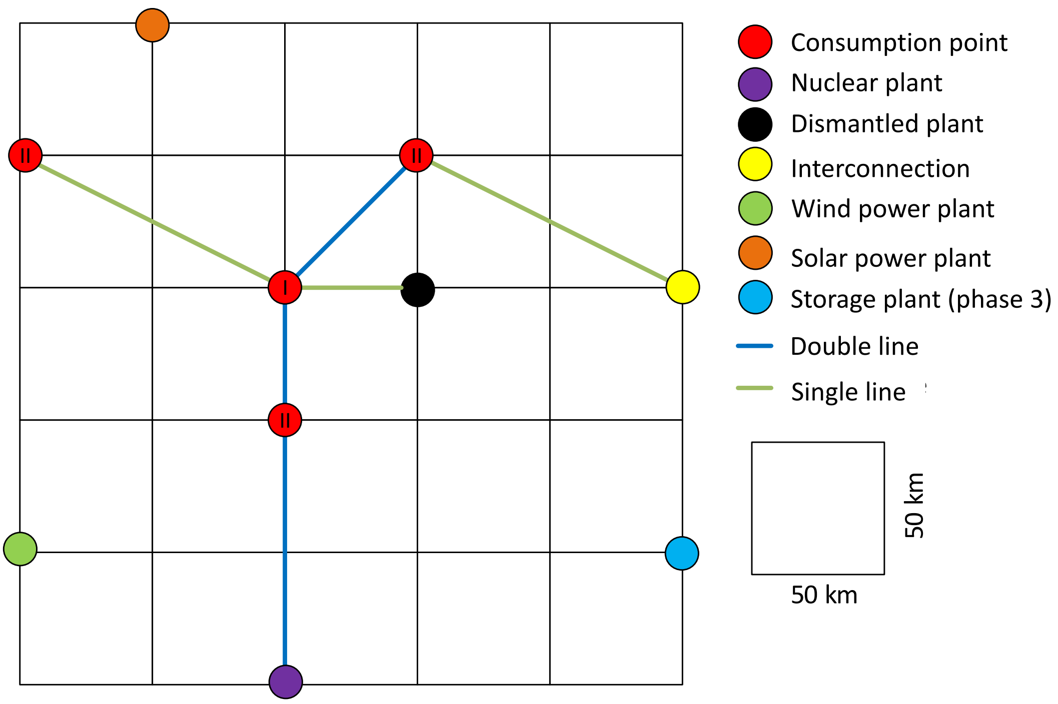
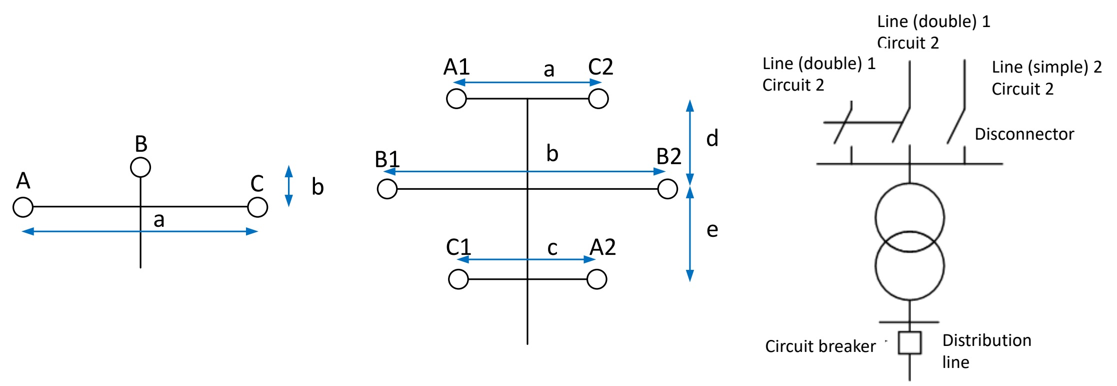
Smart Grid Course Project Instructions

A 220 kV transmission network (detailed in the figure below) supplies four distribution networks (represented as type I and type II consumption points). A nuclear power plant is also connected to the transport network and this is also interconnected with another transport network through the interconnection point. In recent years the system has been affected by different difficulties, as a consequence of the increase in consumption and the shut-down of a gas plant that has become obsolete.



Note that the consumption, generation and interconnection points are connected through simple lines (figure on the left) or double lines (figure in the middle). In addition, in each substation (consumption and generation points) there is a transformer (oversized) that transforms the transmission voltage level to that of distribution and generation, and there is also the switchgear for maneuvering (switches and disconnectors).



According to the group, the characteristics of the assets and the transport network are:

Group:	**I**	**II**	**III**	**IV**	**V**	**VI**
Nominal power of the nuclear plant	500 MW (connected to 25 kV in MV at 1.05 pu)	425 MW (connected to 25 kV in MV at 1.05 pu)	400 MW (connected to 25 kV in MV at 1.05 pu)	0 MW	450 MW (connected to 25 kV in MV at 1.05 pu)	475MW (connected to 25 kV in MV at 1.05 pu)
Peak power consumption of type I load	250 MW (connected to 36 kV)	375 MW (connected to 36 kV)	225 MW (connected to 36 kV)	200 MW (connected to 36 kV)	300 MW (connected to 36 kV)	350 MW (connected to 36 kV)
Peak power consumption of type II load	180 MW (connected to 36 kV)	140 MW (connected to 36 kV)	160 MW (connected to 36 kV)	140 MW (connected to 36 kV)	120 MW (connected to 36 kV)	150 MW (connected to 36 kV)
Conductor caracteristics	Type: Cardenal Composition: 54 Al + 7 Ac; Max. current: 888,98 A					
Simple line characteristics	$a = 11\,m$ $b = 2\,m$	$a = 10\,m$ $b = 3\,m$	$a = 12\,m$ $b = 1\,m$	$a = 11\,m$ $b = 1\,m$	$a = 9\,m$ $b = 3\,m$	$a = 10\,m$ $b = 2\,m$
Double line characteristics	$a = c = 6\,m$ $b = 8\,m$ $d = e = 5{,}5\,m$	$a = c = 6\,m$ $b = 7\,m$ $d = e = 6\,m$	$a = c = 6{,}5\,m$ $b = 7\,m$ $d = e = 5\,m$	$a = c = 6\,m$ $b = 7\,m$ $d = e = 5\,m$	$a = c = 6\,m$ $b = 7\,m$ $d = e = 6{,}5\,m$	$a = c = 6\,m$ $b = 8\,m$ $d = e = 6{,}5\,m$
Quater of the year	T3: (Jul-Sep)	T1: (Jan-Mar)	T2: (Apr-Jun)	T4: (Nov-Dic)	T3: (Jul-Sep)	T1: (Jan-Mar)
Price of imported MWh [1]	P_{Valley}= 40 €/MWh P_{Flat}= 60 €/MWh P_{Peak}= 100 €/MWh	P_{Valley}= 45 €/MWh P_{Flat}= 65 €/MWh P_{Peak}= 90 €/MWh	P_{Valley}= 50 €/MWh P_{Flat}= 65 €/MWh P_{Peak}= 85 €/MWh	P_{Valley}= 40 €/MWh P_{Flat}= 60 €/MWh P_{Peak}= 90 €/MWh	P_{Valley}= 35 €/MWh P_{Flat}= 60 €/MWh P_{Peak}= 90 €/MWh	P_{Valley}= 40 €/MWh P_{Flat}= 60 €/MWh P_{Peak}= 95 €/MWh
Interruptibility	Line failure rate (single or circuit): 0.05 failures km / year Line repair time: 2 hours. Switching time of the disconnector: 0.5 hours					

[1] The price of the exported MW is 60% of the price of the imported MWh. Valley: 00 -08h weekdays. Saturdays, Sundays and holidays all day. Flat: 08-10h, 14- 18h and 22-00h. Peak: 10-14h and 18-22h

	Transformer failure rate: 0.15 failures / year Line repair time (one line): 8 hours					
Penalty for not providing service	P_P=200 €/MWh	P_P=180 €/MWh	P_P=220 €/MWh	P_P=110 €/MWh	P_P=150 €/MWh	P_P=230 €/MWh

The objective of the work is to approach the study of the electrical system which has to be able to satisfy the electrical demand. To do this, it is proposed to improve the electrical system from two projects based on the use of renewable resources (for each group) and the possibility of rehabilitating an old dismantled plant.

Group:	I	II	III	IV	V	VI
Renewable Project 1	Solar Plant: Space = 80 ha (41,68N; 1,16E)	Solar Plant: Space = 60 ha (40,8N; 0.48E)	Solar Plant: Space = 70 ha (40,9N; 0.30E)	Solar Plant: Space = 80 ha (40,9N; 0.30E)	Solar Plant: Space = 70 ha (42,33N; 3.07E)	Solar Plant: Space = 90 ha (42.01N; 1.53E)
Renewable Project 2	Wind Plant: Space = 60 ha (41,6N; 1.74E)	Wind Plant: Space = 80 ha (42,28N; 3.16E)	Wind Plant: Space = 70 ha (41,01N; 0.35E)	Wind Plant: Space = 60 ha (41,01N; 0.35E)	Wind Plant: Space = 70 ha (42,37N; 3.08E)	Wind Plant: Space = 70 ha (42,14N; 1.38E)
Dismantled plant[2]	Transformer: 220/25 kV (200 MVA, u_k=10.5%)					

Finally, to the resulting system the following Smart Grid use cases should be applied.

Group:	I	II	III	IV	V	VI
Use Case	Voltage regulation	Contingency Analysis	Volt VAR Optimization	Demand Response – Utility Commanded Load Control	Provide Pricing Signal to Charge/Discharge Storage	Distributed Energy Resource Forecasting

[2] De la central solo queda la edificación, la acometida eléctrica y el transformador de potencia.

Minimum tasks to perform:

I. Study of the current system:

- Model the demand and generation profile for a 24-hour work day:
  - Carry out a statistical analysis of the data from in Spain during a quarter: https://www.esios.ree.es/en/analysis
    - Indicators of consumption -> Indicators of real time ->Real Demand
    - Indicators of generation -> Indicators of real time ->Real time generation -> select
- Normalize demand and generation profiles (between 0 and 1).
- Model the electrical system with PandaPower (free distribution software) or with other software.
- Carry out the load flow study according to the load and generation profile for 24 h.
  - Consider that the loads have a power factor of 0.98.
  - Consider that the voltage at the generation points must be kept constant.
- Identify the problems of the current system: demand coverage, voltage, overload, interruptibility (for one year), etc.
- Propose solutions to the problems identified.
- Estimate the network operating costs for one year.

II. Upgrading the current network, phase 1.

- Connect generation and demand by selecting the type of line with the lowest cost that guarantees that:
  - The consumption points and the nuclear power plant meet the N-1 criterion.
  - The generation points meet criterion N, except for the nuclear power plant.
  - The interconnection link meets criterion N.
  - Study the possibility of modifying the voltage level of the network.
    - What advantages and disadvantages would it have.
    - Estimate the cost and the possible savings that it would entail.
  - The losses in the transmission lines do not exceed 2% of the nominal value and also that the lines are not overloaded (<80%)[3].
- Carry out the load flow study according to the load and generation profile for 24 h (with the same considerations)
- Identify the problems of the current system: demand coverage, voltage, overload, interruptibility (for one year), etc.
- Estimate the network operating costs for one year and the investment costs[4].

III. Upgrading the current network, phase 2.

- Study the possibility of carrying out the two projects to reduce energy dependence:
  - Determine the characteristics of each power station necessary for each plant.
- Carry out the load flow study according to the load and generation profile for 24 h (with the same considerations as before)

[3] Nominal power usually taken as the maximum power to be able to transfer the line
[4] https://documents.acer.europa.eu/Official_documents/Publications/UIC_Electricity_History/UIC%20report%20%20-%20Electricity%20Infrastructure%20corrected.pdf

- Identify the problems of the current system: demand coverage, voltage, overload, interruptibility (for one year), etc.
- Estimate the network operating costs for one year and the investment costs.

IV. Upgrading the current network, phase 3.

- Study the possibility of rehabilitating the disused plant.
- Study other possibilities to reduce energy dependence.
    - Storage
    - Control and coordination of existing generation
    - Other proposals
- Carry out the load flow study according to the load and generation profile for 24 h (with the same considerations as before)
- Identify the problems of the current system: demand coverage, voltage, overload, interruptibility (for one year), etc.
- Estimate the network operating costs for one year and the investment costs.

V. Designing the Smart Grid Architecture Model for the control of the system.

- Describe the use case of the group using the tables of the template provided.
- Develop the SGAM model out of the use case.
- You have certain freedom of interpretation
- Short is better than long