Instructions:

This is a take-home exam. It is considered “open-book”, and “open-notes”. The use of Mathcad, Matlab, Excel, and similar software is encouraged where it is appropriate. However, circuit simulation software such as PSpice, EMTP, or ATP may only be used to check answers.

You may use whatever references are available to you to better-understand the problems and their solutions. However, the calculations, diagrams, and written answers must be your own work, prepared by each student individually. Copying text from other sources rather than developing your own answer is not acceptable. Direct quotations from any reference materials must be kept to a minimum and those references must be adequately cited.

This is a new, comprehensive exam prepared this semester and is worth 35% of the total course grade. You may contact me, during the exam if you have questions. Please contact me as soon as possible if you believe a problem does not have enough information, or contains some other error.

Copies of the “Course Information” and “Grading Summary” handouts are available on the course web site and in BBlearn. I recommend reviewing these documents before starting the exam.

Please show your work, cite your sources, state your assumptions if necessary, clearly identify your answers, and use appropriate units. Read questions carefully and make sure you answer the question being asked. This is particularly important in questions where you are asked to explain how something works, why something happens, and so on. As with the midterm, your objective should be to convey to me as clearly and succinctly as possible that you have developed a working knowledge of the material and can apply that knowledge to discussing power quality issues and solving problems related to power quality.

Thank you,

Paul Ortmann

Problem 1: Engineering integrity, crediting others, citing sources:

(2 points) Visit the following web site at the University of Idaho Information Literacy Portal and read module 6.4:
http://www.webpages.uidaho.edu/info_literacy/modules/module6/6_4.htm

Afterwards, use the menu on the right side of the webpage to navigate to module 6.5 and read that module, including the comments on each student's work.
1.1)(2 pts) What are the names of the three students used in the plagiarism example in module 6.5?

Problem 2: Power system calculations, capacitor switching, power factor

(25 points) A three-phase, 60Hz distribution system operates at 12.47kV (phase-to-phase) and serves three balanced, linear, three-phase loads all at one location.

Load 1:	2.0 MW, with a lagging power factor of 0.75
Load 2:	1.0 MW, with a lagging power factor of 0.80
Load 3:	0.5 MW, with a lagging power factor of 0.85

The true power factor listed for each load is entirely displacement power factor. The three-phase short circuit duty at the load location is 61MVA. Assume that the system impedance is entirely inductive.

Questions:
2.1)(4 pts) What is the combined displacement power factor of the three loads?
2.2)(5 pts) What is the largest three-phase shunt capacitor bank that can be installed at the load location using a combination of 100kVAR, (single-phase) capacitor units if the steady-state voltage rise when the capacitor bank is switched on cannot exceed 3%.
2.3)(4 pts) What is the combined displacement power factor of the three loads and the capacitor bank you specified in 1.2?
2.4)(4 pts) What will be the frequency of the switching transient when the capacitor you specified in 1.2 is switched on?
2.5)(4 pts) What will be the peak amplitude (NOT RMS) inrush current into the capacitor bank when it is switched on?
2.6)(4 pts) In reality we know the distribution line has some resistance. We also know that current flowing through that resistance causes losses in the distribution line. Calculate the estimated reduction in power system losses (in percent) in the distribution line based on the improved power factor with the new capacitor bank you specified.

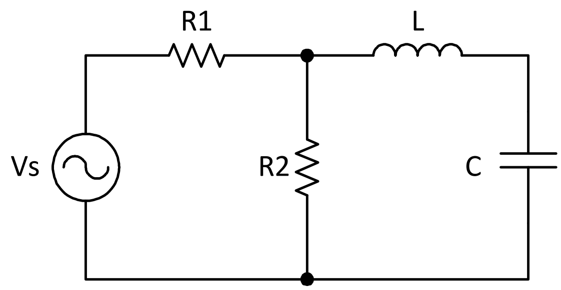
Problem 3: Wiring and grounding – communication systems:
(9 points) A networking cable for a control system consisting of 2 twisted pairs (4 conductors) has been installed in a facility. You have been asked to determine certain performance parameters for the cable installation. A test signal at the maximum communication frequency of the control system is applied to pair 1 at the controller end. Voltages are measured at the controller and the end device on both pairs. These voltages are given below:

	Controller	End device
Pair 1	5.000V	0.750V
Pair 2	0.350V	0.100V

Based on this data calculate the magnitude of the following values in decibels:
3.1) Signal attenuation in pair 1
3.2) NEXT
3.3) FEXT

Problem 4: (20 points) Harmonics, frequency response

A basic RLC circuit is shown below:



Values of the circuit elements are as follows: R1=1Ω, R2=15Ω. At 60Hz, the reactance of the inductor and capacitor are: X_L=1Ω, X_C=9Ω.

the voltage source (Vs) has a fundamental frequency of 60Hz. The voltage source consists of a fundamental frequency component, combined with three harmonic components. No other frequencies are present in the voltage source. The peak (NOT RMS) amplitudes of the components of the voltage source are:

Fundamental 100V
3rd harmonic 20V
5th harmonic 15V
7th harmonic 10V

The components of the voltage source are in-phase, i.e. the positive peaks of the fundamental frequency components coincide with the positive peaks of the harmonic components.

4.1)(4 pts) What is the RMS value of the applied voltage?
4.2)(4 pts) What is the THD of the applied voltage?
4.3)(4 pts) What is the resonant frequency of the circuit?
4.4)(4 pts) What is the RMS value of the current through R1?
4.5)(4 pts) What is the THD of the current through R1?

Short Calculations:

5.1)(4 pts) At a particular non-linear load the true power factor is 90%. The displacement power factor is 95%. What is the total harmonic distortion (THD) of the load's current? Assume the voltage THD is negligible.

5.2)(3 pts) Assume Isc/IL = 150 at the PCC where the nominal voltage is 480V line-to-line. What is the IEEE-519 limit (in percent of the fundamental current) for the 17th harmonic current for a non-linear load that consists entirely of 18-pulse variable speed drives?

5.3)(5 pts) A single-phase load has an apparent power of 1500VA. THD of the supply voltage is 10%. The fundamental component of the supply voltage is 120V (AC, RMS). The fundamental component of the line current is 10A (AC, RMS). What is the THD of the current? Hint: see lecture 19.

Word Problems:

6.1)(6 pts) An industrial facility is regularly impacted by the switching on of a nearby utility capacitor bank each morning. Briefly describe two different techniques the power company could use to reduce or eliminate these capacitor switching transients for this customer without removing the capacitors entirely, and without eliminating switching of the capacitors. Briefly discuss the advantages and the disadvantages of each technique.

6.2)(3 pts) A GFCI circuit breaker on a 120V circuit in a school trips occasionally while the janitor is vacuuming. The Janitor tells you that the vacuum has been checked and it is not faulty. The vacuum has a 100 foot extension cord that is used with it. When the GFCI circuit breaker trips, the janitor has to walk to the other side of the facility, approximately 100 feet away from the outlet where the vacuum is plugged in, to reset the circuit breaker. Describe a likely cause of this problem as discussed in class, and a possible solution.

6.3)(4 pts) Describe what is meant by the term “ground loop”. Describe two problems that might result from a ground loop and a way to “break” a ground loop.

6.4)(3 pts) A power quality recorder installed at the service point for a large industrial facility records voltage and current waveforms immediately prior to, and during a voltage sag. Describe how this information could be used to determine if the voltage sag was caused by an event upstream (on the source side) or downstream (on the load side) of the power quality recorder.

6.5)(3 pts) Describe how the location of a power quality monitor with respect to the source of a transient on the power system affects what the power quality monitor records and why.

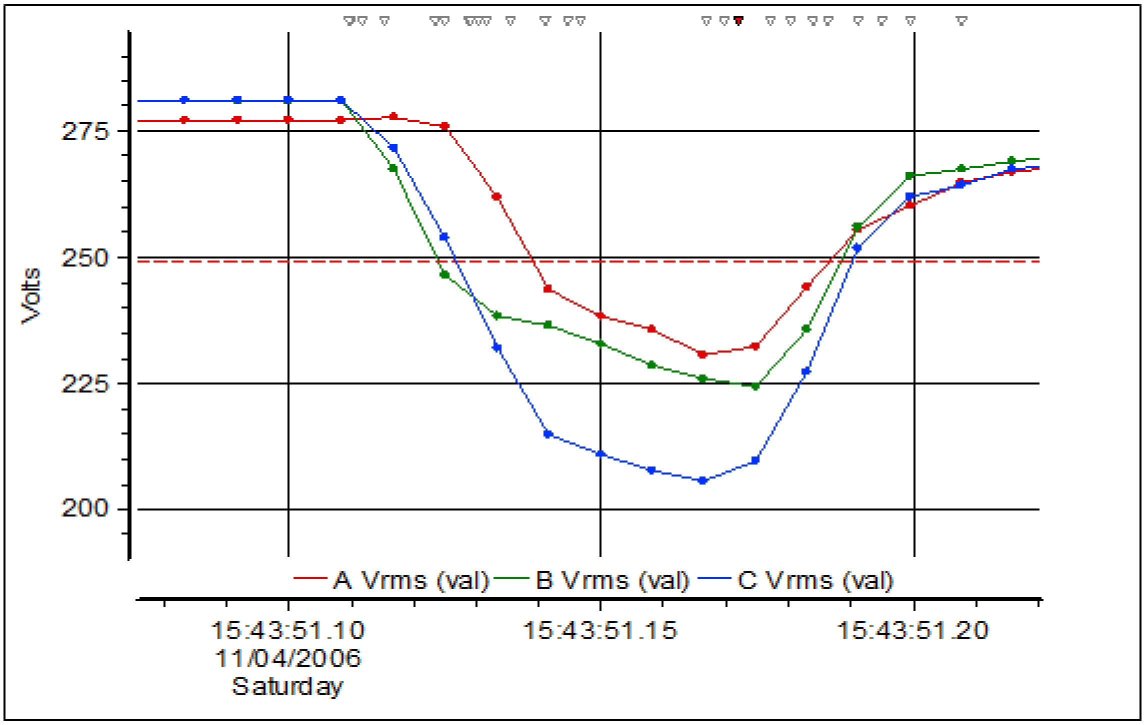
6.6)(3 pts) The PSQ text describes a number of issues associated with using low voltage power quality monitors and VTs and CTs to monitor primary distribution system voltages and currents. For general power quality monitoring in a substation, what type of VT should be used, what type should be avoided, and why?

Terminology and disturbance identification:

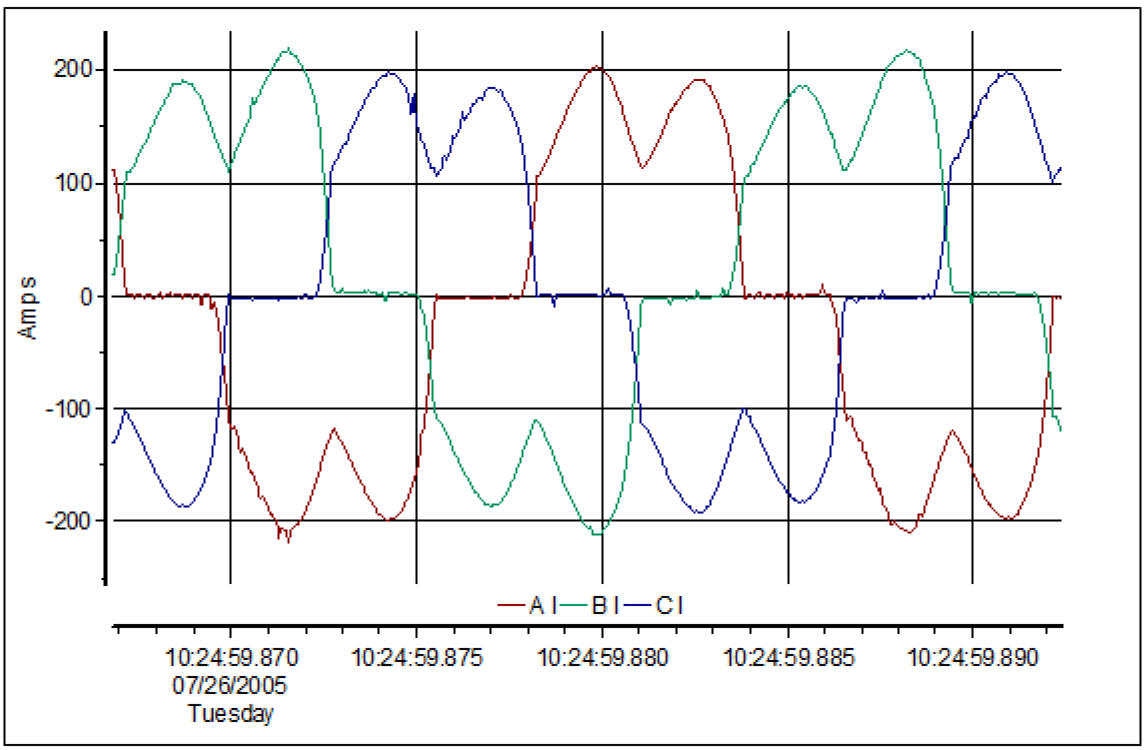
The plots shown in 7.1 and 7.2 (next page) contain a waveform or trend plot showing one or more voltages or currents recorded on a system with a 480V RMS nominal line-to-line voltage. The plots also contain timescale information, and information to identify whether the plotted parameter is voltage or current.

For each plot, classify the electrical disturbance or condition represented in the plot according to one of the different specific classifications of power system disturbances or conditions described in table 2.2 in the class texts. If the plot appears to contain more than one type of disturbance or condition, describe the most prominent disturbance or condition shown. If the plot contains data from more than one phase, describe how many phases appear to be affected. For example, an event might be described as a “momentary, three phase, voltage swell”.

7.1)(3 pts)



7.2)(3 pts)



7.3)(4 pts) Diagnosing Wiring and Grounding Problems:

The channel 1 and Channel 2 voltages and currents in this strip-chart recording were recorded at a split single-phase 120/240V service and show the two line-to-neutral voltages and line currents. What wiring problem does the following strip-chart recording indicate is present?