Allen-Bradley

PowerFlex 700 with Vector Control Option Custom Firmware

"BA" Option - Pump Off Function
Series B

ATTENTION: The custom firmware is designed for a specific application and load condition. It differs from the standard PowerFlex 700 Vector Control product offering and must be installed and run only under this custom application. Attempting to run this custom firmware under any other type of application can result in unpredictable and/or hazardous conditions.

ATTENTION: The drive contains parts and assemblies that are sensitive to electrostatic discharge (ESD). Static control precautions are required when installing, testing, servicing, or repairing parts and assemblies. Component damage can result if ESD control procedures are not followed. If you are not familiar with static control procedures, refer to Guarding Against Electrostatic Damage Data Sheet, publication 8000-4.5.2, or other applicable ESD protection handbook.

The PowerFlex 700 sensorless pump off function is an enhancement to the basic pumpjack oil well application. The pump off function detects when the fluid level in a well drops. Programming then determines if the drive slows down or stops pumping. The low level detection is accomplished by an algorithm that utilizes dynamic motor data, thereby removing the need for external sensors. Productivity can be increased by detecting a low well condition and pumping at a slower rate during the "pump off" condition rather than simply running the pump on a timer.

This custom firmware differs from the PowerFlex 700 Vector Control standard firmware (version 4.006, Series B) in the following ways:

- Custom firmware parameters (see pages 5 through 9).
- Parameter 178 [Sleep Time] maximum value changed from 1000 to 64,800 seconds.
- The PowerFlex 700 Pump Jack Pump Off custom firmware cannot be updated over PowerFlex 700 firmware.

For additional drive information including the basic pumpjack oil well parameter descriptions and other standard firmware parameters, refer to the PowerFlex 700 AC Drives – Frames 0...10 User Manual, Vector Control Firmware 4.001 and Up, publication 20B-UM002.

Custom Firmware Overview

This section provides an overview of the custom firmware functions.

Pump Off Function

The pump off function can be set to use a torque baseline (created when the drive is first run or the commanded speed is changed) or a fixed set point. A fixed set point is useful if the drive is faulting due to well conditions. The drive does not create a new set point based on what can be a "pump off" condition.

Baseline Disable Function

When Pump Off Control is enabled, a torque baseline is created each time the drive is started. The control uses this baseline when parameter 682 [Pump Off Control] is set to option 1, "Baseline Set".

The "Baseline Disable" function disables the calculation of a new torque baseline each time the drive is started. When one of the "Baseline Disable" selections is enabled, the drive uses the torque baseline that was previously calculated and saved.

If a "Baseline Disable" selection is enabled and there is no existing torque baseline (torque values in the baseline are zero), the drive calculates a torque baseline when it is started and a stable running condition is reached.

The saved torque baseline is erased when all "Baseline Dis" selections are off and the drive is running, or when [Pump Cycle Store] is selected.

Downstroke Torque Function

The downstroke torque can change position on some wells. If this happens the variance of the torque waveform can change enough that the position synchronization does not work properly. This can be seen on the position test point (the position continues to reset early). To function properly on these pumps, the torque waveform is averaged over one cycle.

Pump Off Setup

Follow these steps to set up the pump off function.

1. Set parameter 53 [Motor Cntl Sel] to 4, "FVC Vector."
2. Set parameter 641 [OilWell Pump Sel] to 1, "Pump Jack."
3. Set the following parameters according to your equipment. These settings are used to calculate the torque limits based on the gearbox size:
   - Parameter 642[Gearbox Rating]
   - Parameter 643 [Gearbox Sheave]
   - Parameter 644 [Gearbox Ratio]
   - Parameter 645 [Motor Sheave]
4. Uncouple the motor and the load.
5. Run Autotune by setting parameter 61 [Autotune] to 2, "Rotate Tune."
6. Raise parameter 83 [Overspeed Limit] to 20 Hz.
7. Set bit 6, Decel Inhibit, of parameter 238 [Fault Config 1]to disabled (0).
8. Adjust parameter 153 [Regen Power Lim] to limit the amount the system regenerates to the DC bus.

TIP If a DB resistor is not used, we recommend an initial setting of -5%.

Initializing the Pump Stroke Position

Follow these steps to initialize the pump stroke position.

Pump Stroke Position Initialization Steps

Step	Parameter		Description
1	680	[Pump Cycle Store]	Set with the drive operating at normal speed. The drive then calculates the peaks and valleys of the torque signal. This is used to determine the downstroke the next time the drive is started.
2	681	[Set Top of Strok]	Enable. Press Enter when the rod is at the top of the stroke. The parameter value changes back to "Disabled" and the top of stroke position is stored in testpoint 688. Top of stroke occurs when the horse head is at its highest point.
3	689	[Pump Off Setup]	Bit 1, Pos Filter – Sets the level of filtering on torque for position calculation. • 0 = light (default) • 1 = heavy (the effect on the filter can be seen at testpoint 680). Bit 2, Pos Offset – Adjusts correction factor for motor slip in position calculator. • 0 = 400 (default) • 1 = 50 (to see the effect of this check the timing between the position and torque, testpoint 635 and 636)

Pump Stroke Position Initialization Steps (cont.)

Step	Parameter		Description
4	682	[Pump Off Control]	• Disabled - pump off control is not active. • Baseline Set - Uses a torque baseline created when the drive is first run (first ten cycles). **IMPORTANT**: It is critical that this data is gathered from a full well. • Fixed Setpt - Uses the value in parameter 685 [Torque Setpoint].
5	683	[Pump Off Config]	• Automatic - The downstroke torque is used if the position is found. If the position is not found after 6 cycles, the cycle torque is used. • Position - The downstroke torque is used to determine the "pump off" condition. • Cycle - The cycle torque is used to determine the "pump off" condition. The gear ratio and output speed are used to determine the cycle. If the average torque is unstable, compare testpoint 717 to the torque waveform. Testpoint 717 is the calculated position used to determine a full stroke. If the position moves compared to the torque, the gear ratio can be adjusted to account for the motor slip.
6	684	[Pump Off Action]	• Change Spd - The speed is lowered when a "pump off" condition occurs; the drive does not stop. See [Pump Off Speed]. • Always Stop - This stops the drive during a "pump off" condition. • Stop After 1 - The drive first slows down according to the setting in parameter 687. If torque continues to drop, the drive stops. • Stop After 2 - The drive slows down according to the setting in parameter 687 twice before stopping.
7	685	[Torque Setpoint]	This sets the level for a "pump off" condition when [Pump Off Control] is set to Fixed Setpt.
8	686	[Pump Off Level]	Sets the percentage drop in torque that indicates the well is in a "pump off" condition. The pump off level based on the baseline torque can be seen at testpoint 645.
9	687	[Pump Off Speed]	Sets the speed reduction (in percent) from the commanded speed that occurs during a "pump off" condition when parameter 684 is set to Change Spd, Stop After 1 or Stop After 2.
10	688	[Pump Off Time]	Sets the time delay before speed recovers from a "pump off" condition, unless torque continues to drop.
11	178	[Sleep Wake Mode]	Direct - Uses the time in parameter 688 as the time to remain in "pump off" condition. A digital input also needs to be set for Stop.

Custom Firmware Parameters

Advanced Parameter View must be selected (parameter 196 [Param Access Lvl] set to 1, "Advanced").

Parameters 692 through 699 provide various metering points for the function. Refer to pages 8 and 9 for descriptions.

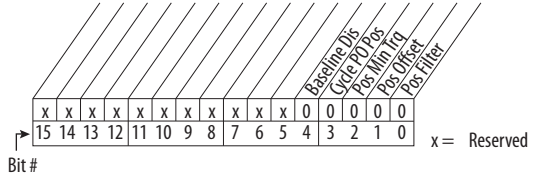
Custom Firmware Parameters

File	Group	No.	Parameter Name and Description See User Manual for symbol descriptions	Values			Related
APPLICATIONS	Oil Well Pump	680	**[Pump Cycle Store]** Used to store the torque waveform over the course of a pump cycle. This is used to determine the downstoke when in "Automatic" or "Position" mode. With the drive running at the desired speed, change [Pump Cycle Store] to "Enabled" and press enter. Over the next few cycles the waveform is stored and [Pump Cycle Store] changes back to "Disabled". If after 5 pump cycles [Pump Cycle Store] has not changed back to "Disabled", waveform variations can be excessive.	Default: Options:	0 0 1	"Disabled" "Disabled" "Enabled"	
		681	**[Set Top of Strok]** Stores the top of pump stroke cycle. With the drive running at the desired speed, change [Set Top of Strok] to "Enabled" and press enter when the rod is at the highest position. [Set Top of Strok] automatically changes back to "Disabled".	Default: Options:	0 0 1	"Disabled" "Disabled" "Enabled"	
		682	**[Pump Off Control]** Used to enable Pump Off control. "Disabled" (0) - Pump Off control is not active. "Baseline Set" (1) - The control uses a torque baseline created after any start of the drive (first ten cycles). **IMPORTANT**: It is critical that this data is gathered from a full well. "Fixed Setpt" (2) - The control uses the value in [Torque Setpoint]. Use the value in [% Drop Torque] as a guideline in "Automatic" or "Position" mode. In "Cycle" mode use [% Cycle Torque] as a guideline.	Default: Options:	0 0 1 2	"Disabled" "Disabled" "Baseline Set" "Fixed Setpt"	

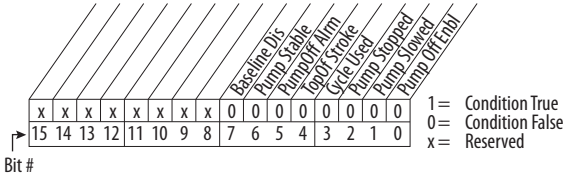
Custom Firmware Parameters (cont.)

File	Group	No.	Parameter Name and Description See User Manual for symbol descriptions	Values	Related
APPLICATIONS	Oil Well Pump	683	**[Pump Off Config]** Sets the torque data to use for Pump Off control. "Automatic" (0) - The downstroke torque is used if the torque waveform synchronizes with previously saved waveform. If the position was not found after 6 cycles, the cycle torque is used. Bit 3 in [Pump Off Status] indicates if cycle torque is used. "Position" (1) - The downstroke torque is used to determine the "pump off" condition. The torque waveform needs to be able to re-synchronize with the previously saved waveform. "Cycle" (2) - The full pump cycle torque is used to determine the "pump off" condition.	Default: 0 "Automatic" Options: 0 "Automatic" 1 "Position" 2 "Cycle"	
		684	**[Pump Off Action]** Selects if the drive changes speed or stops during a "pump off" condition. "Change Speed" (0) - When a "pump off" condition is detected, speed is reduced by a selected percentage and runs for the time in parameter 688. If condition continues, speed is reduced a second time. The pump remains at this speed until the "pump off" condition no longer exists. "Always Stop" (1) - Stops pump when a "pump off" condition is detected. The pump remains stopped for the time entered in Sleep Time parameter 183. "Stop After 1" (2) - When a "pump off" condition is detected, speed is reduced by a selected percentage and runs for the time in parameter 688. The pump stops if torque continues to change at the reduced speed. The pump remain stopped for the time entered in parameter 183. "Stop After 2" (3) - When a "pump off" condition is detected, speed is reduced by a selected percentage and runs for the time in [Pump Off Time], parameter 688. If torque change continues, speed is reduced a second time by the selected percentage. The pump stops if torque change continues at this reduced speed. The pump remains stopped for the time entered in [Sleep Time], parameter 183.	Default: 0 "Change Spd" Options: 0 "Change Spd" 1 "Always Stop" 2 "Stop After 1" 3 "Stop After 2"	
		685	**[Torque Setpoint]** Sets the torque level for Pump Off when Pump Off Control is set to Fixed Setpoint.	Default: 0.0% Min/Max: 0.0/100.0% Units: 0.1%	
		686	**[Pump Off Level]** Sets the percent (%) change in torque from the baseline or setpoint that indicates the well is in a pump off condition. When the pump is started it creates a baseline torque level, assuming the well is full. For example, if the baseline torque is 50% and the [Pump Off Level] is set to 10%, the drive goes into pump off when the torque drops to 45%.	Default: 5.0% Min/Max: 0.0/100.0% Units: 0.1%	

Custom Firmware Parameters (cont.)

File	Group	No.	Parameter Name and Description See User Manual for symbol descriptions	Values	Related
APPLICATIONS	Oil Well Pump	687	**[Pump Off Speed]** Sets the percent drop in speed from the commanded speed during a "pump off" condition.	Default: 20.0% Min/Max: 0.0/100.0% Units: 0.1%	
		688	**[Pump Off Time]** Sets the time the drive continues to run at the reduced "pump off" speed before returning to commanded (full) speed and checking if the "pump off" condition still exists.	Default: 600.0 Secs Min/Max: 120.0/60000.0 Secs Units: 0.1 Secs	
		689	**[Pump Off Setup]** Controls additional Pump Off features.  Option Descriptions Pos Filter — Sets level of filtering on torque for position calculation. 0=Light 1=Heavy. Used to remove extra peaks in the waveform. Pos Offset — Adjusts correction factor for motor slip in position calculator. Set bit if torques and position count are drifting apart. Pos Min Trq — Adjust the minimum torque threshold for the position detector. 0=10% 1=Auto Detect Min Torque. Cycle PO Pos — Use positive level changes for Pump Off in cycle mode. 0= Off 1=On. Baseline Dis — Disables the calculation of a new torque baseline each time the drive is started. The drive uses the torque baseline that was previously calculated and saved.	

Custom Firmware Parameters (cont.)

File	Group	No.	Parameter Name and Description See User Manual for symbol descriptions	Values	Related
APPLICATIONS	Oil Well Pump	690	**[Pump Off Status]** Status of the Pump Off function.  Option Descriptions Pump Off Enbl — Pump off control enabled. Pump Slowed — A "pump off" condition was detected and the drive is running at reduced speed. Pump Stopped — A "pump off" condition was detected and the drive stopped (sleeping). Cycle Used — The cycle torque is used for the pump off detection. TopOf Stroke — The internal position is between 0…500. Top of stroke is 0. PumpOff Alrm — A "pump off" condition was detected, but has not yet triggered event. This is a warning of a pending "pump off" condition. Pump Stable — The pump is running at a stable speed and not calculating the baseline torque. Baseline Dis — Baseline torque calculation is disabled. This bit is set when 689 [Pump Off setup] bit 4 is enabled, or when any of the [Digital InX Sel] parameters are set to selection 61.	Read Only	
		692	**[% Cycle Torque]** Shows the average torque for a full cycle.	Default: Read Only Min/Max: -100.0/200.0% Units: 0.1%	
		693	**[% Lift Torque]** Shows the average rod lift torque.	Default: Read Only Min/Max: -100.0/200.0% Units: 0.1 %	
		694	**[% Drop Torque]** Shows the average rod dropping torque.	Default: Read Only Min/Max: -100.0/200.0% Units: 0.1%	
		695	**[Stroke Pos Count]** Shows the pump cycle position. The top of the stroke is 0 and rolls over at 10,000.	Default: Read Only Min/Max: 0/15000 Units: 0.1	
		696	**[Stroke per Min]** Shows the strokes per minute.	Default: Read Only Min/Max: 0.00/50.00 Units: 0.01	
		697	**[Pump Off Count]** Shows the number of times a "pump off" condition has occurred since this parameter was reset. Count is maintained through power cycle.	Default: 0.0 Min/Max: 0.0/60000.0 Units: 0.1	

Custom Firmware Parameters (cont.)

File	Group	No.	Parameter Name and Description See User Manual for symbol descriptions	Values	Related
APPLICATIONS	Oil Well Pump	698	**[PumpOff SleepCnt]** Shows the number of times a sleep condition has occurred since this parameter was reset. Count is maintained through power cycle.	Default: 0.0 Min/Max: 0.0/60000.0 Units: 0.1	
		699	**[Day Stroke Count]** Shows stroke count for the past 24 hours. This is a rolling counter updated every hour. Uses the powered-up clock for timing. Once the initial 24-hour period has elapsed it is stored in a 14-day buffer. This is an array from 0…13 at testpoint 732; with 732, 0 being the current day; 732, 1 the previous day; and so on. As each day is stored, the Pump Off Count for that 24-hour period is stored in testpoint 731. The array is indexed with value in testpoint 730. With this set up you can access parameters 234 and 235 to view the data, and then set parameters 236 and 237 to testpoint 730 to change the day. The elapsed time for the current day is shown in testpoint 728. The strokes per hour for the past 24 hours are shown at testpoint 733. This array goes from 0…23.	Default: Read Only Min/Max: 0.0/65535.00 Units: 0.1	

New Selection for Existing Parameters

For parameter 361...366 [Digital InX Sel], added a new selection: 61, "Baseline Dis".

Test Points

The following test points are provided for pump diagnostics. Refer to the PowerFlex 700 AC Drives – Frames 0...10 User Manual, Vector Control Firmware 4.001 and Up, publication 20B-UM002, for instructions to access the test points.

Test Points

Test Point	Description
635	Calculated pump position
636	Filtered torque
637	Filtered strokes per minute
638	Pump Off Level %
639	Average drop torque
640	Count of torque above/below pump off setpoint
641	Torque level alarm
642	Torque alarm state
643	Torque alarm timer

Test Points (cont.)

Test Point	Description
644	Baseline torque, calculated on first run or when commanded speed is changed
645	Pump off trip level, x100
646	Pump off detector current value, x100
647	Speed used during pump off
648	Baseline torque after 1st spd change
649	Pump off trip level 1st change
650	Commanded speed
651	Pump jack state: 0 = Initialize baseline torque levels 1 = Running 2 = Delay before returning to run after pump off 3 = Pump off 1 baseline 4 = Pump off 1 run/wait 5 = Pump off 2 baseline 6 = Pump off 2 run/wait 7 = Pump off sleeping/stopped
652	Counter for torque averaging
655	Storage for average torque value
656	Parameter 682 – Pump Off Control
657	Pump off control state
659	Down average calc
660	Up average calc
661	Output frequency
662	Maximum speed detected during cycle
665	Position with top of stroke offset
666	Peak 1 torque
667	Peak 1 position
668	Peak 2 torque
669	Peak 2 position
670	Valley 1 torque
671	Valley 1 rising position
672	Valley 1 min position
673	Valley 2 torque
674	Valley 2 rising position
675	Valley 2 min position

Test Points (cont.)

Test Point	Description
676	Counter for position reconnect
677	Pump status: bit 13 = Pump off disable input active bit 12 = 0 = Position, 1 = Cycle torque used bit 11 = 1 = Top of stroke bit 10 = Position initialization active bit 9 = Sleep mode enabled bit 8 = Sleep is active, drive is stopped bit 7 = Position initialization storing values bit 6 = Detected upstroke bit 5 = Detected downstroke bit 4 = Pump off control active and external disable input off bit 3 = Not used bit 2 = Drive is at commanded speed bit 1 = Upstroke bit 0 = Downstroke
678	State of position detector (1…6) and reconnect (7…14)
679	Torque used to slope detection
680	Heavily filtered torque used for position detection
682	Filter level for above, can be changed
683	Stored values of position 1 for reconnect
684	Stored values of position 2 for reconnect
685	Stored values of position 3 for reconnect
686	Stored values of position 4 for reconnect
687	Stored values of position 5 for reconnect
688	Top of stroke position
689	TRUE if pump off stop enable and PO occurred
690	Used to detect stop while sleeping
691	Parameter 684 – Pump Off Action
692	2ms counter used in Pump Off timing
693	Pump Off time in drive units
694	TRUE if initializing position
695	Amount of dither for position correction
699	Bus Limit Ki
700	Bus Limit Kp
704	Bus Limit Enable
705	Bus Limit reference
706	Time in msec for a stroke based on gear ratio

Test Points (cont.)

Test Point	Description
707	Simulator torque no filtering
708	Position 1 detected during reconnect
709	Position 2 detected during reconnect
710	Position 3 detected during reconnect
711	Position 4 detected during reconnect
712	Position 5 detected during reconnect
713	Full stroke average torque
714	Pump off trip level 1, x100
715	Pump off trip level 2
716	Pump off trip level 3
717	Position used when in full stroke average mode
720	Holds speed reference during startup
721	This shows the sleep time used for pump off, it is parameter 183
722	Counts number of times position reconnect restarted
723	Counts number of sleep states, same as parameter 690
728	Elapsed time in current day 0.0001 hours
729	The start time for a 24-hour cycle, used to determine day
730	Pointer to arrays of data
731	(0…13) • Number of pump off counts in the past 24 hours that the drive was powered. This changes during the current day. • Number of pump off counts in the previous 13 days. The count is pushed down at the end of each day. Number 1 is the previous day, and 13 is 13 days ago.
732	(0…13) Stroke count for the current 24-hour period. Full stroke count for previous days.
733	(0…23) Stroke count per hour, updated once per hour. “0” is the most current.
734	(0…23) Downstroke or cycle torque, updated once per hour. “0” is the most current.

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