Lecture 5
Project Description:
Scenario Risk Estimation for Power Systems

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Learning objectives

- *“Design a workflow on an energy systems example”*
  - *Data pre-processing, standardization, normalization.*
  - *Feature selection*
  - *Model selection and training*

- *“Use scikit-learn package in Python”*
  - *Tools to create and test Python code*
  - *Concepts of packages, modules, import functions, etc.*
  - *Python data structures*

Outline

1. Project objective
2. Problem, data and tasks definition
3. Conditions
4. Evaluation criteria
5. Q&A
6. Project working session (with feedback)

1. Project objective

Objective

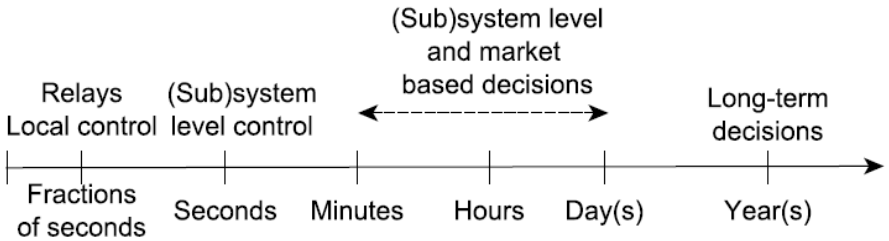
- Design a ML workflow that allow estimating a power system risk index and define its operational state.

- Put into practice all the learning concepts introduced so far (Lectures 1 to 4), including, for instance:
  - How to deal with real world power system data and challenges (w.r.t. data and models)?
  - How to design supervised, unsupervised and/or semi-supervise models? Which model suits my data the best?
  - How to design the ML workflow? Which stages may I disregard (if any)?Why?

2. Problem, data and tasks description

Problem definition

- Power system operational risk can be investigated in different time frames: from near real-time operation to long-term planning (+5 years).



- Evaluating operational risk is getting more complex: uncertainty, less inertia, large number of possible scenarios.

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Problem definition

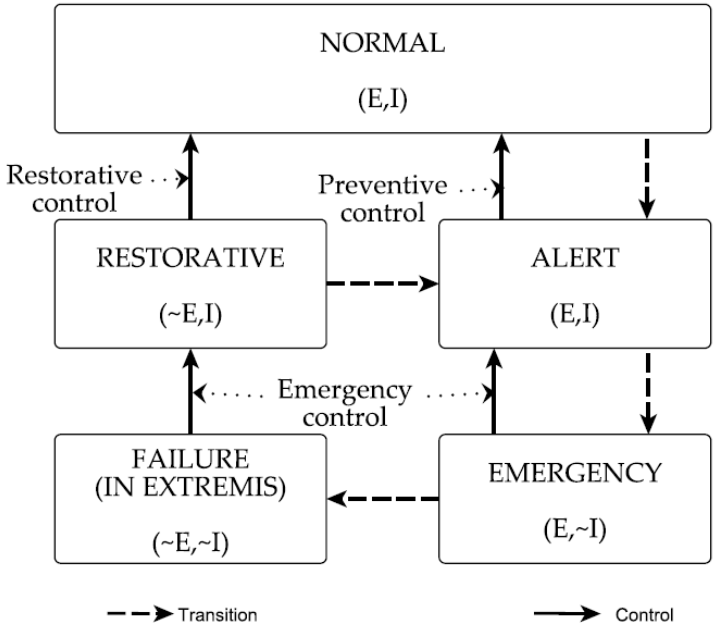
- Operators can perform dynamic simulations with predefined contingency sets to estimate the system's strength.

- Study is done based on power flow analysis: voltage magnitude, active and reactive power flows, angles.

Problem definition

- Power system stability: Rotor angle stability, frequency stability and voltage stability, which can be further classified as small or large disturbance.

- We can translates the operating scenario using a risk measure. Scenario classification (low/medium/high risk) requires the definition of risk thresholds.



Padiyar, K.R. (ed.) (2008). Power System Dynamics, Stability and Control. BS Publications.

Problem definition: Case of study

- IEEE 9 Bus Test Systems (show in Figure 5.1).
- Large number of operating scenarios generated by varying load consumption and generation to different levels.
- Results are collected based on power flow simulations.

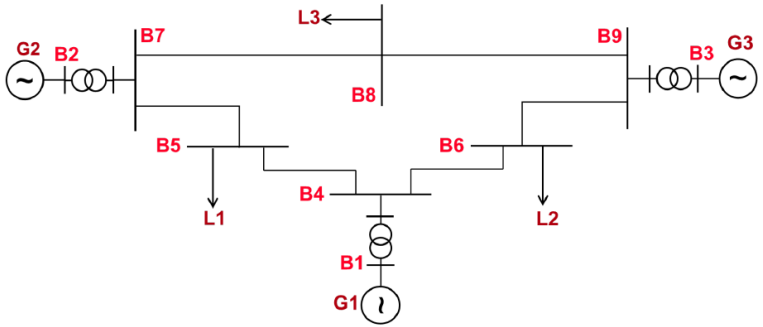


Figure 5.1 IEEE 9 Bus Test System

Problem definition: Data

- The following feature matrix F is constructed:

$$F = (P_i, Q_i, V_i, \theta_i, P_{ij}, Q_{ij}) \text{ for } i = \{1, \dots, 9\}$$

- In total, we have 216 features.

- Note that if the line ij does not exits, then $P_{ij} = Q_{ij} = 0$.

- We call this as the INITIAL DATASET.

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Problem definition: Data

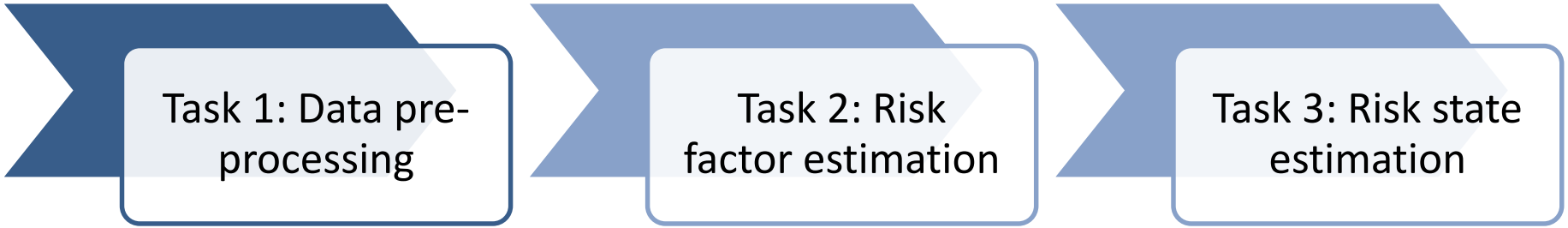
- A risk factor (R) measure is defined to quantify risk against severe disturbances.
- Normalized and continuous value between 0.0 and 1.0.

Class	Safe	Low Risk	Moderate Risk	High Risk
Threshold	$R < 0.1$	$0.1 \leq R < 0.35$	$0.35 \leq R < 0.7$	$0.7 < R$

- In total, 4955 scenarios (samples) are provided.

Task description

- Three tasks are planned for the development of this Project Assignment, as show below.



- Task 2 and Task 3 can be done in parallel.

Task 1: Data pre-processing

- Perform data pre-processing activities: data preparation? data cleaning?, normalization?, standardization? Feature analysis?.

- Some data is missing. Several options can be considered to move forward. These are:

Option 1	Delete the samples with data missing and use the remaining data.
Option 2	Fill in the missing data and use the filled dataset.
Option 3	Option 1 + use a reduced number of features.
Option 4	Option 2 + use a reduced number of features.
Option 5	Option 1 + propose new features

- Choose at least two of these options and provide your arguments for the selection on the project report (more on this to follow).

Task 1: Data pre-processing

- Task 1 Outcomes:

DATASET 1	Resulting dataset from your first option.
DATASET 2	Resulting dataset from your second option.

Task 2: Risk factor estimation

- For each dataset from Task 1, develop a model that allow you to estimate the risk factor for new unseen operational scenarios.
- Provide arguments for the choice and design of your final model(s).
- Provide arguments for the assessment and validation procedure of your final model(s).
- Task 2 Outcomes:

MODEL 1	Selected final model to perform risk factor estimation for the DATASET 1
MODEL 2	Selected final model to perform risk factor estimation for the DATASET 2

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Task 3: Risk state estimation

- For each dataset from Task 1, develop a model that allow you to estimate the risk state for new unseen operational scenarios.
- Provide arguments for the choice and design of your final model(s).
- Provide arguments for the assessment and validation procedure of your final model(s).
- Task 3 Outcomes:

MODEL 3	Selected final model to perform risk state estimation for the DATASET 1
MODEL 4	Selected final model to perform risk state estimation for the DATASET 2

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3. Conditions

Project conditions & report

- You will work on pairs.
- Decisions need to be made together, but Tasks can be done individually.
- We recommend to split the tasks. Any member must be capable to argue any decision made.
- At least one of the models must be a *deep neural network (Lecture 6)*.
- One report per pair. The report must follow the proposed structure with a maximum number of pages of 10.

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Project conditions & report

- During the Practicums in Week 7 and 8: Feedback meetings with Lecturer and/or TA.

- Deadline for delivering Report + Py Code: **January 15, 2022.**

Project conditions & report

- Deliverables: Python code + report.

- Report structure:
  - Members, emails, student numbers.
  - Summary (less than 200 words)
  - Detailed ML pipeline (include workflow figure)
  - **Task 1:** selected options, argumentation for the selection, model(s) developed, results, validation, comparisons.
  - **Task 2:** argumentations for the model(s) developed, validations, results, comparisons.
  - **Task 3:** argumentations for the model(s) developed, validations, results, comparisons.
  - Conclusions (less than 200 words)

4. Evaluation criteria

Evaluation criteria

- A report can be considered **INADMISSIBLE**, which will render a FAIL grade for the group, if
  - English written is not understandable (e.g., full of typos).
  - Deep neural networks were not used (as one of the tested models)
  - Figures are not legible.
  - The report does not follow the proposed structure.

- If the report is considered **ADMISSIBLE**:
  - English will **not** render extra points.
  - Quality of the Python code will **not** render extra points.

- The next assessment rubric will be used.

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Criterion	Weight [%]	1		4		6		8		10
Data analysis and pre-processing	10	No data analysis. No argumentation for data-preprocessing choices (e.g. normalization, standardization).				Basic data analysis. Only very basic argumentation for data-preprocessing choices (e.g. normalization, standardization).				Excellent data analysis including statistical characterization and feature correlation. Solid argumentation for data-preprocessing choices (e.g. normalization, standardization).
Feature selection	15	No explicit feature selection.				Heuristic selection of features, accompanied by explanation of their relevance for the model.				Use a well-defined feature selection procedure and explain how the final feature list was obtained.
Performance indicators (e.g. loss function, error quantification, convergence criteria)	10	No argumentation for the selection of performance indicators.				Basic argumentation for the selection of performance indicators used during the development and validation of the ML models.				Clear and strong argumentation for the selection of performance indicators used during the development and validation of the ML models.
Hyperparameter tuning	20	Use of the default hyperparameters from Scikit Learn.				Test of some hyperparameter values (limited number of test) within a limited range. No argumentation for the range selection for the hyperparemter search.				Proper use of the hyperparameters tuning functions of Scikit Learn (e.g., GridSearch, RandomSearch). Proper argumentation for the range selection for the hyperparemeter search.

Criterion	Weight [%]	1	4	6	8	10
Appropriate use of data	10	No use of validation or test sets		Mechanical use of train/validation/test without demonstration or explanation.		Proper argumentation for and use of validation and test sets. Maximise data efficiency e.g. using cross-validation.
Model selection	20	No argumentation provided for the final selection of the presented model. No comparison of models.		Basic argumentation for the final selected model.		Clear and strong argumentation for the final selected model based on comparison with other models and analyses on the data.
Overall coherence of project and report	10	No connectivity of the different sections in the report.		Minimal connectivity of the report sub-sections.		Excellent alignment of the report sub-structrure with valid and clearly described design choices throughout.
ML pipeline description (including figure)	5	No arguments for the design of the ML pipeline. Basic block diagram figure to represent the ML pipeline.		Basic ML pipeline design. No solid arguments to support design choices. Basic block diagram figure to represent the ML pipeline.		Excellent ML pipeline design and description with solid arguments to support design choices. Excellent block diagram figure to represent the ML pipeline including inputs, outputs and models tested/developed.

5. Q&A

6. Project working session (with feedback)

- Working groups on **Brightspace**.
- Go to **Brightspace** and download the CSV that contain the data (perform an initial check).
- Start drafting a ML workflow for your application.