# **ELG4125** Case Journaling

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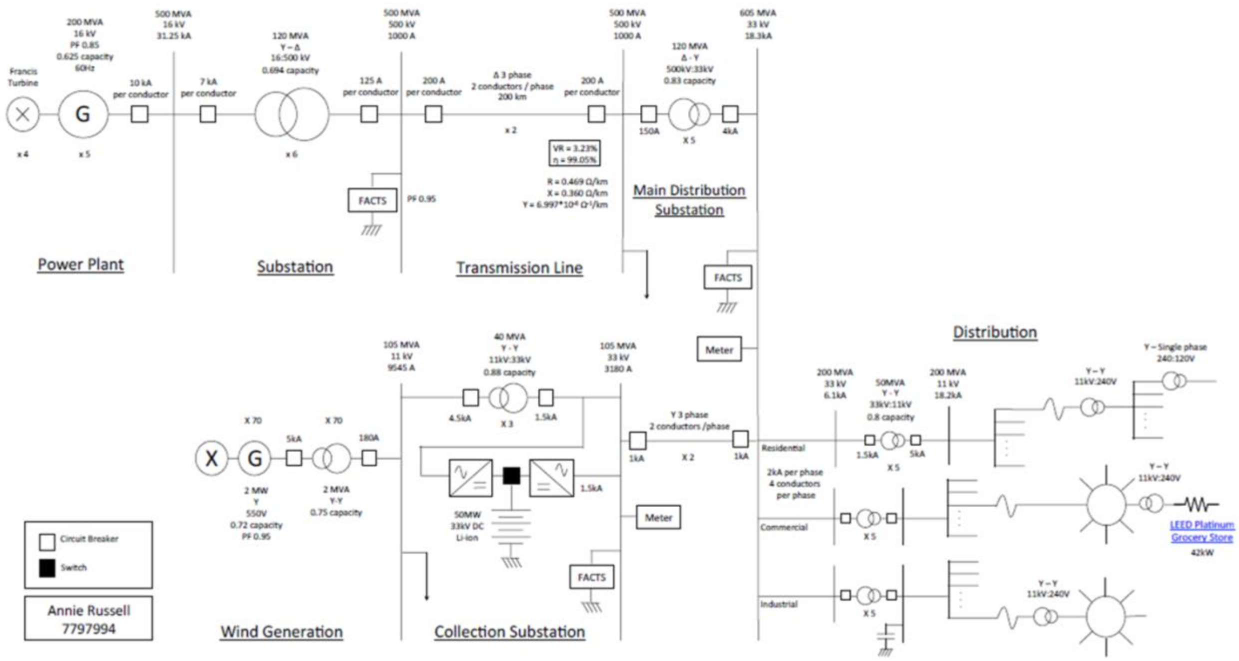
This journaling document contains several tasks related to the ELG4125 Case 1.

# A Typical “Whole” Power System

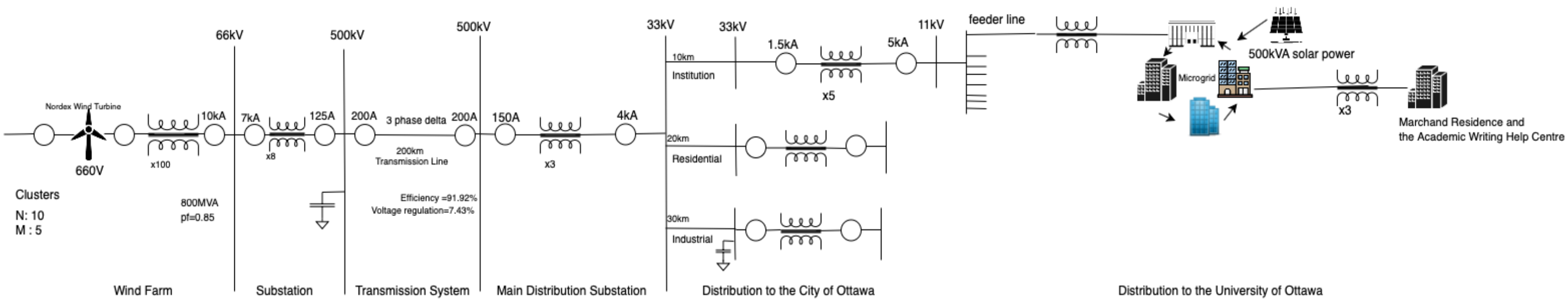
(This block diagram describes the building blocks of a particular project therefore; it should be used as a guide only when you draw the block diagram of your project)

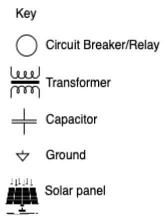



## Case Statement

Consider a power plant of 800 MVA (Wind Farm) that delivers a transmission line system with a voltage of 500 kV. The transmission line feeds the city of Ottawa that is 200 km away from the power plant. University of Ottawa represents one of the loads in the city of Ottawa with a thermal power plan. It is proposed to turn the campus into a micro-grid with the addition of 500 kVA solar power. For this case, it is required to provide a complete design work for the above power system.

# Case Block Diagram




## Power Plant, Substation, and Transmission System

Design and size the required power plant including wind turbines, components, and specifications

| Power Plant Components | Product Type | Rating | Specification |
|---|---|---|---|
| Wind Turbines | Nordex – N131/3300 | 3MW | a. Rated power: 3.3MW<br>b. Rotor Diameter: 131m<br>c. 3 stage gearbox<br>d. Rated speed:11.2rpm<br>e. Cut in wind speed: 3m/s<br>f. Cut out wind speed: 25m/s<br>g. Anti-Icing System |
| Circuit Breaker | Siemens-Live Tank Circuit Breakers | 72.5-800kV | a. Operates within -60 to 55 degree Celsius |
| Generators | Nordex -Doubly Fed asynchronous generator | 660V | a. Liquid/ air cooling<br>b. Grid Frequency 50/60Hz |

<u>Pictorial Representation of the components of the power plant</u>


*Figure 1: The Nordex Wind Turbine*

***Double click on video above to play***

*Figure 2: Live Tank Circuit Breakers*


*Figure 3: Nordex Doubly Fed asynchronous generators*

Design and size the required transmission substation including transformers, other components, and specifications.

| Transmission Substation Components | Product Type | Rating | Specification |
|---|---|---|---|
| Transformer | ABB WindStar Transformers | >10MVA | a. Frequency: 50/60 Hz<br>b. Cooling: KFWF<br>c. Single and 3 phase transformer |
| Circuit Breaker | Siemens-Live Tank Circuit Breakers | 72.5-800kV | a. Operates within -60 to 55 degree Celsius |
| Capacitors | GE High Voltage Capacitors | 390 farads | • 25-1100kVAR for single phase units<br>• 300 to 400kVAR for three phase units |

*Figure 4: The ABB WindStar transformer*

*Figure 5: The Live Tank Circuit Breakers*

*Figure 6: GE High voltage capacitors*

Design and size the required transmission system including towers, circuits, conductors, insulators, and other specifications. Calculate the related efficiency and voltage regulation

| **Transmission System Components** | **Product Type** | **Rating** | **Specification** |
|---|---|---|---|
| Transmission Line | ABB UHVDC(Ultra High Voltage Direct Current) lines | - | a. Resistance: 0.052mohms |
| Transmission Towers | Tublar Steel Towers | 130kV | a. Nominal voltage of 11Kv<br>b. Design Bending Stress: 26kg f/mm2 |
| Conductors | Aluminium Conductor Steel Reinforced Cable | - | a. Size: 36.5<br>b. Permittivity:28<br>c. Density: 2.7 |
| Insulators | Siemens Long Rod Insulators | 550kV | a. Inductance: 0.2796 |

*Figure 7: The UHVDC lines*

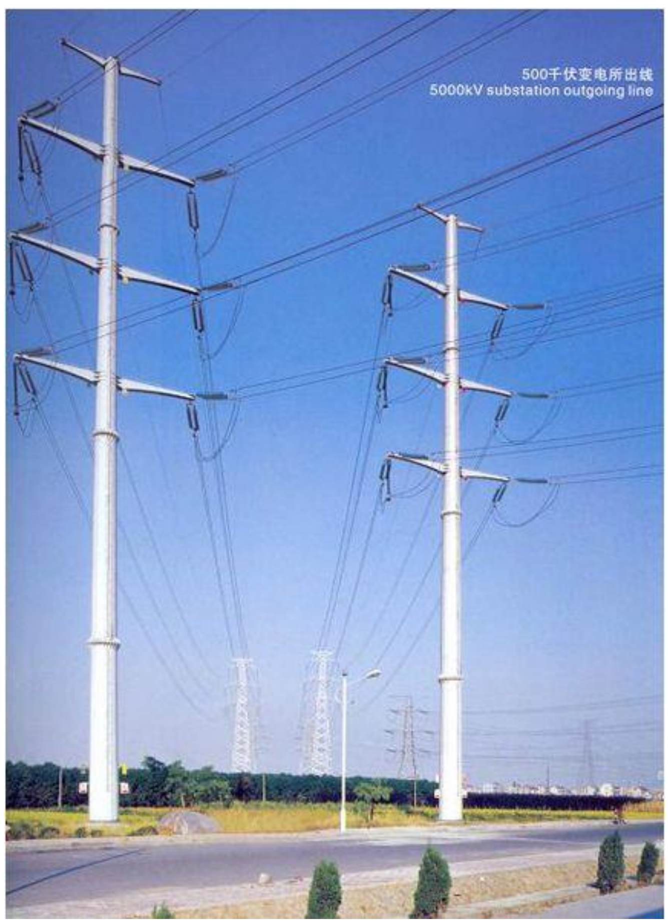



*Figure 8: Tublar Steel Pole Towers*

*Figure 9: The ASCR conductors*

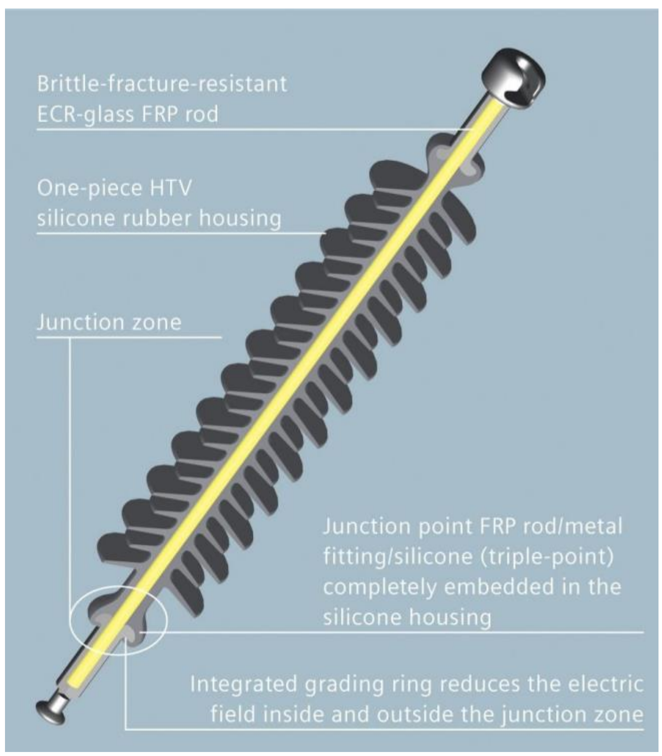



*Figure 10: The SIEMENS silicone long rod insulators*

# Calculation of the efficiency and Voltage Regulation of the transmission system

$$I_r = \frac{P}{\sqrt{3} \times V \times pf} = \frac{800MVA}{\sqrt{3} \times 500kV \times 0.85} = 1086.78A, \measuredangle I = cos^{-1}(0.85) = 31.8^o$$

$$R = 0.052 \times 10^{-3} ohms \times 200km = 10.4ohms, P_{loss} = 3(1086.78)^2(10.4kohms) = 36.9MW$$

$$\chi_L = \frac{\chi}{km} \times 200km = 0.2796m \times 200km = 55.92ohms$$

$$\Upsilon = \pi \frac{1}{2\pi fc} \times 200km = \frac{1}{2\pi 60Hz \times 390 \times 10^3} \times 200km = 1.36 \times 10^{-3} ohms$$

Impedance relay circuits, using nominal π method gives us;

$$A = 1 + \frac{YZ}{2} = 1 + \frac{j1.36 \times 10^{-3}(10.6 + j55.92)}{2} = 0.962 + j7.21 \times 10^{-3} ohms$$

$$B = Z = (10.6 + j55.92) ohms$$

$$C = Y\left(1 + \frac{YZ}{4}\right) = -4.901 \times 10^{-6} + j1.334 \times 10^{-3} ohms$$

$$D = A = 0.962 + j7.21 \times 10^{-3} ohms$$

Voltage at the receiving end, $V_s = AV_r + BI_r = 462.85kV \measuredangle 7.61^o$
Current at the receiving end, $I_s = CV_r + DI_r = 1509.2A \measuredangle 54.23$
Output Power = $V_s \times I_s = 698.5MW$

$$Efficiency, \eta = \frac{P_{out} + P_{loss}}{P_{in}} \times 100 = 91.92\%$$

$$Voltage\ regulation = \frac{V_s - V_r}{V_r} \times 100 = 7.43\%$$

# Distribution System and Protection

| Distribution System Components | Product Type | Rating | Specification |
|---|---|---|---|
| Distribution poles | Tublar Steel Poles | 130kV | c. Nominal voltage of 11Kv<br>d. Design Bending Stress: 26kg f/mm2 |
| Distribution Transformer | Pylon transformer | 11kV | a. Delta-wye connection<br>b. Three phase transformer<br>c. Nominal voltage of 400V |

## Calculation of the efficiency and Voltage Regulation of the distribution system

$$I_r = \frac{P}{\sqrt{3} \times V_r \times pf} = \frac{300MVA}{\sqrt{3} \times 33kV \times 0.85} = 16466.3178A, \measuredangle I = cos^{-1}(0.85) = 31.8^o$$

$$R = 0.052 \times 10^{-3} ohms \times 200km = 10.4ohms, P_{loss} = 3(1086.78)^2(10.4kohms) = 36.9MW$$

$$\chi_L = \frac{\chi}{km} \times 200km = 0.2796m \times 200km = 55.92ohms$$

$$\Upsilon = \pi \frac{1}{2\pi fc} \times 200km = \frac{1}{2\pi 60Hz \times 390 \times 10^3} \times 200km = 1.36 \times 10^{-3} ohms$$

Impedance relay circuits, using nominal π method gives us;

$$A = 1 + \frac{YZ}{2} = 1 + \frac{j1.36 \times 10^{-3}(10.6 + j55.92)}{2} = 0.962 + j7.21 \times 10^{-3} ohms$$

$$B = Z = (10.6 + j55.92)ohms$$

$$C = Y\left(1 + \frac{YZ}{4}\right) = -4.901 \times 10^{-6} + j1.334 \times 10^{-3} ohms$$

$$D = A = 0.962 + j7.21 \times 10^{-3} ohms$$

Voltage at the receiving end, $V_s = AV_r + BI_r = 926.48kV\measuredangle 7109.22^o$
Current at the receiving end, $I_s = CV_r + DI_r = 15982.424A\measuredangle 31.93$
Output Power = $V_s \times I_s = 145MW$

$$Efficiency, \eta = \frac{P_{out} + P_{loss}}{P_{in}} \times 100 = 99.62\%$$

$$Voltage\ regulation = \frac{V_s - V_r}{V_r} \times 100 = 5.43\%$$