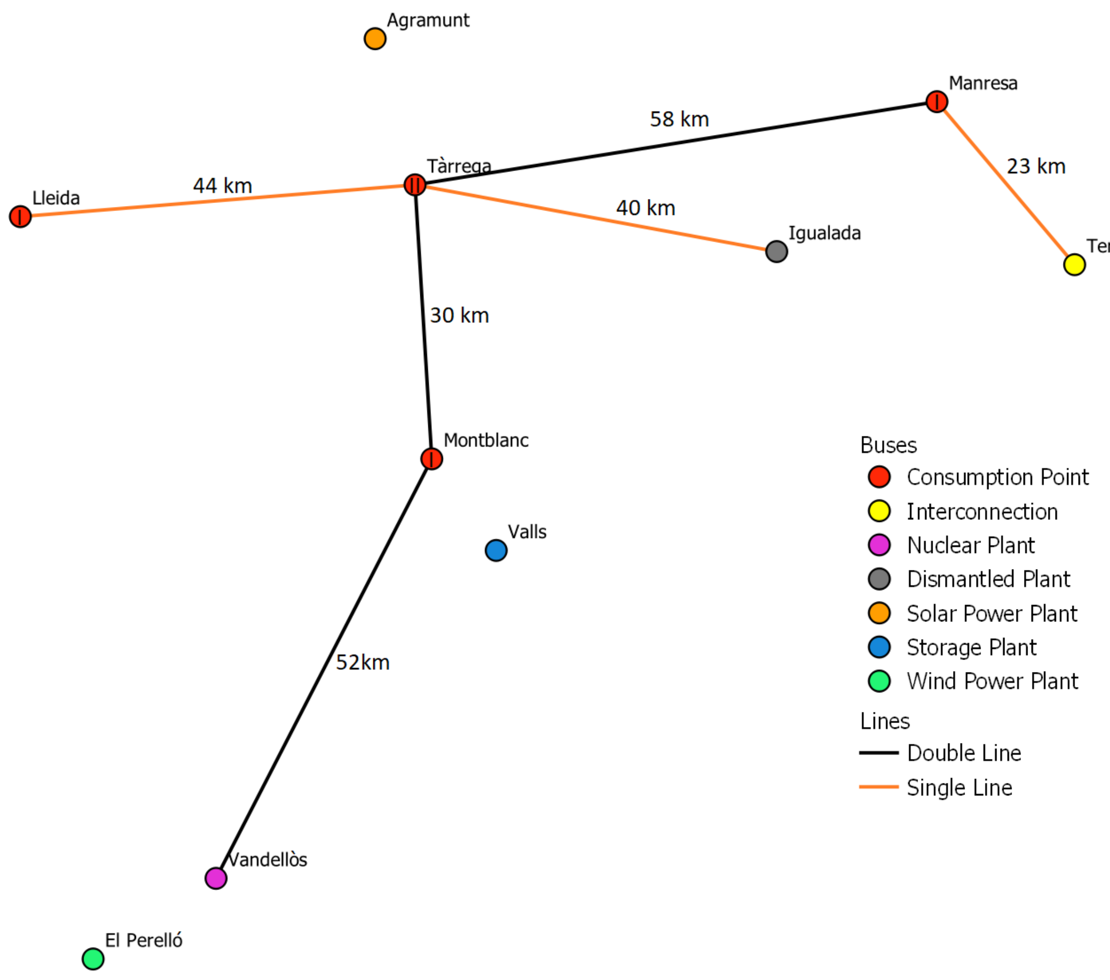
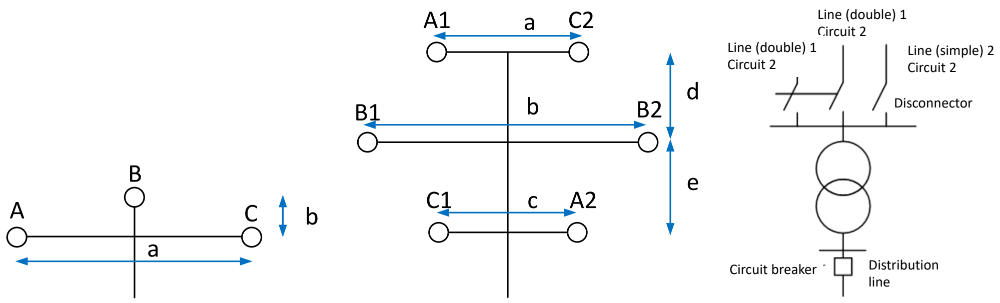
Smart Grid Course Project Instructions

A 110 kV transmission network (detailed in the figure below) supplies four distribution networks (represented as type I and II consumption points). A nuclear power plant is also connected to the transmission network and is interconnected with another transmission 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 shutdown of a gas plant that has become obsolete.



Note that the consumption, generation, and interconnection points are connected through simple lines (figure 1 on the left) or double lines (figure 1 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 manoeuvring (switches and disconnectors).



single line　　double line　　switching configuration

Fig. 1: Line configurations

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	260 MW (connected to HV side)	180 MW ((connected to HV side))	250 MW (connected to HV side)	150 MW (connected to HV side)	220 MW (connected to HV side)	175 MW (connected to HV side)
Peak power consumption of type II load	160 MW (connected to MV at 20 kV)	150 MW (connected to MV at 20 kV)	140 MW (connected to MV at 20 kV)	90 MW (connected to MV at 20 kV)	110 MW (connected to MV at 20 kV)	130 MW (connected to MV at 20 kV)
Peak power consumption of type I load	70 MW (connected to MV at 20 kV)	55 MW (connected to MV at 20 kV)	65 MW (connected to MV at 20 kV))	75 MW (connected to MV at 20 kV)	90 MW (connected to MV at 20 kV)	80 MW (connected to MV at 20 kV)
Conductor characteristics	Type: Cardenal Composition: 54 Al + 7 Ac; 30.42 mm diameter, 0.062 Ω/km, k_g=0.809 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	$a = c = 6\,m$ $b = 8\,m$ $d = e = 5{,}5\,m$	$a = c = 6\,m$ $b = 7\,m$ $d = e = 6\,m$	$a = c = 6{,}5\,m$ $b = 7\,m$ $d = e = 5\,m$	$a = c = 6\,m$ $b = 7\,m$ $d = e = 5\,m$	$a = c = 6\,m$ $b = 7\,m$ $d = e = 6{,}5\,m$	$a = c = 6\,m$ $b = 8\,m$ $d = e = 6{,}5\,m$

Quarter 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 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**
Agramunt Solar Power Plant (1.08664, 41.79154)	Renewable Project 1 Space = 100 ha	Renewable Project 1 Space = 120 ha	Renewable Project 1 Space = 150 ha	Renewable Project 1 Space = 300 ha	Renewable Project 1 Space = 90 ha	Renewable Project 1 Space = 120 ha
El Perelló Wind Power Plant (0.71262, 40.87541)	Renewable Project 2 Space = 400 ha	Renewable Project 2 Space = 500 ha	Renewable Project 2 Space = 400 ha	Renewable Project 2 Space = 600 ha	Renewable Project 2 Space = 400 ha	Renewable Project 2 Space = 400 ha
Dismantled plant[2]	Transformer: 110/20 kV (200 MVA, u_k=10%)					

[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

[2] All that remains of the power station is the building, the electrical connection and the power transformer.

Smart grid use case and SGAM

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

Group I: Lleida: Lleida, a metropolitan city, needs help with ageing infrastructure. The city administration wants to integrate various renewable energy sources into their current grid. The challenge is to ensure that energy flow is managed efficiently while dealing with the old infrastructure.

Group II: Igualada. In Igualada, a remote island community, it is looking to be self-sustainable in terms of energy. They have access to solar, wind, and a small diesel generator. The community wants to harness solar and wind energy effectively, store it, and reduce their reliance on diesel generators.

Group III: Terrassa. In Terrassa, a tech-savvy university campus, wants to implement a microgrid that can manage energy consumption based on real-time needs and pricing. The aim is to ensure efficient energy consumption during peak hours and incorporate demand-response mechanisms.

Group IV: Montblanc. In Montblanc, a large industrial park aims to have a consistent power supply across all its factories. The park management wants to integrate on-site renewable energy sources and ensure power is evenly distributed, especially during high-demand periods.

Group V: Tàrrega. Tàrrega is embarking on a smart city project. The city administration wants to create an interconnected network of homes that can share energy. Homes with surplus energy should be able to feed it back into the grid, benefiting other homes.

Group VI: Manresa Grid Zone. Near Manresa, a grid zone is known for its vast hydropower resources. This zone often has excess power which can be exported. The grid management wants to establish a framework where excess energy can be transferred to neighbouring zones or stored for future use.

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 Spain for 2 weeks (in the corresponding quarter): https://demanda.ree.es/visiona/seleccionar-sistema
    - Real Demand
    - Generation, considering the different types you use
- Normalise demand and generation profiles (between 0 and 1).
- Model the electrical system with PandaPower
  - First, model the system with the peak demand
  - Model the system using the hourly changing demand
- Carry out the load flow study according to the load and generation profile for 24 hours.
  - 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)
- 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)

[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.

V. Designing the Use Case and the Smart Grid Architecture Mode

Use Case Design:

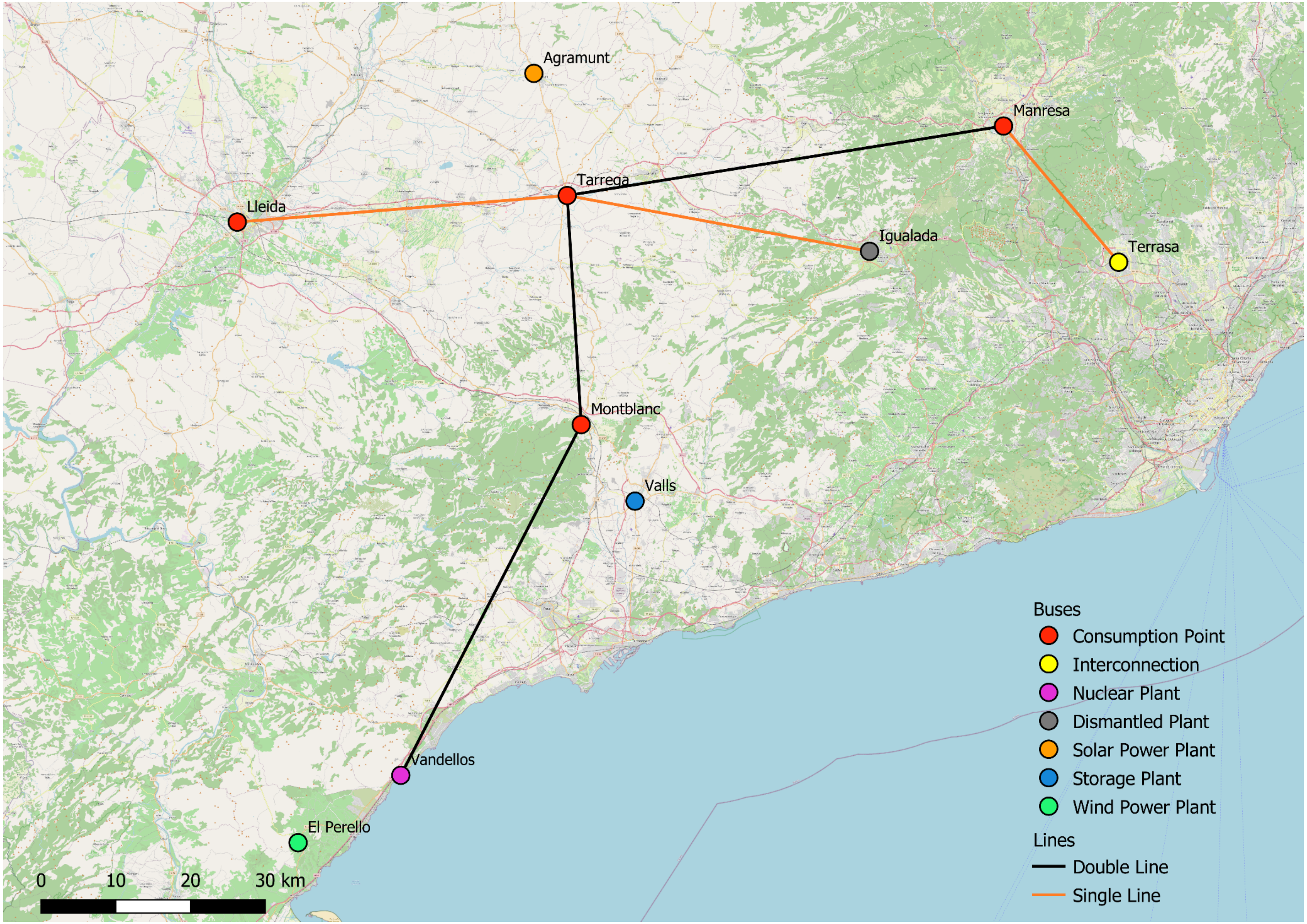
- Identify potential use cases for the given scenario.
- Describe one of the identified use cases in detail. Mention the actors, preconditions, postconditions, main flow, and alternative flows.
- Highlight any relationships between the use cases you've identified.

SGAM Design:

- Business Layer Creation: Identify and describe the main objectives, services, and stakeholders relevant to the scenario. What are the business goals, and who are the main actors?
- Function Layer Creation: Detail the primary functions and operations required to achieve the business objectives. What processes and tasks need to be performed?
- Component Layer Creation: Identify the physical components and devices relevant to the scenario. What are the main pieces of infrastructure or equipment?
- Communication Layer Creation: Determine the communication protocols and methods for interacting components. How will information be transmitted between devices?
- Information Layer Creation. Detail the types of data and information that will be processed and shared. What data formats, standards, or schemas are relevant?

Please consult databases on use cases to complete the descriptions:

- https://smartgrid.epri.com/Repository/Repository.aspx
- https://smart-grid-use-cases.github.io/docs/


Agramunt
Manresa
Tarrega
Lleida
Igualada
Terrasa
Montblanc
Valls
Vandellos
El Perello
0
10
20
30 km
Buses
Consumption Point
Interconnection
Nuclear Plant
Dismantled Plant
Solar Power Plant
Storage Plant
Wind Power Plant
Lines
Double Line
Single Line