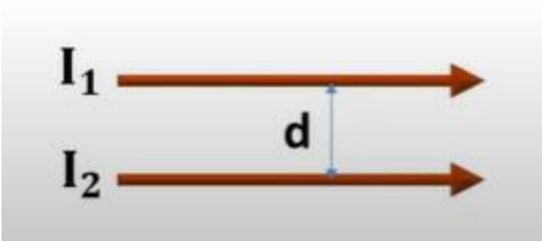
Where

Isc: Short circuit current.

T: Short circuit duration.

Due to magnetic field, a Force will be created which may happen the short circuit.

$$\mathbf{F} = \frac{(\mathbf{2} \times \mathbf{I1} \times \mathbf{I2})}{\mathbf{D}}$$



Picture IV.2 : Distance between two conductors

Where

I1, I2 : are the current value on the bus bar 1 and 2 respectively.

d: distance between the both bars

IV.1.3.2. Short circuit calculation in medium voltage

It's depends on the network voltage if each area, we have this table:

Table IV.1: Global power value and short circuit level as per grid network voltage

NETWORK VOLTAGE KV	MVA sc	SC LEVEL KA
11	**500**	26.2
13.8	**500**	20.9
22	**750**	19.7

$$\mathbf{SC\ level} = \frac{\mathbf{MVAsc}}{\sqrt{3} * \mathbf{V(KV)}}$$

Where:

$\mathbf{V(KV)}$: Line voltage.

$\mathbf{MVAsc}$: It's power value fixed by electrical providing company.

Ex:

$$\mathbf{Isc} = \frac{\mathbf{10^{\wedge}6}}{\sqrt{\mathbf{3}} * \mathbf{34.5} * \mathbf{10^{\wedge}3}}$$

$$= \mathbf{17kA}.$$

And as per this value we purshase a switchgear same or in the next value, we have this table for standards switchgear with rating current of short circuit.

In our case we have to use 20KA who can bear that huge value before breaking during 1 second.

Table IV.2: MV switchgear standards value

MV SWITCHGEAR S.C LEVELS
16KA
20KA
25KA
31KA
40KA
50KA
60KA

IV.1.3.3 Short circuit calculation in low voltage transformer side (secondary winding)

Those laws are used only in the secondary winding of transformer before going to any load.

$$\mathbf{Isc\ fault} = \boldsymbol{S}(\mathbf{tr})/(\sqrt{\mathbf{3}} * \mathbf{Z}\% * \mathbf{Vs})$$

$$\mathbf{Isc\ fault} = \frac{\boldsymbol{S}(\mathbf{tr})}{(\sqrt{\mathbf{3}} * \mathbf{Z}\% * \mathbf{Vs})}$$

Where

$\mathbf{S(tr)}$: is the apparent power of transformer.

$\mathbf{Vs}$: Line voltage in no load conditions in the secondary

$\mathbf{Z\%}$:Transformer impedance percentage.

So:

$$\mathbf{Isc\ fault} = \frac{\mathbf{31500 * 10^\wedge 6}}{\sqrt{\mathbf{3}} * \mathbf{0.04} * \mathbf{6600}}$$

$$= \mathbf{70kA.}$$

IV.1.3.3. Short circuit calculation in any point of power line up to the load:

$$\mathbf{Isc\ fault} = \frac{\mathbf{Vline}}{(\sqrt{\mathbf{3}} * \mathbf{Ztotal})}$$

And:

$$\mathbf{Ztotal} = \mathbf{Ztransformer\ Source} + \mathbf{Z\ cable}$$

We have to use impedance value referred to the secondary winding not per-unit but in ohms so for that:

$$\mathbf{Ztransformer} = \mathbf{Zbase} * \mathbf{Z\%.}$$

$$\mathbf{Zbase(ohms)} = \frac{\mathbf{Vl^\wedge 2}}{\mathbf{S}}$$

$$\mathbf{Zbase(ohms)} = \frac{\mathbf{6600^\wedge 2}}{\mathbf{31500 * 10^\wedge 3}}$$

$$= \mathbf{0.808}$$

So

$$\mathbf{Ztransformer} = \mathbf{0.808} \times \mathbf{0.04}$$

$$= \mathbf{0.0323.}$$

Z cable is depend to the type of cable and we have:

Cable specification: TMY-1(40*5)

As per the table we got this cable resistance value:

$$\mathbf{Rcable} = \mathbf{0.550\ ohm/km} = \mathbf{0.00055 ohm/\ meter.}$$

And suppose we have 45 m cable length from secondary winding of transformer to our studying point:

So

$$\mathbf{Z\ total} = \mathbf{0.0323} + (\mathbf{0.550/1000}) * \mathbf{45}$$

$$= \mathbf{0.057\ ohms}$$

So

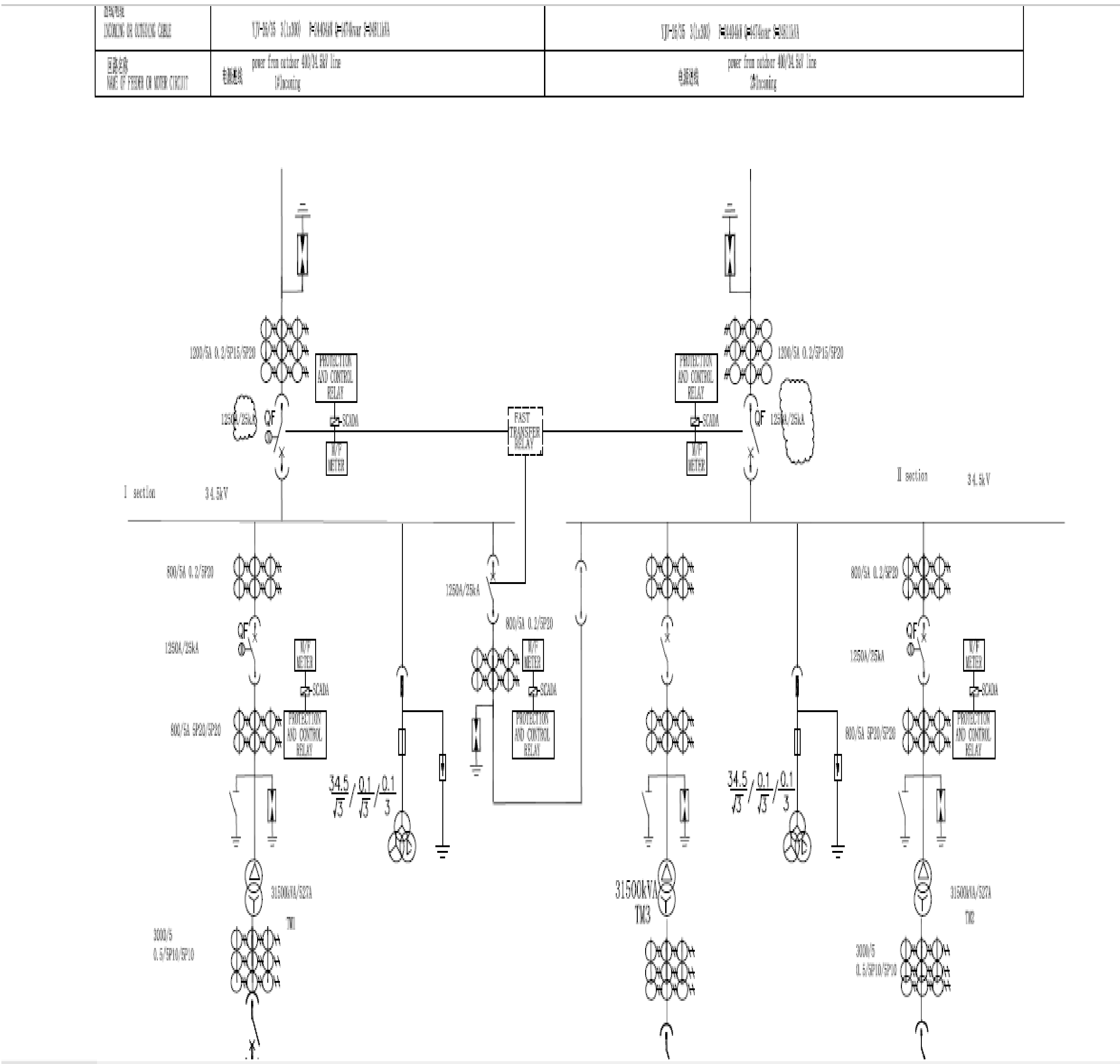
$$\mathbf{Isc\ fault} = \mathbf{6600}/(\sqrt{\mathbf{3}} * \mathbf{0.057})$$

$$= \mathbf{66.5KA.}$$

IV.2. Electrical drawing reading

Reading electrical diagrams is based on several foundations that enable you to understand the mechanism of the device and fix technical problems by facilitating the process of tracking faults and limiting as much as possible the problem, and this is by knowing the electrical symbols of various devices and so on.

In this axis we will discuss reading the diagram of the protection cell of the electric transformer No. 2 with a capacity of 31.5MVA.



Picture IV.3 : SLD of the main substation of 34.5/6.6KV.

IV.2.1. 400/34.5KV single line drawing

This scheme represent the single line diagram of the substation of pellet plant which:

Two main incomer lines of 34.5KV where both lines have the same parameters as following:

IV.2.1.1. Incomer switchgear

a. Type of electrical cable from 400KV substation to 34.5KV substation

YJV-26/35 3 (1*300).

Active energy: P=24404KW.

Apparent energy: S=24811KVA

Reactive energy: Q =4474 KVAR.

Power factor: PF=0.97

Those two lines before feeding three transformer, it has been protected by two switchgears(incomer and transformer cells) , those protection cells have three CT in each Incomer line ,in the line there are three CT for each phase with this proprieties :

b. CT type

CT ratio: 1200/5A

CT accuracy class: 0.2/5P15/5P20

0.2: error percentage of measuring in normal condition

5p15 mean:

5: percentage of error ratio.

P: CT using purpose (protection)

15: accuracy limit factor mean that in case of fault, if the current go up to

15 times from the ratting current of the primary, so the error percentage

Will reach up to five percent.

b. Surge protector

Both lines are also protected by two surge protector (overvoltage protector), the wiring of this protection embody the neutral system wiring which is IT system.

c. VCB type

Each line of 34.5KV have two vacuum circuit breakers from ABB for the protection of line from main 400kv substation until pellet plant substation with the proprieties:

Rating current (I.e.): 1250A

Rating short circuit breaking current (Isc):25KA

Rating duration short circuit current: 4s

The breaker is controlled by a REF 615 relay, which is interconnected with relay of auther line by the fast transfer SE3000 relay based on SCADA communication system, these communication ensure many technical association such as interlocking circuits …

IV.2.2. Transformer switchgear

after that , the line no 1 will feed bus bar for feed TM1 (31.5MVA) transformer only ; where the second line feed a bus bar for feed again two transformer TM2 (31.5MVA) and

TM3 (31.5MVA).

All bus bar have a same dimension and proprieties

Operating voltage: 35KV.

BUS bar type: TMY-3*(80*8).

To enhance the protection on the three lines into the primary of the transformer we have another two CT with ratio of 800/5A and accuracy class of 0.2/5P20 .Those CT used for protection purpose between the transformer panel and the incomer panel.

After that and before reaching the transformer we have to customize a special protection of the transformer, which contain

Rating transformer current: 527 A.

Two CT where the parameters are:

CT Ratio: 800/5A

CT accuracy: 5p20 and 5p20

A VCB proprieties:

Rating current (Ie): 1250A

Rating short circuit breaking current(Isc):: 25KA

Surge protector TBP-B-42/280.

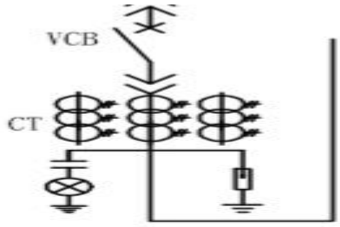
Earthling switch NO: JN22B-34.5/25.

The coupling of all transformer is delta-star which gives us an opportunity to get the neutral line by extracting it from the tie point in the secondary coil of the transformer, and this is what embodies another type of neutral system represented in the T-N system.

IV.2.3. 6.6 KV incoming from the transformer

In the secondary of each transformer we are getting 6.6KV for feed the two plants pellet and beneficiation.

From the transformer TM2 we get 6.6KV going directly into the panel switchgear number 204AH with the protection components as following

系统排列图 System Arrangement Diagram	Ie=3150,Id=31.5kA(4S),ich=80kA	
	主母线 Main bus TMY−3*(2*(120*10))6.6kV	
	屏上设备 前视排列 SWITCHGEAR EQUIPMENT FRONT 接地排 TMY−1*(40*5)	
	开关柜编号 SWITCHGEAR NO.	204AH
	KYN28A−12开关柜外形尺寸(W×D×H) SIZE OF KYN28A−12 SWITCHGEAR SHELL	1000X1800X2300
	额定电流(A) RATED CURRENT(A)	2756A
一次设备 Primary equipment	VD4 真空断路器规格 VD4 VACUUM CIRCUIT BREAKER	3150A,31.5kA
	隔离手车规格 DISCONNECTING SWITCH	
	LZZBJ9−10 型电流互感器规格 变比 LZZBJ9−10 CURRENT TRANSFORMERS TYPE & RATIO 动稳定63KA,热稳定4S/31.5KA	3000/5A 0.5/5P10/5P10
	高压熔断器规格 HV FUSE SPECIFICATION	
	JDZX11−6.6 电压互感器规格 变比 JDZX11−6.6 VOLTAGE TRANSFORMERS TYPE & RATIO	
	过电压保护器型号及规格 OVERVOLTAGE PROTECTOR TYPE & SPCIFICATION	TBP−B−8.4/131
	接地开关规格 EARTHING SWITCHES TYPE	
	零序电流互感器规格 ZEAO SEQUENCE CURRENT TRANSFORMER TYPE	
	所用变规格 THE VARIABLE TYPE	
二次设备 Secondary equipment	综合测控保护装置 Combined Protection Type	REF615 (50HZ) HCFFAEAGNDC2DAA11E
	状态指示仪 THE VARIABLE TYPE	HDKZ−5
	多功能仪表 MULTI−FUNCTION INSTRUMENT	PZ96−E4/CP
	二次回路参考图号 C & I DWG. NO.	
	回路名称 NAME OF FEEDER OR MOTER CIRCUIT	6.6KV 2# Incoming 6.6KV 2段电源进线
	出线电缆 INCOMING OR OUTGOING CABLE	
	出厂编号 FACTORY NO.	
	设备容量 (kVA/kW) CAPACITY OF FEEDER OR MOTOR CIRCUIT	

Picture IV.4 : TM2 transformer secondary line cell technical card.

NB: As we are remarking that in parallel with the line of 6.6kv we have two lines one for overvoltage protection another have a capacitance with a green indication lamps for power availability informing.

IV2.3.1 Measurement of voltage and current circuit drawing

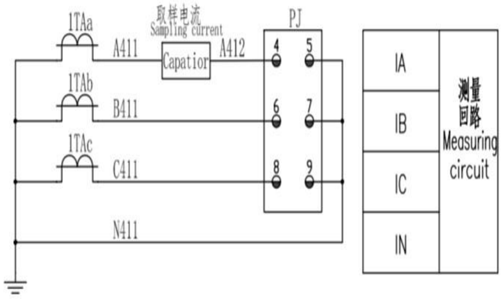
In order to obtain the current and voltage measurements, CT and VT were provided for each phase and the neutral as well, and then the measurements were sent to the display device (PJ device)

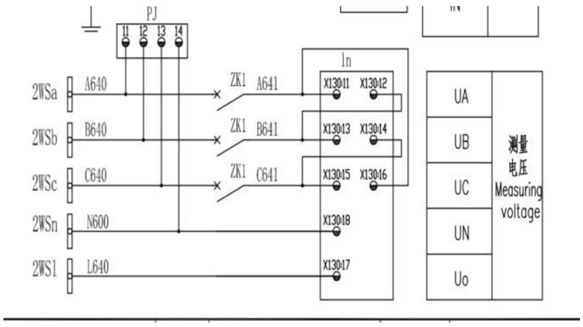
As these measurements are not included at all in the principle of electrical protection, they are used just for the user to know the process of his system.

For the CT, one side is connected the the PJ port; another side is shorted and grounded also.

For the VT , is connected in parallel so it use only one for the measuring and protection purpose ,from each phase we have one party connected to the PJ device Porte as well neutral measuring party .

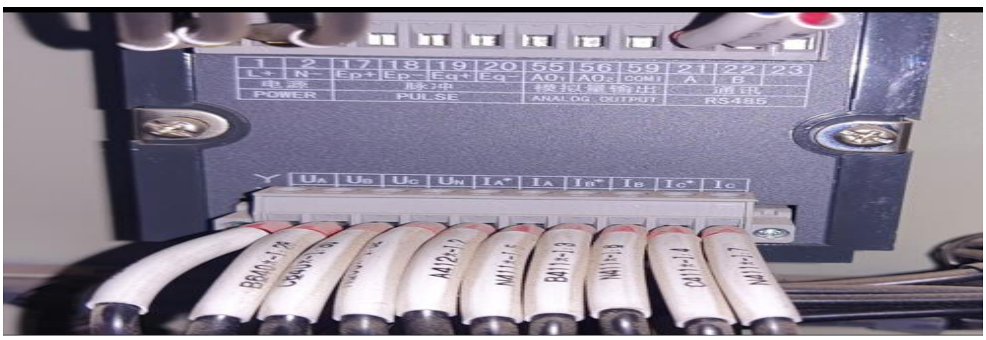
+





Picture IV.5 : Measuring CT connection drawing **Picture IV.6 :** VT connection drawing

This both drawing is embodied through the following wiring, where the cables can be traced through the same Tag name located at both ends of the cable.



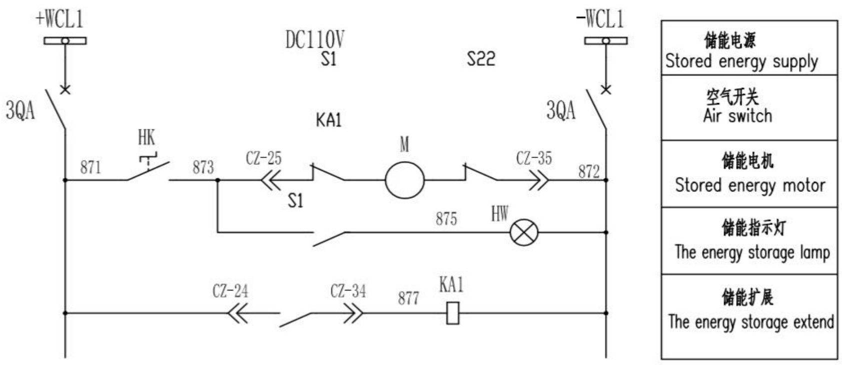
Picture IV.7 : Whole Wiring of the PJ device

This device is powered by 110VDC connected on 1-2 gates and communicate with the SCADA system by the two gates number 21/22 based on RS485 protocol.

Picture IV.8 : The display of the PJ device

IV2.3.2 ABB VCB spring drawing

The operation of the VCB is based on one spring powered by its motor, The function of the charging motor (M) is to compress the main closing spring which is the mechanical stored energy mechanism. The energy required to trip or open the circuit breaker is provided by the tripping spring, while the energy required to close the circuit breaker is supplied by the closing spring

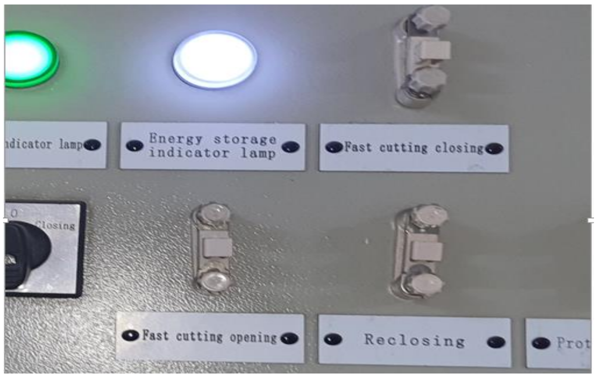


Picture IV.9: Drawing of spring charging operation

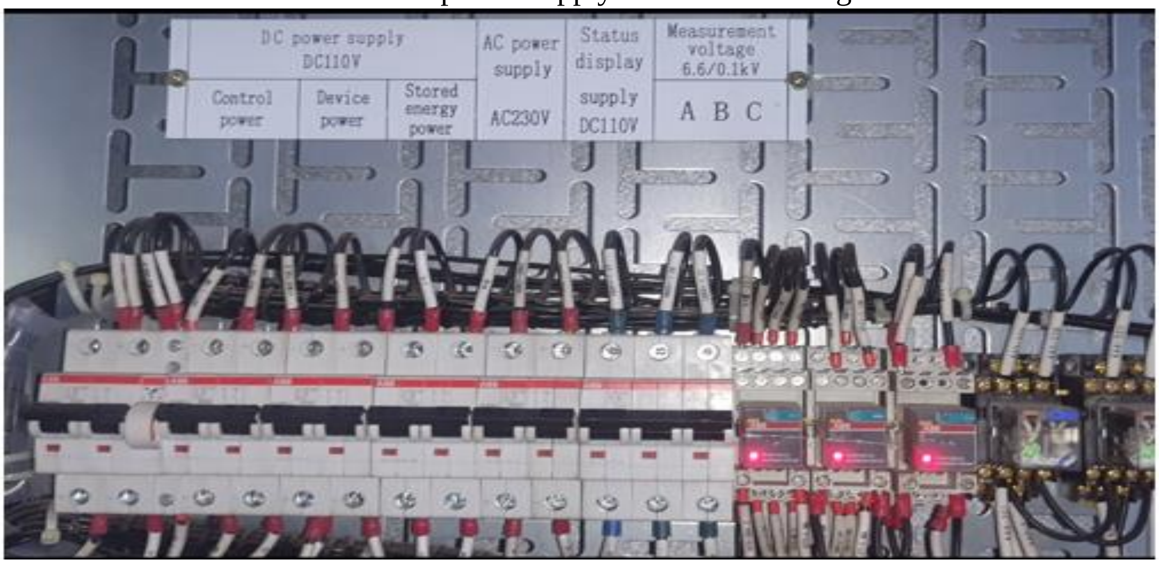
The feeding of motor is by 110VDC coming from WCL1 breaker, if charging of spring is required so we press HK NO push button, power will flow up to the motor, then motor will start running until the operation completion, at that time CZ-24/CZ-34 will close and S1 NO contact will close also which make in indication lamp glowing and KA1 will energize and at same time KA1 NC contact will open and the motor stop.

Picture IV.10 : Spring charging Indication lamp With tag name

Picture IV.11 : informing white indication lamp for spring charging



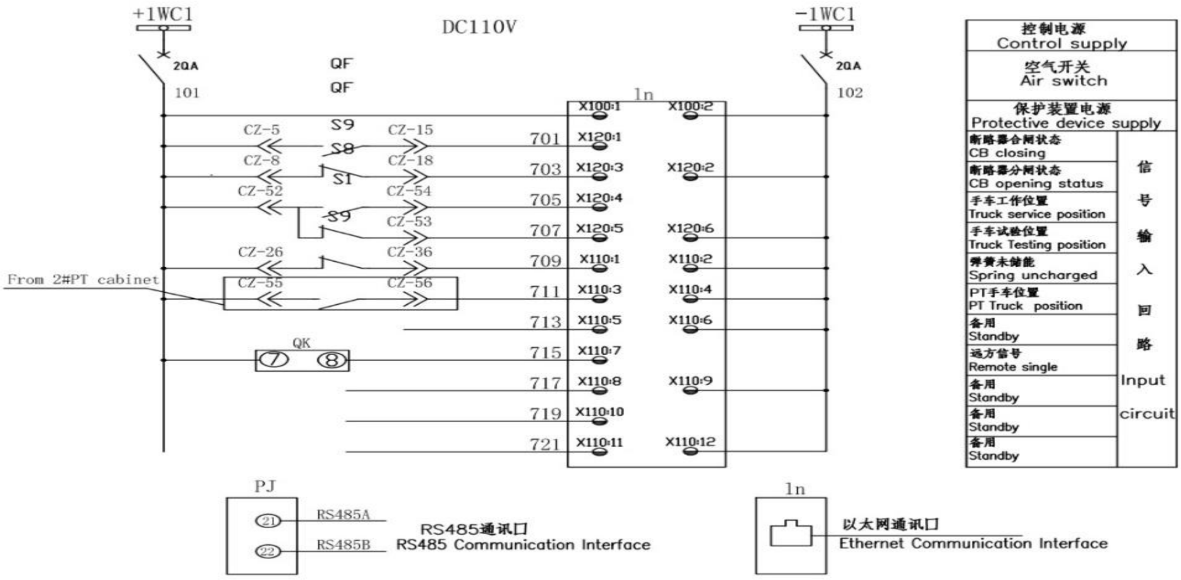
Picture IV.12 : DC AC power supply for whole switchgear control devices



IV.2.3.3 The input and the output signal of the REF615 drawing

a. REF615 Input signals

In order for the protection cell to recognize the various positions of the VCB and to take the necessary decisions of disconnecting, connecting and warning automatically or from the user, the relay must be permanent Communication and reception of various binary signals as per the programmation of user.



Picture IV.13: Ref615 input signals connection drawing

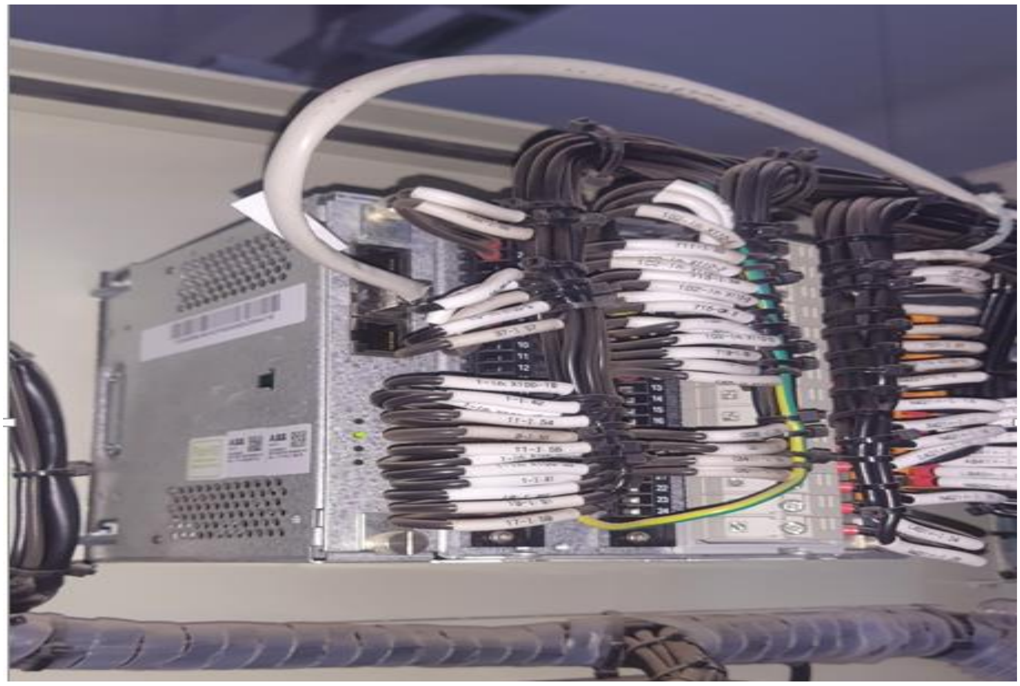
The ref615 is powered also from MCB WC1 110VDC (20A), connected to the ref615 gate X1001.

While the VCB finish closing operation, So CZ-5/CZ-15 NO contact close and ref615 receive the closing feedback, the same thing is happening in case of opening of the VCB with the contact CZ-8/CZ-18 NO, this contact will close and the ref615 sense the operation and treat it.

Two inputs for rack in and rack out position of the VCB , NO for rack in position(CZ-52/CZ-54) under label of ‘ truck service position ‘ , NO contact also (CZ-52/CZ-53) for rack out position of breaker under label of‘ truck testing position ‘

For spring incharged informing to the system, there is NC contact, in case of last alarm, so this contact will change his state …

While selecting remote control, the selector switch will close and allow flow of signal to the ref615 in X110:7.



Picture IV.14 : Ref615 backside wires connection place

IV.2.3.4REF615 output signals

The relay issues different commands based on programming the disconnection and connection settings from the user in precise time conditions that vary according to the setting, by sending output signals to the VCB, the local control panel, and the control room as well.

A

a.Closing blocking electromagnet

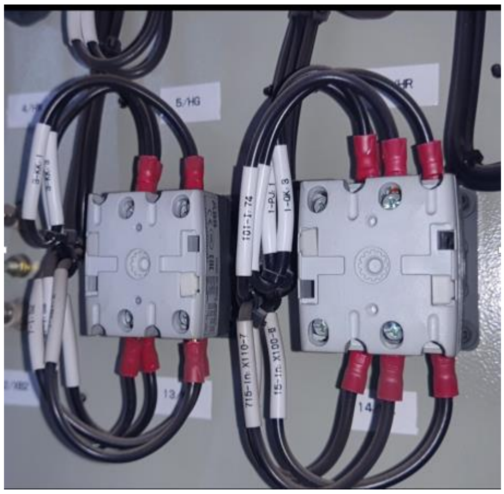
As we talk, there is a link between the switchgears, in this element we have a link between the incomer 1 and the incomer 2, further we have an electrical interlock between incomer 2 and the bus tie cells for protection purpose (NC contact B003CZ-7/B003CZ-17), in case of closing, the hole line should be healthy and allow signal to reach to the closing coil.

b.Manual closing

If we want to perform a VCB closing in local, we have to put the selector switch (QK) in local position, then select ON position from (KK) switch, who make the closing coil energize.

c. Manual opening

If we want to perform a VCB opening in local, we have to put the selector switch (QK) in local position, then select OFF position from (KK) switch (CZ31-CZ30) ,for that M01 will energize at the level of ABB VCB.



Picture IV.15 : KK and QK selector switch **Picture IV.16 :** back side connection of QK and KK

d. Under voltage release

One from the fault is the under voltage, for that X100:10/X100:11 will open, who make MU coil de-energize and relay will send trip order to the breaker

e. Remote closing:

For perform closing operation from the CCR or remote based on the SCADA system , we have to give clearance from panel by putting the selector switch (QK) in remote position , then we have to close X100:6/ X100:7 from control SCADA room.

f. Remote opening

Same thing as remote closing operation, but we have to close X100:8 / X100:9, from control SCADA room.

g. Protection trip and high differential trip

Those orders are given directly from relay itself after receiving information from CT and VT , after that it will detect the faults and many contact in series will close …

h. High differential trip

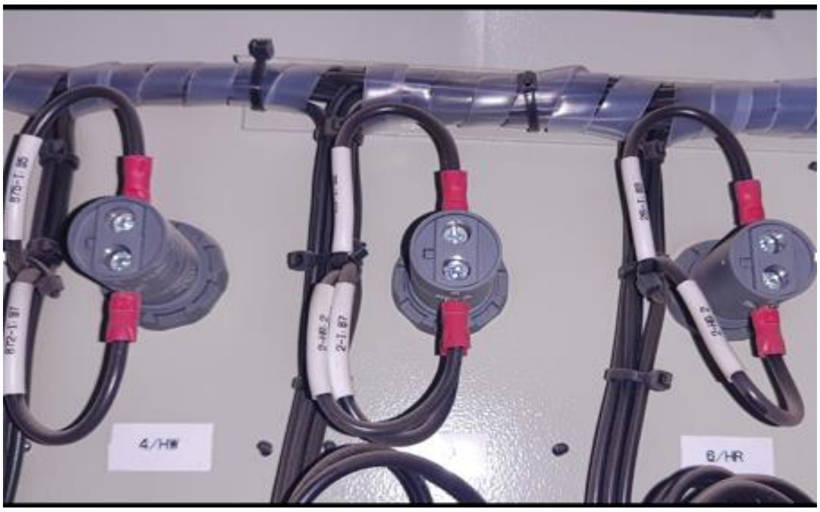
This part achieves the differential protection that depends on the comparison between the primary and secondary coils, and accordingly, ref615 issues an order to separate

The signal is coming after closing of the NO contact X100:8/X100:9 in level of 34.5kv switchgear.

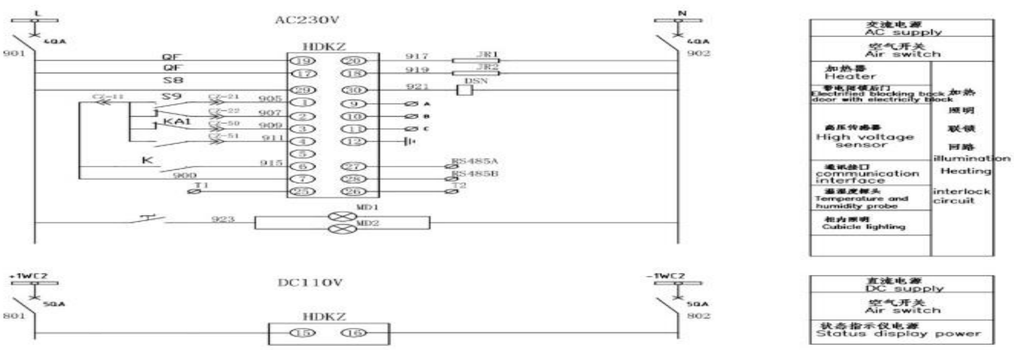
i. Indication lamps

Green indication lamp for VCB closing it glow after CZ-9/CZ-19 NO contact closing.
Red indication lamp for VCB closing it glow after CZ-23/CZ-33bg NO contact closing.

Picture IV.17: Indicators of MV feeder's status



Picture IV.18 : Indicators of MV feeder's status back side wirin



Picture IV.19: HDKZ MV feeder power status display drawing

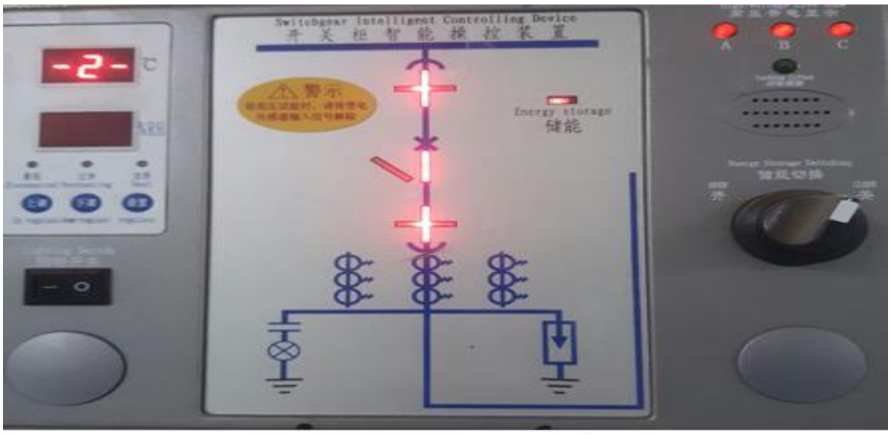
V. 2.3.4.Power Status display drawing HDKZ

This scheme represent the HDKZ device for power status informing,for if the power is existing on the bus bar, if the relay is close or open, if the VCB is in rack out or not…

It also knows the presence of power on each phase by displaying three bright lamps that work in accordance with the high voltage sensors, which are connected to the device as a digital input at the entrances 906/907/909 with a common feed from outlet 915 passing through the switch K in series with CZ-11

It also displays the humidity level of the cell and provides a heater to reduce it in order to preserve sensitive devices. This heater (two resistors JR1/JR2) takes phase through output 917/919 by parallel after entering this phase by parallel also from input 19 and 20 directly from the MCB QF

This device is fed with 110VDC through the two inputs 15/16 and communicates with other devices such as ref615 via the RS485 protocol at the two inputs A and B.



Picture IV.20 : Hdkz MV feeder power status display

IV.3. Etap program simulation

to study the general condition and in general of electrical network from the first to to the last feeding point we relied on the ETAP program which enabled us to obtain important data especially the analysis of the feeding line, where Online Predictive Simulation analysis is a powerful analytical tool that predicts system behavior in response to operator-reported actions and events through the use of archived and real-time data.

IV.3.1. The experiments carried out on the program

In this study, the implementation of the single feed line in the stop condition was addressed, the load flow analysis and the extraction of the current value for each transformer or load, the percentage of voltage drop for both main lines, the power factor for each load, the voltage ratio in each bus bar, and then the creation of short circuits in Each energy level in order to identify the value of short circuit currents

IV.3.2. The values entered into the program

a. Hassi line

Voltage: 400KV

Short circuit energy: 3200MVAsc

Short circuit impedance X/R : 66

Length to the substation: 45KM

Impedance: R-T1= 0.02

R-T2= 0.02

X=Y=0.04

b. Maktaa line

Voltage: 400KV

Short circuit energy: 3000MVAsc

Short circuit impedance X/R : 64

Length to the substation: 47KM

Impedance: R-T1= 0.02

R-T2= 0.02

X=Y=0.04

c. Transformers

TRX1/TRX2

Ratio: 400/34.5KV

Apparent energy: 180MVA

Impedance: taken typical data

Z%= 14.5

X/R = 42

TM1/TM2/TM3

Ratio 34.5/6.6KV

Apparent energy 31.5MVA

Impedance: taken typical data

Z%= 7 , X/R = 27.3

1TM1/1TM2/2TM1/2TM2/3TM1/TM2/4TM1/4TM2

Ratio 6.6/0.4KV

Apparent energy 2MVA

Impedance: taken typical data

Z%= 5.75, X/R = 7.098

5TM

Ratio 6.6/0.4KV

Apparent energy 0.8MVA

Impedance: taken typical data

Z%= 5.75, X/R = 7.096

d.Total load energy is 27000KW

Suppose it Represent LV and MV motors

TM1/TM2

MV motors (6.6KV) power: 8000KW

Full load amps: 790.7 A

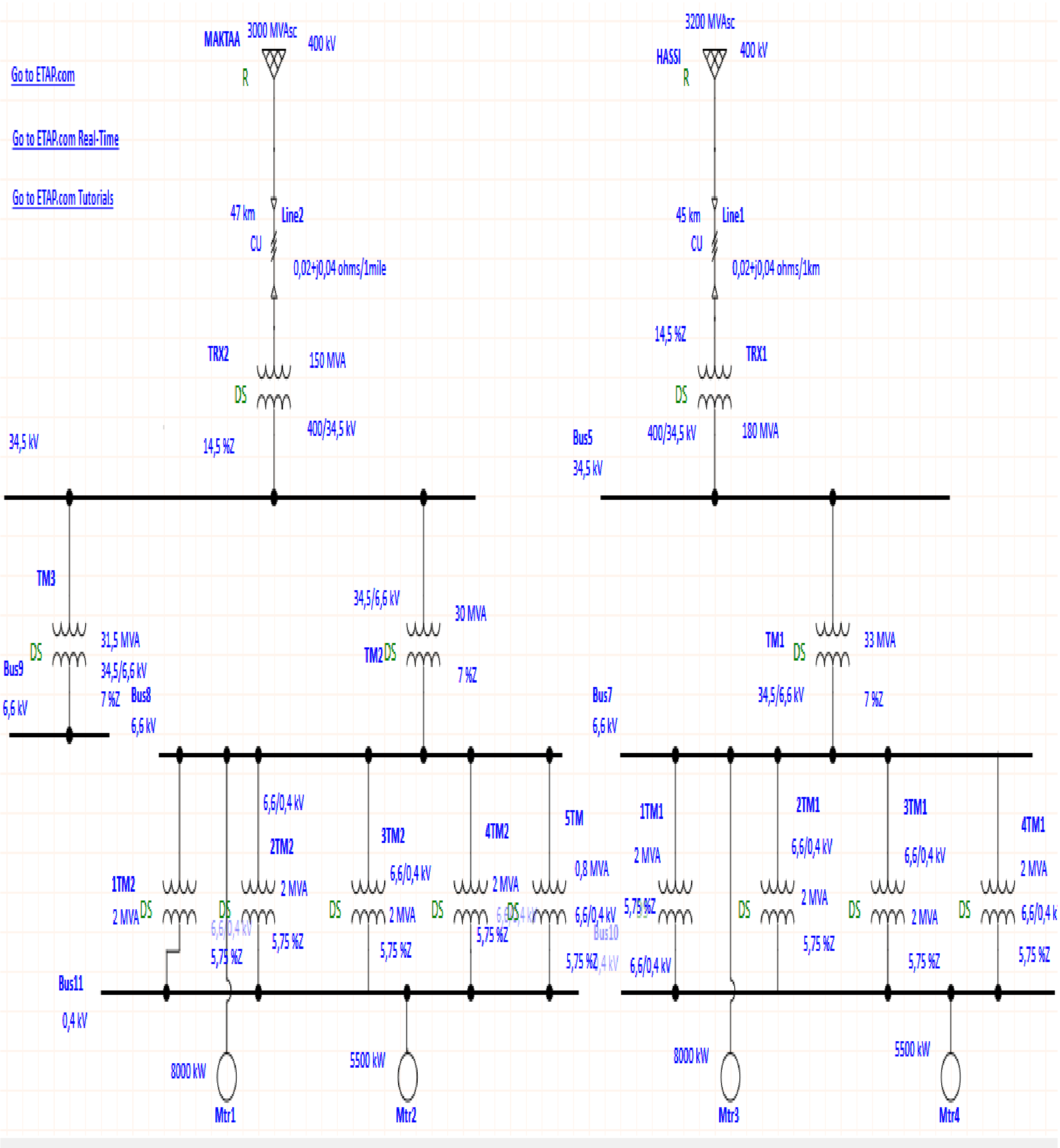
PF: 93.35

LV motors (400V) power: 5500KW

Full load amps: 9003 A

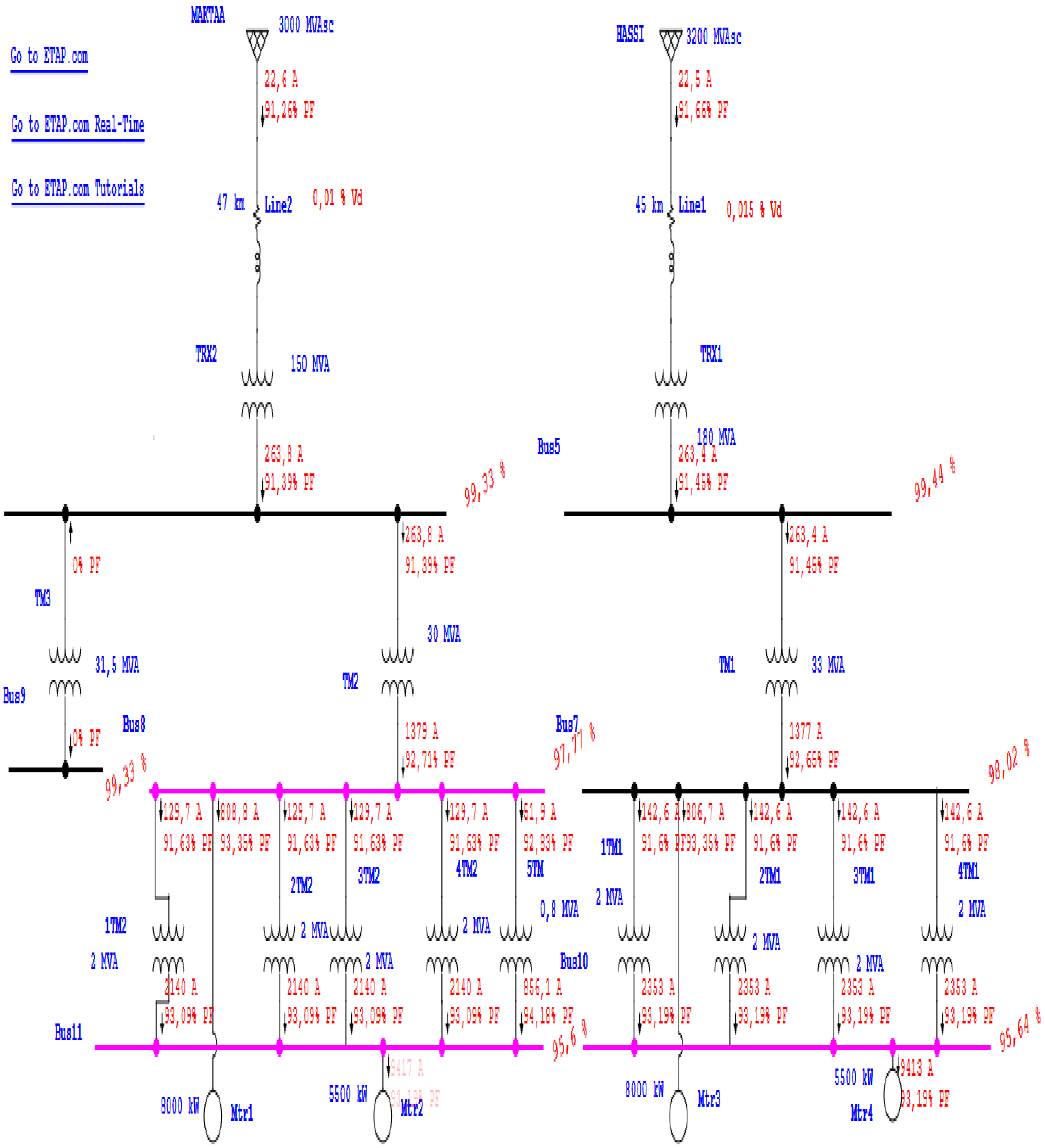
PF: 19

IV.3.3. single line diagram 400/34.5/6.6/0.4KV



Picture IV.21 single line diagram 400/34.5/6.6/0.4KV

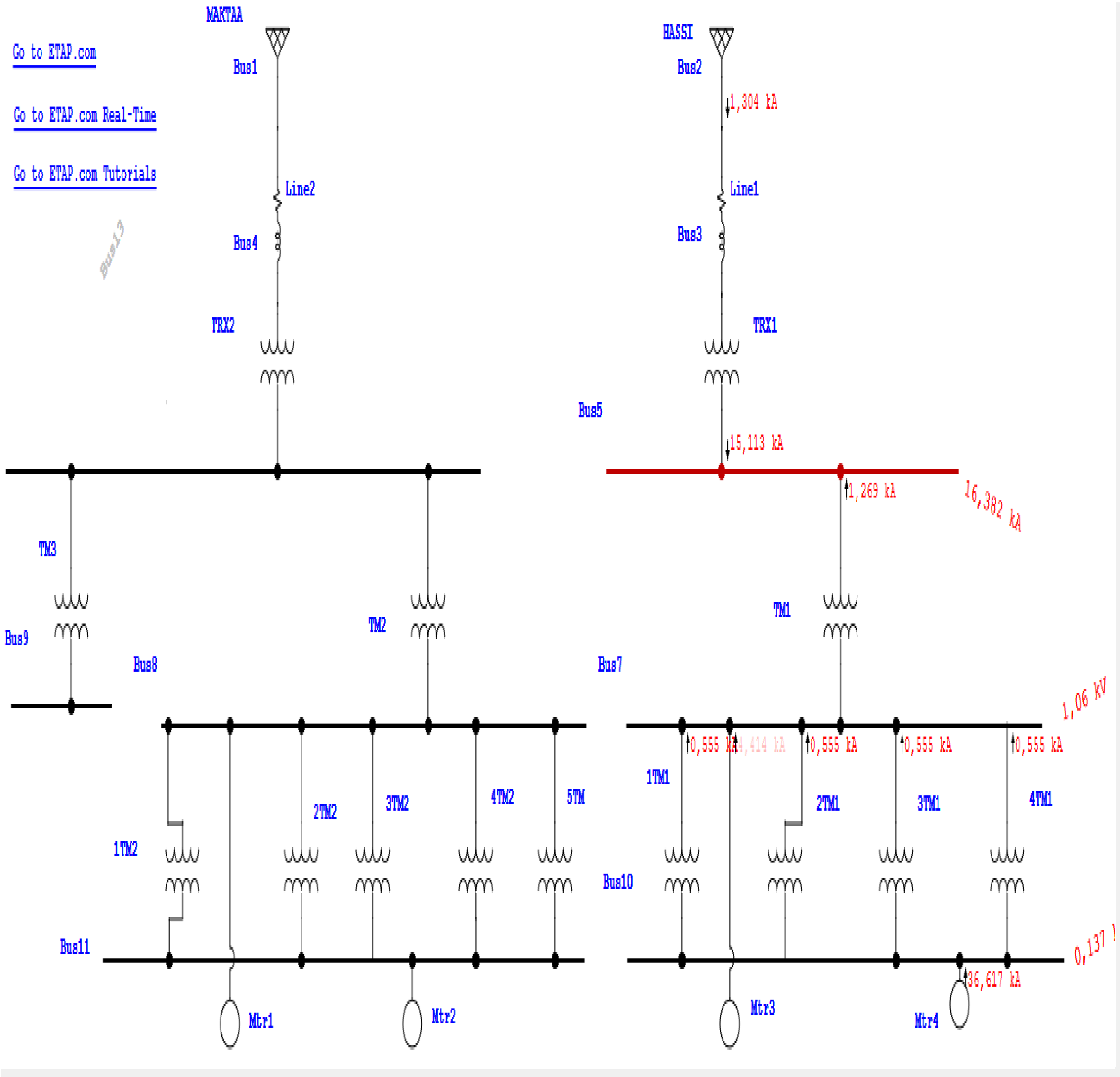
IV.3.4. Load flow analysis



Picture IV.22Load flow analysis

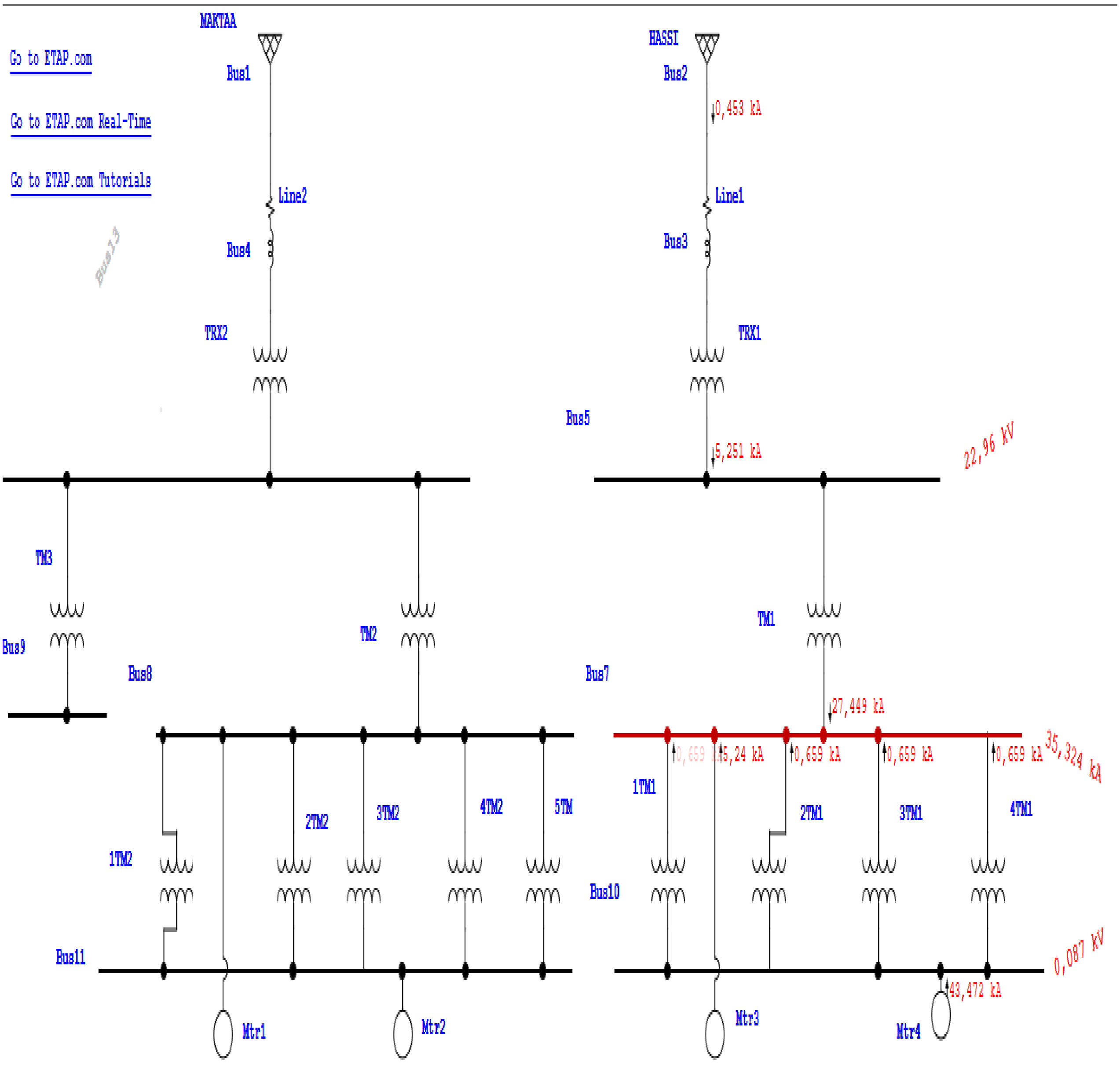
IV.3.1. Short circuit analyses

a. In bus of 34.5KV



Picture IV.23 Short circuit analyses In bus of 34.5KV

b. In bus of 6.6KV



Picture IV.24 Short circuit analyses In bus of 6.6KV

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Conclusion

Electrical engineering has many branches and broad fields, as the electrical Protections branch is considered a branch in itself, because of its utmost importance in The stability of the power transmission and distribution system. Experts seek to devise New means and devices that are more feasible to control electrical phenomena, so this Field is developing rapidly in keeping with the acceleration of the world energy needs. In this research, we have presented an explanation of the most important devices And protection techniques adopted in modern factories, such as the TOSYALI factory, Which is considered one of the most energy-consuming heavy industry factories with a Total of 1110MW, counting all its production units.

This large consumption of energy made manufacturers provide primary and Secondary protections with international specifications to cope with any electrical faults And seek to limit their negative effects.

Through our research, we gained an idea of what the major international companies Have achieved in the field of electric coasters. We have become aware of the principle of The work of many measuring and processing protection devices. We also got acquainted With the most important calculations used in this field, using the ETAP program, which Gives an opportunity to model any electrical network in addition to In addition, we have Discussed electrical diagrams, which are the only way to track and find faults in the field Of electricity

And with the deepening of this field, it must be recalled that electricity is dangerous And is not dealt with except by the means and behaviors stipulated by international Standards. Human life deserves to be viewed from this aspect and to be preceded over Any material or technical goal.