**МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ**
**ЧЕРНІВЕЦЬКИЙ НАЦІОНАЛЬНИЙ УНІВЕРСИТЕТ**
**ІМЕНІ ЮРІЯ ФЕДЬКОВИЧА**

**Навчально-науковий інститут фізико-технічних та комп'ютерних наук**
**кафедра електроніки і енергетики**

# Розрахунок сонячної електростанції 11 МВт (Асуан, Єгипет)

**Кваліфікаційний проект**

**Рівень вищої освіти - перший (бакалаврський)**

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**Educational and scientific institute of physical, technical and computer sciences**
**department of electronics and power engineering**

**Explanatory note**

ForBachelor degree project

# Theme: 11 MW solar power plant calculation (Aswan, Egypt)

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**Chernivtsi –2022**

**Анотація**

У кваліфікаційному проекті представлені результати розрахунку сонячної електростанції потужністю 11 МВт, розташованої в Асуані в Єгипті. Вибираються сонячні батареї, інвертори, трансформатори, вимикачі, трансформатори струму та вимірювальні трансформатори напруги, кабелі та шини, релейний захист та вимикачі. Спроектована однолінійна схема.

Проект написаний англійською мовою і містить: 46 сторінок, 21 рисунок, 20 таблиць, 19 посилань та 1 аркуш графічної частини формату А3.

Ключові слова: сонячна енергетика, електростанція, трансформатори, вимикачі, релейний захист, запобіжники.

**Annotation**

The qualification project presents the results of the calculation of a 11 MW solar power plant located on Aswan in Egypt. Solar panels, inverters, transformers, switches, current transformers and voltage measuringtransformers, cables and buses, relay protection and breakers are selected. A single-line circuit is designed.

The project is written in English and contains: 46 pages, 21 figures, 20 tables, 19 references and 1 sheet of A3 graphic part.

**Keywords:** solar power, power plant, transformers, circuit breakers, relay protection, fuses.

Кваліфікаційний проект містить результати власних досліджень. Використання ідей, результатів і текстів наукових досліджень інших авторів мають посилання на відповідне джерело.

_____ Елбаз Ахмед Хамед Хамед Хамед

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## INTRODUCTION

Over the past 50 years global warming has affected the world in undeniable way, the average global temperature has increased at the fastest rate recorded in history. In fact NASA experts has stated that all but one of the 16 hottest years in the recorded 134-year have accrued since 2000. Global warming occurs when $CO2$ and other green house gases collected in the atmosphere absorbs sunlight and solar energy reflected from earth surface. Normally, this radiation should escape into the space , but the pollutants caused by burning fossil fuels and industrial wastes prevent the heat to escape earth's atmosphere and trap it down causing severe damage to the environment, that’s known as the greenhouse effect.

As engineers, we have to play an enormous role in solving the universe

Problems. We are clearly affected by the harmful impacts on the environment and

Random usage of energy source.

We must strive to expand the use ofclean energysource, renewable sources, to

Generate a clean and continuous source of Energy.

# CHAPTER 1. THEORETICAL PART

## 1.1 Renewable Energy

Renewable energy is energy produced from sources like the sun and wind that are naturally replenished and do not run out. Renewable energy can be used for electricity generation, space and water heating and cooling, and transportation.Non-renewable energy, in contrast, comes from finite sources that could get used up, such as fossil fuels like coal and oil.

The major types or sources of renewable energy are:

- Solar energy from the sun
- Geothermal energy from heat inside the earth
- Wind energy
- Biomass from plants
- Hydropower from flowing water

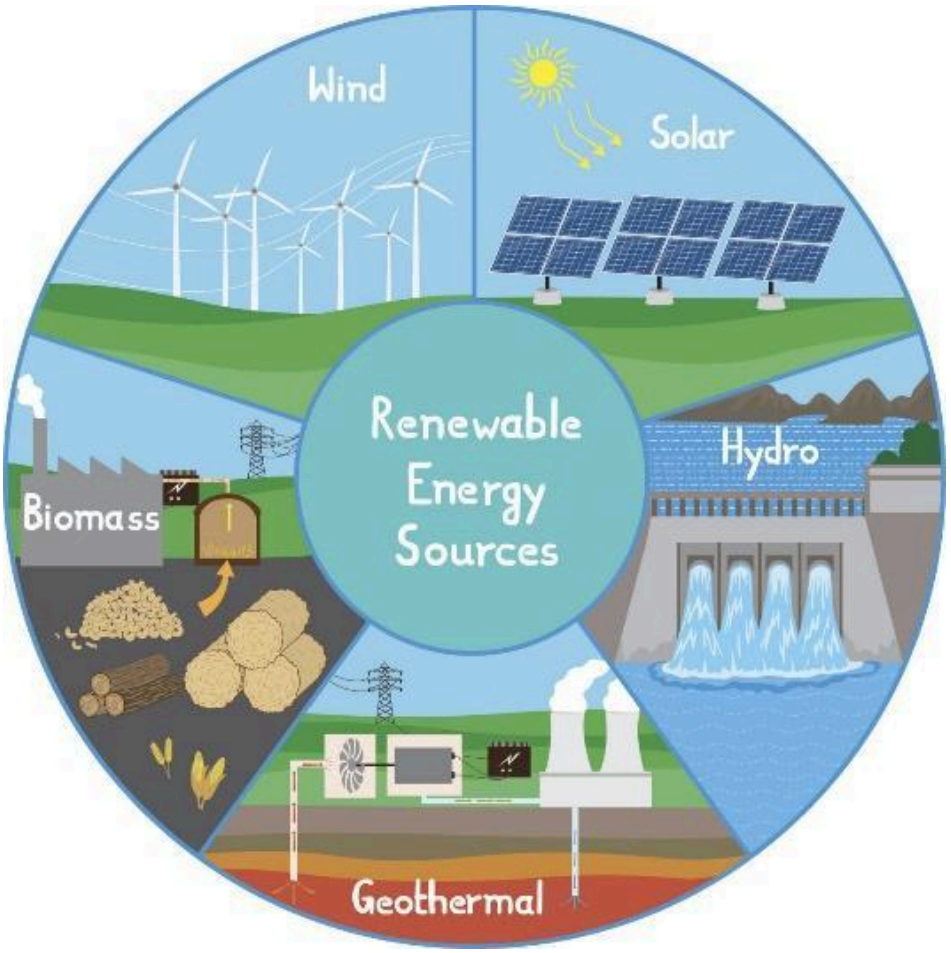



Figure.1.1 renewable energy sources

They are called renewable energy sources because they are naturally replenished. Day after day, the sun shines, plants grow, wind blows, and rivers flow.

**Benefits of Renewable Energy**

The advantages of renewable energy are numerous and affect the economy, environment, national security, and human health. Here are some advantages of Renewable Energy:

- Enhanced reliability, security, and resilience of the nation's power grid
- Job creation throughout renewable energy industries
- Reduced carbon emissions and air pollution from energy production
- Expanded clean energy access for non-grid-connected or remote, coastal, or islanded communities.

## 1.3 Solar Energy

Solar energy can be converted directly or indirectly into other forms of energy,

such as heat and electricity, electricity can be produced directly from solar energy

using photovoltaic devices or indirectly from steam generators using solar

thermal collectors to heat a working fluid.

**Solar Technologies**, There are three main ways to harness solar energy: photovoltaics, solar heating & cooling, and concentrating solar power. Photovoltaics generate electricity directly from sunlight via an electronic process and can be used to power anything from small electronics such as calculators and road signs up to homes and large commercial businesses. Solar heating & cooling and concentrating solar power applications both use the heat generated by the sun to provide space or water heating in the case of SHC systems, or to run traditional electricity-generating turbines in the case of CSP power plants.



Figure.1.4 Photovoltaic solar power plant

**Photovoltaic technology:**

PV is the most common form used to generate electrical power from solar energy; PV Technology becomes a several billions dollar industry worldwide due to the late concerns of the rising levels of global warming, and as the fossil fuel running out crises causing its price to increase rapidly which led to regional and international conflicts.

PV system is commonlymounted on top of buildings or in unshaded sunny space where each cell converts the light of the sun into electrical energy, which can then be used to power buildings with electrical power. Solar Cell often made from semiconductors material such as silicon or germanium that produces energy via the photovoltaic effect.

## 1.4 Solar Thermal Energy

Known as Concentrated Solar Power (CSP).

· Look similar to photovoltaic PV cells; but they work differently.

CSP cells draw in a concentrated beam of sunlight, reflecting it through a system of mirrors causing heat generation that in turn heats water causing steam that activates a turbine to produces electricity through a conventional generator. Where PV produces energy from light, CSP produces energy from heat.



Figure.1.5 Concentrated Solar Power plant

## 1.5 Solar power in Egypt

Egypt is geographically located between latitudes 22 and 31.5 North, and thus Egypt is considered in the heart of the global solar belt, and thus it is considered one of the richest countries in the world with solar energy.

In Egypt, there is one of the largest solar power stations in the world (Benban solar park) is located in the city of Aswan and it consists of 32 power stations.

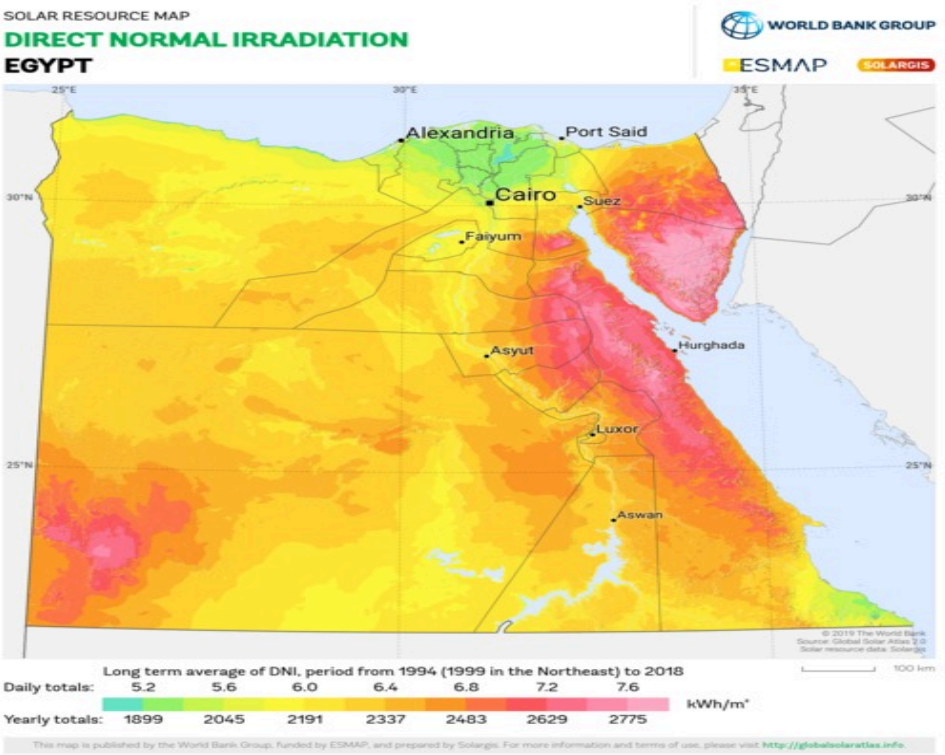



Figure.1.6 illustrative map of DNI in Egypt

## 1.6 Solar Panels

Solar panels are used to collect solar energy from the sun and convert it into electricity.

There are 4 types of solar panels available on the market today:

monocrystalline, polycrystalline, PERC, and thin-film panels.

**Monocrystalline solar panels:**

Also known as single-crystal panels, these are made from a single pure silicon crystal that is cut into several wafers. Since they are made from pure silicon, they can be readily identified by their dark black color. The use of pure silicon also makes monocrystalline panels the most space-efficient andlongest-lasting among all three solar panel types.

**Polycrystalline solar panels:**

As the name implies, these come from different silicon crystals instead of one. The silicon fragments are melted and poured into a square mold. This makes polycrystalline cells much more affordable since there is hardly any wastage, and gives them that characteristic square shape.

PERC solar panels, are an improvement of the traditional monocrystalline cell.This relatively new technology adds a passivation layer in the rear surface of the cell.

**Thin-film solar panels:**

Thin-film panels are characterized by very fine layers that are thin enough to be flexible. Each panel does not require a frame backing, making them lighter and easier to install. Unlike crystalline silicon panels that come in standardized sizes of 60, 72, and 96-cell counts, thin-film panels can come in different sizes to suit specific needs. However, they are less efficient than typical silicon solar panels.

Unlike crystalline panels that use silicon, thin-film solar panels are made from different materials. These are:

- Cadmium telluride (CdTe)
- Amorphous silicon (a-Si)

· Copper indium gallium selenide (CIGS)

**Solar Panel Types by Efficiency**

Monocrystalline panels have an efficiency rating over 20%.

PERC panels add an extra 5% efficiency thanks to their passivation layer.

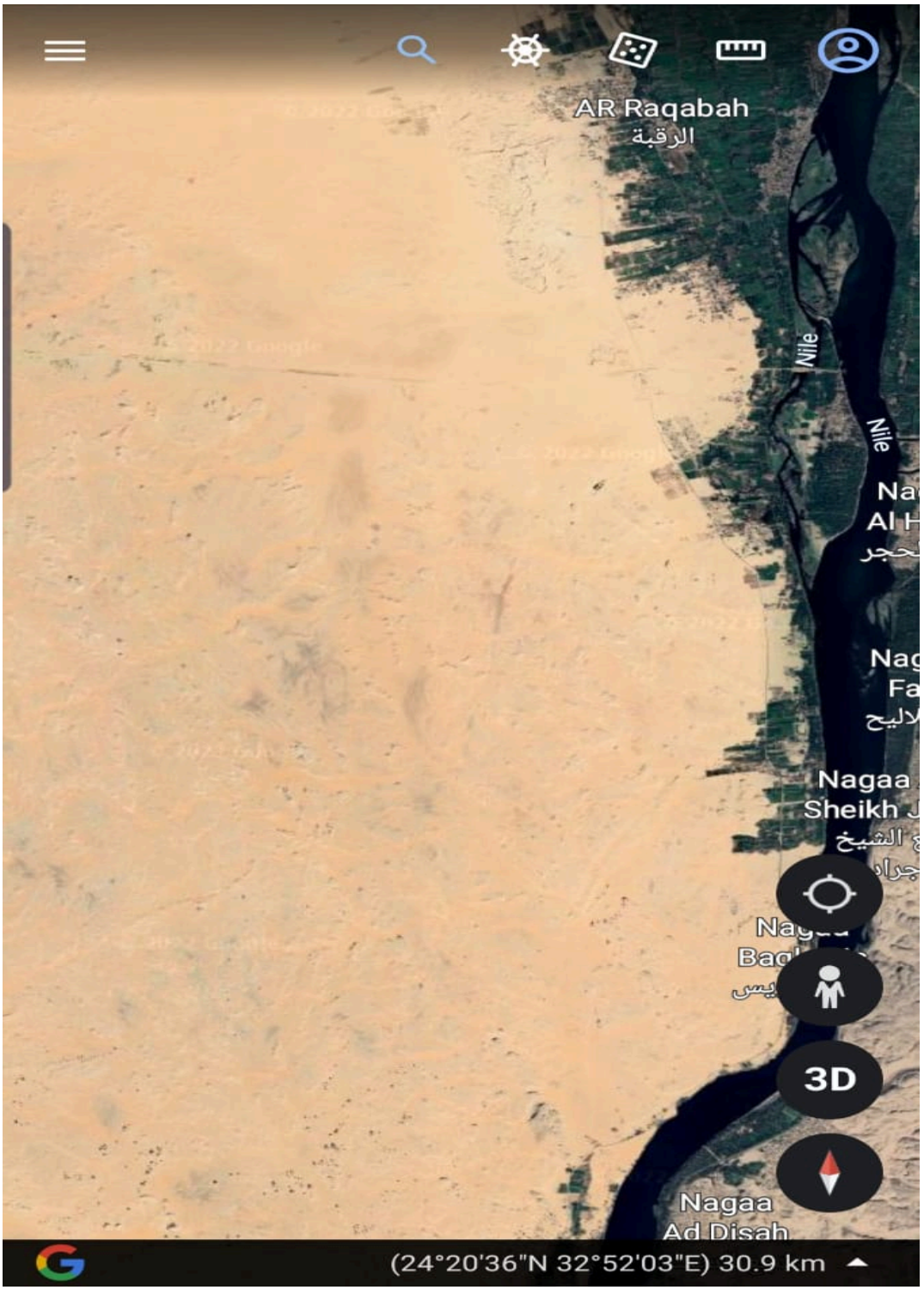
Polycrystalline panels hover somewhere between 15-17%.

# CHAPTER 2. CALCULATION AND CHOICE EQUIPMENT

## 2.1 Determination place and it's characteristic

We decided to build our solar power station 28 km north of Aswan city.

This place is perfect to make a solar station on it due to the big amount of solar radiation that falls on the ground there, and that According to methodological data form GLOBAL SOLAR ATLAS.



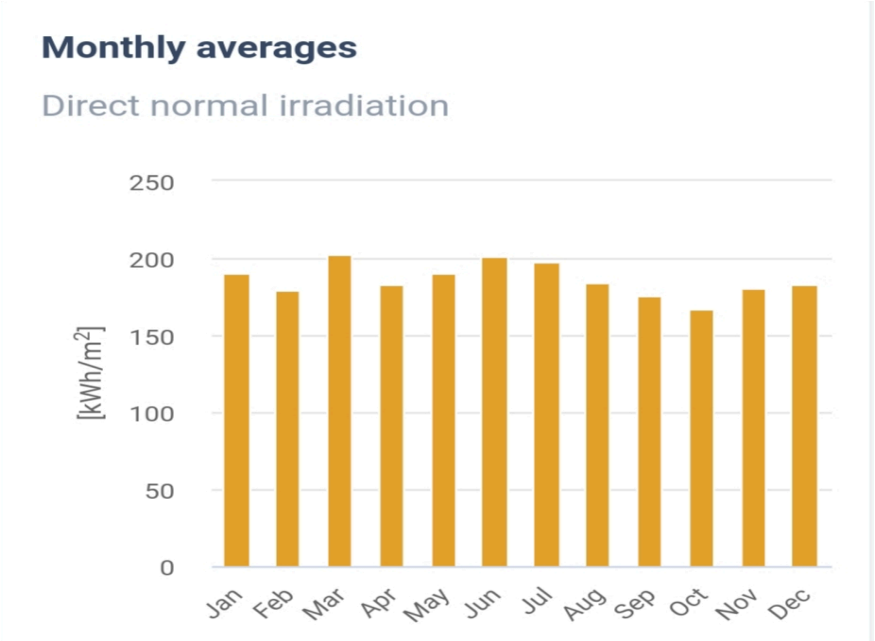



Figure.2.1 scheme of monthly DNI in Aswan

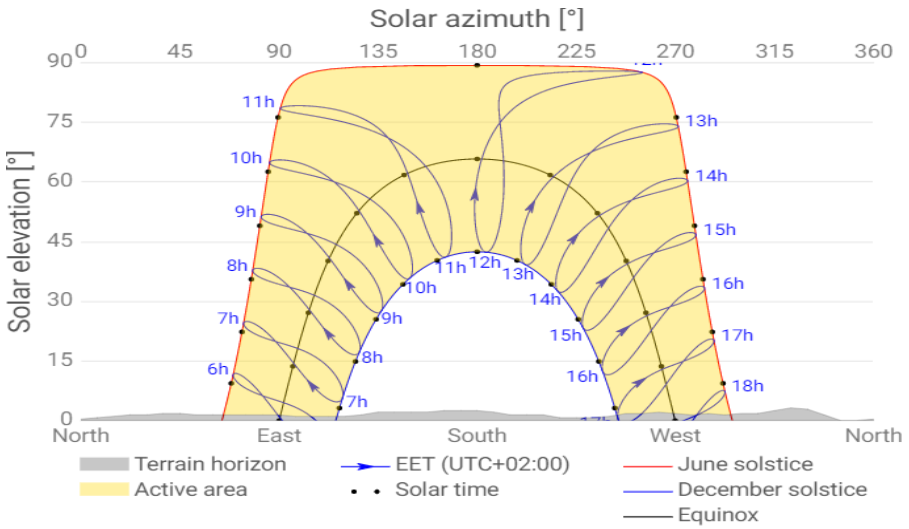



Figure.2.1 scheme of solar azimuth in Aswan

## 2.2 Monocrystalline panel

For this project , we chose a Monocrystalline panels with high efficiency because we have specific area.

**Single-crystal panel, Cortex P3 series Bifacial 560 W**

Table 2.1

| Characteristic | The value of the characteristic |
|---|---|
| Model type | Monocrystalline |
| Maximum Power (Pmax): | 560 Wp |
| Voltage at Maximum Power (Vmpp).In | 42 V |
| Current at Maximum Power (Impp).In | 13.35 A |
| Open Circuit Voltage (Voc): | 50.2 V |

| | |
|---|---|
| Short Circuit Current (Isc): | 14.12 A |
| Panel Efficiency: | 21.73 % |
| Panel Dimension (H/W/D) : | 2274x1133x35 mm |
| Weight : | 30.2 kg |
| Cell Number : | 120 |
| junction Box Protection Class : | IP 68 |

Next we need to determine the Number of panels that used for the plant.

Our design is 11MW on grid and to calculate number of panels we use this formula

$$\text{Number of panels} = \frac{p_t}{Pmax\ of\ single\ panle} = \frac{11MW}{0.560KW} = 19642 \qquad (1)$$

The installation of panels is towards the south at an angle 30°, which provides the greatest amount of solar radiation on the solar cells .

### 2.3 Selection and calculation of the number of inverters and their load

We use in this solar power plant a 3 phase inverter type ATO-OGI-200kW. Has suchcharacteristics:

Table 2.2

| characteristics | The value of the characteristic |
|---|---|
| Rated output power: | 200kW |
| Rated voltage: | 480V |
| Rated current: | 417A |
| Frequency: | 50Hz |
| Efficiency: | 93% |
| Size (D*W*H) | 1000*1200*1800mm |




Fig.2.3 Appearance of the inverter

**For inverter:**

V*in* = 480 V, I*in* =417 A

For panel:

V*p* = 42 V, I*p* = 13.35 A

Parameter list and protection for inverter. Table2.3

**Parameter List**

| | | |
|---|---|---|
| Model | | ATO-OGI-200kW |
| Size (D*W*H) | | 1000*1200*1800mm |
| Weight | | 1350kg |
| Certificate | | CE, UL, SA, SAA, VDE |
| Warranty period | | 24 months |
| **AC Input** | Rated voltage | AC input voltage is the same value as the AC output |
| **DC Input** | Rated voltage | 240V/ 300V/ 360V/ 480V/ 600V DC (can be customized) |
| | Rated current | 417A @480V DC |
| **AC Output** | Rated output power | 200kW |
| | Output waveform | Pure sine wave |
| | Rated voltage | 208V/ 220V/ 230V/ 240V/ 380V/ 400V/ 415V/ 460V/ 480V (optional) |
| | Phase | 3 phase 4 wire+PE wire (single phase/ split phase can be customized, please contact us by email) |
| | Rated phase current | 303A @380V AC |
| | Frequency | 50Hz or 60Hz |
| | Power factor | >0.99 |
| | Overload ability | 150%, 5 seconds |
| | Efficiency | >93% |
| | Waveform distortion rate | THD<3% |
| | Dynamic response (0 to 100% load) | 5%, ≤50ms |
| | Display | LCD |
| | Running mode | Working continously |
| | Electrical insulation properties | 2000Vac, 1min |
| | Communication interface | RS485 (optional), it can remote control the start/stop of the inverter and convey the data as below:<br>1. Input DC current<br>2. Input DC voltage<br>3. Output AC current<br>4. Output AC voltage<br>5. Power consumption (kWH)<br>6. Some fault information |
| **Protection Function** | Protection | Input reverse polarity, under voltage, over-voltage, output over-current, short circuit, overheating |
| | Colling method | Fan-cooled |
| | Short-circuit protection | No automatic recovery, need to restart the machine |
| **Working Environment** | Noise (1 meter) | ≤50dB |
| | Degree of protection | IP20 (indoor) |
| | Working altitude | ≤2000m |
| | Working temperature | -25~+55℃ |
| | Relative humidty | 0~90%, non-condensing |
| **Note** | The above parameters are for reference only, can be customized according to customer's requirement! | |

To determine number of panels that used in a one module, must calculate how many panels could connected in series & parallel with one inverter.

N*p* (series) $=\frac{480}{42}\simeq 11$

N*p* (parallel) $=\frac{417}{13.35}\simeq 31$

Number of panel = 11 × 31 = 341

And to determine the power of module, must calculate voltage & current of the module.

$V_{mod}$ = 11 ×42 = 462 V

$I_{mod} = 31 \times 13.35 = 413.85$ A

Next we find power of the moduleAccording to the formula:

$$P = I \times V \quad (2)$$

$P_{inv} = 462 \times 413.85 = 191.2$ KW

Number of modules = $\frac{19642}{341}$ = 57 modules

But we will use 56 modules to make this scheme have better stability and will be more uniticated.

Drawing of one module, consists of 31 lines connected in parallel and 11 panels in each line connected in series.

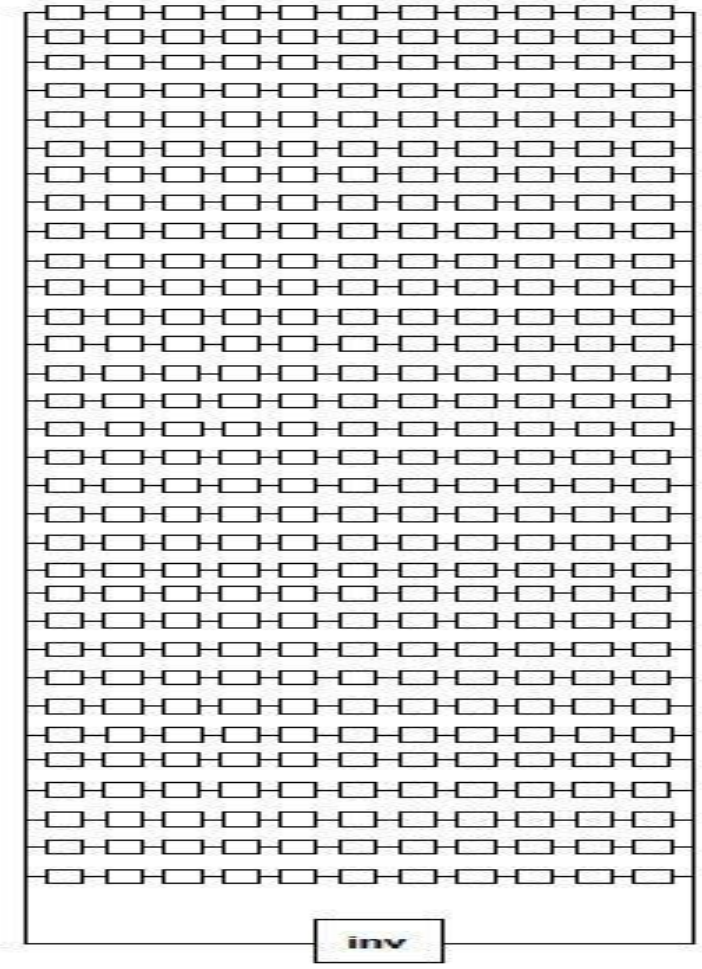



Fig.2.4 illustrative drawing of module

## 2.4 Selection and calculation of transformers (11/0.4)

Table 2.4

| model | Rated capacity(KVA) | Connection symbol | High-voltage | Trapping range | Low-voltage | No-load loss | Load loss | No-load current | |
|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| SC10-800 | 800 | Yyn0 or Dyn11 | 15<br>20<br>22 | 5% | 0.4 | 1775 | 7910 | 1.2 | |



Fig.2.5 SC10-800 transformer

We will connect 4 inverter (module) with one transformer and determine transformers we need

Number of transformer = $\frac{56}{4}$ = 14 transformers

## 2.5 Selection and calculation of transformer (66/11)

8 MVA 8000 KVA 66 KV oil immersed power transformer:

Table2.5

| Rated Power (KVA) | High Voltage (KV) | H.V.Tap range | Low Voltage (KV) | Connection symbol | Short Circuit Impendence (%) | No-load loss(KW) | On-load loss(KW) |
|---|---|---|---|---|---|---|---|
| 8000 | 63<br>66<br>69 | ±8x1.25% | 6.3<br>6.6<br>10.5<br>11 | YNd11 | 9 | 11.2 | 40.4 |



Fig.2.6 8000 KVA 66 KV power transformer

We will connect a seven transformer 11/0.4 with one big transformer 66/11, so we will need to use two transformer (66/11)at the power station we make.

## 2.6 Selection and calculation of cables

Cable sizing is the process of selecting appropriate sizes for electrical power cable

Conductors. Cable sizes are typically described in terms of cross-sectional area.

The proper sizing of cables is important to ensure that the cable can:

• Operate continuously under full load without being damaged

• Provide the load with a suitable voltage (and avoid excessive voltage drops)

• Withstand the worst short circuits currents flowing through the cable

To determine types of cables we need, we must calculate the flowing current between any connection in the system.

According to connection Y/Y

$$S=\sqrt{3} \times U_{LL} \times I \quad \textbf{(3)}$$

$I_1$=13.35 A, when $I_1$is a flowing current in the module between panels

**Selection cable:**

Rated Current: 20 Amp Black Two Core Round Electric Wire 220V, Wire Size: 1.5 Mm Dia

**Table2.6**

| | |
|---|---|
| Wire Size | 1.5 mm Dia |
| Rated Current | 20 Amp |
| Number Of Core | 2 |
| Usage/Application | Electrical Fitting |
| Voltage | 220 v |
| Color | Black |
| Conductor Material | Copper |



Fig.2.7 Black Two Core Round Electric Wire

I2= 13.35 × 31 = 413.85 A, when I2 is a flowing current between panels and inverter

**Selection cable:**

$F_e=I/j_{ec}$ economically size of cabel **(4)**

$j_{ea}$ =1.4 for aluminum

$j_{ec}$ =2.5 for cupper

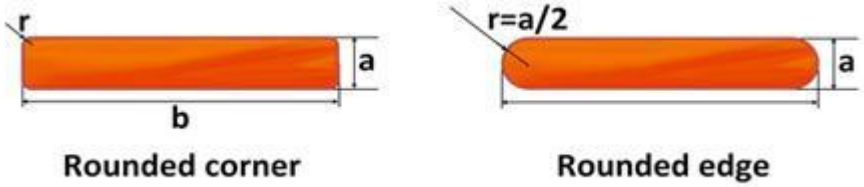
$F_{e=413.85/}$ 2.5= 165.54 **mm²**

**Table2.7. RECTANGULAR SHAPED BARE COPPER BUSBARS**

| Size | a (mm) | b (mm) | X-Section (mm²)* | Unit Weight (kg/m) |
|---|---|---|---|---|
| 25x3 | 3 | 25 | 74 | 0,66 |
| 30x3 | 3 | 30 | 89 | 0,80 |

| | | | | |
|---|---|---|---|---|
| 25x4 | 4 | 25 | 99 | 0,88 |
| 30x4 | 4 | 30 | 119 | 1,06 |
| 20x5 | 5 | 20 | 99 | 0,88 |
| 25x5 | 5 | 25 | 124 | 1,10 |
| 30x5 | 5 | 30 | 149 | 1,33 |
| 30x10 | 10 | 30 | 299 | 2,65 |
| 32x10 | 10 | 32 | 319 | 2,83 |
| 40x5 | 5 | 40 | 199 | 1,77 |
| 40x10 | 10 | 40 | 399 | 3,54 |
| 50x5 | 5 | 50 | 249 | 2,22 |
| 50x10 | 10 | 50 | 499 | 4,43 |
| 50x15 | 15 | 50 | 749 | 6,65 |
| 60x5 | 5 | 60 | 299 | 2,66 |
| 60x10 | 10 | 60 | 599 | 5,32 |
| 60x12 | 12 | 60 | 719 | 6,39 |
| 60x15 | 15 | 60 | 899 | 7,98 |
| 75x6 | 6 | 75 | 449 | 3,99 |
| 80x5 | 5 | 80 | 399 | 3,55 |
| 80x10 | 10 | 80 | 799 | 7,10 |
| 80x15 | 15 | 80 | 1199 | 10,65 |
| 80x20 | 20 | 80 | 1599 | 14,20 |
| 90x10 | 10 | 90 | 899 | 7,99 |
| 92x5 | 5 | 92 | 459 | 4,08 |
| 100x5 | 5 | 100 | 499 | 4,44 |
| 100x8 | 8 | 100 | 799 | 7,10 |
| 100x10 | 10 | 100 | 999 | 8,88 |
| 100x12 | 12 | 100 | 1199 | 10,66 |
| 100x15 | 15 | 100 | 1499 | 13,32 |
| 100x20 | 20 | 100 | 1999 | 17,76 |
| 100x30 | 30 | 100 | 2999 | 26,64 |
| 110x6 | 6 | 110 | 659 | 5,86 |
| 120x5 | 5 | 120 | 599 | 5,33 |

| | | | | |
|---|---|---|---|---|
| 120x10 | 10 | 120 | 1199 | 10,66 |
| 120x12 | 12 | 120 | 1439 | 12,79 |
| 120x15 | 15 | 120 | 1799 | 15,99 |
| 120x20 | 20 | 120 | 2399 | 21,32 |
| 125x10 | 10 | 125 | 1249 | 11,11 |
| 128x5 | 5 | 128 | 639 | 5,69 |
| 130x7 | 7 | 130 | 909 | 8,09 |
| 140x10 | 10 | 140 | 1399 | 12,44 |
| **ROUNDED SHAPE COPPER BARS** | | | | |
| Delivered in diameters of Ø 8-10-12-14-15-16-18-20-22-24-26-28-30-32-34-35-36 mm and in lengths 2 - 6 m. | | | | |




Rounded corner Rounded edge

| | |
|---|---|
| **MATERIAL** | Cu-OF / Cu-ETP |
| **Cu CONTENT** | min. %99.90 |
| **STANDARD** | TS 435, EN 13601 |
| **CONDUCTIVITY** | 57 – 58 µS |
| **TYPE** | Rounded corner, rounded edge |
| **TEMPER** | Semi-hard |
| **DELIVERY** | Cut in 2 – 6 m (6.5-19 ft) lengths, on wooden pallets and PE covered acc. to customer requirements. |

$$I_{3,1} = \frac{200}{0.4 \times \sqrt{3}} = 288 \text{ A}$$

**Selection cable:**

Hi-Flex 300 Amp 40mm² Battery / Starter / Inverter / Welding PVC Cable Wire

Single insulated battery / starter cable

Resistant to petrol, lubrication oils and diluted acids

40mm² Cable

300 Amps

12.7mm Overall Diameter of Cable



Fig.2.8 Hi-Flex 300 Amp 40mm² wire

$$I_{3,2} = \frac{800}{0.4 \times \sqrt{3}} = 1154.7 \text{ A}$$

$F_e = I/j_{ec}$ economically size of cabel

$F_e = 1154.7/ 2.5 = 461.88$ **mm²**

Section of cable $I_{3,2}$ determined from Tabl2.7. RECTANGULAR SHAPED BARE COPPER BUSBARS.

$$I_{4,1} = \frac{800}{11 \times \sqrt{3}} = 41.98 \text{ A}, \quad I_{4,2} = \frac{7 \times 800}{11 \times \sqrt{3}} = 293 \text{ A}$$

**Selection cable:**

$F_e = I/j_{ec}$ economically size of cabel

$F_e = 41.98/2.5 = 16.79$ mm², $F_e = 293/ 2.5 = 117.2$ mm²

**6.35/11kV CU/XLPE/CTS/PVC 3C POWER CABLE** **Table2.8**

| nominal area of conductor | maximum conductor resistance at 20 °C | thickness of xlpe insulation | thickness of copper tape | appro. overall diameter | appro. cable weight | standard packing length | drum size | appro. gross weight |
|---|---|---|---|---|---|---|---|---|
| Sqmm | Ohm/Km | mm | mm | mm | kg/km | Metre ±10% | | KG |
| 35 | 0.524 | 3.4 | 0.06 | 41.74 | 2137 | 500 | D-16 | 1169 |
| 50 | 0.387 | 3.4 | 0.06 | 44.31 | 2582 | 500 | D-17 | 1391 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 70 | 0.268 | 3.4 | 0.06 | 48.18 | 3320 | 500 | D-22 | 1760 |
| 95 | 0.193 | 3.4 | 0.06 | 52.26 | 4206 | 500 | D-23 | 2203 |
| 120 | 0.153 | 3.4 | 0.06 | 56.54 | 5123 | 500 | D-24 | 2662 |
| 150 | 0.124 | 3.4 | 0.06 | 58.9 | 5940 | 500 | D-25 | 3070 |

$$I_5 = \frac{8000 \times 2}{66 \times \sqrt{3}} = 139.96 \text{ A}$$

**Selection cable:**

66kv High Voltage Power Cable 630mm2 500mm2 400mm2

Application:

Construction, Underground, Industrial, Power Station

Voltage:

Super-high Voltage Cable

Current:

DC Cable

Insulation Material:

XLPE

Sheath Material:

PVC

Material Shape:

Round Wire

Wire Core Material:

Bare Copper Wire

Voltage Degree:

48/66kv to 127/220kv

| Section | Insulation Thickness | Metallic Sheath Thickness | Sheath Thickness | Overall Diameter | Cable Weight | Electrical Resistance |
|---|---|---|---|---|---|---|
| | | | | | | DC.20ºC |
| No.xmm2 | mm | mm | mm | mm | kg/km | Ω/km |
| 48/66 kV | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1×185 | 14.5 | 2.0 | 4.0 | 68.3 | 5250 | 0.0991 |

## 2.7 Calculate Resistivity of transformers & lines

To calculate the Resistivity of our small and big (high voltage) transformers we will use this formula:

$$X_T = \frac{U_K(\%) \cdot U_{BH}^2}{100 \cdot S_{T\,HOM}} \tag{5}$$

$X_{Ts}$=$\frac{5 \times 11000^2}{100 \times 800000}$ = 7.56 Ohm, this is the value Resistivity of transformers (11/0.4)

$X_{Th}$=$\frac{9 \times 66000^2}{100 \times 8000000}$ = 49 Ohm, and this is the value Resistivity of transformers(66/11)

To calculate the Resistivity of lines, we should determine the length of cables and work according to formula:

$$R = \rho \frac{l}{F}, \quad r_o = \frac{\rho}{F} \tag{6}$$

When *P* is a constant Resistivity of cable material, and L is the length of cable and *F* is the cable diameter

*P* for cupper is =0.018 Ohm

$L_1$ = 300 m, $L_2$ = 320 m

$L_{3,1}$ = 50 m

$R_{3,1}$ = 0.018 ×$\frac{50}{40}$ = 0.0225 Ohm

$L_{3,2}$ = 485 m

$R_{3,2}$ = 0.018 ×$\frac{485}{499}$ = 0.0175 Ohm

$L_{4,1}$ = 40 m

$R_{4,1}$ = 0.018 ×$\frac{40}{35}$ = 0.02057 Ohm

$L_{4,2}$ = 3000 m

$R_{4,2}$ = 0.018 ×$\frac{3000}{120}$ = 0.45 Ohm

$L_5$ = 60 km

R5 = 0.018 $\times \frac{60000}{185}$ = 5.8378 Ohm

## 2.8 Calculate of short current

We will calculate short current to help to determine the parameters of current trasformer by this furmula:

$$I_K^{(3)} = U_{C.H.} / \sqrt{3} \cdot z = U_{C.H.} / \sqrt{3} \cdot \sqrt{(\sum R)^2 + (\sum X)^2} \quad (7)$$

$$Ik1 = \frac{11000}{\sqrt{3} \times (R4,1 + R4,2)} = 13496 \text{ A}$$

$$Ik2 = \frac{66000}{\sqrt{3} \times \sqrt{(R4,2^2 + XTh^2)}} = 777.6 \text{ A}$$

$$Ik3 = \frac{66000}{\sqrt{3} \times R5} = 6527.3 \text{ A}$$

Then we will calculate Iy to help in determining the fuses by the furmula:

$$I_y = I_K^{(3)} \cdot \sqrt{1 + 2(k_y - 1)^2} \quad k_y = 1,2 \ldots 1,3 \quad (8)$$

Ky = 1.25 , $\sqrt{1 + (2 \times 0.25^2)}$ = 1.06

Iy = Ik × 1.06

Iy1 = Ik1 × 1.06 = 13496 × 1.06 = 14305.7 A

Iy2 = Ik2 × 1.06 = 777.6 × 1.06 = 824 A

Iy3 = Ik3 × 1.06 = 6527.3 × 1.06 = 6918.9 A

## 2.9 Selection of current transformers

We use Current transformers to measure the current of another circuit , current transformers have a Turns Ratio which mean for example 1000 : 5 , the flowing electrical current is transferred from the primary coil which is 1000 A to 5 A in the secondary coil , and that is why the current transformer is used for :

• Operate the measuring devices

•Monitor the high voltage lines

• Operate electrical protection devices

According to the parameters of Ik we have we will determine the current transformers

**Bus current transformers TSHL-20** **Table2.9**

| | |
|---|---|
| Rated voltage / kV | 20 |
| Maximum operating voltage/ kV | 24 |
| Rated primary current/ A | 3000, 4000, 5000, 6000, 8000, 10000, 12000 14000, 15000, 16000, 18000 |
| Rated frequency of alternating current/ Hz | 50 or 60 |
| Number of secondary windings | 2 or 3 |
| Rated secondary current/ A | 1; 5 |
| Accuracy class:<br>- secondary winding for measurements<br>- secondary winding for protection | 0,2; 0,2S; 0,5; 0,5S; 5P; 10P<br>5P; 10P |
| Rated secondary load at power factor cos = 0.8, V • A:<br>- secondary winding for measurements<br>- secondary windings to protect the accuracy class 5P<br>- secondary windings to protect the accuracy class 10P | <br>30*<br><br><br>30 |
| Nominal limiting multiplicity of secondary windings for protection, not less than:<br>- for accuracy class 10P at rated primary currents, A:<br>3000<br>4000<br>5000; 6000<br>8000<br>10000; 12000; 14000; 15000; 16000; 18000<br>- for accuracy class 5P at rated primary currents, A:<br>6000; 8000; 10000<br>12000; 14000; 15000; 16000; 18000 | <br><br>13<br>15<br>16<br>14<br>12<br><br>20 |
| Test voltage, kV:- full storm impulse<br>- one minute industrial frequency | 125<br>65 |

**SDH-60 2000/5A ct current transformer High accuracy SDH Class 0.5 window type current transformer CT1**

**Application:**

1. Current measurement, monitoring and protection for electrical wiring and equipment.

2. Current and power measurement for electric motors, lighting, air compressor, heating
3. Current, power and energy monitoring device.
4. Relay protection device.

Technical data: Table2.10

| Electrical Parameter | | Mechanical Parameter | |
|---|---|---|---|
| Frequency | 50/60Hz | Case | PC/UL94-V0 |
| Rated Input | 1A-5000A | Bobbin | PBT |
| Measuring range | 5%In-120%In | Core | Silicon steel |
| Rated Output | 1A,5A | Construction | Screw |
| Ratio Voltage | 0.72KV (AC) | Operating Temp | -25℃~+75℃ |
| Dielectric strength | 3.0KV/1mA/1min | Operating Humidity | ≤85% |
| Insulation Resistance | DC500V/100MΩ min | Output Connection | Terminal |




CE RoHS ISO SDH-60

Fig.2.9 SDH-60 2000/5A current transformer

**5kV Thru 69kV Current Transformers (Outdoor)**

**Models JCK-3 /JCK-4**

5kV to 8.7kV, 60kV to 75kV BIL 5A to 800A

**DIMENSIONS**

Height: 13.63”

Width: 7.88”

Length: 11.00

**FREQUENCY**

50-60 Hz

According to the parameter of this current transformer (single phase) we will need to use 3 of it

Table2.11

| JCK-3/ JCK-4/ DATA TABLE | | | | | | | |
|---|---|---|---|---|---|---|---|
| Current Ratio (Amps) Pri : Sec | IEEE Accuracy Class 60 Hz Burden Meter Class | | Continuous Thermal Current Rating Factor | Mechanical Limit, Amps | One Second Thermal Limit, Amps | Catalog Number | |
| | B0.1 B0.2 | B0.5 | @ 30°C Amb. | | | JCK-3 5,000 V BIL 60 kV | JCK-4 8,700 V BIL 75 kV |
| Single Ratio | | | | | | | |
| 5:5 | 0.3 | 0.3 [1] | 3.0 | 3400 | 1900 | 753X051001 | 754X051001 |
| 10:5 | 0.3 | 0.3 | 3.0 | 3400 | 1900 | 753X051002 | 754X051002 |
| 15:5 | 0.3 | 0.3 | 3.0 | 5100 | 2850 | 753X051003 | 754X051003 |
| 20:5 | 0.3 | 0.3 | 3.0 | 6800 | 3825 | 753X051004 | 754X051004 |
| 25:5 | 0.3 | 0.3 | 3.0 | 8500 | 4775 | 753X051005 | 754X051005 |
| 30:5 | 0.3 | 0.3 | 3.0 | 10200 | 5725 | 753X051006 | 754X051006 |
| 40:5 | 0.3 | 0.3 | 3.0 | 13600 | 7650 | 753X051007 | 754X051007 |
| 50:5 | 0.3 | 0.3 | 3.0 | 17000 | 9550 | 753X051008 | 754X051008 |
| 75:5 | 0.3 | 0.3 | 3.0 | 21250 | 11775 | 753X051009 | 754X051009 |
| 100:5 | 0.3 | 0.3 | 3.0 | 34000 | 19125 | 753X051010 | 754X051010 |
| 150:5 | 0.3 | 0.3 | 3.0 | 42500 | 23575 | 753X051011 | 754X051011 |
| 200:5 | 0.3 | 0.3 | 3.0 | 56100 | 38250 | 753X051012 | 754X051012 |
| 300:5 | 0.3 | 0.3 | 3.0 | 85000 | 46750 | 753X051013 | 754X051013 |
| 400:5 | 0.3 | 2.5 | 2.5 | 85000 | 47600 | 753X051014 | 754X051014 |
| 600:5 | 0.3 | 2.0 | 2.0 | 85000 | 51000 | 753X051015 | 754X051015 |
| 800:5 | 0.3 | 1.5 | 1.5 | 85000 | 51000 | 753X051016 | 754X051016 |

**<u>Current transformer COF (25 - 170 kV)</u>**

**Reliable oil-insulated top-core design current transformer for outdoor use**

**Applications:**

- Revenue metering
- Protective relaying
- System control and indication of power flow

**Table2.12**

| | |
|---|---|
| Installation | Outdoor |
| Design | Top coretype |
| Insulation | Oil-paper |
| Highest voltage for equipment | 25 - 170 kV |
| Max. primary current | Up to 3,400 A |
| Short-circuit current | Up to 120 kA/1 sec |
| Insulators | Porcelain (silicon rubber optional) |
| Creepage distance | ≥ 25 mm/kV (longer on request) |
| Service condition | |
| • Ambient temperature | -40 ºC to +40 ºC (standard) |
| • Design altitude | Maximum 1000 m (standard) |
| | *Other temperatures and altitudes are possible |
| Accuracy | Meets all IEEE metering and protection classes (0.3%, 0.15%, C100, C200, C400 and C800) IEC also available on request |

## 2.10 Determining of single breakers & fuses

We use breakers to protect our system from damage caused by Overload or Overcurrent, and it is like an automatic switcher and it have parameters.

**Single breaker (SB)**

Module:

Miniature Circuit Breakers (MCB)

These breakers have the breaking capacity (Icu) complying with the Standard IEC 60947-2 and the energy selectivity limits refer to this Standard.

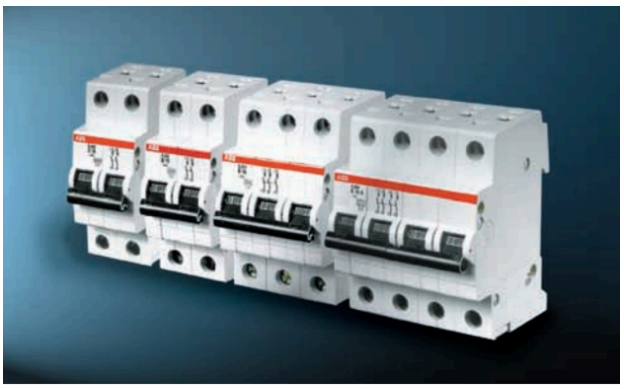


Figure.210 miniature circuit breaker(MCB)

### 11KV and 630A OUTDOOR 11KV Vacuum Circuit Breaker (SB1)

**Table2.13**

| | |
|---|---|
| Power | 11KV , 630A,20/25KA |
| Rated Current | 630/800/1250A |
| No. of breaks / pole | 1 |
| Brand | BUSH ELECTROMECH,ABB VD4/VIND |
| Rated making current (kApeak) | 65.75 |
| Rated short time withstand current | 26.3 |
| First pole to clear factor | 1.5 |
| Opening time (MS) | 40 +- 10 |
| Closing time (MS) | 60 +- 15 |
| Reclosing time (MS) | 300 |
| Contact stroke (mm) | 20 |
| Weight (approx.) (Kg) | 850 |
| Power Freq. withstand voltage (kV RMS) | 28 |
| Impulse withstand voltage (kVpeak) | 75 |
| Rated frequency (Hz) | 50 |
| Creepage distance to earth (mm) | 450 |
| Rated normal current (A) | 1250 |
| Rated breaking current (kA) | 26.3 |

## OUTDOOR HIGH VOLTAGE VACUUM CIRCUIT BREAKER ZW32-12 (SB2)

**Table2.14**

### Specifications

| No. | Item | Unit | Data |
|---|---|---|---|
| 1 | Rated voltage | kV | 12 |
| 2 | Rated frequency | Hz | 50 |
| 3 | Rated current | A | 630 |
| 4 | Rated short-circuit opening current | kA | 20 |
| 5 | Rated peak withstand current(peak) | kA | 50 |
| 6 | Rated short-time withstand current | kA | 20 |
| 7 | Rated short-circuit closing current(peak) | kA | 50 |
| 8 | Mechanical life endurance | time | 10000 |
| 9 | Rated short -circuit current opening frequency | time | 30 |
| 10 | Power frequency withstand voltage(1 min):among phases,to ground/fracture | kV | 34/42/48 |
| 11 | Lighting impluse withstand voltage(peak):among phases,to ground/fracture | kV | 75/85 |
| 12 | Secondary loop 1 min power frequency withstand voltage | kV | 2 |

**Outdoor Sf6 Gas Circuit Breaker 66kV/132kV (SB3&SB4)** **table2.15**

| No. | Item | Unit | Data |
|---|---|---|---|
| 1 | Rated voltage | KV | 145 |
| 2 | Rated frequency | Hz | 50/60 |
| 3 | Rated current | A | 3150 |
| 4 | 1min power frequency withstand voltage | KV | 265 |
| 5 | Lingthning impluse withstand voltage(peak value | KV | 650 |
| 6 | 5 min power frequency voltage at zero gas pressure | KV | 109 |
| 7 | Rated short circuit breaking current | KA | 80...100 |
| 8 | Rated out-of-phase breaking current | KA | 10 |
| 9 | Rated cable(line) charging breaking current(peak) | A | 50 |
| 10 | Rated gas pressure | MPa | 0.5 |
| 11 | Main loop resistance | uΩ | ≤45 |
| 12 | Operation sequence | | O-0.3s-CO-180s-CO |
| 13 | SF6 gas leakage rate(per year) | % | ≤1 |
| 14 | Moisture content(V/V) | ppm | ≤150 |
| 15 | Across the open contacts | mm | ≥3950 |
| | Creepage distance | | |
| | TO earth | | ≥3950 |
| 16 | Mechanical life | times | 10,000 |

| 11KV Drop out Fuse (F1) | Table2.16 |
|---|---|
| Voltage | 11/22/33KV |
| Usage/Application | Substation and Overhead |
| Current Rating | 200/400/600/800 amp |
| Fuse Type | Resettable Fuse |
| Color | Gray and Brown |
| Brand | NATIONAL |
| Material | Polymeric and Porcelain |
| Poles Description | 3 Pole |
| Power Source | Electric |
| Minimum Order Quantity | 01 Set |

**SMDPower Fuses - Outdoor Transmission (F2)**

Rated nominal voltage69 KV, Maximum current 100 A and Interrupting 50 or 60 Hz



Figure2.12 SMDPower Fuses – Outdoor

## 2.11 Determining of measuring voltage transformer

11KV Power Measurement Oil Type Combined Transformer

Table 2.17

| | |
|---|---|
| Product name | Oil type combined transformer |
| Material | Copper + stainless steel |
| Color | brown |
| Rated voltage | 3.6-12KV |
| Current ratio | 5/5-300/5 |
| Voltage transformation ratio | 10/0.1 |
| Accuracy Class | 0.2S/0.5 |

| Feature | Three phase three wire |
|---|---|



Figure.2.11 Measurement Oil Type Combined Transformer

**Three Epoxy Cast Resin High Voltage Potential Transformer.**

Potential Transformer: 66kV

Table 2.18

| **Material** | Epoxy Cast Resin |
|---|---|
| Phase | Three |
| Frequency | 50 Hz |
| Usage/Application | Industrial |
| Country of Origin | Made in India |
| Maximum System Voltage | 245 kV |
| Ambient Temperature | -30 To 50 Degree Celsius |
| Primary Rated Current | 5000 A |
| Secondary Rated Current | 10 A |
| Minimum Order Quantity | 1 |

**Design & Structure**

- Optimized Design for Measuring
- Lean manufacturing concept applied to the whole supply chain

- External insulation with procelain or composite insulator



Figure.2.13 Epoxy Cast ResinPotential Transformer

## 2.12 Determining of relay protection

AM5 protection relay with overcurrent IDMT earth fault overload RS485. **Table2.19**

| | | |
|---|---|---|
| Auxiliary power supply | Rated input | AC/DC 220V 110V,DC48V |
| | Range | rated voltage*(1±20%) |
| | Power consumption | ≤10W(DC) |
| Rated voltage | Rated input | AC 100V/100/($3^{1/2}$)V |
| | Range | 1~120V |
| | Accuracy | ±0.5% |
| | Power consumption | ≤0.5VA(single phase) |
| Rated current | Rated voltage | AC 5A/1A |
| | Range | 0.04In~15In |
| | Accuracy | ±0.5% |
| | Power consumption | ≤0.5VA(single phase) |

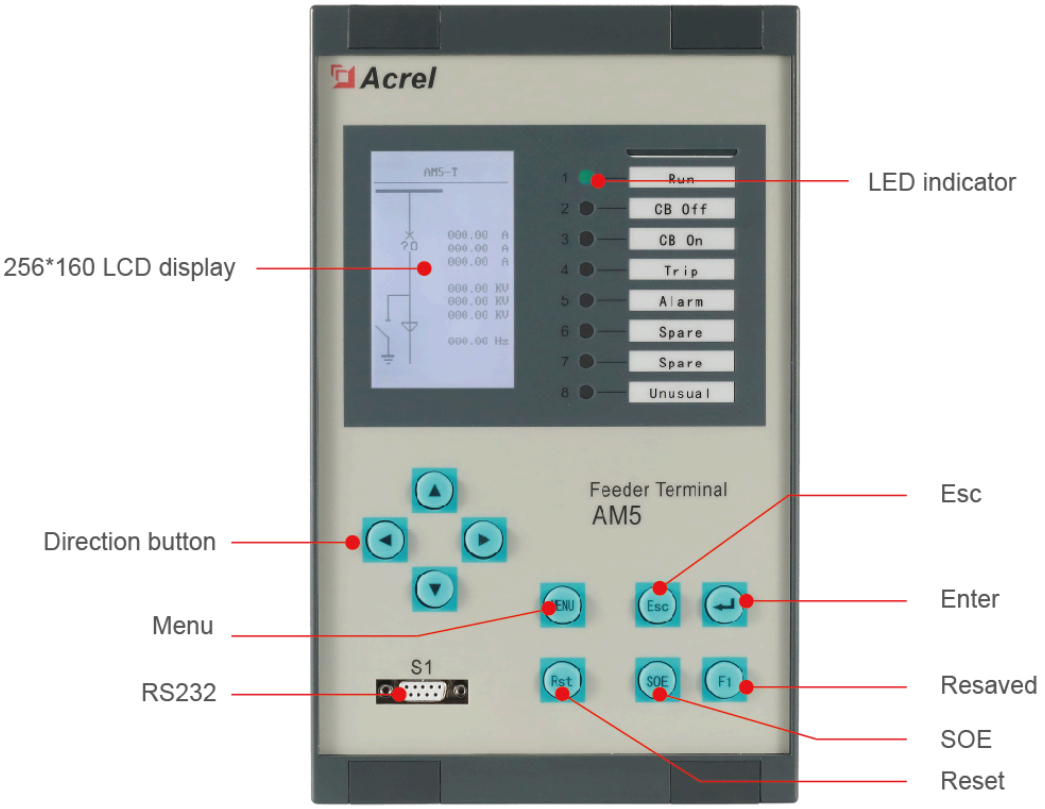



Fig.2.14 AM5 protection relay with overcurrent IDMT

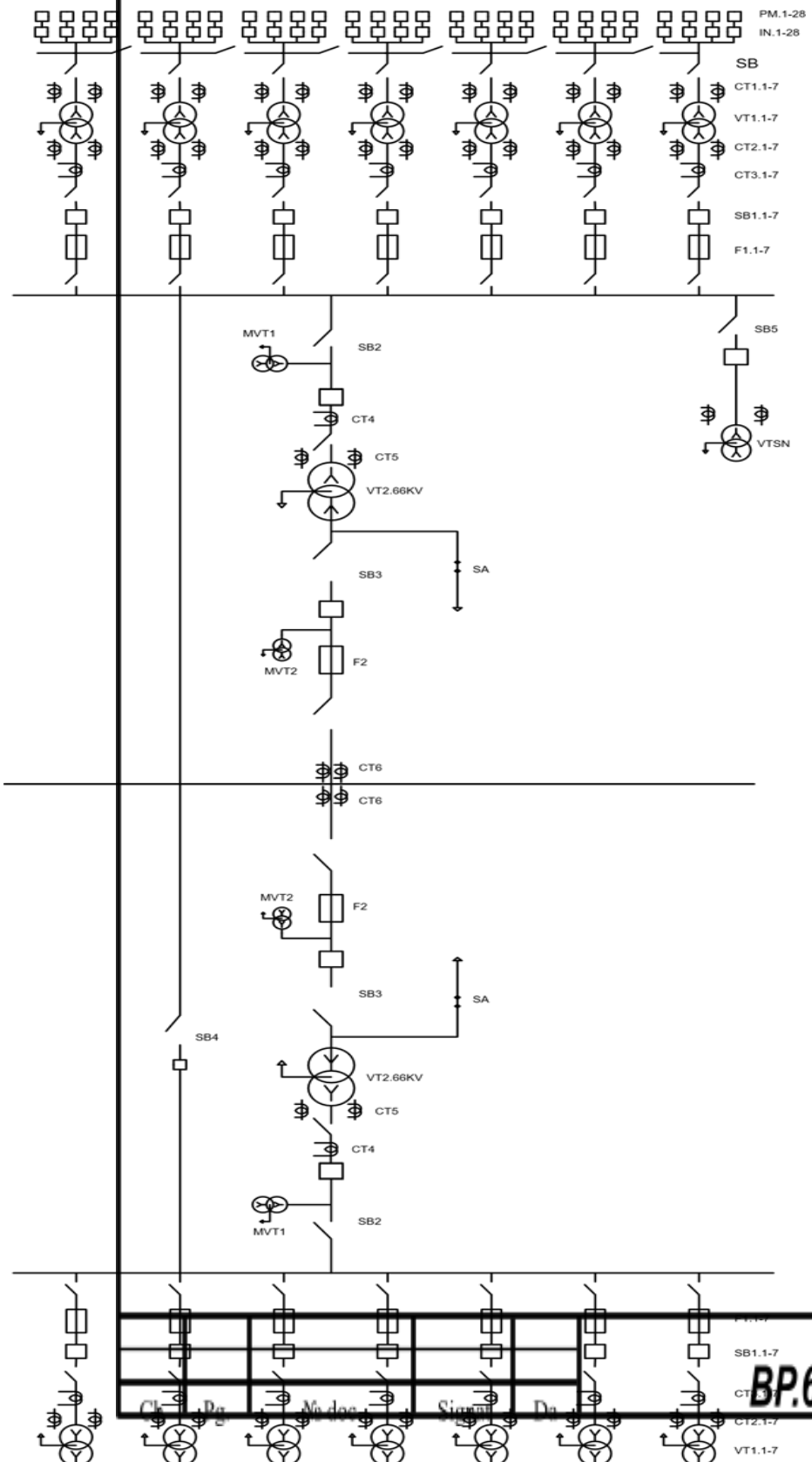
Figure 2.15. oneline scheme

# CHAPTER 3. TECHNICAL ECONOMIC CALCULATION

The cost of a solar plant includes the cost of devises from panels, inverters, transformer, cables, breakers ... etc.

**Table3.1**

| N | Name of device | Number | Price | Total cost |
|---|---|---|---|---|
| 1 | Single crystal panel 560 w | 19642 | 235$ | 4 615 870 $ |



| | | | | |
|---|---|---|---|---|
| 2 | 3 phase inverter type ATO-OGI-200kW | 56 | 65 916 $ | 3 691 296 $ |
| 3 | SC10-800 transformer | 14 | 3400 $ | 47 600 $ |
| 4 | 8 MVA 66 KV transformer | 2 | 200000 $ | 400000 $ |
| 5 | Cable 1.5 Mm Dia Roll 90 m | 190 Roll | 7.15 $ per Roll | 1358.5 $ |
| 6 | RECTANGULAR BARE COPPER BUSBARS40x5 X-199 | 17920 m | 35 $ per meter | 627200 $ |
| 7 | Cable Hi-Flex 300 Amp 40mm² | 700 m | 1.5$ per meter | 1050 $ |
| 8 | RECTANGULAR BARE COPPER BUSBARS50x10 X-499 | 13580 m | 70 $ per meter | 950600 $ |
| 9 | 11kV CU/XLPE/CTS/PVC 3C POWER CABLE35mm | 560 m | 20 $ per meter | 11200 $ |
| 10 | 11kV CU/XLPE/CTS/PVC 3C POWER CABLE120mm | 12000 m | 70 $ per meter | 840000 $ |
| 11 | 66kv High Voltage Power Cable | 60 Km | 3.5 per meter | 210000 $ |
| 12 | Bus current transformers TSHL-20 | 2+2 | 512 $ | 2048 $ |
| 13 | 5kV Thru 69kV Current Transformers (Outdoor) | 2*3 | 110 $ | 660 $ |
| 14 | Current transformer COF (25 - 170 kV) | 15+14 | 420 $ | 12180 $ |
| 15 | circuit breaker (SB) | 14 | 190 $ | 2660 $ |
| 16 | OUTDOOR 11KV Vacuum Circuit Breaker (SB1) | 15 | 31200 | 468000 $ |
| 17 | VACUUM CIRCUIT BREAKER ZW32-12 (SB2) | 2 | 7000 $ | 14000 $ |
| 18 | Circuit Breaker 66kV/132kV | 3 | 20000 $ | 60000 $ |
| 19 | Switch XPA | 12 | 190 $ | 2280 $ |
| 20 | 11KV Drop out Fuse (F1) | 14 | 104 $ | 1456 $ |
| 21 | SMD Power Fuses - Outdoor Transmission (F2) | 2 | 150 $ | 300 $ |
| 22 | 2000/5A current transformer | 14 | 12 $ | 168 $ |
| 23 | Voltage transformer self need | 1 | 3400 $ | 3400 $ |
| 24 | Measuring voltage transformer MV1 11KV | 2 | 560 $ | 1120 $ |
| 25 | Measuring voltage transformer MV266KV | 2 | 650 $ | 1300 $ |
| 26 | Relay protectionovercurrent IDMT | 49 | 777 $ | 38073 $ |
| **The total cost** | | | | **12003819.5 $** |

## CONCLUSIONS

- In this qualifying work was considered the design of solar power plant with a nominal capacity of 11 MWwhich is located in Aswan (Egypt)
- Chosen 19642 monocrystalline solar panels
- Chosen devices and equipment such inverter, transformer, cables, fuses, breakers…..etc.
- Drawing illustrative scheme of plant
- Calculate technical economic cost of the plant 12003819.5$

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## APPENDIX. OCCUPATIONAL SAFETY

Working safely around high-voltage conductors is a challenge for many workers . High-voltage systems are generally associated with utility services and heavy industry, such as pulp mills, sawmills, and mining operations. With care and precise planning, you can operate equipment and tools safely around these potentially lethal power lines.

This part is designed for workers who must work *close* to high-voltage equipment and conductors. It explains why high-voltage systems are dangerous. It lists the minimum distances you must keep away from live power lines and explains what you should do if you can't maintain these limits of approach. It also describes common problem areas and gives safe work practices for working close to overhead lines around construction sites and for operating equipment around power lines.

**Identifying High-voltage overhead conductors**

Overhead high-voltage conductors are usually installed at the top of utility poles. If there is more than one conductor, they are usually placed side by side on a cross arm. If there is a transformer on the pole, the high-voltage conductors are mounted above it. These are general guidelines. Employers are responsible for accurately determining the voltage of all conductors on the pole or in the work area.

**Why energized high-voltage systems are dangerous**

Accidents involving high voltages can result in severe injuries and death. When an electric current passes through the body, it generates heat and can extensively damage internal tissues. In some cases, the entry and exit wounds are so severe that a foot or hand has to be amputated. The electric current can also stop the heart.

Electricity seeks all paths to the ground. That path might include a tree, mobile equipment, or the human body. If a part of the equipment you are operating contacts a live power line, then anything in contact with your equipment will also become energized. The earth itself could become energized for some distance around your

unit. Similarly, the ground could become energized if a tree makes contact with a power line or if a broken power line falls to the ground.

When the electrical flow reaches the ground, it spreads out like ripples in a pool of water. The voltage is very high where electrical contact is made with the ground. Farther away from this point, the voltage gradually drops off. Wet ground will extend the distance and the danger.

The voltage at the contact point is approximately the same as the line voltage. With power lines up to and including 60 kV (60,000 V), the voltage drops to zero about 10 m (33 ft.) away from the contact point with the ground. With higher voltages, such as those carried by the lines along transmission rights-of-way, the voltage might not drop to zero until you are as far away as 32 m (105 ft.).

**Step potential**

Step potential is the voltage difference between two places that are a step apart on energized ground. For example, if you are standing on energized ground, there could be a significant difference in voltage between where one foot and the other are placed, and an electric current could flow up one leg and down the other.

If your feet are close together and touching, you are fairly safe. Since there is almost no voltage difference between the places where your feet stand, there is little reason for electricity to seek a path through your body.If you find yourself on energized ground and need to move away, you can avoid electric shock or electrocution because of step potential by making sure there is no space between your feet. Shuffle your feet while moving out of the energized area. When shuffling, keep your feet touching at all times to maintain the same voltage in both feet.Similarly, rescue workers must not enter an area that might be energized. Anyone trying to reach an injured worker in an energized area would be exposed to the same danger of step potential. The power lines must be de-energized and grounded before rescue workers or first aid attendants approach.

**Touch potential**

Touch potential is another danger that comes from the difference in voltage. It occurs when you touch something that is energized while standing on lower-voltage ground. For example, if a tree or equipment is in contact with a power line, it will be energized to the same voltage as the power line; the surrounding ground will be energized to a lower voltage. If you touch the energized equipment or tree at the same time as you touch the ground with your feet, electricity will flow through your body from the higher voltage tree or equipment to the lower voltage ground.

**Safety in the event of power line contact**

Power lines can be brought down in a number of situations, including storms, trees, ice, and motor vehicle accidents. Even if the power line does not come down, if it is in contact with a tree, vehicle, or mobile equipment, the ground will be energized and so will the tree, vehicle, or equipment.

**Workers in a vehicle or mobile equipment**

If electrical contact is made, *stay in the vehicle or mobile equipment if it is safe to do so.*

You are relatively safe inside your vehicle as long as you don't touch or step onto anything outside the vehicle that will provide a path for the current to flow to ground. Wait until the owner of the power system

has verified that the power lines have been de-energized and grounded. In one incident, for example, the raised box of a dump truck hit a

60 kV (60,000 V) power line. The driver stayed in the truck and was

not injured, although all 18 tires were damaged by the electrical current.

If the vehicle is not damaged and is not entangled with the power line, it is safe to drive slowly out of the energized area, at least 10 m (33 ft.) clear of the wires and any wet ground. Because of the danger of exploding tires, large mobile equipment with inflated rubber tires should be moved to an open space away from workers and other equipment. There is a danger of exploding tires for up to 24 hours.

If you must abandon your vehicle because of an emergency such as a fire, be aware that the ground below your machine may be energized and use *extreme caution.*

To make a safe escape, keep both feet together and hands by your sides, and make a short jump from your vehicle. The goal is to ensure that your entire body clears the vehicle and that you land on your feet without stumbling. Don't allow any part of your body to touch the vehicle while you are touching the ground.

Don't take steps away from the vehicle. It is safest to *shuffle* away without moving your feet more than a few centimetres (a couple of inches) at a time. Keeping your feet together will ensure that you don't straddle two zones with different voltages.

**Rescue work around power lines**

The main role for rescue workers near downed power lines or energized equipment is to stop people from getting hurt. Here are some safe work practices:

1. **Treat downed lines and anything in contact with a power line as** Energized wires seldom leap about and give off sparks, so you have no way of knowing whether or not they are energized. Even if the line is not energized, automatic switching equipment may restore power to the line without warning.

2. **Park well** When you arrive at the scene, park your vehicle well away from any downed lines. At night, shine a flashlight through the window to make sure you are not parked anywhere near a downed power line.

3. **Stop traffic and keep people** Workers on foot or in vehicles may not see lines that are lying on the ground. The ground surrounding a downed line will be energized. If a live wire comes in contact with a vehicle, or anything else, that object becomes energized. Secure the area and keep everyone back at least

10 m (33 ft.) — more if the voltage is over 60 kV (60,000 V).

4. **Don't let yourself become a victim.** Regardless of how badly someone is injured, you cannot help if you are electrocuted. Never touch anything that is in contact with a downed power line, including injured or trapped victims, puddles,

vehicles, or trees. Don't use a dry stick or piece of rope or hose as they will not offer any protection. Don't enter an area that might be

5. **Call the owner of the power system and 911 (or other local emergency number)** A crew with proper training and equipment will arrive as soon as possible.

6. Accept confirmation that the system has been de-energized and is safe only from a representative of the power system who is on site.

**General limits of approach**

The key to safety is to keep a safe distance from overhead and underground power lines. Part 19 of the Regulation lists the distances that workers must keep away from exposed energized conductors.

Table -1A in the Regulation gives the general limits of approach. This is the minimum distance from overhead energized high-voltage lines that non-qualified workers and their materials, equipment, and machinery must maintain.

The limits of approach vary with the voltage. The tools and equipment that you hold or operate are an extension of your reach. You must ensure that you have enough room for movement with your tools without violating these limits.

**Table 1A: Minimum approach distance for working close to exposed electrical equipment and conductors**

| Voltage, phase to phase | Minimum distance | |
|---|---|---|
| | Meters | Feet |
| Over 750 V to 75 kV | 3 | 10 |
| Over 75 kV to 250 kV | 4.5 | 15 |
| Over 250 kV to 550 kV | 6 | 20 |

**Table 1B: Minimum clearance distance for passing under exposed electrical equipment and conductors**

| Voltage, phase to phase | Minimum distance | |
|---|---|---|
| | Meters | Feet |
| Over 750 V to 75 kV | 2 | 6.5 |
| Over 75 kV to 250 kV | 3 | 10 |
| Over 250 kV to 550 kV | 4 | 13 |

**Working inside the limits of approach**

After first checking the worksite, you may find that the minimum distance from the electrical conductor cannot be maintained. If inadvertent movement by a worker or equipment may result in either coming closer than these minimum distances, you must follow these steps before proceeding with work:

1. Call the owner of the power system and arrange for a worksite meeting to decide whether the energized electrical conductors can be:

- Displaced or rerouted, or
- De-energized (isolated and grounded), or
- Visually identified and effectively

2. Get assurance in writing from the owner of the power system indicating which of the three actions will be taken and when this will be done. The owner of the power system will do this on form 30M33, available from any WorkSafeBC office or the owner of the power system. No work can be done within the limits of approach until one of the conditions in step 1 has been met and the completed form 30M33 is on site. It takes time to complete the form 30M33 process, so it's important to plan

3. Inform all workers near the power lines of the information in form 30M33. Make sure they are trained in appropriate safe work procedures.

4. Designate a qualified safety watcher who can monitor equipment and material movement and give an instant "stop" signal to the equipment operator when the equipment or load is too close to the electrical conductor. Workers, equipment, tools, and loads must not contact the guarding under any

**Construction sites near power lines**

Each year workers in many places die or are seriously burned as a result of unsafe work practices around energized conductors. The following information is a reminder to operators of construction equipment and to construction and maintenance workers who must work near power lines:

Most power lines are found overhead; however, some are buried just a short distance below the surface of the

The normal operating range of your machine or equipment can often reach either the overhead or the underground power lines above or below

Supervisors and operators of equipment can prevent electrical accidents through knowledge of electrical systems and safe work.

**Pruning or falling trees near power lines**

Workers have been killed or injured when doing tree care work or falling trees near power lines. Before workers prune or fall trees close to a power line, a qualified person must inspect the worksite to identify any hazards, including situations where any part of a tree is within the general limits of approach or could fall within that distance. The owner of the power system must authorize the person doing the inspection and ensure that the person is qualified.

If tree pruning or falling will come within the general limits of approach, workers must be authorized by the owner of the power system to do the work. Normally the only worker authorized to do this work will be a qualified electrical worker, a certified utility arborist, or an apprentice utility arborist working under the direct supervision of a certified utility arborist or a qualified electrical worker.

**3 keys of electrical safety**

1. **Look up and down.**

All workers who operate machinery or equipment that could come in contact with power lines should look up and check for overhead power lines before beginning work or identify underground power lines in the vicinity. Plan your work to prevent electrical contact.

2. **Keep back — Know your limits.**

When operating machinery or equipment in close proximity to power lines, always maintain the limits of approach: 3–6 m (10–20 ft.), depending on the voltage. Use a spotter to make sure you keep equipment away from power lines.

Where any portion of a machine or equipment may come closer than the minimum distance prescribed, form 30M33 must be completed before work begins. This allows the owner of the power system to provide some form of protection.

On the ground stay at least 10 m (33 ft.) away from operating equipment because if it contacts an energized line the electricity will go to ground. The operator should be on the vehicle with everyone else clear of the vehicle when the boom is in motion. If you must approach, ensure the equipment is not operating.

**3. Stay back, and call for help.**

Stay back at least 10 m (33 ft.) from a fallen power line, exposed underground power line, or any object in contact with the line. If the machinery you are operating contacts an energized line, move it away from the line to break contact. If you can't do this, stay put in the machine until help arrives.