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Industrial Automation

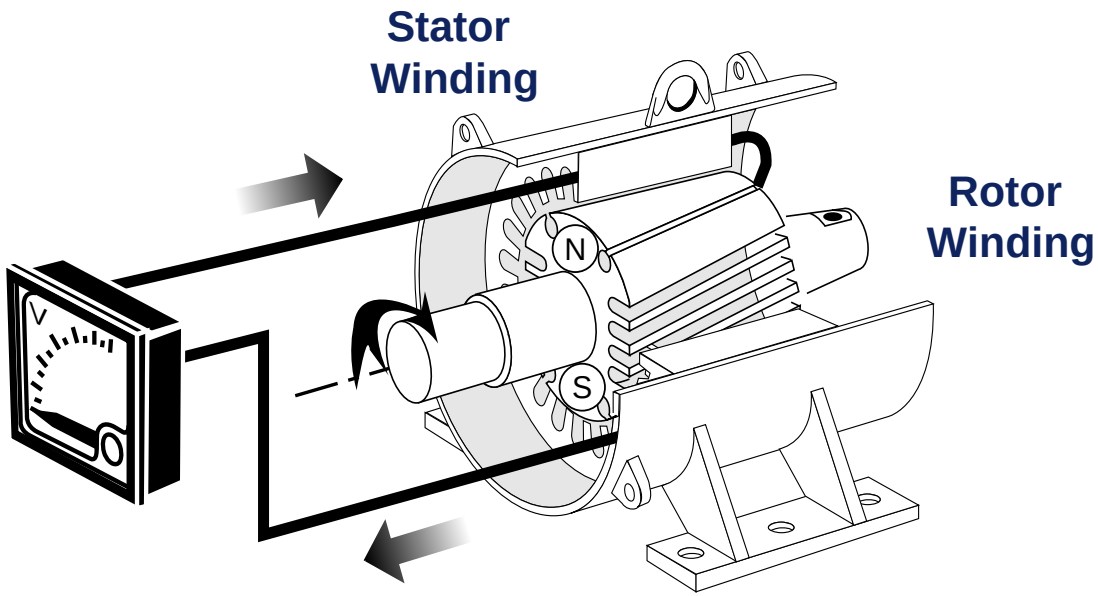
# AC Generator

Basics

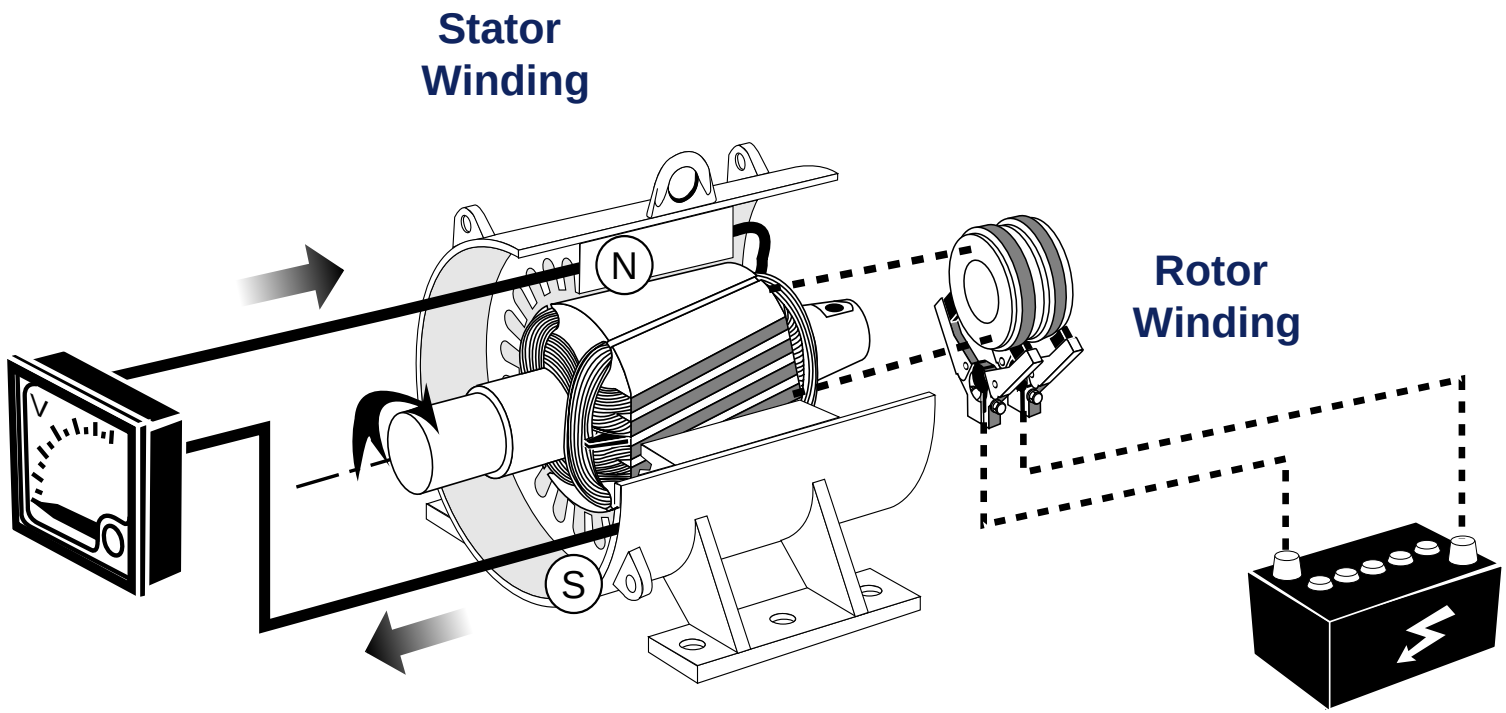
LEROY SOMER

KATO Engineering Inc.
Leroy Somer North America

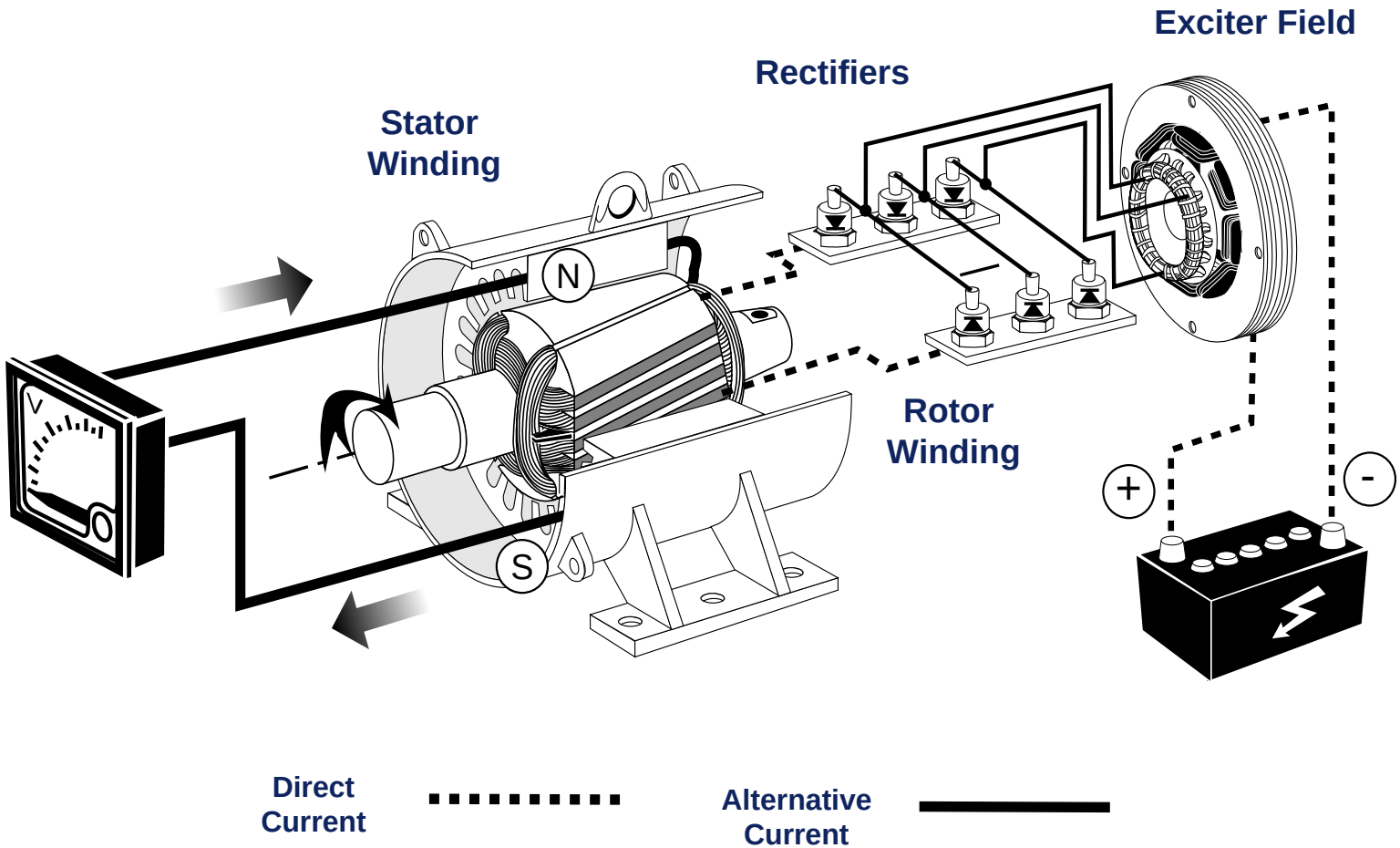
# Alternator Principle



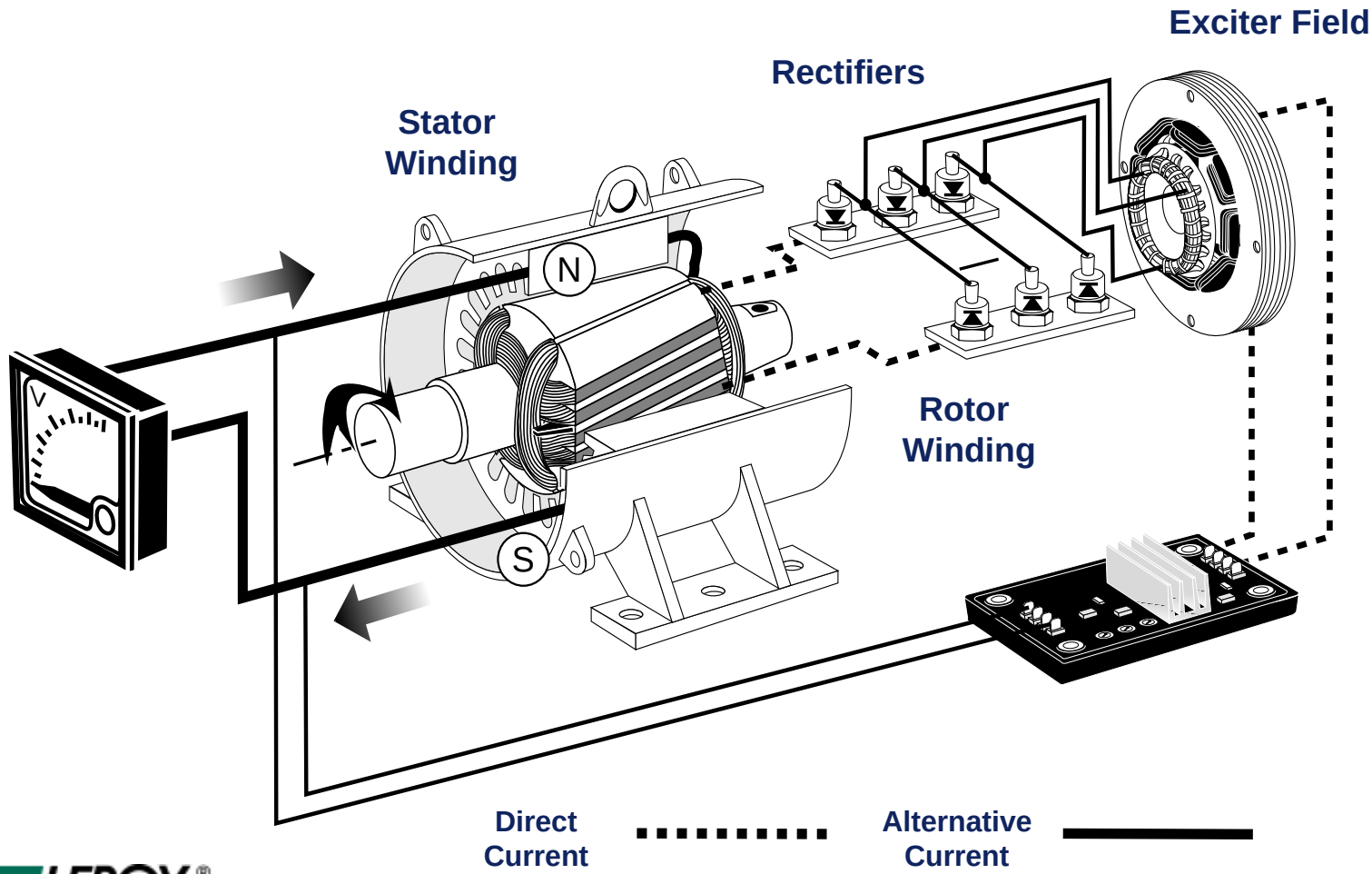
# Alternator Principle



# Alternator Principle



# SHUNT Principle



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# AC Generator

## Excitation System

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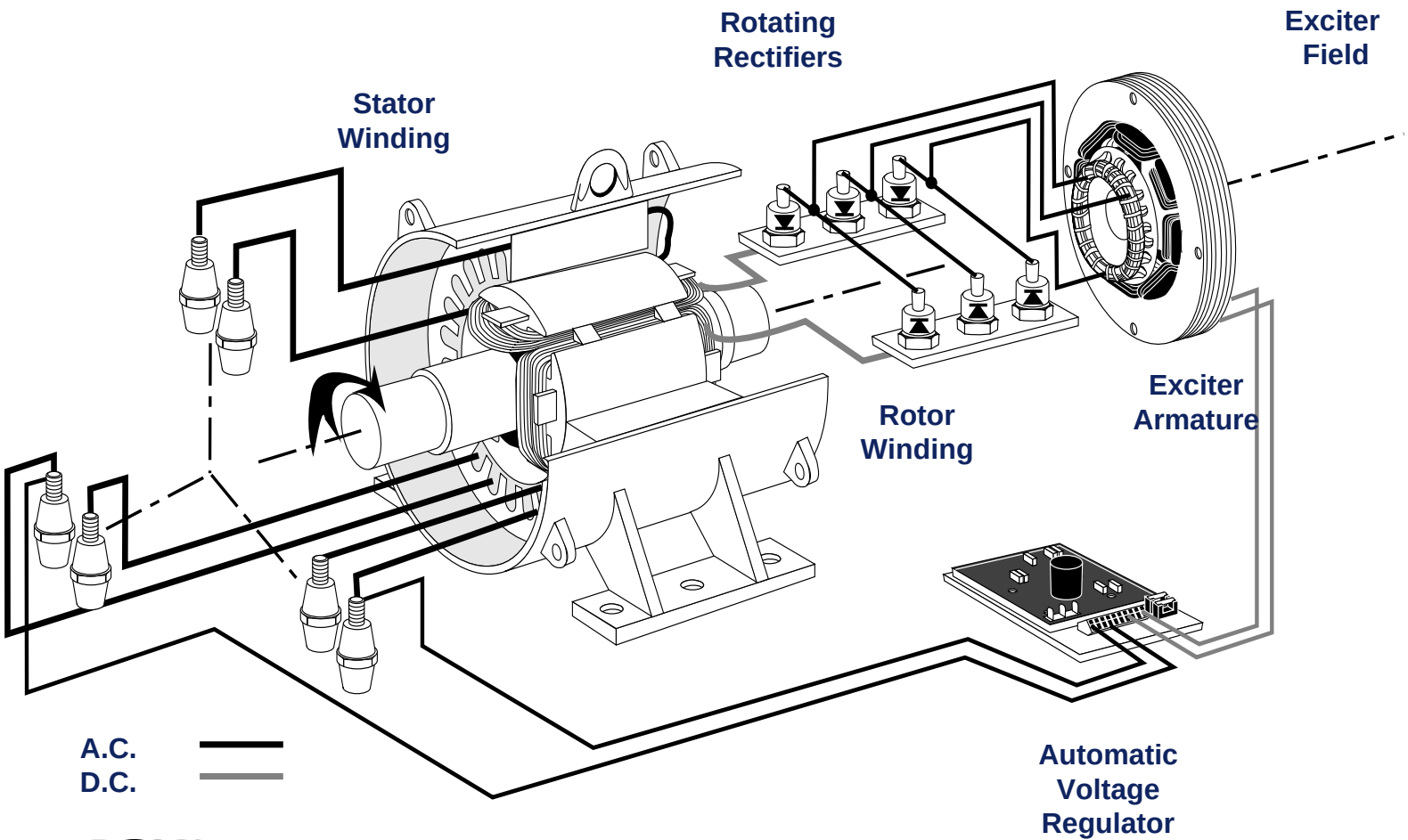
# SHUNT


Rotating
Rectifiers
Exciter
Field
Stator
Winding
Exciter
Armature
Rotor
Winding
A.C.
D.C.
Automatic
Voltage
Regulator

# SHUNT + PMG

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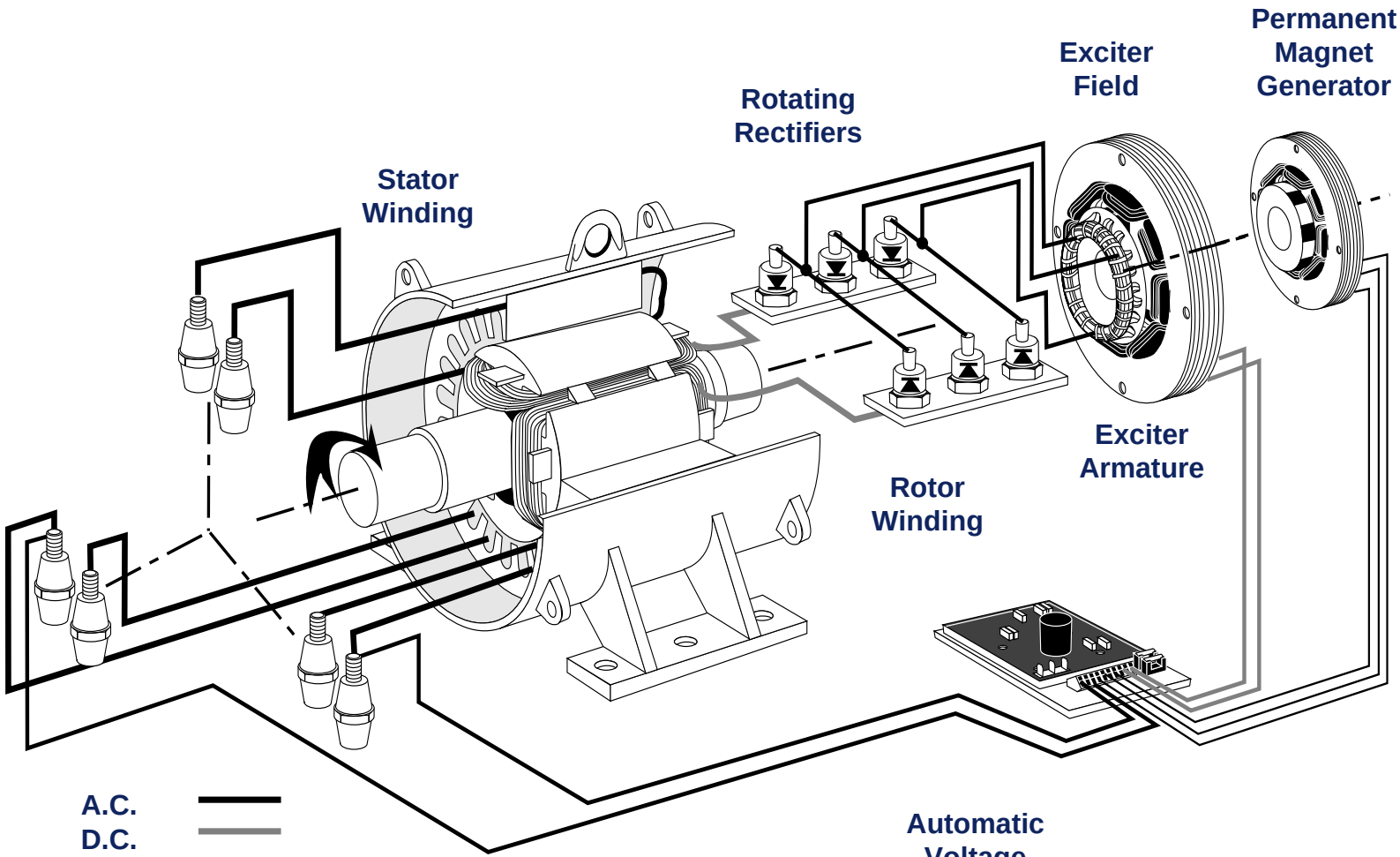
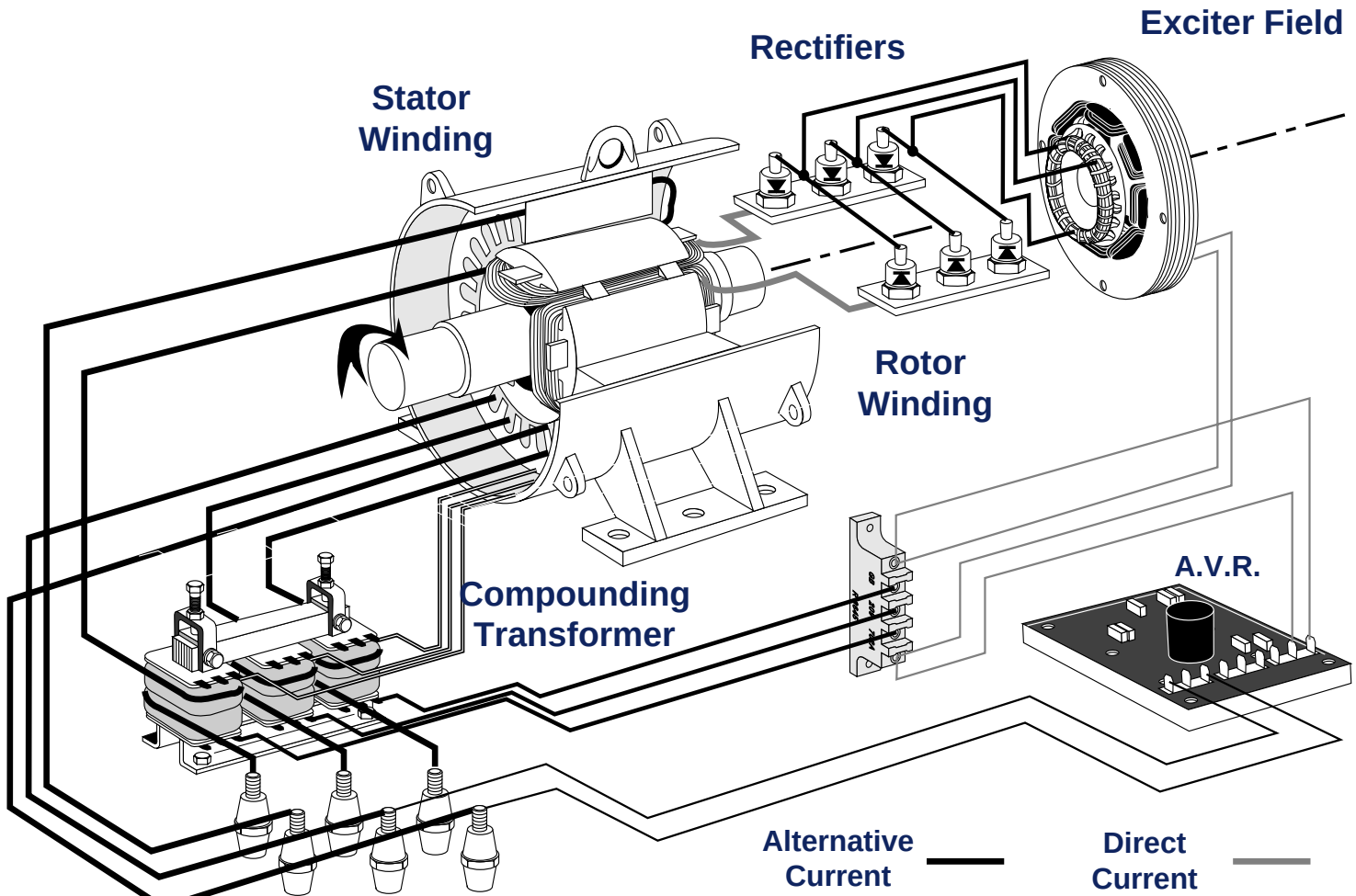



LEROY SOMER

# Compound


Exciter Field
Rectifiers
Stator Winding
Rotor Winding
A.V.R.
Compounding Transformer
Alternative Current
Direct Current

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# AREP

## Excitation System

LEROY SOMER

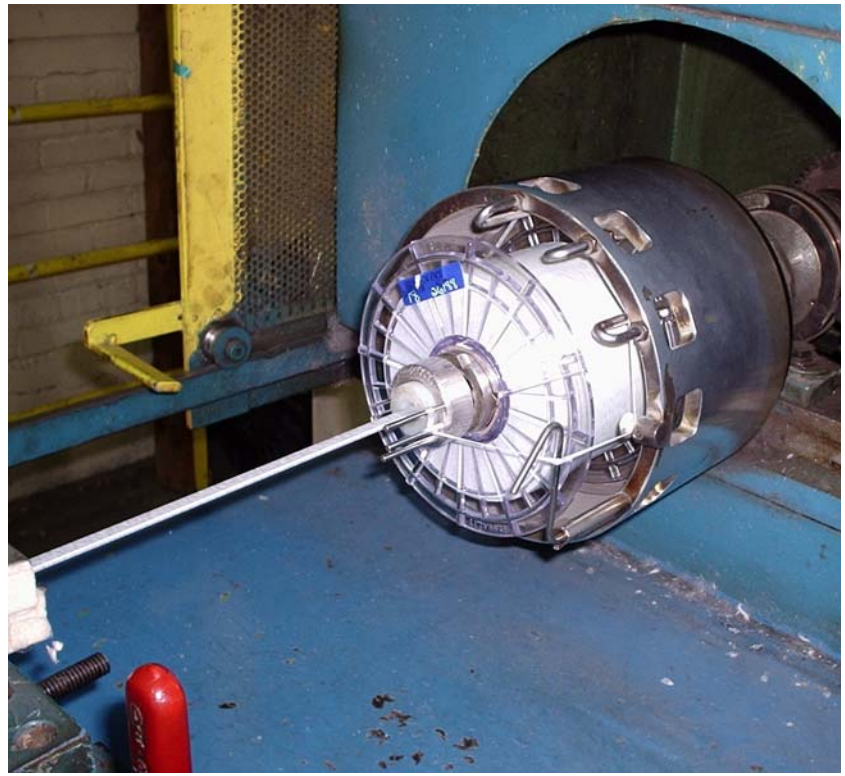
KATO Engineering Inc.
Leroy Somer North America

# History

- LS started to develop excitation systems using auxiliary windings in 1950s
- The first systems were designed to provide:
  - a low voltage power source to a voltage regulator or,
  - used to provide the no load excitation while current or compound transformers would provide the additional excitation under load.
- The current system uses 2 independent auxiliary windings to provide power to a voltage regulator.
- Today, LS offers 3 different excitation systems in the Industrial range:
  - Shunt
  - AREP
  - Shunt with PMG

# AREP Components

- 2 auxiliary windings built from heavy film coated magnet wire with an overcoat of fiberglass.
- Generator stator core
- Adapted voltage regulator



AREP

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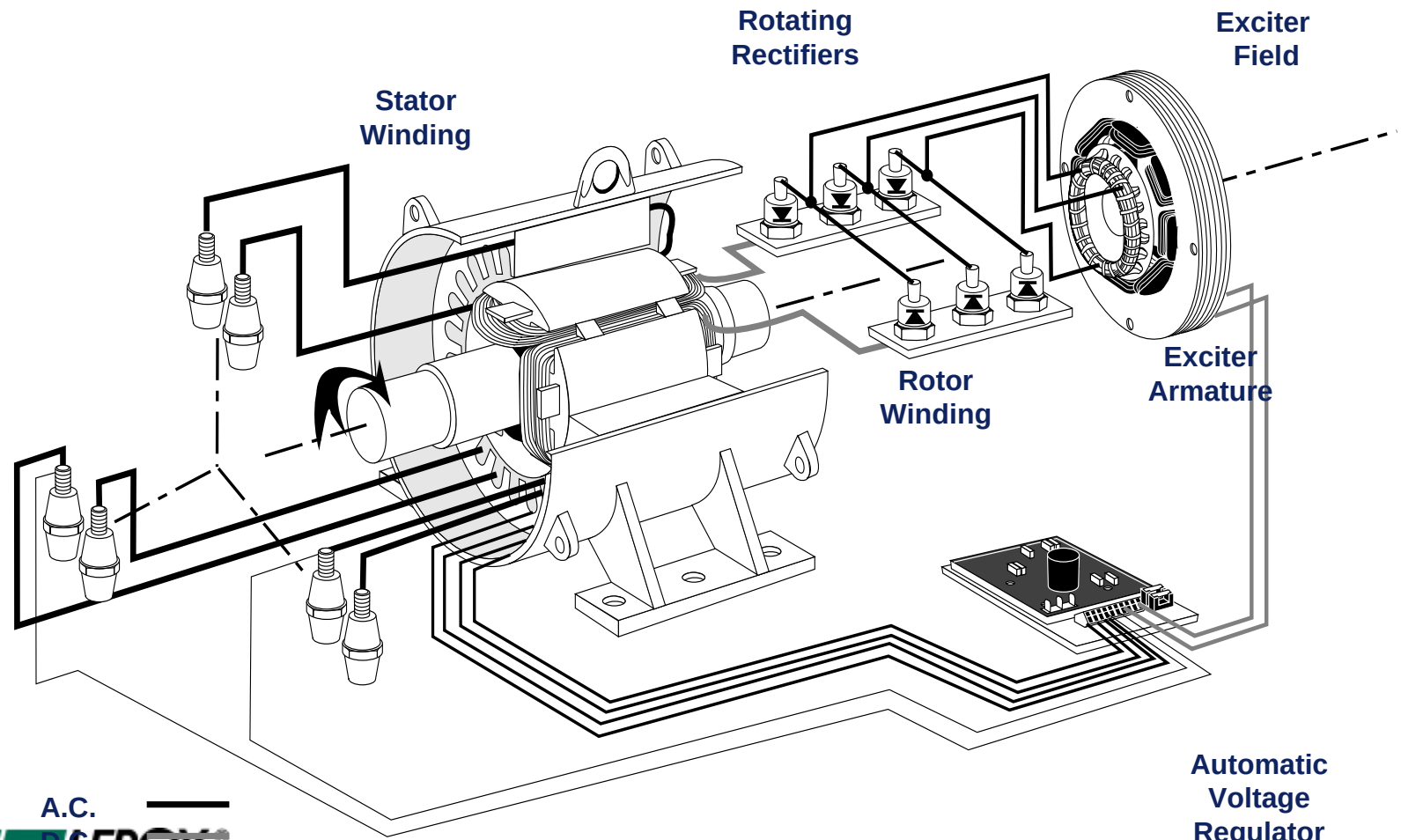


LEROY SOMER

# AREP Auxiliary Windings

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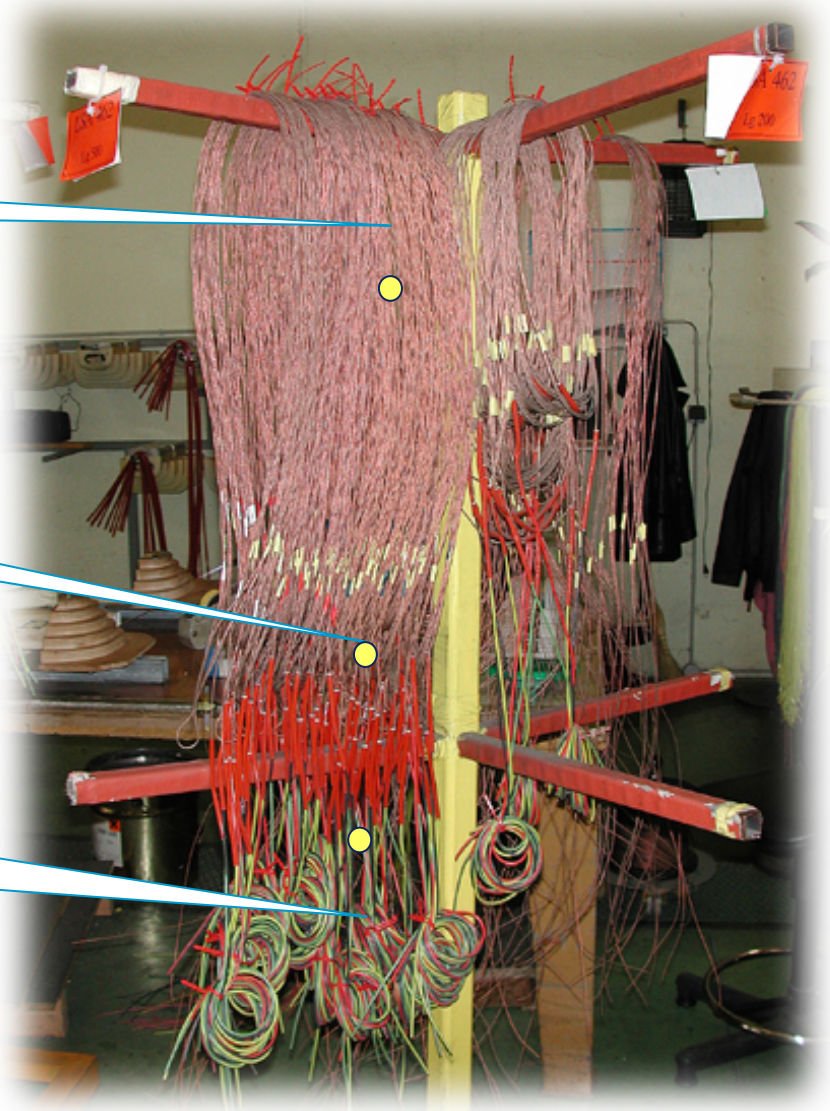
AREP coils

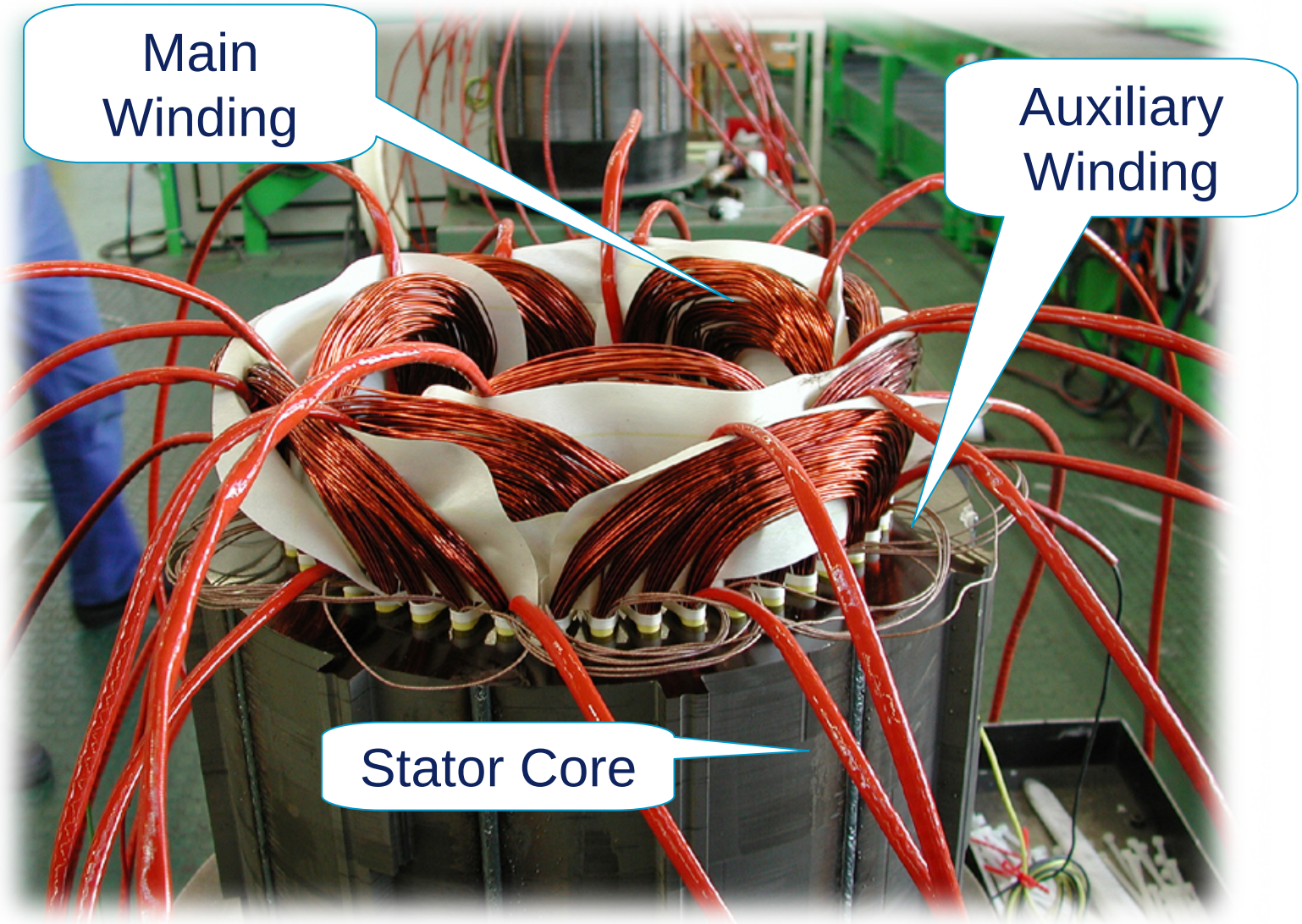
Connections

Connection leads



LEROY SOMER

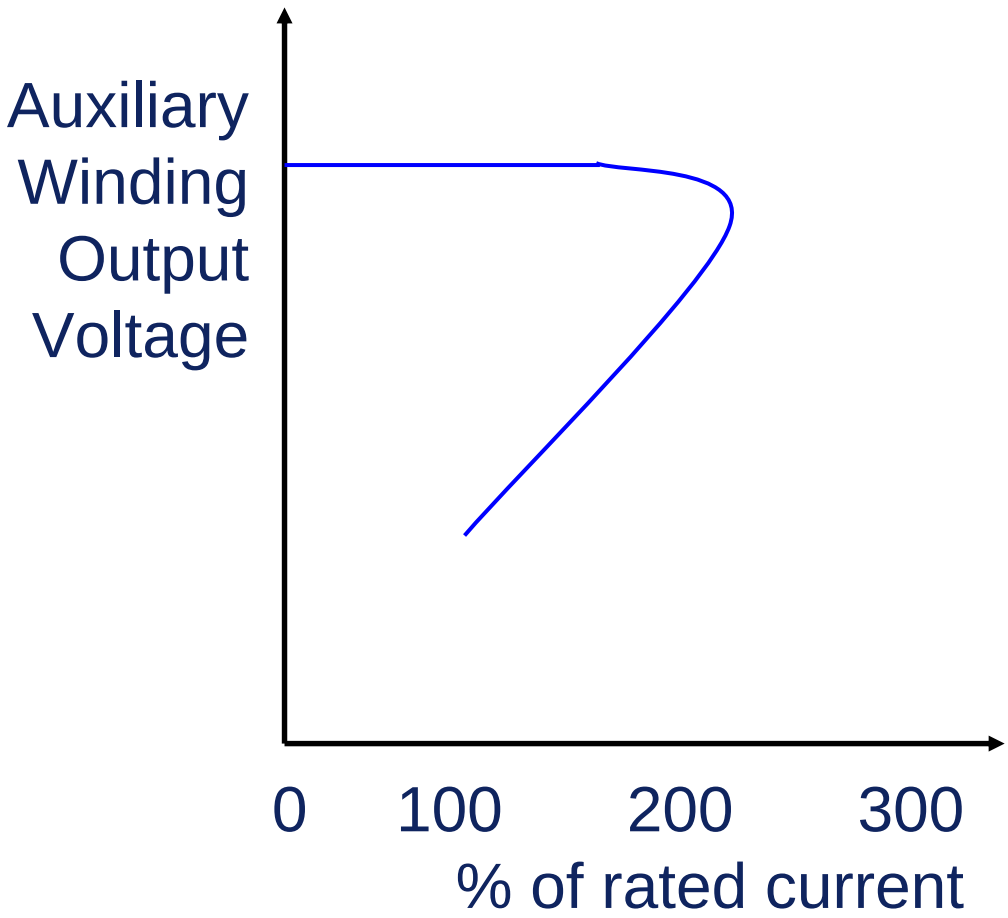
# Complete Stator Windings



# AREP Auxiliary Windings

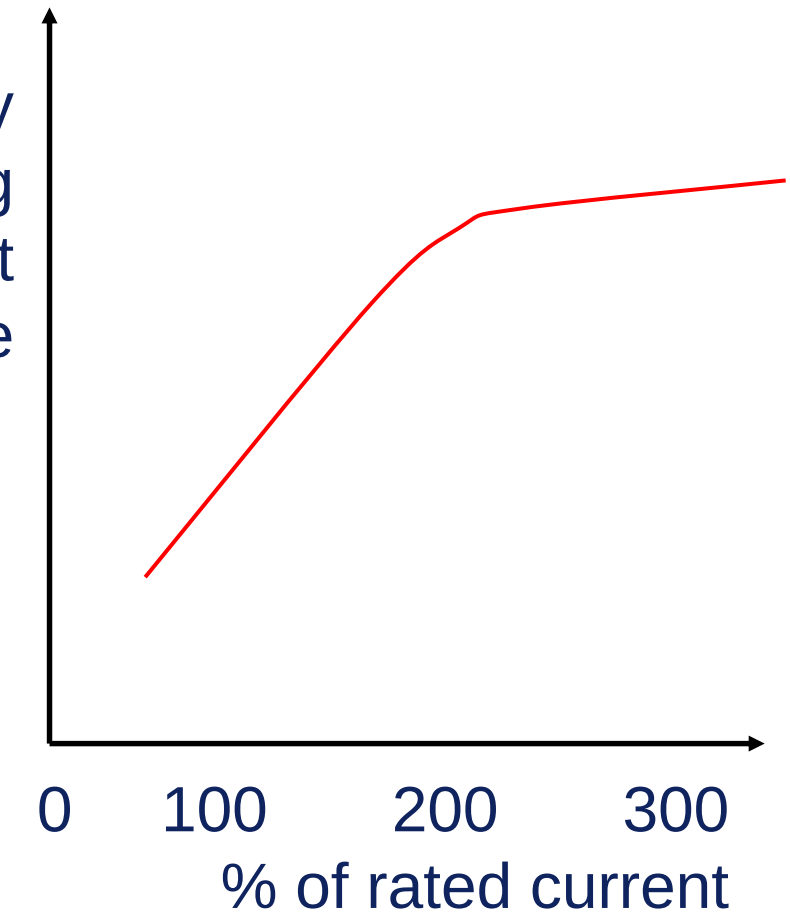
# SHUNT Auxiliary Winding

- Provides most of the no load excitation current.
- The output is constant up to 150-200% of rated load.
- Above these levels, the regulator does not get enough power from this auxiliary winding alone and the generator voltage collapse.



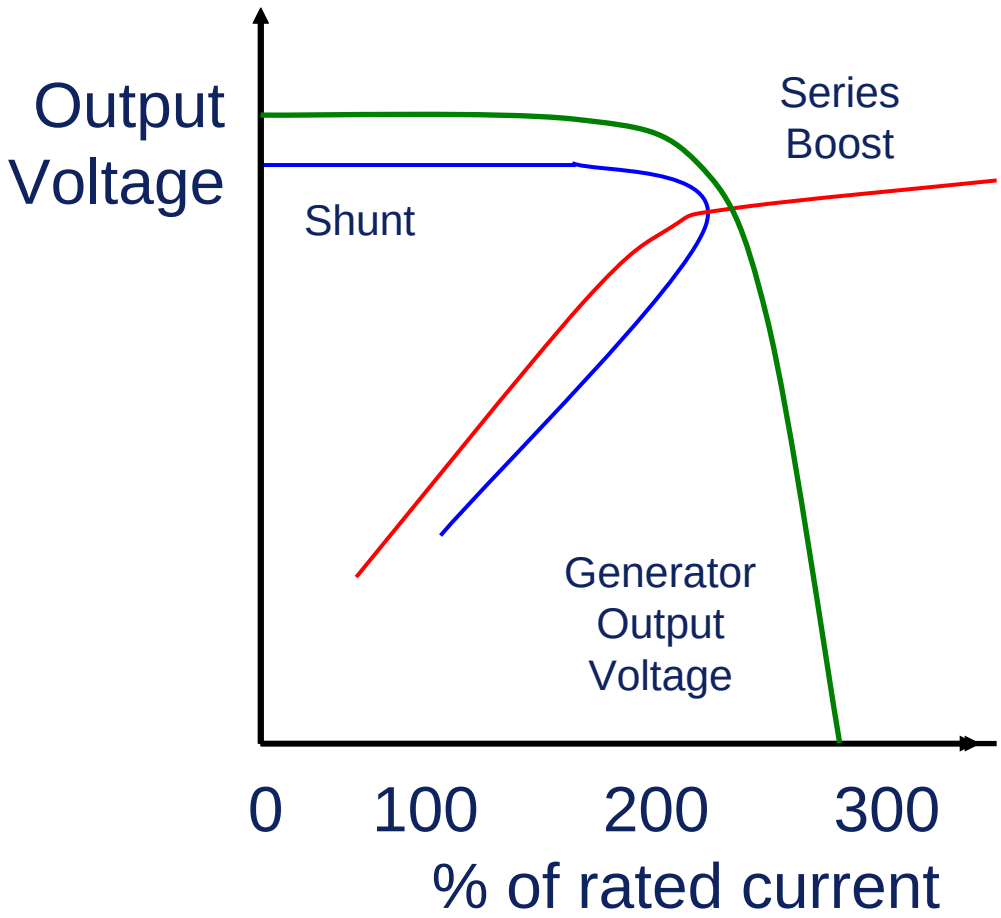
# Series Boost Auxiliary Winding

- Provides little if any excitation at no load.
- The output increases with the load and varies with the Power Factor.
- The output voltage saturates between 250-300% of rated current. That leveled value is calculated to be sufficient for the regulator to provide the 250-300% short circuit current.

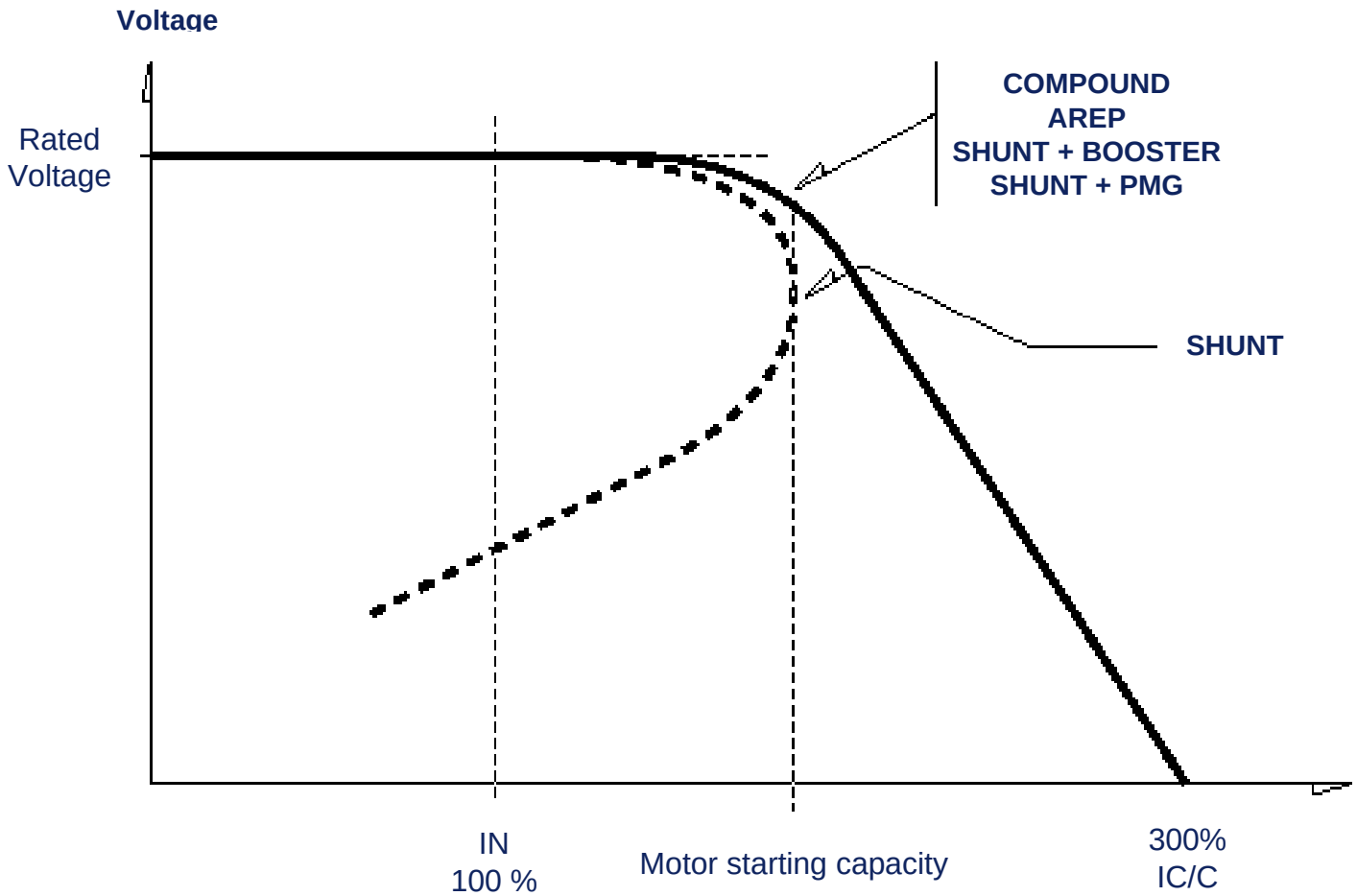


# Auxiliary Winding Output

- The 2 auxiliary windings provide a constant power source for the voltage regulator.
- The combined output of the 2 auxiliary windings provide the short circuit current capability.



# Overload Characteristics

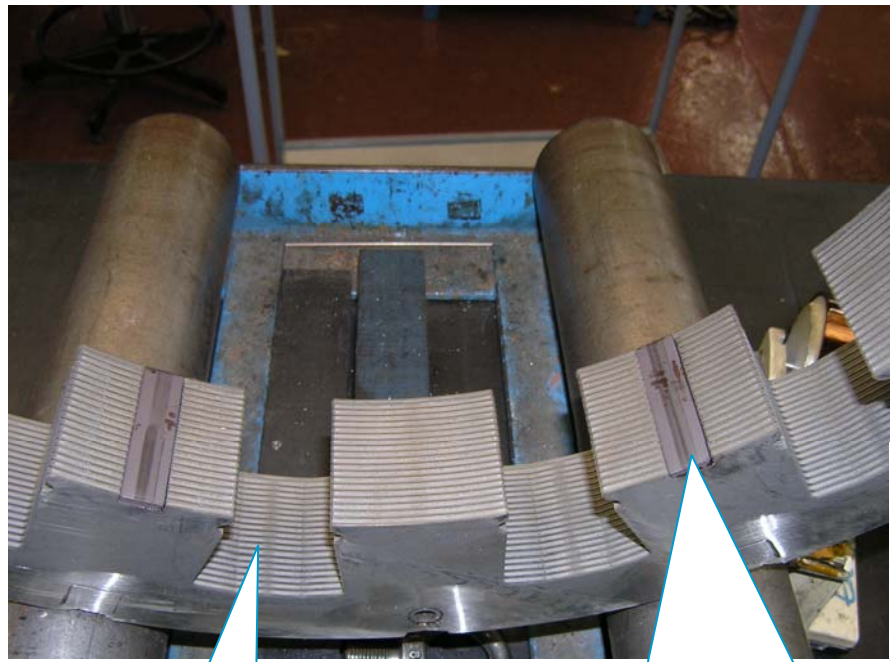


# Advantages - Disadvantages

| | Self Excited (SE) | AREP ™ | Permanent Magnet Generator (PMG) |
|---|---|---|---|
| Motor starting capability | Standard | **High** | **High** |
| Short circuit current capability | None | **300% @ 60Hz** | **300% @ 60Hz** |
| Susceptibility to non-linear loads | Maximum | **Minimum** | **Minimum** |
| Number of components | **Minimum** | **Minimum** | Maximum |
| Retrofitability | N/A | No | Yes |
| Generator length | **Minimum** | **Minimum** | Maximum |
| Price | **$$** | **$$** | $$$ |
| Stator design | **Standard** | Special | **Standard with PM attachment** |
| Voltage build up | Uses residual magnetism | **Uses residual magnetism and Permanent Magnet Inserts on some frames** | **Positive from permanent magnets** |

# Permanent Magnet Insert

- The AREP™ excitation system relies on residual magnetism for voltage build-up.
- Permanent Magnet Inserts have been developed to fit inside the pole(s) of the exciter field.
- The PMI are a standard feature of the LSA50-51 series generators and optional on the other series.



# Excitation System Offering

| Generator Series | SE | AREP | PMG |
|---|---|---|---|
| LSA42.2 | X | X | N/A |
| LSA43.2 | X | X | X |
| LSA44.2 | X | X | X |
| LSA46.2 | X | X | X |
| LSA47.2 | X | X | X |
| LSA49.1 | | X | X |
| LSA50.1 | | X | X |
| LSA51.2 | | X | X |

# Excitation System Offering

| Stator winding | SE | AREP™ | PMG |
|---|---|---|---|
| LV (0V – 999V) | X | X | X |
| MV (1,000V – 4,999V) | X | X | X |
| HV (5,000V – 14,999V) | X | X | X |
| Random Wound | X | X | X |
| Form Wound | X | X | X |

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# AC Generator

## Applications

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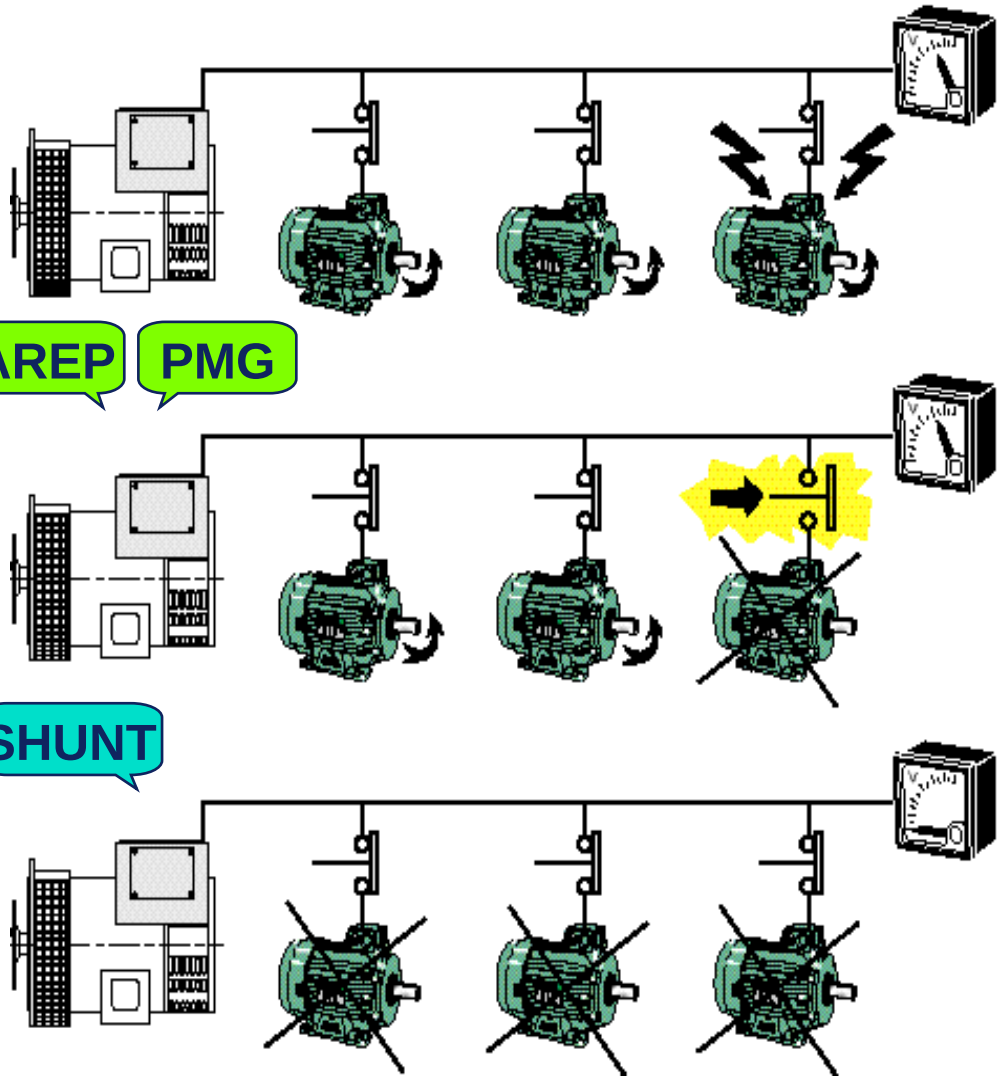
# Selective Tripping



Overload or short
in the installation

AREP

PMG

**AREP or PMG**

The alternator provides
short circuit current for 10 seconds
The breaker trips
The fault is cleared
Power continues to be available to the other loads

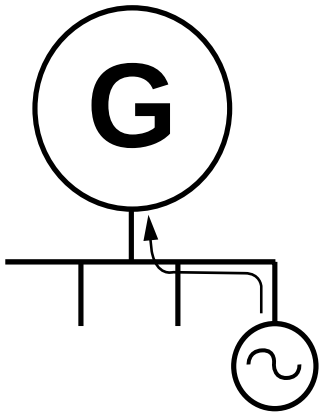
SHUNT

**SHUNT**

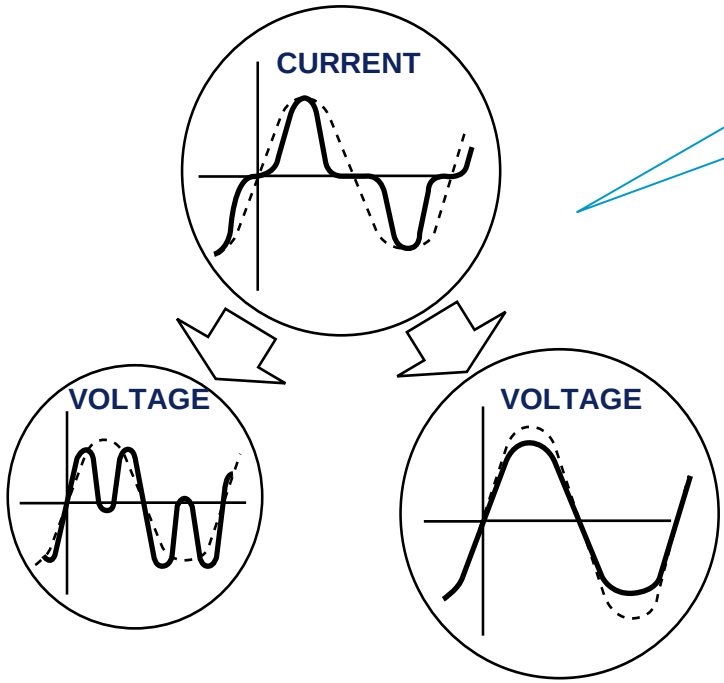
The alternator cannot hold voltage and
collapse
Power is interrupted for all connected loads.

# Non Linear Arcing Loads

APPLICATIONS
- Supermarkets
- Green houses



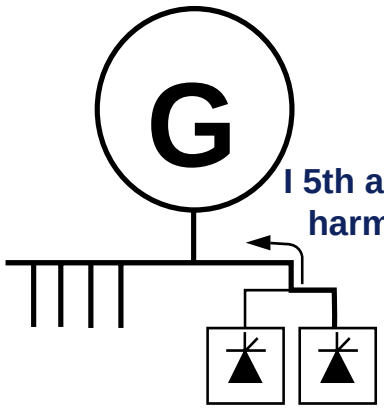

I 3rd harmonic




Distorted voltage wave form  Near normal wave form

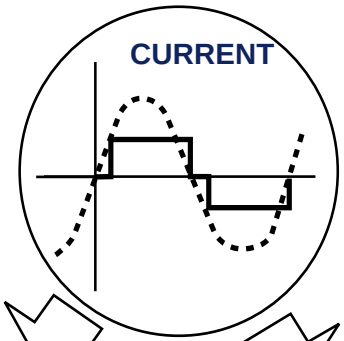
The voltage harmonics will be proportional to the load current harmonics, the generator inherent harmonics and the reactance of the generator

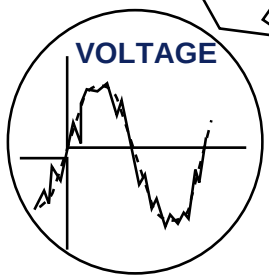
# Non Linear Thyristor Loads



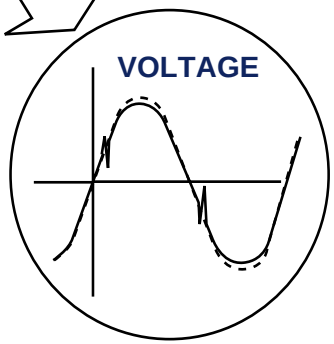

I 5th and 7 th harmonics

Variable speed Inverter, UPS ...




. Distorted voltage wave form disturbing the other loads

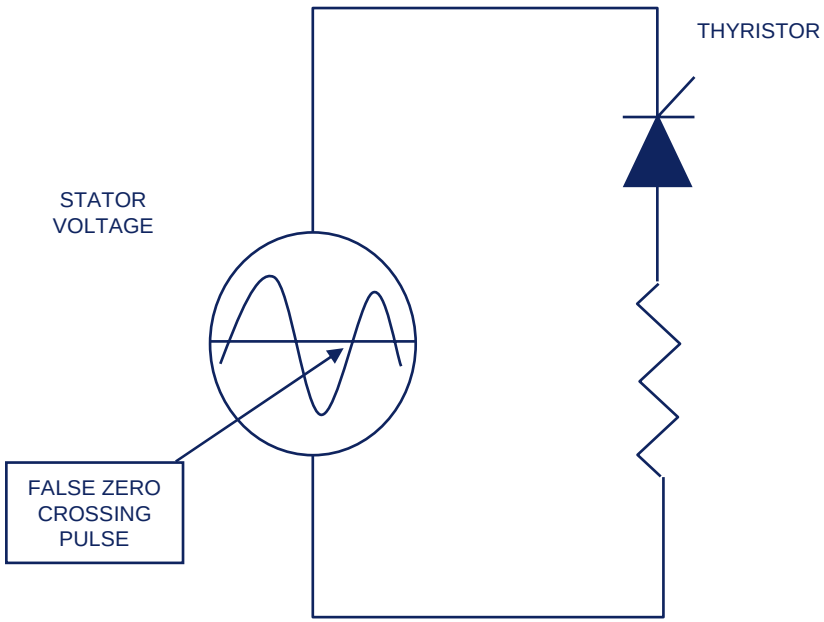



. Near normal wave form

APPLICATIONS
- Pumping stations
- Data center
- Banks
- UPS

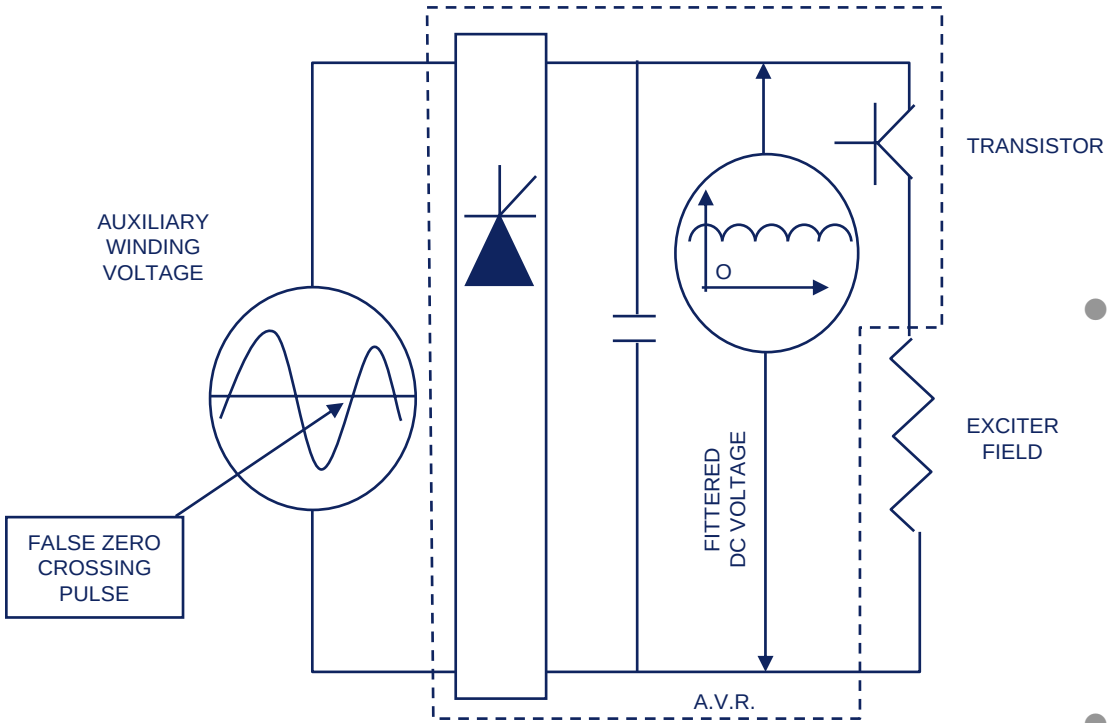
The voltage harmonics will be proportional to the load current harmonics, the generator inherent harmonics and the reactance of the generator

# Non Linear Loads




- The load current distorts the generator sine wave.
- Current spikes can cause multiple false zero crossings.
- Multiple false zero crossings can cause instability and faulty operation.

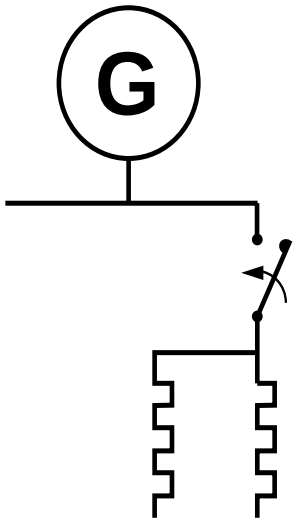
# Non Linear Loads



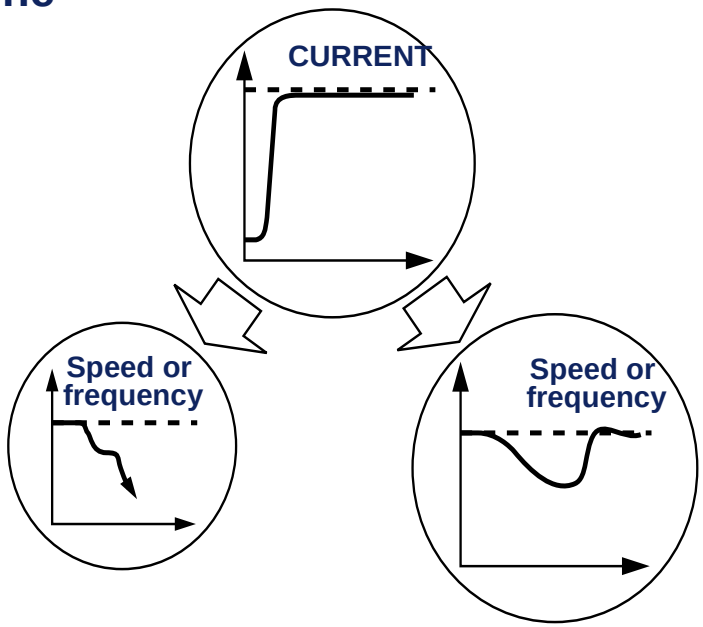

- LS excitation systems use transistor in Pulse Width Modulation instead of SCR.
- The induced false zero crossings caused by a distorted wave form does not affect the AREP™ AVR.
- The auxiliary winding voltage is rectified and filtered.

# Block Loading

**Application: 100 % load is applied in one step on a turbocharged engine**




**100 % load**



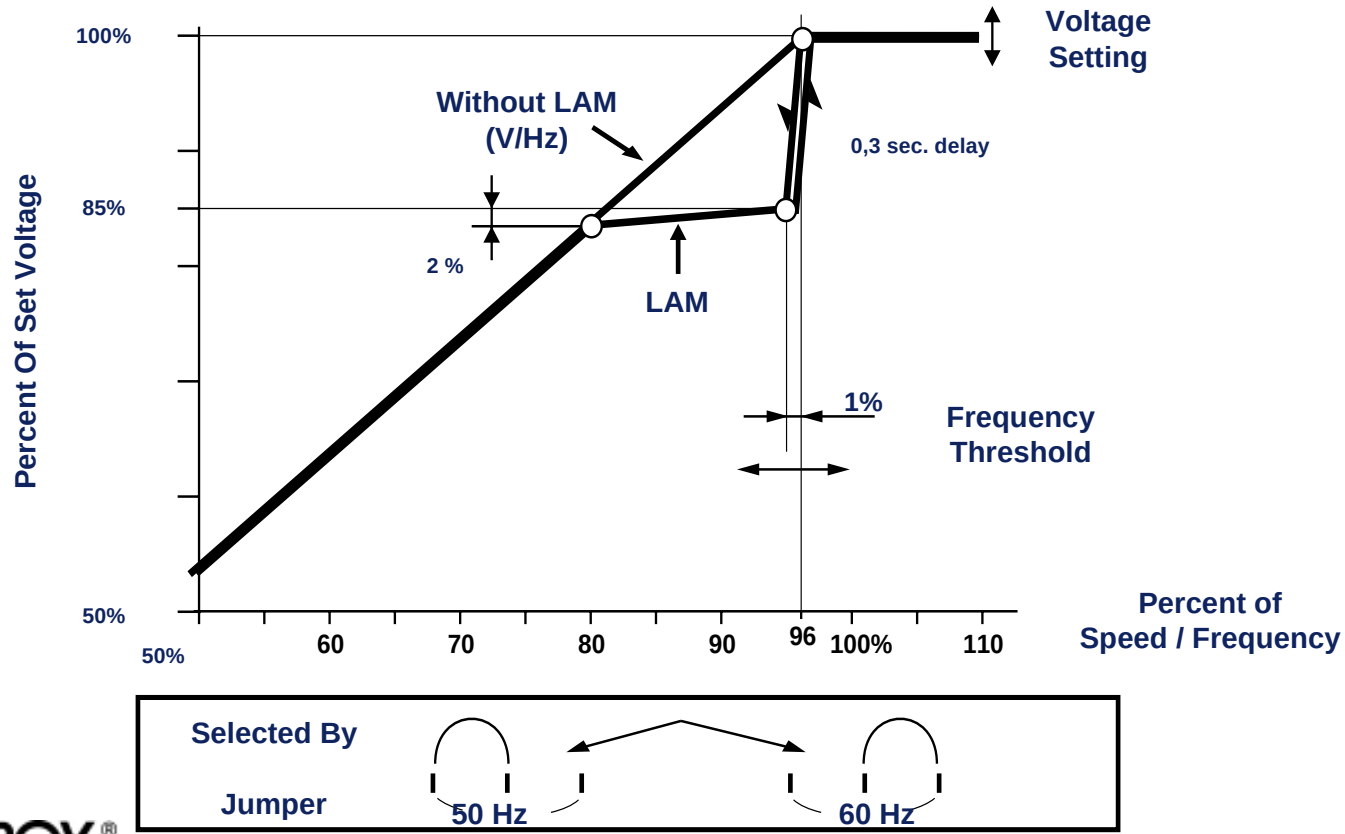

**The engine stalls**

No load acceptance module

**The engine recovers**

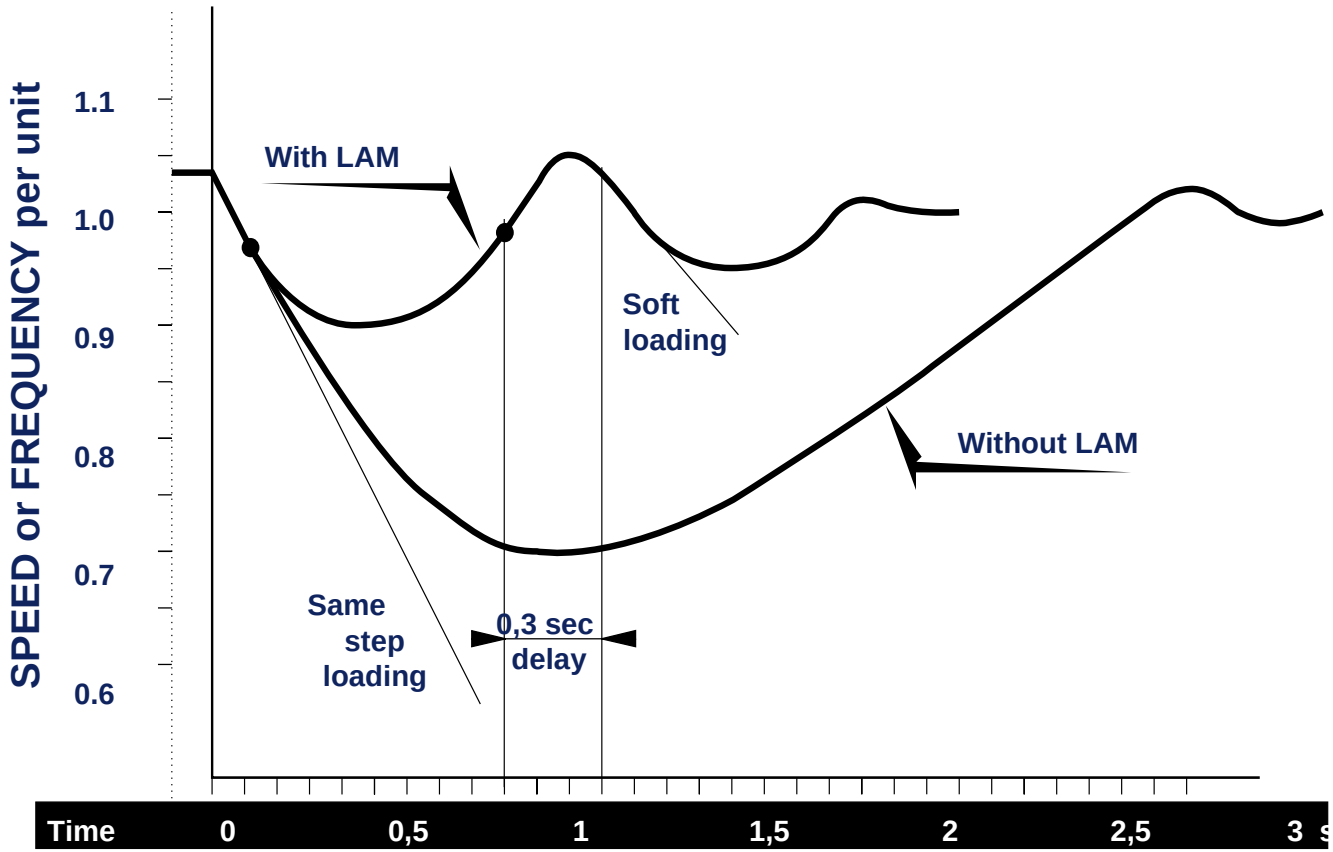
Load acceptance module

# Under Frequency Operation




A.V.R. - R 438 - R 448 - R 449

# LAM PRINCIPE



# When to specify SE?

- The SE system has been used successfully for decades.
- It is simple and the lowest cost system.
- It is the shortest version.
- Protection device coordination can be challenging as this system does not support short circuit current.
- Power interruptions are possible in case of a short circuit which at the same time “protects” the alternator.
- Inrush kVA and non linear loads are a small portion of the load.

# When to specify AREP™?

- The AREP™ system has been used for years.
- It is simple and provides many features at a minimal price adder.
- It is the shortest version.
- The application requires a high motor starting capability.
- The sustained short circuit current capability allows breaker coordination maintaining power to sensitive loads.
- Inrush kVA and non linear loads can be a significant portion of the load.

# When to specify PMG?

- The PMG excitation system has been used for years.
- It is simple and provides many features at a premium.
- It is the longest version.
- The application requires a high motor starting capability.
- The sustained short circuit current capability allows breaker coordination maintaining power to sensitive loads.
- Inrush kVA and non linear loads can be a significant portion of the load.

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# AREP

## Automatic Voltage Regulators

LEROY SOMER

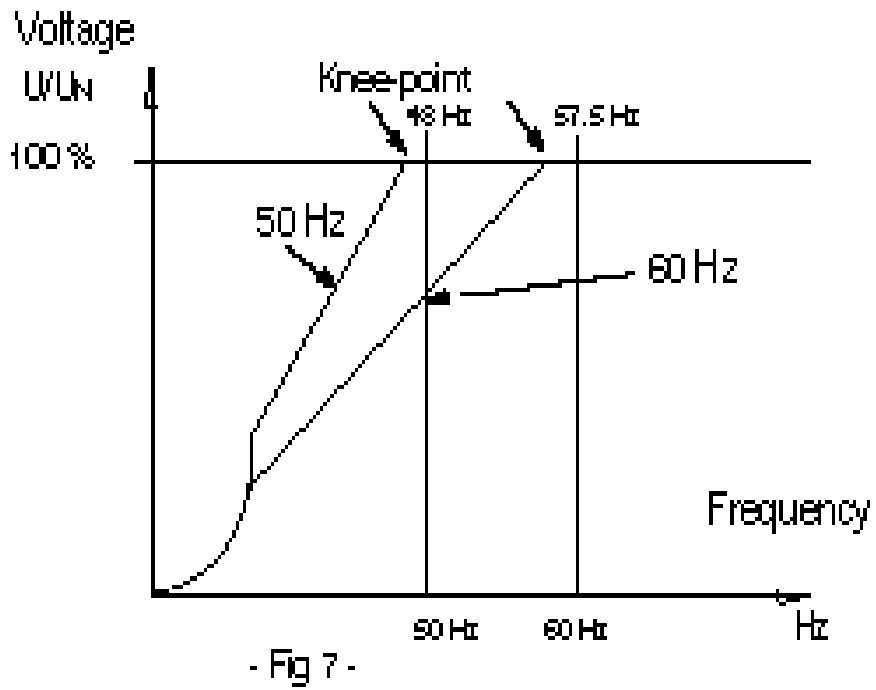
KATO Engineering Inc.
Leroy Somer North America

# Voltage Regulator Family

| Alternator Type | Shunt | AREP | PMG |
|---|---|---|---|
| LSA42.2 | R230 | R438 | |
| LSA43.2 - 44.2 | R230 | R438 | R438 |
| LSA46.2 | R448 | R448 | R448 |
| LSA47.2 | R448 | R448 | R448 |
| LSA49.1 | | R448 | R448 |
| LSA50.1 - 51.2 | | R449 | R449 |

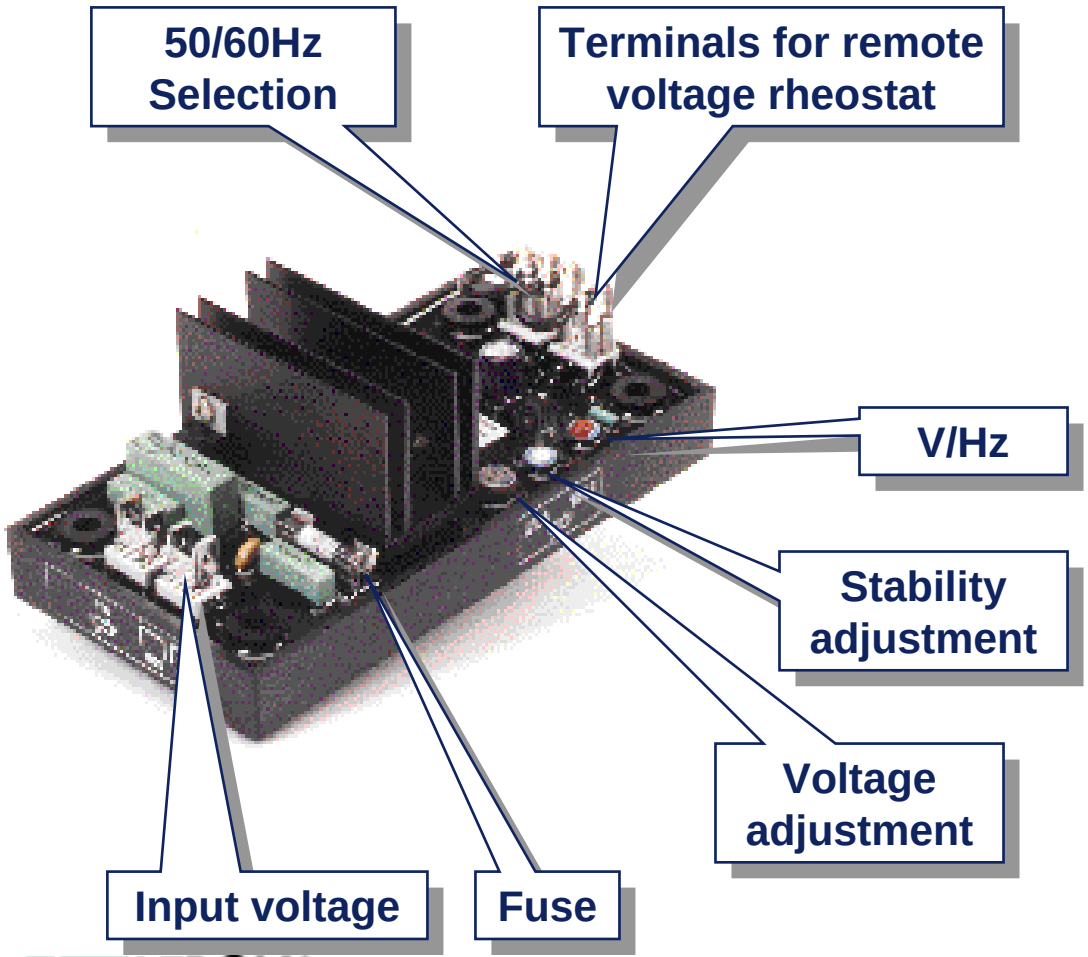
# R230 Voltage Regulator

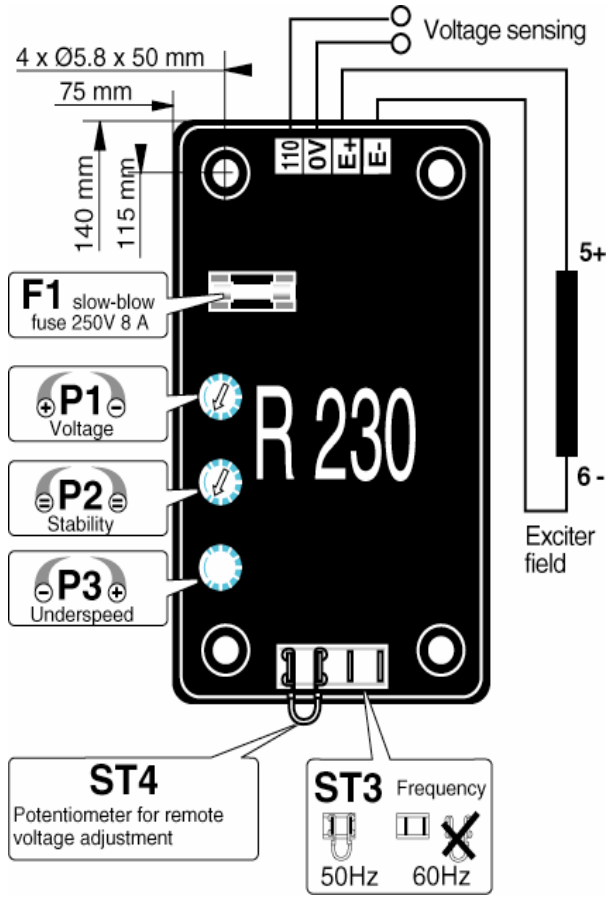
- Shunt excitation system
- Voltage regulation ± 0,5%
- Voltage power and sensing 85V to 139V
- 50 / 60 Hz
- Underspeed protection
- Option: remote voltage rheostat
- No paralleling capability



- Fig 7 -

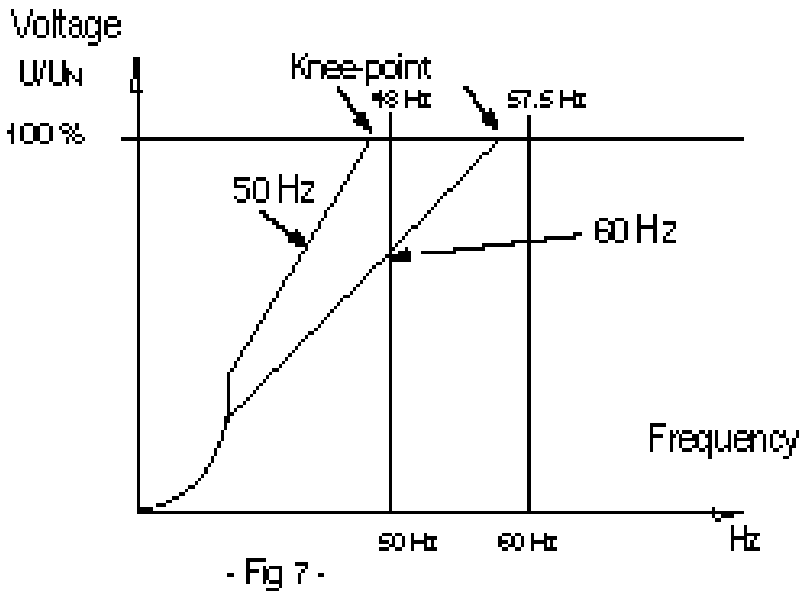
# R230 Voltage Regulator



# R438 Voltage Regulator

- Designed for AREP / PMG excitation systems
- Voltage regulation accuracy: ± 0,5%
- Multiple input sensing voltage
- 50 / 60Hz under speed protection
- Built-in Load Acceptance Module
- Short circuit current level adjustment
- Voltage regulator immune to distorting loads
- Paralleling capability
- Optional modules available for Power Factor / kVAR regulation and three phase sensing.
- Isolating transformer in AVR
- AVR encapsulated to withstand high vibrations



- Fig 7 -

# R438 Voltage Regulator

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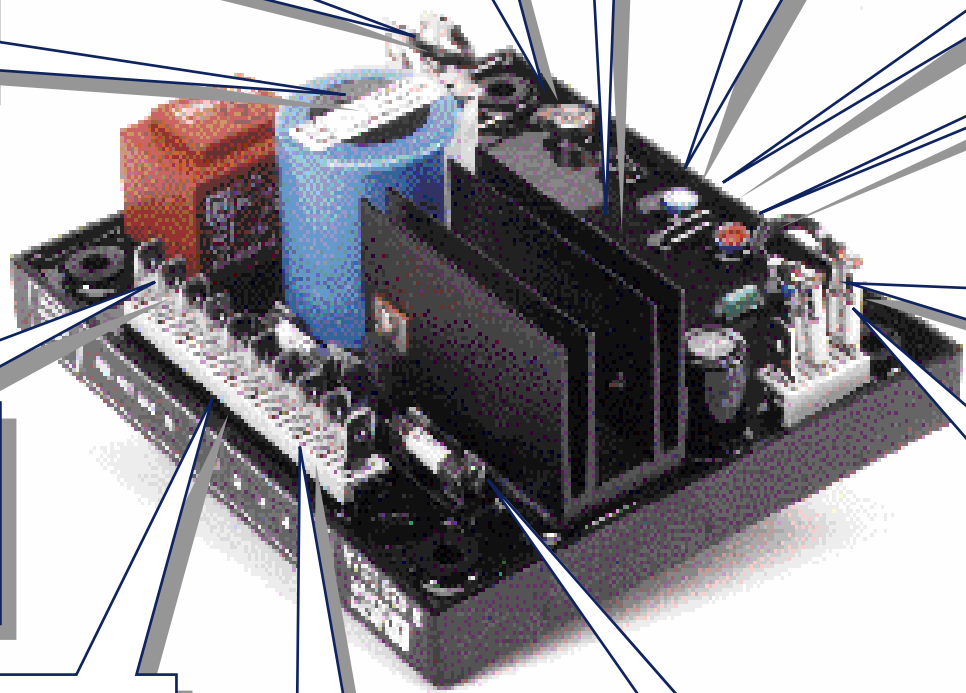


3 phase sensing module
Remote voltage rheostat
Droop CT

Voltage rheostat

LAM

Stability rheostat

Response time strap

Droop potentiometer

V/Hz

Maximum excitation current rheostat

95-140V
170-260V
340-520V
Sensing voltage

50/60Hz

Terminals for exciter field

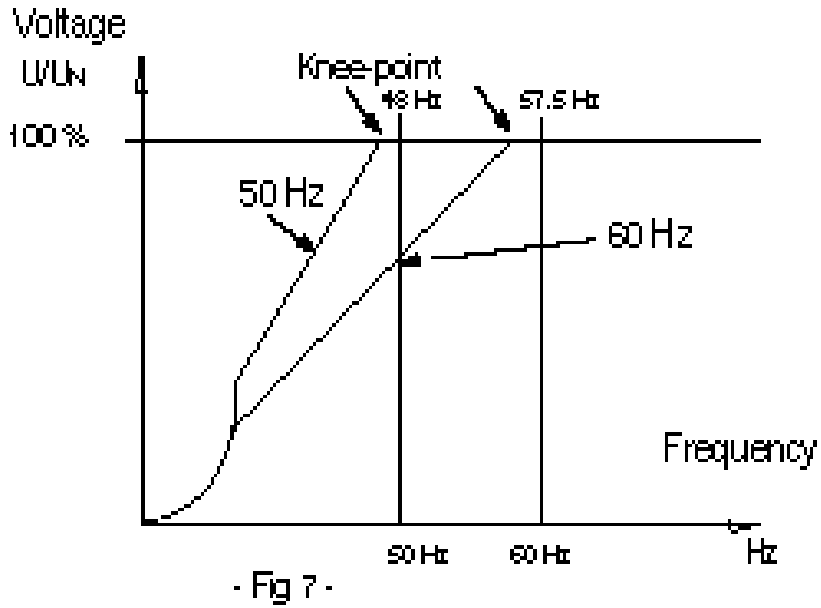
Power input

Fuse

LEROY SOMER

# R448 & R449 Voltage Regulators

- Designed for SHUNT / AREP / PMG excitation systems
- Voltage regulation accuracy: ± 0,5%
- Multiple input sensing voltage
- 50 / 60Hz under speed protection
- Built-in Load Acceptance Module
- Short circuit current level adjustment
- Voltage regulator immune to distorting loads
- Paralleling capability
- Optional modules available for Power Factor / kVAR regulation and three phase sensing.
- Isolating transformer in AVR
- AVR encapsulated to withstand high vibrations



- Fig 7 -

# R448 & R449 Voltage Regulators

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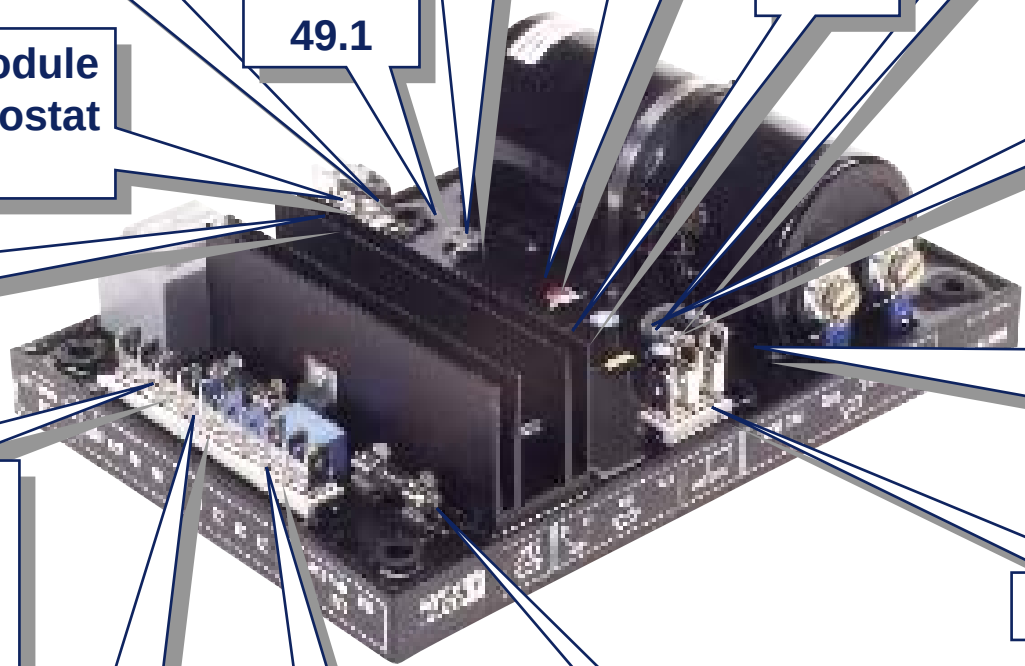

AREP or PMG

Voltage rheostat

Stability rheostat

V/Hz

46-47.2
49.1

LAM

Response time strap

3 phase sensing module
Remote voltage rheostat
Droop CT

Droop potentiometer

Maximum excitation current rheostat

95-140V
170-260V
340-520V
Sensing voltage

50/60Hz

Terminals for exciter field

Power input

Fuse

LEROY SOMER

# Voltage Regulator Options

| Excitation System | AVR | 600V 60Hz | Remote Voltage rheostat | Load Acceptance Module | Paralleling Capability | PF Controller R726 | 3 Phase Sensing | EMI kit R791 |
|---|---|---|---|---|---|---|---|---|
| SHUNT | R230 | No | Option | No | No | No | No | Option |
| | R448 | No | Option | Standard | Standard | Option | Option | Option |
| AREP | R438<br>R448<br>R449 | Option | Option | Standard | Standard | Option | Option | Option |
| SHUNT + PMG | R438<br>R448<br>R449 | Option | Option | Standard | Standard | Option | Option | Option |

# Excitation System Comparison

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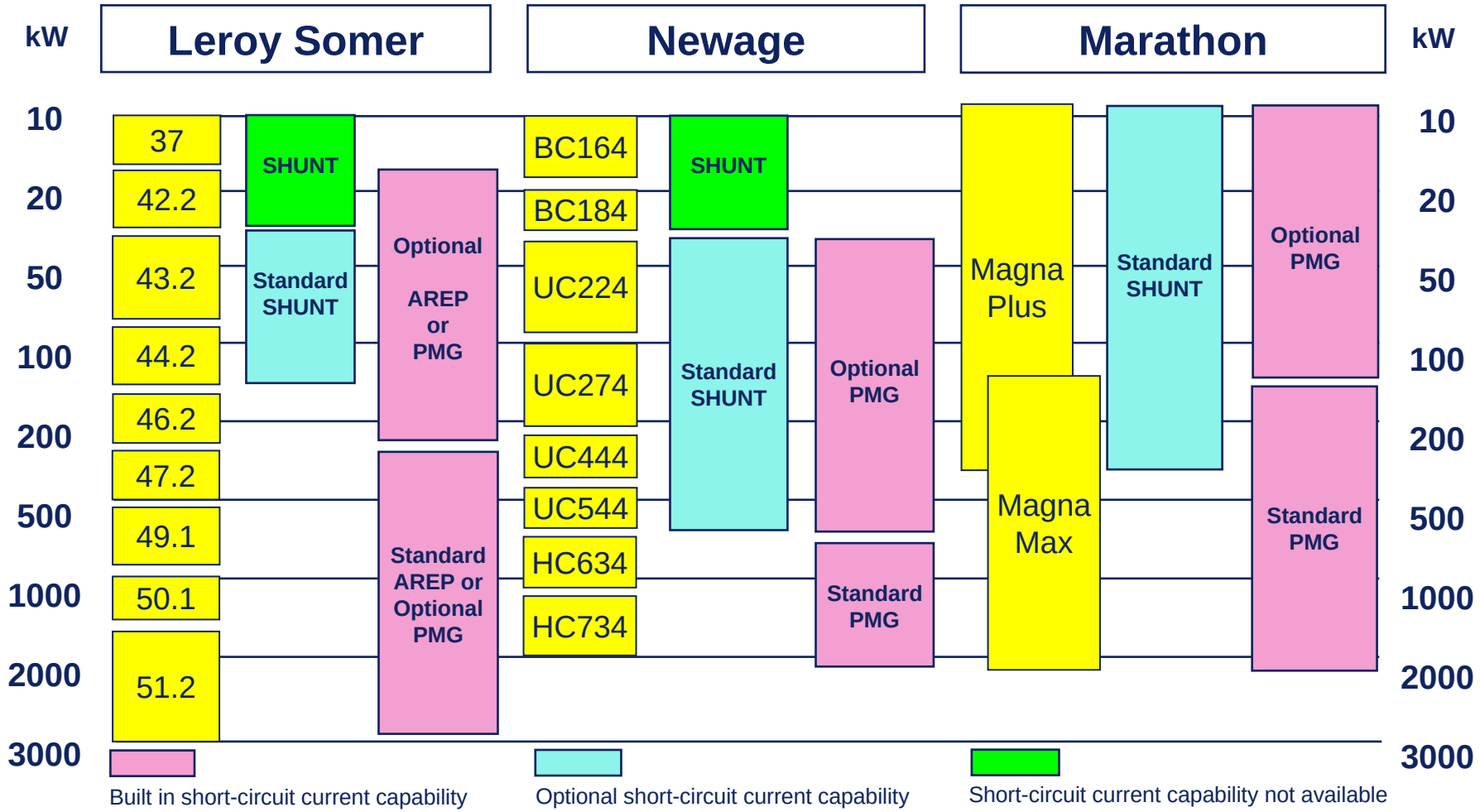


LEROY SOMER

EMERSON
Industrial Automation

# Thank You

LEROY SOMER

KATO Engineering Inc.
Leroy Somer North America

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# Back Slides

## Voltage Regulator Performance

LEROY SOMER

KATO Engineering Inc.
Leroy Somer North America

# AVR Performance

EMERSON
Industrial Automation

**ALTERNATOR RANGE FROM 8 TO 2150 KW**

| Automatic Voltage Regulation | R 230 | R 438 | R 448 | R 449 |
|---|---|---|---|---|
| STANDARD Range (KVA) | 8 - 165 | 15 - 165 | 150 - 880 | 900 - 2100 |
| Excitation | SHUNT | AREP/PMG | SHUNT/AREP/PMG | AREP/PMG |
| B U I L T I N F U N C T I O N S | | | | |
| Voltage regulation accuracy (Steady state) | ± 0,5% | ± 0,5% | ± 0,5% | ± 0,5% |
| Load Acceptance Module (LAM) | Not avail. | Option | Option | Option |
| Under speed protection (U/F) | Option | Option | Option | Option |
| Overvoltage Protection | Not avail. | Not avail. | Not avail. | Not avail. |
| Loss of sensing protection | Not avail. | Option | Option | Option |
| Maximum excitation limit | Option | Option | Option | Option |
| Voltage sensing | 1/2 ph or 1 or2 ph | 1 ph or 2 ph | 1 ph or 2 ph | 1 ph or 2 ph |
| AVR input power | 1/2 ph or 1 or2 ph | PMG or aux. wind. | PMG or aux. wind. | PMG or aux. wind. |
| A C C E S S O R I E S | | | | |
| Parallel droop kit (1F) | Not avail. | CT | CT | CT |
| Power factor control (2F: paralleling with mains) | Not avail. | R 726 module | R 726 module | R 726 module |
| Voltage equalization before coupling (3F) | Not avail. | R 726 module | R 726 module | R 726 module |
| Three phase sensing | Not avail. | R 731 module | R 731 module | R 731 module |
| EMI supression class N (VDE 0875) | BUILT IN | BUILT IN | BUILT IN | BUILT IN |
| EMI supression class K (VDE 0875) | R 791 module | R 791 module | R 791 module | R 791 module |
| Remote voltage control | Option | Option | Option | Option |
| Manual regulation | Option | Option | Option | Option |
| Short circuit current capacity (BOOSTER) | Not avail. | BUILT IN | BUILT IN | BUILT IN |
| Short circuit current level adjustment | Not avail. | BUILT IN | BUILT IN | BUILT IN |
| Loss of sensing protection | Not avail. | BUILT IN | BUILT IN | BUILT IN |

LEROY SOMER

# AVR Performance

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| From 8 to 165 KW | LEROY SOMER | LEROY SOMER | NEWAGE | MARATHON |
|---|---|---|---|---|
| Automatic Voltage Regulation | R 230 | R 438 | SX 460 | SE 100 |
| STANDARD Range (KW) | 8 - 165 | 15 - 165 | 8 - 200 | 6 - 400 |
| Excitation | SHUNT | AREP / PMG | | |
| BUILT IN FUNCTIONS | | | | |
| Voltage regulation accuracy (Steady sta | ± 0,5% | ± 0,5% | ± 1,5% | ± 1% |
| Load Acceptance Module (LAM) | Not avail. | Option | Not avail. | Not avail. |
| Under speed protection (U/F) | Option | Option | UFRO=U/F | Option |
| Overvotage Protection | Not avail. | Not avail. | Not avail. | Not avail. |
| Loss of sensing protection | Not avail. | Option | Option | Not avail. |
| Maximum excitation limit | Option | Option | Not avail. | Option |
| Voltage sensing | 1/2 ph or 1 or2 p | 1 ph or 2 ph | 2 ph | 1 ph |
| AVR input power | 1/2 ph or 1 or2 p | aux wind | 2 ph | 1 ph |
| | | | | |
| ACCESSORIES | | | | |
| Parallel droop kit (1F) | Not avail. | Option | Not avail. | Not avail. |
| Power factor control (2F: paralleling wi | Not avail. | Option | Not avail. | Not avail. |
| Voltage equalization before coupling (3 | Not avail. | Option | Not avail. | Not avail. |
| Three phase sensing | Not avail. | Option | Not avail. | Not avail. |
| EMI supression class N (VDE 0875) | BUILT IN | BUILT IN | Option | Option |
| EMI supression class K (VDE 0875) | R 791 module | Option | Not avail. | Not avail. |
| Remote voltage control | Option | Option | Option | Option |
| Manual regulation | Option | Option | Not avail. | Not avail. |
| Short circuit current capacity (BOOSTEI | Not avail. | BUILT IN | Not avail. | Not avail. |
| Short circuit current level adjustment | Not avail. | BUILT IN | Not avail. | BUILT IN |
| Loss of sensing protection | Not avail. | BUILT IN | BUILT IN | Not avail. |

# AVR Performance

EMERSON
Industrial Automation

| **from 165 to 540 KW** | LEROY SOMER | NEWAGE | | MARATHON | |
|---|---|---|---|---|---|
| Automatic Voltage Regulation | R 448 | SX 460 | SX 440 | SE 100 | DVR 2000 |
| STANDARD Range (KW) | 165 - 540 | 8 - 200 | 250 - 670 | 6 - 400 | 400 - 1925 |
| | | | | | |
| B U I L T I N F U N C T I O N S | | | | | |
| Voltage regulation accuracy (Steady state) | ± 1% | ± 1,5% | ± 1% | ± 1% | ± 0,25% |
| Load Acceptance Module (LAM) | Option | Not avail. | Not avail. | Not avail. | Option |
| Under speed protection (U/F) | Option | UFRO=U/F | UFRO=U/F | Option | Option |
| Overvotage Protection | Not avail. | Not avail. | Not avail. | Not avail. | Option |
| Loss of sensing protection | Option | Option | Option | Not avail. | Option |
| Maximum excitation limit | Option | Not avail. | Not avail. | Option | Option |
| Voltage sensing | 1 ph or 2 ph | 2 ph | 2 ph | 1 ph | 3 ph |
| AVR input power | aux wind | 2 ph | 2 ph | 1 ph | 3 ph |
| | | | | | |
| A C C E S S O R I E S | | | | | |
| Parallel droop kit (1F) | Option | Not avail. | Option | Not avail. | BUILT IN |
| Power factor control (2F: paralleling with mains | Option | Not avail. | Option | Not avail. | Option |
| Voltage equalization before coupling (3F) | Option | Not avail. | Not avail. | Not avail. | -- |
| Three phase sensing | Option | Not avail. | Option | Not avail. | BUILT IN |
| EMI supression class N (VDE 0875) | BUILT IN | Option | Option | Option | Option |
| EMI supression class K (VDE 0875) | Option | Not avail. | Not avail. | Not avail. | Option |
| Remote voltage control | Option | Option | Option | Option | Option |
| Manual regulation | Option | Not avail. | Not avail. | Not avail. | Option |
| Short circuit current capacity (BOOSTER) | BUILT IN | Option | Not avail. | Not avail. | BUILT IN |
| Short circuit current level adjustment | BUILT IN | Not avail. | Not avail. | BUILT IN | Option |
| Loss of sensing protection | BUILT IN | BUILT IN | BUILT IN | Not avail. | BUILT IN |