PowerXL™

DG1 Variable Frequency Drives
Load balancing in multi motor applications

Level 1	1 – Fundamental – No previous experience necessary 2 – Basic – Basic knowledge recommended 3 – Advanced – Reasonable knowledge required 4 – Expert – Good experience recommended

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Contents

Danger! - Dangerous electrical voltage!

- Disconnect the power supply of the device.
- Ensure that devices cannot be accidentally restarted.
- Verify isolation from the supply.
- Cover or enclose any adjacent live components.
- Follow the engineering instructions (AWA/IL) for the device concerned.
- Only suitably qualified personnel in accordance with EN 50110-1/-2 (VDE 0105 Part 100) may work on this device/system.
- Before installation and before touching the device ensure that you are free of electrostatic charge.
- The functional earth (FE, PES) must be connected to the protective earth (PE) or the potential equalization. The system installer is responsible for implementing this connection.
- Connecting cables and signal lines should be installed so that inductive or capacitive interference does not impair the automatic control functions.
- Suitable safety hardware and software measures should be implemented for the I/O interface so that an open circuit on the signal side does not result in undefined states.
- Deviations of the mains voltage from the rated value must not exceed the tolerance limits given in the specification, otherwise this may cause malfunction and/or dangerous operation.
- Emergency stop devices complying with IEC/EN 60204-1 must be effective in all operating modes. Unlatching of the emergency-stop devices must not cause a restart.
- Devices that are designed for mounting in housings or control cabinets must only be operated and controlled after they have been properly installed and with the housing closed.
- Wherever faults may cause injury or material damage, external measures must be implemented to ensure a safe operating state in the event of a fault or malfunction (e.g. by means of separate limit switches, mechanical interlocks etc.).
- Frequency inverters may have hot surfaces during and immediately after operation.
- Removal of the required covers, improper installation or incorrect operation of motor or frequency inverter may destroy the device and may lead to serious injury or damage.
- The applicable national safety regulations and accident prevention recommendations must be applied to all work carried on live frequency inverters.
- The electrical installation must be carried out in accordance with the relevant electrical regulations (e. g. with regard to cable cross sections, fuses, PE).
- Transport, installation, commissioning and maintenance work must be carried out only by qualified personnel (IEC 60364, HD 384 and national occupational safety regulations).
- Installations containing frequency inverters must be provided with additional monitoring and protective devices in accordance with the applicable safety regulations. Modifications to the frequency inverters using the operating software are permitted.
- All covers and doors must be kept closed during operation.

To reduce the hazards for people or equipment, the user must include in the machine design measures that restrict the consequences of a malfunction or failure of the frequency inverter (increased motor speed or sudden standstill of motor). These measures include: – Other independent devices for monitoring safety related variables (speed, travel, end positions etc.).

– Electrical or non-electrical system-wide measures (electrical or mechanical interlocks).

– Never touch live parts or cable connections of the frequency inverter after it has been disconnected from the power supply. Due to the charge in the capacitors, these parts may still be alive after disconnection. Consider appropriate warning signs.

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1 General

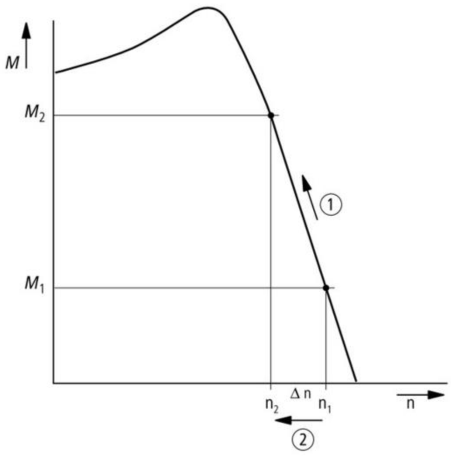
In cases, in which multiple motors are fixed permanently our coupled via friction, an equal load sharing between the motors is required. Already small differences in the mechanical structure of the drives inside the system or manufacturing tolerances can lead to an unbalanced load sharing. Beside an oversizing other measures exist to balance the load to ensure a reliable operation of the application and to prevent overload situations for single motors.

Like in many other cases, multiple solutions exist, differing in complexity and costs. There is a fundamental interest to choose the variant with the best value for money. In the end the application determines, which kind of solution can be chosen. This application note describes three of the possible solutions in connection with variable frequency drives and provides an indication of the right solution.

The following chapters describe, how the different solutions work. The table below gives an overview about the substantial features and differences.

	Control via slip	Droop function	Torque control
Control mode	Speed control	Speed control	1 motor with speed control, the other ones with torque control
Number of variable frequency drives	1 variable frequency drive per motor; connecting multiple motors in parallel to the output of one device is possible.	1 variable frequency drive per motor	1 variable frequency drive per motor
Load balancing via	Slip	Load dependent corrective value	Torque control
Accuracy of balancing	+	++	+++
Motors (power, manufacturer)	Equal motors necessary	Different motors possible	Different motors possible
Mechanical coupling between the motors	Preferably coupled via friction; fixed mechanical coupling possible in some applications.	Preferably coupled via friction; fixed mechanical coupling possible in some applications.	Fixed coupling and coupling via friction possible. In case of coupling via friction a speed limitation is recommended.

2 Load balancing via slip



The speed of a three phase induction motor depends on the load. When it is supplied with the voltage and frequency according to its name plate, an unloaded motor turns with nearly synchronous speed, while the speed at rated load corresponds to the rated speed. In case of a 50 Hz mains supply and a four pole motor this means, that the unloaded motor turns with approximately 1500 rpm and at rated load e.g. with 1470 rpm. The difference between synchronous speed and the speed of the motor axis is called slip.

In the example on the left the motor is loaded with torque M_1 and it turns with the speed n_1. The load is increased up to M_2 ① → The speed drops down to n_2 ②.

This behavior is utilized in a slip dependent load balancing. This simplest kind of “automatic” load sharing presumes, that the mechanics as well as the motors of all parts of the system are identical. In theory all motors have to carry the same load per definition, but tolerances, temperature dependency and small mechanical differences let the loads drift apart, even when the motors were equally loaded at the point of start.

But how does load balancing work? The motor with the highest load drops in speed and in this case the other one(s) have to carry more load than before. The load is now more or less balanced. There is no possibility for load adjustment and the sharing is defined by the system. Therefore it makes sense to add some margin when calculating the motor powers.

The variable frequency drive DG1 has to work in the motor control mode “Freq Control” (P8.1 = 0). In case each motor has its own variable frequency drive, they must have identical parameter settings.

Parameter	Name	Range	Default
P8.1	Motor Control Mode	Freq Control (0) Speed Control (1) Open Loop Speed Control (5) Open Loop Torque Control (6)	Freq Control (0)

It is also possible to connect multiple motors in parallel to one variable frequency drive. It has to be noted, that each motor must have its own motor protection, because the total current is “known” by the variable frequency drive, but not how it is shared between the single motors.

3 Load balancing via drooping

In case speed controlled drive systems are mechanically connected through form fit or friction, the fastest drive takes the load and pulls the other ones, which are less, or in extreme cases, not loaded. To counteract this effect, the speed reference will be corrected, depending on the load. At load increase, the droop function reduces the resulting speed reference (set reference – speed reduction), the motor falls back a little bit in its speed and the other motors inside the system take more load automatically.

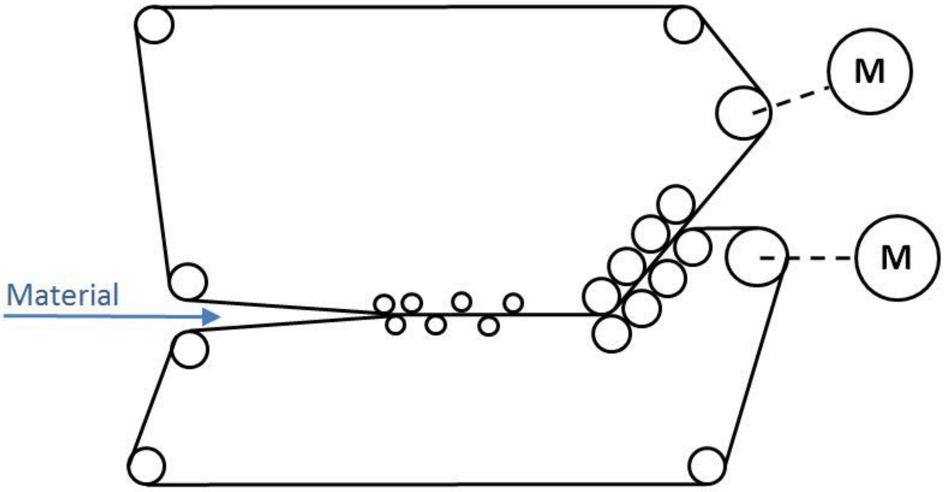
Application experience shows, that it is of advantage in many cases to have one motor inside the system, where the droop function is disabled (P8.13 “Load Drooping” = 0.00 %), while it is enabled (P8.13 “Load Drooping” different from 0.0 %) for all other motors inside the system. The set value of P8.13 is the percentage of speed by which the speed drops in case the motor is loaded with rated torque. With reduced load, the speed reduction will be reduced accordingly.

In exceptional cases it can also be advantageous to enable the droop function for all motors.

The variable frequency drive DG1 has to work in the motor control mode “Open Loop Speed Control” (P8.1 = 5) to achieve the best result.

Parameter	Name	Range	Default
P8.1	Motor Control Mode	Freq Control (0) Speed Control (1) Open Loop Speed Control (5) Open Loop Torque Control (6)	Freq Control (0)
P8.13	Load Drooping	0.00 % … 100.00 %	0.00 %

3.1 Application example



Material is transported through the machine by means of two conveyor belts. Each belt is driven by its own motor. Because of the contact pressure, the two belts are connected mechanically. In case one of the two motors tries to run a little bit faster than the other one, it leads to an unequal load sharing.

Without an enabled droop function, motor 1 takes 80 % of its rated load, motor 2 85 %. Because of the higher load, motor 2 becomes warmer than motor 1, possibly one can also see the difference in speed on the material which is transported between the belts.

Now the droop function will be enabled with P8.13. The system will change to equal load sharing iteratively. Values at the beginning (we are looking to the system at an output frequency of 40 Hz, P1.9 = 50 Hz, P8.13 = 10.00 %):

Resulting speed of motor 1: 40 Hz – ((10 % · 50 Hz) · 80 %) = 36 Hz

Resulting speed of motor 2: 40 Hz – ((10 % · 50 Hz) · 85 %) = 35,75 Hz

Motor 2 now runs slower than motor 1 → The load of motor 1 increases → Therefore the load of motor 2 is reduced ……. . This is a repetitive process until an equal sharing of the load is achieved. Remaining differences in load can be adjusted with 8.13.

4 Adjustable load balancing via torque control

Inside this system, one motor is speed controlled and the other one(s) torque controlled. The speed controlled motor determines the speed of the system, while the torque is the control variable for the other motors. Here it is possible to use motors of different ratings and it is also possible to set individual shares of the load. A torque control is much more complex than the principles described in chapters 2 and 3. On the other hand you have much more possibilities to adopt the control to the application, which results in a higher accuracy. Nevertheless the other principles are useful in simple applications because of their simplicity and value for money.

Torque control is extensively described inside the application Note „AP040167EN Torque Control". Please refer to this document.

One important aspect must be mentioned here: A torque controlled motor always tries to bring the required torque (or tension in case of linear movements) to the load. When this is not possible, the torque is used for acceleration to the maximum possible speed. This is not critical as long as the motors are connected together mechanically, e.g. when all pinions work on the same geared ring. In cases where the speeds of the motors involved are not synchronized mechanically and a slip in speed is possible, it is strongly recommended to limit the speed of the torque controlled motor. The necessary aspects and settings are comprehensively described in the application note AP040167EN mentioned above.