PowerXL DG1 Multi-Master/Lead-Lag Functionality

Introduction

The PowerXL DG1 drive has the functionality to perform a Multi-Master/ Lead-Lag application. In this mode, the internal PID controller of the drive regulates all pumps. One of the pumps will always operate as the regulating pump or Master and the additional pumps will act as followers or Slaves. This application is capable of running a system of up to five total drives. By communicating over a RS485 communication bus, the system will bring in additional pumps to meet increased demand while trying to conserve energy. If demand drops, additional pumps will de-activate and the Master pump may even shut down until demand increases again. The following information explains how the algorithm works and how to properly configure the system for optimal performance.

Operation Procedure

Figure 1 below shows a three pump system. Pump P1 is the regulating pump with pump P2 and pump P3 as followers. The speeds of the pumps are shown in curve "A". When the regulating pump notices an increased demand and cannot produce it by itself or is running at maximum frequency, it will request for another pump to start via the RS485 communication bus. The next pump will accelerate while the regulating pump begins to drop in speed until the outputs on each drive are equal based off the demand requirement and current draw to conserve energy required. Figure 1 below shows a scenario where pumps P2 and P3 were ramped up to meet demand.
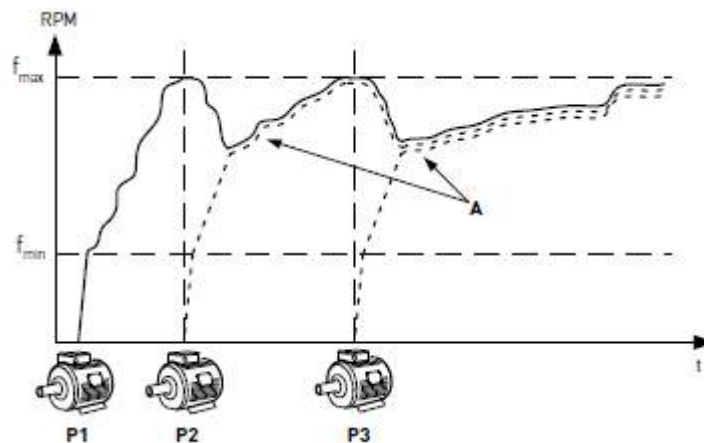

Figure 1: Multi-Master/Lead-Lag Control Curve

When the regulating pump sees that there is too much capacity (output drops down to minimum speed), it will request the previously added pumps to drop out and the regulating drive will ramp back up to meet the demand. If there are no slave pumps running when the regulating pump sees that it is not required to output flow, it will go into Sleep mode (if enabled). The regulating pump will manage all the auxiliary pumps in the system, including start/stop, setting of output frequency, and rotational direction of pump based off the drive status measurements. It also will provide motor data back from the following pumps.

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The system is typically laid out with up to five drives mounted to five pumps. One drive will always be the Master or regulating drive but there can be multiple Masters that will act as Slaves when they are not active Masters. All Masters must have the Run command wired into them for operation. Each drive/pump combination can have an interlock used to disable the drive if there is a failure at the motor and it needs to be removed. If a drive's interlock is not closed, that pump will not be active in the control scheme. If the interlock for the Master drive is not closed, the entire system won't operate. For a drive to be a Master or backup Master, the sensor feedback must be wired to the drive. This allows the PID Feedback signal to be sent to each potential Master drive.

Refer to Figure 2 for a general layout. Drive 1 and Drive 2 are setup as Master and Backup Master and Drive 3 is a Slave. With multiple Masters, the backup Master will be a slave when it is not called to be the Master.
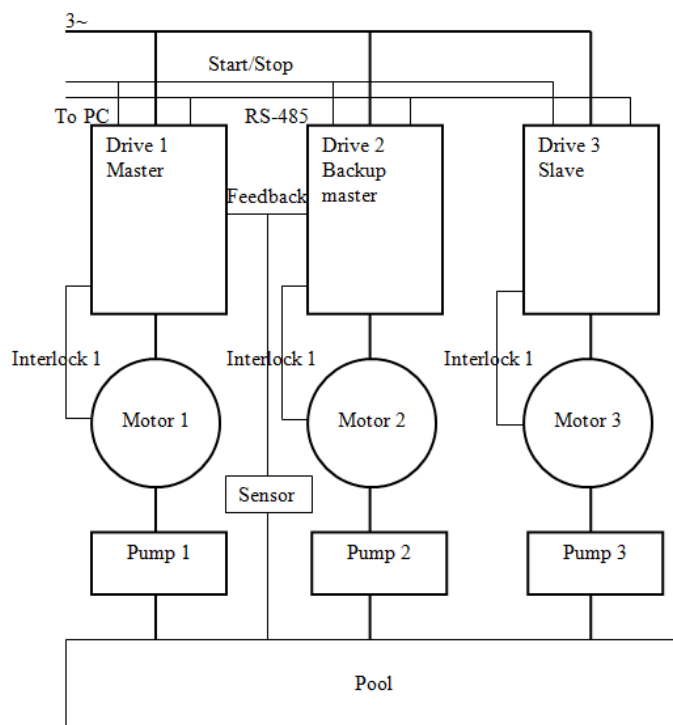

Figure 2: Multi-Master/Lead-Lag System Layout

Sample Control Schemes

Figures 3-5 below show a basic control scheme layout for three different types of transducers. These figures show the wiring of the analog signals to each of the Master drives as well as the RS-485 communication bus between all drives. In addition to the wiring shown below, the Run command must also be fed in parallel to each Master drive. This will allow the system to Run regardless of which drive is the Master.

If Safe Torque Off (STO) is utilized, these inputs should be run in parallel to each drive. If the STO on a Slave drive opens, the system can be configured to send the signal back to the Master and shut down the system with a slight delay. If the STO on the Master drive opens, the entire system will immediately shut down.

Please see each control scheme below and the specific notes pertaining to each scheme.
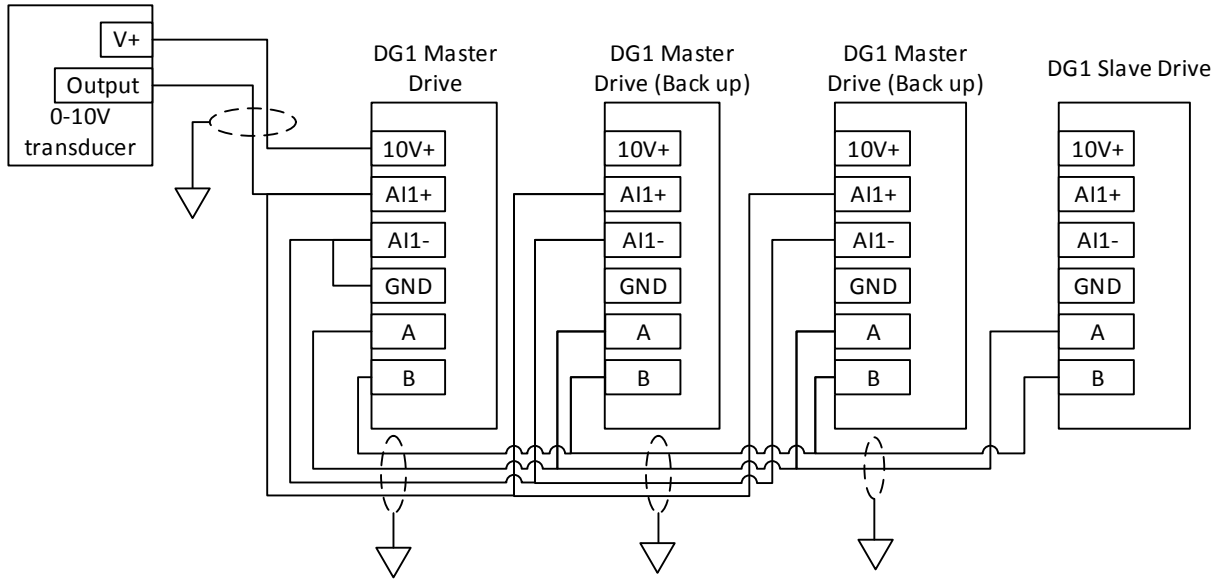
Figure 3: Control Scheme with 10V supply and a 0-10V transducer

For the control scheme in Figure 3, please note the following:

- The 10V+/24V+ supplies along with Grounds for each Master should be connected. When connecting multiple power supplies together, it is advised to use a feedback diode to prevent power supplies back feeding on themselves.

- The Run commands need to be wired into each Master drive.

Parameter	First Drive Setting	Last Drive Setting
P2.1 – AI1 Mode	0-10V	0-10V
P2.2 – AI1 Signal Range	0-100%	0-100%
Jumper	AI1: 0 to 10 V [OFF ON / 1] AI1: 0 to 20 mA	AI1: 0 to 10 V [OFF ON / 1] AI1: 0 to 20 mA
RS485 Terminating Resistor	Res_Conn / Res_Disconn	Res_Conn / Res_Disconn

Figure 4: Control Scheme with 10V supply and a 4-20mA transducer

For the control scheme in Figure 4, please note the following:

- The 10V+/24V+ supplies along with Grounds for each Master should be connected. When connecting multiple power supplies together, it is advised to use a feedback diode to prevent power supplies back feeding on themselves.

- The Run commands need to be wired into each Master drive.

- All Master drive analog inputs should be set up for voltage on the terminals except for the last Master in the line.

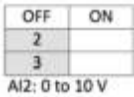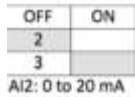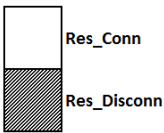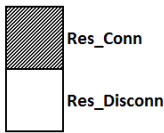| Parameter	First Drive Setting	Last Drive Setting
P2.11 – AI2 Mode	0-10V	0-20mA
P2.12 – AI2 Signal Range	0-100%	0-100%
Jumper		
RS485 Terminating Resistor		

Figure 5: Control Scheme with External Supply and a 4-20mA transducer

For the control scheme in Figure 5, please note the following:

- The 24V+ supplies along with Grounds for each Master should be connected. When connecting multiple power supplies together, it is advised to use a feedback diode to prevent power supplies back feeding on themselves.

- The Run commands need to be wired into each Master drive.

- All Master drive analog inputs should be set up for voltage on the terminals except for the last Master in the line.

Parameter	First Drive Setting	Last Drive Setting
P2.11 – AI2 Mode	0-10V	0-20mA
P2.12 – AI2 Signal Range	0-100%	20-100%
Jumper		
RS485 Terminating Resistor		

Parameters

The table below shows the setup parameters. This menu is visible in both Single and Multi drive modes.

Panel Code	Parameter	Default	Range	Modbus ID	Description
P18.3.1	Multi-pump mode	0	0-1	2279	0 = Disable 1 = Single Drive 2 = Multi Drive (multi-follower)
P18.3.2	Drive ID	0	0-5	2278	Each drive in multi drive system has to have a unique, and non-zero number. If a drive has a zero ID, it will be regard as isolated single drive. For a multi-drive system, the lower number drive has higher priority to compete for master.
P18.3.3	Number of Motors	1	0-5	342	Total number of motors/pumps connected to this drive in single drive mode. When in multi drive, this limits the amount of active drives running at a time.
P18.3.4	Regulation Source	0	0-1	2284	0 = Network 1 = Feedback Drives that have been connected with both start/stop signal and PID feedback can be set as "Feedback", so they will have ability to be master.
P18.3.5	Recovery Method	0	0-1	2285	0 = Automatic 1 = Stop This parameter is for slaves when multi drive system loses the master. The slave drive can continue run if it is set to be "Automatic", however the slave drive will stop immediately if it is set to be "Stop".
P18.3.6	Callback Source	0	0-1	2286	0 = No Action 1 = Safety Torque Off Sometimes some information needs to be callback from slave to master and affect whole system; if slave drive has a callback source as STO, when it suffers STO fault, master drive will answer this callback and shutdown whole system.
P18.3.7	Add/Remove Pump Rule	0	0-1	2311	0 = Drive ID 1 = Run Time In default, MPFC system will add/remove pump according to their drive ID, from small to large; and the order can also depend on each slave drive's running time. It will add the drive has shortest running time and remove the drive has longest running time first.
P18.3.8	PID Bandwidth			343	The same as Single Drive mode
P18.3.9	Staging Frequency	P1.2	P1.1 - 400	2315	Master drive can only add pump when output frequency is over staging frequency and feedback is out of bandwidth.
P18.3.10	De-Staging Frequency	P1.1	0 - P1.2	2316	Master drive can only reduce pump when output frequency is below de-staging frequency and feedback is out of bandwidth.
P18.3.11	Add/Remove Delay			344	The same as Single Drive mode
P18.3.12	Interlock Enable			350	The same as Single Drive mode But in Multi Drive mode, system only detect Interlock 1
P18.3.13	Include Freq Converter			346	Not available for Multi Drive mode
P18.3.14	Auto-Change Enable			345	Not available for Multi Drive mode
P18.3.15	Auto-Change Interval			347	Not available for Multi Drive mode
P18.3.16	Auto-Change Freq Limit			349	Not available for Multi Drive mode
P18.3.17	Auto-Change Motor Limit			348	Not available for Multi Drive mode
P18.3.18	Run Time Enable	0	0-1	2280	The run time counter will start counting only if this parameter is enabled.
P18.3.19	Run Time Limit	0.0	0.0-300000.0	2281	If drive run time is over this limit, its network status will be "Need Alternation". Limit equals 0 means run time counter disabled.
P18.3.20	Run Time Reset	0	0-1	2283	One-time parameter. If set to be 1, it will clear run time counter.

P18.3.21	Damper Start			483	Not available for Multi Drive mode
P18.3.22	Damper Time Out			484	Not available for Multi Drive mode
P18.3.23	Damper Delay			485	Not available for Multi Drive mode

The table below shows the status parameters. This menu is visible only in multi drive mode.

Panel Code	Parameter	Default	Range	Modbus ID	Description
P18.1.1.x	Operation Mode	0	0-2		0 = Offline (For single drive mode or slave drive which has lost master in multi drive mode) 1 = Slave Drive (Operate as an auxiliary drive in multi drive mode) 1 = Master (Operate as the regulating drive of the Multi drive system)
P18.1.2.x	Multi-pump Status	5	0-5		0 = Stopped (For master or single drive which is stopped) 1 = Sleep (For master or single drive which is asleep) 2 = Regulating (For master or single drive which is running) 3 = Wait for CMD (For slave drive which is stopped) 4 = Following (For slave drive which is running) 5 = Unknown (Status for disconnected drives showing on other drives' menu)
P18.1.3.x	Network Status	0	0-4		0 = Disconnected (For disconnected slave drive or single drive) 1 = Fault (For drives that suffer fault) 2 = Pump Lost (For drives that lose interlock signal) 3 = Need Alternation (For drives that run time is over limit) 4 = No Error

The table below shows the measurement parameters. This menu is visible only for Master drives.

Panel Code	Parameter	Default	Range	Modbus ID	Description
P18.2.1.x	Latest Fault Code				These measurement parameters of all drives within multi drive system can be seen from master drive's menu.
P18.2.2.x	Output Frequency				
P18.2.3.x	Motor Voltage				
P18.2.4.x	Motor Current				
P18.2.5.x	Motor Torque				
P18.2.6.x	Motor Power				
P18.2.7.x	Motor Speed				
P18.2.8.x	Run Time				

Installation Settings

Follow the below steps to perform the installation of the system.

1. Make all hardwire connections between drives.

    a. Terminal A/B for RS485 – connect up to every drive in the scheme (both Master and Slave devices).

    b. Power Supply – connect up every drive with feedback diodes if using multiple drives supplies (with ext. supply this is not required) to prevent back feeding on individual Master devices.

    c. GND – connect up every drive GND terminals to keep a common control level.

    d. Digital Inputs – connect up any Digital inputs used on the potential Master drivers.

    e. Analog Inputs – connect up analog feedback and set point values to the desired master drives.

    f. Safe Torque Off (STO) – connect up all the drives to the STO terminals in series (both Master and Slave devices).

2. On the keypad or PC tool, set all drives to the Multi-Pump application (P21.1.2 Application).

3. Go through the Start Up wizard to set up the motor parameters and control places. (Either Local or Remote Reference parameters should be set for PID Control 1 to follow PID control loop operation.)

4. Set the Baud rate (P20.2.3) and communication mode (P20.2.1) to the desired communication speed and Modbus-RTU. The Slave address (P20.2.2) for each drive should be different. Set up any additional control functions required.

5. Set Drive ID's (P18.3.2) to different ID's for each drive being used in the Multi-drive sequence.

6. The Master drives that have the Start/Stop signal and PID feedback connected to them should have PID Feedback connection regulation source (P18.3.4) to "PID Controller 1". (The lowest drive ID typically will have higher priority in the desired master drives but this is not always true. If a fault occurs or a pump is lost in the master drive, it will hand over control over to the next master that is available.)

7. Select the functions for the other Multi-drive functions if the defaults are not desired. With the default values, the system can safely operate. The table on the following page shows the default values.

    a. Recovery Method (P18.3.5)

    b. Callback Source (P18.3.6)

    c. Add/Remove Drive Selection (P18.3.7)

    d. PID Bandwidth (P18.3.8)

    e. Staging Frequency (P18.3.9)

    f. De-Staging Frequency (P18.3.10)

    g. Add/Remove Delay (P18.3.11)

    h. Interlock (P18.3.12)

8. Once set, copy the parameters to the keypad (P21.1.4) to back up the parameters.

9. With the drives connected, the Master drive should start seeing the additional slave drives and the setup is done. The system can now be started.

Note: When the keypad is used as the set point source, changes are not communicated to other Master drives. If the set point is changed on one Master, it is required to manually change the set point on the other Masters. This will allow the system to keep the desired set point if it switches to a Backup Master.

Parameter	Parameter Name	Master/Backup Master Drive Setting	Slave Drive Setting
P21.1.2	Application	Multi-Pump	Multi-Pump
P20.2.1	Communication Mode	Modbus RTU	Modbus RTU
P20.2.2	Slave Address	Varies	Varies
P20.2.3	Baud Rate	9600	9600
P1.11	Remote Control Place	I/O terminal	I/O terminal
P1.14	Remote Reference	PID Control 1	PID Control 1
P3.37	Motor Interlock 1	Varies	Varies
P10.11	PID1 Keypad Set Point 1	Varies	Varies
P10.14	PID1 Set Point Source	Keypad	Keypad
P10.32	Feedback Source 1	AI2	AI2
P18.3.2	Drive ID	Varies	Varies
P18.3.3	Number of Motors	Varies	Varies
P18.3.4	Regulation Source	PID Controller 1	Network
P18.3.5	Recovery Method	Automatic	Automatic
P18.3.6	Callback Source	No Action	No Action
P18.3.7	Add/Remove Pump Rule	Drive ID	Drive ID
P18.3.8	PID Bandwidth	10	10
P18.3.9	Staging Frequency	60	60
P18.3.10	De-Staging Frequency	0	0
P18.3.11	Add/Remove Delay	10	10

Application Specifics

Master Handover

When a drive is setup as the Master drive, it will maintain the master functionality as long as it does not meet the following status.
1. A Fault occurs except for STO. (If Master drive has STO fault, the whole system will be shut down and it will remain in the Master position).
2. The interlock signal is lost when the interlock function is used and enabled.
3. The regulation source (P18.3.4) changes from feedback to network.

The next master drive will be chosen based off the following criteria.
1. The drive is within the Multi-Pump and Fan control network and communication is OK.
2. Regulation source (P18.3.4) is set at feedback.
3. No active faults and interlock signal is present (if enabled).
4. The smallest ID number if Add/Remove Pump Rule (P18.3.7) is drive ID. If it is set for Run Time, it will look for the shortest run time.

Master Lost

If there is a communication loss between the Master and Slave drives over 5 seconds, there will be a new Master generated from the slaves that lost contact with their master via competition, while the former Master will still be an isolated Master. The new Master will be chosen according to the following criteria.

1. Regulation Source (P18.3.4) must be set to feedback.
2. No active faults and interlock signal is present if enabled.
3. Has the smaller ID number.

The new Master will continue regulating if the former Master was running. If there is not a drive that satisfies the above conditions in the detached slaves, the slave drives will follow the Recovery Method Setting (P18.3.5): Continue Running or Stop Immediately. If communication resumes, all slaves will stop when resumed Master drive is stopped/asleep condition.

System Redundancy

The PowerXL DG1 supports up to 5 drives in the multi-master/lead-lag network with 1 motor connected to each drive. The status of all the connected slave drives can be seen from the Master drive's keypad and PC tool. The parameter Number of Motors (P18.3.3) defines the active amount of motors that can be enabled at one time. For example, there are 5 drives in the system but it only requires running 2 at a time. With P18.3.3 set to 2, only 2 drives will be running at one time. The additional 3 will be seen but used as backup drives. The backup drives will be introduced if one of the 2 active drives fails or based off the run time if enabled.

Backup Slave

During operation, if a slave drive is stopped due to a fault, interlock lost or other reasons not coming from the master command signal, the master will add on an additional backup slave immediately instead of waiting for the feedback to change.

Slave Callback

In cases where the slave drives behavior affects the entire system, for instance if one slave drive sees STO fault while its Master drive has not since they are connected with different signals, the whole system will shut-down if the slave drive has Callback Source Setting (P18.3.6) set for "STO".

Fire Mode

If Fire Mode is used on the digital inputs and is enabled when the Multi-Master/Lead-Lag system is operating, the functionality is dependent on which drives sees the Fire Mode input. When the Master sees the Fire Mode, the system will continue to run at the Fire Mode set frequency. If a slave drive gets the call for Fire Mode, it will go into Fire Mode and run at the desired frequency but it will also disconnect itself from the master drive. The Master drive will continue to run as normal with additional slave drives present.

Keypad Stop button

By default, the keypad is always active for stopping the drive based off the Keypad Stop (P7.5) parameter. When the Master drive keypad Stop button is pressed, the operation will shut down the whole system regardless of where the control source is coming from. If a slave drive receives the keypad Stop operation, it will stop itself but also change itself into the single drive mode (P18.3.1) for maintenance.

Additional Help

In the US or Canada: please contact the Technical Resource Center at 1-877-ETN-CARE or 1-877-386-2273 option 2, option 6.

All other supporting documentation is located on the Eaton web site at www.eaton.com/Drives

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