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Induction and Synchronous Motors when applied to Island Power

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KATO ENGINEERING™

Contents:

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Induction and Synchronous motors

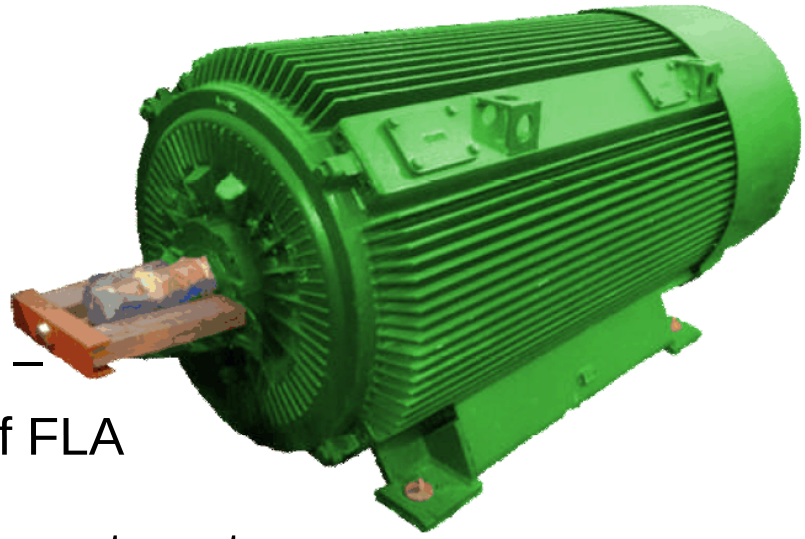
Each have their characteristics and more importantly starting requirements on island power.

Note: API 546 call synchronous “machines” since they can be either be motors or generators.

First some motor basics

Motor loads on Generators

Induction Motor



99.9% of all industrial motors

- Easy to start with good starting torque – starting current typically 600-650% of FLA
- Simple construction so they are easy to automate manufacturing even in larger sizes. (Lower cost)
- Induction motor limited in size to about 25,000HP.
- Around 20,000HP the cost of both motors types are similar so little installed base above 20,000HP

Motor loads on Generators

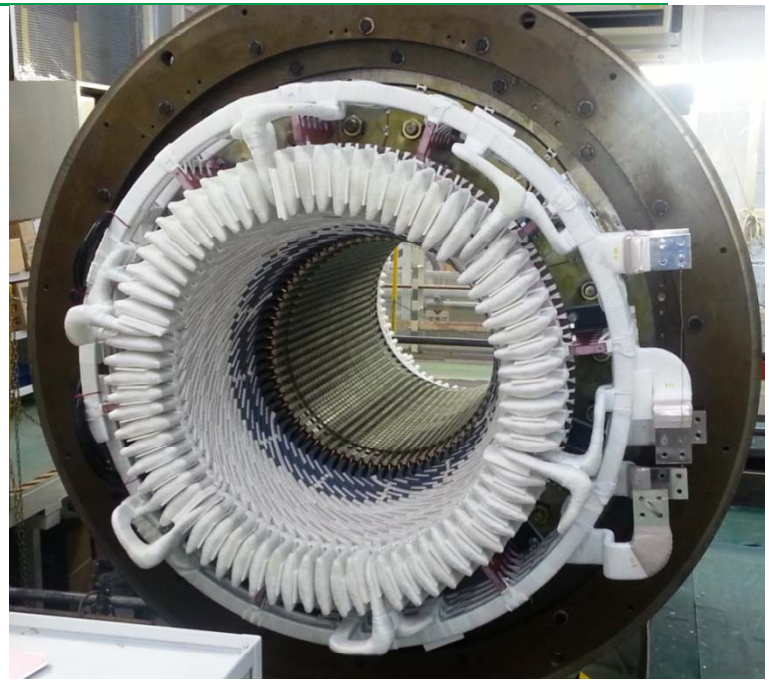
Induction Motor – construction

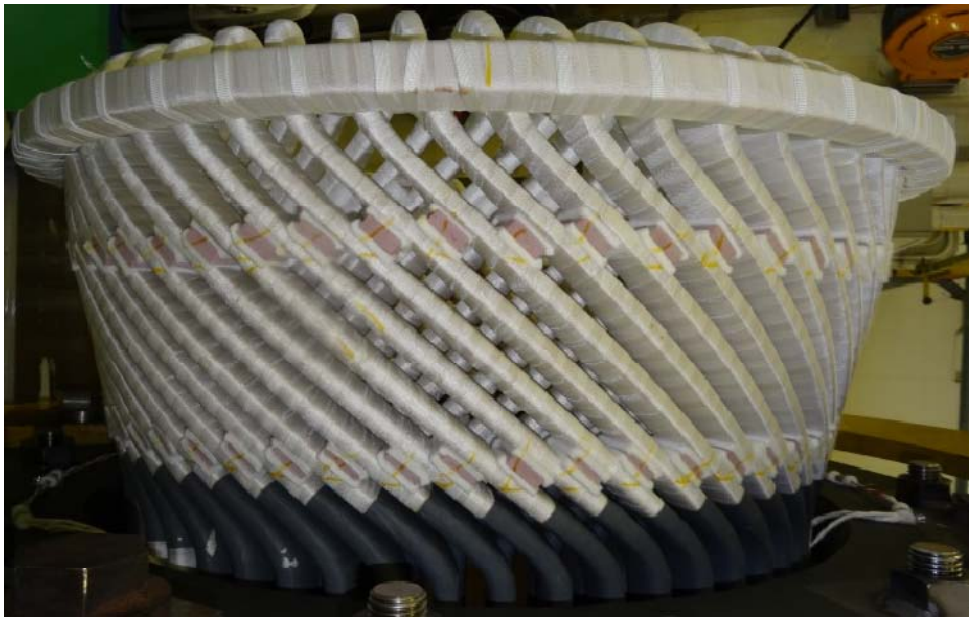
Stator -

The stator windings determine the

- Voltage – insulation system
- Speed – with some slip

How the coils connection determines the number of poles: Speed = 7200/P





The actual speed is a less than the calculated due to slip.

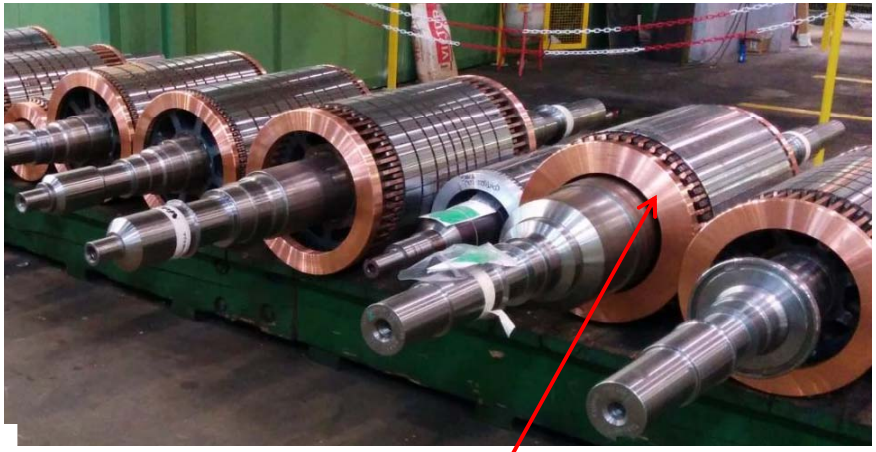
Note: the higher efficiency the lower the slip or the closer to sync speed of 3600 (2P), 1800RPM (4P), and so on. LRA's are higher.

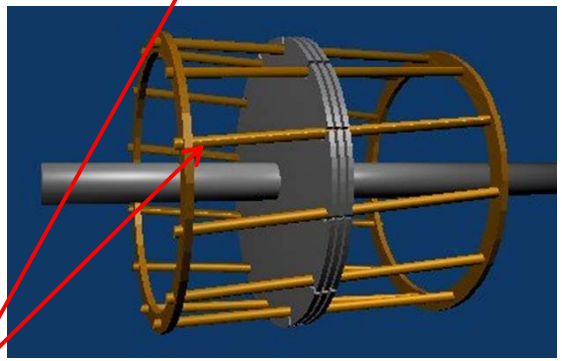
Motor loads on Generators

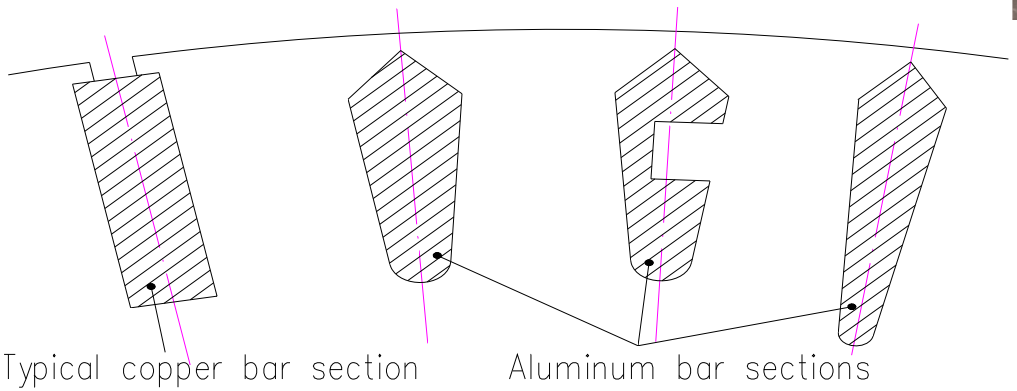
Induction Motor – construction

Rotor determines:

- Starting characteristics
- Efficiency
- Easy to build (automate)







Rotor bars shape and resistance creates the motor Speed-Torque curve.

High resistance bars create good starting torque but lower efficiency.

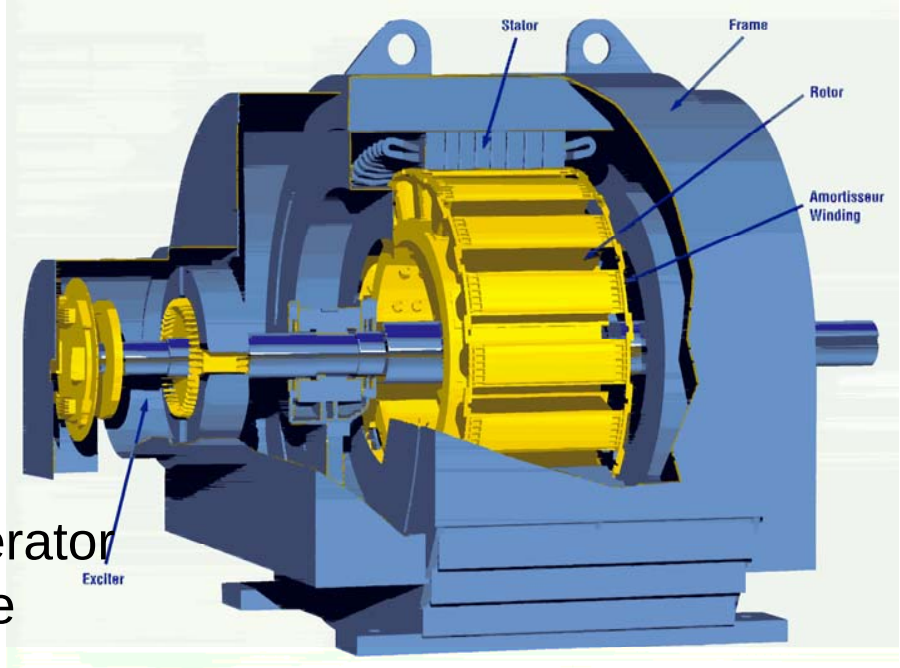
End Rings
Connect the rotor bars to make the “Squirrel Cage”

Motor loads on Generators

Synchronous Motors –

What is the difference -

- No slip
- Improve system Power Factor
- Starting is a problem
- Higher Efficiency
- Available in larger sizes
- High starting amps
- Rotors are harder to build



What is the difference between a generator and sync motor – one is driven and the other is the driver.

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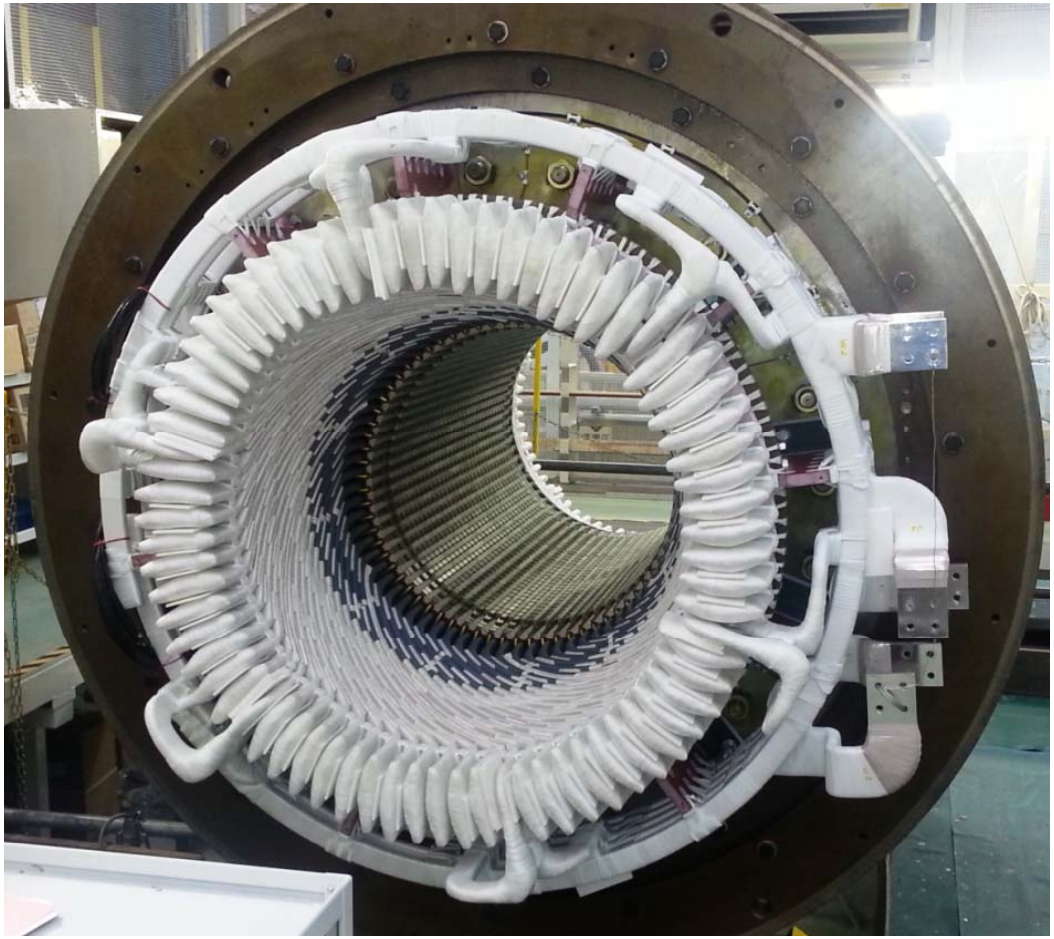
Synchronous Machines – Construction

Stator – no difference from induction

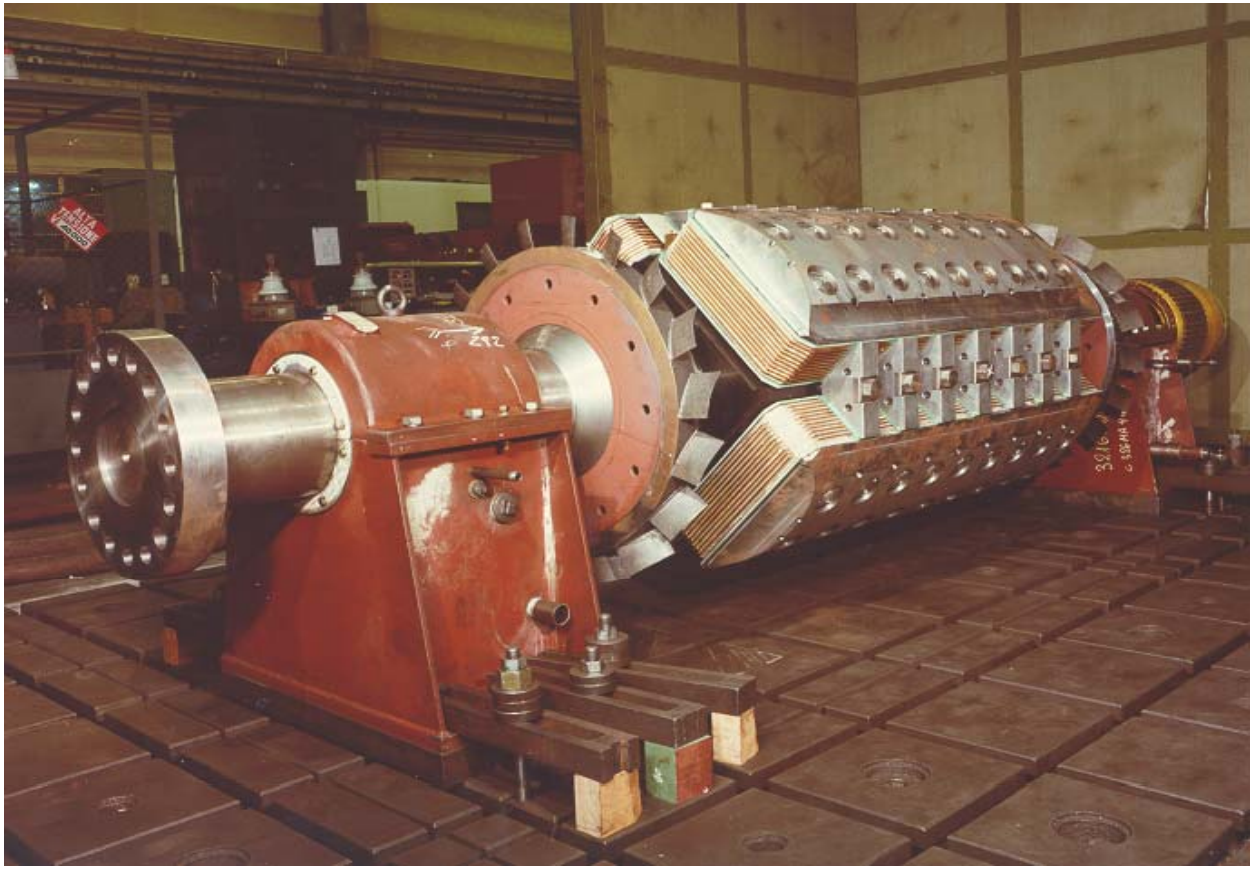
Rotor

It looks like the generators earlier in the session



Motor loads on Generators

Synchronous Motors – Construction



Rotor

No rotor bars –

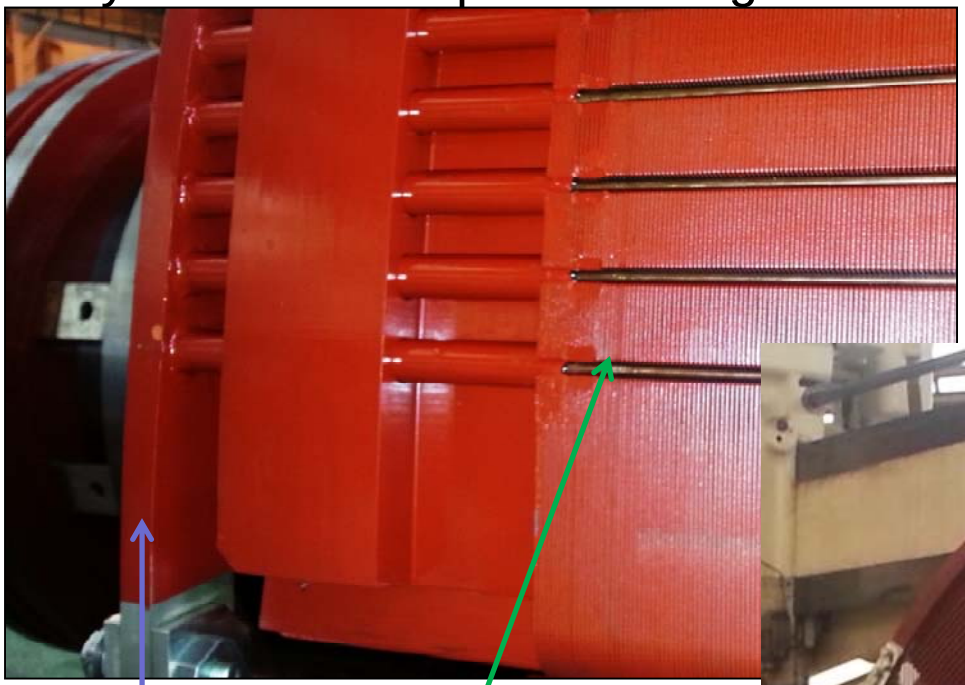
Must have magnets.

How do you start something that only runs at sync speed?

Common starting methods - Cost / Starting Amps

Direct on Line – (DOL) common for induction.

Synchronous requires adding rotor bars and building a “squirrel cage”.



Because the rotors bars are very small and providing only 20% torque but still 600-700% LRA’s.

Must start unloaded!

Motor loads on Generators - Starting

DOL

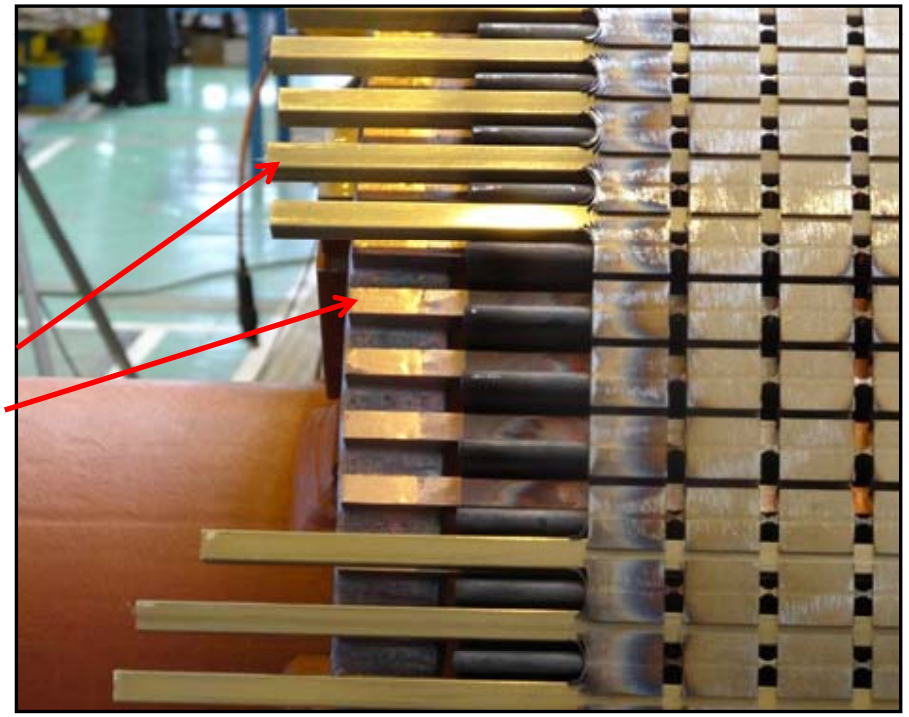
What about building lower inrush induction motors?

450% to 550% depending on the starting requirements not very expensive $$. Lower Efficiency and reduced PF.

300-400% requires special double rotor bar construction.

Outside bar is for starting

Inside bar for running



Disadvantages:

- Very low starting torque.
- $$$$
- Even worse PF and efficiency

Motor loads on Generators - Starting

Pony Motor – option for Synchronous motors

Very large synchronous motors may use a smaller induction motor attached to the “rear” of the synchronous motor.

A 20,000HP Synchronous motor might need a 2000HP induction “Pony” motor.

Once the rotor of the synchronous motor is up close to speed it can be “started” with almost no inrush.

Advantages – the only inrush is of the much smaller motor

Disadvantage – mechanically very large train. Once the sync motor starts then pony will be turn off so it becomes an efficiency loss.

Cost is more subjective - $$ or $$$

Motor loads on Generators - Starting

Soft Starters – option for Induction Motors

Are soft on the started load and on the power line by varying the voltage. (like a ceiling fan controller).

- 50% voltage relates to 50% inrush or 300% LRA's
- 50% voltage also means 25% torque.

Typical LRA's reduction from 600% to 300-400% on centrifugal loads. (not much reduction on CT Loads)

These are often used for larger LV and smaller MV motors as they are less expensive than a mechanical contactor. $-$$

Motor loads on Generators - Starting

VFD starting and VFD operation

For Island power – 100% starting torque on Induction or Sync at max Motor Full Load Amps!

- Can start any load
- Low harmonic VFDs now available in any size.

Disadvantage – very expensive – but there are options and cost are coming down.

Motor loads on Generators - Starting

VFD starting verses VFD operation

Starting an unloaded centrifugal load means the starting amp may not exceed 25%

So a 10,000HP motor can be started with a 2500HP VFD and then bypassed.

Then VFD can then be used to start other motors. It requires 2 contactors per motor but they only have to be load rated.

13kV input with 13kv output VFD VVI are becoming available

VFD starting verses VFD operation

13kV input with 13kv output VFD VVI are becoming available which use to be only possible with LCI (1970's technology using SCR's).

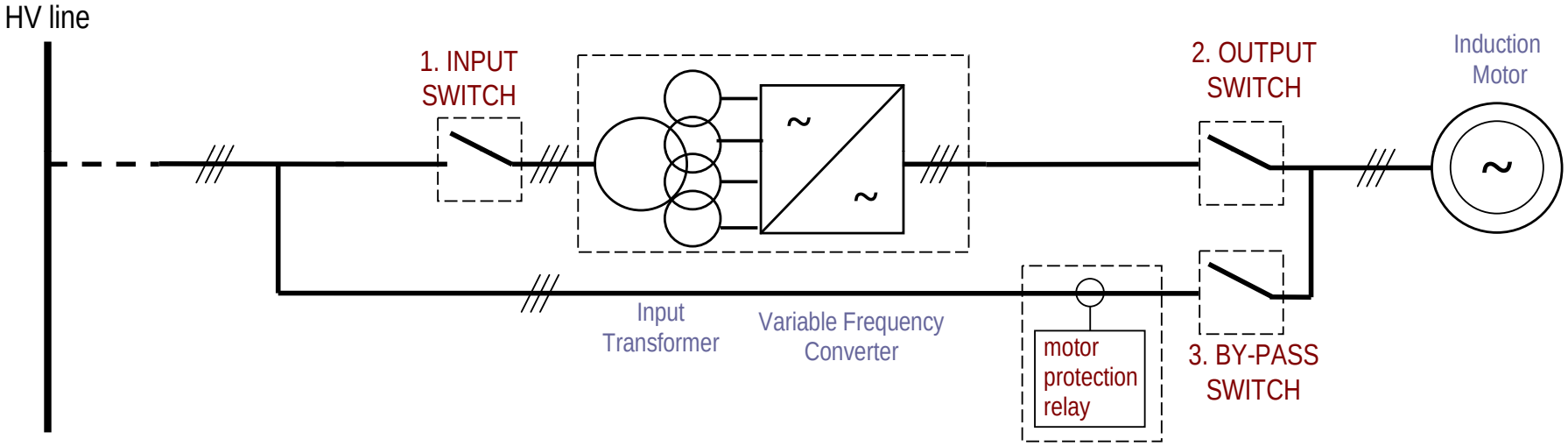
VVI low harmonics and continued cost reductions with time. Eliminates the motor and harmonic issues of LCI.

The switchgear cost and even with a smaller VFD it is a $$$ solution.

Note: the motors do not have to be the same size!

Motor loads on Generators - Starting

VFD starting verses VFD operation



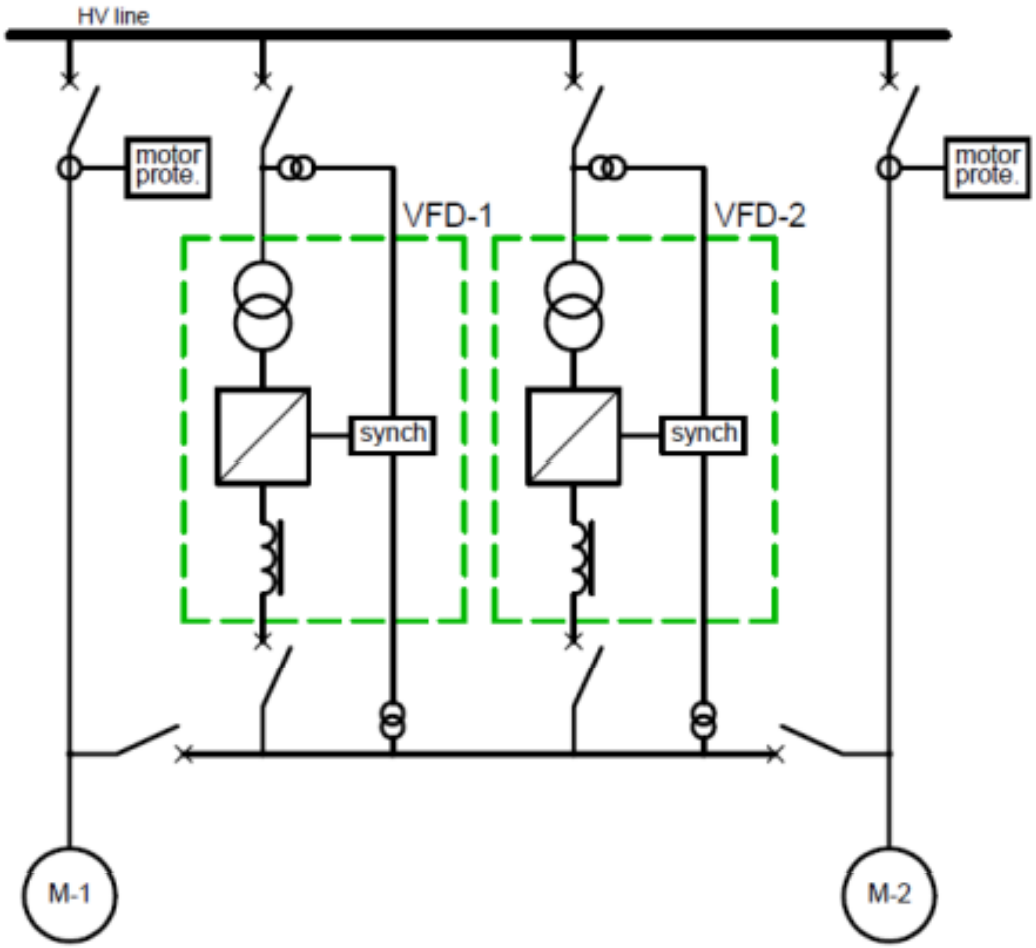
Standard Bypass shown for 2 motors but 5 motors is not uncommon.

5 motors depending on one VFD!

VFD starting verses VFD operation

Redundancy can also be accomplished with a second VFD.

Once again starting 5 motors is not uncommon



VFD starting verses VFD operation

Note: from 500HP to about 2000HP

LV and MV motors and VFD's are both stocked.

A 480V VFD system on 2000HP will be less expensive than a 2000HP MV motor even starting DOL.

There are trade offs like reliability for the LV 2000HP motor.

Comparison of Motor and Starting vs LRA

Motor Type	Starting	Cost *	LRA #	Gen Cost **
Induction	DOL	$	+600%	$$$
Induction	Soft Starter	$	350-450%	$$
Induction	VFD Start	$$$	100%	$
Induction	VFD Continuous	$$$$	100%	$
Synchronous	DOL	$	+650%	$$$+
Synchronous	Pony Motor	$$$	100%	$
Synchronous	VFD Start	$$$	100%	$
Synchronous	VFD Continuous	$$$$	100%	$

* Relative to motor size and motor type
\# Typical motor designs
** Estimated and depends on allowable voltage dip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