Automated Guided Vehicles (AGVs)

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Automated Guided Vehicle (AGV)

Definition - An AGV is an independently operated vehicle that moves material along defined paths between defined delivery points or stations. Typically the paths are defined by either using wires embedded in the floor or reflecting paint strips on the floor.

Some of the more advanced technologies use laser triangulation or inertial guidance systems on-board the vehicles, with distributed calibration stations for position updating.

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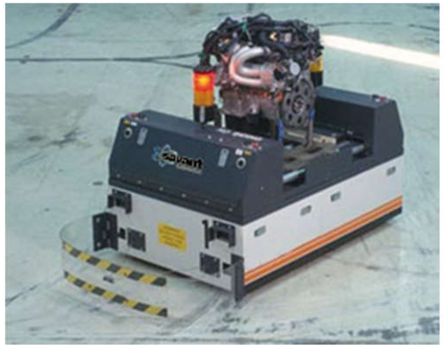
AGV classification

Driverless trains - AGV is a towing vehicle used to tow one or more trailers forming a train between stations.

Pallet trucks - Used to move palletized loads along predetermined routes. Typically, personnel will steer the AGV to the pallet, acquire the pallet, then steer it to the guide-path where the automated guidance system will then move it to its destination. In a sense, it can be thought of as an automated forklift.

Unit load carriers - Move unit loads from from one station to another station. A unit load is a collection of items that is delivered repetitively as a unit.



AGV applications

Driverless train operations - Movement of large material quantity over large distances (between buildings, warehouses).

Storage/distribution systems - Uses unit load carriers and pallet trucks to transfer material between stations, sometimes interfacing with other automated systems such as an AS/RS (Automated Storage and Retrieval System). Works well in assembly operations where the unit loads (or kits) can be transferred from a central storage area to assembly sites.

Assembly line operations - AGV's become part of the assembly operation by transferring material along an assembly line (such as moving an engine block between operational stations)

Flexible manufacturing systems (FMS) - AGV's are used to transfer parts, materials and tooling between the FMS process stations.

Miscellaneous applications - Non-manufacturing applications include the handling of sensitive waste, transportation of material at hospitals, mail transportation.

AGV guidance and control

Guidance and control functions:

Vehicle guidance - on-board control system to move the vehicle along pre-defined paths by a feedback loop between the control system and the guide wire (or paint). More modern systems use inertial guidance to move the AGV between calibration stations. In situations where the guide wire or paint is discontinuous, the control system uses dead reckoning to transition these points.

Traffic control - collision avoidance between multiple AGV's. The control system is designed with blocking algorithms that use a combination of on-board vehicle sensing and zone control.

Systems management - programming interfaces and algorithms for moving AGV's between stations, and for scheduling the movement of multiple AGV's.

AGV material handling analysis

Terms:

- v_c - AGV average speed
  (c = conveyor, carrier, cart, etc.)
- v_e - AGV empty speed
- T_h - load handling time
- L_d - destination distance
- L_e - empty move distance
- T_f - traffic factor (<= 1)
- E_h - handling system efficiency
- A - proportion of time vehicle is operational
- AT- available time in min/hr/veh
- E - worker efficiency
- R_{dv} - rate of deliveries per vehicle
- n_c - number of carriers required
- R_f - specified flow rate of system (del/hr)
- T_c - delivery cycle time (min/del)
- T_L - time to load at load station (min)
- T_U - time to unload at load station (min)
- WL - workload (total work in min per hour)

AGV material handling analysis

Equations:

del cycle time	$T_c = T_L + T_U + L_d / v_c + L_e / v_e$	(min)
available time	$AT = 60\ A\ T_f E$	(min/hr/veh)
rate of del per vehicle	$R_{dv} = AT / T_c$	(num del/hr/veh)
work by handling system per hr	$WL = R_f T_c$	(min/hr)
num of vehicles for workload	$n_c = WL/AT = R_f / R_{dv}$	(num of veh for work load)

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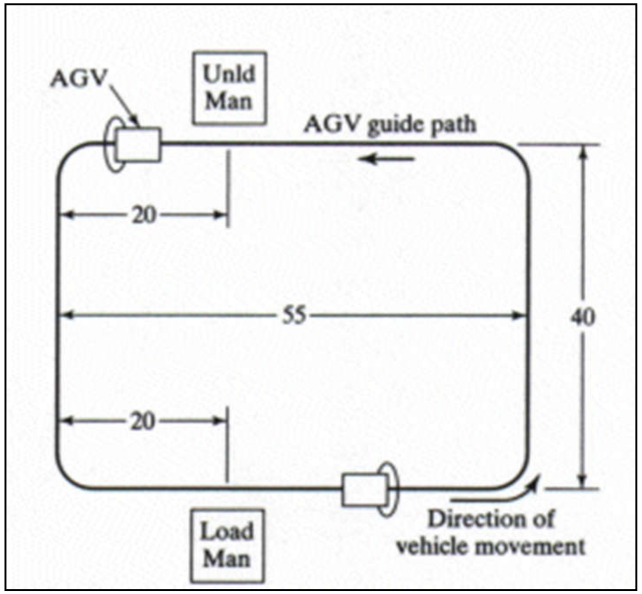
AGV example (from text)

Given the AGV layout in the figure and the info listed, determine the number of vehicles required for a delivery (flow) rate of 40 del/hr.



Info:

Loading time = 0.75 min Unloading time = 0.5 min
Vehicle speed = 50 m/min Availability = 0.95
Traffic factor = 0.9 (from fig) =>L_d = 110 m ; L_e = 80 m
E = 1

Solution:

Ideal cycle time/del/veh = T_c = 0.75 + 0.5 + 110/50 + 80/50 = 5.05 min

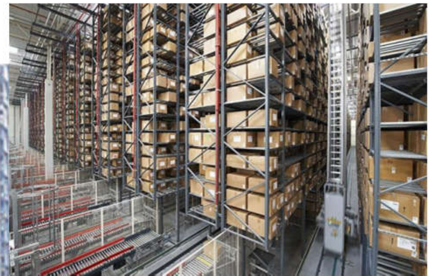
Compute workload = WL = (40) (5.05) = 202 min/hr

Available time = AT = (60) (0.95) (0.90) (1.0) = 51.3 min/hr/veh

Num of vehicles = n_c = 202/51.3 = 3.94 veh => 4 vehicles!

Automated Storage and Retrieval System (AS/RS)

Definition - An AS/RS is a combination of equipment and controls which handles, stores, and retrieves materials with precision, accuracy, and speed under a defined degree of automation. (Materials Handling Institute).



AS/RS classification

Unit load AS/RS - Large automated system designed to use S/R machines to move unit loads on pallets into and out of storage racks.

Mini-load AS/RS - Smaller automated system designed to move smaller loads into and out of storage bins or drawers.

Man-on-board AS/RS - Uses personnel to pick items from racks or bins, reducing transaction time.

Automated item retrieval system - Items to be moved are stored in single file lanes, rather than in bins or drawers.

AS/RS applications

Unit load storage and handling - Warehousing for finished goods/products.

Order picking - Used to store and retrieve materials in less than full unit load quantities, such as man-on-board or mini-load applications.

Work-in-process - Support just-in-time production activities, buffer storage, and as integral part of assembly systems.

The S/R is a large Cartesian type robot that integrates modern control technology, I/O, and sensors (compartment identification) to move between storage compartments. AS/RS control is integrated with modern material management software for real-time inventory control, storage transactions, and material delivery.

AS/RS material handling analysis

Terms:

C – capacity per aisle

x - width of unit load

y - length of unit load (in horizontal direction)

z - height of unit load (in vertical direction)

n_z - number of vertical compartments

n_y - number of horizontal compartments

U - system utilization per hr

W - width of AS/RS rack

H - height of AS/RS rack

L - length of AS/RS rack

v_z - vertical speed (m/min, ft/min)

v_y - horizontal speed (m/min, ft/min)

t_z - vertical travel time (min)

t_y - horizontal travel time (min)

T_{cs} - single command cycle time (min/cycle)

T_{cd} - dual command cycle time (min/cycle)

T_{pd} – pickup and deposit time (min)

R_{cs} - num of single commands per hr

R_{cd} - num of dual commands per hr

R_c - total cycle rate in cycles/hr

R_t - num transactions per/hr

AS/RS material handling analysis

Equations:

AS/RS dimensions	$W = 3\,(x + a)$	$a = 6$ in
	$L = n_y\,(y + b)$	$b = 8$ in
	$H = n_z\,(z + c)$	$c = 10$ in
capacity per aisle	$C = 2\,n_y\,n_z$	
single command cycle	$T_{cs} = \text{Max}\,\{L/v_y\,,\,H/v_z\} + 2\,T_{pd}$	"*uniform racks, random storage*"
dual command cycle	$T_{cd} = \text{Max}\,\{1.5\,L/v_y\,,\,1.5\,H/v_z\} + 4\,T_{pd}$	
utilization	$60\,U = R_{cs}\,T_{cs} + R_{cd}\,T_{cd}$	
hourly cycle rate	$R_c = R_{cs} + R_{cd}$	
num transactions per hr	$R_t = R_{cs} + 2\,R_{cd}$	

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Electric drives

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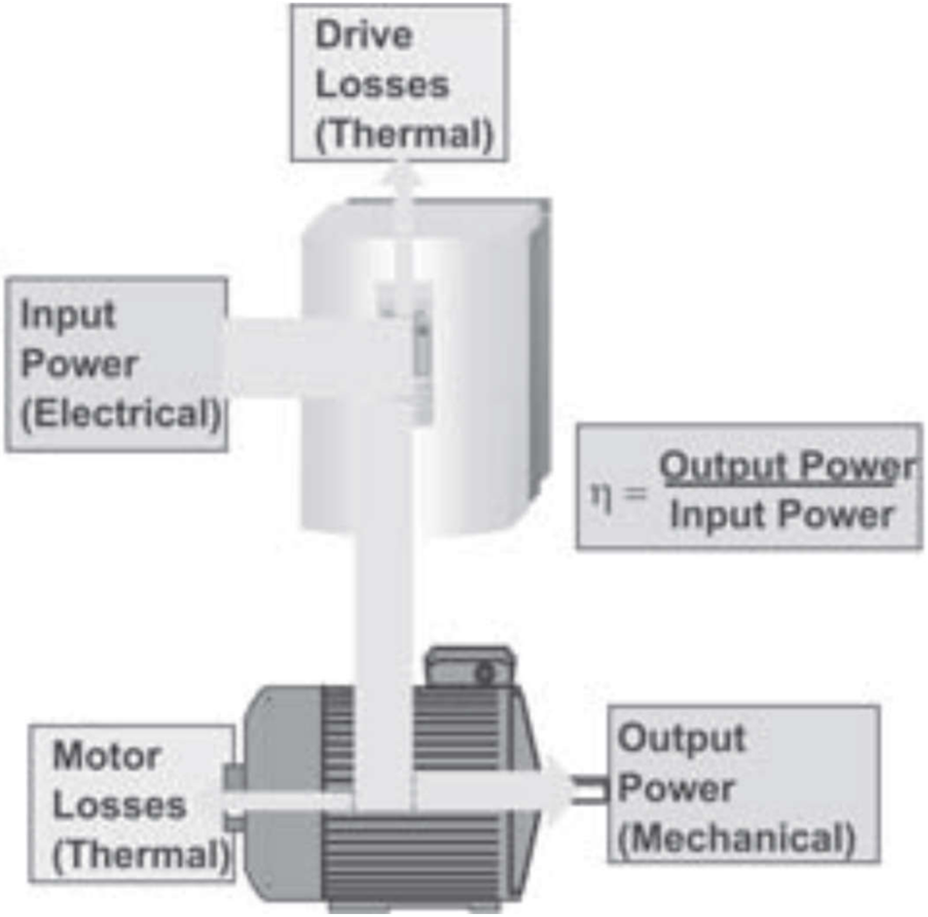
Main assumptions



$$P_{in} = \sqrt{3} \times U \times I \times \cos(\varphi)$$

$$P_{out} = T \times 2\pi \times \frac{n}{60}$$

$$\eta = \frac{P_{out}}{P_{in}}$$

The efficiency of the drive system

The total efficiency of the drive system depends on the losses in the motor and its control. Both drive and motor losses are thermal, so they appear as heat. Input power to the drive system is

electrical in form, while output power is mechanical. That is why calculating the coefficient of efficiency (η) requires knowledge of both electrical and mechanical engineering.

Electrical input power Pin depends on voltage (U), current (I) and the power factor (cosϕ). The power factor tells us what proportion of the total electric power is active power and how much is

so called reactive power. To produce the required mechanical power, active power is required. Reactive power is needed to produce magnetization in the motor.

Mechanical output power Pout depends on the required torque (T) and rotating speed (n). The greater the speed or torque required, the greater the power required. This has a direct effect

on how much power the drive system draws from the electrical supply. As mentioned earlier, the frequency converter regulates the voltage, which is fed to the motor, and in this way directly

controls the power used in the motor as well as in the process being controlled.

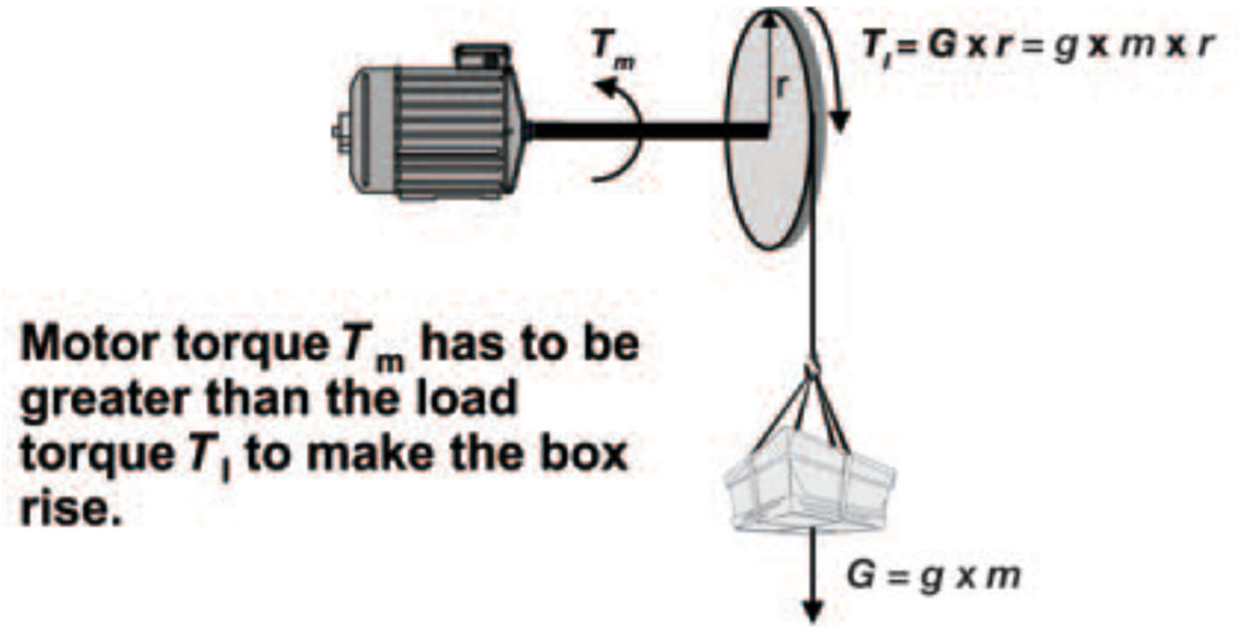
Electrical switching with transistors is very efficient, so the efficiency of the frequency converter is very high, from 0.97 to 0.99. Motor efficiency is typically between 0.82 and 0.97 depending

on the motor size and its rated speed. So it can be said that the total efficiency of the drive system is always above 0.8 when controlled by a frequency converter.

The load, friction and inertia resist rotation

The motor must produce the required torque to overcome the load torque. Load torque consists of friction, inertia of the moving parts and the load itself, which depends on the application. Innthe example in the diagram, the motor torque has to be greater than the load torque, which is dependent on the mass of the box, if the box is to rise.

Load factors change according to the application. For example, in a crusher, the load torque is dependent not only on friction and inertia, but also on the hardness of the crushed material. In fans and blowers, air pressure changes affect the load torque, and so on.

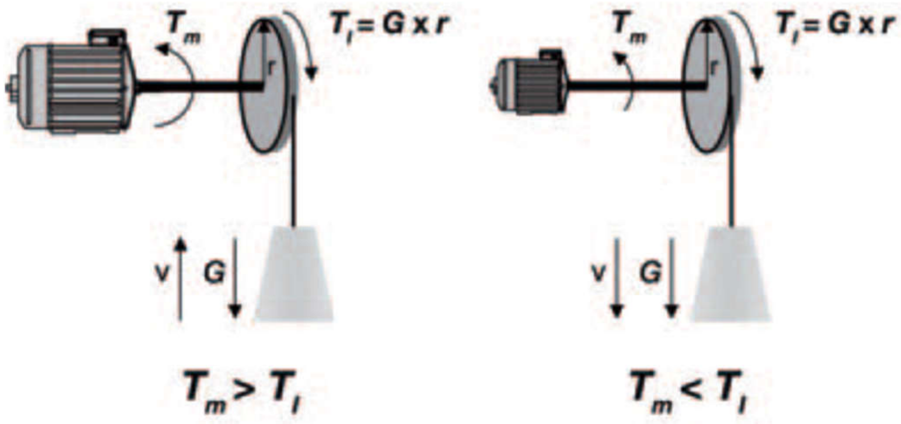


The motor has to overcome the loading torque

In any case, the loading torque has to be known before selecting the motor for the application. The required speed also has to be known. Only then can a suitable motor be selected for the application.

If the motor is too small, the requirements cannot be met and this might lead to serious problems. For example, in crane applications, a motor that is too small may not be able to lift the required load quickly enough to the desired height. It might even drop the load completely, as shown in the diagram. This could be disastrous for people working at the harbour or site where this crane would be used. To calculate the rated torque of the motor the following formula can be used:

$$T[Nm] = 9550 \times \frac{P[kW]}{n[1/min]}$$

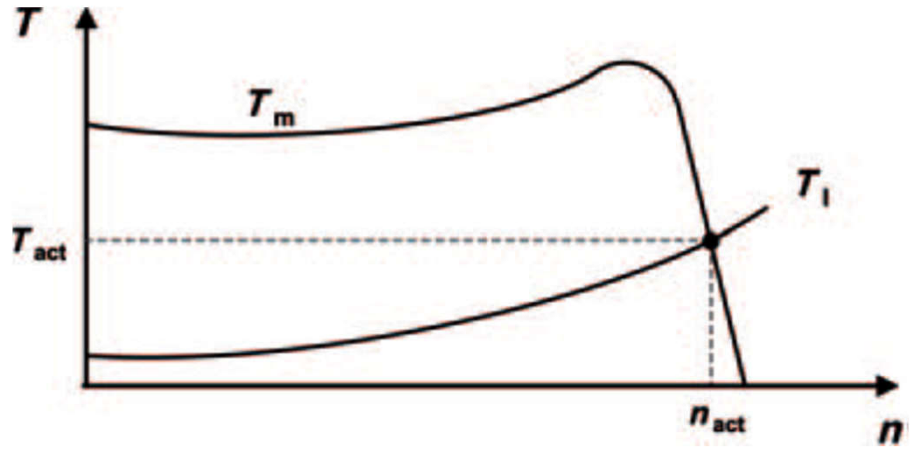


The drive torque and load torque are equal at nominal speed

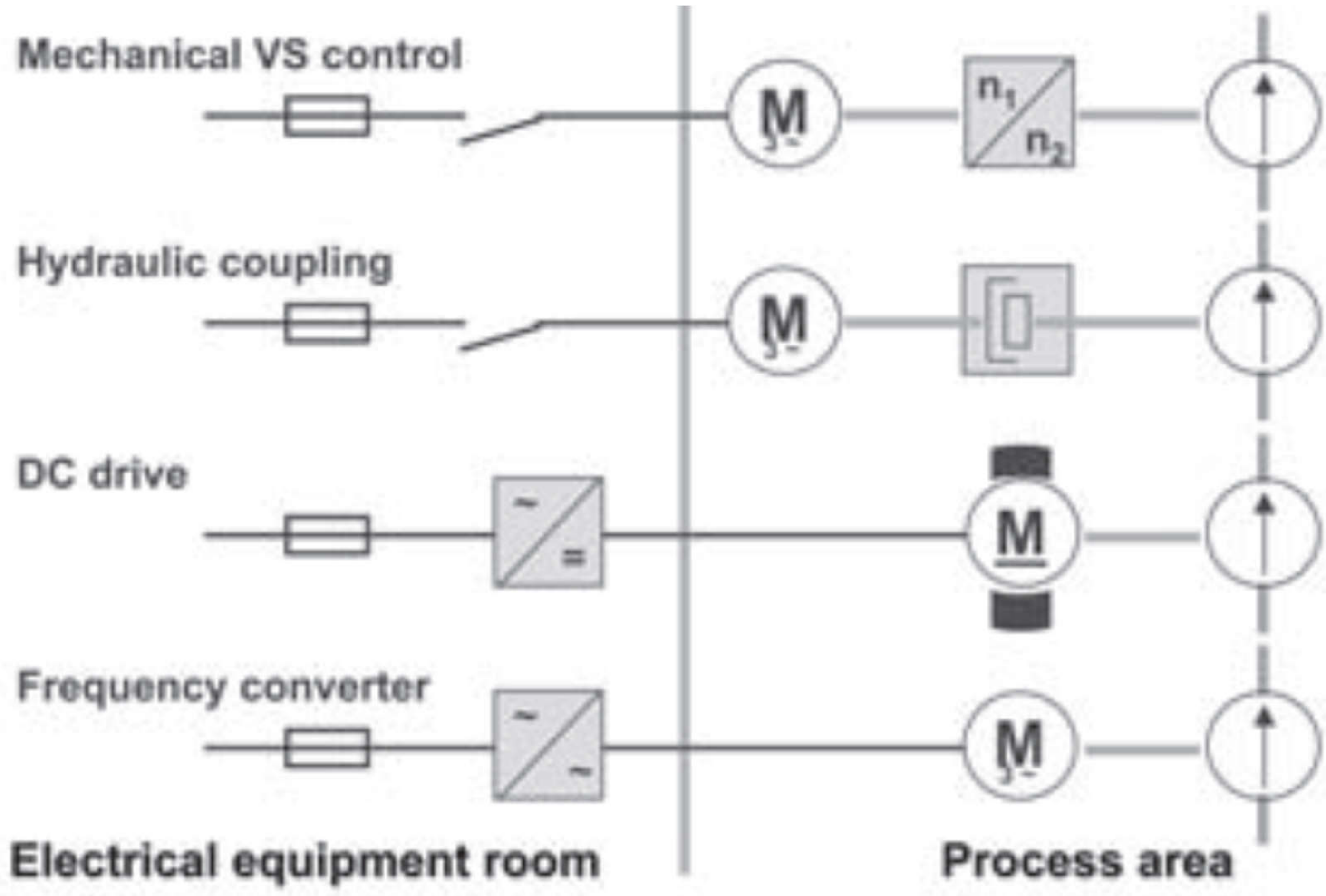
A motor's torque/speed curve is unique and has to be calculated for every motor type separately. A typical torque/speed curve is shown in the graph as Tm. As can be seen, the maximum load torque is reached just below nominal speed.

Load torque Tl usually increases with speed. Depending on the application it can be linear or quadratic. The motor will automatically accelerate until the load torque and motor torque are equal. This point is shown on the graph as the intersection of Tm and Tl. Actual torque (Tact) is shown on the y-axis and actual speed (nact) on the x-axis.

These are the principles that govern how an ordinary squirrel cage motor works. With a frequency converter, optimal control performance can be obtained from the motor and the whole drive system.



Motor control



Mechanical, hydraulic and electrical VSDs

Above are the four most common VSDs in the industrial sector. Mechanical variable speed control usually uses belt drives, and is controlled by moving conical pulleys manually or with positioning motors.

Hydraulic coupling

In hydraulic coupling, the turbine principle is used. By changing the volume of oil in the coupling, the speed difference between the driving and driven shafts changes. The oil amount is controlled with pumps and valves.

DC drive

In the DC drive, a DC converter changes the motor supply voltage fed to the DC motor. In the motor, a mechanical inverter, a commutator, changes direct current to alternating current.

AC drive

In the frequency converter or AC drive, a standard squirrel cage motor is used, so no mechanical inverters are required. The speed of the motor is regulated by a frequency converter that changes the frequency of the motor voltage, as presented earlier in this guide. The frequency converter itself is controlled with electrical signals. The diagram shows the location of the control equipment for each type of VSD. In mechanical and hydraulic VSDs, the control equipment is located between the motor and the working machine, which makes maintenance very difficult. In electrical VSDs, all control systems are situated in an electrical equipment room and only the driving motor is in the process area. This is just one benefit of electrical VSDs.

Electrical VSDs dominate the market

Here are the four most important arguments for using electrical VSDs, presented along with estimated VSD market shares in Europe in 2000. The four main benefits of using electrical VSDs

are highlighted at the turning points of the speed curve.

Maintenance costs

Direct on-line starting stresses the motor and also the electrical equipment. With electrical VSDs, smooth starting is possible and this has a direct effect on maintenance costs.

Productivity

Process equipment is usually designed to cater for future productivity increases. Changing constant-speed equipment to provide higher production volumes requires money and time.

With the AC drive, speed increases of 5 to 20 percent are not a problem, and the production increase can be achieved without any extra investment.

Energy saving

In many processes, production volumes change. Changing production volumes by mechanical means is usually very inefficient. With electrical VSDs, changing the production volume

can be achieved by changing the motor speed. This saves a lot of energy particularly in pump and fan applications, because the shaft power is proportional to the flow rate to the power of three.

Higher quality

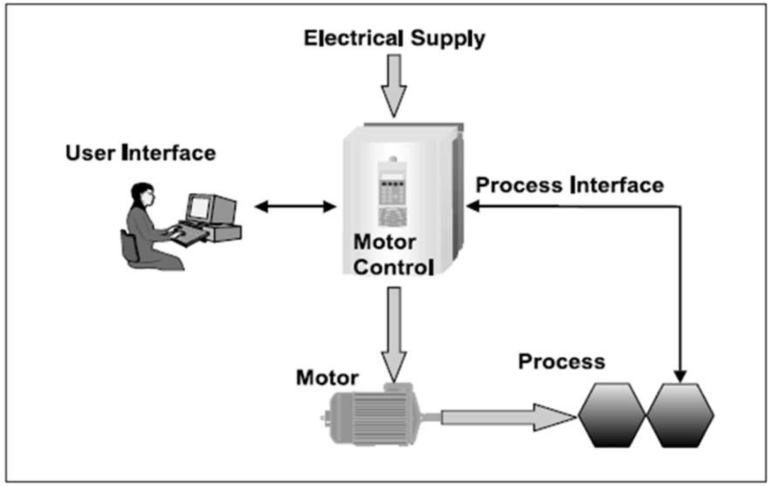
The accurate speed control obtainable with electrical VSDs results in process optimization. The optimal process control leads to the best quality end product, which means the best profit for the customer.

The basic functions of an AC drive

In this diagram, the basic functions of an AC drive are presented. There are four different components in AC drive motor control. These components are the user interface, the motor, the electrical supply and the process interface.

An electrical supply feeds the required electricity to the drive; one selection criteria for the drive is the supply voltage and its frequency. The AC drive converts the frequency and voltage and feeds the motor. This conversion process is controlled by signals from the process or user via the process and user interfaces.

The user interface provides the ability to observe the AC drive and obtain different process information via the drive. This makes the drive easy to integrate with other process control equipment and overriding process control systems.



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A motor's load capacity curves with an AC drive

If the motor is driven without a frequency converter, its load capacity curves cannot be modified. It will produce a specified torque at certain speed and maximum torque cannot be

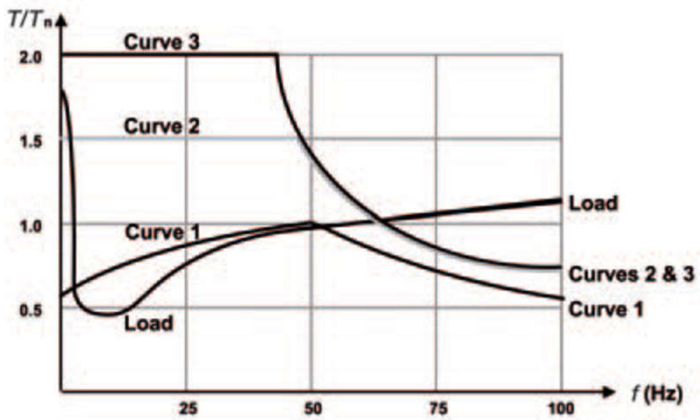
exceeded.

With a frequency converter drive, there are different loading options. The standard curve, Curve 1 in the diagram, can be used continuously. Other curves can only be used for certain periods

of time, because the motor's cooling system is not designed for this kind of heavy use.

These higher load capacity levels might be needed, for example, during startup. In certain applications, as much as twice the amount of torque is required when starting. With a frequency converter this is possible, meaning that a motor can be dimensioned according to its normal use. This reduces the investment cost.

To be able to use these features it is very important that the load, the AC drive and the motor are compatible. Otherwise the motor or the converter will overheat and be damaged.



Features

Reversing

Reversing the motor rotation is simple to accomplish with an AC drive. With ABB's frequency converters it can be achieved simply by pressing one button. Furthermore, it is possible to set different acceleration and deceleration ramp times. The ramp form can also be modified according to the user's wishes. In the diagram (above, left) an S-ramp has been presented. Another possibility could be a linear ramp.

Torque control

Torque control is relatively simple with an AC drive. Torque boosting, which was presented earlier, is necessary if a very high starting torque is required. Variable torque U/f settings

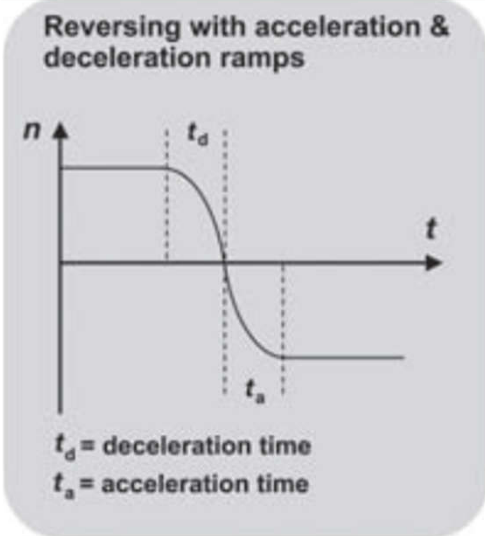
mean that maximum torque can be achieved at a lower speed of rotation than normal.

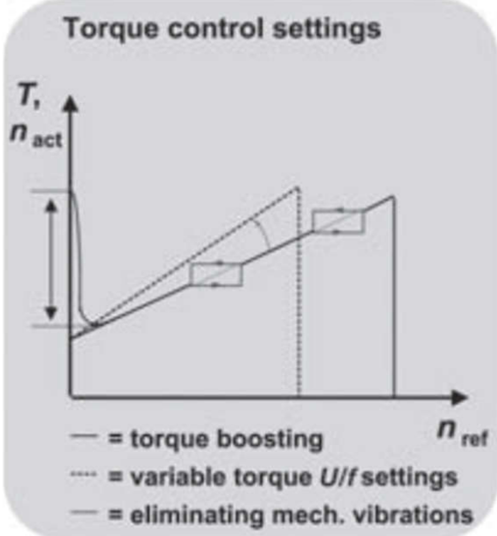
Eliminating mechanical vibrations

Mechanical vibrations can be eliminated by by-passing critical

speeds. This means that when a motor is accelerated close to its critical speed, the drive will not allow the actual speed of the motor to follow the reference speed. When the critical point

has been passed, the motor will return to the regular curve very quickly and pass the critical speed.





Features

Power loss ride-through

The power loss ride-through function is used if the incoming supply voltage is cut off. In such a situation, the AC drive will continue to operate using the kinetic energy of the rotating motor. The drive will be fully operational as long as the motor rotates and generates energy for the drive.

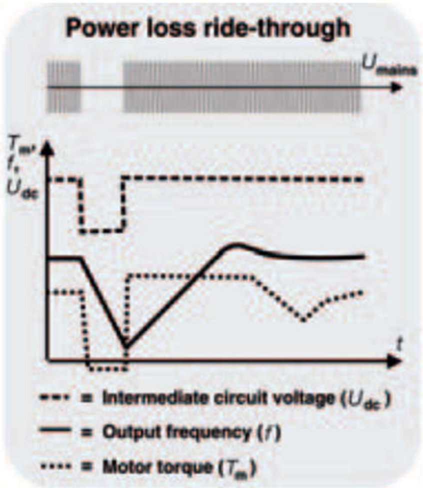
Stall function

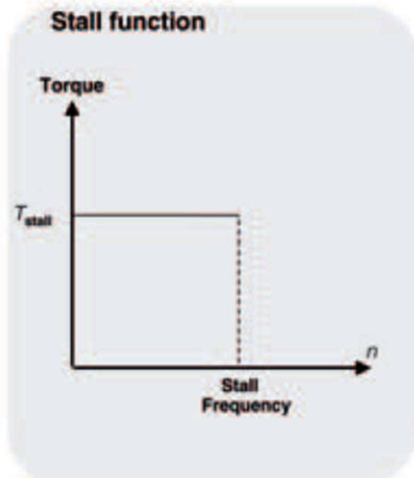
With an AC drive, the motor can be protected in a stall situation with the stall function. It is possible to adjust supervision limits and choose how the drive reacts to the motor stall condition. Protection is activated if three conditions are met at the same time.

1. The drive frequency has to be below the preset stall frequency.

2. The motor torque has to rise to a certain limit, calculated by the drive software.

3. The final condition is that the motor has been in the stall limit for longer than the time period set by the user.



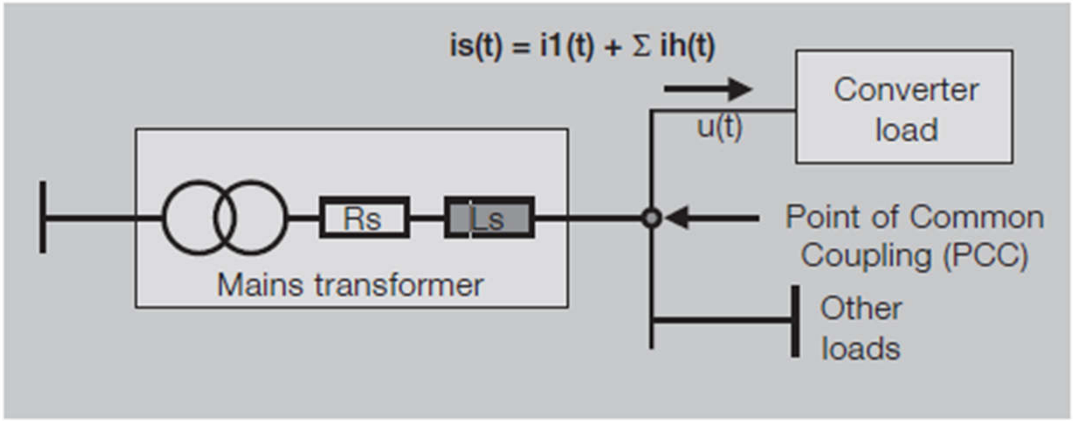


Features

Some new drive installations can have their bearings fail only a few months after startup. Failure can be caused by high frequency currents, which flow through the motor bearings.

Harmonic currents are created by non-linear loads connected to the power distribution system. Harmonic distortion is a form of pollution in the electric plant that can cause problems if the voltage distribution caused by harmonic currents increases above certain limits.

All power electronic converters used in different types of electronic systems can increase harmonic disturbances by injecting harmonic currents directly into the grid. Figure shows how the current harmonics (ih) in the input current (is) of a power electronic converter affect the supply voltage (ut), when passing through the transformer short circuit impedance.



Motor control

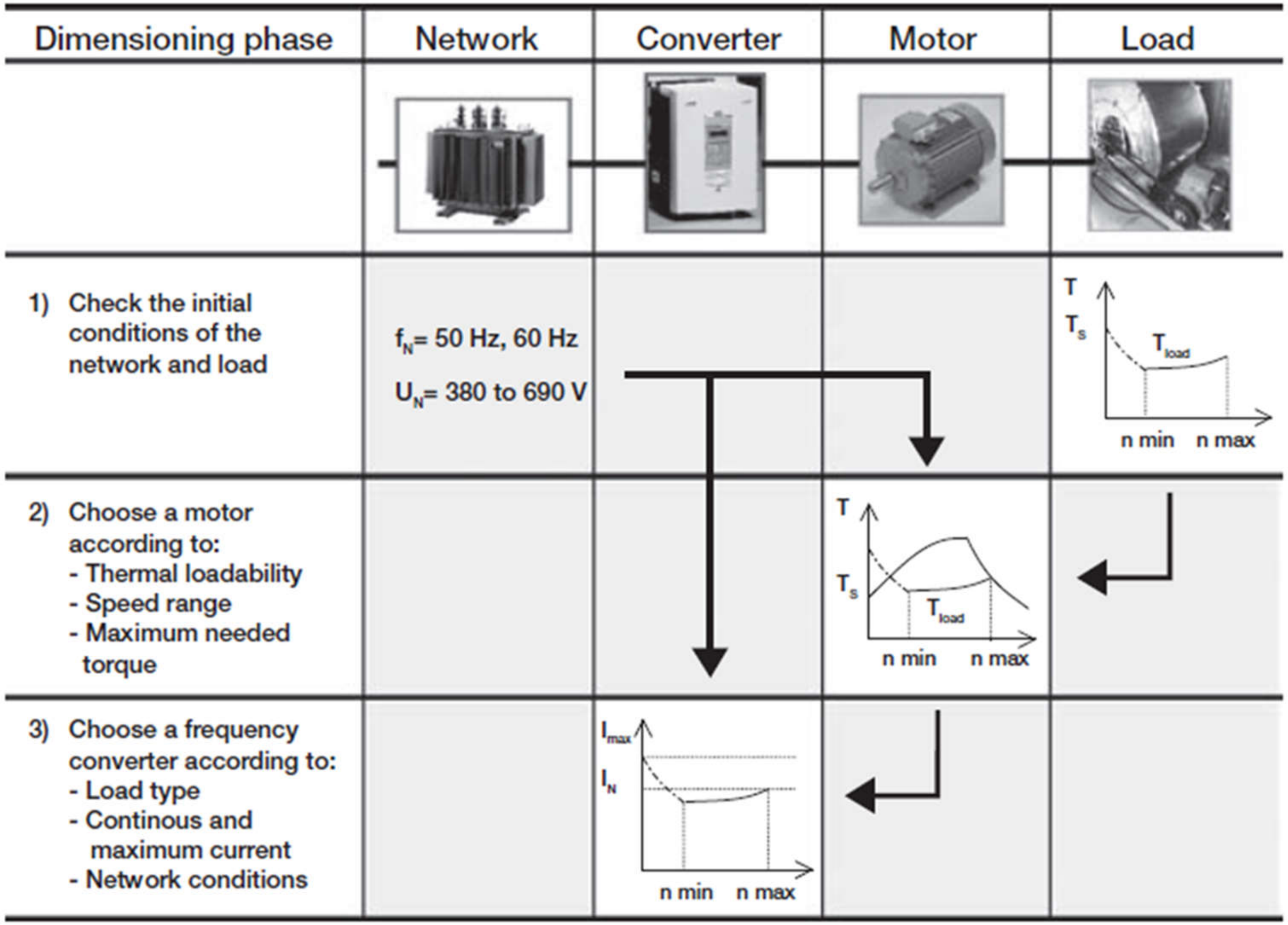


Figure 3.1 General description of the dimensioning procedure.

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