

# Data Acquisition System for Synchronous Generator Transient Performance



**SCHWEITZER  
ENGINEERING  
LABORATORIES**



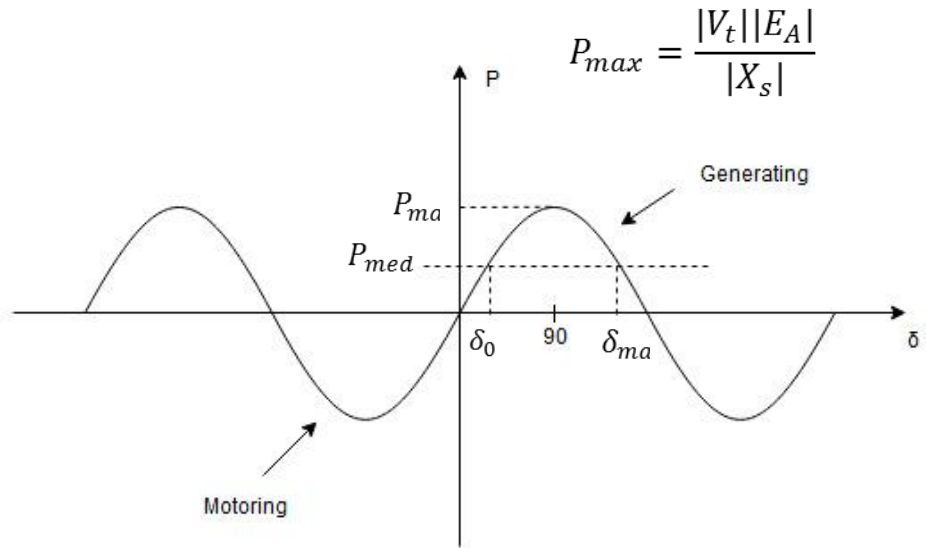
# Agenda

- Project Specifications, Constraints, and Deliverables
- Project Learning
- Project Topology
- Project Cost Estimation
- Project Schedule
- Potential Problems



# Problem Statement

After a fault clears in the system, the angle of the generator will increase and exceed  $\delta_{max}$ . The generator may slip a pole.



# Goal of the Project

Design and implement a system to acquire measurements from a synchronous generator in transient conditions



# Measurement Requirements

- Terminal Voltage and Current
- Field Voltage and Current
- Torque and Power
- Speed and Frequency
- Load phase angle and shaft position



# Data Acquisition Device Requirements

- Sampling rate of at least 10 kHz
- Measurements must be time synchronized
- Monitoring and storing streamed measurements



# What do we need ?

1. Data acquisition device with multiple inputs high sample rate capability
2. High quality sensors for measuring analog inputs



# Data Acquisition Device

Sampling rate	1.25MS/S
AI	8 differential or 16 single ended
DI / DO	24

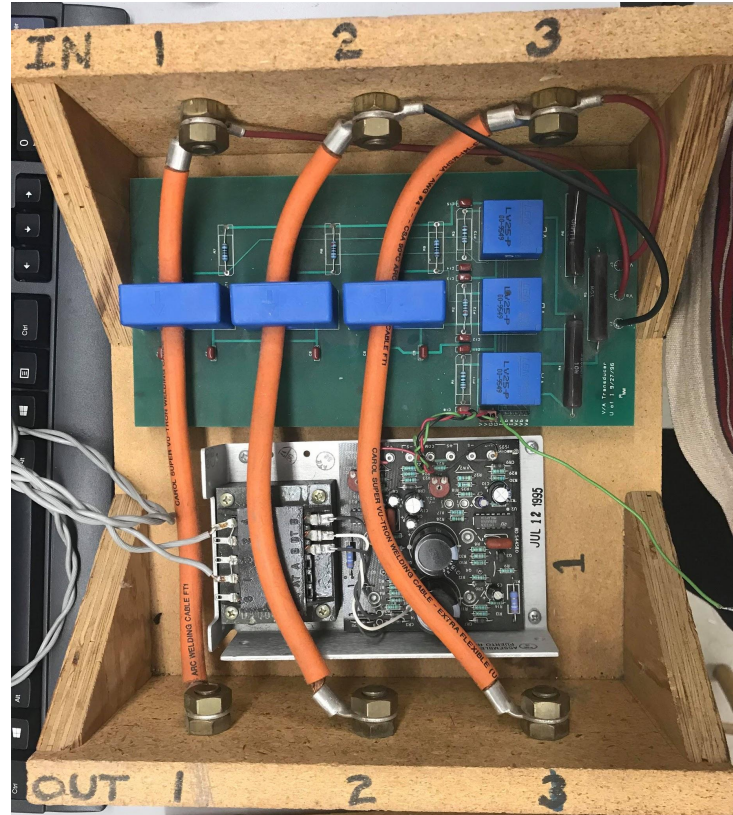
NI PXI 6251



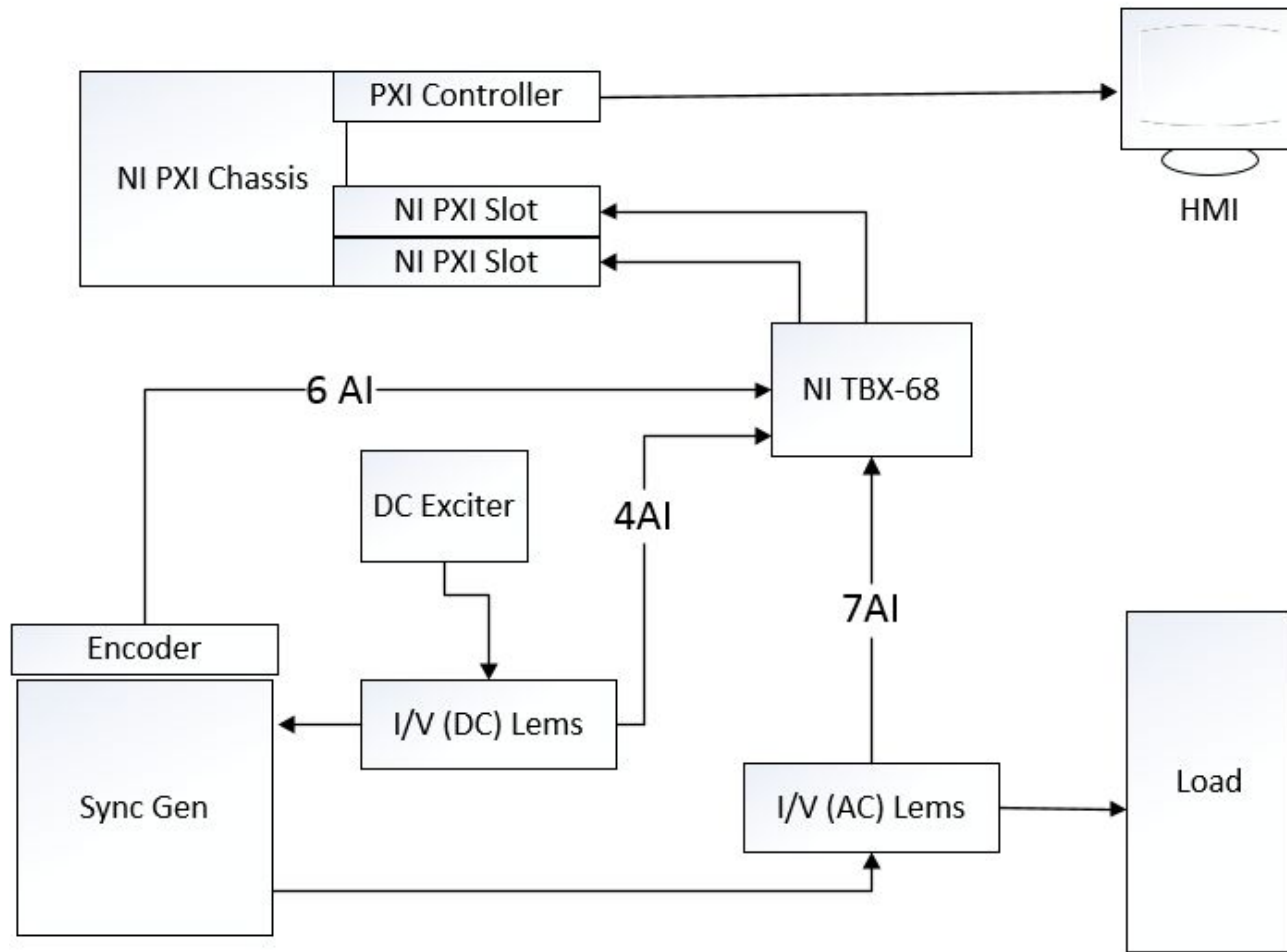


# Analogue Input Sensors

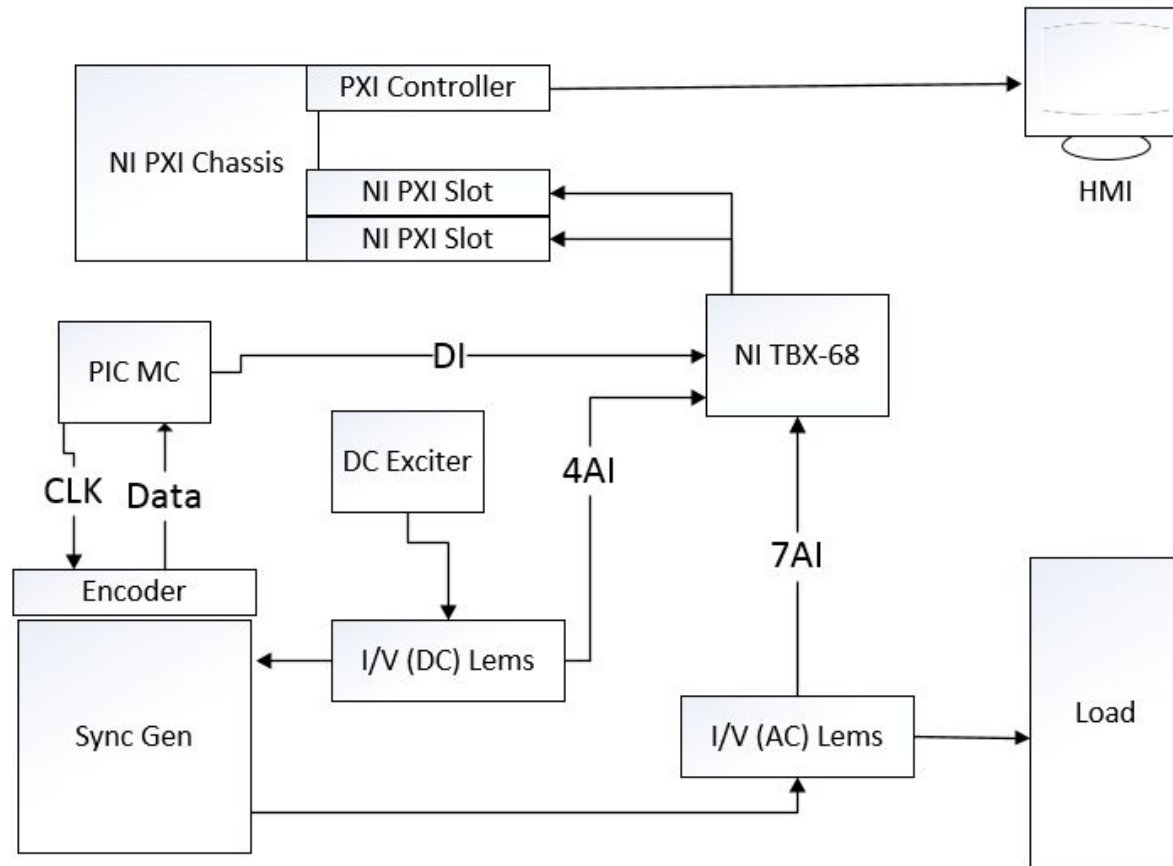
- LEM Box



# Topology-A

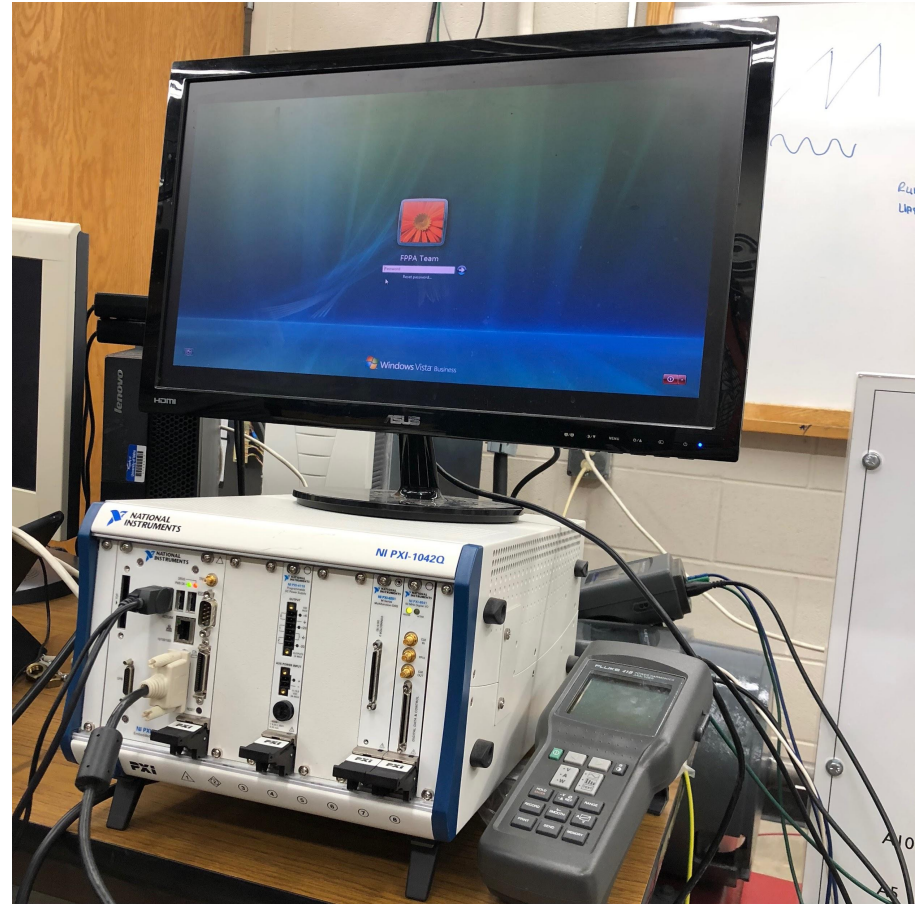


# Topology-B



# Testing PXI 6251

We were unable to perform the test. The PXI 8108 was password locked from past project team.

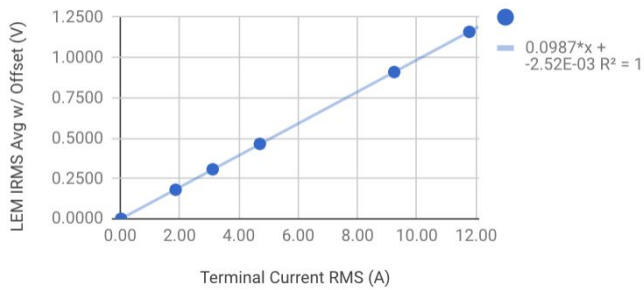


# LEM Test Setup

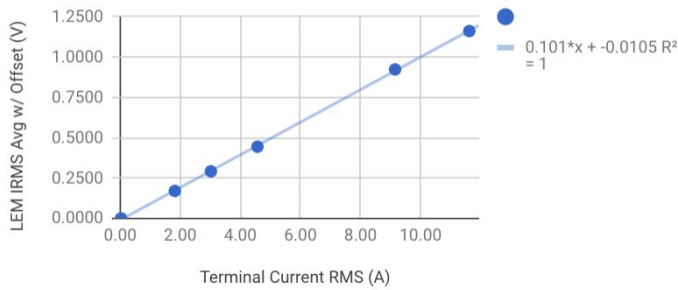


# Testing Result (AC/DC)

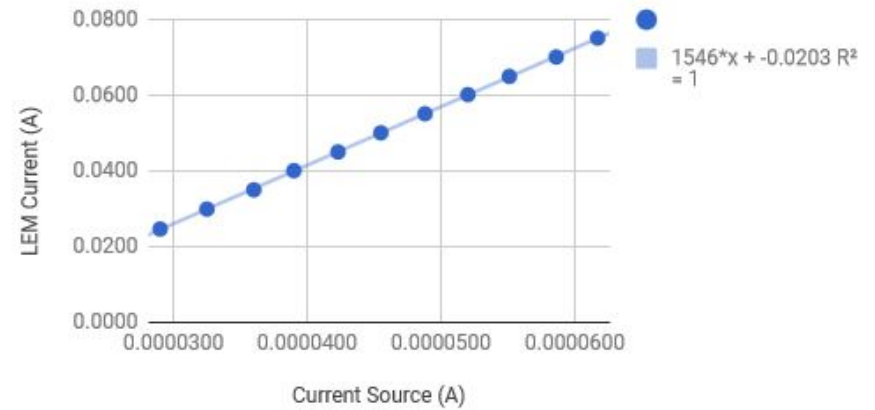
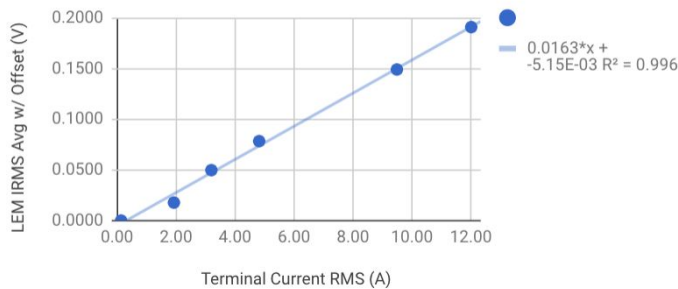
Phase A



Phase B



Phase C



# DC Test

Board	Measurement	Equation	R <sup>2</sup>
1 L-L	Current in vs. Current out	$y = 1556*x - 0.0203$	1
	Current in vs. Voltage Rm out	$y = 0.204*x + 2.59E-03$	1
	Voltage in vs. Voltage out	$y = 0.0181*x - 2.6E-03$	1
2 L1-L2	Current in vs. Current out	$y = 281*x - 5.25E-03$	1
	Current in vs. Voltage Rm out	$y = 1.05*x + 5.41E-03$	1
	Voltage in vs. Voltage out	$y = 0.181*x + 8.64E-03$	1
2 L1-L3	Current in vs. Current out	$y = 1553*x + 3.47E-03$	1
	Current in vs. Voltage Rm out	$y = 0.196*x - 2.13E-03$	1
	Voltage in vs. Voltage out	$y = 0.0186*x + 8.22E-03$	1



# AC Test

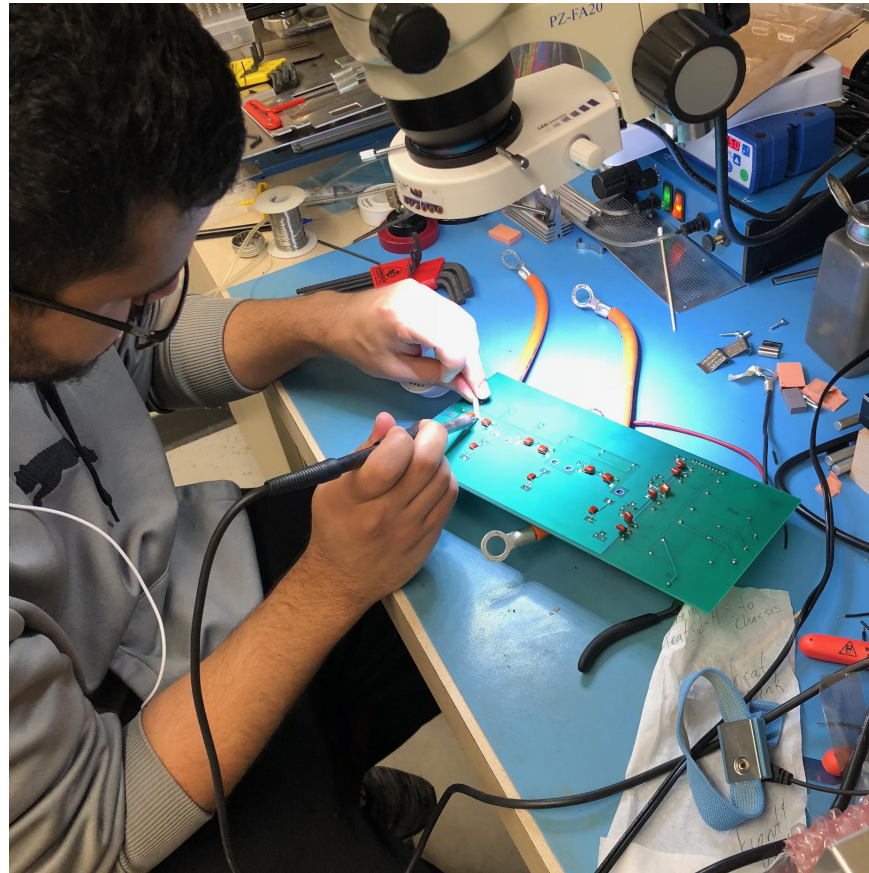
Phase A	$y = 0.0987*x - 2.52E-03$	$R^2 = 1$
Phase B	$y = 0.101*x - 0.0105$	$R^2 = 1$
Phase C	$y = 0.0163*x - 5.15E-03$	$R^2 = 0.996$

x  $\equiv$  Terminal RMS Current (A)  
y  $\equiv$  LEM RMS Current Avg w/ Offset (V)

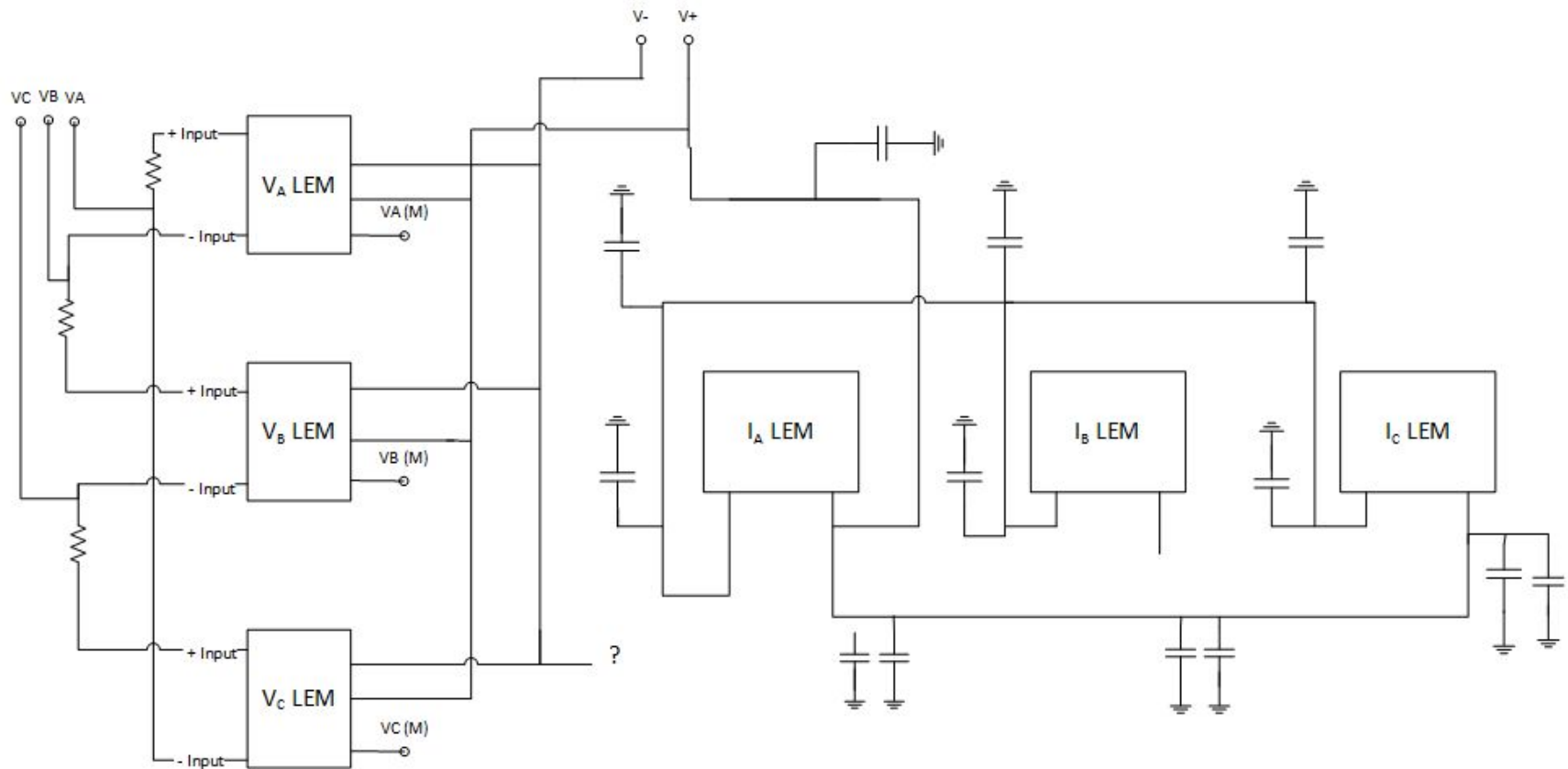




# LEM Box Reverse Engineering



# First Draft of LEM Schematic



# Challenging Tasks

Measurement of:

- Load Angle
- The shaft position
- Torque



# Incremental Optical Encoder

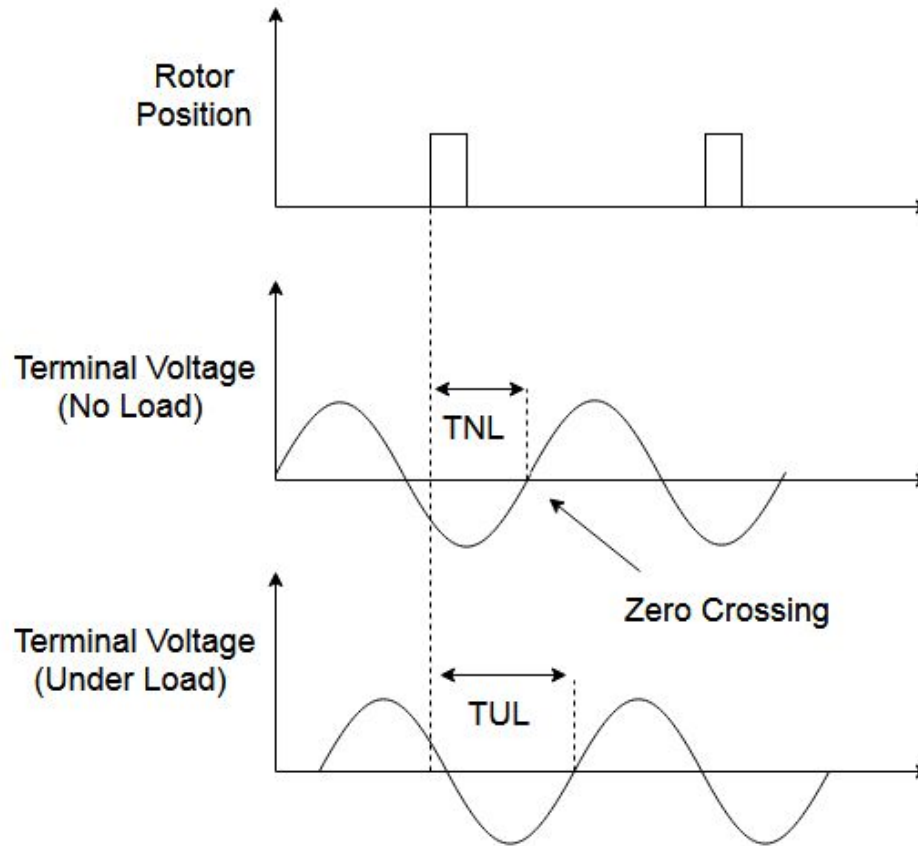
- 2160 cycles per shaft turn.
- Max RPM 12,000



# Measuring the Load Angle

TNL: Time in no load condition

TUL: Time in under load condition



# Measuring the Load Angle

1. We measure and store the angle under no load once

$$\theta_{UL} = \frac{T_{UL}}{T} \times 360$$

2. Calculation of the angle when we add a load

$$\delta = \left( \frac{T_{UL}}{T} \times 360 \right) - \theta_{NL}.$$



# Torque Transducer

Torque Range = 113 N-m

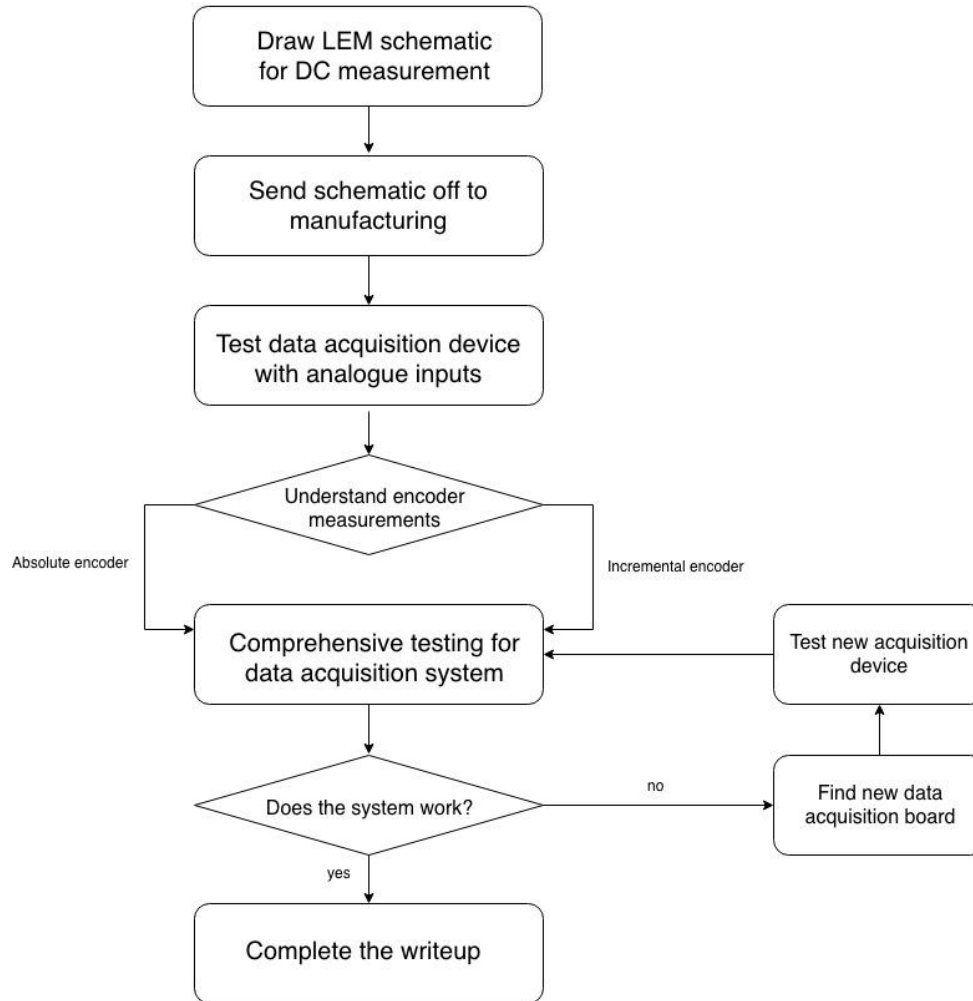
Torque overload = 226 N-m



MCRT® MODEL	TORQUE RANGE		TORQUE OVERLOAD		SPEED RATING* (RPM)		SHAFT STIFFNESS**	ROTATING INERTIA	MAX WT.
	[lbf-in]	[N-m]	[lbf-in]	[N-m]	Code N	Code C	[lbf-in/radian]	[ozf-in sec <sup>2</sup> ]	[lbs]
48201V(25-0)	25	2.82	50	5.65	0 to ±8,000	0 to ±15,000	1,800	0.031	10
48201V(5-1)	50	5.65	100	11.3	0 to ±8,000	0 to ±15,000	5,000	0.031	10
48201V(1-2)	100	11.3	200	22.6	0 to ±8,000	0 to ±15,000	12,000	0.031	10
48201V(2-2)	200	22.6	400	45.2	0 to ±8,000	0 to ±15,000	26,000	0.031	10
48202V(5-2)	500	56.5	1,000	113	0 to ±7,000	0 to ±12,000	66,000	0.032	10
48202V(1-3)	1,000	113	2,000	226	0 to ±7,000	0 to ±12,000	85,000	0.032	10



# Plan for Completion





# Dates & Goals

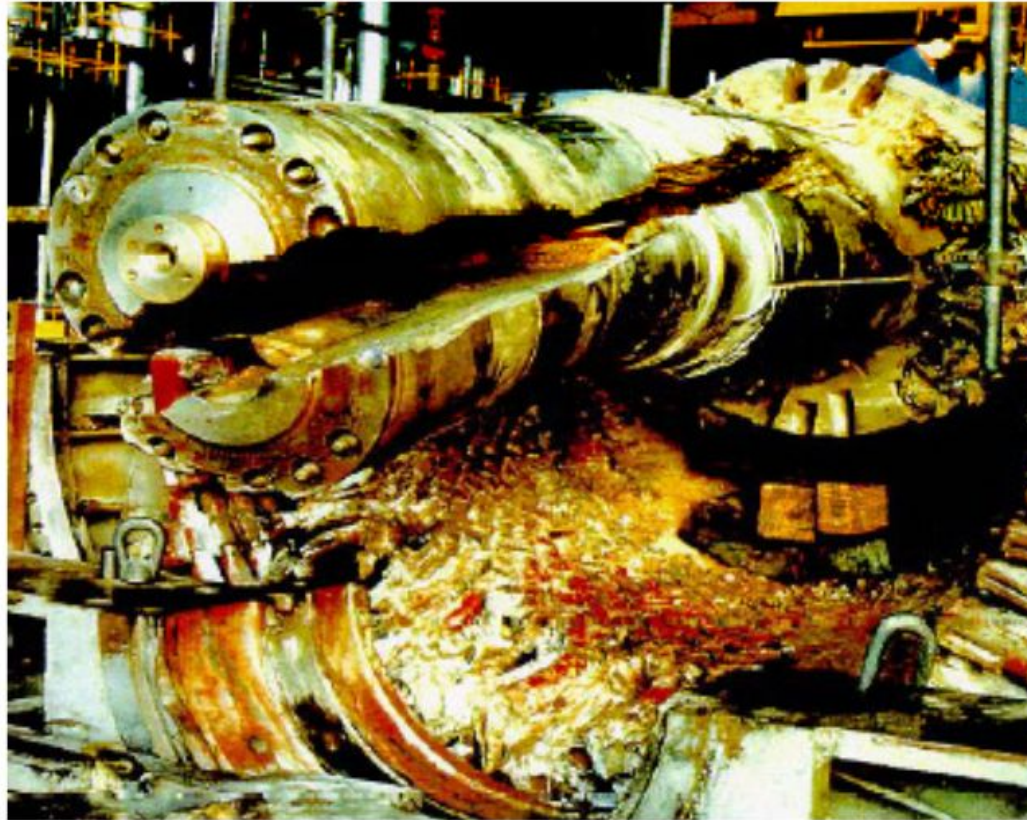
- 11/6 - Test PXI 6251
- 11/16 - Test Encoder
- 11/27 - Snapshot 2
- 12/7 - Send off LEM PCB for printing
- 3/6 - Snapshot 3
- 4/20 - Project Validation
- 4/27 - Design Expo
- 5/4 - Final Deliverables



# Project Budget

	B	C	D	E	F	G	H	I	J	K	L	M	N
<b>Capstone Project Budget - Fall/Spring</b>													
<b>Project:SEL- Data Acquisition System for Synchronous Generator Transient Performance</b>													
Last Updated <b>10/30/2018</b>													
	<b>2018</b>												
Expense Items	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr			Item		
										Total			
Data Acquisition device				\$ 4,000							\$ 4,000		
Design LEM box	\$ -	\$ -	\$ 707								\$ 707		
Cable			\$ 350								\$ 350		
Extra Hardware	\$ -		\$ 250								\$ 250		
Poster							\$ 100				\$ 100		
											\$ -		
											\$ -		
											\$ -		
											\$ -		
											\$ -		
											\$ -		
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											\$ -		
											\$ -	<b>Expenses</b>	
											\$ 5,407	<b>Subtotal</b>	
										<b>Totals</b>	<b>\$ 5,407</b>	<b>\$ 5,747</b>	<b>\$ 340</b>
											Budget	Excess	





Source: North West University (South Africa )

Thank you  
Any Questions?



# Appendix A: Equipment

## PXI 6251: Data acquisition device



# Appendix A: Equipment

NI TBX-68: Convert all the I/O to screw  
Terminals



# Appendix A: Equipment

NI PXI 8108: Acts as a compact modular PC platform for testing, measurement, and control systems



# Appendix A: Equipment

LEM Box: Acts as a high accuracy step down for analogue signals to protect the data acquisition board

