Capacitor Assisted Motor Starting

Paul B. Steciuk
NEPSI – Northeast Power Systems, Inc.

EasyPower®
Power made easy.

NEPSI – BACKGROUND

- Established in 1995
- Based in Queensbury, NY
- Key products designed and manufactured by NEPSI
  - Medium-voltage metal-enclosed products (2.4kV – 38kV) 200 kV BIL Max
    - Shunt Power Capacitor Banks (capacitive vars)
    - Harmonic Filter Banks
    - Shunt Reactor Banks (inductive vars)
    - Hybrid Shunt Capacitor and Shunt Reactor Banks
    - actiVAR™ – Thyristor-switched harmonic filter banks (2.4kV – 13.8kV)
    - Medium Voltage Surge Protection Products
      - RC Snubbers
      - Motor Surge Protection
      - Medium-Voltage Transient Voltage Surge Protection
- Service
  - Startup | Commissioning | Maintenance
  - Power System Studies
    - Harmonic Analysis, Power Factor, Motor Start,

NEPSI

Northeast Power Systems, Inc.

actiVAR

FAST VAR SWITCHING

The Cost Effective Alternative to VFD Starters

EasyPower®

Power made easy.

WHAT CAN THE actiVAR™ BE USED FOR?

- It is a **cost effective alternative to VFD motor starters** where speed or process control is not required

Capacitor Assisted Motor Start

- Fast “local” supply of reactive power
- Voltage Support
  - Large motor starts (voltage sag/flicker mitigation)
  - Impact loading of large motors
  - Loss of generation
- Meet utility interconnect requirements
  - Inrush current limits
  - Voltage sag limits

5000 HP ACROSS-THE-LINE MOTOR START

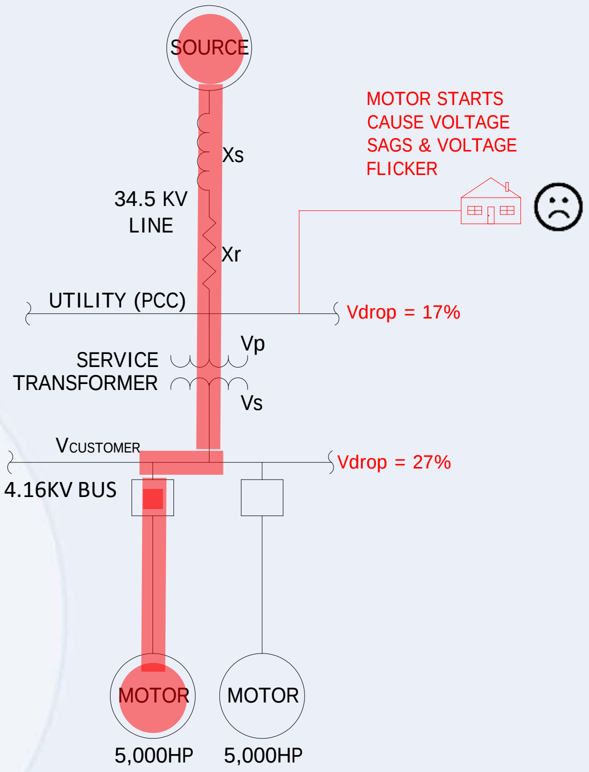
Starting Power Flow
@ XFMR Secondary
Real: 2.5 MW
Reactive: 14 MVAR

Starting Current
328A @ 34.5kV
2745A @ 4.16kV

Starting Torque
0.37 PU (of rated torque)

Starting Time
9.1 Seconds

Full Load Current
(FLA) ≈626 amps

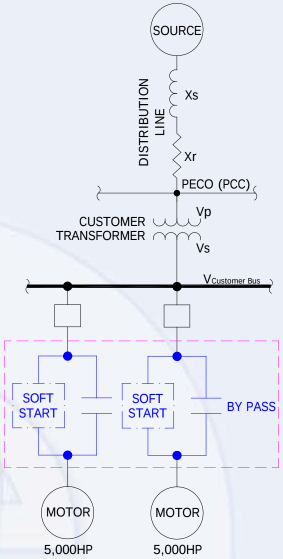


TYPICAL PROBLEMS ASSOCIATED WITH ACROSS-THE-LINE STARTING OF LARGE MOTORS

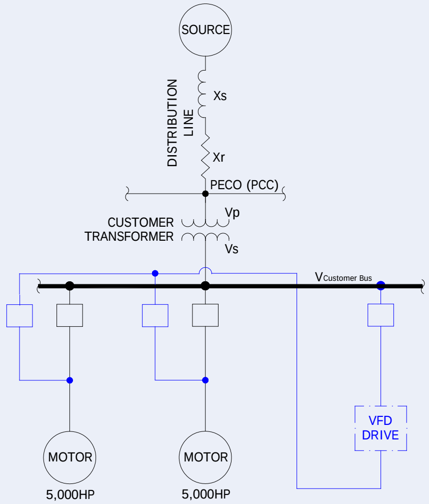
- Voltage sags
- Reduced starting torque of motor
  - Increased starting times
  - Increased motor heat
  - May cause motor to not start
- Motor and transformers may need to be larger to overcome motor starting torque requirements
- May not meet utility interconnect requirements

VOLTAGE SAG MITIGATION OPTIONS FOR LARGE MOTOR STARTS

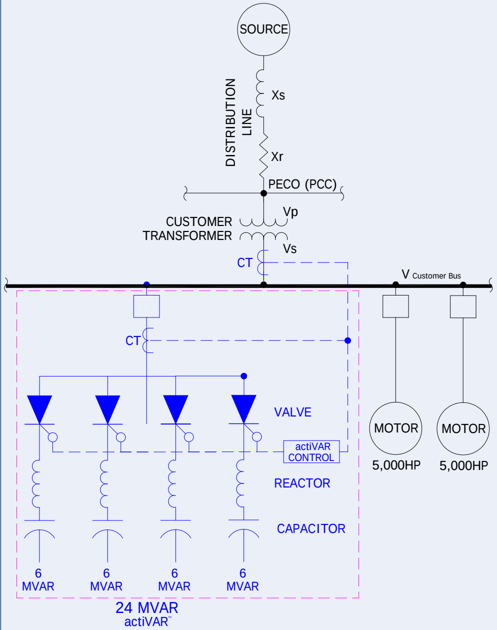
RVSS Start



VFD Start



activAR™ Start



COMPARISION OF VOLTAGE SAG MITIGATION OPTIONS

RVSS Start

Advantages
- A potentially low cost option
- Soft mechanical start

Disadvantages
- May not be able to meet starting torque requirements
- May not meet interconnect requirements
- Requires E-House Space
- Produce Harmonics

VFD Start

Advantages
- Provides near rated torque at starting
- Soft mechanical start
- Meets utility voltage sag/inrush limits

Disadvantages
- **Requires E-house space**
- Requires M_n+1 additional motor starters
- Synch Transfer Controls
- **High installed cost $$$$$**
- Produce harmonics
- Long delivery time
- **Complexity of equipment**
- May require cooling equipment

actiVAR™ Start Capacitor Assisted Motor Start

Advantages
- Provides near rated torque at starting
- Meets interconnect requirements
- Lower cost
- Simplest to install and maintain
- E-House not required – Outdoor rated

Disadvantages
- Does not provide a soft start function for mechanical loads that require it

EasyPower Power made easy.

NEPSI Northeast Power Systems, Inc.

actiVAR™ ASSISTED MOTOR START

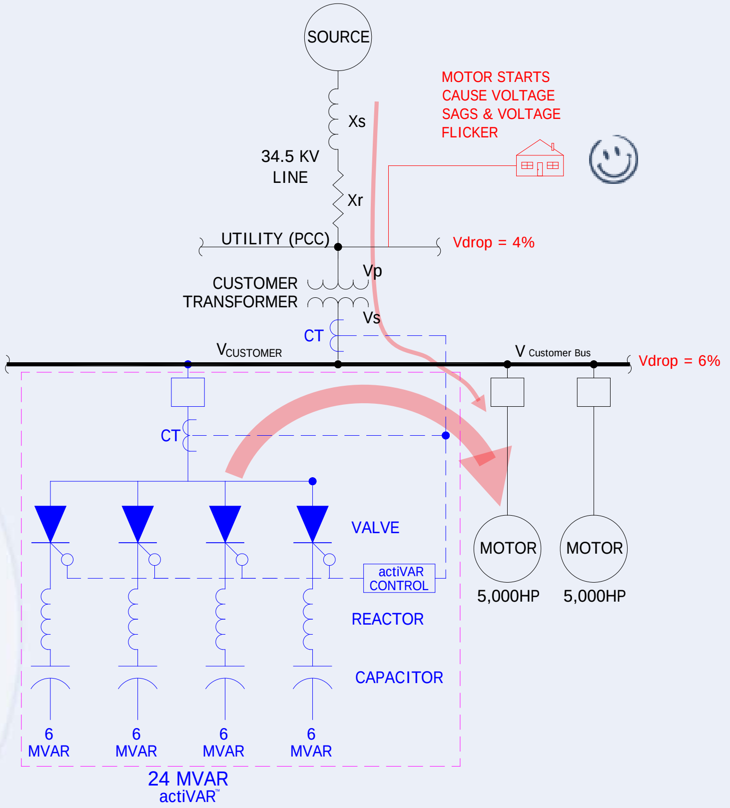
Starting Power Flow @ XFRM Secondary
Real: 4.6 MW
Reactive: 2.5 MVAR

Starting Current
92A @ 34.5kV
770A @ 4.16kV

actiVAR™ Power Flow (VAR Supply to Motor)
Real: ≈ 0 MW
Reactive: 21.3 MVAR

Starting Torque
0.63 PU (of rated torque)

Starting Time
3.7 Seconds



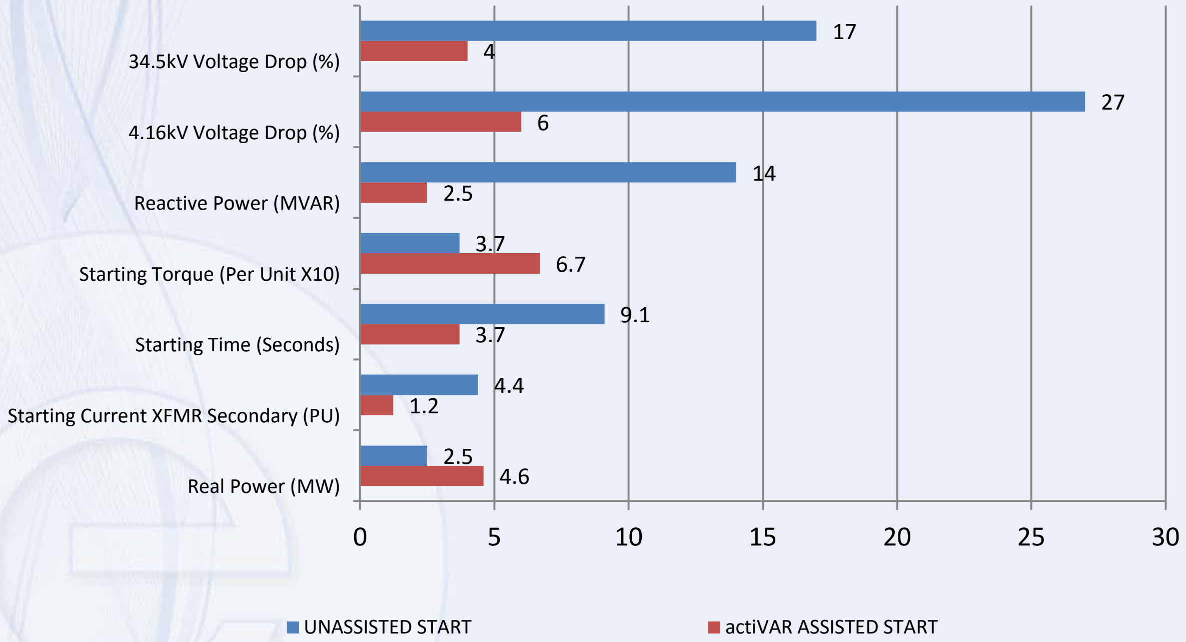
BENEFITS OF USING THE actiVAR

- The actiVAR™ is a fast local supply of VARs
- The reduction in var flow through the source impedance reduces voltage sag at transformer primary and secondary
- Utility voltage sag, flicker, and inrush limits are met
- Power quality is improved throughout the system
- The motor starts faster due to higher starting torque
- Less heating in the motor during motor start

EasyPower Power made easy.

NEPSI Northeast Power Systems, Inc.

actiVAR™ PERFORMANCE



** Per Unit Starting Current Based on FLA = 624 Amps*

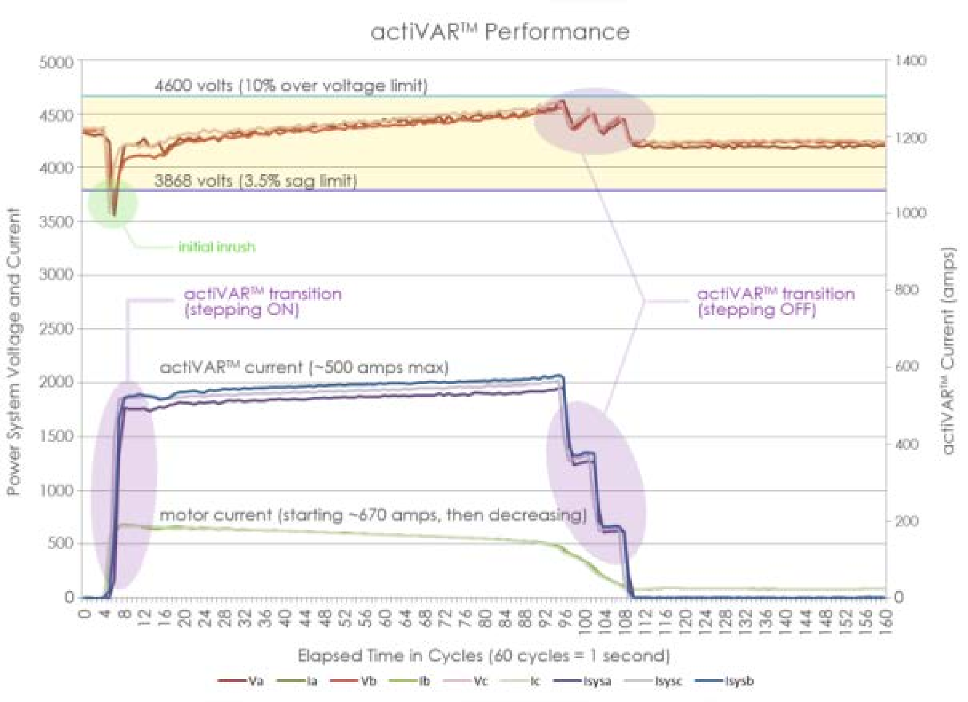
KEY TAKE AWAY

- Voltage drop is significantly reduced to within utility voltage drop limits.
- Starting Torque Proportional to V^2, translating to quicker motor starts
- Current through service transformer allows customers to meet utility maximum inrush current limits
- Higher voltage to motor results in higher available real power to motor

EasyPower Power made easy.

NEPSI Northeast Power Systems, Inc.

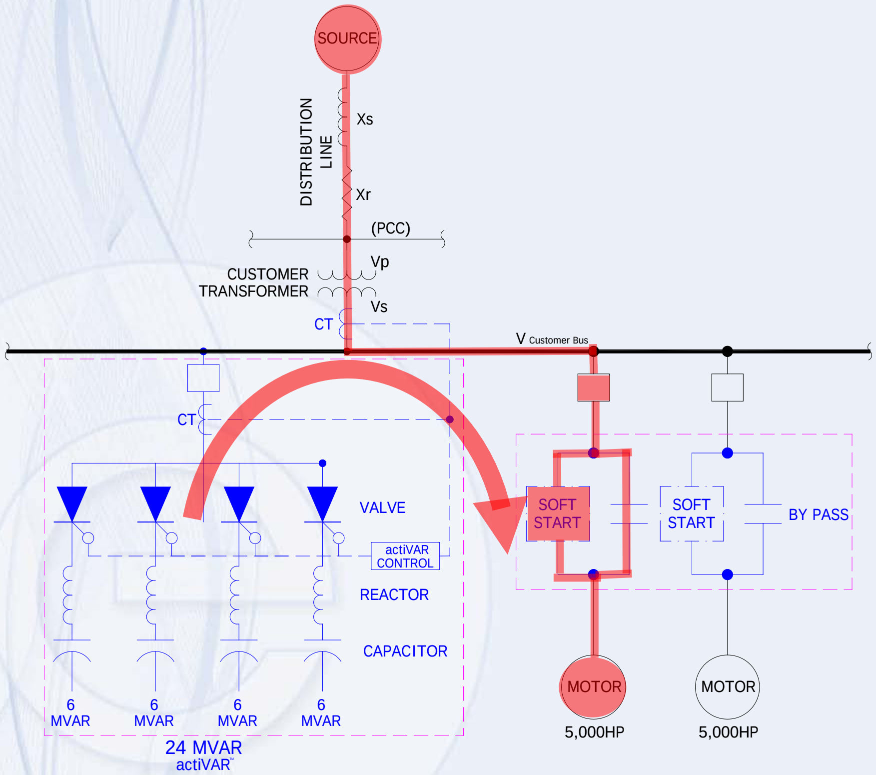
actiVAR™ – BASIC OPERATING SEQUENCE



STEP-BY-STEP OPERATING SEQUENCE OF actiVAR™

1. actiVAR™ sits ready for action, monitoring for a motor start
2. actiVAR™ senses voltage drop and flow of current when motor starts - transitions on, applying an appropriate amount of capacitance (VARs) to maintain system voltage
3. As motor comes up to speed, the actiVAR™ senses the rise in system voltage and drop in motor VAR requirements and transitions off the appropriate amount of capacitance to maintain system voltage
4. After motor start, the actiVAR™ sits ready for action, waiting for next motor start

actiVAR ASSIST WITH RVSS



RVSS + actiVAR™ Start

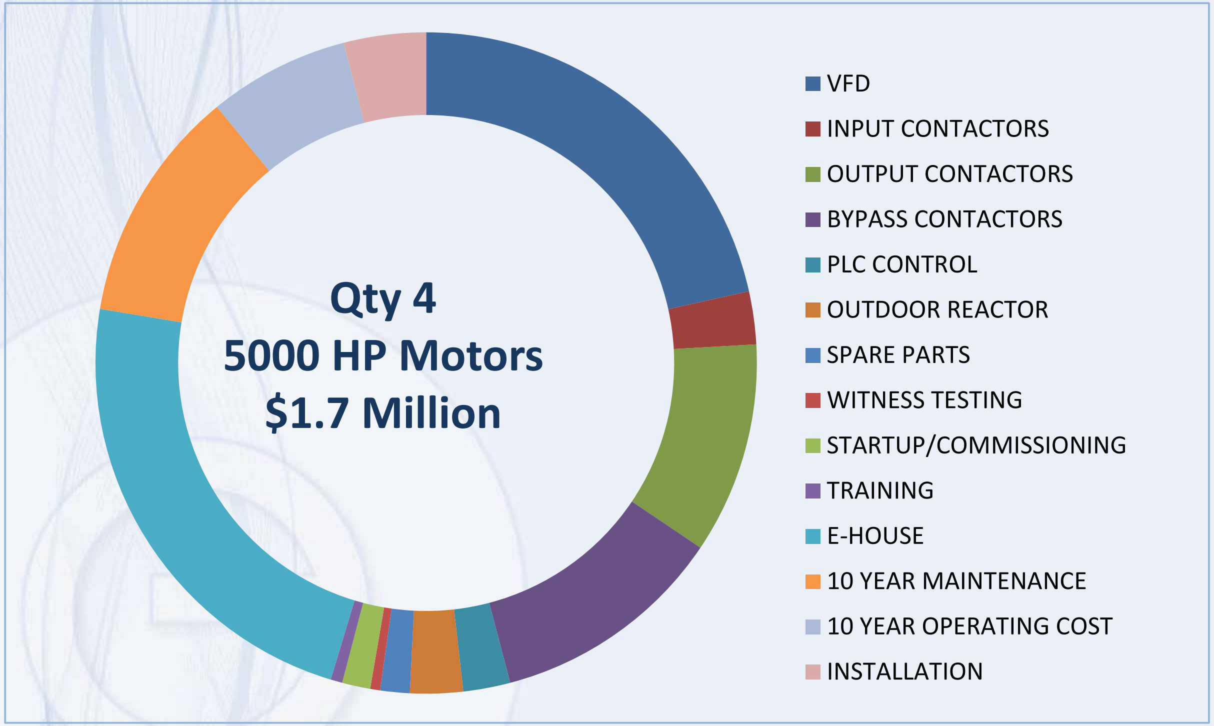
Advantages

- Lower cost than VFD start
- Extends the functional range of soft start option to higher HP ratings
- Provides "automatic redundancy" in functional HP range of soft start
- Soft mechanical start
- Starting impact < running impact
- Soft start harmonics are reduced while actiVAR is active

Disadvantages

- More complicated than either alone
- Produce some harmonics – but at a lower level than standalone RVSS

VFD START – COST COMPONENTS



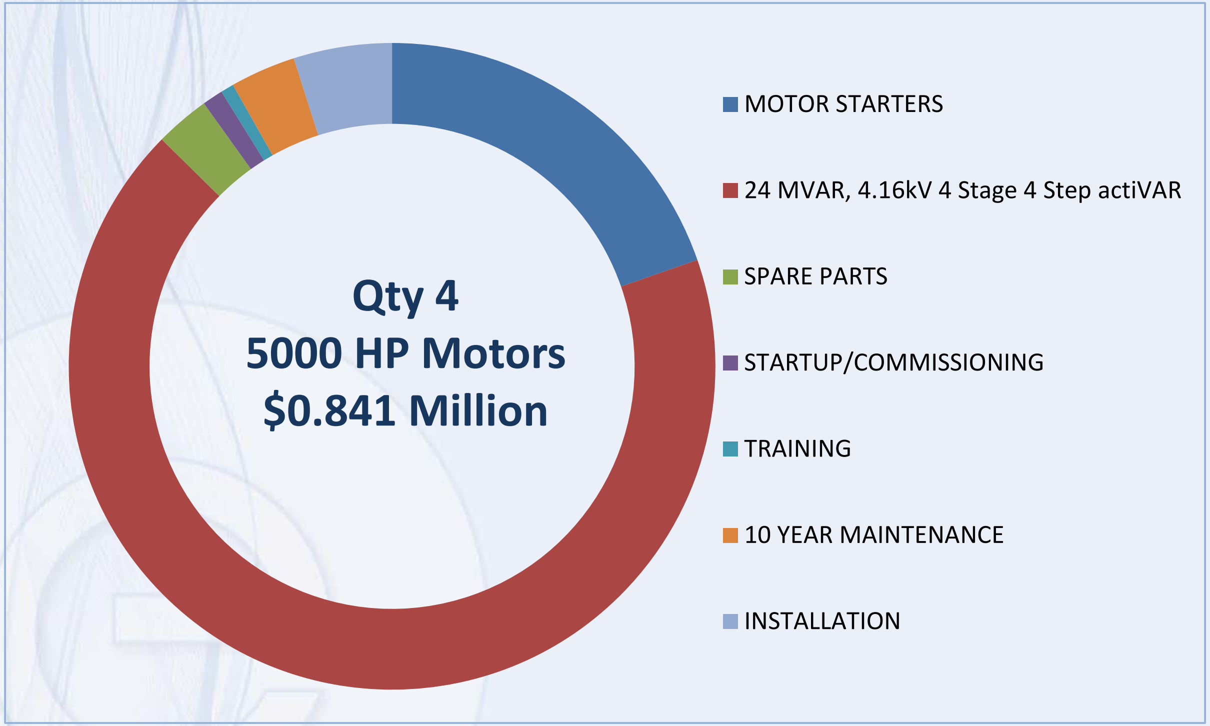
Key Cost Factors

- VFD and E-House costs are significant
- Input and output contactors, VFD Bus, PLC contribute additional cost

** Basis of costs available on request*

NEPSI Northeast Power Systems, Inc.

actiVAR™ START – COST COMPONENTS

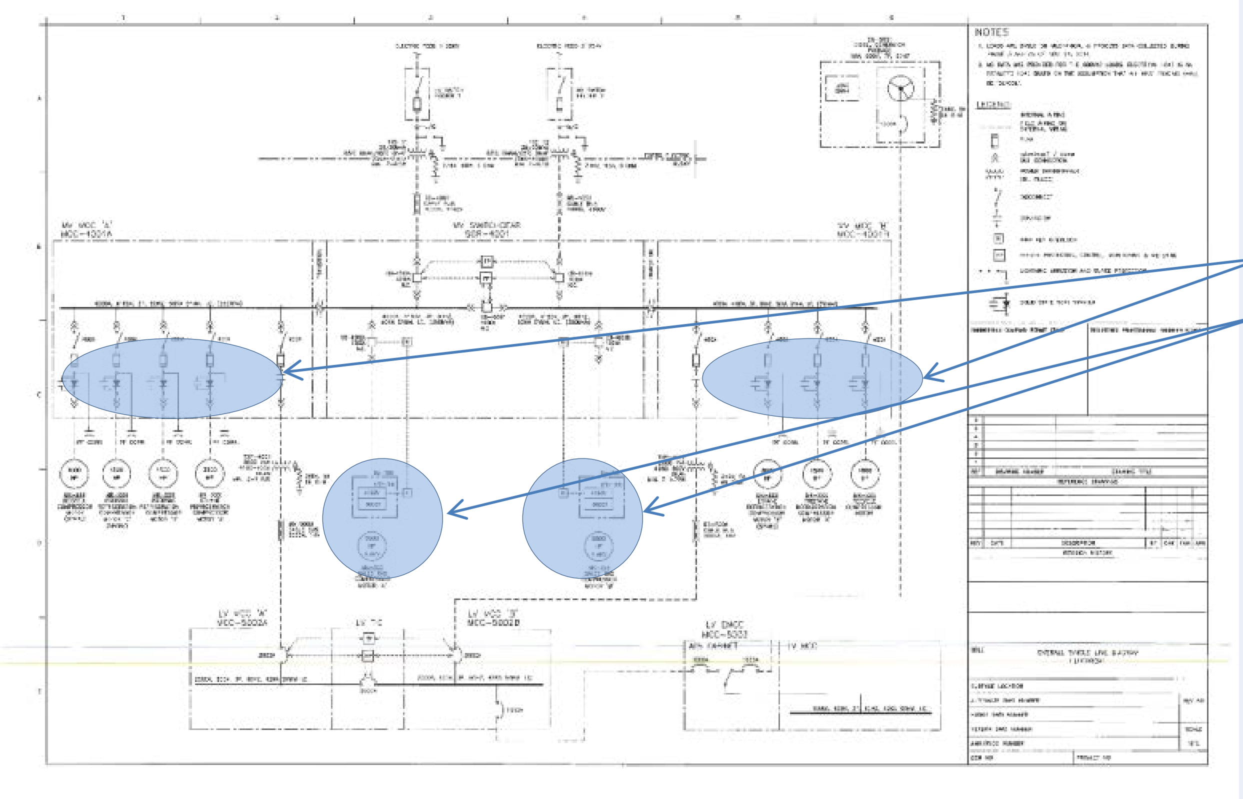


Key Cost Factors

- actiVAR™ dominates the initial cost
- Without the costs associated with the E-House or the synch switchgear, the actiVAR™ saves significantly on equipment cost

actiVAR™ - a lower cost alternative

DEEP CUT GAS PLANT APPLICATION - USING RVSS AND VFD'S



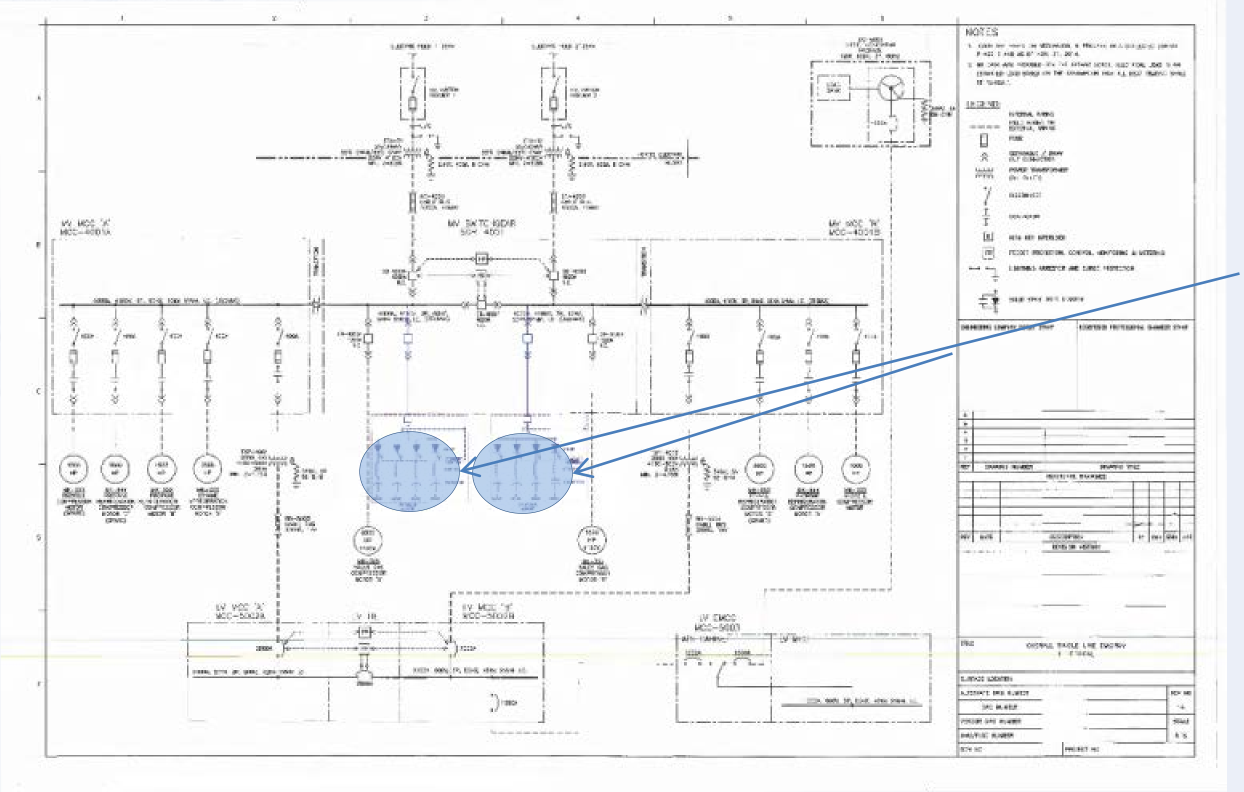
Required Equipment For Starting Motors

- 7 RVSS starters
- Two 9,500 HP VFD starters
  - E-house space
  - Complexity
  - Possible need for cooling equipment
  - Lead-time

EasyPower Power made easy.

NEPSI Northeast Power Systems, Inc.

DEEP CUT GAS PLANT APPLICATION USING actiVAR™

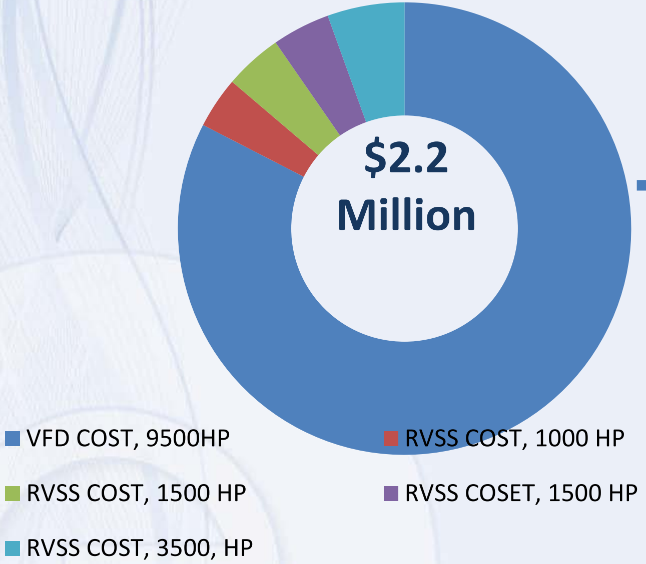


Required Equipment For Starting Motors with actiVAR™

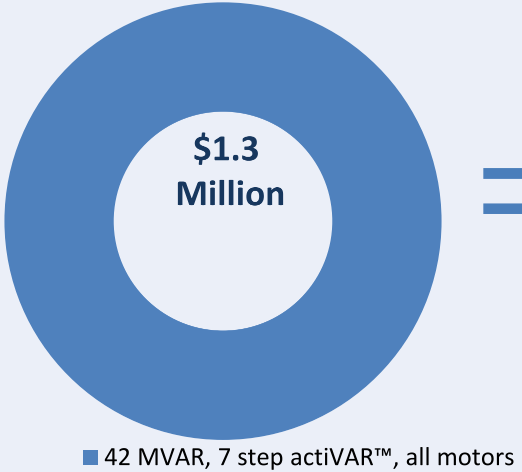
- Qty (2) 42 MVAR actiVARs™
  - No E-house space
  - Comes fully assembled
  - Can be set up with a tie breaker to allow for redundancy
  - Simplicity
- Feeder breaker for each actiVAR™

DEEP CUT GAS PLANT - SAVINGS WITH actiVAR™

RVSS/VFD



actiVAR™



SAVINGS

$900,000

Savings for total plant implementation: $1,750,000

EasyPower
Power made easy.

NEPSI
Northeast Power Systems, Inc.

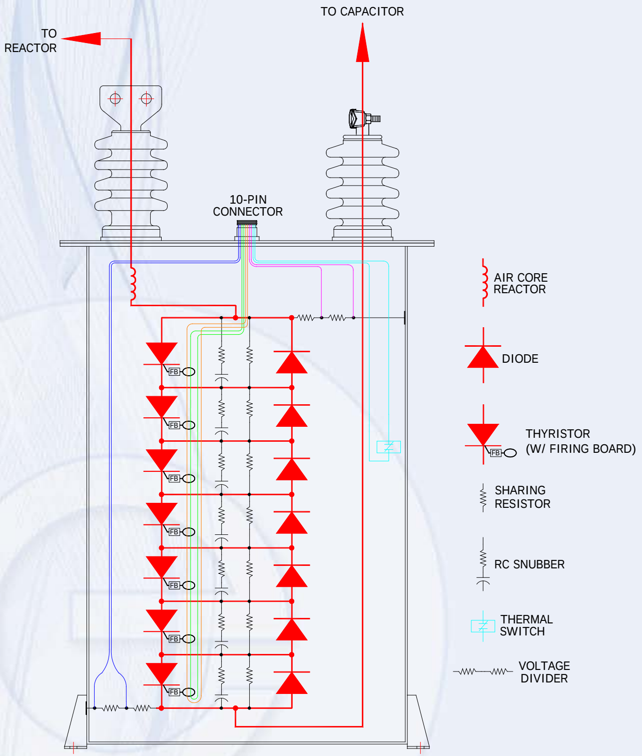
TSC STAGES USE THYRISTOR VALVES FOR SWITCHING

THYRISTOR VALVE - DETAILS

- Maintenance free device
- Can be regarded as a single-phase solid-state switch
  - Transient free switching
  - No moving parts
- Sub-quarter-cycle response time
- Diodes hold capacitors at negative peak voltage when gated off
- Valves turns on (gate on) and off (gate off) at negative peak (full cycle conduction)

"FAST VARS"

THYRISTOR VALVE - INTERNAL SCHEMATIC



THYRISTOR VALVE INTERNAL SCHEMATIC

THYRISTOR VALVE SCHEMATIC

- Valve Tank – 16 gauge stainless
- Cover – 0.25” Stainless
- Oil Cooled & Insulated (non-PCB)
- 2 – Porcelain Bushings (95kV BIL)
- 10-Pin Connector for control and monitoring
- Provided with and without cooling fins – fins.
  - Cooling fins allow for continuous operation of valve
- Series & parallel connected diodes and thyristors for bi-directional control of current
- Transient current (di/dt) and transient voltage (dv/dt) protection
- Diodes keep capacitors in a charged state
- Self-monitoring | self-protecting
- N+1 and N+2 designs for higher reliability

actiVAR™ Project Picture

Pipeline Motor Start Application – 5000 HP Induction Motor

EasyPower
Power made easy.

NEPSI
Northeast Power Systems, Inc.

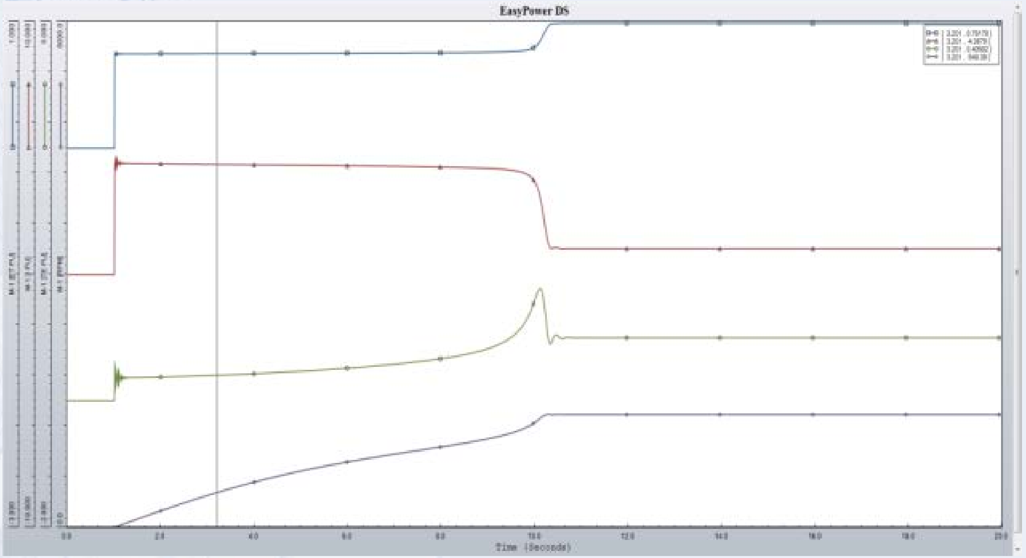
actiVAR™ Project Picture

Pipeline Motor Start Application – 5000 HP Induction Motor

actiVAR™ Project Picture

Pipeline Motor Start Application – 10,000 HP Synchronous Motor

MOTOR START ANALYSIS – Dynamic Analysis



Typical plot output from dynamic analysis software showing motor terminal voltage, motor current, motor speed, and motor torque versus time

DYNAMIC ANALYSIS (EasyPower)

- Performed by NEPSI for all actiVAR™ orders and RFQ's
- Accurately calculates motor starting time, motor current, voltage, torque, power, and speed for the entire starting period
- Determines whether a motor will start or not start
- Accurately predicts actiVAR™ performance
- Requires more Data
    - System impedance data
    - Motor impedance data; torque speed curves and inertia data
    - Load torque and inertia data
- Also used to check for resonance concerns (harmonic analysis)

EasyPower
Power made easy.

NEPSI RESOURCES TO ASSIST IN APPLICATION OF actiVAR™

- Contact NEPSI about your application
  - NEPSI will provide motor start and actiVAR™ performance study, quote, and drawings to allow for comparison against alternate technologies
- Web – nepsi.com/actiVAR™
  - Product literature
  - Guide form specifications
  - Case studies
  - actiVAR™ calculator for motor starting applications
  - actiVAR™ RFQ form to fill out and submit

Typical Starting Characteristics – 5000 HP Induction Motor

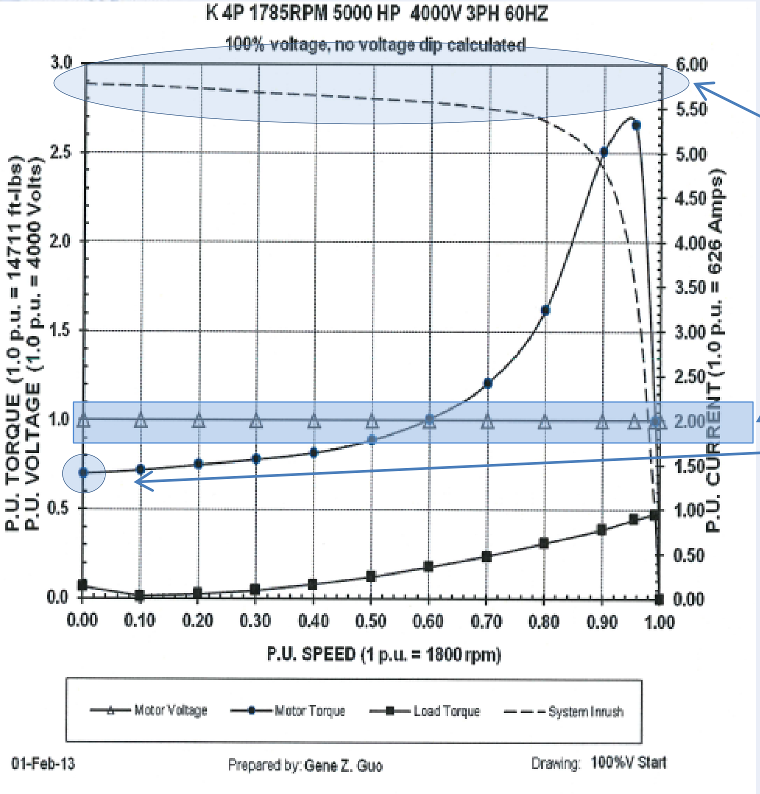


Fig. 1 Starting Characteristics (Rated Voltage, Valve Closed)

- High starting current
- Motor torque-speed curve is often based on 1 PU terminal voltage
- Medium voltage motors often have low starting torque
- Load torque curve superimposed on motor torque-speed curve

TYPICAL MOTOR DATA SHEETS

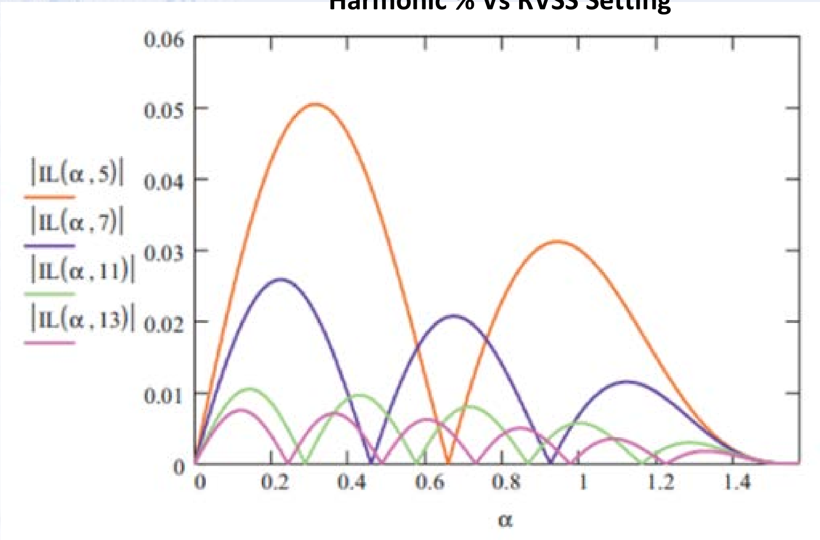
- Supplied by manufacturer

Model	5K861274C1
Type	K
Enclosure	WPII
Frame size	8612S
Horsepower	5000
Voltage	4000
Phase	3
Frequency	60
Synchronous Speed (rpm)	1800
Full Load Speed (rpm)	1785
Insulation Class	B
Service Factor	1.15
Temperature Rise at S.F. (°C)	75 RISE BY RTD
Full Load Current (amps)	626
Locked Rotor Current (amps)	3612
NEMA Code Letter	F
Full Load Torque (lb. ft.)	14711
Locked Rotor Torque (% Rated torque)	70
Breakdown Torque (% Rated torque)	266

% Efficiency (load)	
1.25	0.964
1.00	0.966
0.75	0.967
0.50	0.958
% Power Factor (load)	
1.25	0.891
1.00	0.892
0.75	0.890
0.50	0.879
Safe Stall Time (seconds)	13
Motor Inertia (lb. Ft. ^{2})	5550
Approximate Net Weight (lbs.)	31010
Type Bearings	SLEEVE (INSULATED)
Lubrication	FORCED OIL
End Play (inches)	0.5 MIN
Rotation (viewed from opposite drive end)	CW
Outline	34C110584-001
Motor equivalent circuit parameters (Zb=3.842 Ω)	X1pu: 0.113; X2pu=0.084; Xmpu=5.265 R1pu: 0.004; R2pu=0.009

RVSS HARMONICS

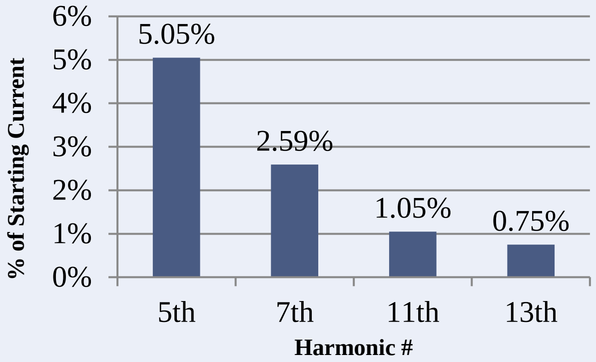
Harmonic % Vs RVSS Setting



RVSS Harmonics

- Harmonic magnitudes vary with soft starter settings
- Magnitude can be significant (% of motor start current)
- Harmonics can cause spurious plant PQ issues

Maximum Distortion



Return

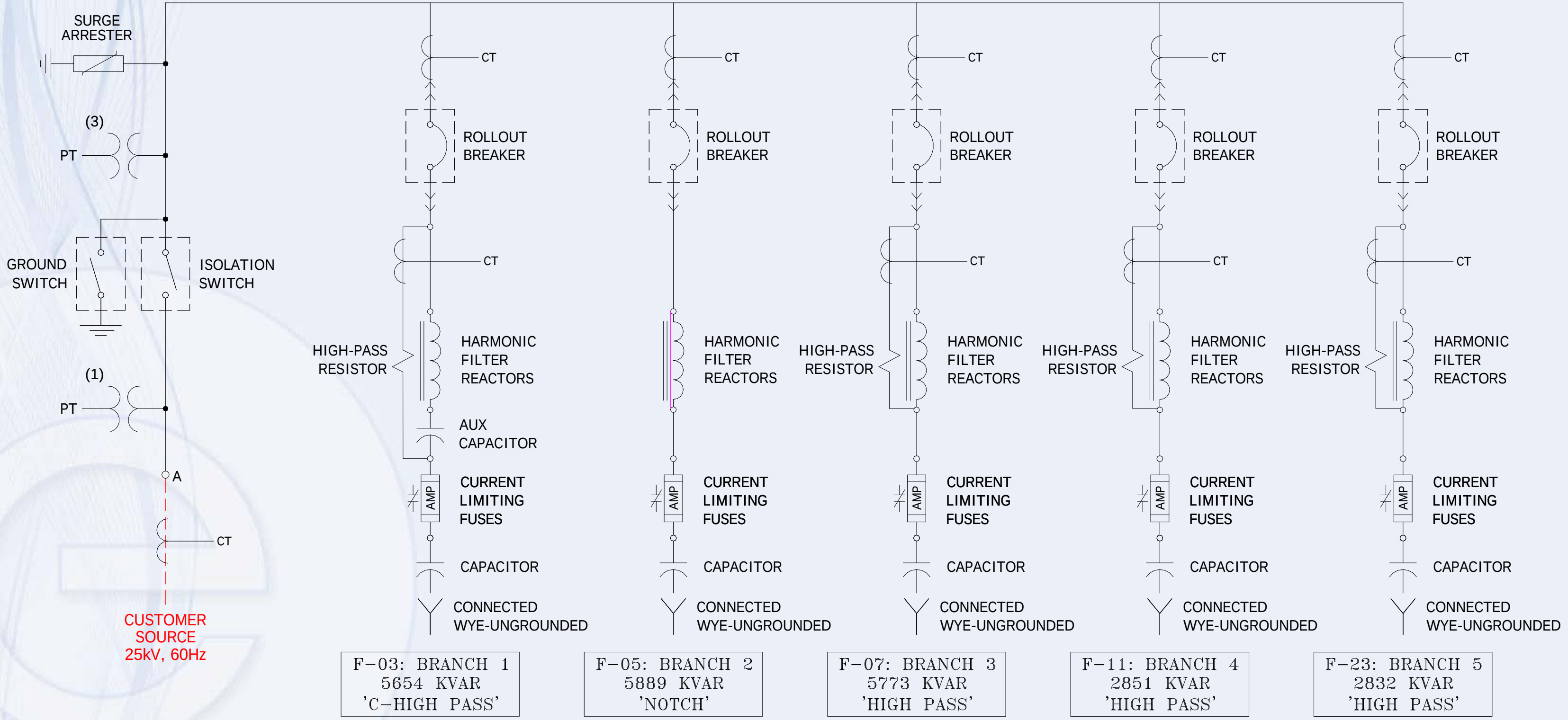
LARGE HARMONIC FILTER SYSTEMS

Red Chris Mine - British Columbia

C-High Pass, High Pass, and Notch Filter Branches

23 MVAR, 24.9 kV, 5-Stage, All-Inclusive Harmonic Filter System

LARGE HARMONIC FILTER ONE-LINE DIAGRAM



EasyPower
Power made easy.

Background

NEPSI
Northeast Power Systems, Inc.