

Introduction to Grid Power Flow Simulation

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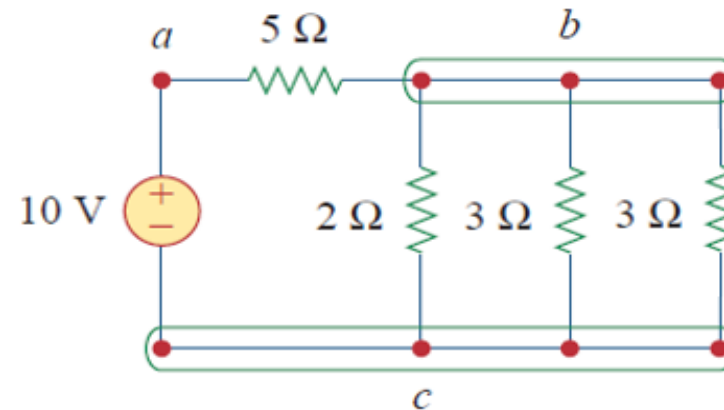
University of California Riverside

Objectives

- Learn some basic circuit notions that are applied to power grid
- Learn about the sections of a power grid
- Learn what AC quantities are
- Learn to use the “Tennet Power Flow Simulator”
- Build custom models in “Tennet Power Flow Simulator”
- Get a basic idea of how the electrical power grid works

Electrical Circuit Nodes

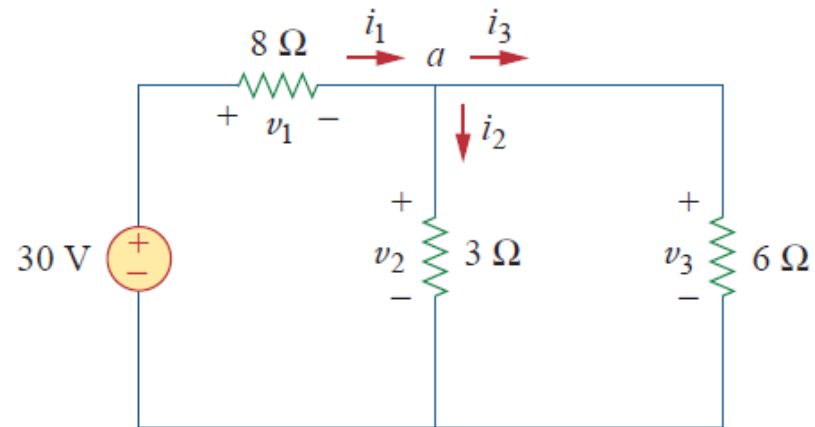
- In electrical circuits a node is the point of connection between two or more electrical elements.



- All the three points that form 'node *b*' constitute a single point. The same is true of the four points forming node *c*.

Characteristics of Nodes

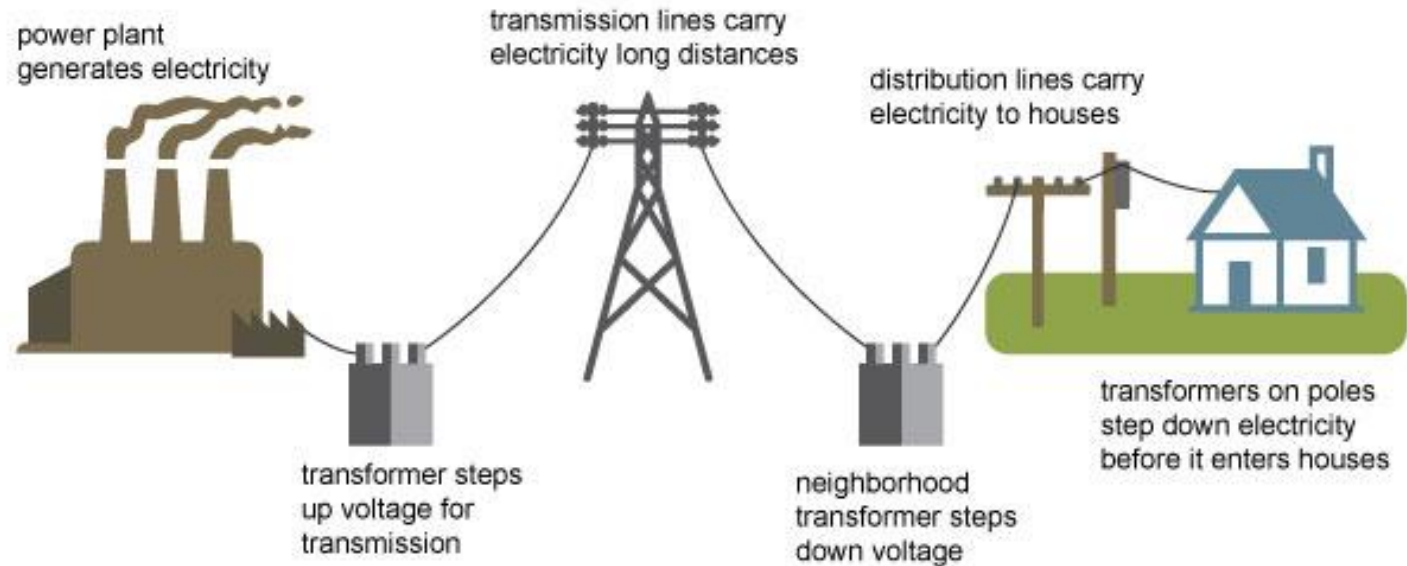
- Each node has a single voltage value.
- The sum of currents entering a node must equal the sum of currents leaving a node (Kirchhoff's Current Law).



- Here, at 'node a', $v_2 = v_3 = 6\text{V}$ and $i_1 = 3\text{A}$, $i_2 = 2\text{A}$ and $i_3 = 1\text{A}$. v_1 is 24V .

Electrical Grid

Electricity generation, transmission, and distribution

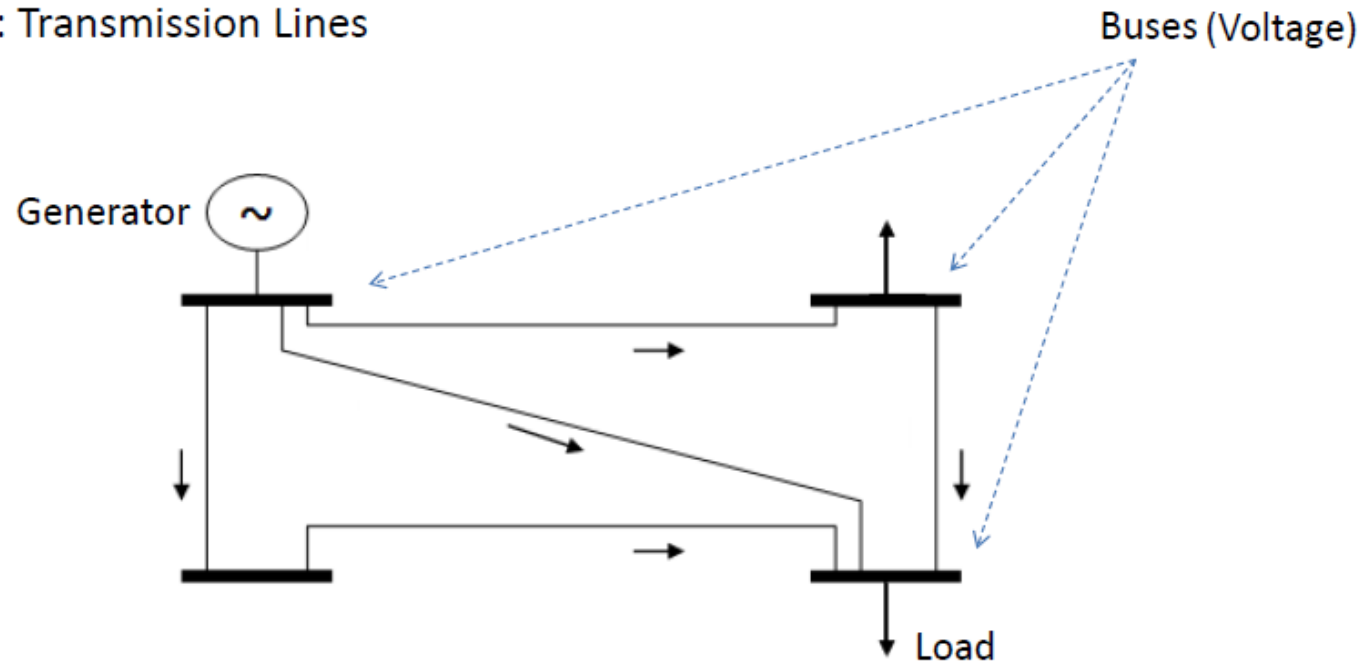


Source: Adapted from National Energy Education Development Project (public domain)

Electrical Grid Circuit (Buses)

Nodes: Buses

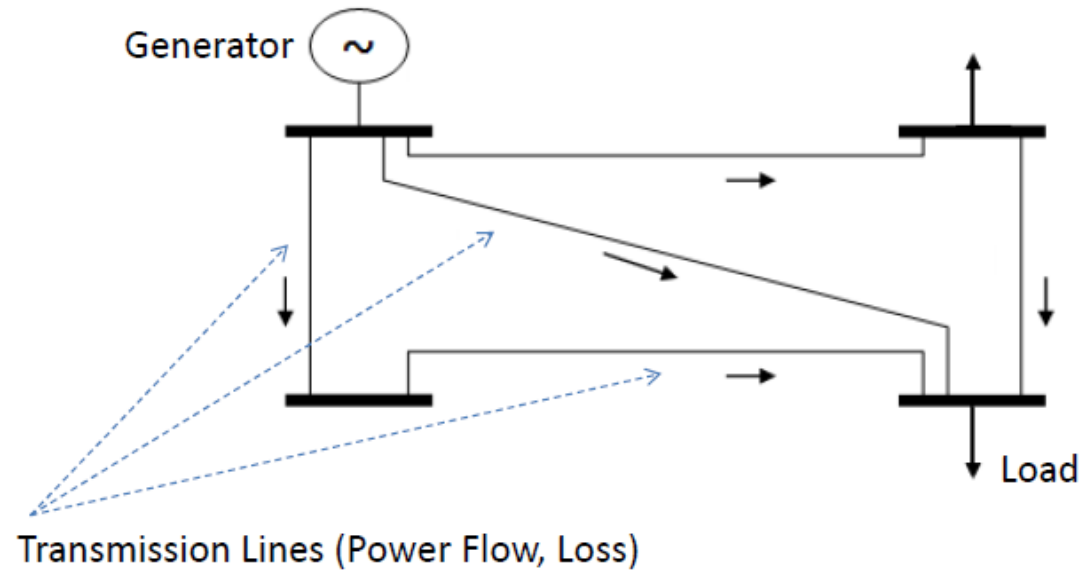
Links: Transmission Lines



Electrical Grid Circuit (Transmission Lines)

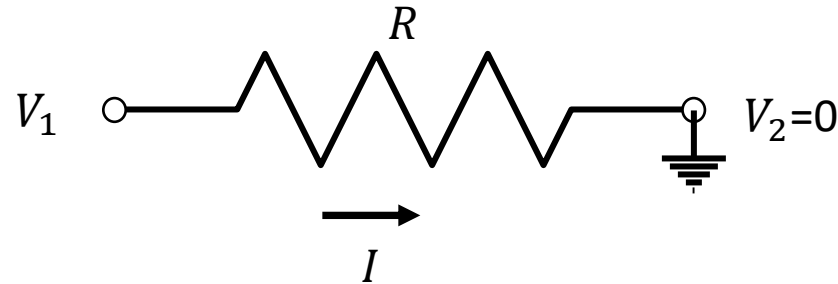
Nodes: Buses

Links: Transmission Lines



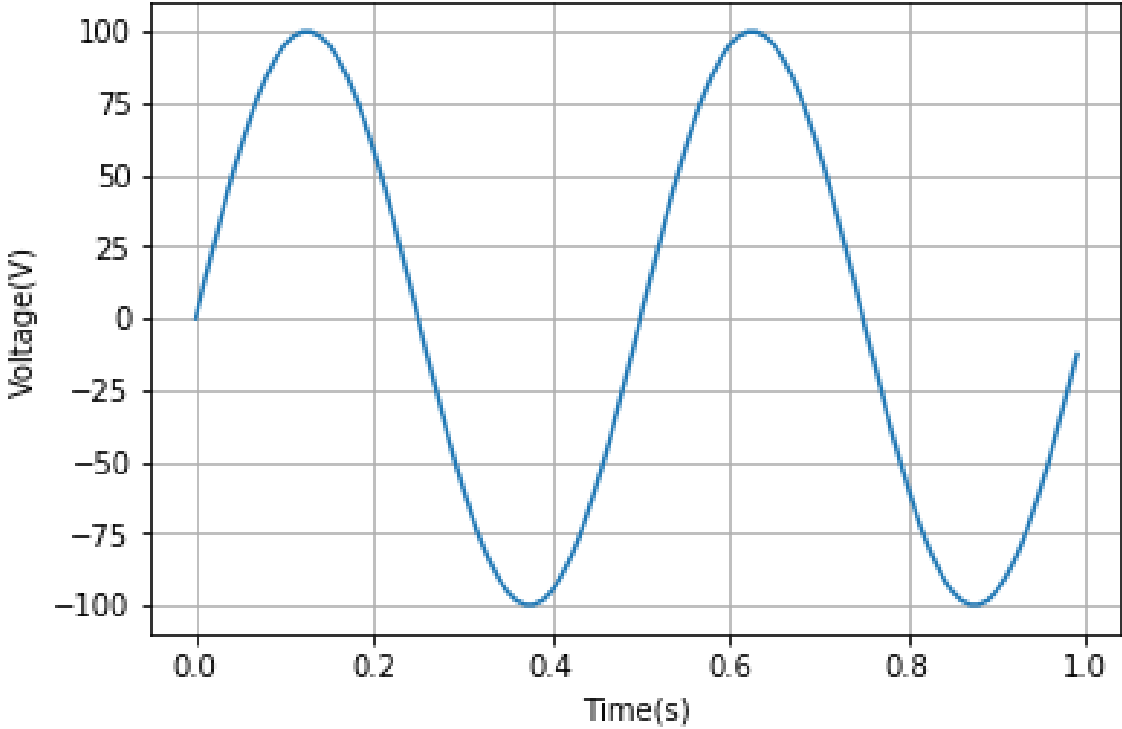
Power Flow

- In the circuit below there are two nodes with voltage V_1 and V_2 . They are connected by a line with resistance R .



- Current through the line, $I = \frac{V_1 - V_2}{R} = \frac{V_1}{R}$
- So, power flow, $P_{12} = (V_1 - V_2)I$
- In power grids all the quantities are AC signals

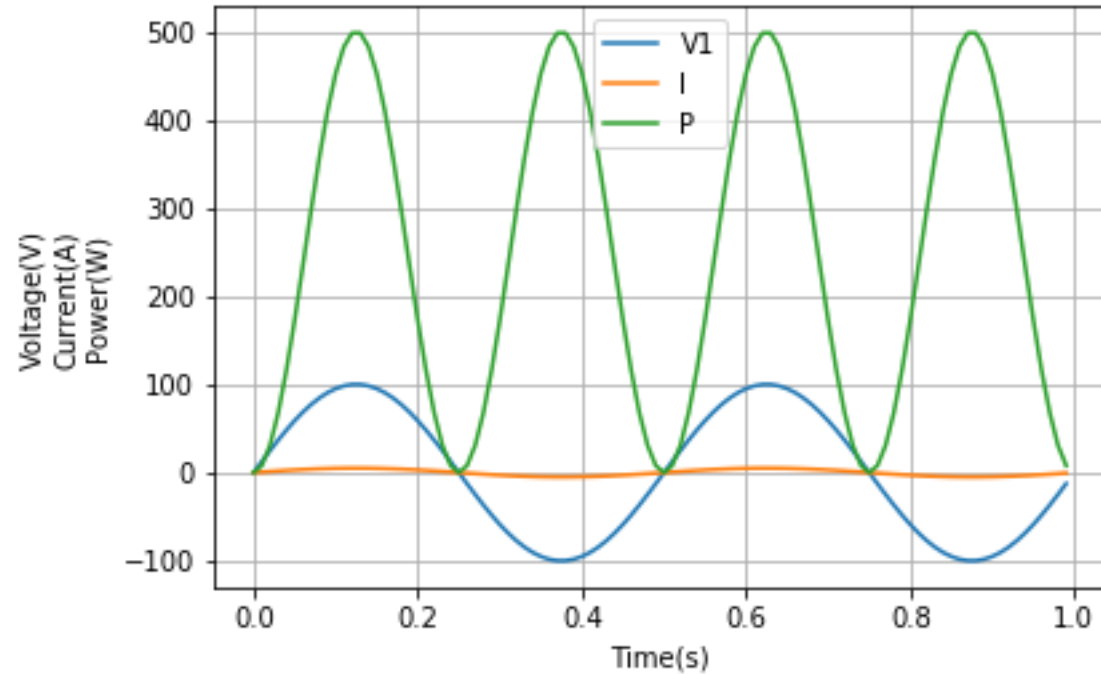
AC Voltage



AC Voltage Equation

- AC Voltage can be expressed as:
- $V(t) = V_{max} \sin(2\pi ft + \varphi)$
- Where
 - $V(t)$ = Voltage value at time t
 - V_{max} = Maximum value of the voltage (amplitude)
 - f = Frequency of the AC Voltage
 - φ = Initial phase

AC Voltage, Current and Power



Tennet Power Flow Simulator

- Link: <https://www.tennet.eu/our-key-tasks/innovations/powerflow-simulator/>

Introduction

The TenneT power flow simulator gives you the opportunity to operate and build your own electrical grid. It allows you to experience the real-life challenges that transmission system operators like TenneT face every day and it shows you what TenneT does to ensure a reliable and uninterrupted supply of electricity. The "Learn" section playfully guides you through different scenarios and challenges that you need to complete. In the "Explore" section you are free to try out all the functionalities of the system and you can even build your own grid in the "expert mode". It is also possible to save the grid that you've built, so that you can continuously keep working on it.

The tool works best within
- GoogleChrome 74+
- Firefox 60+

start simulation in new window >

 Click Here

Tennet Power Flow Simulator

The screenshot displays the interface of the Tennet Power Flow Simulator. A central white dialog box is open, featuring the Tennet logo at the top. The dialog contains a welcome message, a disclaimer, and a 'Close' button. To the left of the dialog, there are two circular gauges labeled '50Hz' and 'CO2 content'. In the top right corner, there are navigation links for 'Explore', 'Play', and 'Settings'. The bottom right corner shows the 'Artelys' logo and the text 'OPTIMIZATION SOLUTIONS'. A yellow arrow points to the 'Close' button in the dialog box.

50Hz


CO2 content

Tennet

Explore Play Settings

Welcome to the TenneT power flow simulator!

Dear visitor,
With this tool we want to give you the opportunity to operate your own electrical grid. It allows you to experience how many factors you have to keep an eye on, to avoid disturbances in the grid and to uphold a safe electrical supply. This demonstration tool is not connected to our real grids: therefore you can feel free to go to the limits and test out all constellations that interest you.



Disclaimer
The information contained on this website is for general information purposes only and does not accurately represent the European electricity grid. The data used in this model related to electricity generation, load and transmission is only symbolic and does not reflect real data from electricity markets or physical assets. TenneT assumes no responsibility for errors or omissions in the contents of this site. In no event shall TenneT be liable for any damages arising out of or in connection with the use of the service on this site. TenneT reserves the right to make additions, deletions, or modifications to the contents of the website at any times and without prior notice.
For a better user experience, we recommend using Chrome or Firefox.

Always show at startup Close

Close

Artelys | OPTIMIZATION SOLUTIONS

Tennet Power Flow Simulator



Tennet Power Flow Simulator

- In the top right corner:
- Discover different built in models and explore them
- Play with the challenges given



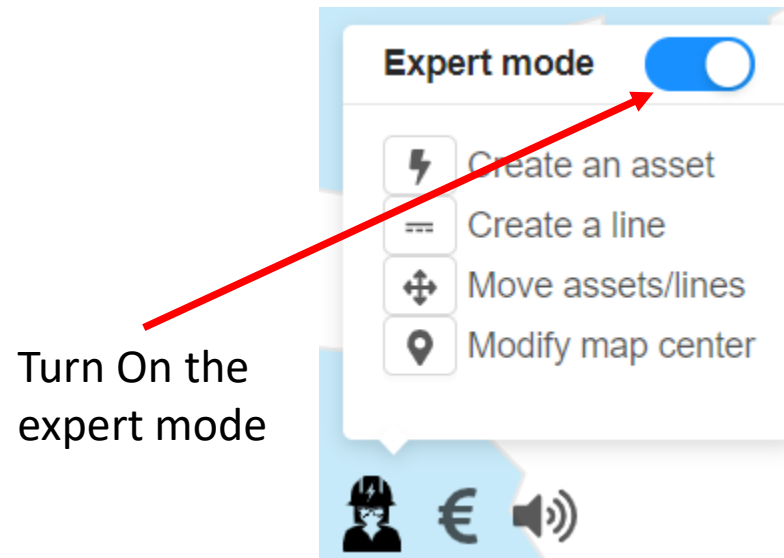
Tennet: Build Your Own Models



Click Explore

Tennet: Build Your Own Models

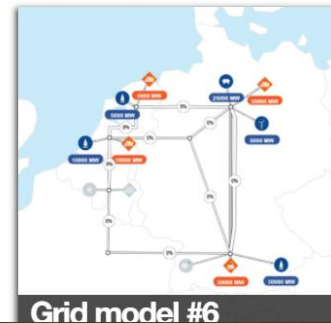
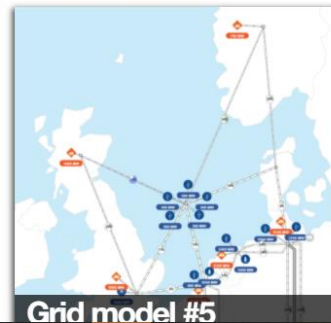
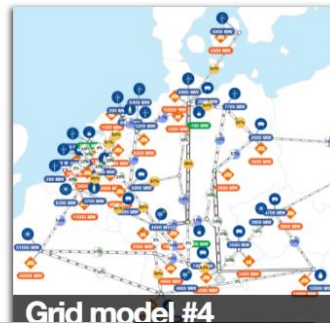
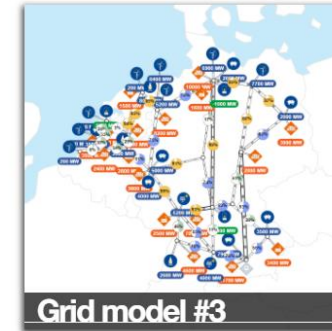
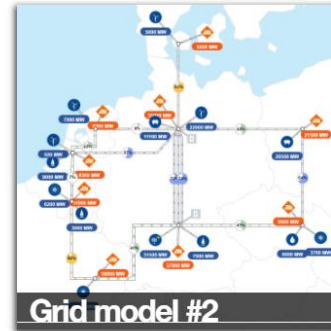
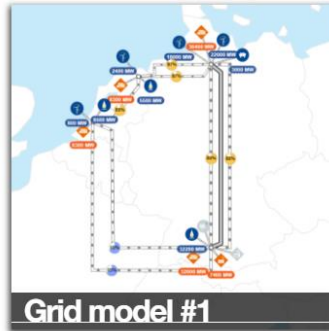
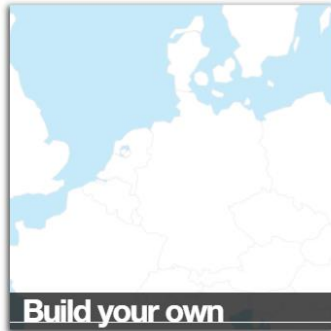
- Go to bottom left and turn on Expert mode



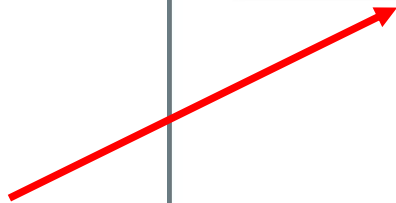
Tennet: Build Your Own Models

👁 Explore: feel the power system

Freely explore and modify electricity power grid models



Go to build your own

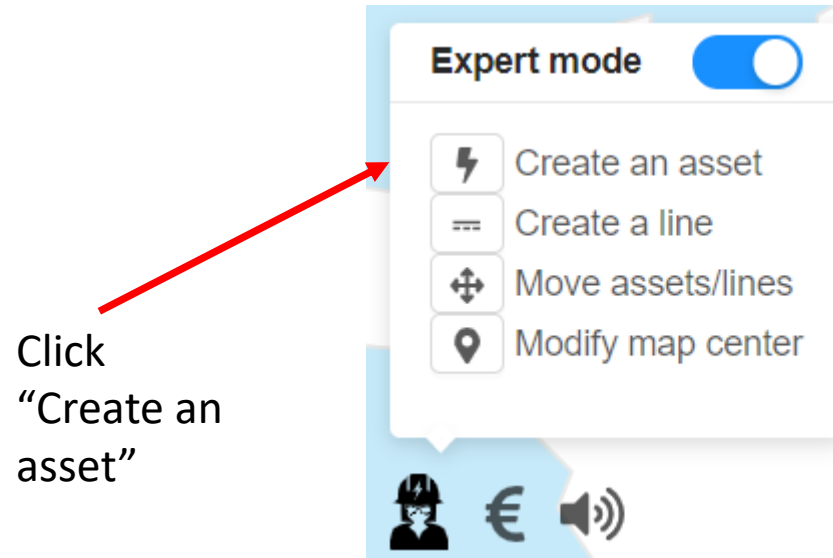


Tennet: Build Your Own Models



Click Expert Mode Icon

Tennet: Build Your Own Models

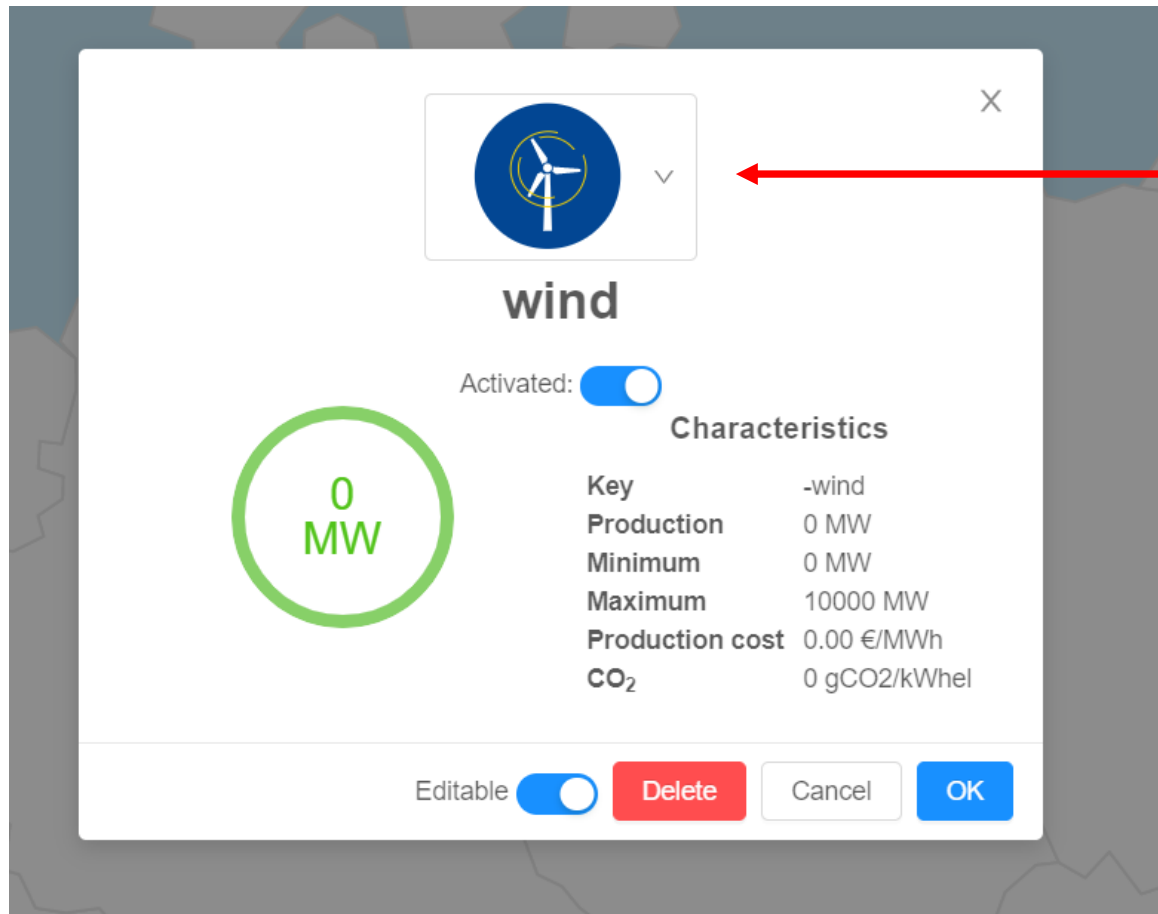


Tennet: Build Your Own Models



Now click
anywhere inside
the map

Tennet: Build Your Own Models



Click the drop-down menu and choose from the options

Tennet: Build Your Own Models

wind

Activated:

0 MW

Characteristics

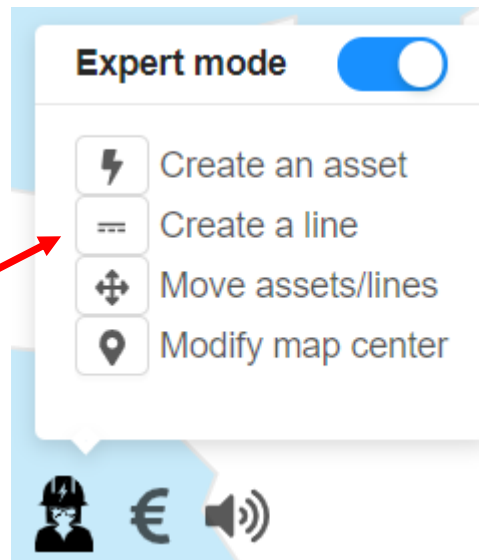
Key	-wind
Production	0 MW
Minimum	0 MW
Maximum	10000 MW
Production cost	0.00 €/MWh
CO ₂	0 gCO ₂ /kWhel

Editable Delete Cancel OK

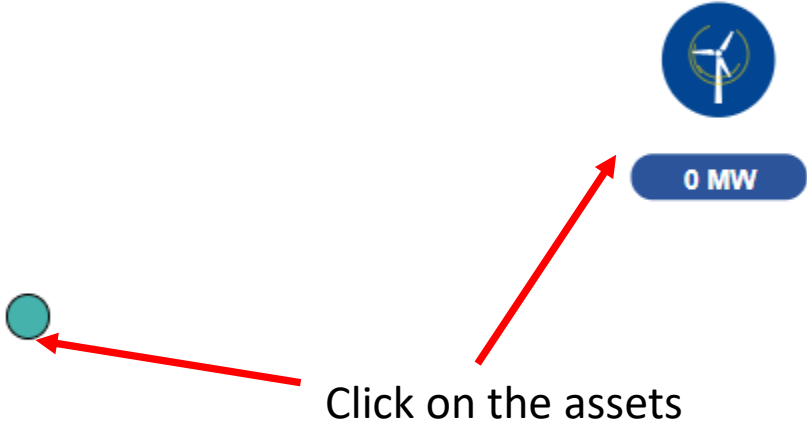
Change the
parameters

Tennet: Build Your Own Models

After
placing the
assets click
“Create a
line”

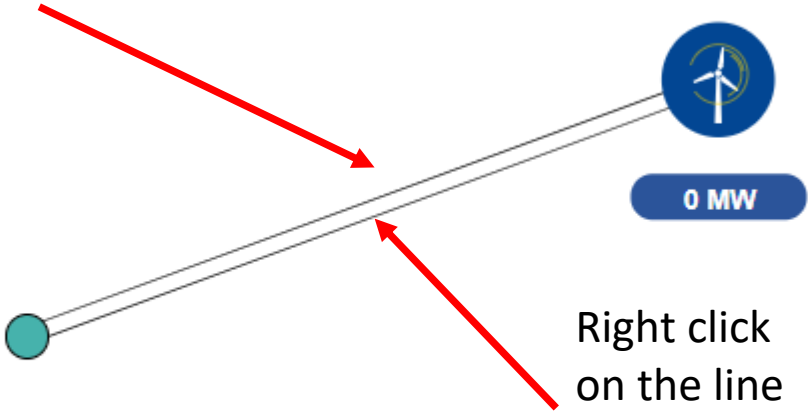


Tennet: Build Your Own Models



Tennet: Build Your Own Models

A transmission line will be created



Tennet: Build Your Own Models

bus ↔ bus wind ✕

Activated:

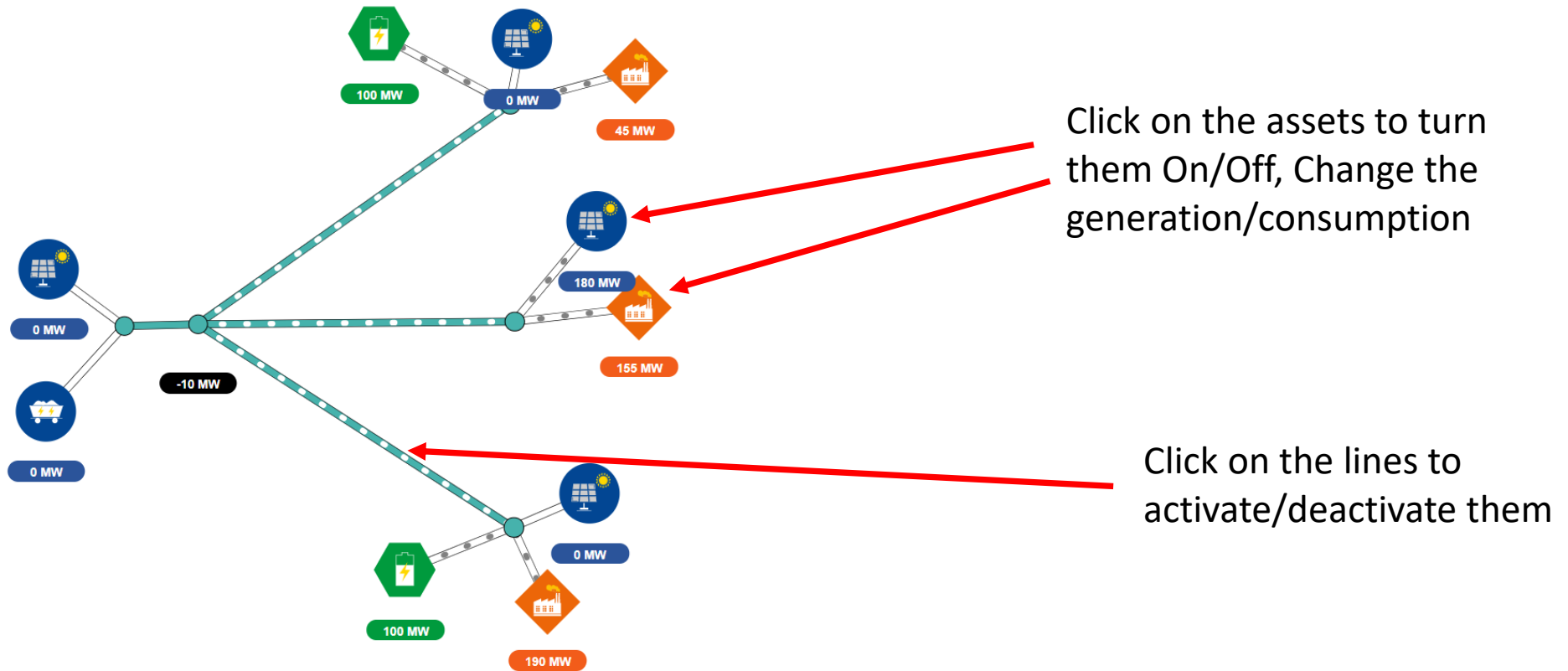
Load 0% **Characteristics**

Key	XSVhU3fqSY
Capacity	1000 MW
Load	0 MW
Reactance	0.174 Ω
Commercial availability	<input type="checkbox"/>

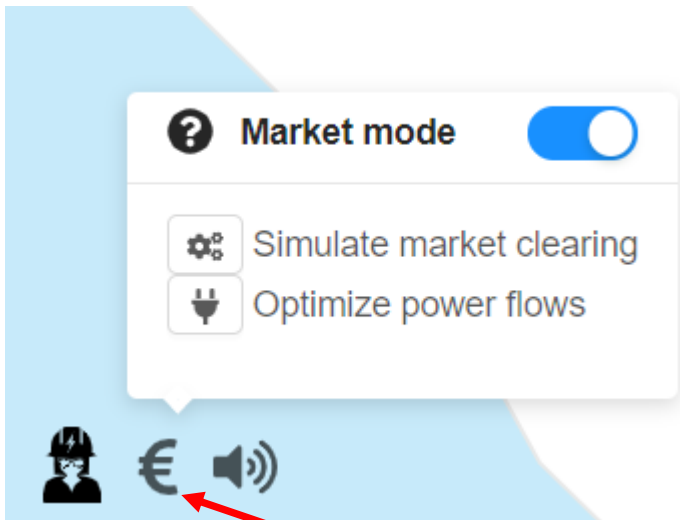
Editable Delete Cancel OK

Change the parameters

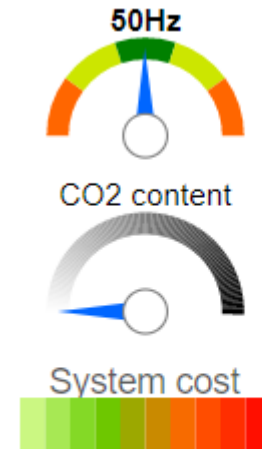
Tennet: Build Your Own Models



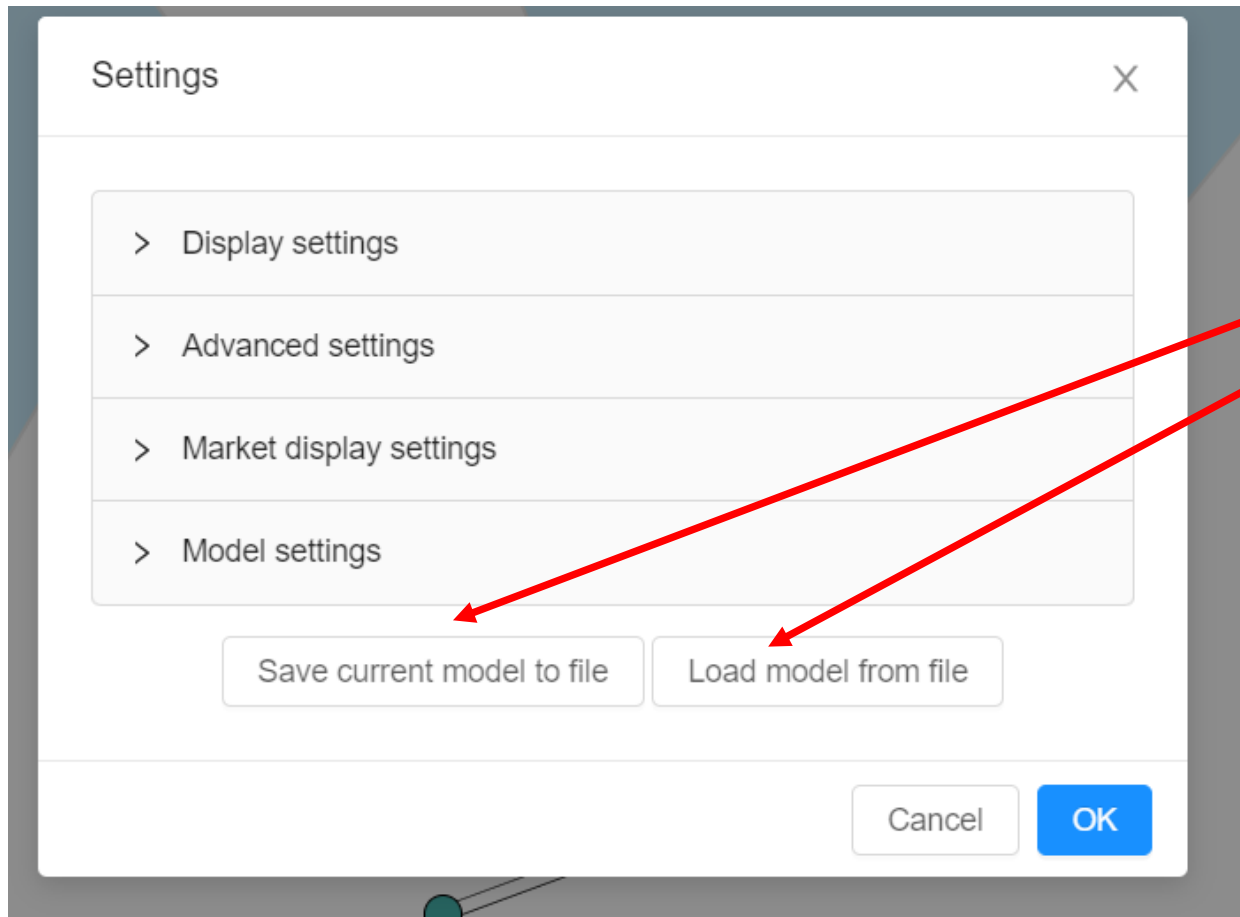
Tennet: Build Your Own Models



You can turn on the market mode to see system cost

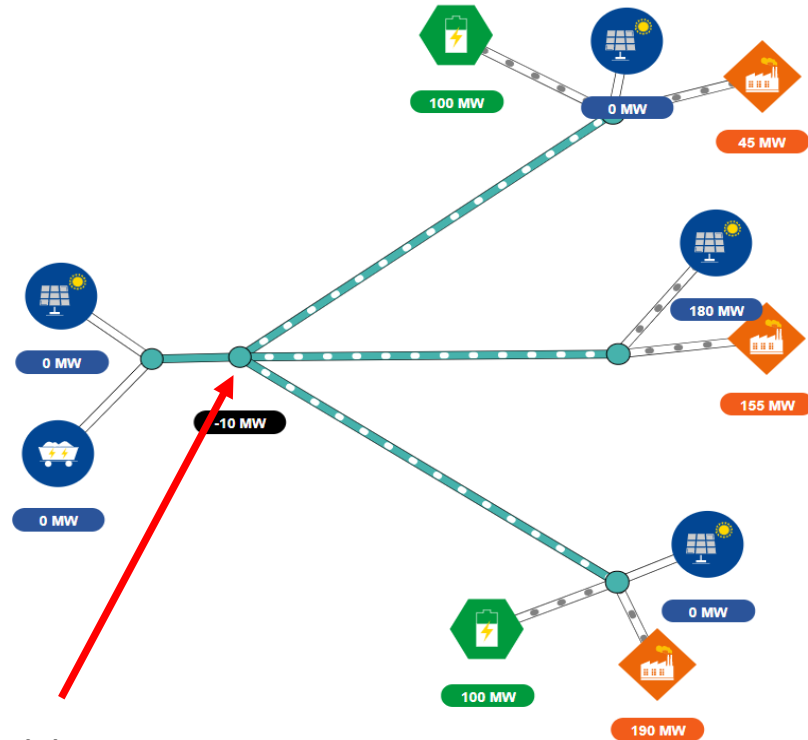


Tennet: Build Your Own Models



You can save and load your models from "Settings"

Assignment



Connect two more busses to this bus

- Add two more busses with the bus shown in figure
- Add a new solar generation, battery storage and load with the following specifications:
 - Solar: Maximum 200 MW
 - Load: Maximum 200 MW
 - Battery Storage: Maximum 100 MW and Minimum -100 MW
- Try out different values of generation and line capacity and see at what values the line capacity reaches 80%
- Note the values and present them in a table

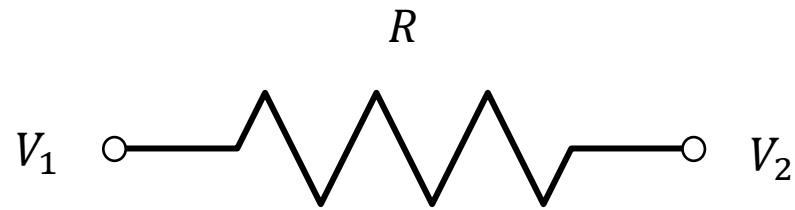
Assignment

- Challenges:
 - Frequency must stay within the green range
 - CO2 content must be low
- Bonus points will be given for models with low system cost in market mode

Advanced Topics

Problems with DC Voltage

- In electrical grids, a standard value of Voltage must be maintained.

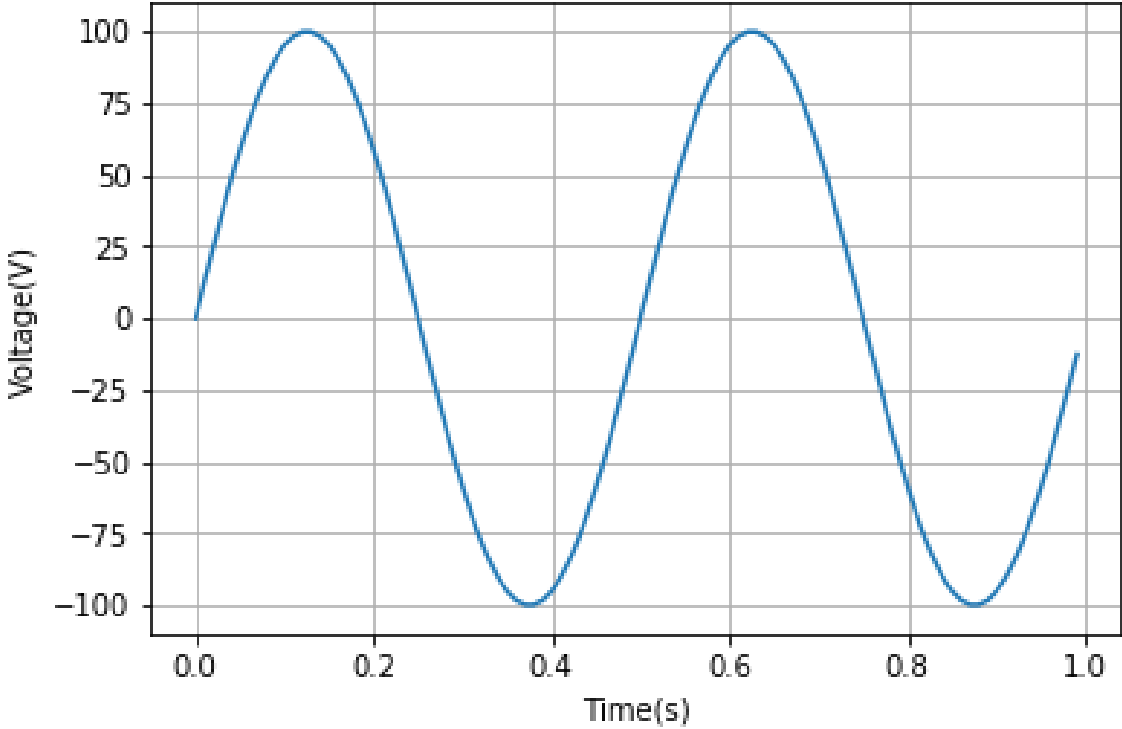


- If $V_1 = V_2$ then current through the resistor R , $I = \frac{V_1 - V_2}{R} = 0$
- So, power flow, $P_{12} = (V_1 - V_2)I = 0$

Solution: AC Voltage

- The grid supplies AC voltage which we get in our house, office, schools etc.
- AC means Alternating Current where voltages and currents are functions of time (change with time).

AC Voltage



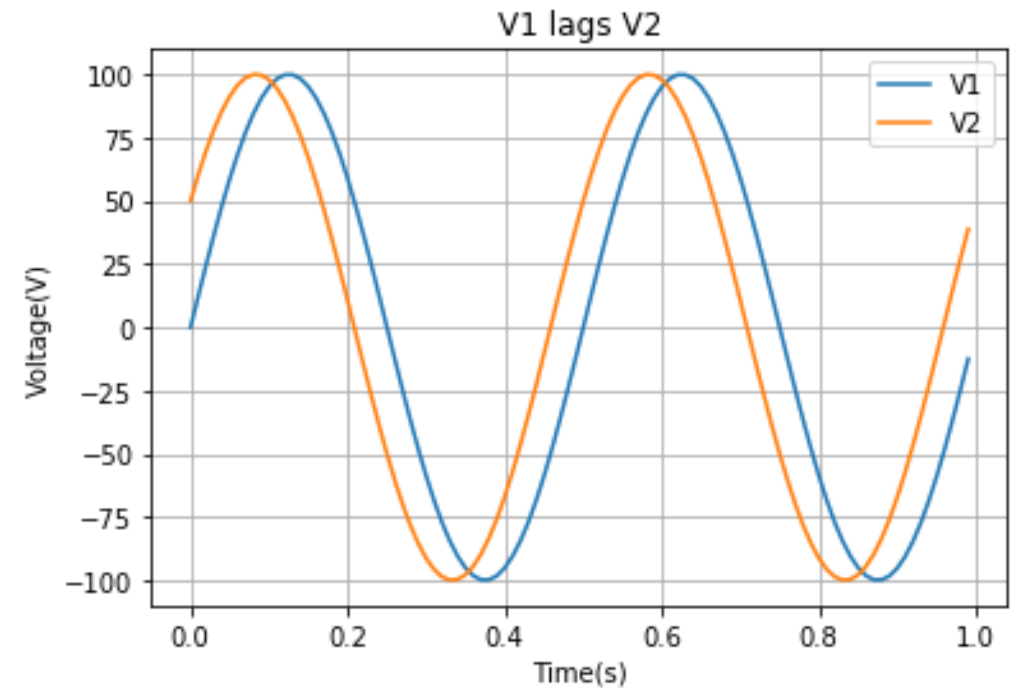
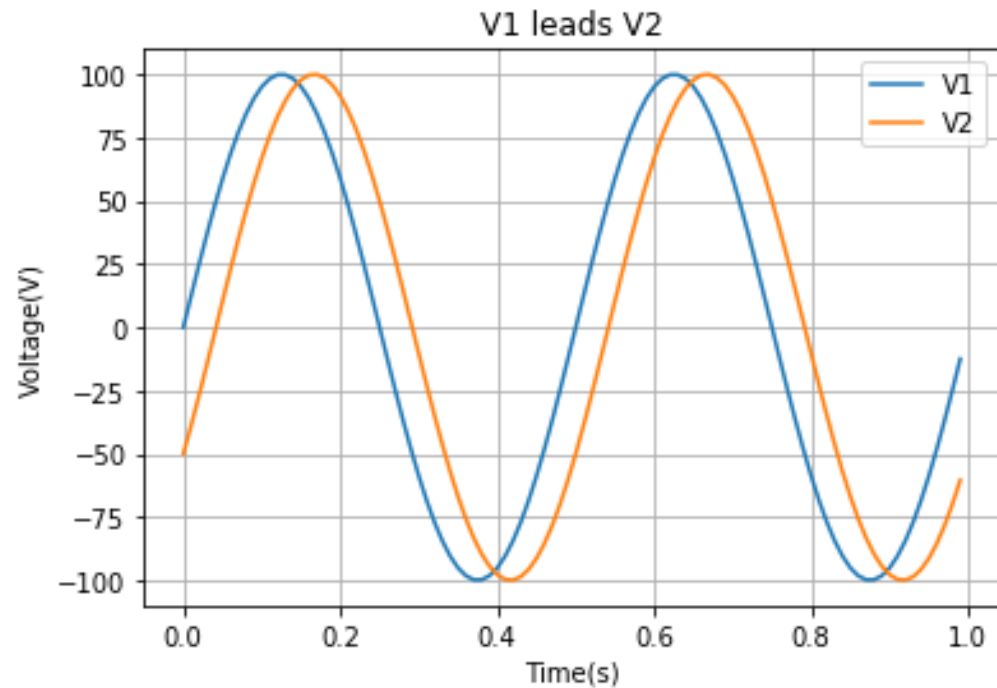
AC Voltage Equation

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- Where
 - $V(t)$ = Voltage value at time t
 - V_{max} = Maximum value of the voltage (amplitude)
 - f = Frequency of the AC Voltage
 - φ = Initial phase
- In grids a standard frequency must also be maintained

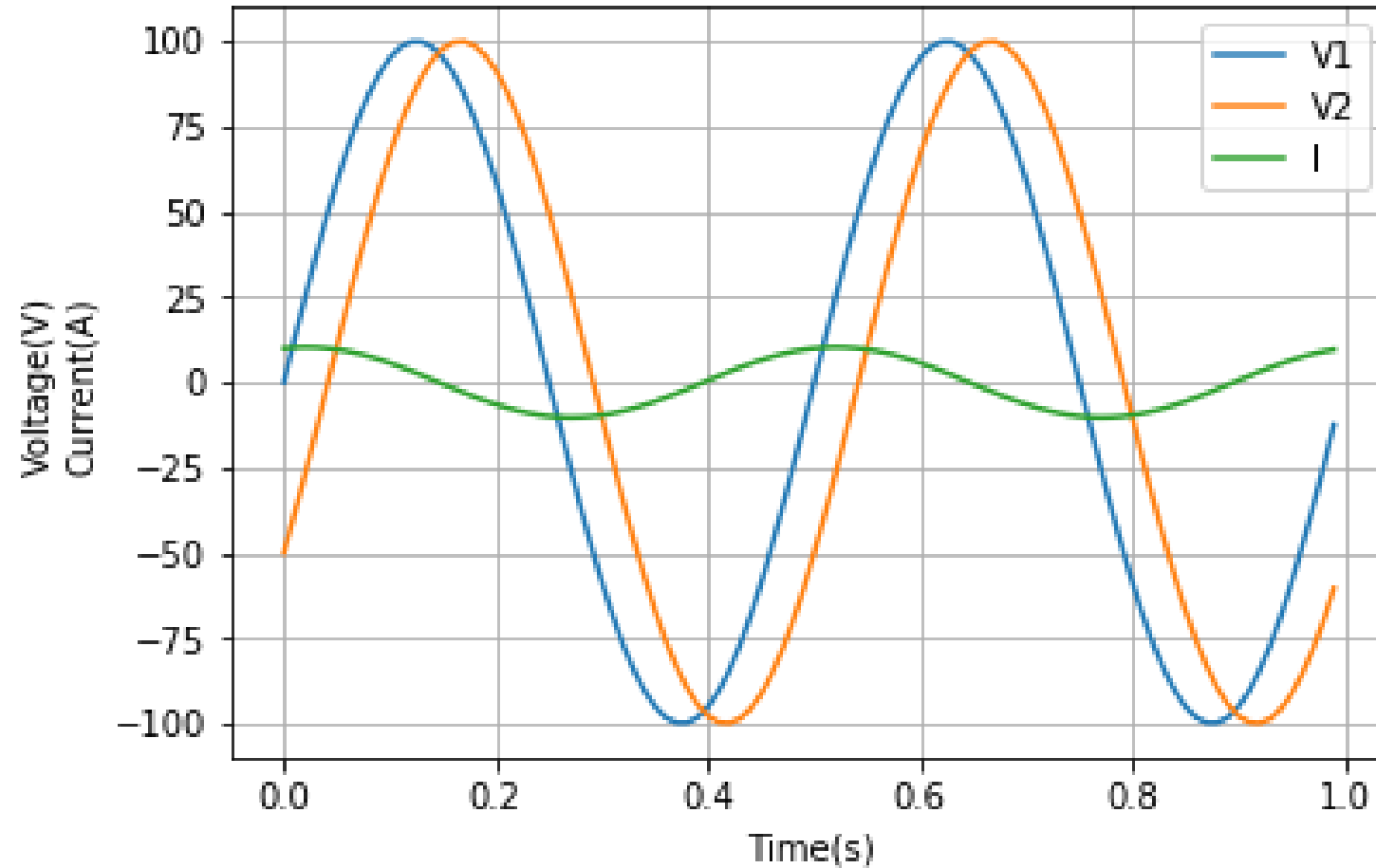
Voltage Difference Through Phase Difference

- Let two voltage signals $V_1(t)$ and $V_2(t)$ with the same amplitude and same frequency but with different initial phase φ_1 and φ_2 respectively.
- Then
- $V_1(t) = V_{max}\sin(2\pi ft + \varphi_1)$ and
- $V_2(t) = V_{max}\sin(2\pi ft + \varphi_2)$
- If $\varphi_1 > \varphi_2$ then V_1 leads V_2
- If $\varphi_1 < \varphi_2$ then V_1 lags V_2

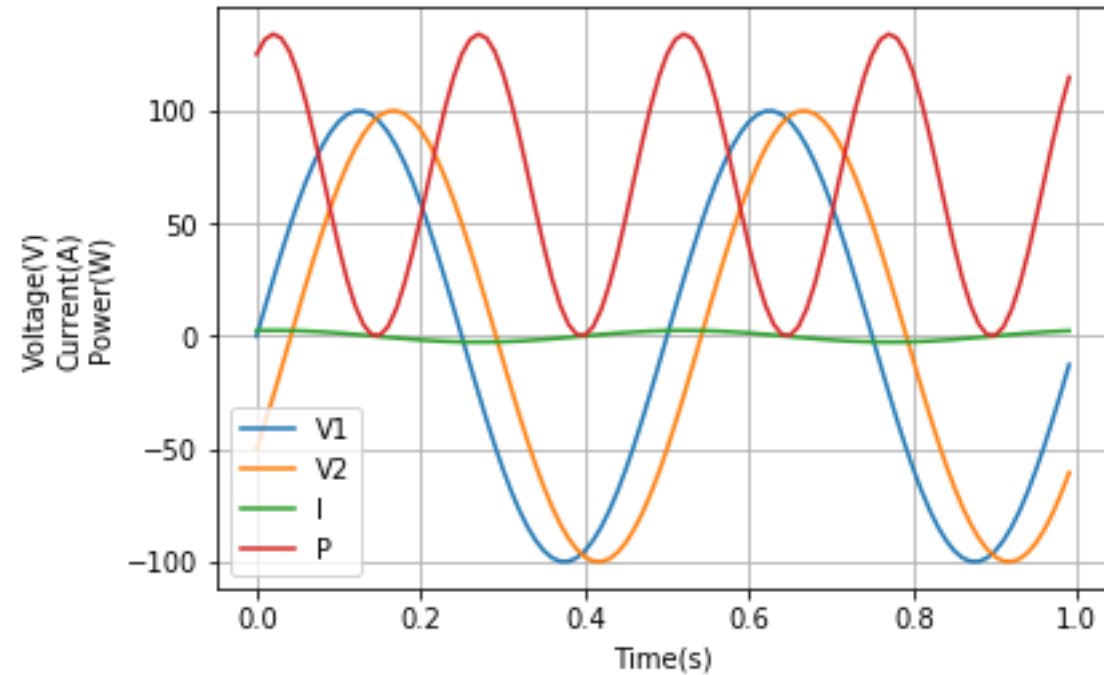
Voltage Difference Through Phase Difference



Current Due to Phase Difference



Power Flow due to Current Flow



THANK YOU!!