Generator Motoring Protection – Are You Protected?

Dale Finney, Michael Thompson,
Normann Fischer, and Amandeep Kalra
Schweitzer Engineering Laboratories, Inc.

Outline

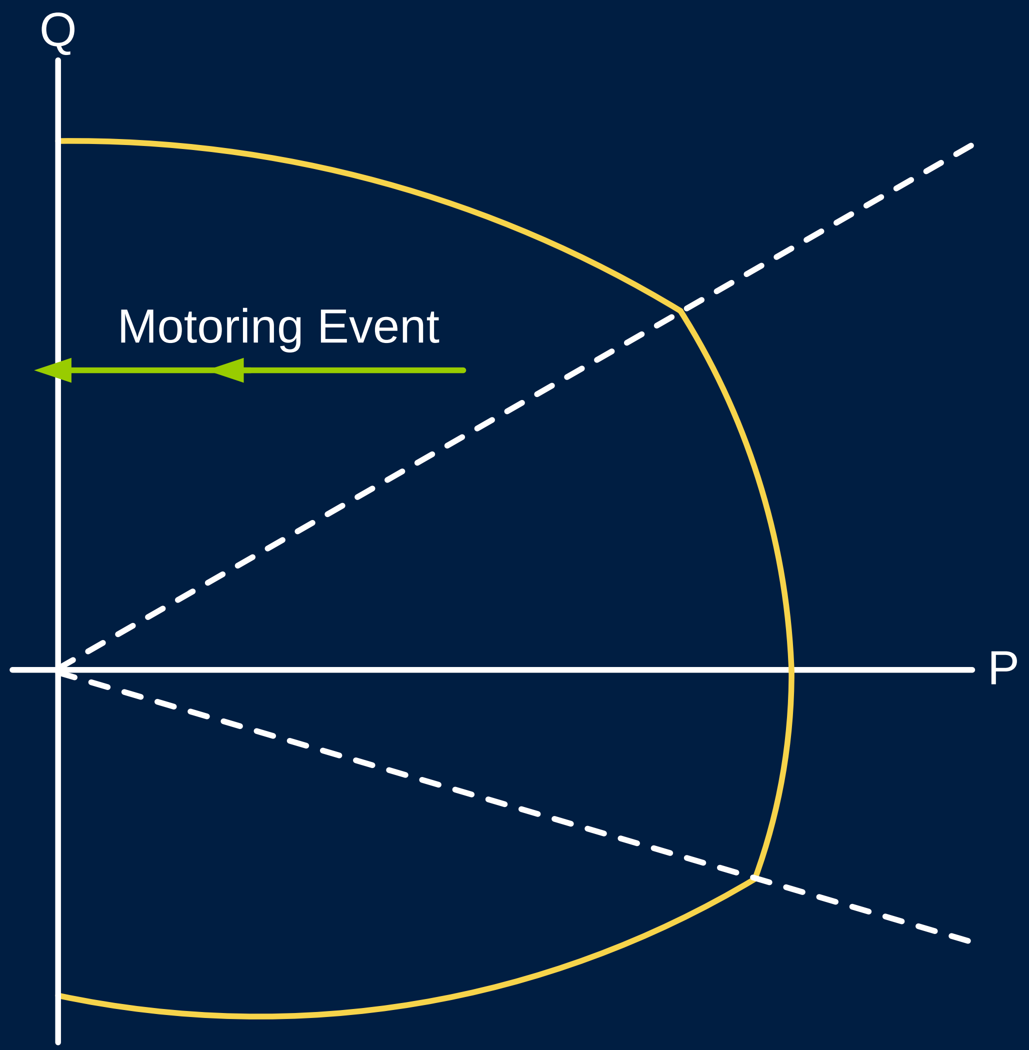
- Motoring protection
- Instrument transformer errors
- Directional power relays
- New algorithm
- Algorithm implementation on automation controller

Generator Motoring

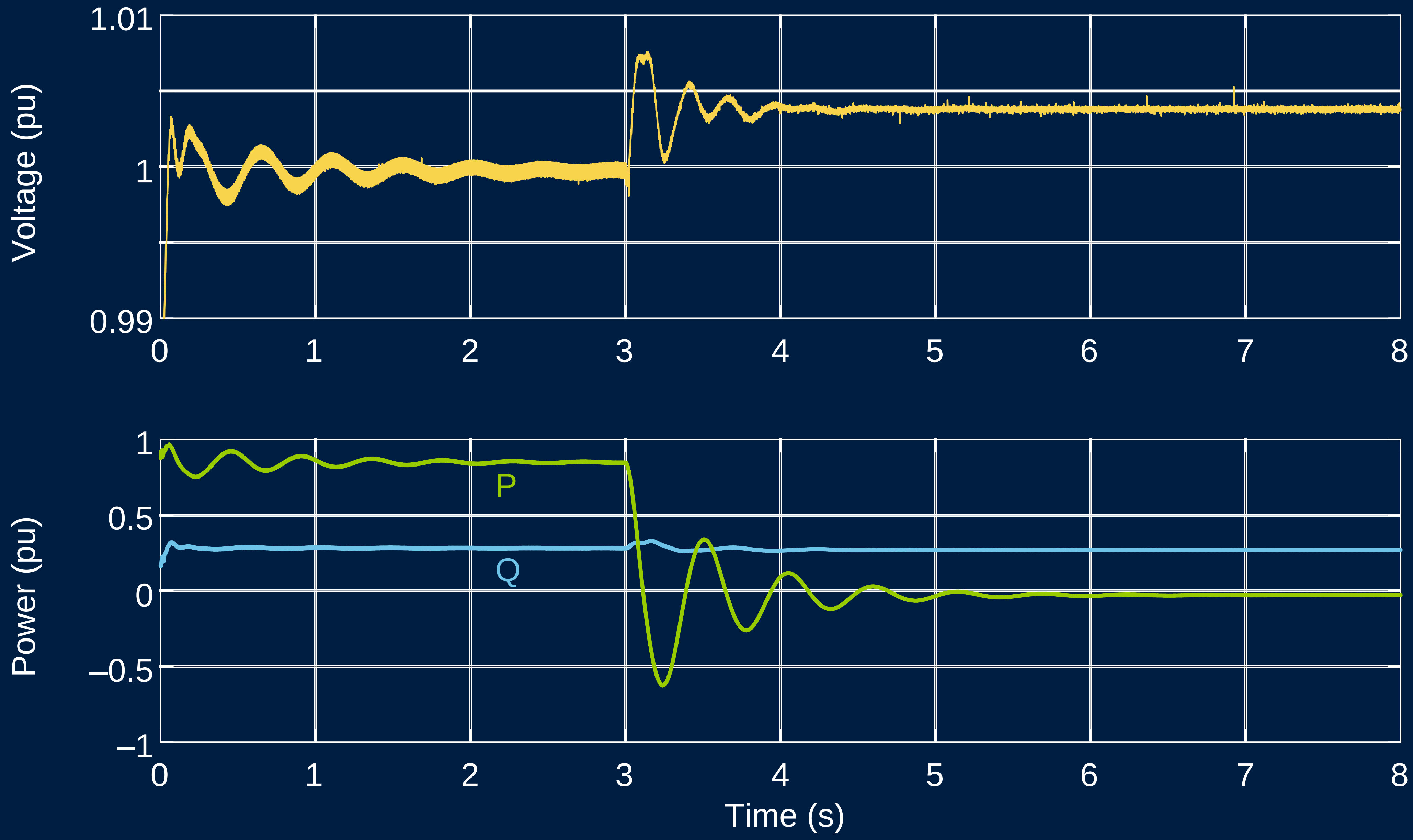
- Directional power relays serve two purposes
  - Control during sequential shutdown
  - Protect during inadvertent motoring
- Steam turbines draw low motoring power
- Windage without steam flow can overheat turbine

Inadvertent Motoring

- Sequential shutdown
  - P and Q are ramped to zero
  - Ensuring that valves are closed prevents overspeed
- Inadvertent motoring
  - P is slightly negative
  - Q is near pre-event levels

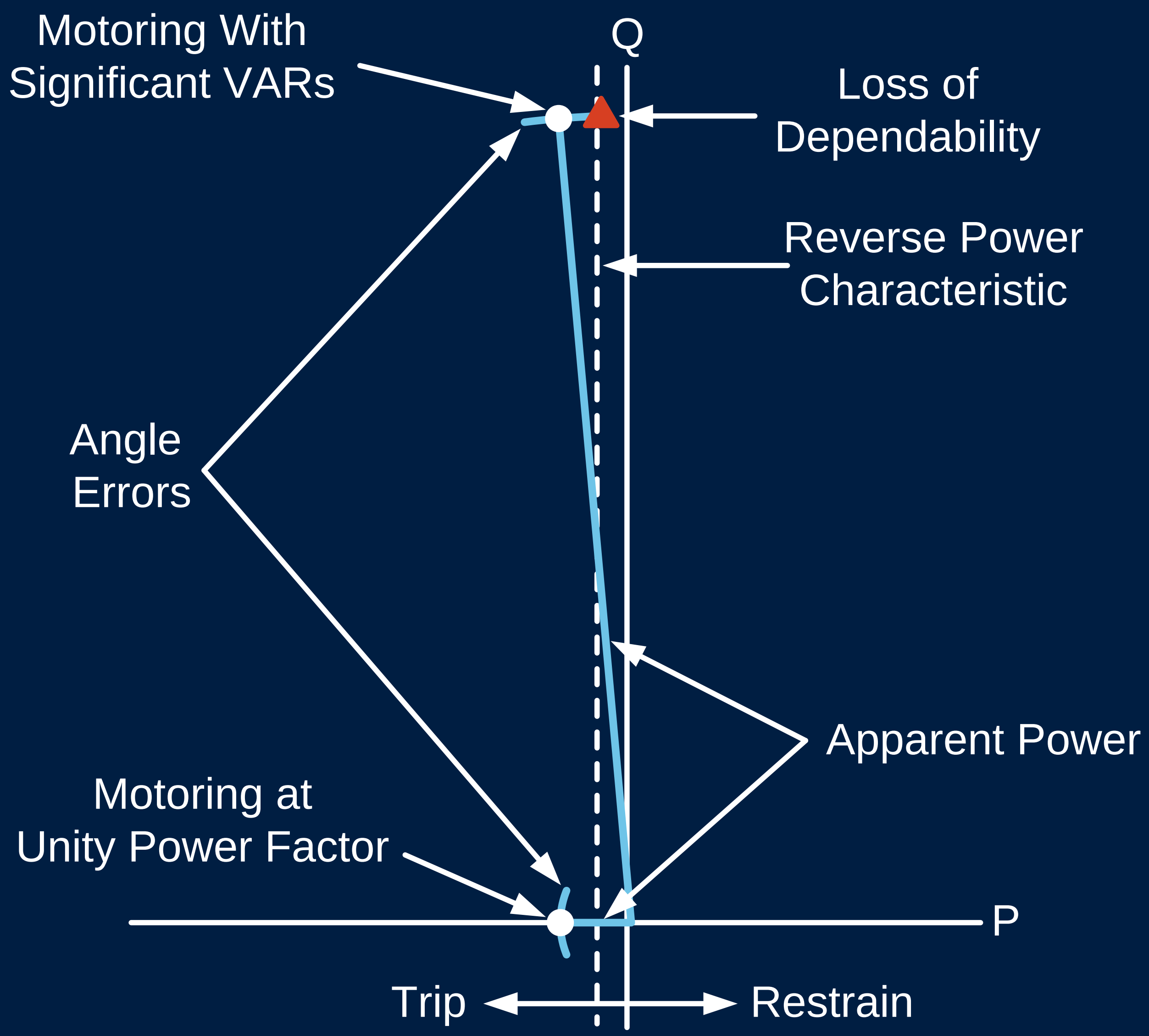


Motoring Simulation (AVR in Service)



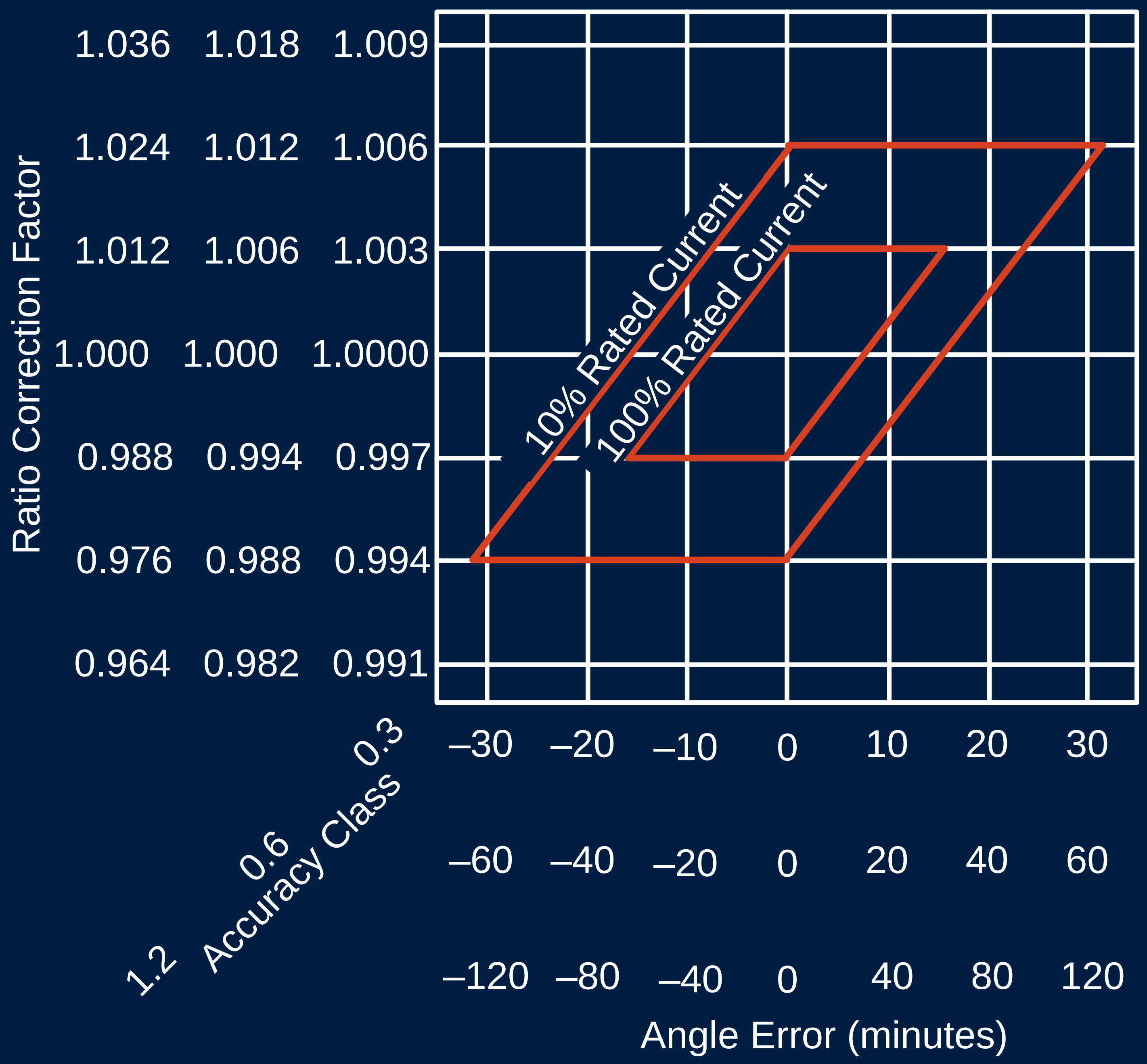
Loss of Dependability

- Angle error is magnified
- 0.25 degree *total* error can cause loss of dependability
- Reverse power relays that operate reliably for normal shutdown may *not* protect

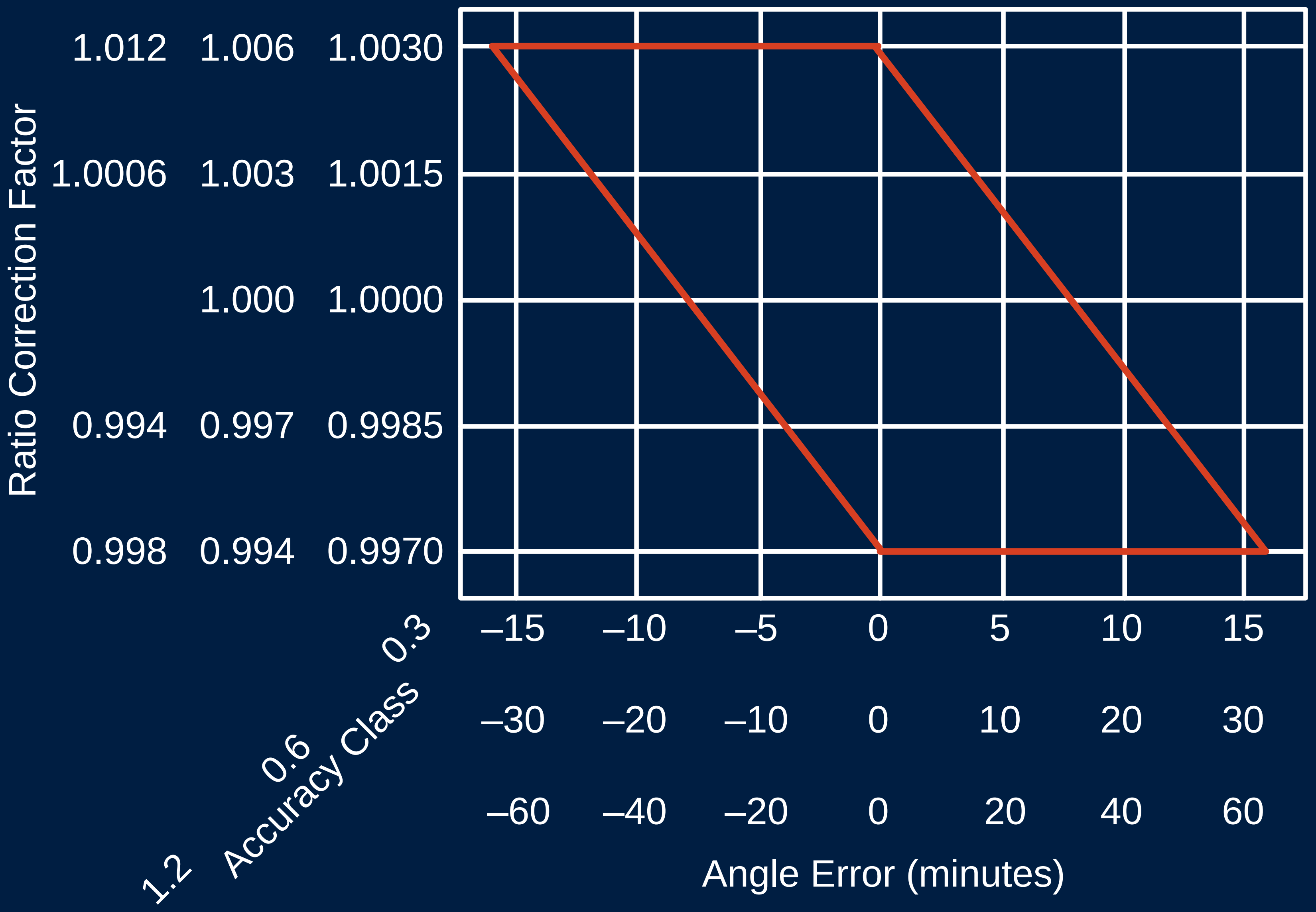


IEEE C57.13 – Metering CTs

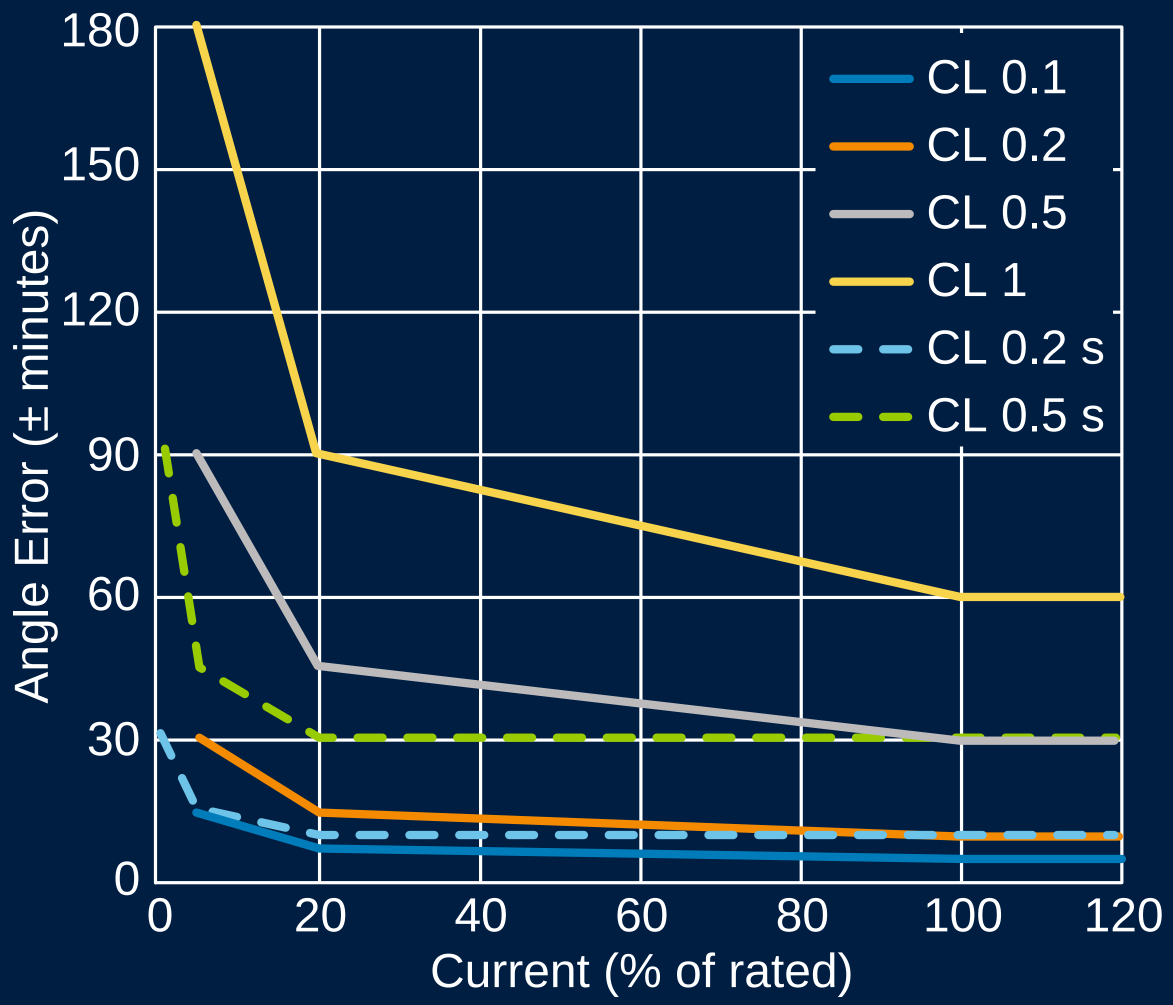
- Metering CTs – specified down to 10% rated current
- Relay CTs – no angle error limit specified



IEEE C57.13 – Metering VTs



IEC 61869-2 and IEC 61869-3



Relay CTs

Class 5P – ±60 minutes

Class 10P – not specified

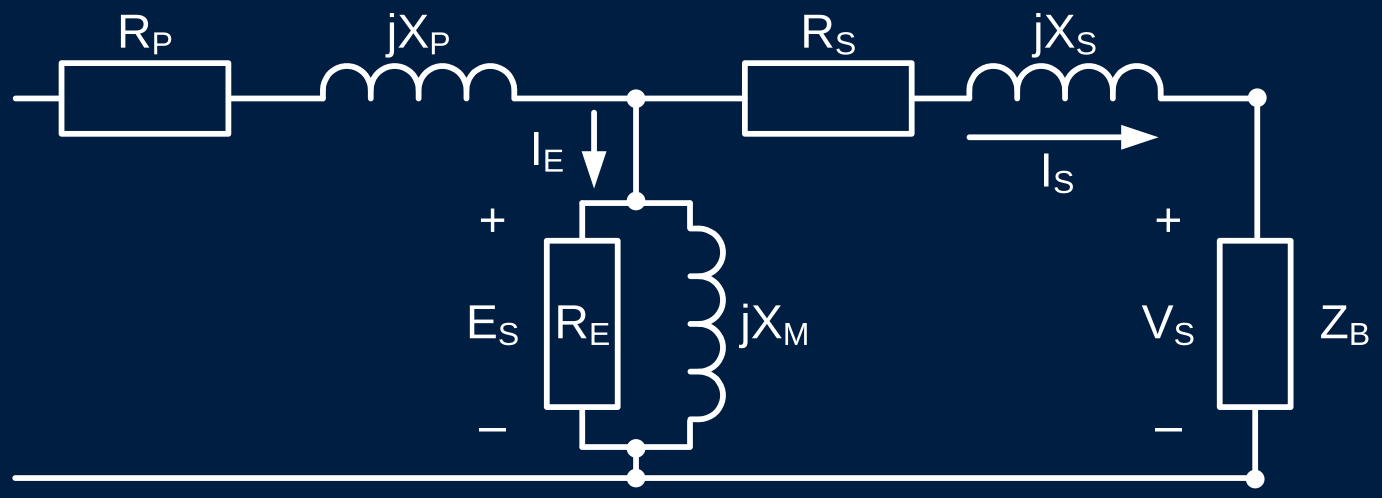
IEC 61869-2 and IEC 61869-3

Protection VT Angle Error Limits

Class	Angle Error Limit (minutes)
3P	±120
6P	±240

Instrument Transformer Errors

- Use of protection CTs for reverse power is common practice



- Angle error specifications are at standard burden
  - Lowest errors may not occur at standard burden
  - Low burden is best for transient performance

Example of Manufacturer's Test Data

ANSI 0.3B-1.8

Ratio	Burden (VA)	Power Factor (lag)	Current (%)	Ratio Correction Factor	Ratio Error (%)	Phase Error (minutes)
8000:5	45	0.9	100	1.0009	–0.09	3.3
			10	0.9991	–0.161	10.6

ANSI C400

Ratio	Burden (VA)	Power Factor (lag)	Current (%)	Ratio Error (%)	Phase Error (minutes)
8000:5	100	0.5	100	–0.18	2

Example of CT Field Tests

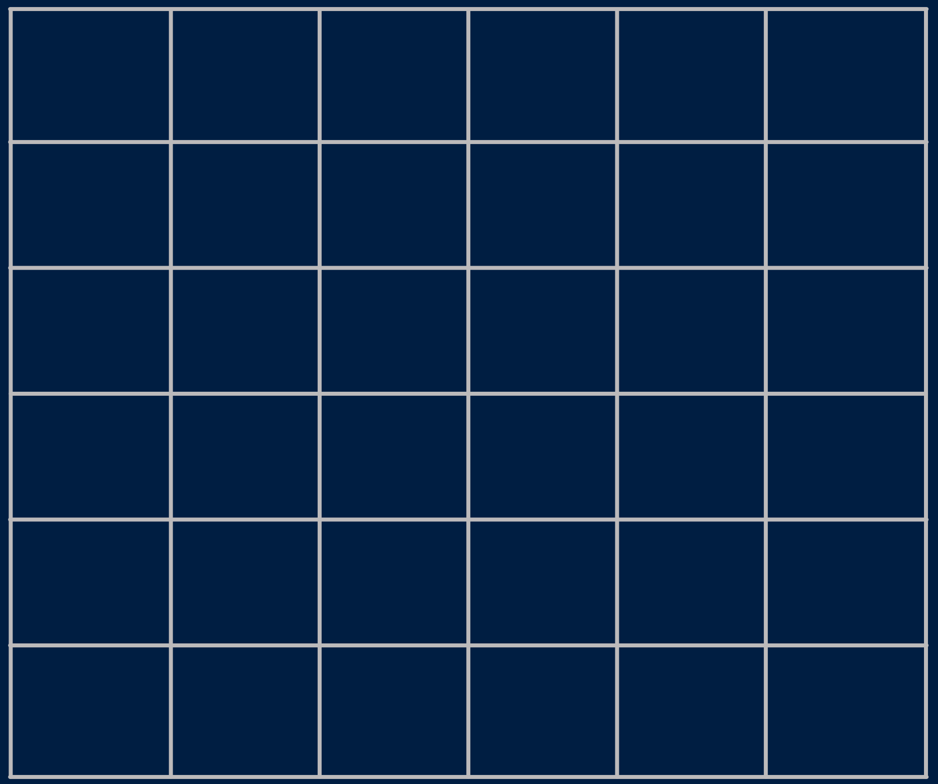
Connected Burden (VA / PF)	Phase Displacement in Minutes at % Rated Current					
	1	5	10	20	50	100
200 / 0.5	2.63	0.83	0.42	0.21	0.06	0.04
100 / 0.5	2.75	1.02	0.64	0.39	0.21	0.13
50 / 0.5	2.80	1.11	0.77	0.52	0.31	0.22
25 / 0.5	2.75	1.15	0.83	0.59	0.37	0.27

Relay Tests at Non-Unity Power Factor

Pre-Event Power Factor	VAR Loading (per unit)
0.900 lagging	0.48
0.950 lagging	0.33
0.990 lagging	0.14
0.995 lagging	0.10
0.999 lagging	0.04
1.000	0
0.999 leading	–0.04
0.995 leading	–0.10
0.990 leading	–0.14
0.950 leading	–0.33
0.900 leading	–0.48

Test Results

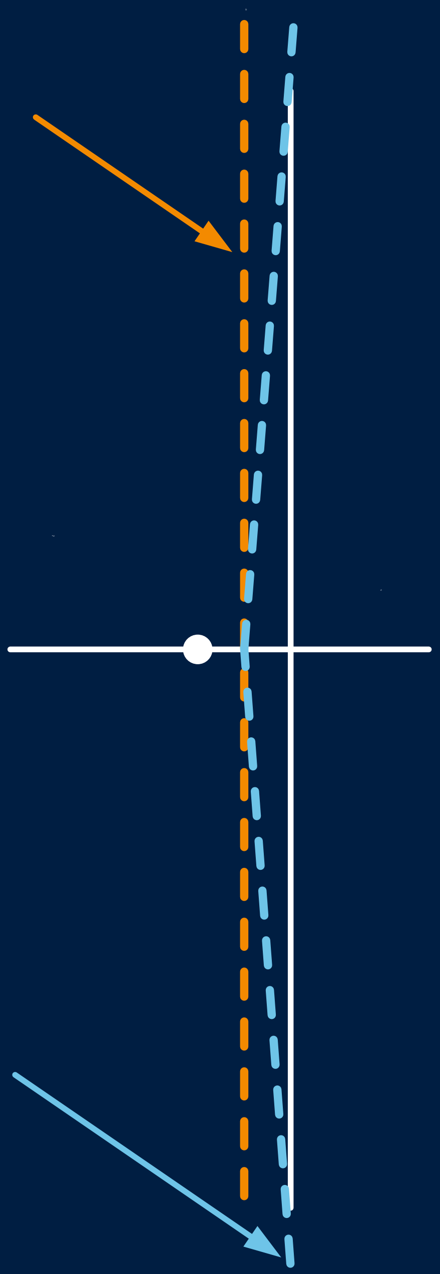
- Electromechanical
  Tilt in characteristic
- Analog, solid-state
  Severe loss of sensitivity
- Microprocessor-based
  Good performance



Are You Protected?

- Microprocessor technology is part of answer
  - Benefits from factory calibration
  - Includes three-phase calculation
  - Responds to fundamental frequency component
- Microprocessor technology does not account for instrument transformer errors
- New algorithm is needed!

Dependability-Biased Characteristic



Application Guidelines

- Enable new algorithm when
  - Motoring power is low (less than 5%) ***and***
  - VARs during motoring may be significant ***and***
  - Angle errors are significant or are not known
- Bias angle setting is not critical

Validation Testing

- New algorithm was implemented on real-time automation controller
- This approach allows new protection algorithms to be quickly implemented, tested, and tuned
- Approach validates algorithm on generator operating in power system

Automation Controller Characteristics

- CT and VT inputs
- RMS and phasor calculations
- Advanced math and logic functions
- High-speed, fixed-rate processing

Controller Logic Implementation

```
VAR_INPUT
Static : BOOL; //Setting to select threshold type dynamic or fixed
PU : REAL; //Setting for Reverse Power Pick Up Value in VA range from -100 VA to 100 VA in steps of 0.01 VA
PTCON : BOOL; //Setting to select connection type either WYE or Delta
P_Dynamic : REAL; //Setting to select dynamic or static threshold
Rev_PU_tim: REAL; //Setting to select Pick-Up Time (2000 msec for testing)
REV_RST_tim : REAL; //Setting to select Reset Time (3000 msec for testing)
Proc_Int : REAL; //Setting for processing interval (10 msec for testing)
P_Thresh : REAL; //Setting for Threshold Value
Py: REAL; // Real Power Value for Wye Connection
Sy : REAL;// Apparent Power Value for Wye Connection
PD : REAL; // Real Power Value for Delta Connection
SD : REAL; // Apparent Power Value for Delta Connection
```

```

IF PTCON THEN // PTCON variables define the connection type selected by the user.
P_Dynamic := PU+Sy*TAN(0.0349); // IF PTCON is True then user selected a WYE Connection. The angle is in radians (2°/57.3 = 0.0349)
ELSIF NOT PTCON THEN
P_Dynamic := PU+SD*TAN(0.0349); // IF PTCON is True then user selected a Delta Connection. The angle is in radians (2°/57.3 = 0.0349)
END_IF


IF Static THEN
P_Thresh := PU; //For test case static Value will be 69*0.0125 =(0.865), where 69 is the voltage and 0.0125 is the minimum current
ELSIF NOT Static THEN
P_Thresh := P_Dynamic;
END_IF
```

Conclusions

- Relays that operate dependably for normal shutdown may fail to protect for inadvertent motoring
- New algorithm has dynamic operating characteristic
  - Characteristic includes dependability bias
  - Adaptive characteristic mitigates security reduction
  - Scheme is simple to apply
- Relays should be tested with realistic inadvertent motoring conditions

Questions?