C37.96-2012 – IEEE guide for the Protection of AC Motor Protection

PSRC J10 working group, 2007-2012

PSRC general meeting

September, 2013

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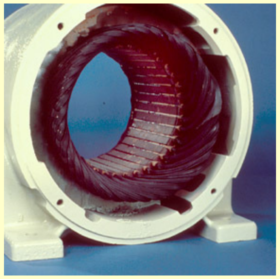
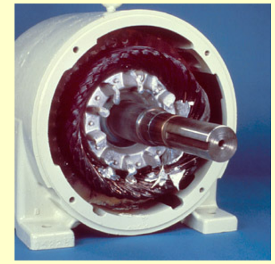


Prem Kumar, *Chair*
Dale Finney, *Vice Chair*



Hasnain Ashrafi
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Steve Conrad
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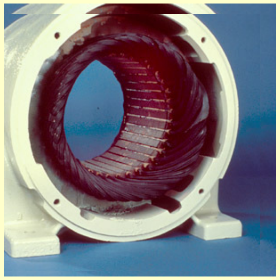
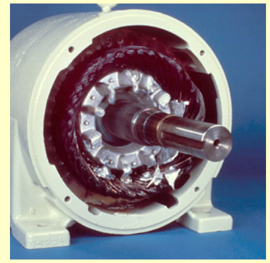


Document
Developed under PSRC



- C37.96-2012 : IEEE guide for AC Motor Protection.
- Revised and approved for publication on 5th December 2012.
- Previous revision was released in 2000

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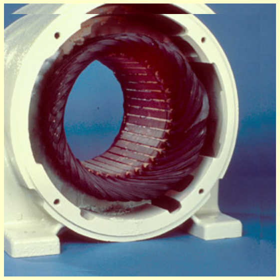
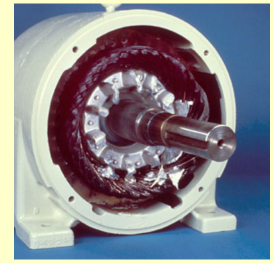


Balloting



- Total 95 Balloters
- 27 Comments received, 1 negative comment
- Recirculation had 3 comments.

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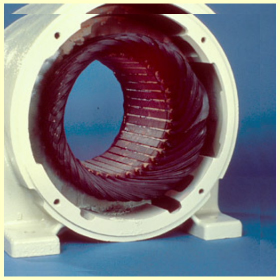
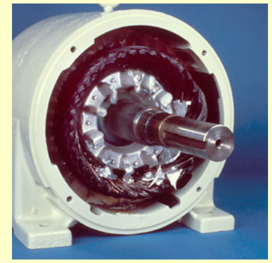


C37.96 New items



- 15 specific additions/enhancements
- ASD protection enhancements based on J1 group work
- Motor Bus transfer relevant protection issues based on J9 group work.
- Motor surge protection relevant issues
- Microprocessor relay setting example

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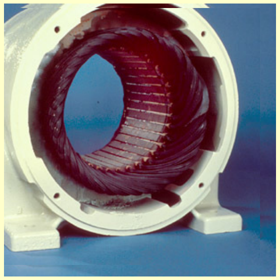
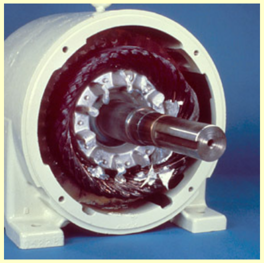


C37.96 New items



1. ASD Protection enhancements
2. Motor failure data-reasons for protection
3. Insulation class data -setting relevance
4. Motor NEMA standard data
5. Application of low ratio CTs for small motors
6. Reduced Voltage starting-setting issues
7. Motor Surge Protection
8. CT location for PF correction CAPS

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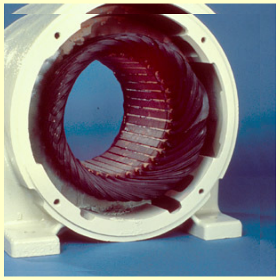

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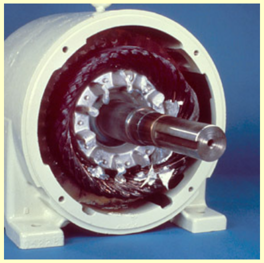
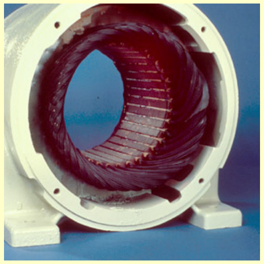
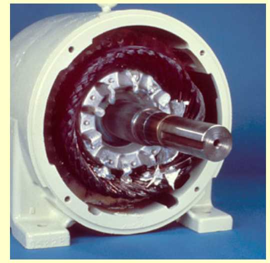


9. Motor Bus transfer
10. Motor relay/fuse coordination issues
11. Toroidal Ground Sensor issues
12. Breaker Failure Protection small motors
13. Understanding motor data sheets
14. Enhanced Motor tutorial material
15. Motor setting example



1a-ASD Protection Enhancements



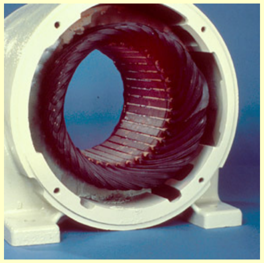
– ASD usage has increased
– ASD Controlled motors, the operating frequency impacts the motor characteristics

a) Starting,

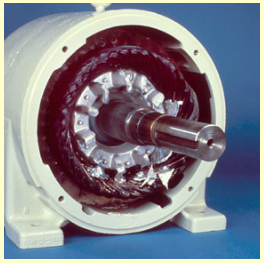
b) Running,

c) Abnormal operation and fault conditions

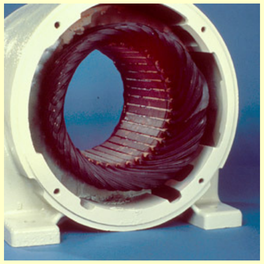
– ASD vendors provide motor protection functions part of drive system



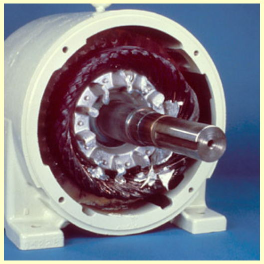
1b-ASD System Issues



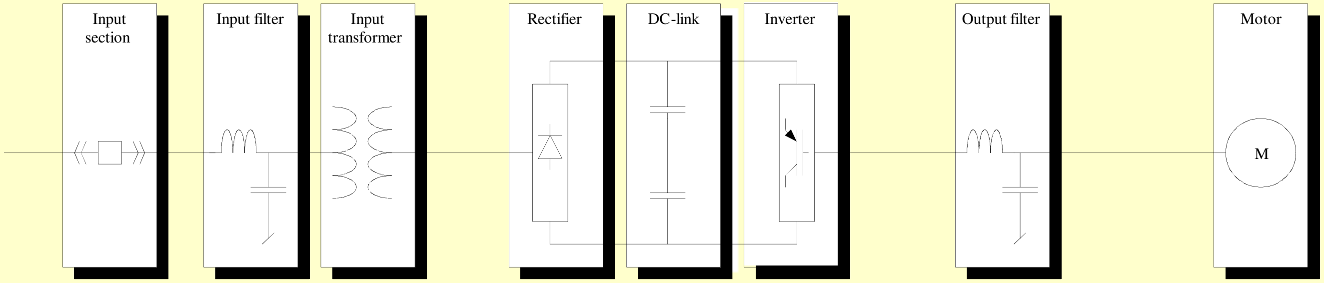
- Better process control-ability to vary process speed
- Efficiency-affinity laws power savings
- Soft Start Capability
- Short Circuit Current Reduction
- Bus transfer issues
- Issues with PF correcting CAPS



1c- ASD and Motor System Basic Blocks of an ASD



Input: Zone 1	Drive: Zone 2	Output: Zone 3
Transformer	Power Electronics	Motor



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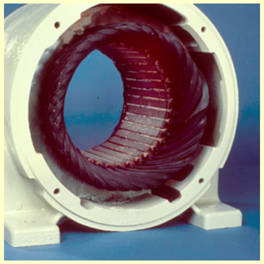
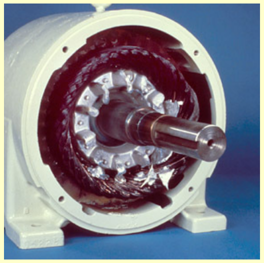


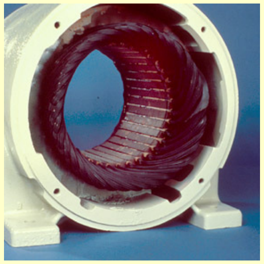
1d-ASD Protection Enhancements

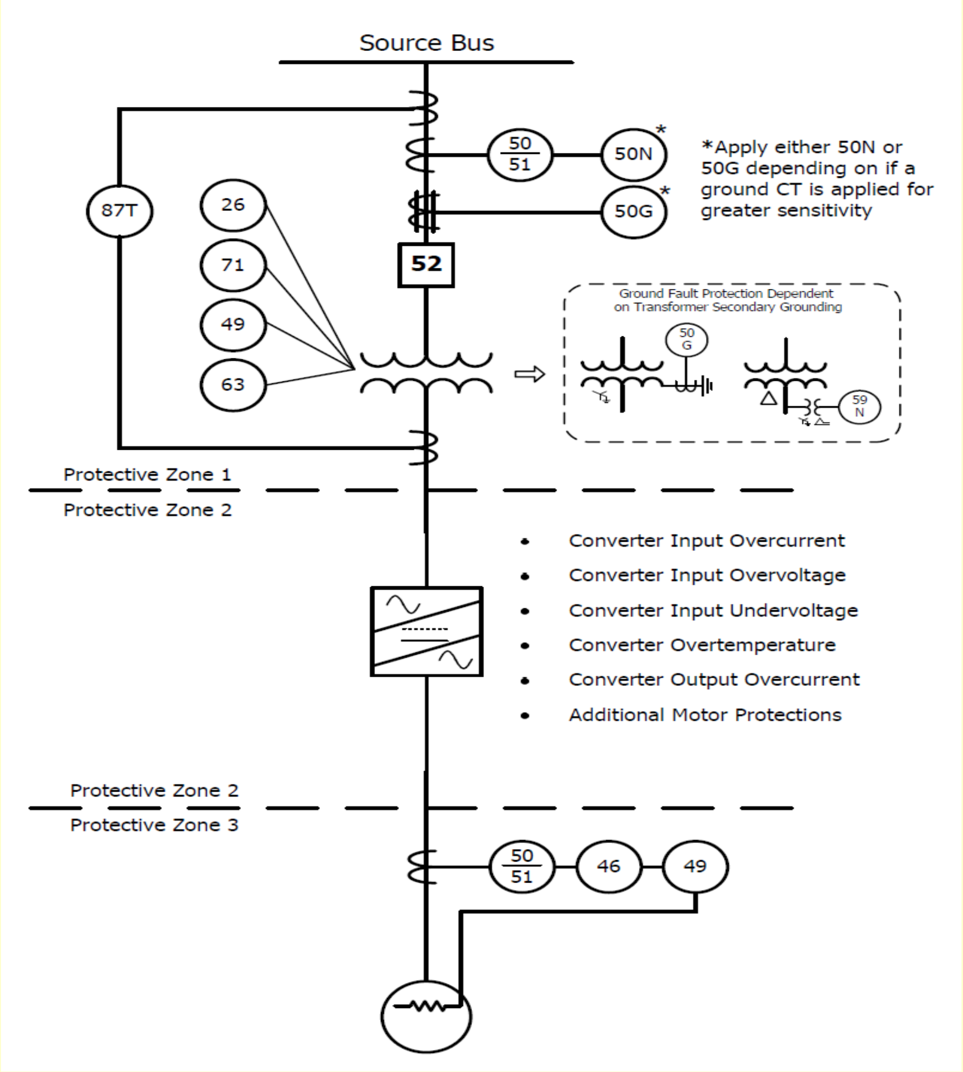


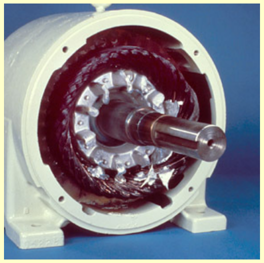
Adjustable-Speed Motor Protection

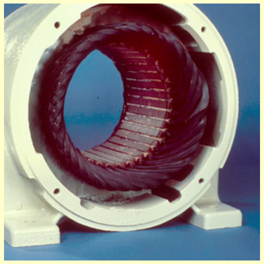
- Three zone Protection strategy
  - Zone 1 Input Transformer Protection
  - Zone 2 Power Electronics Protection
  - Zone 3 Motor Protection

1e- ASD Protection zones

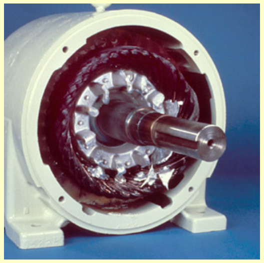






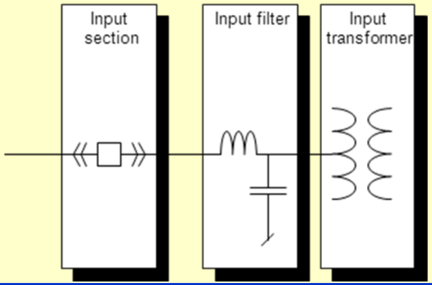


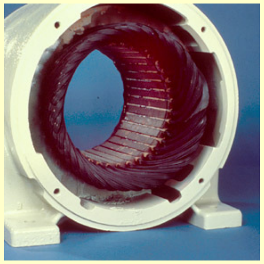
1f-ASD Protection
Zone 1



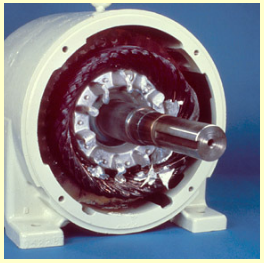
Adjustable-Speed Motor Protection

- Overcurrent protection
- Limitations of differential protection for multi winding transformers
- Issues with Zone 1 protections are harmonics, co-ordination with supply breaker, for multi winding transformer differential protection



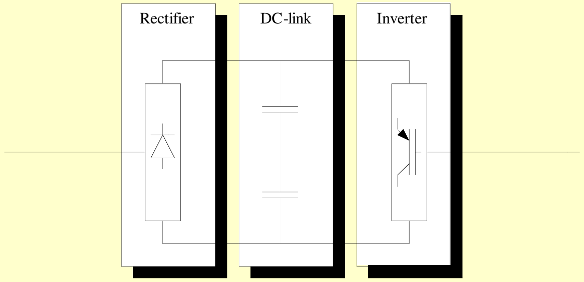


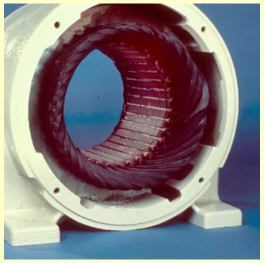
ASD Protection Zone 2 Issues



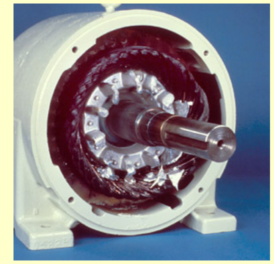
The ASD vendor provides this area of protection
for power electronics including rectifier, DC link and inverter

- DC Bus over voltage
- DC Bus under voltage
- Rectifier and Inverter over temperature
- Loss of control power
- Converter over current
- Inverter over current
- Additional Motor Protections

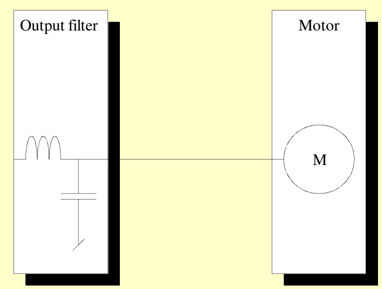




ASD Protection Zone 3 issues



- Thermal model of motor has limited value
- CTs saturate at low frequency
- Frequency capability of relay is important consideration depends on where process operates
- For large motors consider additional protection
  - Overcurrent.
  - Differential
  - Ground protection



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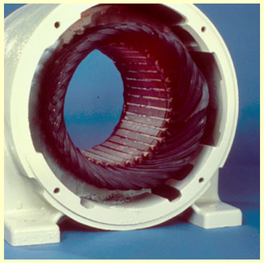
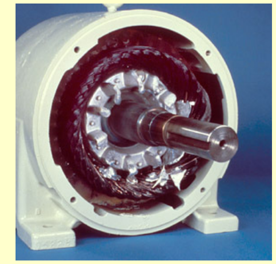


2-Motor Failures data



Failed Component	Induction Motors	Synchronous Motors	Wound Rotor Motors	Direct Current Motors	Total (All Types) Numbers	Total (All Types) Percentage	Protection
Bearings	152	2	10	2	166	43.7%	38, 39
Windings	75	16	6	-	97	25.56%	26, 46, 49, 50, 50N, 51, 51N, 51R, 59,87
Rotor	8	1	4	-	13	3.4%	21, 26, 46, 49, 50, 50N, 51, 51N, 51R, 59, 87
Shaft or Coupling	19	-	-	-	19	5.0%	37, 39
Brushes or Slip Ring	-	6	8	2	16	4.2%	40, 53, 55
External Devices	10	7	1	-	18	4.7%	27, 32, 40, 47, 53, 55, 60, 63, 64, 78, 81
Not Specified	40	9	-	2	51	13.4%	
Total	304	41	29	6	380	100%	N/A

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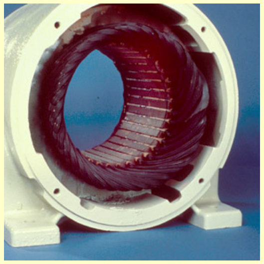
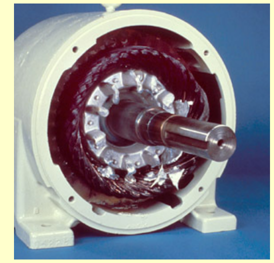


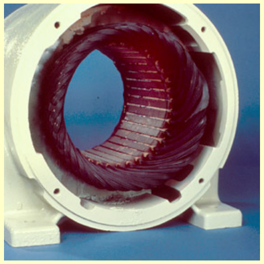
3a-Insulation Class (NEMA)



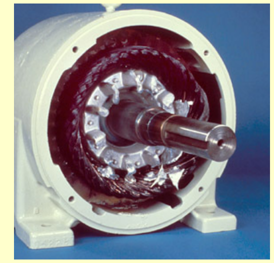
Service factor = 1

Machine Rating	Temperature Measurement	Insulation Class °C			
		A	B	F	H
All horsepower ratings	RTD	60	80	105	125
≤ 1500 hp	Embedded Detector*	70	90	115	140
> 1500 hp and ≤ 7 kV		65	85	110	135
> 1500 hp and > 7 kV		60	80	105	125

*Embedded detectors are located within the slot of the machine and can be either resistance elements or thermocouples



3b-Insulation Class (NEMA)



Service factor = 1.15

Machine Rating	Temperature Measurement	Insulation Class °C			
		A	B	F	H
All horsepower ratings	RTD	70	90	115	135
≤ 1500 hp	Embedded Detector*	80	100	125	150
> 1500 hp and ≤ 7 kV		75	95	120	145
> 1500 hp and > 7 kV		70	90	115	135

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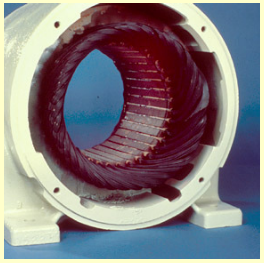
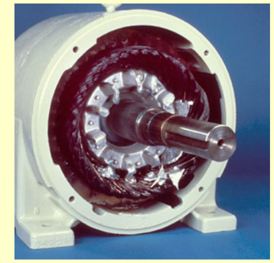


4-Motor Characteristics (NEMA)



Design	Locked Rotor Torque *	Pull-up Torque*	Breakdown Torque*	LR Current*	Slip %
A	70-275	65-190	175-300	Not defined	0.5-5
B	70-275	65-190	175-300	600-800	0.5-5
C	200-285	140-195	190-225	600-800	1-5
D	275	Not defined	275	600-800	≥5
IEC H	200-285	140-195	190-225	800-1000	1-5
IEC N	75-190	60-140	160-200	800-1000	0.5-3

* percent of rated load torque or load current

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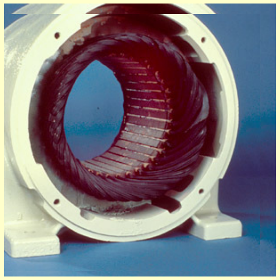
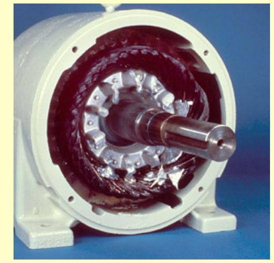


5-Application of low ratio CTs



- MV buses with high fault currents and small motors need careful attention for CT sizing.
- CT sizing evaluated for proper protection operation.
- Could require a separate high ratio CT be used for SC protection.
- MV contactors with fuses low ratio CT Ok.
- Modern microprocessor relay advanced algorithms can provide correct phasor estimation during high current faults.

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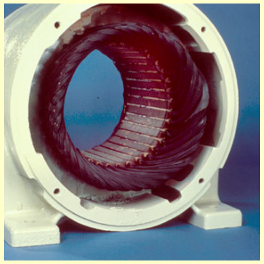
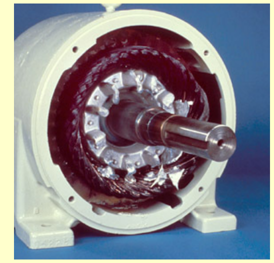


6-Reduced Voltage Starting



Starter Type	% Motor Voltage During Start	% Motor Current at Locked Rotor	% Line Current at Locked Rotor	% Torque at Locked Rotor
Primary Reactor				
80% Tap	80	80	80	64
65% Tap	65	65	65	42
50% Tap	50	50	50	25
Auto Transformer				
80% Tap	80	80	64	64
65% Tap	65	65	42	42
50% Tap	50	50	25	25
Wye/Delta Start				
Wye Start	58	58	33	33

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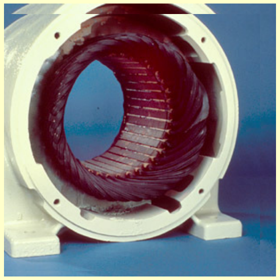
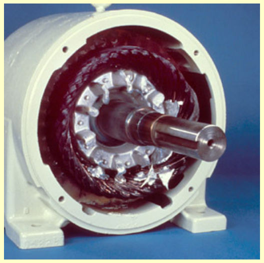
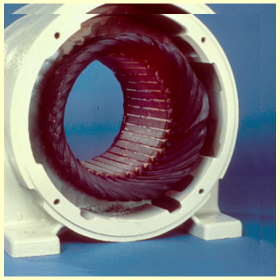


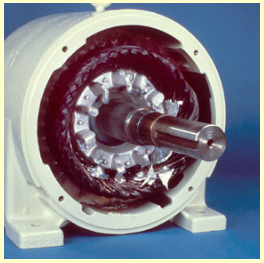
7a-Surge Protection



- Types of insulation-Ground wall and turn
- Steady state and steep fronted voltages
- Motor Surge Capability Withstand Requirements from NEMA MG-1-2009 and IEC 60034-15-15: 2009
- Equivalent NEMA and IEC BILs for commonly used Motor Voltages
- Various Surge Protection Techniques and Features



7b-Surge Protection Techniques



- Effective shielding of overhead lines supplying the plant.
- Surge Arrestors at the motor terminals.
- Surge Capacitors at the motor terminals.
- Low ground resistance at the service entrance and supply switchgear.
- Single end grounding at the motor or supply end depending on cable shielding / raceway / arrangement.

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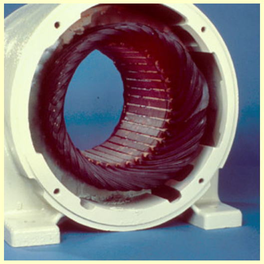
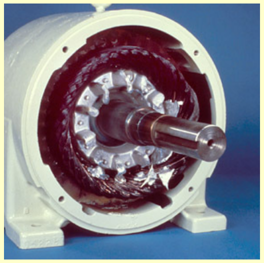
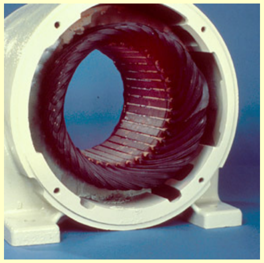


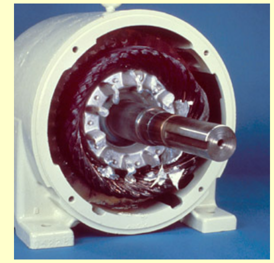
8 PF CAP CT Location



- CT placed before the PFCC
  - CT will see motor amps minus PFCC amps
  - Less accurate for OL setting
  - Protection can clear PFCC faults
- CT placed after the PFCC
  - CT will see motor amps
  - Upstream protections need to detect PFCC faults



9a-Motor Bus Transfer (MBT)



Required to maintain continuity of critical processes in a generating or industrial plant during the following periods

- Planned transfers
  - Maintenance or startup/shutdown
- Emergency transfers
  - Loss of present source due to a fault

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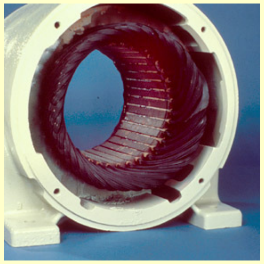
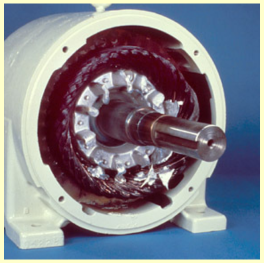


9b-Risk to Motors



- A poor transfer can result in a significant angle between the new source and the motor bus at the instant of closing.
  - This results in very high transient torque and current.
  - Damage can be immediate or cumulative.

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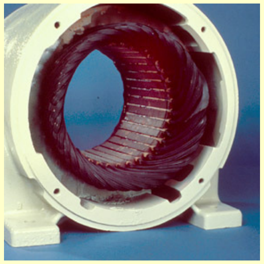
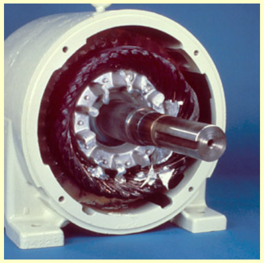
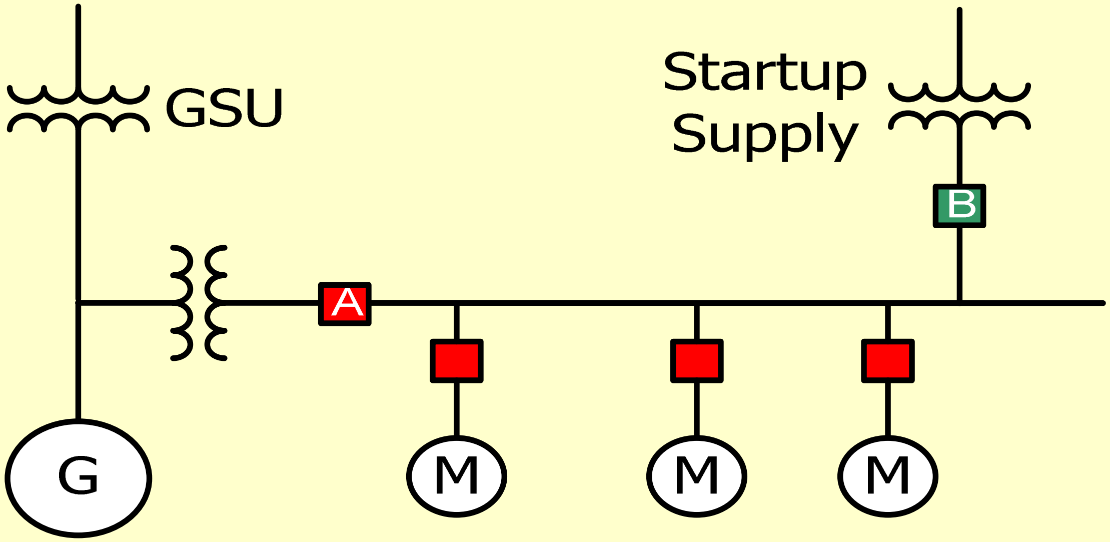


9c-Where is MBT needed?





Unit Connected Generator

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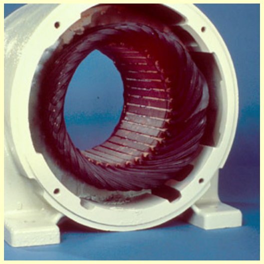
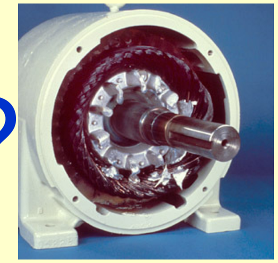
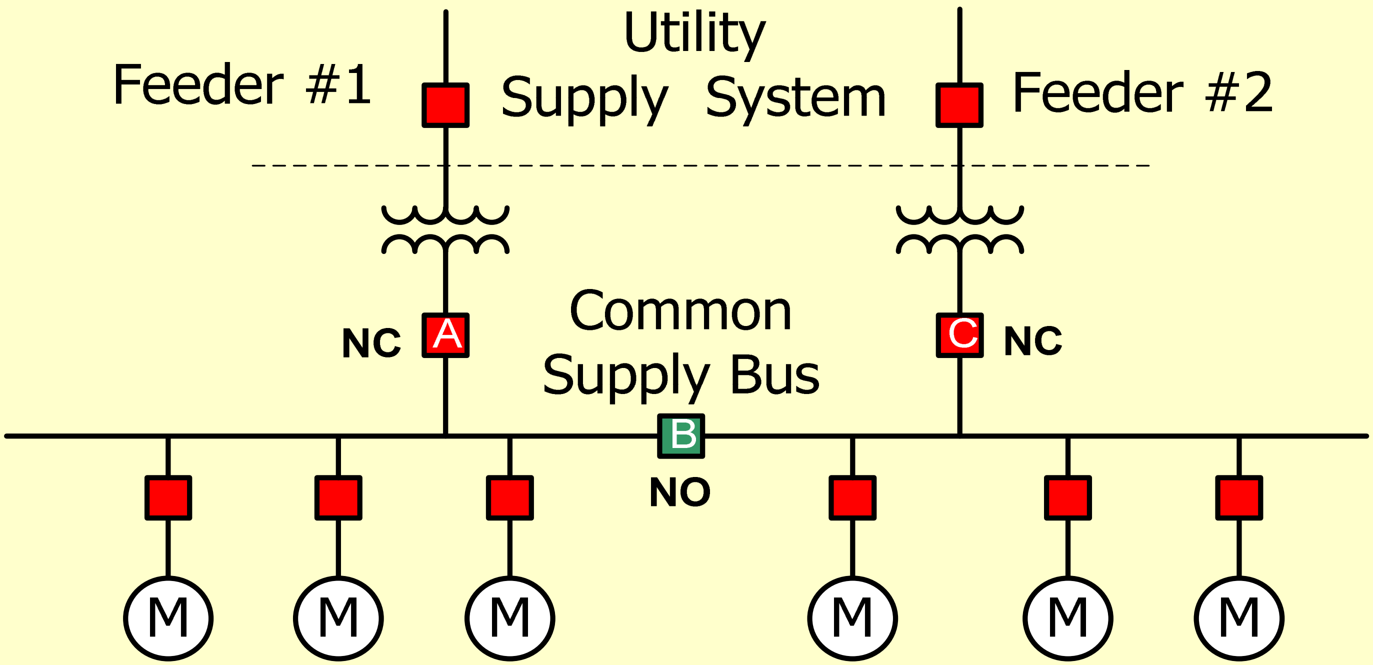
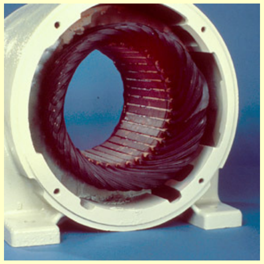


9d-Where is MBT needed?

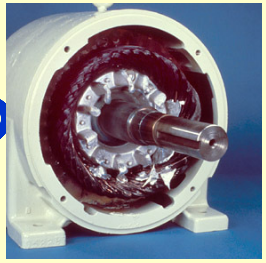




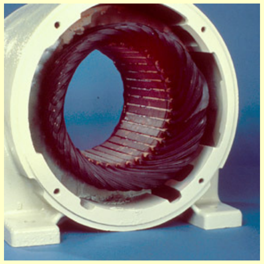
Industrial Facilities



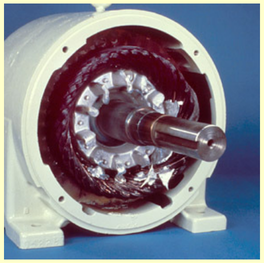
9e-When it is needed?



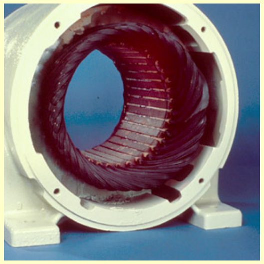
- Planned transfers
  - Maintenance or startup/shutdown
- Emergency transfers
  - Loss of existing source due to a fault



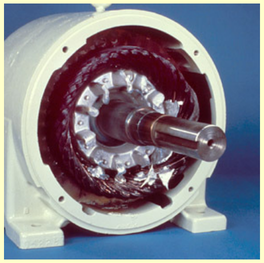
9f-Types of MBT



- **Closed Transition**
  - Hot Parallel Transfer
- **Open Transition**
  - Fast
  - In-Phase
  - Residual Voltage



9g-Hot Parallel Transfer



Steps:

1. Check synchronism
2. Check that new source voltage is acceptable
3. Close new source breaker
4. Open old source breaker

– Ensure that paralleling is temporary

– Cannot be used for emergency transfer

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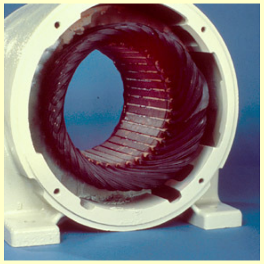
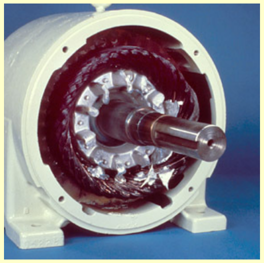
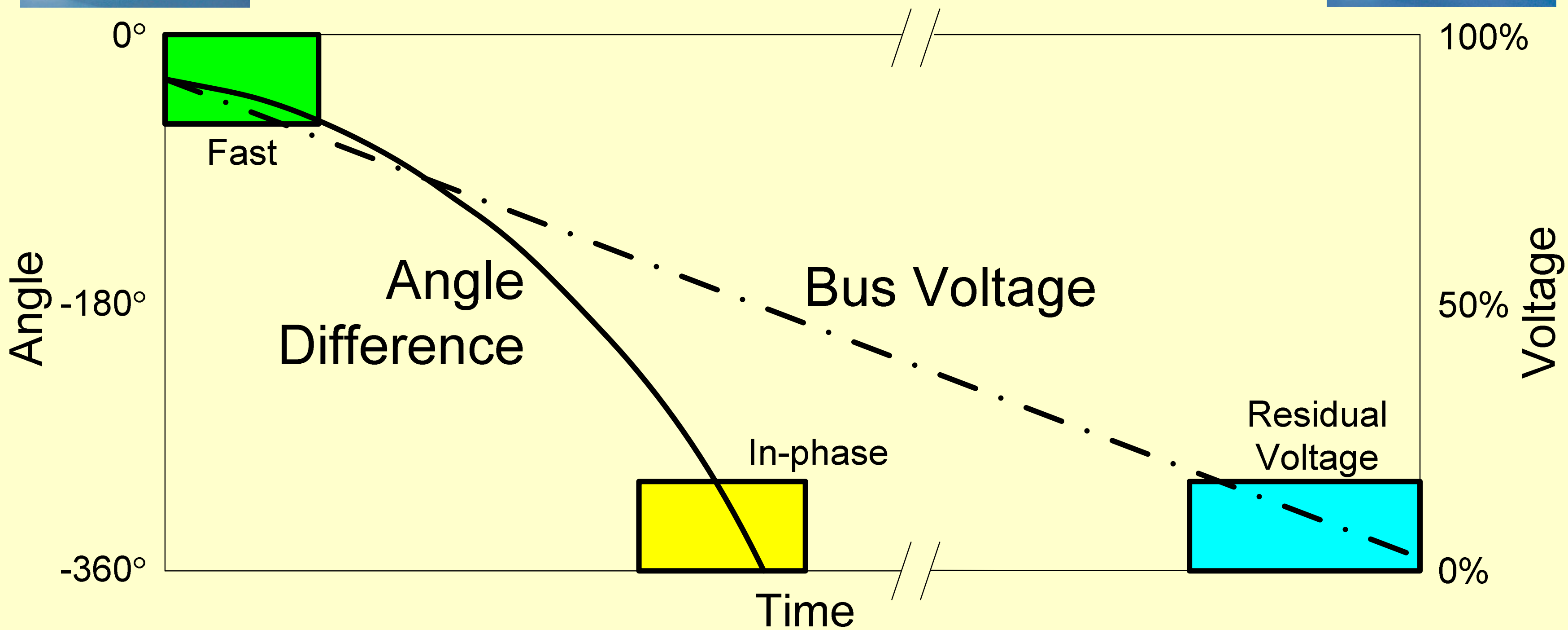


9h-Open Transfers





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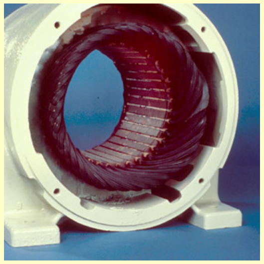
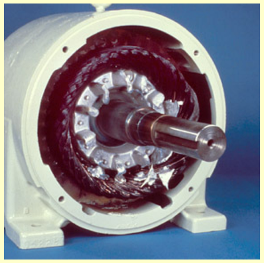
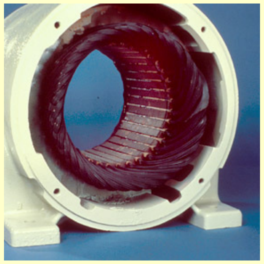


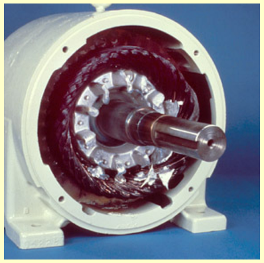
9i-Fast Transfer



- Requires sync-check supervision and possibly a high-speed sync-check
- Checks upper/lower voltage on the new source
- Must continuously check for rapidly changing conditions across the open new source breaker



9j-In-Phase Transfer



- Predicts movement toward synchronism between the motor bus and the new source
- Checks upper/lower voltage on the new source and slip frequency
- Must compensate for breaker closing time

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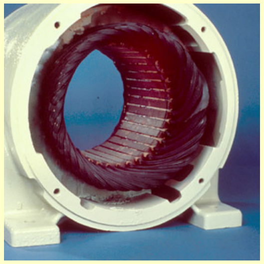
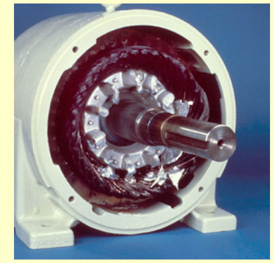


9k-Residual Transfer



- Unsupervised as to phase angle or slip frequency,
- Checks that bus voltage is below lower limit (~ < 0.25 pu).
- Frequency may decay past the motor stall point - load shedding may be required

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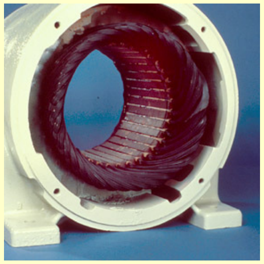
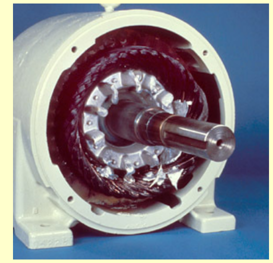


10a-Application of Fuses



- Medium voltage, Class E2 starters, IEEE C37.46 – 2010, R-Rated current limiting fuses provides short circuit protection.
- Preferred standard interruption rating is 40 or 50 kA symmetrical per UL 347 – 2009.

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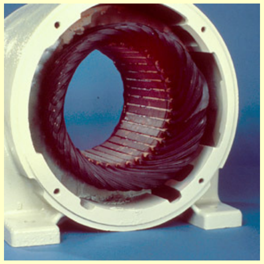
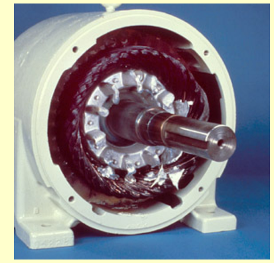
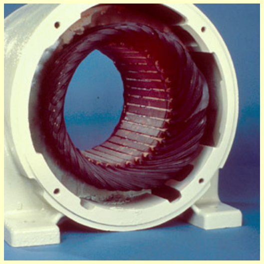


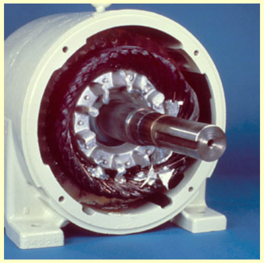
10b-Application of Fuses



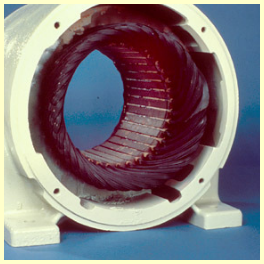
- Fuse fatigue is a major concern for starting of large motors.
  - Select a fuse whose melting time is 125% of the acceleration time of the motor with its load connected at the locked rotor current value.
  - If unknown assume LRA to be six times FL and acceleration=10 sec.



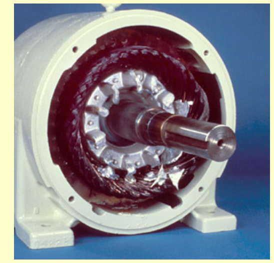
10c-Application of Fuses



- For fused contactor applications
  - Size CTs for OL conditions only
  - OL relay protection is not intended operate to interrupt fault.
- Therefore CT saturation is not of great concern
  - CL fuse is sized to interrupt fault



11-Ground Sensor Relay



- Supplied by a core-balance CT to provide sensitive protection (5-12 A)
- Limited by the capacitive unbalance
- Asymmetrical breaker pole closing combined with the cable/motor/surge capacitance produces current transient.
- lightning or switching surge can also cause a trip.

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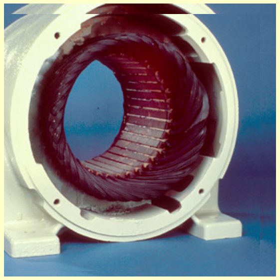
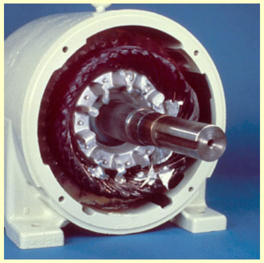


12.Breaker Failure Protection



- Needed because backup relay pickup (switchgear incomers) could still be less than locked rotor current and cannot sense motor feeder breaker failure.
- Can occur for small motors

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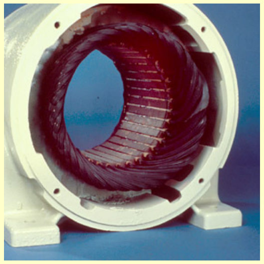
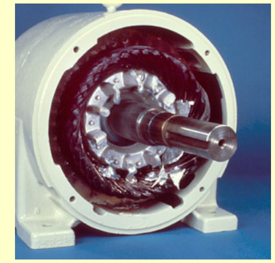


13a-Deriving settings from Nameplate and Data Sheets



- These parameters provide the information necessary to configure various thermal and short circuit protection elements
- For medium/large motors thermal damage curves are typically provided and starting curves at rated and reduced voltage

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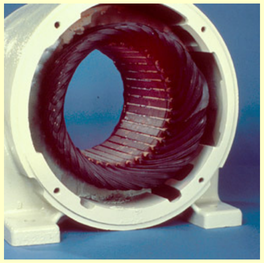
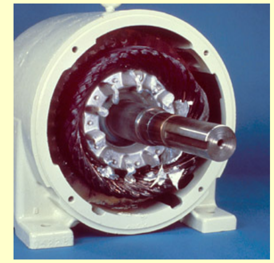


13b-Available Data



- Full load current
- Locked rotor amps
- Safe stall time at ambient temp
- Safe stall time at operating temp
- Maximum ambient temperature and rated temperature rise or insulation class
- Cooling time constants

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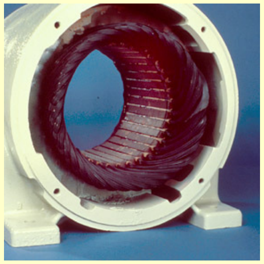
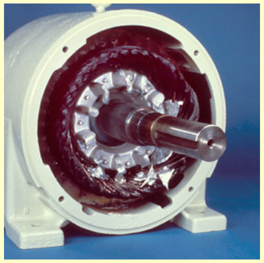
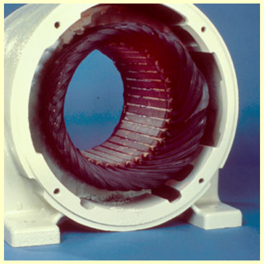


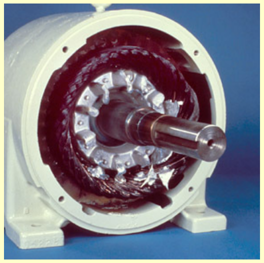
13c-How is it used?



- In some cases the data is entered directly into the relay.
- In other cases procedures are provided for deriving the settings



13d-Other Functions



- Maximum starts per hour or minimum time between starts can be entered to protect the motor against frequent starting
- If cooling times are unavailable, the relay may be able to learn the cooling time based on the motor state and RTD measurements

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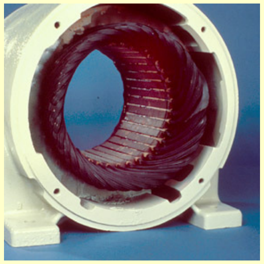
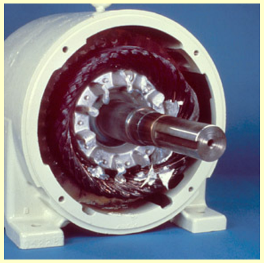
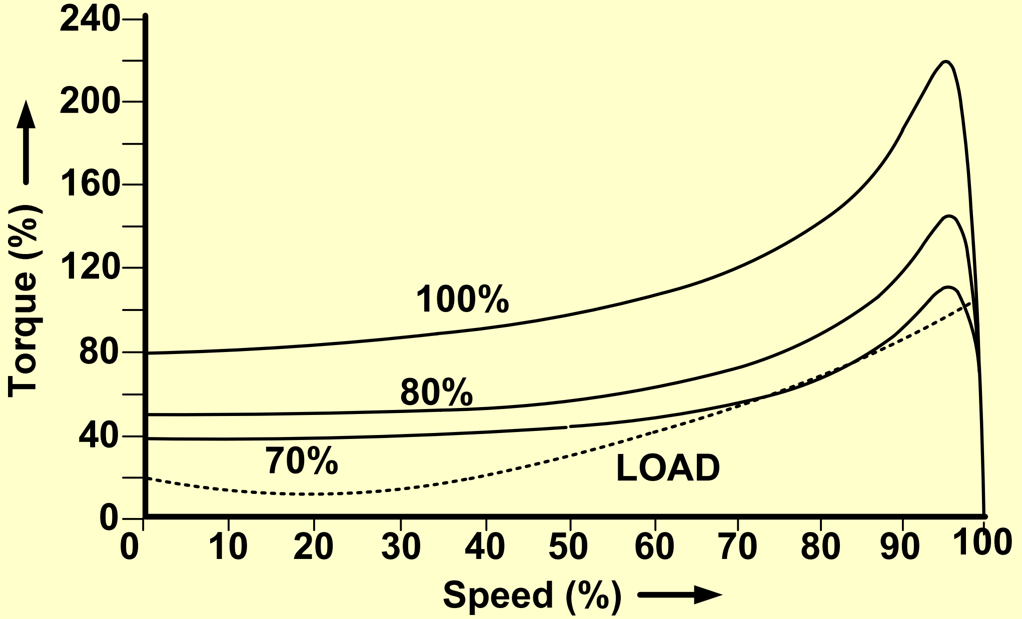


14-Annex Material





- Acceleration Time
- Voltage Dip Calculation and Resulting Torque

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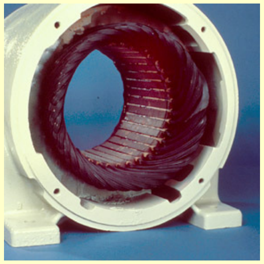
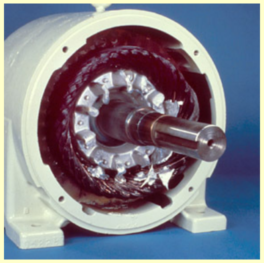
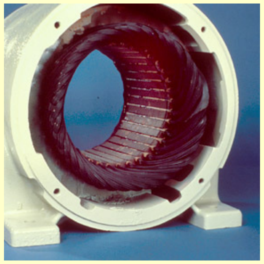


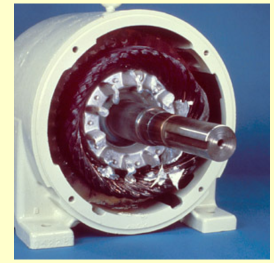
15a-Relay Setting Example

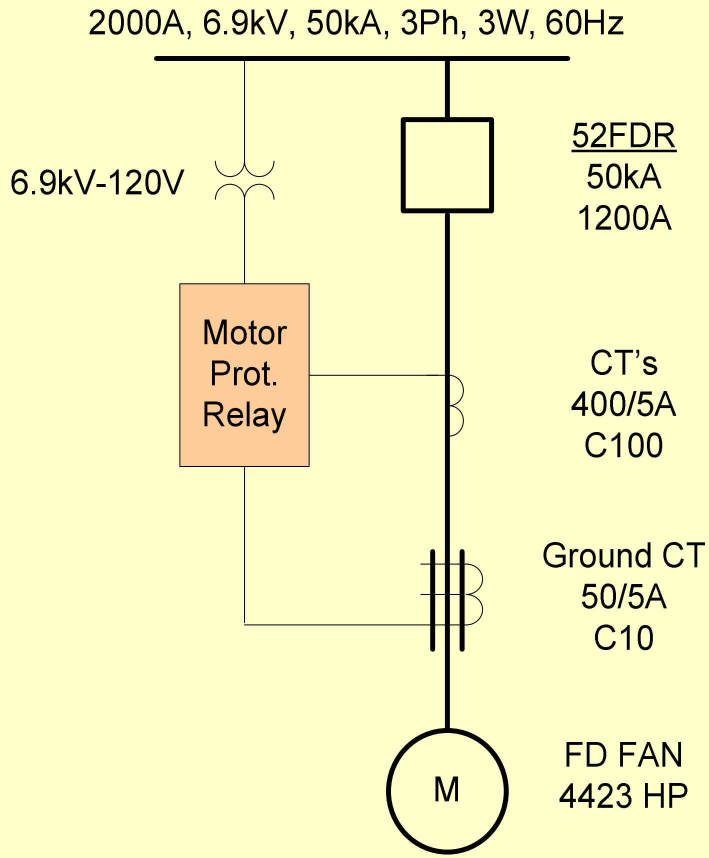


- Annex A-3 added to show how to set multifunction motor protection relay
- Source for input data for determining various settings
  - Single Line Diagram for CT, VT ratio, system information
  - Motor Data Sheet for motor information
  - Motor Thermal Curve
- calculate each setting from available data.

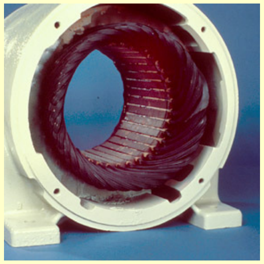
15b-Relay Setting Example

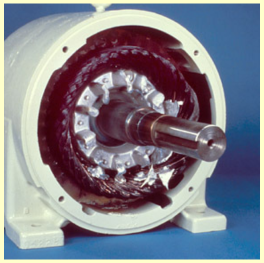


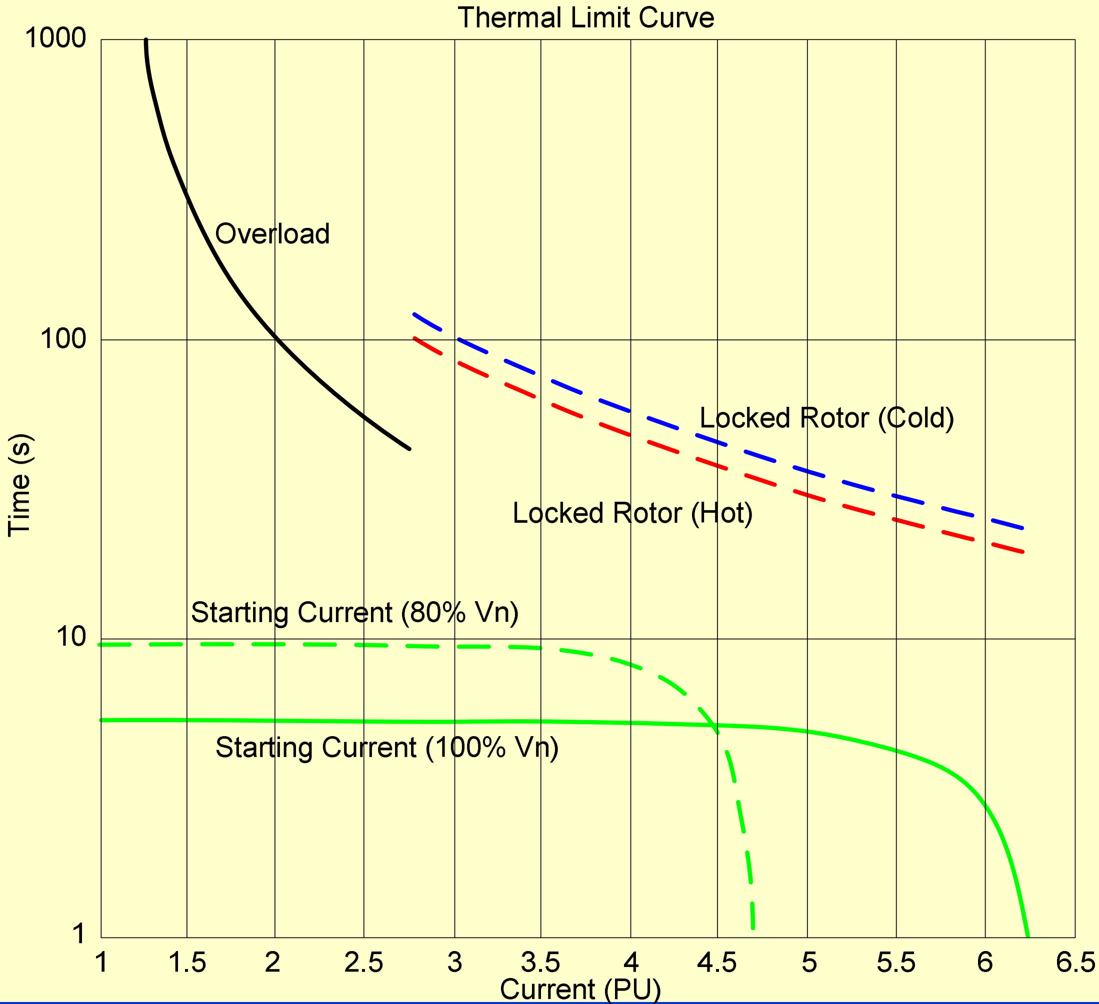




15c-Relay Setting Example







Thanks

Questions?

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