Technical Note 194

Permanent magnet motors with 580 series drives

Motor design and commissioning

The following technical note will assist with identification of the type and characteristics of a permanent magnet motor selected to be paired with the 580 series drive. It addresses how to distinguish between an internally mounted permanent magnet motors (IPM) and surface mounted permanent magnet motor (SMPM) and commissioning considerations for these motor technologies with an ACH580 drive. Both permanent magnet motor technologies require a drive to run the motor. This technical note does not apply to the ABB cooling tower direct drive, that is packaged with the ACS880+N5350 or the ABB “EC Titanium”, which is an IPM motor. We begin with a general overview of the motor technology and the differences in design between them. These design differences can lead to different motor control considerations when commissioning. Concepts from this technical note can also be used for retrofit jobs. It is recommended that the entire technical note be reviewed before commencing with any retrofit project. This technical note is written for someone with experience in working with VFDs and motors in applications.

Topics to be covered are:

1. Motor technology overview
2. Identifying needed drive parameters from motor nameplate
3. Commissioning parameters
4. Troubleshooting

Both IPM and SMPM motor technologies are synchronous motors and are more efficient than equivalent HP rated induction motor technology. The primary difference in the design and operation of these two PM motor technologies is the placement of the permanent magnets related to the rotors of the motor.

SMPM motors have permanent magnets mounted on the outside of their rotors. Figure 1 illustrates the internal rotor and stator for a SMPM motor. You will notice that the permanent magnets in the motor construction are located on the surface of its rotor.

IPM motors have permanent magnets mounted inside their rotors. Figure 2 illustrates the internal rotor and stator for a IPM motor. You will notice that the permanent magnets in the motor construction are located inside or embedded within its rotor.

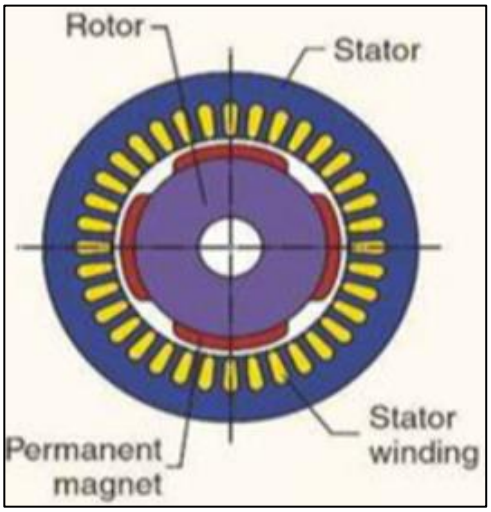


Figure 1 SMPM motor cross section

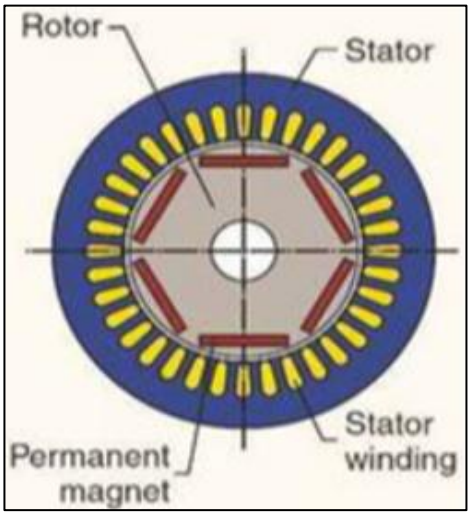


Figure 2 IPM motor cross section

Figure 1 & 2 image source https://www.evehicletechnology.com

The magnets in both SMPM and IPM motors can have different orientations than the motor examples in Figure 1 and 2. These figures are practical examples used to present general magnet location, not orientation. Another example can be referenced at: https://www.youtube.com/watch?v=dWCUUgDGXjc

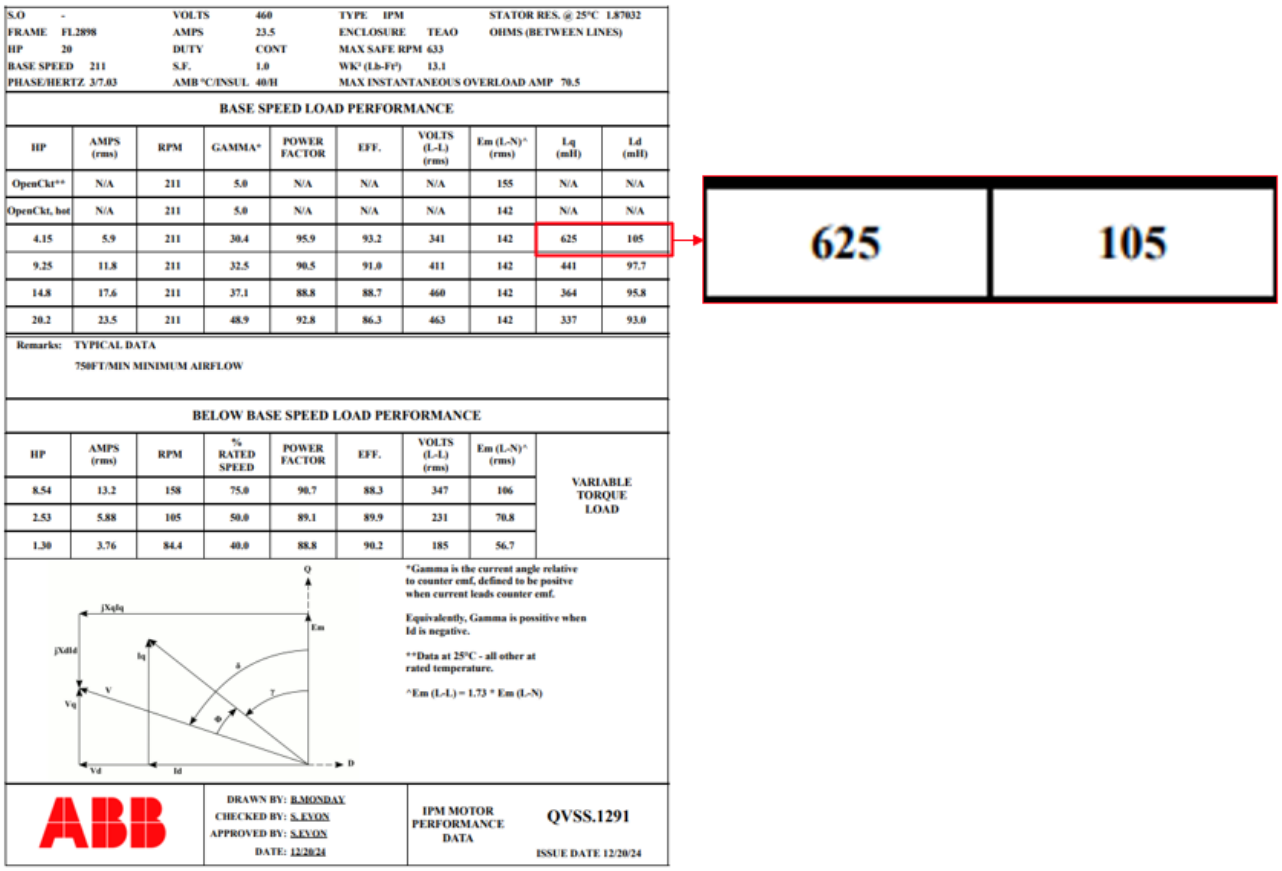
Motor technology overview

Both technologies have high efficiencies. IPM motors have more efficiency and more mechanical strength potential for high-speed operation. Lq/Ld ratio is the inductance ratio of the d-axis (direct), which refers to the main flux direction with the q-axis (quadrature) direction which is the main torque producing direction. The IPM motors have a wider difference in Lq/Ld ratio than SMPM motors, which allows them to generate torque using both magnetic and reluctance torque. The only time you will find this is in a salient pole (IPM) with buried or interior permanent magnets. The Ld/Lq in a surface mounted permanent magnet motor approximately equals 1, which results in them using magnetic torque only.

How do you tell if you have an internally mounted PM motor or externally mounted PM motor?

The characteristic of a motor where the d and q axis inductances are different is called "saliency". An IPM motor is salient and an SMPM motor is non-salient.

Figure 3 illustrates a motor data sheet. In this data you can locate the Lq/Ld ratio. In this example, the Ld is 105 and the Lq is 625 which indicates it is an IPM motor.



S.O	-	VOLTS	460	TYPE	IPM		STATOR RES. @ 25°C	1.87032	
FRAME	FL2898	AMPS	23.5	ENCLOSURE	TEAO		OHMS (BETWEEN LINES)		
HP	20	DUTY	CONT	MAX SAFE RPM	633				
BASE SPEED	211	S.F.	1.0	WK² (Lb-Ft²)	13.1				
PHASE/HERTZ	3/7.03	AMB °C/INSUL	40/H	MAX INSTANTANEOUS OVERLOAD AMP		70.5			

BASE SPEED LOAD PERFORMANCE

HP	AMPS (rms)	RPM	GAMMA*	POWER FACTOR	EFF.	VOLTS (L-L) (rms)	Em (L-N)^ (rms)	Lq (mH)	Ld (mH)
OpenCkt**	N/A	211	5.0	N/A	N/A	N/A	155	N/A	N/A
OpenCkt, hot	N/A	211	5.0	N/A	N/A	N/A	142	N/A	N/A
4.15	5.9	211	30.4	95.9	93.2	341	142	625	105
9.25	11.8	211	32.5	90.5	91.0	411	142	441	97.7
14.8	17.6	211	37.1	88.8	88.7	460	142	364	95.8
20.2	23.5	211	48.9	92.8	86.3	463	142	337	93.0

Remarks: TYPICAL DATA
750FT/MIN MINIMUM AIRFLOW

BELOW BASE SPEED LOAD PERFORMANCE

HP	AMPS (rms)	RPM	% RATED SPEED	POWER FACTOR	EFF.	VOLTS (L-L) (rms)	Em (L-N)^ (rms)	
8.54	13.2	158	75.0	90.7	88.3	347	106	VARIABLE TORQUE LOAD
2.53	5.88	105	50.0	89.1	89.9	231	70.8	
1.30	3.76	84.4	40.0	88.8	90.2	185	56.7	

*Gamma is the current angle relative to counter emf, defined to be positive when current leads counter emf.

Equivalently, Gamma is possitive when Id is negative.

**Data at 25°C - all other at rated temperature.

^Em (L-L) = 1.73 * Em (L-N)

ABB

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IPM MOTOR PERFORMANCE DATA

QVSS.1291

ISSUE DATE 12/20/24

Figure 3 IPM motor data sheet

Identifying the PM motor parameters

The motor inductive values and BEMF voltage are important values for setting up a drive with a permanent magnet motor to ensure the proper control and optimized performance of the system. Nameplate data provided on each motor should also be used to ensure proper setup of the drive to control the motor.

Permanent magnet motor nameplates are located on the side of the motor and includes all applicable ratings, appropriate markings, a catalog number, and a serial number, which allow identification of each unit. The motor nameplate contains electrical information necessary for proper setup of the drive. Figure 4 highlights the key pieces of information that needs to be programmed into the drive. In some cases, permanent magnet motors may include two nameplates, sometimes on opposite side of the motor. One of these nameplates may have the back EMF information while the other does not, so ensure to locate that information prior before attempting to program a drive with a PM motor.

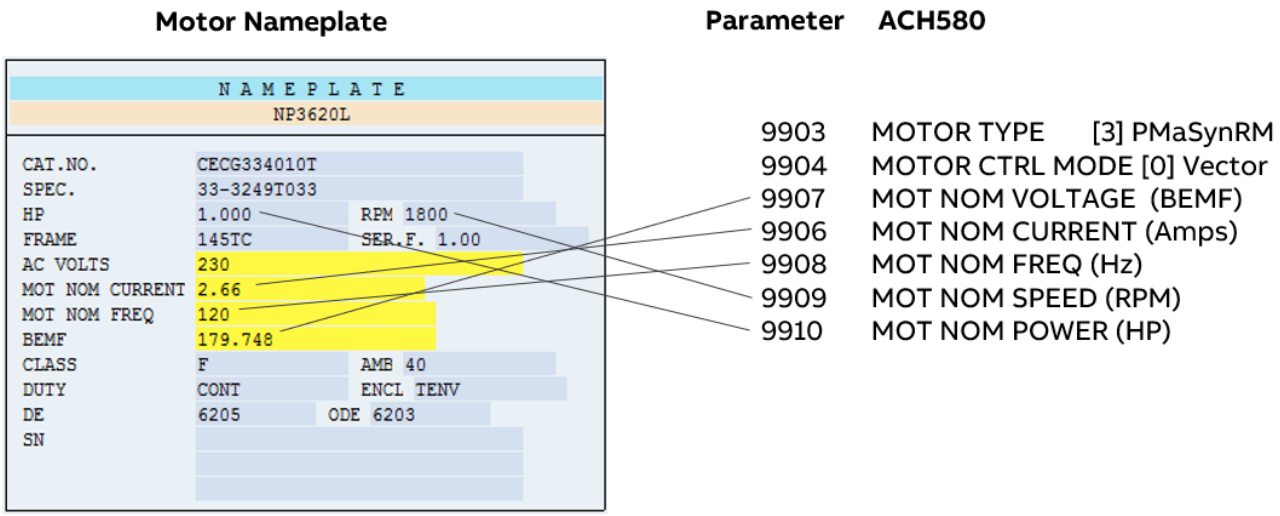

Figure 4 PM motor nameplate

When commissioning a SMPM motor, use **[1] Permanent Magnet Motor** in **99.03 "Motor Type"**. For IPM motors, use **[3]**, **PMaSynRM** in Parameter **99.03 "Motor Type"**. Though this selection is typically used for Ferrite Assisted Synchronous Reluctance Motors, which is a type of IPM, it is ideal for the commissioning of IPM motors. ABB has refined the default parameters for this motor type to simplify the commissioning process for IPM motors and this motor type selection also unlocks parameters for additional tuning if necessary.

All permanent magnet motors shall have parameter **99.04 "Motor Control Type"** configured for **[0] Vector**. These types of motors require field-oriented control which is a process of the transforming the motor currents into a rotating coordinate system.

One of the most common mistakes in the commissioning of a permanent magnet motor, is the failure to locate the back EMF value and properly enter that into **99.07 "Motor Nominal Voltage"**. In a permanent magnet motor, the rotor generates its own magnetic field. A voltage is induced in the stator windings when the rotor is in motion and will rise linearly with speed. A drive uses stator resistance, inductance, and back EMF to control the speed of the motor.

Drive commissioning parameters

Table 1 below lists the parameters that must be input for the commissioning of a PM motor. Some parameters will default to these settings when **99.03** is set to **[3] PMaSynRM**. Regardless, program and verify each of these parameter's settings prior to starting the motor.

Table 1 Commissioning parameter values

Parameter	Name	Value Examples	Description
99.03	Motor type	[1] Permanent Magnet Motor	Select for SMPM motor type
99.03	Motor type	[3] PMaSynRM	Select for IPM motor type
99.04	Motor control mode	[0] Vector	Vector mode must be used with PM motors
99.06	Motor nominal current	Motor nameplate*	FLA of motor
99.07	Motor nominal voltage	Motor nameplate*	Enter Back EMF from motor nameplate
99.08	Motor nominal frequency	Motor nameplate*	Default is 60.0 Hz, verify nameplate value
99.09	Motor nominal speed	Motor nameplate*	Enter synchronous speed of motor nameplate
99.10	Motor nominal power	Motor nameplate*	Motor HP
99.13	ID run requested	Standstill	Vector mode sets ID run to Standstill
21.01	Start mode	Automatic	Default mode, best for most PM applications
21.03	Stop mode	Application based*	Default is coast, application specific
21.13	Auto phasing mode	[5] Turning 2 +	Rotates motor to a known angle (Only applies to IPM motor setup when 99.03 is set to [3] PMaSynRM.)
30.11	Minimum speed	Motor nameplate*	Application based
30.12	Maximum speed	Motor nameplate*	Synchronous speed or Max rpm for application
30.17	Maximum current	Motor nameplate*	Set to SF of the motor nameplate.

Programming notes

"Motor nameplate *" referenced in Table 1 refers to using actual motor nameplate data.

"+" referenced in Table 1 refers to a setting that is visible when parameter **99.03** is set to **[3] PMaSynRM**.

Selecting PMaSynRM motor type (99.03):

Sets **21.13** to **[Turning 2]** automatically (verify).

Enables visibility to parameter group 227 for the troubleshooting section of this technical note.

Selecting Vector control mode (99.04):

Sets **99.13** "**ID run request"** to standstill and initiates an ID run message. Press hide and continue to enter changes.

Note: After all entries are completed, pressing hand on the control panel and start the drive ID run.

Currently, it is not advisable to operate multiple PM motors either SMPM or IPM motors with a single ACH580 drive. Do not specify or install the ACH580 drive in a multi-motor PM motor application without consulting ABB Product Management and ABB Applications Engineering teams for approval.

Troubleshooting

Certain load characteristics may result in a PM motor faulting when attempting to start the motor. These applications can require additional tuning. The following sections provide troubleshooting and tuning direction if the drive has issues starting the motor.

1. As the first step in troubleshooting, verify that the motor data is correct in Group 99.
2. Assuming that it is correct, verify the firmware in the drive. Ensure it is the latest firmware available.

While commissioning issues related to load characteristics are rare, below are a few possible scenarios (and suggested corrective actions) that could be seen in certain application types. Table 2 summarizes the parameters that may be adjusted for high inertia. Table 3 below summarizes the parameters that may be adjusted to apply a smooth start through a scaled voltage approach in cases that there is inconsistent motor control that may create overspeed faults.

Troubleshooting: High inertia loads and IPM motors

When the drive is configured to support IPM motors with parameter **99.03** is set to **[3] PMaSynRM**, parameter **227.21 "Autophasing time"** will be visible. If the motor shaft does not come to a complete stop after initial motor autophasing, then increase autophasing time (227.21) by one second increments. Autophasing is the process of the drive injecting current into the motor to align the rotor shaft prior to normal operation. High inertia loads may require a longer time for the rotor shaft to come to a complete stop, thus an increase to parameter autophasing time may be required. If the application has a low inertia and a faster startup time is desired, then decrease this time from the default 5 seconds.

Table 2 Tuning parameters for high inertia and high starting loads

Parameter	Name	Default	Notes
227.21	Autophasing time	5.0 seconds	Increase if the rotor does not come to a complete stop after autophasing. Usually only needs to be adjusted for high inertia loads or faster start times on low inertia loads.

Troubleshooting: Motor control

Vector control of a PM motor without a position sensor can be challenging depending on the motor characteristics and load properties. If there is inconsistent motor control, meaning the motor may start and go into overspeed, overcurrent, or will not start consistently, it may be necessary to adjust the speed controller values in parameters 25.02 and 25.03. It may be necessary to increase or decrease parameters **25.02 "Speed proportional gain"** and **25.03 "Speed integration time"** to tune or detune the speed control. If adjustments to the group 25 parameters are not successful, return them to the default value.

Change the value of parameter **21.23** to **[2] "Start only"**. During smooth start, the drive outputs a fixed current magnitude defined in parameter **21.24 "Smooth start current"**. Because the current and frequency output is independent of the actual shaft position it can be considered to have similar operation to scalar mode. When 21.23 is set to "Start only", the drive remains in smooth start until parameter 23.02 Speed reference ramp output increases past the value set in parameter **21.25 "Smooth start speed"**. Above that speed, the drive operates in normal vector control.

The default for parameter 21.24 is 50 percent, but for IPM motors this should be programmed to 25 percent to start. If you fail to start the motor, it is okay to increase this by 5 percent at a time and repeatedly test to see if you can start the motor till you have reached 50 percent. SMPM motors can use the 50 percent default. In general, the optimal amount of smooth start current is a function of inertia. Large loads will require more current and smaller loads will require less current.

Table 3 Smooth start parameters

Parameter	Name	Default	Notes
21.23	Smooth start	[0] disabled	Change to [2] start only. Selects the forced current vector rotation mode at low speeds. When the smooth start mode is selected, the rate of acceleration is limited by the acceleration and deceleration ramp times. If the process driven by the permanent magnet synchronous motor has high inertia, slow ramp times are recommended. Can be used for permanent magnet synchronous motors only.
21.24	Smooth start current	50%	Current used in the current vector rotation at low speeds. Increase the smooth start current if the application requires motor shaft swinging needs to be minimized. Note that accurate torque control is not possible in the current vector rotation mode. Used for permanent magnet synchronous motors only.

Summary

The 580 series can support your application needs by controlling either SMPM or IPM motor technology. These highly efficient motors are more and more common in today's applications. It is important to understand the commissioning steps that include new values that need to be entered such as back EMF to successfully commission these motors with the ACH580 drive. Reach out to your local ABB Drive Specialist if there are questions.