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DYNAMIC POSITIONING CONFERENCE
October 15-16, 2013

RISK SESSION

High Energy Fault Performance Design Verification Strategy for Common Main Power Bus DP Power Plants

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High Energy Fault Performance Design verification Strategy for Common Main Power Bus DP Power Plants.

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MARINE TECHNOLOGY SOCIETY
DYNAMIC POSITIONING COMMITTEE
16 Oct 2013

- **Objective:**

  to verify that the effect of a main bus disturbance will be as predicted in the FMEA and fault coordination studies.

- **Method:**

  1. to safely apply a fault that causes a dip in bus voltage and observe the response of the main power protection and power management system
  2. to safely apply a fault that causes full ground currents in the bus and observe the response of the main power protection and power management system.

  - The main bus voltage is very stable and to cause a momentary dip requires a significant step load to be applied to the bus.
  - Typically, the referenced studies predict the duration of the fault to be in order of 100 to 500 milliseconds.
  - High currents and transient behavior can be expected.

- **Design the test to limit plant exposure high stress**

- **Identify stakeholders**
  - Owners
  - Vessel technical Staff
  - Classification Societies
  - USCG
  - Shipyard
  - Equipment manufacturers

- **Procedure**
  - Do not execute without procedure
  - Master clock timing
  - Identify Data logs
  - Must include return of Plant to operational configuration

- **Data Logs: Critical**
  - To fully achieve objectives, off-site personnel will likely need to participate. They will need data.
  - Traditional “signed off” witness test sheets are not practical for such tests.
  - Data will be used to verify the math model of the power plant.

- **Confidence in *Plant Mathematical Model* will dictate the extent of practical tests through out the life of the vessel.**

Short Circuit Test Objectives

1. The fault currents are as predicted. (Math Model verification)
2. Tie breakers open and split the plant into independent 11kV segments.
3. Main bus voltage recovers successfully
4. The breaker feeding the fault opens.
5. Generators do not loose synchronism.
6. Transformer re-magnetization is successful.
7. Generators and critical DP loads return to operation without manual intervention.
8. Loads with a DC Bus link do not fail on over voltage. (voltage doubling effect)

Ground fault Test Objectives

1. The ground fault currents are as predicted. (Math Model verification)
2. Tie breakers open and split the plant into independent 11kV segments.
3. Main bus voltage to ground recovers successfully
4. The breaker feeding the fault opens.
5. Generators and critical DP loads remain operation without manual intervention.

Documents:

Set Up Specific

1. **Plant System Overview Short Circuit Tests One Line Diagram**
2. **Short Circuit Study**
3. **Coordination Study**
4. **Test procedure**
5. **Set up of protection relays for data logging**
6. **Set up of AGP for data logging and event capture.**
7. **Set up of relay in Fault Breaker**

Monitoring specific

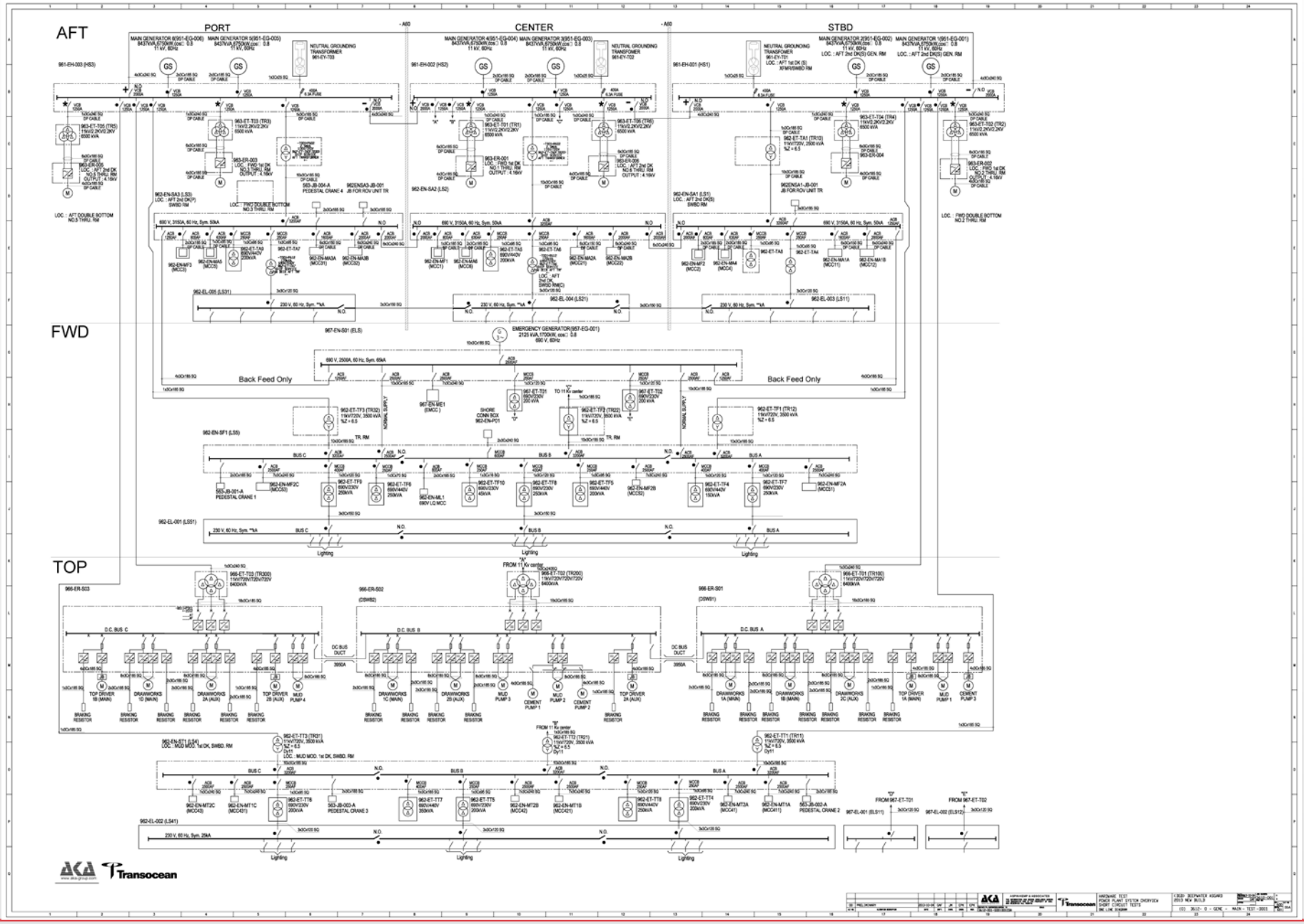
1. **Test Generator Short Circuit Tests Block Diagram**
2. **Short Circuit Fault Test Schematic**
3. **Ground Fault Test Schematic**

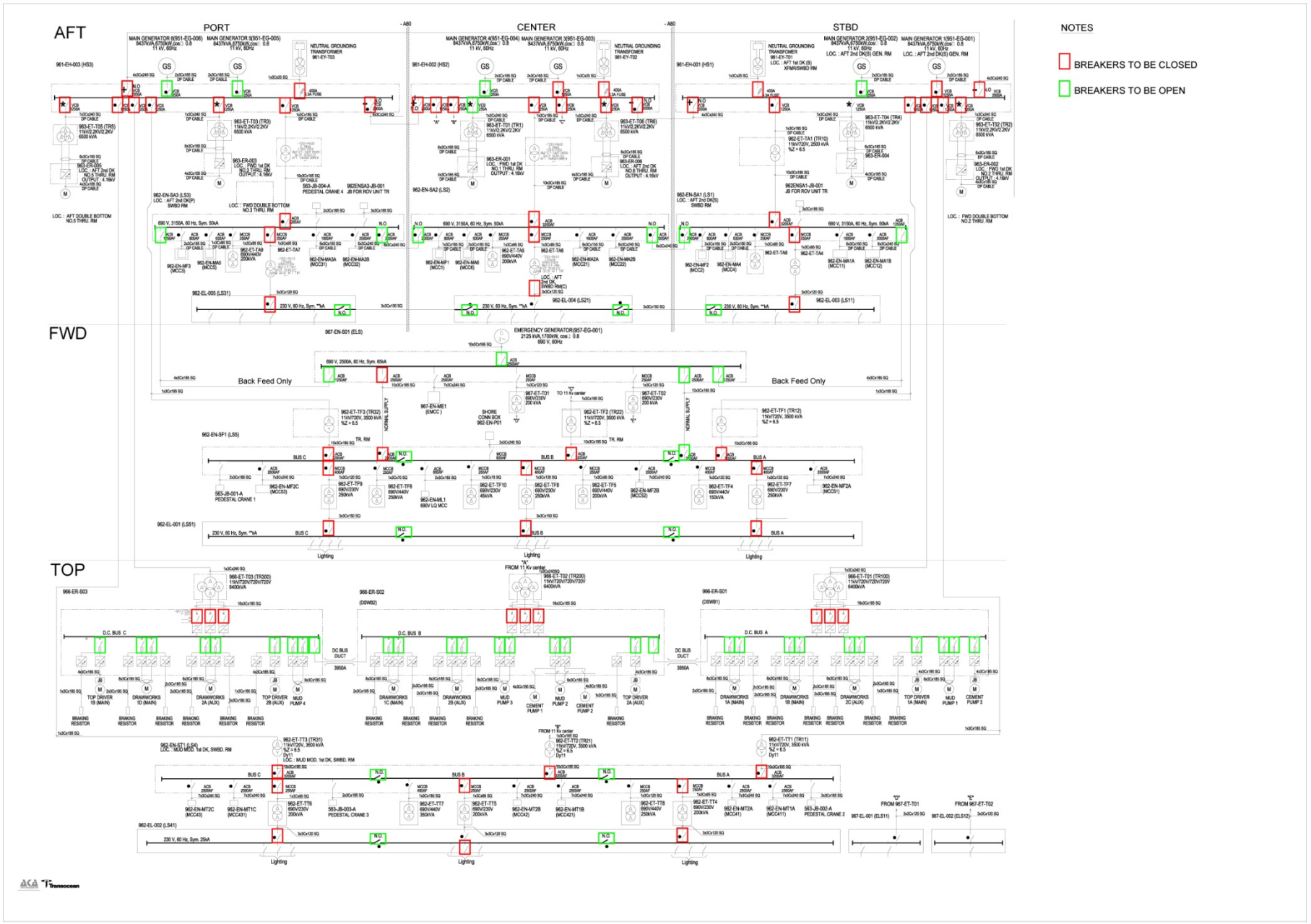
Ground fault specific

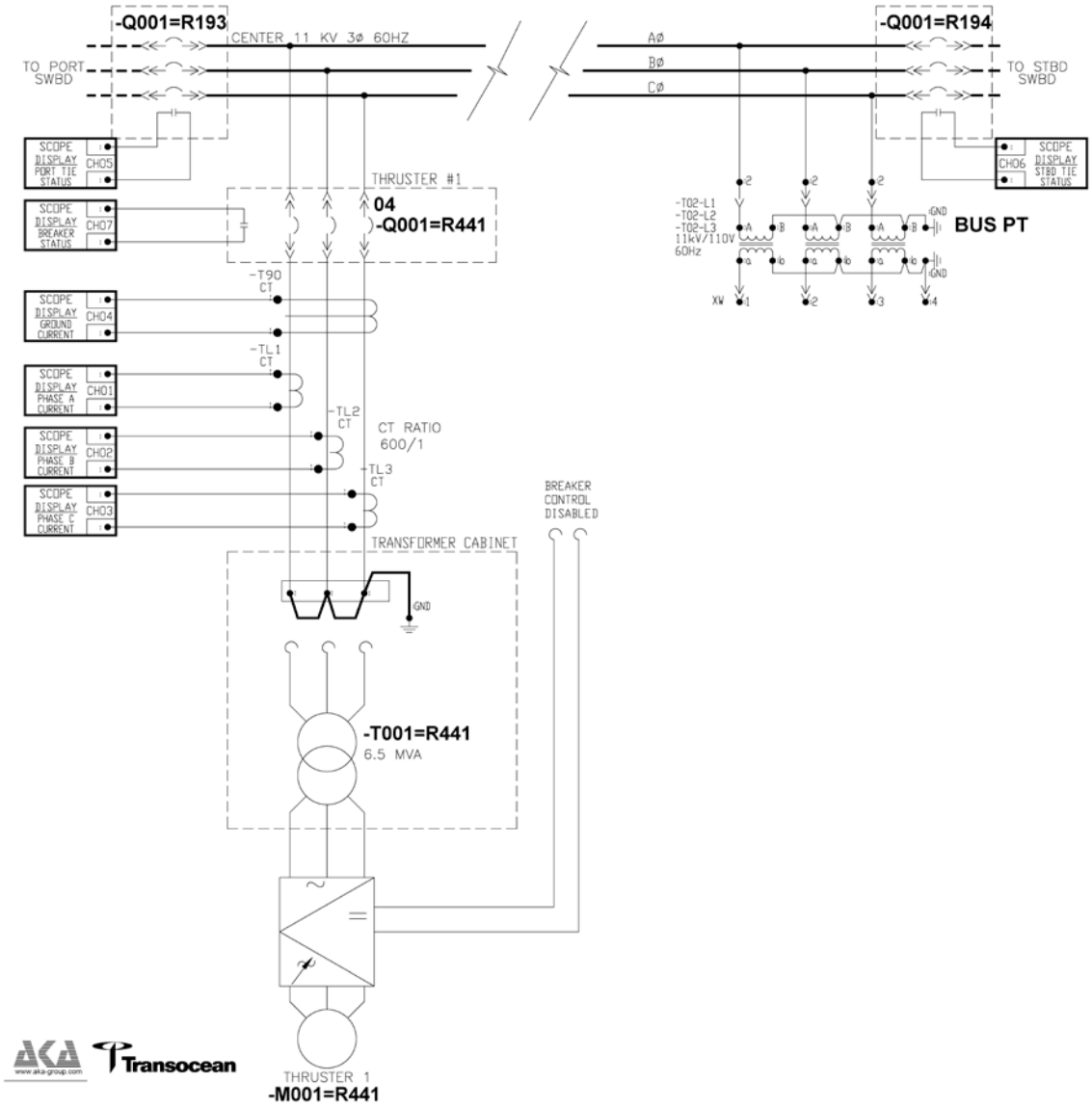
1. **Simplified Three Bus System Phase To Ground Test One Line Diagram**

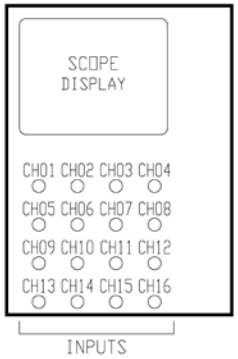
Phase Short Circuit specific

1. **Simplified Three Bus System 3 Phase Short Circuit One Line Diagram**


AFT
PORT
CENTER
STBD
FWD
TOP
Back Feed Only
Back Feed Only
EMERGENCY GENERATOR(957-EG-001)
2125 kVA,1700kW, cos□ 0.8
690 V, 60Hz
Lighting
Lighting
Lighting
Transocean

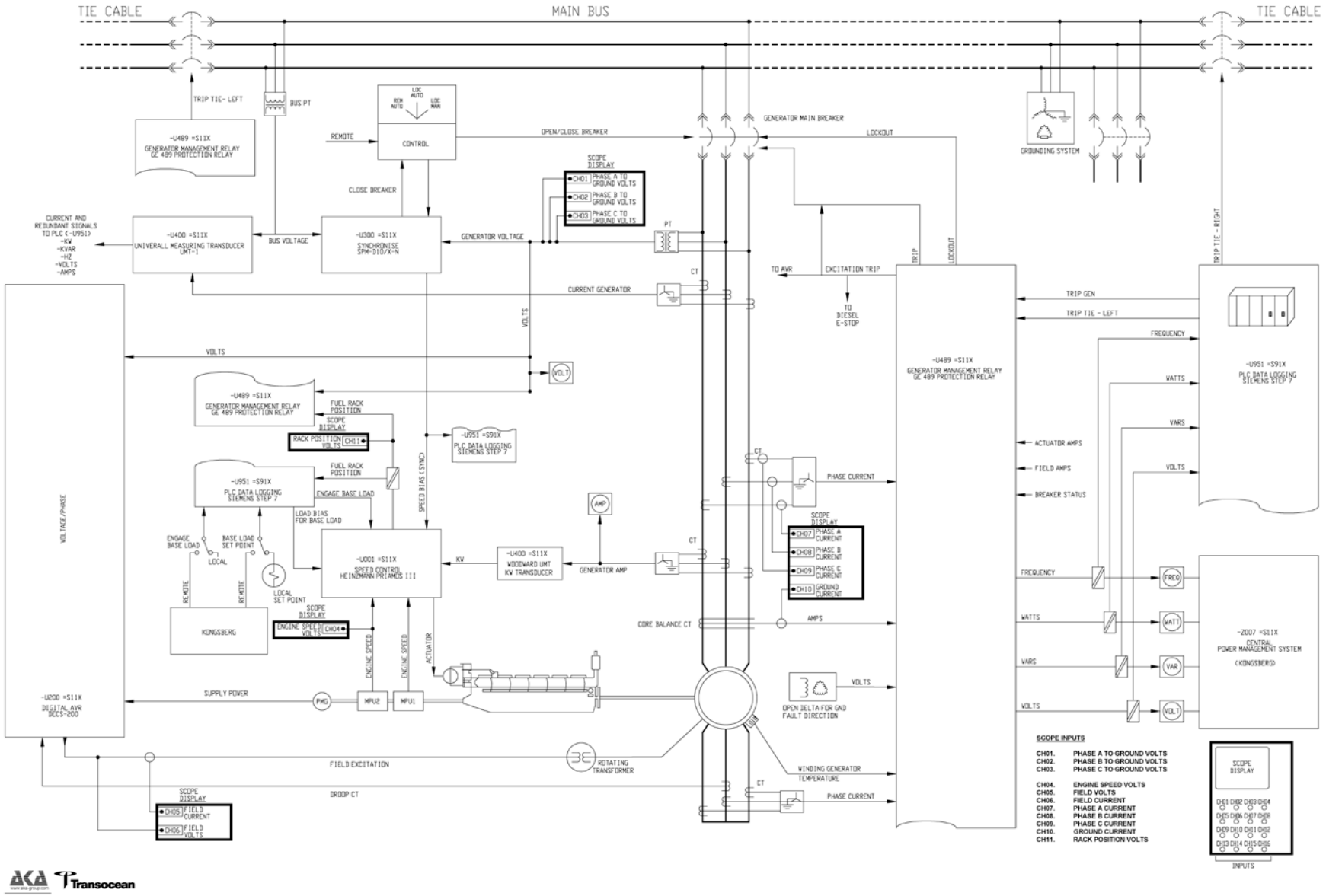

AFT
PORT
CENTER
STBD
FWD
TOP
NOTES
BREAKERS TO BE CLOSED
BREAKERS TO BE OPEN
Back Feed Only
Back Feed Only





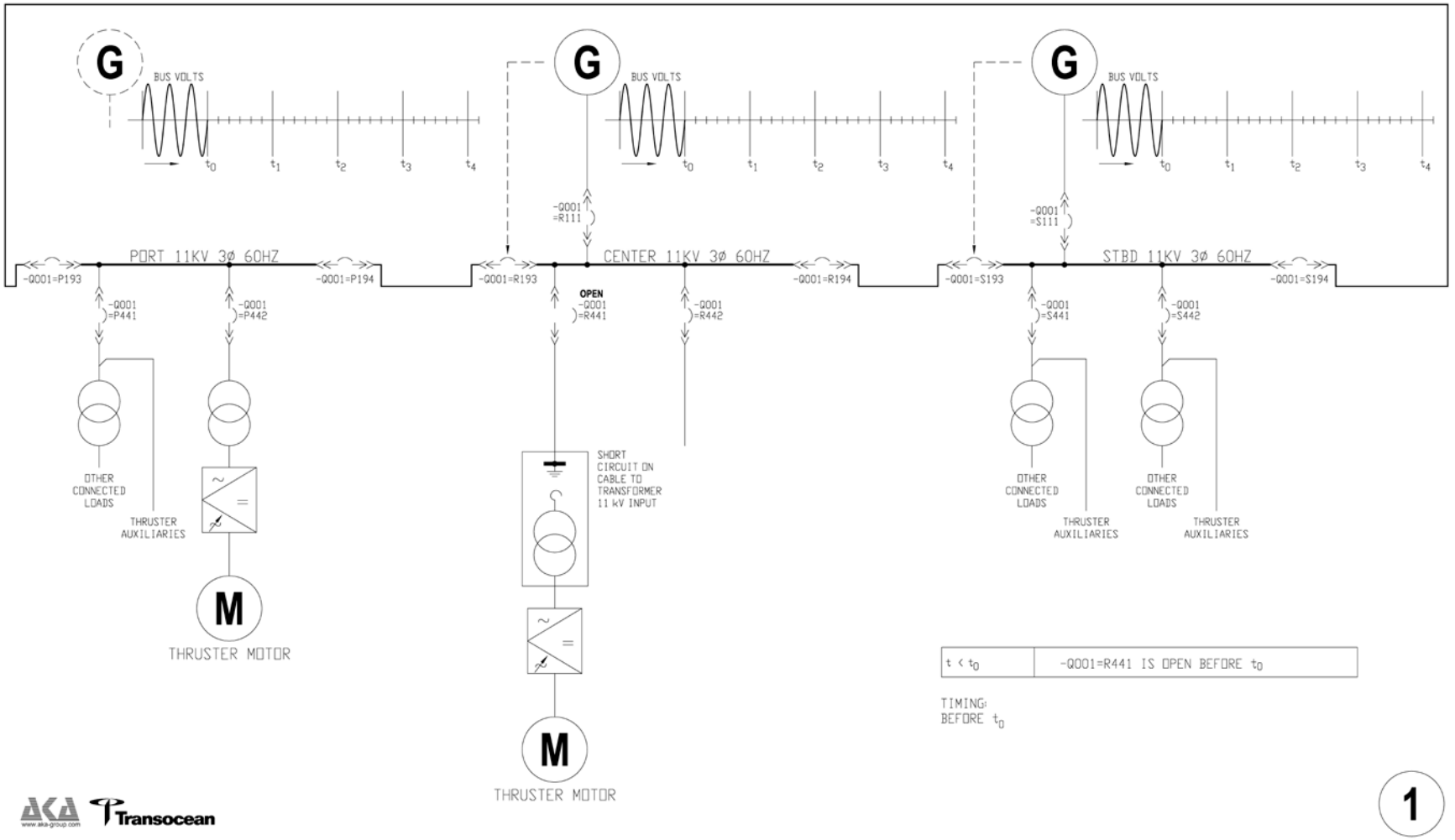
SCOPE INPUTS

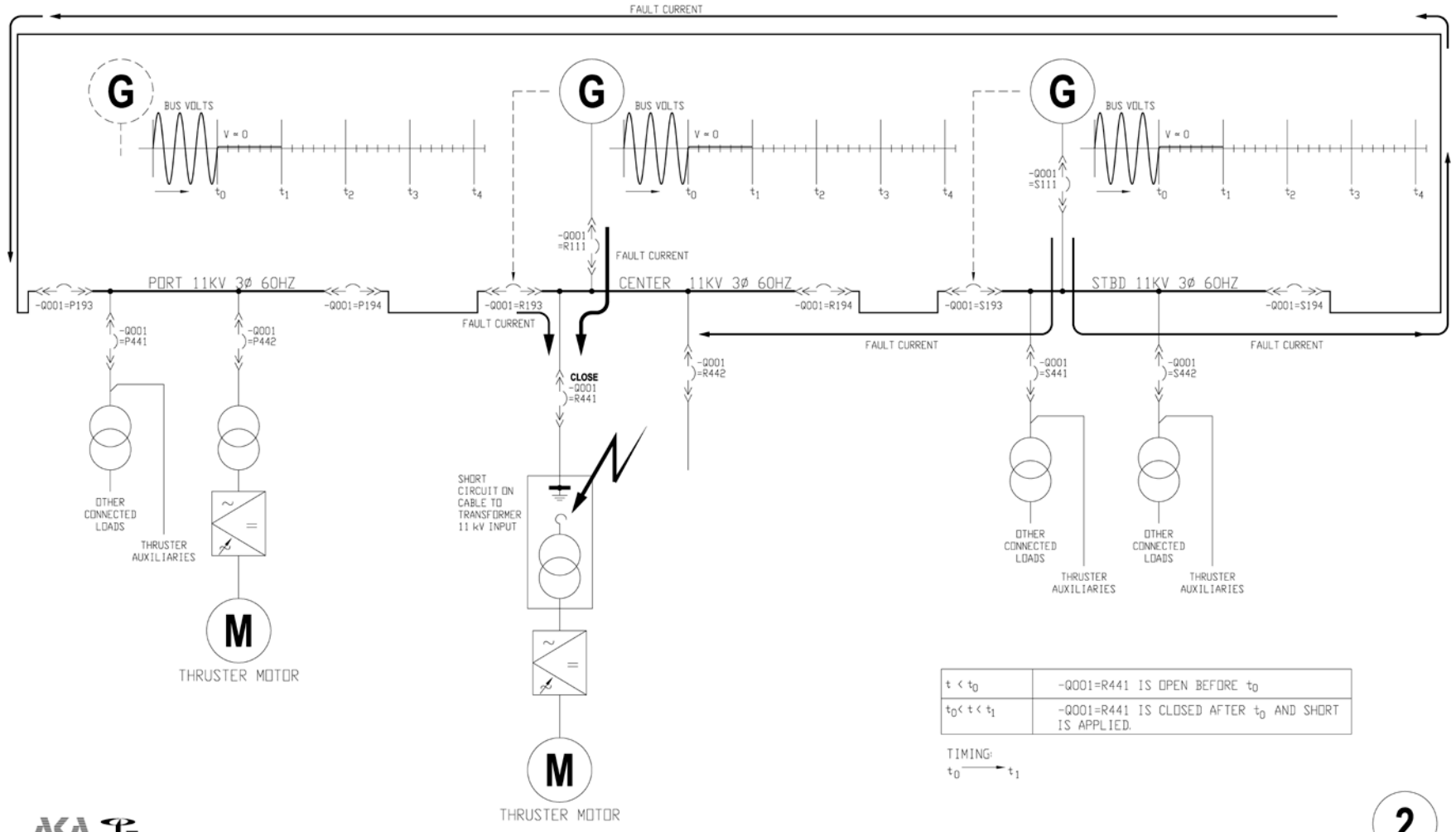
CH01.	GROUND CURRENT
CH02.	PHASE A CURRENT
CH03.	PHASE B CURRENT
CH04.	PHASE C CURRENT
CH05.	PORT TIE STATUS
CH06.	STBD TIE STATUS
CH07.	BREAKER STATUS


TIE CABLE
MAIN BUS
TIE CABLE
TRIP TIE- LEFT
BUS PT
-U489 =S11X
GENERATOR MANAGEMENT RELAY
GE 489 PROTECTION RELAY
REMOTE
CONTROL
OPEN/CLOSE BREAKER
GENERATOR MAIN BREAKER
LOCKOUT
GROUNDING SYSTEM
CLOSE BREAKER
SCOPE DISPLAY
CH01 PHASE A TO GROUND VOLTS
CH02 PHASE B TO GROUND VOLTS
CH03 PHASE C TO GROUND VOLTS
CURRENT AND REDUNDANT SIGNALS TO PLC (-U951)
-KW
-KVAR
-HZ
-VOLTS
-AMPS
-U400 =S11X
UNIVERALL MEASURING TRANSDUCER UMT-1
BUS VOLTAGE
-U300 =S11X
SYNCHRONISE SPM-D1D/X-N
GENERATOR VOLTAGE
PT
CT
CURRENT GENERATOR
TO AVR
EXCITATION TRIP
TRIP
LOCKOUT
TO DIESEL E-STOP
TRIP TIE - RIGHT
TRIP GEN
TRIP TIE - LEFT
FREQUENCY
WATTS
VARS
VOLTS
VOLTS
VOLT
-U489 =S11X
GENERATOR MANAGEMENT RELAY
GE 489 PROTECTION RELAY
FUEL RACK POSITION
SCOPE DISPLAY
RACK POSITION VOLTS CH11
-U951 =S91X
PLC DATA LOGGING SIEMENS STEP 7
-U951 =S91X
PLC DATA LOGGING SIEMENS STEP 7
FUEL RACK POSITION
ENGAGE BASE LOAD
LOAD BIAS FOR BASE LOAD
SPEED BIAS (SYNC)
VOLTAGE/PHASE
ENGAGE BASE LOAD
BASE LOAD SET POINT
LOCAL
REMOTE
REMOTE
LOCAL SET POINT
KONGSBERG
-U001 =S11X
SPEED CONTROL HEINZMANN PRIAMOS III
KW
-U400 =S11X
WOODWARD UMT KW TRANSDUCER
GENERATOR AMP
AMP
CT
PHASE CURRENT
SCOPE DISPLAY
CH07 PHASE A CURRENT
CH08 PHASE B CURRENT
CH09 PHASE C CURRENT
CH10 GROUND CURRENT
CORE BALANCE CT
AMPS
SCOPE DISPLAY
ENGINE SPEED VOLTS CH04
ENGINE SPEED
ENGINE SPEED
ACTUATOR
-U200 =S11X
DIGITAL AVR DECS-200
SUPPLY POWER
PMG
MPU2
MPU1
VOLTS
OPEN DELTA FOR GND FAULT DIRECTION
ACTUATOR AMPS
FIELD AMPS
BREAKER STATUS
FREQUENCY
WATTS
VARS
VOLTS
FREQ
WATT
VAR
VOLT
-Z007 =S11X
CENTRAL POWER MANAGEMENT SYSTEM (KONGSBERG)
FIELD EXCITATION
ROTATING TRANSFORMER
WINDING GENERATOR TEMPERATURE
DROOP CT
SCOPE DISPLAY
CH05 FIELD CURRENT
CH06 FIELD VOLTS
PHASE CURRENT
SCOPE INPUTS
CH01. PHASE A TO GROUND VOLTS
CH02. PHASE B TO GROUND VOLTS
CH03. PHASE C TO GROUND VOLTS
CH04. ENGINE SPEED VOLTS
CH05. FIELD VOLTS
CH06. FIELD CURRENT
CH07. PHASE A CURRENT
CH08. PHASE B CURRENT
CH09. PHASE C CURRENT
CH10. GROUND CURRENT
CH11. RACK POSITION VOLTS
SCOPE DISPLAY
INPUTS

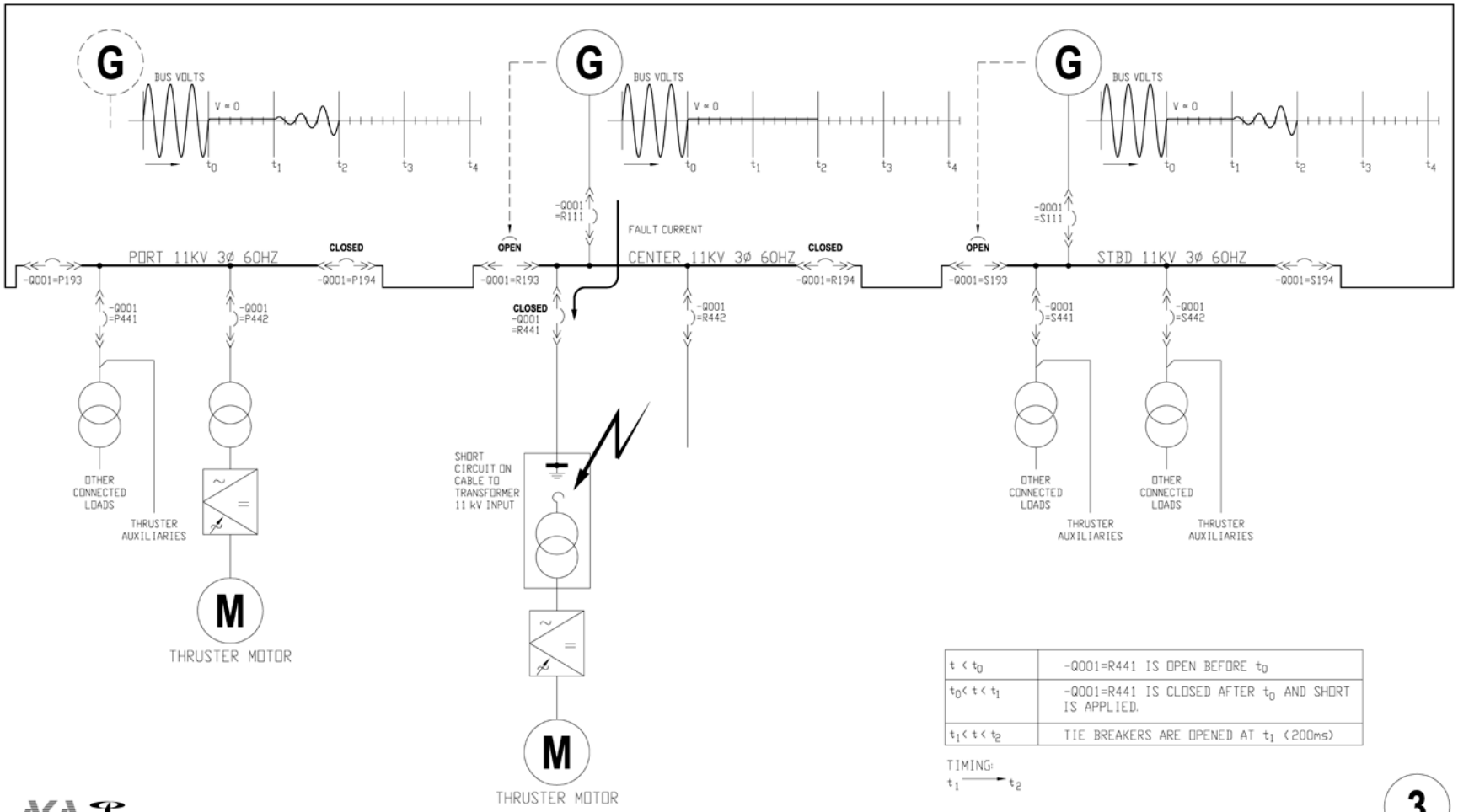
Center Generator Scope Inputs

CH01	Phase A To Ground Volts	(Voltage Probe)
CH02	Phase B To Ground Volts	(Voltage Probe)
CH03	Phase C To Ground Volts	(Voltage Probe)
CH04	Engine Speed	(Voltage Probe)
CH05	Field Volts	(Voltage Probe)
CH06	Field Current	(Voltage Probe)
CH07	Phase A Current	(Current Probe)
CH08	Phase B Current	(Current Probe)
CH09	Phase C Current	(Current Probe)
CH10	Ground Current	(Current Probe)
CH11	Rack Position	(Voltage Probe)
CH12	Q01=R441 Fault Breaker Status	(Voltage Probe)


G
BUS VOLTS
t_0 t_1 t_2 t_3 t_4
-Q001 =R111
-Q001 =S111
PORT 11KV 3Ø 60HZ
CENTER 11KV 3Ø 60HZ
STBD 11KV 3Ø 60HZ
-Q001=P193
-Q001=P194
-Q001=R193
-Q001=R194
-Q001=S193
-Q001=S194
-Q001 =P441
-Q001 =P442
OPEN
-Q001 =R441
-Q001 =R442
-Q001 =S441
-Q001 =S442
OTHER CONNECTED LOADS
THRUSTER AUXILIARIES
SHORT CIRCUIT ON CABLE TO TRANSFORMER 11 kV INPUT
M
THRUSTER MOTOR
$t < t_0$
-Q001=R441 IS OPEN BEFORE t_0
TIMING: BEFORE t_0
1



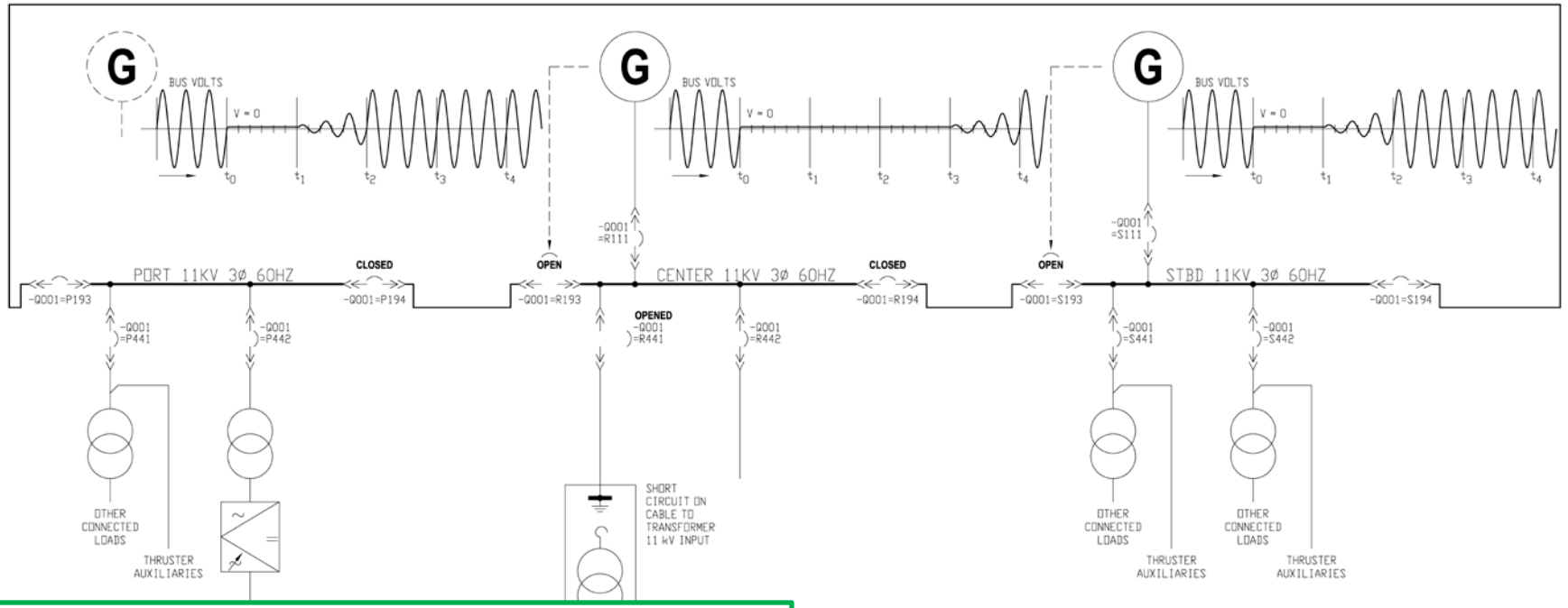
Objective:
The fault currents are as predicted.



3

Objective:

Tie breakers open and split the plant into independent 11kV segments. Stbd Main bus voltage recovers successfully.



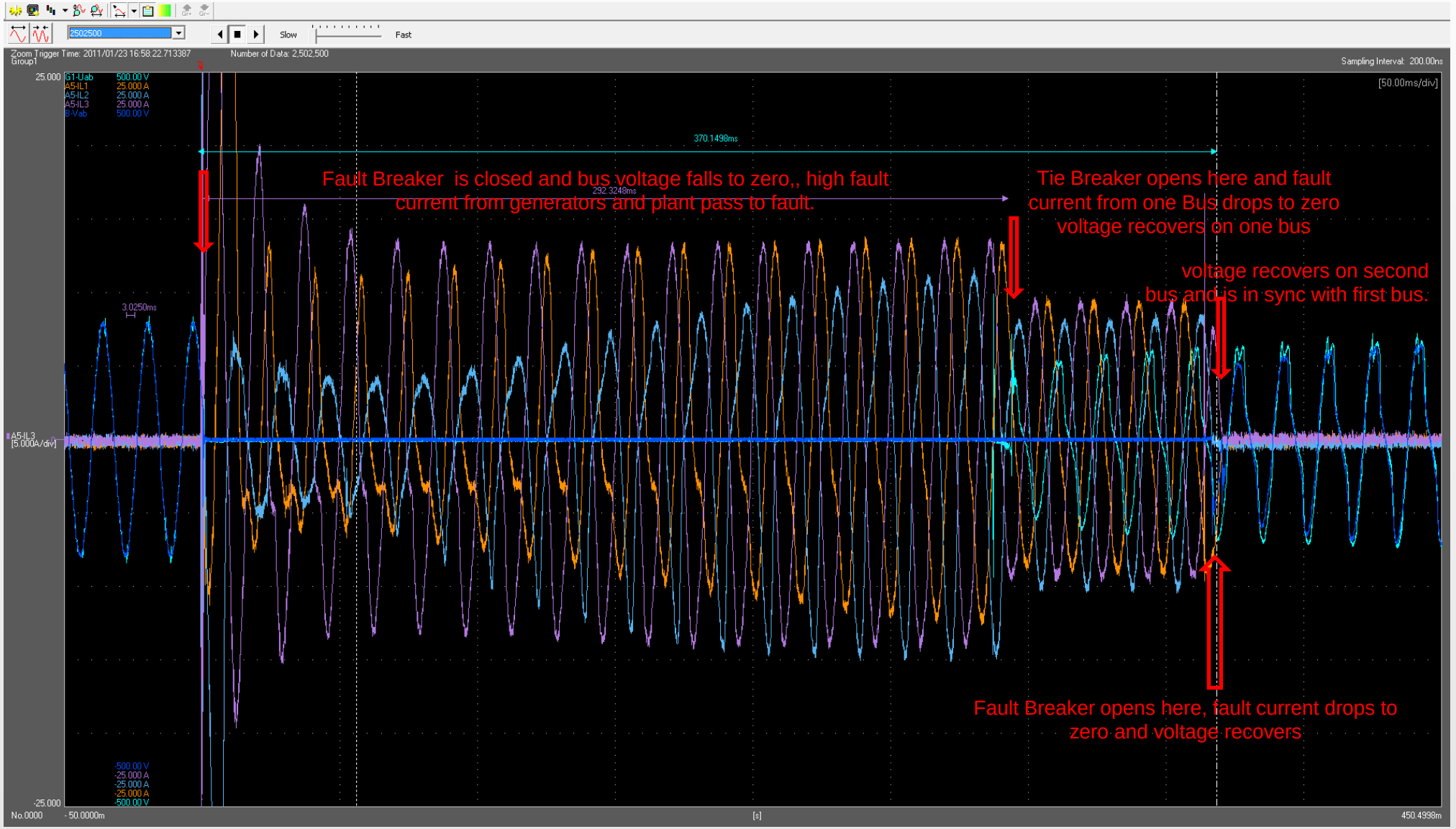
Objective:

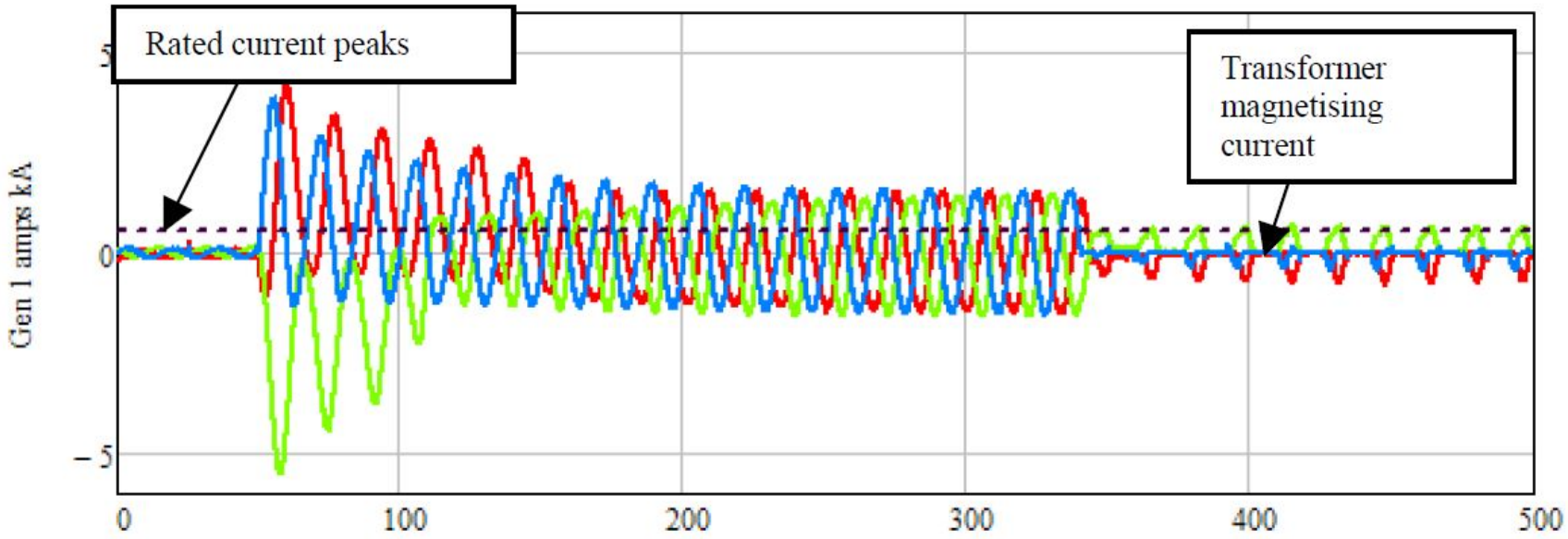
The breaker feeding the fault opens.
Generators do not loose synchronism.
Transformer re-magnetization is successful.
Generators and critical DP loads return to operation without manual intervention.
Loads with a DC Bus link do not fail on over voltage. (voltage doubling effect)

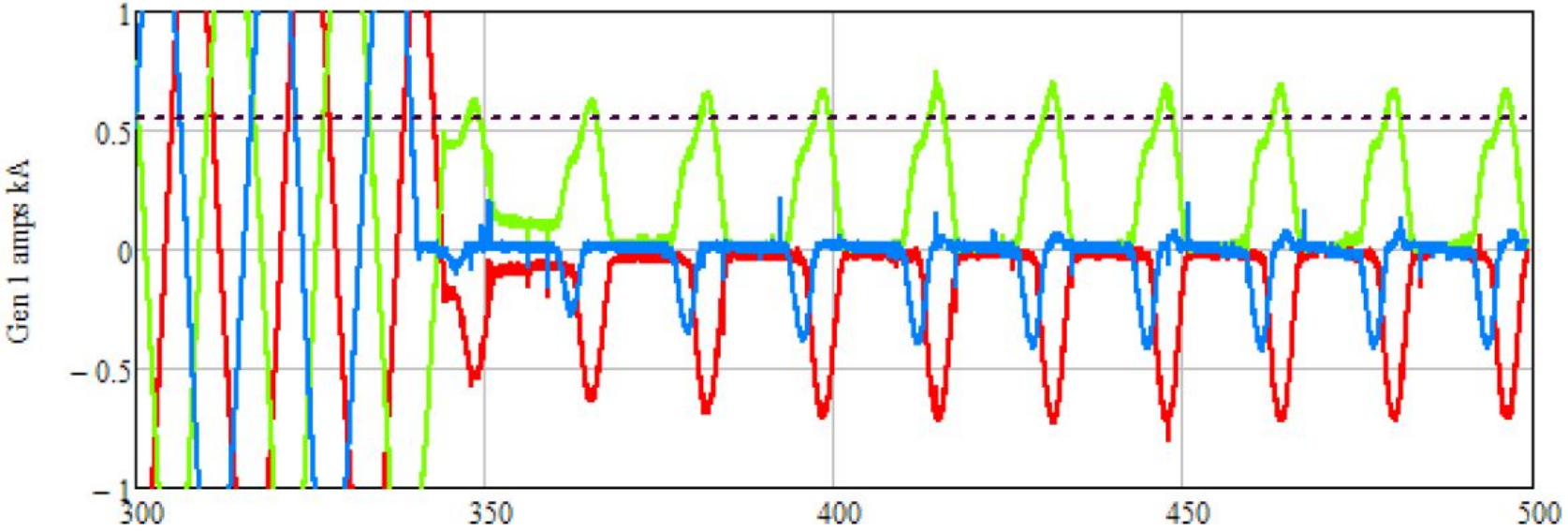
$t < t_0$	-Q001=R441 IS OPEN BEFORE t_0
$t_0 < t < t_1$	-Q001=R441 IS CLOSED AFTER t_0 AND SHORT IS APPLIED.
$t_1 < t < t_2$	TIE BREAKERS ARE OPENED AT t_1 (200ms)
$t_2 < t < t_3$	-Q001=R441 IS OPENED AT t_3 (400ms)
$t_3 < t$	-Q001=R441 IS OPENED AT t_3 (400ms)

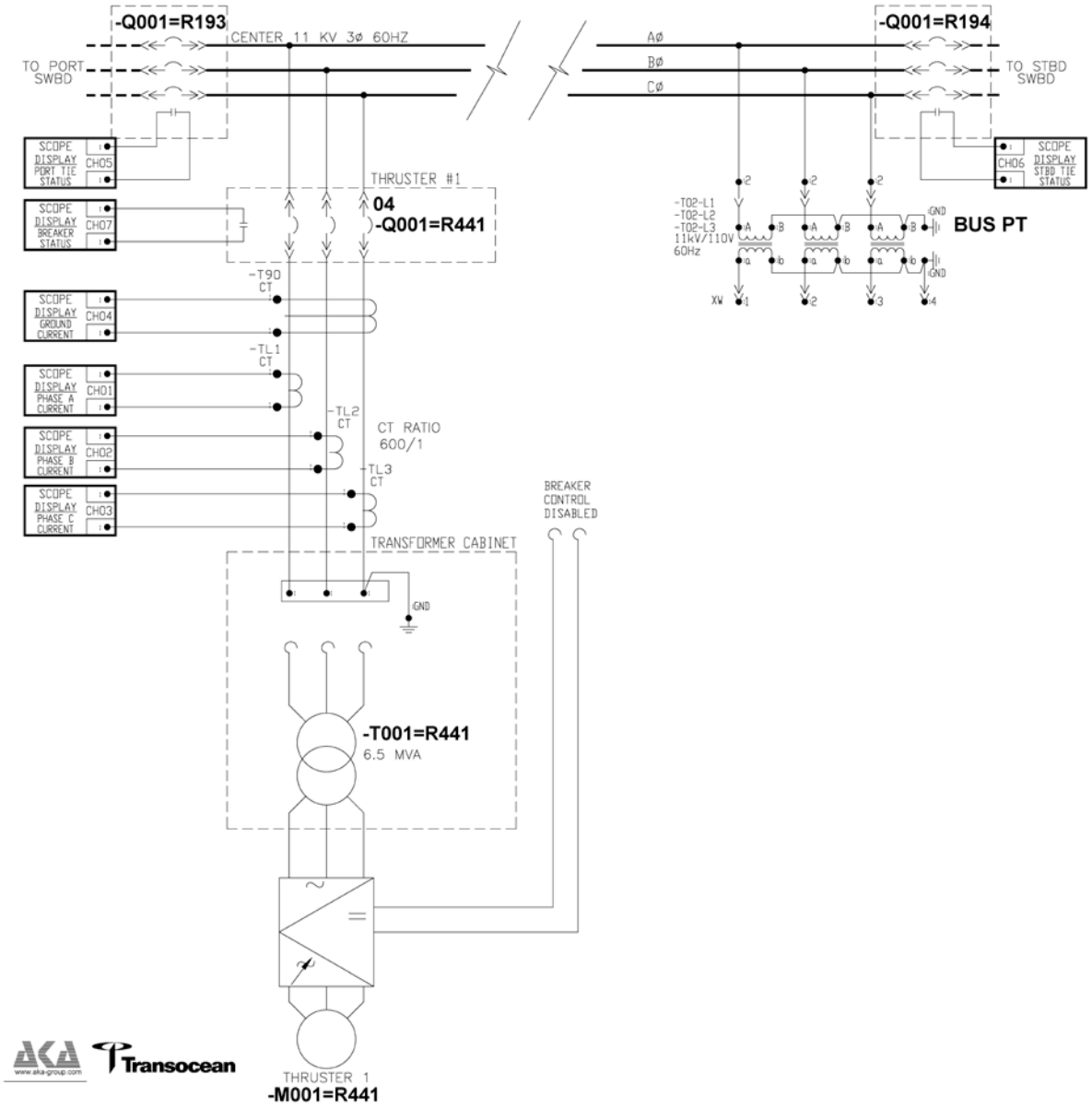
TIMING: $t_2 \rightarrow t_3 \rightarrow t_4$

4


Slow
Fast
Zoom Trigger Time: 2011/01/23 16:58:22.713387
Number of Data: 2,502,500
Group1
Sampling Interval: 200.00ns
[50.00ms/div]
25.000
G1-Uab 500.00 V
A5-IL1 25.000 A
A5-IL2 25.000 A
A5-IL3 25.000 A
B-Vab 500.00 V
370.1498ms
292.3248ms
3.0250ms
Fault Breaker is closed and bus voltage falls to zero,, high fault current from generators and plant pass to fault.
Tie Breaker opens here and fault current from one Bus drops to zero voltage recovers on one bus
voltage recovers on second bus and is in sync with first bus.
A5-IL3
[5.000A/div]
Fault Breaker opens here, fault current drops to zero and voltage recovers
-500.00 V
-25.000 A
-25.000 A
-25.000 A
-500.00 V
-25.000
No.0000
- 50.0000m
[s]
450.4998m

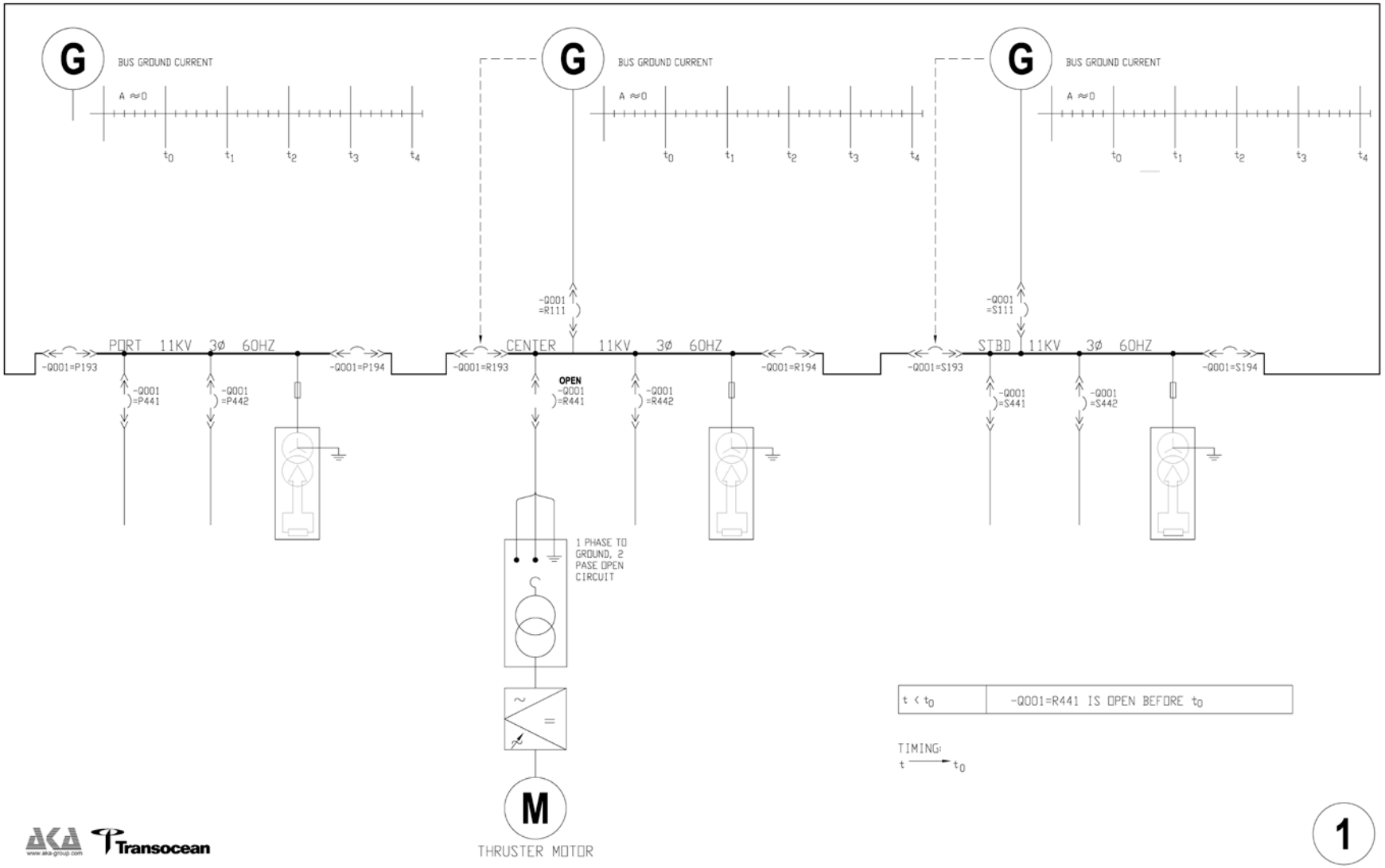

Rated current peaks
Transformer magnetising current
Gen 1 amps kA
5
0
– 5
0
100
200
300
400
500

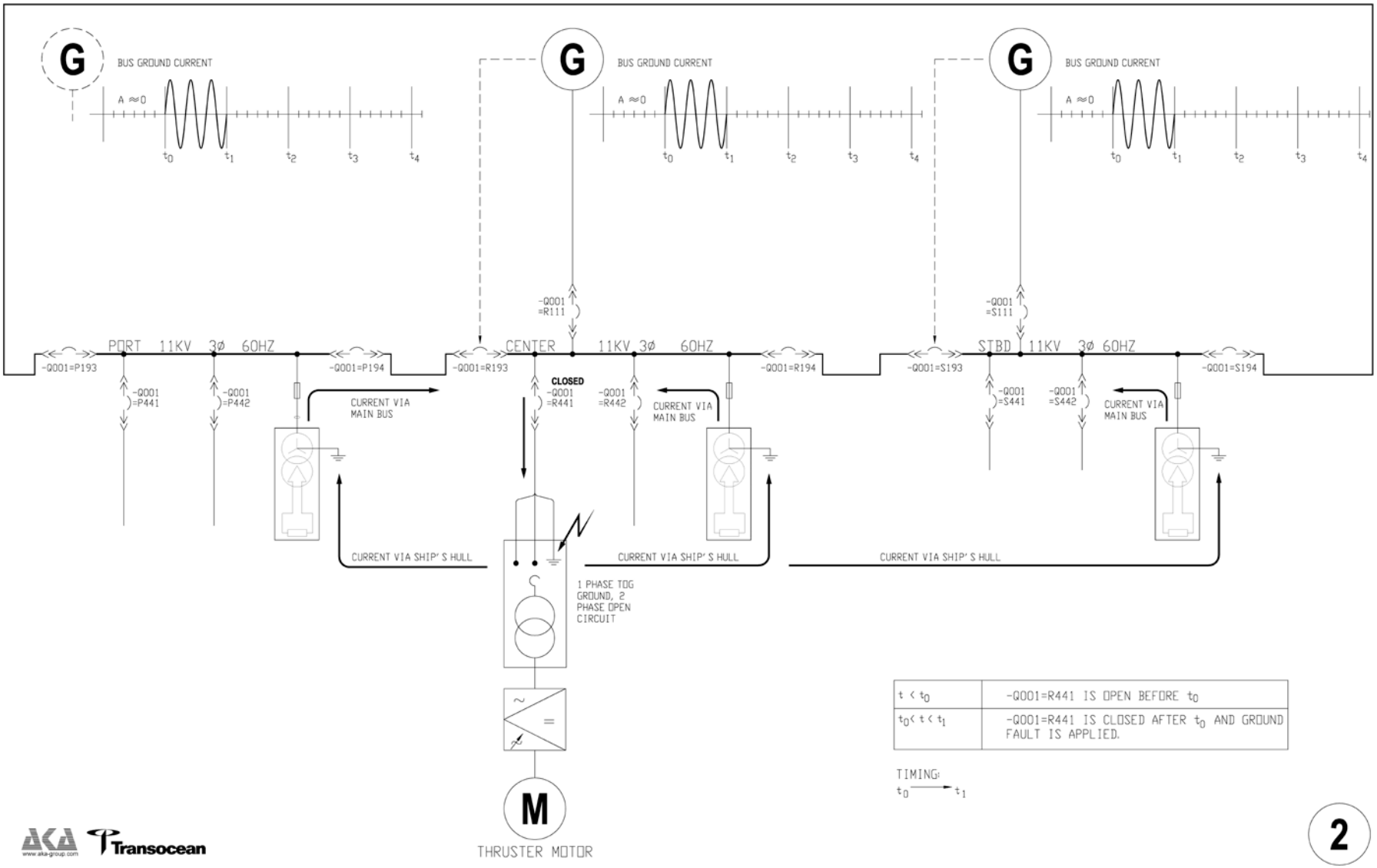

Gen 1 amps kA
1
0.5
0
– 0.5
– 1
300
350
400
450
500



SCOPE INPUTS

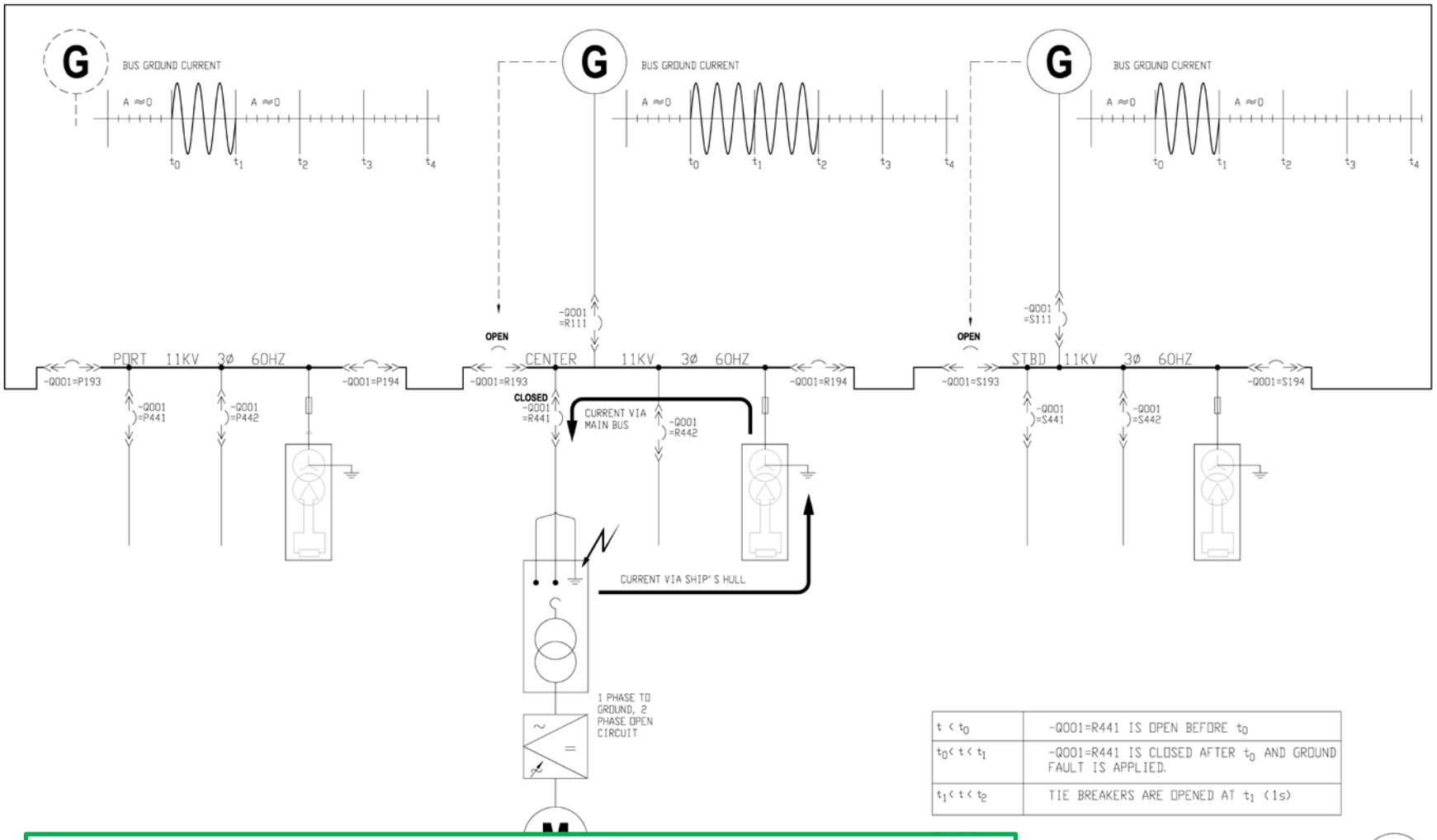
CH01.	GROUND CURRENT
CH02.	PHASE A CURRENT
CH03.	PHASE B CURRENT
CH04.	PHASE C CURRENT
CH05.	PORT TIE STATUS
CH06.	STBD TIE STATUS
CH07.	BREAKER STATUS


G
BUS GROUND CURRENT
A ≈0
t_0 t_1 t_2 t_3 t_4
PORT 11KV 3ø 60HZ
CENTER 11KV 3ø 60HZ
STBD 11KV 3ø 60HZ
-Q001=P193
-Q001=P194
-Q001=R193
-Q001=R194
-Q001=S193
-Q001=S194
-Q001 =R111
-Q001 =S111
-Q001 =P441
-Q001 =P442
OPEN
-Q001 =R441
-Q001 =R442
-Q001 =S441
-Q001 =S442
1 PHASE TO GROUND, 2 PASE OPEN CIRCUIT
M
THRUSTER MOTOR
t < t_0
-Q001=R441 IS OPEN BEFORE t_0
TIMING:
t → t_0
1



Objective:

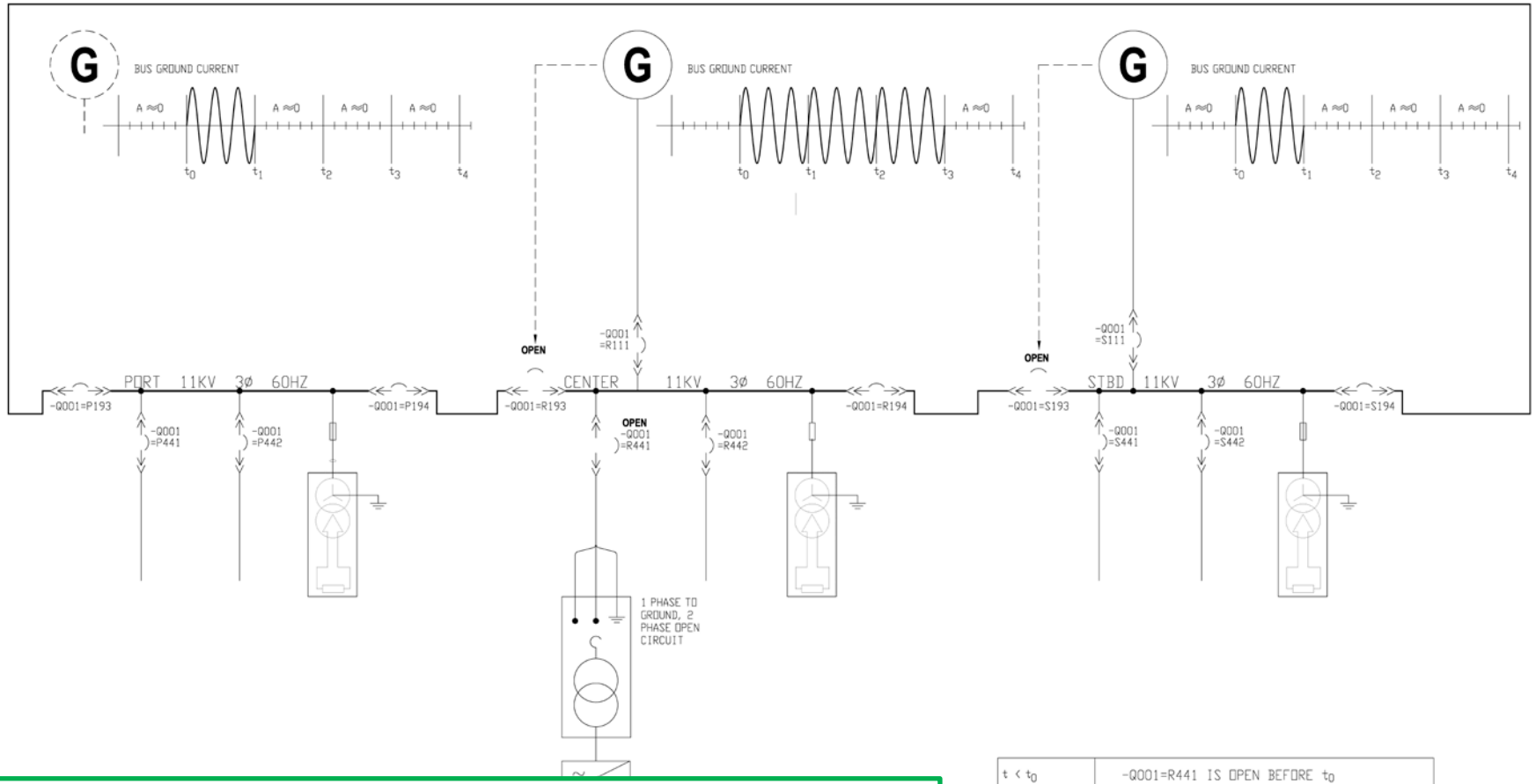
The ground fault currents are as predicted



Objective:

Tie breakers open and split the plant into independent 11kV segments. Stbd Main bus voltage to ground recovers successfully

3



$t < t_0$	-Q001=R441 IS OPEN BEFORE t_0
$t_0 < t < t_1$	-Q001=R441 IS CLOSED AFTER t_0 AND GROUND FAULT IS APPLIED.
$t_1 < t < t_2$	TIE BREAKERS ARE OPENED AT t_1 (1s)
$t_2 < t < t_3$	-Q001=R441 IS OPENED AT t_3 (1.5ms)
$t_3 < t$	SYSTEM STABLE

TIMING: $t_2 \rightarrow t_3 \rightarrow t_4$

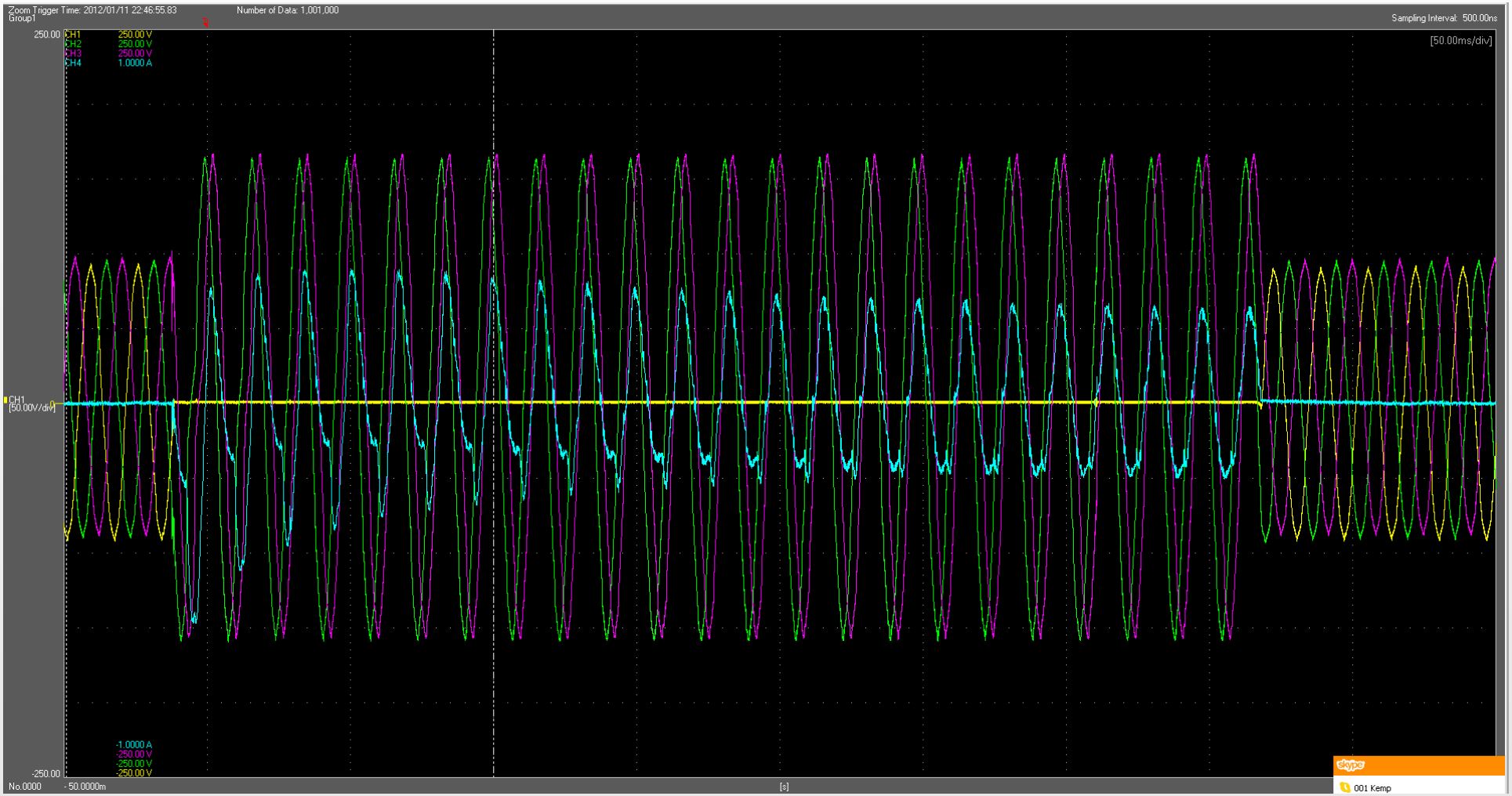
4

Objective:

Main bus voltage to ground recovers successfully

The breaker feeding the fault opens.

Generators and critical DP loads remain operation without manual intervention.


Zoom Trigger Time: 2012/01/11 22:46:55.83
Group1
Number of Data: 1,001,000
Sampling Interval: 500.00ns
[50.00ms/div]
250.00
CH1 250.00 V
CH2 250.00 V
CH3 250.00 V
CH4 1.0000 A
CH1
[50.00V/div]
-1.0000 A
-250.00 V
-250.00 V
-250.00 V
-250.00
No.0000
- 50.0000m
[s]
skype
001 Kemp

- **Conclusion**
  - It is possible to demonstrate DP power and propulsion plant response to an aggressive power disturbance.
  - Measures can be taken to limit the physical stress of demonstration
  - The confidence in the plant is not due to such demonstrations alone.

    The health of the entire infrastructure must endure similar aggressive disturbance verification (much less energy involved, but aggressive none the less).

- **The Question that will drive design:**

With a well designed, documented and tested plant;

How will it respond to a "Known" failure, when there is at least one hidden failure in the plant?