TRAINING PROGRAMME WITH SIMULATION FOR CONTROL CENTRES

Aets
apave

Created in 1997 as a subsidiary of the APAVE group, AETS has been providing specialist services to institutional clients (European Commission, Agence Française de Développement, World Bank, among others) and their beneficiaries, as well as to private clients. These services are based on the management of development and cooperation projects, the implementation of European Union and national public policies, or basic infrastructure and production sector projects in a field of intervention that includes:

PERMANENT STAFF	YEARS IN OPERATION	OFFICES	COUNTRIES WORKED IN
70+	23 years	8	150+

AETS is certified ISO 9001 et ISO 14001

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BACKGROUND

To promote operational coordination between Transmission Owning/Operating Members and actual day-to-day information sharing/exchange between Operational Coordination Centre. Capacity building will be extremely important to ensure good coordination, information, skills development and operationalisation of the grid system.

To facilitate efficient trading of power between entities in the different countries that are interconnected in the region.

In order to achieve efficient electricity systems, it is essential to have competent human resources that are in line with the evolution of the electricity industry. In addition, lack of skills is a real issue to address in order to deal with the inadequate human resources that hinder the establishment and smooth running of the regional electricity market. The various recent studies on the situation of human resources in the member utilities have highlighted a number of areas of expertise that need to be strengthened.

For its operationalisation, Control Centres will need experienced and skilled personnel that know the grid system and the operational procedures.

INTRODUCTION

There are a number of vacancies in the operational planning, operation areas and other experienced individuals who perform more complex tasks. The remaining staff are performing very narrow scope of work tasks. Their possibilities of training by simply carrying out their activities as network operators are very limited. Thus, it is imperative that these agents receive additional training and acquire greater practical experience. Concerning the inexperienced staff, it is necessary to get further training and obtain hands on experience.

Many other factors, such as an organisation not in line with operational needs, poor identification of training needs or the lack of a corporate culture on training issues can affect the implementation of good training. It is therefore particularly important to associate participation in training sessions with the establishment of a corporate culture associated with the corresponding good practices. In addition to the organisational factors, there are those relating to the employees' profile. Workforce is made up of a wide range of individuals of different ages, educational level and abilities to learn. Some people are more comfortable with technology than others, while others respond better to visual information rather than written text. Although it is this great diversity which generates the dynamic, creative workforce, it is also this very diversity that makes knowledge transfer such a challenge.

It sounds easy, but knowledge transfer is a complex process especially concerning the transfer of tacit knowledge as opposed to explicit knowledge.. This is why it is essential, from the very beginning of the training sessions, to identify the knowledge that needs to be acquired and to ensure that the timing and content of the courses match everyone. Generally speaking, there is no single type of training, but there is a need to constantly adapt the content and its methodology according to the trainees.

From our experience, we have been focusing on the use of power system simulation tools and practical case studies. Through the sixteen (16) courses proposed, our methodology allows a team work associating concrete case studies and promoting the acquisition of the required skills.

Regarding the management of electrical networks, it is important to position this training in an organisational process allowing all dispatching and planning operators and the staff concerned to:

1. Receive an initial training programme in order to acquire the necessary basic knowledge and skills.
2. Ensure that all operators or dispatchers, managers and support engineers receive this training programme as proposed.
3. That the personnel in charge of defining operational rules and procedures follow this training.
4. That the operational procedures are adapted to the different tools used by dispatchers and engineers (SCADA systems, EMS / MMS functions, network simulator).
5. That dispatchers, managers and support engineers receive comprehensive training on operational procedures.

What does AETS propose?

- The usage of multiple simulators which represent real events management processes, which participants will most probably be facing in real life.
- The simulators will be installed on desktop computers and will be independently running. This will increase the knowledge transfer and the gain of skill for each and every participant.
- Classroom should be limited to 10 participants for better interaction between the instructor and the participants. To promote teamwork and knowledge sharing, it will be recommended to have two participants per laptop.
- The use of the simulators for extended time. This will permit the participants to continue the learning process and automatically gaining skill. AETS can develop custom simulators adapted to customers' grid system.
- To keep at least one selected computer with the simulators installed on it. This will give the chance for the real time personnel to continuously practicing how to solve events. Using specialised simulators prepare the dispatchers to see events as challenging and not overburden. They will know what should be to process in solving issues. This will be creating awareness for the real time personnel. They will see developing pattern from real time, and be better prepared to bring the grid system in safer operating zone.
- The courses presented are part of a Continuing Education Programme. Most of them were approved for training in NERC Continuing Education Programme. Since dispatchers are working on shift, it is proposed to have several sessions for each utility.

Concerning the training:

Profile of the participants: Managers, planning engineers, support engineers and dispatchers or trainers. In order to take full advantage of this training, it is necessary that the participants already have basic knowledge and experience.

The complete training programme consists of sixteen (16) courses. Thirteen (13) courses are considered as the core module, while three (3) others are optional.

Below are the core training modules with the suggested duration for each course :

- Frequency Control (2 days)
- Voltage Control (2 days)
- Scheduling Power Exchanges (2 days)
- Congestion Management (2 days)
- Voltage Stability (2 days)
- Angle Stability (2 days)
- Phase Angle Management (2 days)
- Voltage Collapse (2 days)
- Islanding (2 days)
- Power Oscillation (2 days)
- Restoration (2 days)

The optional modules are listed below:

- Review of fundamentals (1 day)
- Active and reactive power (1 day)
- Geomagnetic disturbances (1 day)

The first two (2) optional modules are dedicated to trainees with limited knowledge of electrical systems or who have just taken up their position.

In addition, AETS can offer :

1. The use of the simulators for an extended period of time after completing the training modules. This will allow participants to continue the learning process and automatically acquire skills.

2. To specifically train future trainers by reinforcing both the content of our training courses and by being able to adapt several of these specialised simulators to meet the other needs of electricians.

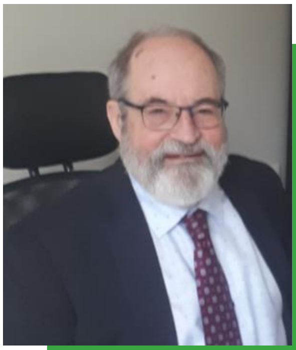
3. To provide a station equipped with all the simulation modules that can be installed in control rooms and centres of expertise. This will allow personnel to train continuously in event resolution. The use of specialized simulators prepares dispatchers to see events as a challenge and not as an overload.

OUR TEAM

Joseph Ordoqui

Joseph Ordoqui (economist, tariffs) is an electrical engineer and energy sector consultant, with expert knowledge in planning and economic and financial studies of production means and networks. Having graduated from Supélec Joseph now possesses over 30 years of experience in the industry, mainly in the area of pre-investment studies for electrical infrastructure projects financed by international institutions. He has provided assistance to numerous governments and electrical companies in the area of energy policies, development of electrical systems and the identification and evaluation of projects.

Marcel Martin



Marcel Martin (trainer, network management specialist) possesses a unique expertise for developing dynamic training simulators. Marcel has developed various real-time electrical network management tools and participated in the development of portable webs used for the management of electrical networks. He worked for large real-time and deferred electrical networks, such as: Hydro Québec 50 GW, Alberta Electric System Operator 10 GW, Midwest ISO 200 GW, Saudi Electric Company 60 GW, TSN (Nigeria) 5 GW, WAPP 15 GW. Marcel is certified as a “Reliability Coordinator” by the North American Electric Reliability Corporation (NERC), the highest level of certification for the management of real-time networks. Additionally, he obtained the certification “NERC Training Provider” for the “Continuing Education” programme. NERC includes more than 1 500 GW of energy production and transmission.

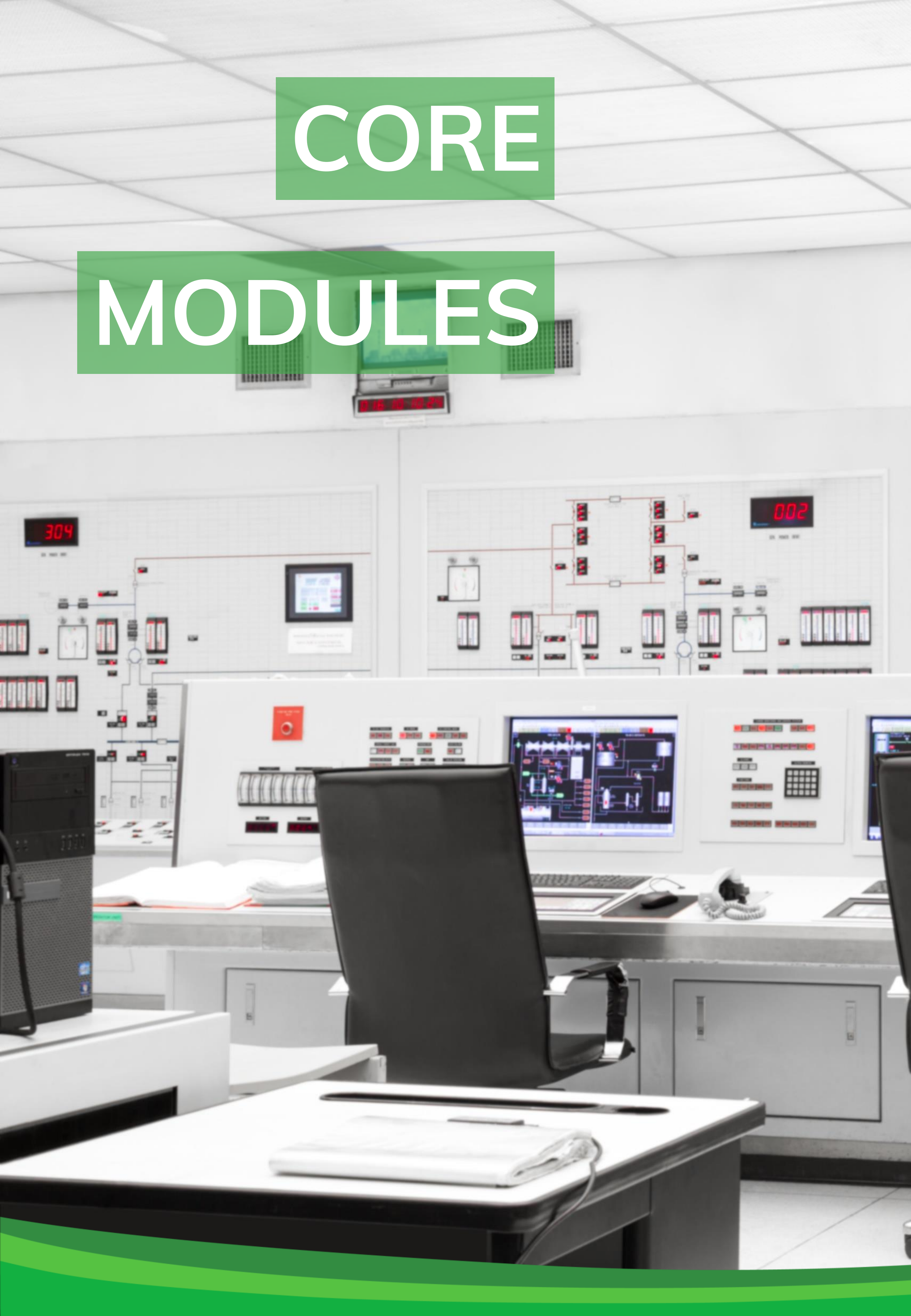
Jérôme Gaonach

Jérôme Gaonach (Smart Grid expert) is an expert consultant in the area of network management systems (SCADA/EMS/DMS) as well as in Smart Grid technologies. With over 25 years of experience as an engineer in the energy sector, Jérôme has worked for some of the largest industrials groups, namely, Schlumberger Industries, AREVA and ALSTOM before turning to the consulting industry. Having graduated from Supélec, he has extensive experience in information technologies and more specifically in solutions that promote the integration of renewable energy in networks.

Jorge Rola

Jorge Rola (Smart Grid expert) is an engineer specialising in Advanced Distribution Management Systems (ADMS) for the management of electrical distribution networks. A graduate from Supélec, Jorge has over 30 years of experience in the area of automation, and the progressive digitisation of alternating and continuous electrical transport and distribution networks, in large companies such as CEGELEC, ALSTOM, AREVA and Schneider Electric. Today, bolstered by this vast experience, he works as a consultants in the area of digital transformation of utilities, which is increasing in response to the major challenge posed by global warming.

CORE MODULES



1. CORE MODULES

1.1 Frequency Control

Content

- Introduction to Frequency Control
- Governor System Components and Operation
- Automatic Generation Control
- Reserve Policies
- Impact of Frequency Deviations
- Underfrequency Protection
- Nature of Frequency Deviation
- Staged Response to a Generation Loss
- Frequency Control
- Role of the System Operators
- Summary of Frequency Control

Learning objectives

- Identify frequency control fundamentals
- Identify system components and operation
- Define automatic generation control
- List the different reserves and their function
- Identify impact of frequency deviations
- Define under-frequency protection
- Explain the droop characteristic of generator units
- Explain the effect of different droop settings on the MW loading of units
- Discuss isochronous droop characteristics
- Describe the MW distribution between two units that have the same droop characteristic and the same capacity, same droop characteristic and different capacities, different droop characteristics and the same capacity, and different droop characteristic and different capacities
- Discuss the MW distribution outcomes between three units that have different droop characteristic and different capacities
- Discuss the MW distribution outcomes between six units that have same droop characteristic and different capacities
- Explain how automatic generation control (AGC) regulates frequency and changes the output of the units under its control
- Explain how automatic generation control (AGC) forces the units not under its control to move back to their previous output while its corrects the frequency

Simulators

- Speed Droop and AGC Simulator
    - Simulate and experience the full frequency deviation with a Woodward governor control Simulate and experience the effect of putting generators same size, same speed droop setting in parallel; generators different size, same speed droop setting in parallel; generators same size, different speed droop setting in parallel; generators different size, different speed droop setting in parallel.
- Transmission Line Relief Simulator for Frequency Control
    - Control the frequency, the generators loading limits and the lines loading limits with the Transmission Line Relief Simulator.
    - Increase the load to the peak of the day (which is close to the maximum of the small system). Correct the frequency using the AGC which is working with regulating reserves (amount limited to the max. output of the specific units). Remove overload on lines by redispatching and reconfiguring the grid system. Remove overload on units letting the units working with their speed droop.

Practical cases

- Nigeria Frequency Control
    - The participants will properly manage the frequency using the simulators with different scenarios. Most of the Nigeria power plants modelled with the number of units as well as their size. Units can be put in / out of service. The MW output can be increased / decreased for each generating unit. Generating units can be place on frequency responsive mode or not. The total load can be increased / decreased.
- Frequency Control on the Interconnected System WAPP
    - Control the frequency, the ACEs and the load flow on an interconnecting simulator from Côte d'Ivoire, Ghana, Togo, Benin, Nigeria and Burkina Faso.

Duration: 2 days

1.2 Voltage Control

Content

- Introduction to Voltage Control
- Causes of Low Voltage
- Causes of High Voltage
- Effects of Low Voltages
- Effects of High Voltages
- Use of Voltage Control Equipment
- Role of the System Operator
- Summary of Voltage Control

Learning objectives

- Identify flow of reactive power
- Define the causes of low voltage
- Define the causes of high voltage
- Identify effects of low voltage
- Identify effects of high voltage
- Define the purpose and operation of voltage control equipment

Simulators

- MVAR Flow
    - This simulator demonstrates what parameters make move the MVAR on a grid system. Show how the MVAR flow can help with the voltage
- LINE LOADING AND VOLTAGE
    - Experience increasing load on a single line but with a generating station compensating for the MVAR flow. Determine the SIL of the line.
- LINE LOADING AND VOLTAGE NO GENERATOR AT THE END
    - Experience increasing load on a single line but with no compensation equipment at the end of the line. Experience the effect of changing the load power factor on the receiving voltage. Determine the MVAR flow direction when increasing the load as well as changing the load power factor.
- Using the Voltage Control Simulators
    - Simulate and experience of operating lines at SIL level, increasing load and controlling the voltage using capacitor bank, decreasing load and controlling the voltage using reactors, changing the power factor and controlling the voltage and using capacitors and / or reactors, Changing the length of the lines and repeating the same simulations.

Simulators

- Unit adjustment for Voltage output
  - The participants have to try increasing a bus voltage using specific generating units' set point. All generating units are set on automatic voltage regulator. The participants will have to do the same exercise but using the global command for the power plant.
- Unit adjustment for Voltage output two plants
  - The participants have to try increasing a bus voltage using specific generating units' set point. All generating units are set on automatic voltage regulator. The participants will have to do the same exercise but using the global command for the power plant but this time on different power plants.
- Effect of Changing LTC
  - The load tap changers are having huge effect on the voltage from the generation up to the load. Determine the main effect of their usage.
- Transformers in parallel with LTC
  - Increase / decrease the loading in this substation while changing the LTC. Experience the effect of having transformers operating in parallel with different LTC set point. Participants can create circulating current between the transformers.
- Loading Transformer with Cap
  - Increase/decrease the transformer loading and determine the MVAR flow direction.
- Voltage capacitors and reactors
  - Correct the voltage in this grid system while increasing the loading and tripping line using shunt equipment. Experience the effect of correcting the power factor on the load flow as well as on the voltage.
- SVC
  - Operate a small grid system taking out an SVC. Operate the same system using the SVC. Determine the effect on the voltage and on the SVC when tripping lines at different loading level.

Duration: 2 days

1.3 Scheduling Power Exchanges

Content

- Introduction to Scheduling of Power Exchanges
- Policy 2 Interchange Scheduling and Accounting Between Control Areal
- Scheduling Power Exchanges and Effects on:
    - The load flow
    - Frequency
    - Generation control
    - ACE management
- Power Products and Scheduling of Power Exchanges
- Inadvertent Description
- Inadvertent Management
- Role of the System Operator
- Summary of Scheduling of Power Exchanges

Learning objectives

- Identify Areas and scheduling
- Define different Power Products
- Categorise highest priorities between Power Products
- Identify the ACE function
- Control the ACE with the scheduling
- Define the purpose and operation of ACE

Simulators

- Using the Scheduling Simulator:
    - Experience basic scheduling between Areas, Experience scheduling several products between Areas Control the ACE while scheduling between Areas,
- Using the Inadvertent simulator:
    - Experience different inadvertent scenarios,
    - Schedule the inadvertent pay back for in peak, out of peak inadvertent, compute total in peak inadvertent, compute total out of peak inadvertent

Practical cases

- WAPP Exchange programme
    - Programme exchanges between the control centres
    - Correct the Area Control Error for each control centre

Duration: 2 days

1.4 Congestion Management

Content

- Introduction to Congestion Management
- TTC – ATC – TRM – CBM
- Procedure
- Interchange Scheduling and Accounting Between Control Areal
- Transmission Line Relief Methods
- Re-dispatching
- Reconfiguration

Learning objectives

- Describe the TTC – ATC – TRM – CBM
- Define the seven steps to apply from the WAPP iRO-006 to solve congestion on the grid system
- Determine the elements that will define the steps to apply to solve congestion on the grid system
- Explain the elements that will end of the Congestion Management
- Describe the system functions and roles of the different participants of a Congestion Management process
- Outline the negative impacts of Congestion Management on the energy markets
- Determine the different relief actions that can be taken to relieve a congestion on the grid system

Simulators

- Minimum Cost Congestion
  - Using this simulator to determine the minimum cost of different scheduling from different power plants
- Phase Shifting Transformers in Paralleled lines
  - Using this simulator define the new maximum TTC available on parallel lines
- Transmission Distribution Factor
  - Using this simulator determine the loading on different lines in a small grid system following diverse configurations. This represent a new method for the real time operation to avoid overloading lines on a grid system.
- Transmission Line Relief Congestion Management
  - With this simulator experience controlling the frequency with a semi-automatic generation control system. Manage overloads on lines as well as on generating units by either reconfiguring the grid system and/or re-dispatching the generation. The passing mark for the participants is to bring the loading to 4 000 MW respecting the base frequency and the lines and generating loading limits.

Duration: 2 days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1.5 Voltage Stability

Content

- Introduction to Voltage Stability
- Types of Voltage Instability
- P – V Curves
- Long Term Voltage Instability
- Classical Voltage Instability
- Short Term or Transient Voltage Instability
- Preventing Voltage Instability
- Role of the System Operator
- Summary of Voltage Instability

Learning objectives

- Define voltage stability vs voltage instability
- Identify the voltage instability types
- Describe how the loss of load diversity affect the voltage stability
- Describe the PV curve and the voltage instability zone
- Describe how adding voltage compensation equipment affect the PV curve and the voltage stability
- Describe the long term voltage instability process
- Describe the role of tap changing equipment on the voltage stability

Simulators

- Reactive Power Flow MVAR
    - This simulator demonstrates what parameters make move the MVAR on a grid system. Shows how the MVAR flow can help with the voltage
- Line Loading and Voltage
    - Experience increasing load on a single line but with a generating station compensating for the MVAR flow. Determine the SIL of the line.
- Line Loading and Voltage no Generator at the end
    - Experience increasing load on a single line but with no compensation equipment at the end of the line. Experience the effect of changing the load power factor on the receiving voltage. Determine the MVAR flow direction when increasing the load as well as changing the load power factor.
- Effect of Changing LTC
    - The load tap changers are having huge effect on the voltage from the generation up to the load. Determine the main effect of their usage.

Simulators

- Loading Transformer with Cap
    - Increase/decrease the transformer loading and determine the MVAR flow direction.
- Transformer in parallel with LTC
    - Increase / decrease the loading in this substation while changing the LTC. Experience the effect of having transformers operating in parallel with different LTC set point. Participants can create circulating current between the transformers.
- Unit adjustment for Voltage output
    - Experience changing the voltage on a bus using the generating voltage regulator on a single generator than with a global MVAR command for the power plant.
- Unit adjustment for Voltage output two plants
    - Experience changing the voltage on a bus using the generating voltage regulator on single generator in different power plants, than with a global MVAR command for the power plants.
- Voltage capacitors and reactors
    - Correct the voltage in this grid system while increasing the loading and tripping line using shunt equipment. Experience the effect of correcting the power factor on the load flow as well as on the voltage.
- Power Voltage P-V Curve
    - In function of voltage compensation shunt equipment determine the maximum MW transfer on this system. Experience the change of the PV curve as compensation is added. At maximum compensation look at the voltage reversal on the PV curve as the MW transfer is increased.
- Static Voltage Compensator SVC
    - Operate a small grid system taking out an SVC. Operate the same system using the SVC. Determine the effect on the voltage and on the SVC when tripping lines at different loading level.

Duration: 2 days

1.6 Angle Stability

Content

- Introduction to Angle Stability
- Definition of Angle Stability
- Active Power and the Power Angle Curve
- Types of Angle Stability
- Steady State Stability/Instability
- Transient Stability/Instability
- Oscillatory Stability/Instability
- Introduction to the Swing Equation
- Synchorphasor Measurements
- Role of the System Operator
- Summary of Angle

Learning objectives

- Define angle stability vs angle instability
- Identify the angle instability types
- Describe how the loss of load diversity affect the voltage stability
- Describe the PV curve and the voltage instability zone
- Describe how adding voltage compensation equipment affect the PV curve and the voltage stability
- Describe the long term voltage instability process
- Describe the role of tap changing equipment on the voltage stability

Simulators

- Active Power Flow MW
    - This simulator demonstrates what parameters make move the MW on a grid system. This is the basic for understanding the power angle.
- Reactive Flow MVAR
    - This simulator demonstrates what parameters make move the MVAR on a grid system. Shows how the MVAR flow can help with the voltage
- Active and Reactive Power Flow MW and MVAR
    - This simulator aggregates the two other simulators and explain how, on a grid system, the MW can flow in one direction and at the same time on the same line the MVAR can flow in the opposite direction.
- Angle Swing Demo
    - The participants will experience angle swing on the grid system when power angles change and/or there is small or large power fluctuation on the grid system.

Simulators

- Load Angle Stability
    - This simulator uses the equal criterion to establish the stability of a small grid system. The users will increase / decrease the load and check the effect on the loading of the lines, the effect on the voltage. Each time there will be a voltage alarm, the participant will have to correct the voltage at the right level. The most important to check will be on the actual power curve, the effect on the actual curve as well as the curve showing the next contingency power curve. The accelerating / decelerating areas will be automatically calculated. The most important effect will be while tripping lines. The participants will be able to change the operating voltage level by selecting the correct button. The effect on the power curves and the areas will be automatically shown.

Duration: 2 days

1.7 Series Compensation

Content

- Introduction to Series Compensation
- Percentage of Series Compensation
- Series of Compensation Types
- Sub-synchronous Interactions (SSI) - Terms
- SSI Protection Measures
- Protective Relay Considerations for Series Compensated Liles
- Stability and Series Compensation
- Summary of Series Compensation

Learning objectives

- Describe series compensation method
- Define the percentage of series compensation
- Describe the advantages of series compensation
- Describe the disadvantages of series compensation
- Describe the sub-synchronous resonance (SSR) problems with the series capacitors
- Describe the methods to prevent SSR
- Describe the operation of the series capacitors banks

Simulators

- Active Power Flow MW
  - This simulator demonstrates what parameters make move the MW on a grid system. This is the basic for understanding the power angle.
- Reactive Power Flow MVAR
  - This simulator demonstrates what parameters make move the MVAR on a grid system. Shows how the MVAR flow can help with the voltage
- Active and Reactive Power Flow MW and MVAR
  - This simulator aggregates the two other simulators and explain how, on a grid system, the MW can flow in one direction and at the same time on the same line the MVAR can flow in the opposite direction.
- Building Power Curve
  - Build a power curve from 0 degree up to 180 degrees. Experience with different maximum MW power flow, from 1 000 MW up to 10 000 MW
- Building a Power Curve with voltages control
  - Experience building power curves changing the power angle and also changing the sending and receiving voltages. The participants discover the effect of the power angle and the effect of the voltages on the power to transmit

Simulators

- Curve Series V Control
    - Experience building power curves changing the power angle and also changing the sending and receiving voltages. The participants discover the effect of the power angle and the effect of the voltages on the power to transmit. The participants will also discover the effect of adding series compensation on the power curve. Participants will also vary the percentage of series compensation to add affecting the power curve.
- Series Compensation Simulator V4
    - The participants will be able to experience the series compensation on a small grid system. The participants will be able to increase the load, select the percentage of series compensation up to 50% compensation, trip lines, add or remove series compensation on specific lines and observe the results on power curves.

Practical cases

- WAPP Frequency Control With Power Angle
    - This simulator is a representation of the interconnections between Cote d'Ivoire, Ghana, Togo, Benin, Nigeria and Burkina Faso on which a serial compensation has been added to several 225 KV lines. Participants can increase the loading for several substations. They can control the generation at several power plants. Participants can trip lines and see the effect on the power curves of the remaining lines in service. The power angles are calculated for each line. Line protection prevent the reclosing of lines with a power angle greater than 20 degrees. Participants will have to manage the power angles to bring the power angles below 20 degrees, without shedding load.

Duration: 2 days

1.8 Power System Protection

Content

- Introduction to Power System Protection
- Line protection
- Pilot protection
- System protection
- Bus differential
- Voltage protection
- Zones protection
- Backup protection
- Generation protection
- Summary of Power System Restoration

Learning objectives

- Describe the principals causes of system disturbances
- Describe the lines protection
- Describe the pilot protection
- Describe the voltage protection
- Explain the zones protection
- Describe the needs for backup protection
- Describe the generation protection

Simulators

- Backup Protection Simulator
  - Using the backup protection simulator the participants will be able to experience how this kind of protection can save from cascading effect.
- Bus differential Protection Simulator
  - Using the bus differential protection simulator the participants will be able to experience how this protection can save the grid system.
- Transformer differential Protection Simulator
  - Using the transformer differential protection simulator the participants will be able to experience how this protection can protect this very expensive equipment from further damages.
- Voltage Protection Simulator
  - Using the voltage protection simulator the participants will be able to experience how this protection can save the system as well as equipment from damaging due to high voltage excursions.

Simulators

- Zones Protection
  - Using the zones protection simulator the participants will be able to experience how the zone protection is setup and operating on the grid system.
- Distance Relay Scheme Simulator
  - Using the distance relay scheme simulator the participants will experience how this protection is setup and can save the grid system from cascading.

Duration: 1 day

1.9 Power Angle Management

Content

- Introduction to Power Angle Management
- Phase Angle, Power Angle, and Torque Angle
- Power Angle Equation
- Power Angle in a Phase Shifting Transformer
- Management of Power Angle Methods
- Summary of Power Angle Management

Learning objectives

- Differentiate between phase angle voltage-current and phase angle voltage-voltage
- Define phase angle, power angle, torque angle
- Calculate maximum transfer capability for different line voltages
- Calculate maximum transfer capability for different line impedances
- Calculate real power transfer following the phase angle equation

Simulators

- Active Power Flow MW
  - This simulator demonstrates what parameters make move the MW on a grid system. This is the basic for understanding the power angle.
- Reactive Power Flow MVAR
  - This simulator demonstrates what parameters make move the MVAR on a grid system.
- Active and Reactive Power Flow MW MVAR
  - This simulator aggregates the two other simulators and explain how, on a grid system, the MW can flow in one direction and at the same time on the same line the MVAR can flow in the opposite direction.
- Angle Show Demo
  - Showing the magnetic field on a line, this simulator permit increasing the loading on the line and the change in the power angle between the sending end voltage and receiving end voltage.
- Building a Power Curve
  - Build a power curve from 0 degree up to 180 degrees. Experience with different maximum MW power flow, from 1 000 MW up to 10 000 MW.
- Building a Power Curve with voltages control
  - Experience building power curves changing the power angle and also changing the sending and receiving voltages. The participants discover the effect of the power angle and the effect of the voltages on the power to transmit.

Simulators

- Angle Swing Demo
    - The participants will experience angle swing on the grid system when power angles change and/or there is small or large power fluctuation on the grid system.
- Load Angle 5 Lines
    - With this simulator the participants will be able to experience the change of power angle and the load flow on a small 5 lines grid system. Also with this simulator the participants will practice tripping of lines and the effect on the load flow as well as on the power angle.
- Load Angle 10 lines LF
    - The participants will be able to change the voltage levels, the power transfer, and the voltage at the sending end, the voltage at the sending end, the number of lines in service, and the load power factor. The participants will realise the effects of changing any of these elements on the power angles as well as on the receiving end voltage.
- Phase Shifting Transformer
    - Two lines in parallel one line very limited so total transfer limited as well, adding a phase shifting transformer on the limited line, can and increase significantly the total transfer limit, controlling the power angle.

Duration: 2 days

1.10 Voltage Collapse

Content

- Introduction to Voltage Collapse
- Voltage Collapse and Loss of Synchronism
- Example of Classical Voltage Collapse
- Example of Transient Voltage Collapse
- Self-Defeating Effects of Transformers on Load Tap Changers
- Protection related to Voltage Collapse
- Summary of Voltage Collapse

Learning objectives

- Describe how to control power grid loading to avoid voltage collapse
- Discuss the affects reactive support and capacitors have on over and under voltage conditions
- Explain how controlling the reactive output from generators have on system voltage conditions
- Control the transfer of power between two electric systems while maintaining proper voltage levels
- Demonstrate the effects of voltage load shedding on voltage collapse scenarios
- Explain how distributed voltage control can improve system performance
- Explain the self-defeating effect of the LTC during a voltage collapse
- Create overload conditions and analyse voltage conditions for a better understanding of the phenomena
- Create multiple contingencies and analyse combined effects
- Optimise system loading constraints while maintaining good System Operating Limits (SOL) margins

Simulators

- MW Flow
    - This simulator demonstrates what parameters make move the MW on a grid system. This is the basic for understanding the power angle.
- MVAR Flow
    - This simulator demonstrates what parameters make move the MVAR on a grid system. Shows how the MVAR flow can help with the voltage
- MW and MVAR Flow
    - This simulator aggregates the two other simulators and explain how, on a grid system, the MW can flow in one direction and at the same time on the same line the MVAR can flow in the opposite direction.

Simulators

- Angle Swing Demo
  - The participants will experience angle swing on the grid system when power angles change and/or there is small or large power fluctuation on the grid system.
- Voltage Collapse simulator
  - This Simulator is dynamic and the participants have the possibility to check the effect of load changes, MVAR addition, LTC, lines outages and many other features on the voltage control, the grid stability and even going to a voltage collapse. All the results can be seen instantaneously on a single display
  - The participants will be able to change the power factor, to increase the output of costly units and to switch the Under Voltage Load Shedding “On” and “Off” to check the effect of this protection on the stability and the voltage of the grid system.

Duration: 2 days

1.11 Islanding

Content

- Introduction to Islanding
- Islanding Detection
- Governor Control in an Islanded Power System
- Islanded Systems and Frequency Control
- Connecting Islands
- Guidelines for Synchronising Islanded Systems
- Useful Forms and Information for Synchronising Islanded Systems
- Summary of Islanding

Learning objectives

- Describe how to control power grid loading to avoid voltage collapse
- Discuss the affects reactive support and capacitors have on over and under voltage conditions
- Explain how controlling the reactive output from generators have on system voltage conditions
- Control the transfer of power between two electric systems while maintaining proper voltage levels
- Demonstrate the effects of voltage load shedding on voltage collapse scenarios
- Explain how distributed voltage control can improve system performance
- Explain the self-defeating effect of the LTC during a voltage collapse
- Create overload conditions and analyse voltage conditions for a better understanding of the phenomena
- Create multiple contingencies and analyse combined effects
- Optimise system loading constraints while maintaining good System Operating Limits (SOL) margins

Simulators

- Active Power Flow MW
    - This simulator demonstrates what parameters make move the MW on a grid system. This is the basic for understanding the power angle.
- Reactive Power Flow MVAR
    - This simulator demonstrates what parameters make move the MVAR on a grid system. Shows how the MVAR flow can help with the voltage

Simulators

- Active and Reactive Power Flow MW and MVAR
  - This simulator aggregates the two other simulators and explain how, on a grid system, the MW can flow in one direction and at the same time on the same line the MVAR can flow in the opposite direction.
- Speed Droop and AGC simulator
  - Simulate and experience the effect of putting generators same size, same speed droop setting in parallel; generators different size, same speed droop setting in parallel; generators same size, different speed droop setting in parallel; generators different size, different speed droop setting in parallel.
- Transmission Line Relief 4000 Level Simulator
  - Control the frequency, the generators loading limits and the lines loading limits with the Transmission Line Relief Simulator.
  - Control the frequency, the ACEs and the load flow on an interconnecting simulator from Côte d'Ivoire, Ghana, Togo, Benin, Nigeria and Burkina Faso.
- Islanding Simulator

Practical cases

- Experiment Islanding with Grid Different Capacity
  - WAPP Islanding Nigeria
  - WAPP Islanding Burkina Faso (Tamale)
  - WAPP Islanding Burkina Faso (Bogatanga)

Duration: 2 days

1.12 Power Oscillations

Content

- Introduction to Power Oscillations
- Natural Frequency Oscillations
- Oscillations and Excitation Systems
- Additional Causes of Oscillations
- Role of the System Operator
- Summary of Power Oscillations

Learning objectives

- Describe typical oscillation frequencies
- Define oscillations on a grid system
- Describe the oscillation classifications
- Compare power, speed and angle
- Describe the operation of an excitation system and oscillatory stability
- Describe the power system stabilisers and the oscillatory stability

Simulators

- Active Power Flow MW
    - This simulator demonstrates what parameters make move the MW on a grid system. This is the basic for understanding the power angle.
- Reactive Power Flow MVAR
    - This simulator demonstrates what parameters make move the MVAR on a grid system. Shows how the MVAR flow can help with the voltage
- Active and Reactive Power Flow MW and MVAR
    - This simulator aggregates the two other simulators and explain how, on a grid system, the MW can flow in one direction and at the same time on the same line the MVAR can flow in the opposite direction.
- Building Power Curve
    - Build a power curve from 0 degree up to 180 degrees. Experience with different maximum MW power flow, from 1 000 MW up to 10 000 MW.
- Angle Swing Demo
    - The participants will experience angle swing on the grid system when power angles change and/or there is small or large power fluctuation on the grid system.

Practical cases

- WAPP - Frequency and Angular Deviation Control
    - This simulator is a representation of the interconnections between Côte d'Ivoire, Ghana, Togo, Benin, Nigeria, and Burkina Faso. The power curves are presented for each line connecting these countries. Participants can increase the load of several substations. They can control the production of several power plants. Participants can open lines and see the effect on the power curves of the remaining lines in service. Power angles are calculated for each line. Line protection prevents reclosing with a power angle greater than 20 degrees. Participants will have to manage the power angles to bring the power angles below 20 degrees, without loss of load.

Duration: 2 days

1.13 Power System Restoration

Content

- Introduction to Power System Restoration
- Voltage Control and System Restoration
- Frequency Control and System Restoration
- Equipment Issues Related to System Restoration
- Protective Relay Issues Related to System Restoration
- Synchronising and System Restoration
- Summary of Power System Restoration

Learning objectives

- Describe the principals causes of system disturbances
- Define the restoration condition
- Describe the steps to respect in restoration planning
- Describe the voltage related to restoration theory
- Explain why operating the system at reduced voltage in restoration process
- Describe the frequency control in restoration conditions
- Describe the usage of governors to control the frequency in a restoration process

Simulators

- Speed droop and AGC Simulator
    - Using the Speed Droop and AGC Simulator simulate and experience the full frequency deviation with a Woodward governor control
    - Simulate and experience the effect of putting generators same size, same speed droop setting in parallel; generators different size, same speed droop setting in parallel; generators same size, different speed droop setting in parallel; generators different size, different speed droop setting in parallel.
- Restoration Simulator Manual
    - A small system is in black out situation. Restore the system using an isochronous black start unit. This black start unit has a minimum loading of 20 MW and a maximum loading of 100 MW. There is a maximum one minute time delay to load up this unit to 20 MW. There are 6 others coal units to start up with different minimum loading. Before getting those at minimum loading motors have to be started at each plant. More time taken to start up all the motors more waiting time before getting the units to produce MW. Loads with cold load pick up have to be restored as well. The simulator is watching you. If you exceed the loading limits and / or the frequency you will have to face the consequences of your actions.

Duration: 2 days

OPTIONAL MODULES

2. COURS OPTIONNELS

2.1 Fundamentals Review

Content

- Introduction to Fundamentals Review
- Mathematics Review
- DC Electricity Review
- AC Electricity Review
- Protective Relaying Review
- Power System Equipment Review
- Power System Operations
- Simulators

Duration: 1 day

2.2 Active and Reactive Power

Content

- Introduction to Active and Reactive Power
- Review of Active and Reactive Power
- Equations for Power Transfer
- Graphical Tools for Power Transfer
- Power Transfer Limits
- Summary of Active and Reactive Power
- Power Point Presentation
- Simulators

Duration: 1 day

2.3 Geomagnetic Disturbances

Content

- Introduction to Geomagnetic Disturbances
- Sunspots
- The Solar Sind
- Factors that Influence the Impact of GMDs
- Impact of GMDs
- Controlling the Impact of GMDs
- Hydro Quebec GMD Incident
- Role of the System Operator
- Summary of Geomagnetic Disturbances

Learning objectives

- Describe a geomagnetic disturbance
- Define what are sunspots
- Describe the effects of geomagnetic disturbances on the grid system
- Describe how to detect geomagnetic disturbances
- Describe how to protect from geomagnetic disturbances

Duration: 1 day

PRICE - TRAINING

Title of the training	Nber of days	Date of the session	Nber of trainees	Place	Price without added tax for the whole group of trainees (Euros)
Core Courses					
Frequency Control	2 days	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	6 400€
Voltage Control	2 days	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	6 400€
Scheduling Power Exchanges	2 days	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	6 400€
Congestion Management	2 days	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	6 400€
Voltage Stability	2 days	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	6 400€
Angle Stability	2 days	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	6 400€
Power Angle Management	2 days	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	6 400€
Voltage Collapse	2 days	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	6 400€
Islanding	2 days	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	6 400€
Power Oscillations	2 days	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	6 400€
Power System Restoration	2 days	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	6 400€
Series Compensation	2 days	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	6 400€
Power System Protection	1 day	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	3 200€
Optional Courses					
Geomagnetic Review	1 day	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	3 200€
Fundamentals Review	1 day	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	3 200€
Active et Reactive Power	1 day	Contact us	5 to 8	Paris or Pau (for other places, please contact us)	3 200€

Specific conditions of sale

1. Training Location

The trainings can be organized either in the AETS premises in Pau or in Paris.

For other places, consult us.

2. Number of trainees

The maximum number of trainees per course is eight (8).

3. The price includes

- The realization of the training;
- The provision during training of a laptop computer equipped with simulation software;
- One (1) paper and electronic copy of course materials;
- One (1) paper and electronic copy of the simulation workbook;
- Coffee breaks and lunches during the training sessions.

General terms and Conditions of sale

1. Definition

Contract: a professional training agreement between AETS and the Client. This agreement may take the form of a contract in due form, a purchase order issued by the Client and validated by AETS or an invoice issued for the implementation of vocational training actions.

2. Object and scope of application

Any Contract implies the Customer's unreserved acceptance and full and complete adherence to these General Terms and Conditions, which prevail over any other document of the Customer, and in particular over any general terms and conditions of purchase.

No derogation from these General Conditions shall be enforceable against AETS unless it has been expressly accepted in writing by the latter.

3. Contractual documents

The Contract will specify the title of the training, its number of participants, the location, the terms and conditions of its implementation and its price.

4. Postponement/cancellation of a training course by AETS

AETS reserves the right to cancel or postpone planned training courses without compensation, provided AETS should inform the Client with reasonable notice.

5. 5. Cancellation of a training course by the Client

Any training or course started is due in full, unless otherwise expressly agreed by AETS.

Any cancellation of a training course at the Client's initiative must be communicated in writing at least fifteen (15) calendar days before the start of the course. Failing this, 100% of the amount of the training shall remain immediately payable by way of lump sum compensation.

6. Replacement of a participant

Regardless of the type of training, upon written request prior to the start of the training, the Client has the possibility to replace a participant without additional billing.

7. Dematerialization of media

As part of an environmental commitment, all documentation relating to training is delivered on dematerialized media.

8. **Prices and regulations**

The prices are indicated in the catalogue.

Lunches and coffee breaks (except Saturday and Sunday) are included in the price of the training courses. They will not be charged extra.

A minimum deposit of 30% must be paid by the Client at the conclusion of the Contract, the balance will be paid after completion of the training.

All prices are indicated in euros and exclude taxes. They are to be increased by VAT at the rate in force on the day of issue of the corresponding invoice.

Invoices shall be payable thirty (30) calendar days from the date of issue of the invoice, without discount and to the order of AETS.

Any amount not paid on the due date shall give rise to the payment by the Customer of late payment penalties equal to the interest rate applied by the European Central Bank to its most recent refinancing operation (minimum 0%) plus 10 percentage points.

These penalties shall be payable by operation of law, without prior notice of default, from the first day on which payment is late in relation to the due date for payment.

In addition, in accordance with the legal and regulatory provisions in force, any sum not paid on the due date shall give rise to the payment by the Customer of a flat-rate indemnity for collection costs in the amount of forty euros (€40). This indemnity shall be due automatically, without prior formal notice, from the first day of late payment and for each invoice not paid by the due date.

9. Obligations and Liability of AETS

AETS is committed to providing training with reasonable care and diligence. As this is an intellectual service, AETS is only bound by an obligation of means.

Accordingly, AETS shall only be liable for direct damages resulting from the improper performance of its training services, to the exclusion of any consequential or incidental damages, consequential or otherwise.

In any event, AETS' overall liability, in respect of or in connection with the training, shall be limited to the total price of the training.

10. Obligations of the Client

The Customer undertakes to :

- Pay the price of the training;
- Not to make any reproduction of material or documents whose copyright belongs to AETS, without the prior written consent of AETS; and
- Do not use audio or video recording equipment during training sessions without the prior written consent of AETS.

11. Confidentiality and Intellectual Property

It is expressly agreed that any information disclosed by AETS under or in connection with the training shall be treated as confidential (hereinafter "Information") and may not be disclosed to third parties or used for a purpose other than that of the training without the prior written consent of AETS. AETS shall have the exclusive right of ownership of all Information disclosed by AETS, regardless of the nature, medium and method of communication, in or in connection with the Training, and AETS shall have the exclusive right of ownership of such Information. Accordingly, the Customer undertakes to keep the Information in a safe place and to provide at least the same protection measures as it usually applies to its own information. The Client shall be responsible for the respect of these confidentiality and retention provisions by the Learners.

The disclosure of Information by AETS shall in no way be construed as conferring any express or implied right (whether by license or otherwise) to the Information or any other rights in relation to intellectual and industrial property, copyright, trademarks or trade secrets. The payment of the price does not transfer any intellectual property right in the Information.
By way of exception, AETS grants the learner, subject to the rights of third parties, a non-exclusive, non-transferable and strictly personal license to use the training material provided, whatever the medium. The learner has the right to make a photocopy of this material for his/her personal use for study purposes, provided that the AETS copyright notice or any other intellectual property notice is reproduced

on each copy of the training material. The learner and the Client shall not be entitled to do so without the prior consent of AETS:

-To use, copy, modify, create a derivative work and/or distribute the training material except as provided for in these Terms and Conditions;
-To disassemble, decompile and/or translate the training material, unless otherwise provided by law and without the possibility of contractual renunciation;
To sub-license, rent and/or lend the training material;
-To use the associated material for purposes other than training.

12. Protection of personal data

AETS collects personal data in the context of training courses.
Data subjects have a right of access, rectification, deletion, limitation, portability, and attachment of their personal data and may at any time revoke their consent to the processing. In accordance with the essential requirement of security of personal data, AETS undertakes, in the context of the execution of its training courses, to take all useful technical and organizational measures in order to preserve the security and confidentiality of personal data and in particular to prevent them from being distorted, damaged, lost, misappropriated, corrupted, disclosed, transmitted and/or communicated to unauthorized persons. Therefore, AETS undertakes to:

-Process personal data only for the strict necessity of the training courses;
-Conserve personal data for three (3) years or longer to comply with legal obligations, resolve any disputes and enforce contractual commitments ;

13. Communication

The Client expressly authorizes AETS to mention its name, logo and to mention as references the conclusion of an Agreement and any operation resulting from its application in all their commercial documents.

14. Applicable law and jurisdiction
The Agreement and all relations between AETS and its Client shall be governed by French Law. Any dispute that cannot be settled amicably within sixty (60) days from the date of the first presentation of the registered letter with acknowledgement of receipt, which the party raising the dispute must have sent to the other, shall be the exclusive jurisdiction of the Commercial Court of Pau, regardless of the location of the Client, notwithstanding multiple defendants or appeal in warranty.

PRICE - TRAINING ONLINE

Title of the training	Nber of days	Date of the session	Nber of trainees	Place	Price without added tax per trainee (Euros)
Courses					
Frequency Control	2 days	Contact us	6 to 10	Online training	500 €
Voltage Control	2 days	Contact us	6 to 10	Online training	500 €
Scheduling Power Exchanges	2 days	Contact us	6 to 10	Online training	500 €
Congestion Management	2 days	Contact us	6 to 10	Online training	500 €
Voltage Stability	2 days	Contact us	6 to 10	Online training	500 €
Angle Stability	2 days	Contact us	6 to 10	Online training	500 €
Power Angle Management	2 days	Contact us	6 to 10	Online training	500 €
Voltage Collapse	2 days	Contact us	6 to 10	Online training	500 €
Islanding	2 days	Contact us	6 to 10	Online training	500 €
Power Oscillations	2 days	Contact us	6 to 10	Online training	500 €
Power System Restoration	2 days	Contact us	6 to 10	Online training	500 €
Series Compensation	2 days	Contact us	6 to 10	Online training	500 €
Power System Protection	1 day	Contact us	6 to 10	Online training	250 €
Optional Courses					
Geomagnetic Review	1 day	Contact us	6 to 10	Online training	250 €
Fundamentals Review	1 day	Contact us	6 to 10	Online training	250 €
Active et Reactive Power	1 day	Contact us	6 to 10	Online training	250 €

Special conditions of sale

1. Location of training courses

The training is carried out remotely with the use of dedicated tools such as Zoom (or equivalent).

The trainees will have to have a remote connection of internet type.

2. Number of trainees

The number of trainees is between six (6) and ten (10). For more information, please contact us.

3. The price includes

- Carrying out distance learning (using the Zoom tool or equivalent)
- The provision of simulator software licenses during training. The licenses will be installed on the trainees' computers by the trainees themselves.
- Remote support for the installation of simulator software licenses and access to online documentation.
- One (1) electronic copy of the course materials.
- One (1) electronic copy of the simulation workbook.

General terms and Conditions of sale

1. Definition

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2. Object and scope of application

Any Contract implies the Customer's unreserved acceptance and full and complete adherence to these General Terms and Conditions, which prevail over any other document of the Customer, and in particular over any general terms and conditions of purchase.

No derogation from these General Conditions shall be enforceable against AETS unless it has been expressly accepted in writing by the latter.

3. Contractual documents

The Contract will specify the title of the training, its number of participants, the location, the terms and conditions of its implementation and its price.

4. Postponement/cancellation of a training course by AETS

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Any cancellation of a training course at the Client's initiative must be communicated in writing at least fifteen (15) calendar days before the start of the course. Failing this, 100% of the amount of the training shall remain immediately payable by way of lump sum compensation.

6. Replacement of a participant

Regardless of the type of training, upon written request prior to the start of the training, the Client has the possibility to replace a participant without additional billing.

7. Dematerialization of media

As part of an environmental commitment, all documentation relating to training is delivered on dematerialized media.

8. **Prices and regulations**

The prices are indicated in the catalogue.

A minimum deposit of 30% must be paid by the Client at the conclusion of the Contract, the balance will be paid after completion of the training.

All prices are indicated in euros and exclude taxes. They are to be increased by VAT at the rate in force on the day of issue of the corresponding invoice.

Invoices shall be payable thirty (30) calendar days from the date of issue of the invoice, without discount and to the order of AETS.

Any amount not paid on the due date shall give rise to the payment by the Customer of late payment penalties equal to the interest rate applied by the European Central Bank to its most recent refinancing operation (minimum 0%) plus 10 percentage points.

These penalties shall be payable by operation of law, without prior notice of default, from the first day on which payment is late in relation to the due date for payment.

In addition, in accordance with the legal and regulatory provisions in force, any sum not paid on the due date shall give rise to the payment by the Customer of a flat-rate indemnity for collection costs in the amount of forty euros (€40). This indemnity shall be due automatically, without prior formal notice, from the first day of late payment and for each invoice not paid by the due date.

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The disclosure of Information by AETS shall in no way be construed as conferring any express or implied right (whether by licence or otherwise) to the Information or any other rights in relation to intellectual and industrial property, copyright, trade marks or trade secrets. The payment of the price does not transfer any intellectual property right in the Information.
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Risk Management Institutional Strengthening Sustainable Development	Gestion des Risques Renforcement Institutionnel Développement Durable

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