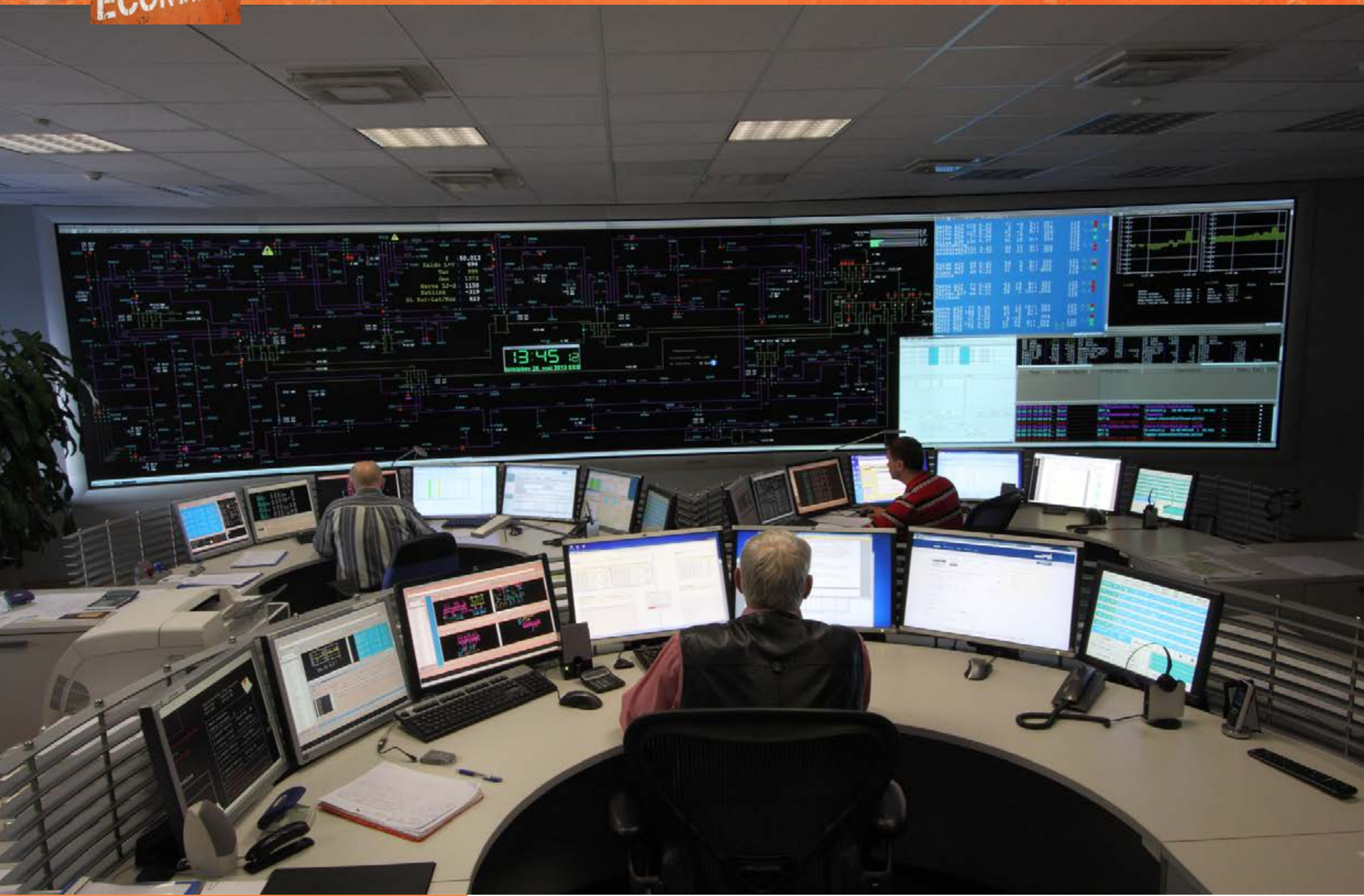
DISPATCH SIMULATOR
FEATURING SMART POWER GENERATION



The purpose of the Dispatch Simulator is to show how a large-scale electricity system is affected by the introduction of considerable amounts of renewable power. Furthermore, the impact of Smart Power Generation on the system is illustrated.

The Dispatch Simulator provides the unique opportunity to try different ways of optimising your power system – either by using only the traditional generation fleet or with the help of Smart Power Generation.

POWER GRID OPERATION

The main purpose of the connected power plants is to generate stable active and reactive power. Grid frequency, which is dependent on the active power balance, is a global variable. The same frequency is seen everywhere in the grid. Voltage, which is dependent on the reactive power balance, is a local variable. The voltage levels in different locations in the grid vary. Managing the grid frequency and voltage are the cornerstones of power system operation and control.

Frequency is managed by bringing on or off generating units, i.e. adjusting the active power, according to the actual demand. In a similar manner, voltage is controlled by adjusting the reactive power of the generators, but unlike active power, reactive power cannot be transmitted over long distances and must hence be generated locally. Power plants with slow dynamics (e.g. nuclear, coal) create the foundation for a stable system, whereas plants with fast dynamics (e.g. gas, hydro) support the system by handling load fluctuations. Therefore, frequency and voltage need to be managed in order to ensure that they are kept within the defined limits. The Dispatch Simulator is limited to considering the frequency balance.

DISPATCH SIMULATOR SET-UP

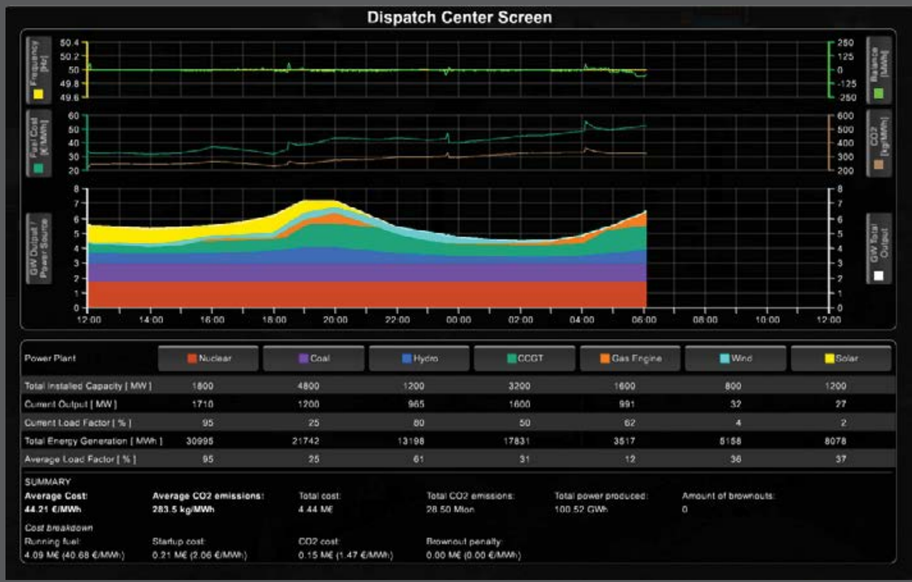
The allocated amount of power used in the Dispatch Simulator is distributed among the different power plant types according to a worldwide average. The used plant characteristics are representative for typical, modern technology. The used load profile is typical for most countries. The total amount of generation capacity in the modelled system is 11 GW, which corresponds to the grid size of e.g. Singapore or New Zealand.

The Dispatch Simulator runs a 24h scenario, during which typical variation in power output from the renewable energy sources (RES) and load swings occur. For example, during any given day, the power demand tends to spike early in the morning, when people wake up and use their appliances to make breakfast and get ready for work. During the middle hours of the day, the load is lower, whereas after office hours are over and people return home, the demand spikes again due to the use of cooking, heating and entertainment electrical equipment. This make the dispatching challenging and requires a flexible and responsive system.

Just as in real life, the nuclear plants are constantly run flat-out to cater for the baseload, whereas the output of the run-of-the-river hydro plants follows the load, maintaining a small reserve capacity in case of unforeseen events. The system automatically strives to operate the coal plants at the highest possible output – their most efficient setting – whereas the gas plants – combined cycle gas turbines (CCGTs) and gas engines – are used for continuously balancing the system.

DISPATCH SIMULATOR OPERATION

Before the simulation is started, you can choose the amount of renewable capacity (wind & solar) and gas engine capacity in the system. These numbers are added to the existing generation capacity. As the simulated day proceeds, the user can make several decisions on how to cope with the fluctuations in load demand and RES generation. For example, you can choose whether to start or stop certain plants; or whether to operate the coal plants in ‘efficiency mode’, i.e. at close to full load, or in ‘spinning mode’, i.e. at a lower load with some reserve capacity available. This will have an impact in the fuel cost and emissions, as well in the “manageability” of your system when it needs to adapt to load changes. For these coal plants, as well as for the CCGT plants, you can decide how many “blocks” are online, manually



WITH SMART POWER GENERATION...

- … the amount of spinning reserve can be substantially reduced when introducing fast-starting stand-by reserves
- … coal & CCGT plants can be utilised more efficiently by running them at a higher load factor
- … the cycling of coal & CCGT plants and the related maintenance costs can be reduced
- … substantial amounts of renewable power can be efficiently integrated in an existing power system
- … sudden variations in output for renewables can be cleverly managed

starting and stopping them according to the system needs.

The simulator will automatically distribute the load between all the "online" blocks housed inside a same plant. Each "block" represents an array of generation units, and they are visible in the main screen in the form of a power bar. When the power bar is green, the block is online, and its load equals the height of the bar. However, when it's yellow, the block is being either started up or cooled down, so it is not dispatchable. Keep in mind that, just like in the real world, they need time to start up and cool down, as well as to accept and reject load. Think one step ahead, or a load swing or lack of renewable capacity may surprise you without enough capacity online!

If gas engine plants are integrated into the grid, the system will gain the capacity of responding to demand variations by immediately starting and stopping these engines in an automated way. Thanks to their superb dynamic capabilities, they can buy time for the dispatcher while the load is adjusted by starting or stopping a bigger generating unit.

SIMULATION OUTCOME

The simulator continuously monitors the active power balance as well as the frequency. Moreover, the fuel cost of produced electricity (€/MWh) and the CO_2 emissions (kg/MWh) are continuously calculated and displayed. Your decisions as a dispatcher will have a great impact on these parameters.

If the demand exceeds the available capacity online, the system will suffer a brownout, i.e. part of the city will be load shed, in order to avoid more harmful issues. Watch out, because this will imply a penalty, plus the sudden load drop may make the frequency rise quickly and will require very careful operation. When sufficient capacity has come online and the system is stable, the load will be reconnected and normality will be regained. If the additional capacity does not come online quickly enough, more load will need to be shed, which will eventually result in a blackout, and hence game is over.

Open the Dispatch Center Screen and check in real time how your power generation portfolio caters to the system load given the generation mix you have decided. You can also see how the starts and stops of the different plants generate additional costs due to maintenance and start-up fuel, plus the costs due to CO_2 emission rights purchase following EU regulation.

Power plant	CCGT	COAL	GAS ENGINE[9]	NUCLEAR[1]	HYDRO	SOLAR[2]	WIND[2]
Capacity/block sizes	4 x 800 MW	4 x 1200 MW	(10-40) x 40 MW	1 x 1800 MW	1 x 1200 MW	1 x (300-1200) MW	1 x (200-800) MW
Fuel	Natural gas	Black coal & Lignite	Natural gas	Uranium	None	None	None
Efficiency at 50% load	44	36	43				
Efficiency at 75% load	50	38	46				
Efficiency at 100% load	56	40	48				
SpinningMode min load (%)	40	40	30				
SpinningMode max load (%)	100	80	100				
EfficiencyMode min load (%)	N/A	80	N/A				
EfficiencyMode max load (%)	N/A	100	N/A				
Start time (min) [WARM][3, 4]	15	60	0.5				
Start time (min) [COLD][3, 4]	60	240	2				
Stop time (min)[5]	30	60	1				
Ramp time at start (min) [WARM][6]	45	60	1.5				
Ramp time at start (min) [COLD][6]	225	300	8				
Ramp time spinning (min)[7]	12	15	1				
Minimum up-time (min)[7]	30	480	5				
Minimum down-time (min)[7]	60	480	0				
Start-up maintenance impact	45€/MW/start	140€/MW/start	0€/MW/start				
Start-up fuel	Gas: 7GJ/MW	LFO: 18GJ/MW[8]	Gas: 0.005GJ/MW				

(1) Nuclear power constantly runs at 100% output and lacks any dynamic capabilities

(2) Solar and wind power are unpredictable and not dispatchable, thus they cannot be started and stopped at will

(3) Time from start-signal to synchronisation

(4) WARM: the block is started within 10h after its previous operation. COLD: the block is started after more than 10h have passed since its previous operation.

(5) Time unloading from 100% load to 0% load.

(6) Time from synchronization to full load (from 10% load to 100% load).

(7) Plant already running at minimum load or above / time from min. load to full output.

(8) LFO used until 25% output is reached

(9) The number of units that start is automatically adjusted to cater for system needs, once coal and CCGT cannot do so.

Fuels	Gas	Coal	Uranium	LFO
Cost €/GJ	12	4	4	20
CO_2 g/MJ	56	104	–	76

THE IMPACT OF SMART POWER GENERATION

As shown by the outcome of the simulation, Smart Power Generation, provided by gas combustion engines, allows the existing power generation fleet to be operated more efficiently and economically. When quick-start-up gas combustion engines fill up the fluctuating net load, coal and CCGT plants can be run flat-out at very high baseload efficiency. SPG allows these plants to run as they were designed for. Consequently, one can choose to optimise the power system with focus on cleaner or on more inexpensive energy, depending on the proportions of the fuels used in the baseload. If CCGT plants, which have low CO_2 emissions but high fuel costs, are used as a larger part of the baseload, gas combustion engines enable very clean energy production. On the other hand, if coal plants fill up most of the baseload with their low fuel costs but high CO_2 emissions, gas combustion engines enable low-cost energy production.

Moreover, a sizeable share of Smart Power Generation will allow you to manage a bigger cost- and emission-free renewable portfolio, without fearing wind and solar unpredictability. In the event of renewable power falter, gas combustion engines can immediately ramp up and take the load, while the rest of the system adjusts to the new climatic conditions. Smart Power Generation has got the dispatcher's back!

GIVE IT A SHOT!

Now you are in position to become a dispatcher for a day and test your power generation portfolio management skills. Try different capacity mixes, with varying amounts of renewable generation, both with and without gas engines into the system. How low can you get the system costs without compromising its integrity?

If affordability, sustainability and reliability are the goals... Smart Power Generation is the answer!

SPG FROM A DISPATCHER'S POINT OF VIEW?

Agility of dispatch:

- Megawatts to grid in 30 sec from start
- 2 minutes to full load from start
- Fast shut down in 1 minute
- Fast ramp rates up & down
- Unrestricted up/down times
- High starting reliability
- Remote operator access including start & stop
- Black start capability

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Available on the App Store

Also available at wartsila.com/en/the-dispatch-simulator

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