

Power System Quality and Reliability

ECEg-6312

WEEK 15

Course Assessment and Evaluation

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Course Assessment and Evaluation

- The overall course grade is determined based on continuous assessment and final examination components as follows:

Table 1: Assessment Breakdown.

No.	Assesment Type	Weight (%)
1.	Individual Assignment	10
2.	Project Work	15
3.	Presentation	5
4.	Mid-Term Examination	20
5.	Final Examination	50
	Total	100

1. Individual Assignment

- **Title:** Power Quality Assessment and Mitigation Design for an Industrial Plant.
- **Objective:** Select an industrial plant in your country and conduct a comprehensive power quality assessment using a Power Quality Analyzer. Identify existing power quality problems, analyze their causes and impacts, and propose appropriate mitigation solutions.

Cont'd...

- **Assignment Tasks**

1. **Industrial Plant Selection:** Select an industrial plant (cement factory, textile factory, beverage factory, etc.).
2. **Provide a brief description of the plant:** Including, Location, Main production processes, Major electrical loads, and Single-line diagram (if available)

Con'd...

- 3. Power Quality Data Collection:** Use a Power Quality Analyzer to measure and record (RMS Voltage, RMS Current, Frequency, Power Factor, Voltage Unbalance, Current Unbalance, Voltage Total Harmonic Distortion (THDv), Current Total Harmonic Distortion (THDi), Voltage Sags, Voltage Swells, Interruptions, Flicker, Transient Events.

Con'd...

- 4. Power Quality Analysis:** Analyze the measured data according to relevant standards (IEEE 519-2022, IEC 61000 Series, and IEEE 1159)
 - Identify and discuss the power quality problems observed.
 - Determine possible sources and causes of each problem.
- 5. Mitigation Design:** Design suitable mitigation measures for each identified problem.

2. Project Work

- **Project Title:** Reliability Assessment and Improvement of a Power Distribution Network
- **Objective:** The objective of this project is to evaluate the reliability performance of a selected power distribution network in your country, identify major reliability issues affecting customers and system operation, and propose appropriate technical solutions to improve system reliability.

Cont'd..

- **Project Tasks:**

1. **Selection of a Distribution Network:**

- **Choose a power distribution network** in your country (such as:
 - Urban distribution feeder,
 - Rural distribution feeder,
 - Industrial distribution feeder,
 - University distribution network, and
 - Substation distribution network, etc.)

Cont'd..

- **Project Tasks:**

- 2. Provide:**

- Network location
 - Network voltage level
 - Number of feeders
 - Number of customers served
 - Single-line diagram (if available)
 - Network characteristics and operating conditions

Cont'd...

Project Tasks:

- 3. Data Collection:** Collect at least one year of reliability data from the selected distribution network, including:
 - Number of interruptions,
 - Interruption duration,
 - Failure frequency,
 - Equipment outage records, Customer outage records,
 - Planned outages, Forced outages, and Customer population)

Cont'd...

Project Tasks:

- 4. Component Reliability Evaluation:** Determine the reliability parameters of major system components:
 - Failure Rate (λ) [failures/year]
 - Repair Time (r) [hours/failure]
 - Annual Outage Duration (U) [hours/year]

Cont'd...

Project Tasks:

5. Calculate the following reliability indices:

- Load Point Reliability Indices
 - Failure Rate
 - Annual Outage Duration
 - Average Repair Time

Cont'd...

Project Tasks:

5. Calculate the following reliability indices:

- Customer-Oriented Reliability Indices
 - SAIFI
 - SAIDI
 - CAIDI
 - ASAI

Cont'd...

Project Tasks:

6. Reliability Performance Evaluation

- **Evaluate:**
 - Feeder reliability performance and Customer service continuity
 - Availability of supply
 - Comparison among feeders
 - Comparison with utility or international benchmarks
- **Discuss:**
 - Worst-performing feeder(s), Major causes of interruptions
 - Contribution of each component to system unreliability

Cont'd...

Project Tasks:

7. Identification of Reliability Problems

- Identify key reliability issues such as:
 - High outage frequency and Excessive outage duration
 - Overloaded feeders and Aging infrastructure
 - Transformer failures and Poor maintenance practices
 - Vegetation-related faults
 - Weather-related outages
 - Lack of feeder automation
 - Insufficient protection coordination

Cont'd...

Project Tasks:

8. Reliability Improvement and Mitigation Measures

- Propose practical mitigation measures such as:
 - Preventive maintenance program
 - Faster fault location and restoration
 - Install sectionalizers and reclosers
 - Capacity upgrading
 - Reconductoring and line refurbishment
 - Feeder automation and SCADA

Cont'd...

Project Tasks:

9. Reliability Improvement Assessment

- Estimate the expected improvement in:
 - SAIFI, SAIDI
 - CAIDI, ASAI, and
 - Customer service reliability
- Compare:
 - Existing system performance
 - Improved system performance

Cont'd...

Project Tasks:

10. Results and Discussion

- Present:
 - Reliability calculations
 - Feeder comparison
 - Benchmark comparison
 - Causes of poor reliability
 - Expected benefits of proposed solutions

Cont'd...

Project Tasks:

11. Conclusion and Recommendations

- Summarize:
 - Reliability performance of the selected network
 - Major reliability challenges
 - Recommended technical solutions
 - Expected improvements after implementation

3. Presentation

Objective

- Students shall present the findings of their Distribution System Reliability Analysis and Improvement Project.
- The presentation should clearly communicate the selected distribution network, reliability assessment methodology, calculated reliability indices, identified reliability problems, proposed mitigation measures, and expected improvements.

Cont'd...

Presentation Requirements:

- Each group shall prepare a professional presentation covering the following sections:

1. Introduction

- Background of the selected distribution network
- Project objectives
- Scope of the study

2. Distribution Network Description

- Network location, Voltage level, Number of feeders and customers, and Single-line diagram (if available)

Cont'd...

Presentation Requirements:

3. Data Collection and Methodology
 - Sources of reliability data
 - Reliability analysis procedure
 - Assumptions made during the study
4. Reliability Analysis
5. Results and Discussion
6. Identified Reliability Problems
7. Proposed Mitigation Measures

4. Mid-Term Examination

- **Mid-Term Examination Instructions:** The mid-term examination consists of two parts with a total of 20 marks.
 - **Part I: Multiple-Choice Questions (12 Marks)**
 - This section contains 6 multiple-choice questions.
 - Each question carries 2 marks and Total marks for Part I: 12 marks.
 - Students are required to select the single best answer for each question.
 - **Part II: Problem-Solving Questions (8 Marks)**
 - This section contains 1 workout (analytical and calculation-based) question.
 - Students are required to show all necessary steps, calculations, and justifications where applicable.
 - Marks are allocated based on the accuracy of the solution procedure as well as the final answer.
 - Total marks for Part II: 8 marks.

Part I: Multiple-Choice Questions (12 Marks)

1. A distribution feeder experiences 120 interruptions per year affecting 2,000 customers. Which reliability index represents the average interruption frequency experienced by customers?
 - A. SAIDI
 - B. CAIDI
 - C. SAIFI
 - D. ASAI
2. According to IEEE 519, Total Harmonic Distortion (THD) is primarily used to quantify:
 - A. Voltage sag duration
 - B. Harmonic distortion relative to the fundamental component
 - C. Power factor correction requirements
 - D. Frequency deviation

Part I: Multiple-Choice Questions (12 Marks)

3. A Dynamic Voltage Restorer (DVR) is primarily installed to mitigate:

- A. Harmonic current distortion
- B. Voltage sag and swell events
- C. Transformer overheating
- D. Frequency instability

4. For a two-state reliability model, availability is given by:

- A. $A = \frac{\lambda}{\lambda + \mu}$
- B. $A = \frac{\mu}{\lambda + \mu}$
- C. $A = \lambda\mu$
- D. $A = \frac{1}{\lambda + \mu}$

Part I: Multiple-Choice Questions (12 Marks)

5. A system consists of two independent components connected in series with reliabilities $R_1=0.95$ and $R_2=0.90$. The system reliability is:
- A. 0.925
 - B. 0.855
 - C. 1.85
 - D. 0.050
6. Which power quality phenomenon is most commonly associated with the operation of nonlinear loads such as variable-speed drives and rectifiers?
- A. Voltage sag
 - B. Harmonics
 - C. Flicker
 - D. Frequency deviation

Part II: Problem-Solving Questions (8 Marks)

1. A radial distribution feeder supplying residential and commercial customers consists of the following components:

System Component	Failure Rate, λ (failures/year)	Average Repair Time, r (hours)
Feeder Section	0.25	8
Distribution Transformer	0.10	12
Circuit Breaker	0.05	4

Assume all components are connected in series.

- Determine the equivalent failure rate of the feeder. (2 Marks)
- Calculate the annual outage duration contributed by each component and determine the total annual outage duration of the feeder. (2 Marks)
- Compute the equivalent average outage duration (repair time) of the feeder. (2 Marks)
- Calculate the feeder availability and unavailability. (2 Marks)

Answer Key

Part I: Multiple Choice

1. C

2. B

3. B

4. B

5. B

6. B

Part II: Problem Solving

1. Given

System Component	Failure Rate, λ (failures/year)	Average Repair Time, r (hours)
Feeder Section	0.25	8
Distribution Transformer	0.10	12
Circuit Breaker	0.05	4

(a) Equivalent Failure Rate

$$\lambda_{eq} = 0.25 + 0.10 + 0.05$$

$$\lambda_{eq} = 0.40 \text{ failures/year}$$

Answer Key

(b) Annual Outage Duration

$$U = (0.25)(8) + (0.10)(12) + (0.05)(4)$$

$$U = 2.0 + 1.2 + 0.2$$

$$U = 3.4 \text{ hours/year}$$

(c) Equivalent Average Outage Duration

$$r_{eq} = \frac{U}{\lambda_{eq}}$$

$$r_{eq} = \frac{3.4}{0.40}$$

$$r_{eq} = 8.5 \text{ hours}$$

Answer Key

(d) Availability

$$A = 1 - \frac{U}{8760}$$

$$A = 1 - \frac{3.4}{8760}$$

$$A = 0.999612$$

$$A = 99.9612\%$$

Unavailability:

$$Q = 1 - A$$

$$Q = 0.000388$$

Thank You!