MV VFD Discussion
MIA Detroit 2016

Tommy Eitenmiller
Business Developer
MV Drives
Siemens Industry, Inc.
Why VFDs

- According to the U.S. Department of Energy, motors account for 70% of all energy consumed by the domestic manufacturing sector and use over 55% of the total electric energy generated in America.

- Large electric motors, those greater than 1000 horsepower, consume over 25% of the total generated electric energy.

- A motor will use 10 to 20 times its capital cost in energy cost per year.

- Motors used on pump and fan applications are the biggest power users.

- Large energy savings are realized by changing these loads from constant speed to variable speed – Retrofit market is as high as 70% in some regions with 1-2 years payback.

- Additional process productivity increases realized – shortens payback period.

Variable Frequency Drives (VFD) are the most efficient method of speed/flow control.
This HP Difference is the Energy Required to Push the Fluid Past the Valve.
Synchronous Speed

- Theoretical Speed
- A well built motor may approach synchronous speed when it has no load.
- Factors
  - Electrical Frequency (cycles/second)
  - # of poles in motor

\[
\text{Synchronous Speed} = \frac{120 \times \text{Frequency}}{\# \text{ of Poles}}
\]
The speed an AC induction motor operates is given by the following equation:

\[
\text{Synchronous Speed} = \frac{120 \times \text{Frequency}}{\text{Number of Poles}}
\]

Where:  
Frequency = Electrical frequency of the power supply in Hz.  
Number of poles = Number of electrical poles in the motor stator.

Motors speed can be changed by altering the electrical frequency, the # of poles, or both.

Motor speed can be changed by altering the # of poles in a motor from 4 to 2:

- 4 pole motor operating on 60 hertz = 1800 rpm.  
- 2 pole motor operating on 60 hertz = 3600 rpm.

We really **CHANGED** speed rather than varied speed!

Motor speed can be changed by altering the frequency of the electrical supply:

- 4 pole motor operating on 50 hertz = 1500 rpm.  
- 4 pole motor operating on 40 hertz = 1200 rpm.

By varying frequency, we can adjust the speed over a wide range or vary the speed precisely using precise changes in the electrical frequency input to the motor.
Many applications require the speed of a process to be varied

Prior to variable speed control, other techniques were used:

- Control valves, dampers and vanes
- Eddy Current clutches
- Hydraulic couplings
- Variable Pitch sheaves
Reasons To Use A VFD

- Energy savings where variable flow control is required. In any situation in which flow is controlled by a throttling device (valve or damper), there is the potential for energy savings by removing the throttle and slowing the fan or pump to regulate flow.

- Optimizing the performance of rotating equipment; e.g. SAG mills, compressors, conveyors, pumps and fans.

- Elimination of belts and gears or other power transmission devices by matching the base speed of the motor to the driven load.

- Automation of process control by using the VFD as the final control element, leading to more efficient part-load operation.

- Reduction of the rating and cost of the electrical distribution system by eliminating motor starting inrush.

- Extending the life of motors, bearings, seals, liners, and belts.

- Reducing noise and environmental impact--electric drives are clean, non-polluting, quiet, efficient, and easy to repair.
What Motors Need From a VFD

- A poly-phase source of voltage/current with good phase balance and little DC component.

- Voltage and frequency independently variable to permit constant flux operation and extended speed operation.

- Limited harmonic content, particularly at the lower harmonics. This lowers $I^2R$ losses and reduces torque pulsations.

- Fortunately, motors are inductive, so that they function as good low-pass filters. This permits the technique of moving harmonics to higher frequencies.

- Tolerably low common-mode voltage.

- Reasonably low $dv/dt$ on the motor terminals, so the voltage step does not appear across the first few turns of the coil nearest the terminal.
Pros & Cons of VFD Use - The Motor Perspective

Pros

- The motor is isolated from the line and is not affected by line unbalance or transients.

- Current is always limited, so the terrible stress of line starting is avoided.

- Variable speed operation usually means lower average load (and temperature) and less bearing wear.

- Efficient operation above and below synchronous speed is possible.

Cons

- Low order harmonics can add to motor losses and create torque pulsations.

- High peak voltages, dv/dt, and common-mode voltage may damage the insulation.

- Bearing currents may become more troublesome.
**Definition of Topology**

**Topology** as it relates to power electronics and variable frequency drive systems simply means:

“the way in which constituent parts are interrelated or arranged”.

![Topology Diagram](certiology.com)
Single rectifier and inverter
- Rectifier produces a constant DC link voltage from a constant voltage/frequency supply
- DC link capacitors filter the DC link voltage and provide energy storage
- IGBT inverter produces a variable voltage, variable frequency supply using pulse width modulation (PMW)
A meaningful differentiation can be made according to the configuration of the DC link. The DC link largely isolates the operation of the converter from the inverter. The input converter determines the power factor and harmonics, while the inverter determines the machine-side properties.

- **Converter without DC-link**
  - Cycloconverter
  - Matrix Converter

- **Current Source Inverters (CSI)**
  - Load Commutated Inverter (LCI) with SCR
  - Current Source Inverter with GTO, SGCT, etc.

- **Voltage Source Inverters (VSI)**

\[
\begin{align*}
\text{AC} & \quad \text{DC} \\
\text{DC} & \quad \text{AC} \\
\text{AC} & \quad \text{AC}
\end{align*}
\]
Current Source VFD

- The power factor is the load power factor times the PU speed.
- The reactive power demand of the motor is passed back to the line.
- High order harmonics are present due to the high di/dt.
- One cannot change the motor current instantaneously, so all the CSI circuits require a capacitive filter on the motor to absorb the high di/dt of the inverter.

Current-fed inverters use a Thyristor converter to control the current.

- Link energy storage is relatively low, and the DC link reactor provides immunity to faults and grounds. Since the current is regulated, inverter faults do not cause high currents.
Voltage-fed VFD’s use a rectifier bridge

- Consistently high P.F. and minimum high-order harmonics
- The reactive power needs of the motor come from the capacitor, and are not reflected to the line

Voltage-fed VFD

The DC link electrolytic capacitors can be a reliability and lifetime issue.

Energy stored in the link is very high compared to the CSI’s, and a fault in the inverter can lead to very high currents.

The motor’s inherent inductance can be conveniently used to filter a PWM voltage wave. However, very fast wave fronts (dv/dt) have become a concern to motor designers and users.
A variable-frequency drive (VFD) is a system for controlling the rotational speed of an alternating current (AC) electric motor by controlling the frequency of the electrical power supplied to the motor.
There are only a few types of power conversion circuits which are widely used:

- Voltage transformation is frequently incorporated into power conversion equipment as dedicated transformers e.g., Perfect Harmony.
- Rectification is the conversion of fixed frequency, fixed voltage AC power into fixed or variable voltage DC power.
- Inversion is the reverse of rectification: changing DC power into AC power.

Power conversion equipment consists of one or more of these basic circuits.

Medium-voltage drives almost always consist of two of these processes, rectification and inversion in sequence.
Components Used In Power Conversion

- The fundamental element in power conversion is the solid state switch. This is a device which can close or open an electric circuit without any moving parts. Practical power switching devices include:
  - The diode or silicon rectifier
  - The transistor
  - The Insulated Gate Bipolar Transistor (IGBT)
  - The Thyristor or silicon controlled rectifier (SCR) also known as the Thyristor
  - The gate turn-off Thyristor (GTO)
  - The integrated gate controlled Thyristor (IGCT)
  - The injection enhanced gate transistor (IEGT)
  - The Symmetrical gate-commutated thyristor (SGCT)

- These devices provide approximations of a perfect switch, in that they have very low voltage drop when on, can support large voltages when off, and change state (from off to on and vice-versa) very quickly.

- These active switching devices are combined with passive components like resistors, inductors (chokes) and capacitors.
Basic Concepts of Power Conversion

- Rectifiers and Converters; the line-side interface. Their purpose is to convert fixed frequency, fixed voltage utility power to fixed or adjustable DC voltage and current.

- The DC link connects the line side conversion to the machine side conversion. It is a filter and energy storage mechanism.

- Inverters; the load side interface. Their purpose is to convert the DC in the DC link into adjustable frequency and adjustable voltage to operate the motor.

Typical AC Inverter System

AC Inverter Technology
Up To 97% Efficiency, including transformers
Line-side converters change fixed voltage, fixed frequency AC power from the utility to DC voltage. They can be constructed of:

- Uncontrolled rectifiers (diodes)
- Controlled rectifiers (Thyristor) Thyristor converters are usually found in current fed circuits where they are regulated to maintain current.

The line side converter controls:

- Input power factor
- Input harmonics

The utility properties are mostly affected by the line-side converter only because the DC link separates the effects of the machine-side converter.

The current-fed power factor is affected by the load power factor and speed.
The bridge rectifier is the workhorse of power electronics.

- It is used in 1 phase and 3 phase versions most commonly.

The output voltage is a DC voltage of a fixed proportion to the AC input, essentially the peak line-to-line input voltage.

This is also used as the input power conversion for PWM AC drives. It has excellent efficiency and uniformly good power factor on the line side.

But the input harmonic currents are large when the load is a capacitor and the source is low impedance.
The Basic AC-DC Rectifier

Three Phase Diode Rectifier with Resistive Load (6 Pulse)

- 3-Phase diode bridge rectifier is the workhorse of power electronics
- Converts three-phase AC to a DC value proportional to the AC input V
- \( h = \) characteristic harmonic
- \( k = \) any integer
- \( q = \) pulse number
- 6-Pulse: \( h = k \times 6 \pm 1 = 5,7,11,13,17,19,23,25\ldots \)
Sources of Harmonics

- Rectifiers (conversion of AC to DC)
- DC and AC Variable speed drives
- Industrial heating controls
- Switch mode power supplies
- Uninterruptible power supplies
- Welding equipment
- Electronic lighting ballasts
- Arc furnaces
- Personal computers (switch mode power supplies)
- Saturation of transformer cores
Effects of Harmonics

- Reduction of power system efficiency.
- Motors: Increased heating due to increased copper and iron losses, decreased efficiency, increased audible noise, possible torque pulsations.
- Transformers: Increased heating due to increased copper and iron losses, increased audible noise.
- Power cables: higher rms current, increased heating due to skin and proximity effect, increased voltage stress and possible corona.
- Capacitors: possible excitation of power system resonance, increased heating and voltage stress, reactance decreases with frequency making capacitors a sink for high freq harmonics.
- Interference with sensitive electronic equipment, error in circuits using zero crossings (notching) and possible errors with electrical meters, generator voltage regulators, etc.
- Switchgear, distribution and relaying: Increased heating, shorten life of insulating materials, can effect protective relays. May require the use of cable, relays, contactors, etc. with higher than normal ratings for both voltage and current.
- RFI generation.
- Telephone interference: can effect telephone systems and other communication equipment.
- Increased installation, operation and maintenance costs.
Multi-pulse Diode Rectifiers

- Reduces harmonics by using sets of phase shifted 3-phase supplies feeding 6-pulse rectifiers in such a way that harmonic frequencies are cancelled and reduced in magnitude.
- Can reduce VFD input harmonics significantly.
- Not effected by power system changes.
- Provides common mode voltage protection for motor and true isolation.
- Simple solution not suffering from the disadvantages of filters and other methods.
- Very good for use with backup generators and weak systems (no capacitive filters, low harmonics).
- Harmonic mitigation decreases with voltage imbalance.
- 18-pulse solution can be implemented with an isolation transformer or a phase shifting autotransformer.
- With diode rectifiers power factor is >0.95 through the load and speed range.
12-pulse

Transformer Phase Shifts:
12-Pulse: 30 deg.
18-Pulse: 20 deg.
24-pulse: 15 deg.
30-pulse: 12 deg.

18-pulse

Characteristic Harmonics: \( h = kq \pm 1 \)

- \( h \) = characteristic harmonic
- \( k \) = any integer
- \( q \) = pulse number

- 6-Pulse: \( h = k \times 6 \pm 1 = 5, 7, 11, 13, 17, 19, 23, 25, \ldots \)
- 12-Pulse: \( h = k \times 12 \pm 1 = 11, 13, 23, 25, 35, 37, \ldots \)
- 18-Pulse: \( h = k \times 18 \pm 1 = 17, 19, 35, 37, \ldots \)
Harmonic Spectrum for 6, 12 and 18 Pulse VFDs

Relative short circuit ratio of the power system is assumed to be between 20 to 50.
MIA Detroit 2016

Pulse Count Comparison

![Graphs showing pulse count comparison with THD values:]
- **6-Pulse Front-end**
  - Current THD = 31.4%
  - Input Current

- **6-Pulse Front-end plus 3% Line Reactor**
  - Current THD = 24.2%
  - Input Current

- **12-Pulse Front-end**
  - Current THD = 9.1%
  - Input Current

- **18-Pulse Front-end**
  - Current THD = 4.8%
  - Input Current
By substituting thyristors for diodes, we can control the DC voltage of the rectifier. (In this form, it is usable as a regulated DC supply like a DC motor drive).

- It also is widely used as the input stage for variable frequency AC drives of the current-fed type.

- The output voltage is a function of the input and the phase delay of the turn on pulse to the SCRs.

- The Thyristor converter cannot be operated into a capacitive load without some buffering inductance because the voltage changes abruptly after commutation.

- This is not an issue for current-fed circuits because they have big DC link chokes.
MIA Detroit 2016

6-Pulse Converter Input Current Waveform

FUND RMS AMPS = 100.0462
HARMONIC CURRENT RATIOS TO FUNDAMENTAL:
3 = 0.0000  5 = 0.2101  7 = 0.1305  9 = 0.0000  11 = 0.0898  13 = 0.0710
15 = 0.0000  17 = 0.0564  19 = 0.0481  21 = 0.0000  23 = 0.0406  25 = 0.0358
27 = 0.0000  29 = 0.0311  31 = 0.0281  33 = 0.0000  35 = 0.0248  37 = 0.0227
39 = 0.0000  41 = 0.0203  43 = 0.0187  45 = 0.0000  47 = 0.0168  49 = 0.0155
K FACTOR = 19.5957  TOTAL RMS CURRENT = 104.3573

VLLRMS = 480  FREQ = 60  IDC = 128.4  ALPHA = 25  MU = 2.7  L3 = 0.00015  PLS = 6
Properties of Thyristors Converters

- The use of phase control permits us to manipulate the output voltage quickly and precisely.

- Although the current can flow in one direction only, when $\alpha > 90$ the link voltage changes polarity and **energy flows back to the line (regeneration)**.

- The phaseback angle $\alpha$ becomes the phase delay of the AC input current; so the displacement power factor of the Thyristor converter is $\cos \alpha$. (not always good)

- Because commutation can occur when the line to line voltage is high, the input current changes rapidly giving rise to **high order harmonics**, as compared to the rectifier bridge.

- Because there is voltage ripple on the output, they must be loaded by some amount of DC link inductance.

- Thyristor converters are simple, cheap, and reliable and can be built in extremely large ratings.
Twelve-Pulse Thyristor Converter
Voltage and Current in 12-pulse Thyristor Converter
Power Factor of Current-Fed Drives on Centrifugal Loads
The function of the inverter is to change the DC link voltage (or current) into AC voltage (or current) of sufficient quality to operate the motor. Both frequency and amplitude must be controlled.

In the current-fed circuits, the amplitude is controlled by the Thyristor converter which functions as a current regulator aided by the link choke. Thus the inverter is concerned only with controlling the output frequency.

In the voltage-fed circuits, both amplitude and frequency are controlled by the output switches when a rectifier input is used.

The process of frequency and amplitude control by the inverter switching pattern is called pulse width modulation.
A switch is used to close or open an electric circuit.

Ideally, such a device would have zero voltage drop when in the on state and an infinite resistance in the off state. Thus it would never dissipate any power.

It could carry current in both directions and block voltage in both directions.

It could change state in infinitely short time and require negligible power to cause the transition.

Mechanical switches are good in the first two regards, but far too slow for practical power electronics circuits. Also, they wear out.

Although semiconductor switches are inferior to mechanical switches in some regards, they are good enough to use in very practical circuits.
We can convert DC voltage into AC by using 2 switches as shown. The amplitude and frequency of the output is controlled by the switching pattern.

The switches may be transistors, IGBTs, GTOs or even thyristors (with additional elements).

Each switch is bypassed by a diode to permit current to flow backwards through the switch when it wants to since the transistor doesn’t conduct in that direction.
Since our switches must be either fully on or off, we can only produce discrete pulses and/or levels at the output.

Starting with the basic square wave which has 50% odd harmonics, we can “eliminate” harmonics by putting additional notches in strategic positions. Each additional pair of switchings enables the elimination of another harmonic.

We really don’t eliminate the harmonics, we just move them to higher frequencies where the motor is a better filter.

Another degree of freedom is provided by multi-level inverters; the ordinary PWM drive has only three levels line-to-line, while the neutral-point-clamped has 5, and the series cell multilevel has 13 to 21 levels.
There are a huge number of PWM strategies each with its own set of advantages and disadvantages. There are 3 categories:

- Carrier methods compare a reference sine wave with a triangular carrier and switch at the crossings. A strong component of carrier frequency is present in the output, which can cause acoustic noise in the motor.

- Look-up methods have the pattern computed off-line and stored in the control.

- Space-vector methods compare the measured stator flux position with a reference and select the switches to move the flux in the desired direction. There is no carrier effect and the harmonics are spread rather than concentrated.
PWM Output Levels indicate the purity of the output waveforms (THD). The more levels, the more sinusoidal the output waveform can be.

- Lower DV/DT levels that stress the motor insulation.
- Lower voltage switching levels appear (Voltage transients) on the motor insulation.
MIA Detroit 2016

Drive Topology Tree
Drive Topology Tree By OEM
MIA Detroit 2016

PWM Current Source Inverter

The Converter section uses silicon-controlled rectifiers (SCRs), Gate commutated thyristors (GCTs) or symmetrical gate commutated thyristors (SGCTs). This converter is known as an active rectifier or an Active Front End (AFE).

The DC Link uses Inductors to regulate current ripple and to store energy for the motor.

The inverter uses Gate Turn-off thyristors (GTOs) or symmetrical gate commutated thyristors (SGCTs) semiconductor switches which are turned on and off to create a pulse-width modulated (PWM) output regulating the output frequency.

Motor frequency determined by output inverter

Motor Voltage determined by converter

Motor Voltage determined by converter

Motor frequency determined by output inverter
All drives save money for fan and pump loads, but not all drives save money equally.

Taking the numbers from the example above and using an average of $0.10 per kWh, the difference can add up quickly: more than $150,000 over five years.
PWM Current Source Inverter – Concerns

• Follows motor PF, improved as motor approaches full load but still only as good as motor design PF always <0.9

• Large harmonic filters and PF correction banks required

• Banks tuned to an operating point based on CSI and utility impedance at site performance degrades away from that “ideal” operating point

• If utility impedance changed, filters likely need retuning, reworking, Increased cost of ownership

• Poor power factor and harmonics generated by the CSI input require very large K-rated transformers or reactor/filter banks

• Risk of filter reactor/capacitor failure cause by overloading induced by unforeseen customer pre-existing harmonics

• Potential motor issues due to common mode voltage when using a transformer-less design.
Neutral Point Clamped Inverter (NPC)

Adding another output voltage level or step:

- Reduces $dv/dt$ on the motor
- Reduces voltage spikes (peak voltages)
- Reduces harmonics
Neutral Point Clamped Inverter (NPC)

The conventional three-level inverter comprises four switches per phase with a diode clamp connected to the mid-point of the dc link.

By closing two of the four switches, the load can be either connected to the top, middle or bottom of the dc link, thereby generating a three-level voltage waveform at the phase leg output.

An LC sine filter connected at the output is used to filter out the high frequency switching components in the output voltage. The NPC medium voltage power circuit must include a sine filter on the motor side.

For the dimensioning of the sine filter the following points have to be considered:

The reactor on the inverter side is defined in such a way, that the inverter ripple current remains acceptable.

The utility side reactor should be selected to sufficiently limit any short-circuit currents.

The filter capacitor is selected in such a way, that the resonance frequency stays close to nine times the fundamental in every operation point.
Neutral Point Clamped Inverter (NPC)

No output filter

NPC Current and Voltage Waveform

With output filter
Neutral Point Clamped Inverter (NPC)

- Larger number of components (when including gate driver in consideration) - reduced reliability
- Requires di/dt filter in DC-link to protect the IGCT - increased space, reduced efficiency
- Output filter is necessary to protect the motor and inverter, even in case of a new motor - increased space, reduced efficiency
- The NPC medium voltage IGCT inverter in combination with a passive filter can meet stringent IEEE 519 requirements - risk of resonance or active resonance control needed
MIA Detroit 2016

Series H-Bridge Inverter

Power cell - integral to multi-cell inverter topology
MIA Detroit 2016

Series H-Bridge Inverter

2 cells pulled
3 cells inserted
MIA Detroit 2016

Series H-Bridge Inverter

2.3–11 KV Drive (750 V Power Cells)
Output Waveforms @ 60 Hz and 30 Hz

Waveforms Remain High Quality at Lower Speeds Due to Multi-Level PWM Output
Power Quality Output

- No common mode motor insulation stress
  - Drive is compatible with both new and existing motors
  - Isolation transformer integral in common mode elimination
- Less than 1% VFD induced torque ripple for any given frequency
- No additional VFD induced motor heating
  - Harmonic Voltage Factor $< 0.020$, well below MG1 limit $= 0.03$
- No dV/dt problems
  - Drive creates no motor voltage insulation stress
Output Harmonics – GH180
Motor Operating from Generator vs. Perfect Harmony

Recirc Pump Motor 2B Temperature Rise
(Based on 3 hour Averages)
Cell Bypass is must not to be confused with VFD Bypass, VFD Bypass is switchgear!
When the control detects that a cell has failed, a command can be sent to close the appropriate contactor.

This simultaneously disconnects the cell output from the circuit and connects the two adjacent cells together, effectively taking the failed cell out of the circuit.

The drive can then be restarted and operation can continue at reduced capacity.

The cell bypass option (U11) a contactor to the output of each cell.

Patented Option
“Uninterrupted” operation is available if one cell or even several cells fail (exception: the currently required motor-emf is larger than the maximum available voltage).

After a cell failure voltage is discontinued for 250ms and then automatically switched on again at a smaller maximum value. If the voltage rating of the converter is sufficiently “oversized” in respect to the voltage rating of the motor, unrestricted operation is possible even if several cells are lost. Beyond that the motor still continues to operate; possibly, however, in field weakening with increased current.

Example:
15 cell, GenIV

without failures
6675 VAC

failure example 1

failure example 2

failure

least amount of working cells for two legs

standard number of working cells for two legs

* \( U_{\text{max,without failure}} \)

\[ \text{failure 1: } U_{\text{max, output}} = \frac{8}{10} \times 6675 = 5340 \text{ VAC} \]

\[ \text{failure 2: } U_{\text{max, output}} = \frac{7}{10} \times 6675 = 4672 \text{ VAC} \]
The table below shows the output voltage capability of a GH180 drives. The gray columns capture the output voltage capability if cells are bypassed at random, assuming full line voltage is available. The highlighted column shows the voltage capability if one cell is bypassed per phase, assuming full line voltage available.

<table>
<thead>
<tr>
<th>Total Number of Cells</th>
<th>Nominal System Output RMS Line-to-Line Voltage Capability</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>All Cells in Service</td>
<td>One (1) Cell Bypassed</td>
</tr>
<tr>
<td>9</td>
<td>4205</td>
<td>3504</td>
</tr>
<tr>
<td>12</td>
<td>5607</td>
<td>4906</td>
</tr>
<tr>
<td>15</td>
<td>7009</td>
<td>6308</td>
</tr>
<tr>
<td>18</td>
<td>8411</td>
<td>7710</td>
</tr>
<tr>
<td>24</td>
<td>11214</td>
<td>10513</td>
</tr>
</tbody>
</table>
One possible solution is to bypass an equal number of cells in all three phases, even though some may not have failed. Obviously, this method prevents unbalance but sacrifices possible voltage capability.
The main effect of voltage unbalance is motor damage from excessive heat.

Voltage unbalance can create a current unbalance 6 to 10 times the magnitude of voltage unbalance.

Consequently, this current unbalance creates heat in the motor windings that breaks down motor insulation causing cumulative and permanent damage to the motor.

The relationship is exponential, and approximately increases by twice the square of the percent of voltage unbalance.
This method takes advantage of the fact that the star-point of the cells is floating, and is not connected to the neutral of the motor. Therefore the star-point can be shifted away from the motor neutral, and the phase angles of the cell voltages can be adjusted, so that a balanced set of motor voltages is obtained even though the cell group voltages are not balanced.

The phase angles of the cell voltages have been adjusted so that phase A is displaced from phase B and from phase C by 132.5 ° instead of the normal 120 °.
Tommy Eitenmiller
Business Developer, MV Drives
Technical Business Development

Siemens Industry. Inc.
Process Industries and Drives Division
100 Technology Dr.
Alpharetta, GA 30005

Mobile: 678-427-3347

E-mail: thomas.eitenmiller@siemens.com