APPLICATION NOTE	AN-MEGA-0015v104EN
Solar Pump using Inverse Operation PID	

Inverter type	FRENIC MEGA
Software version	ROM 1000 or later
Required options	Not required
Related documentation	FRENIC MEGA User's manual
Author	David Bedford
Use	Public, Web
Date	11/01/2012
Version	1.0.4
Languages	English

1. Introduction.

The Solar Pump application consists in pumping water by means of an electrical pump controlled with FRENIC MEGA which is supplied by Solar Panels (DC voltage supply). The output frequency of the FRENIC MEGA must be dependant on the amount of power that can be obtained from the solar panels.

The idea is to run the pump at the maximum possible frequency depending on the solar irradiation. This means that when the solar irradiation is maximum the speed of the motor (output frequency) must be the highest, but when the solar irradiation decreases the speed of the pump should be decreased accordingly.

Additionally to the function explained before, it is important to consider that it is not possible to know the amount of irradiation before running the motor. Due to this effect some problems must be solved.

1) The amount of voltage is not always proportional to the irradiation. When you have maximum irradiation you can get the maximum voltage at the output of the solar panel, but when you get power (current) from the solar panel the voltage drops. Therefore, the maximum speed of the pump is achieved when the solar panel can supply the power without decreasing the inverter DC bus voltage under the Low voltage level (Undervoltage). If the inverter DC bus voltage is under the Undervoltage level then it will stop and will not restart until the DC bus voltage increases again.

2) The only way to get the maximum amount of power is to use an adaptive system that controls the level of voltage at the output of the solar panel. The system must adapt the speed (increase) until the voltage of the DC bus drops to slightly above the Undervoltage level and is stabilized at this working point.

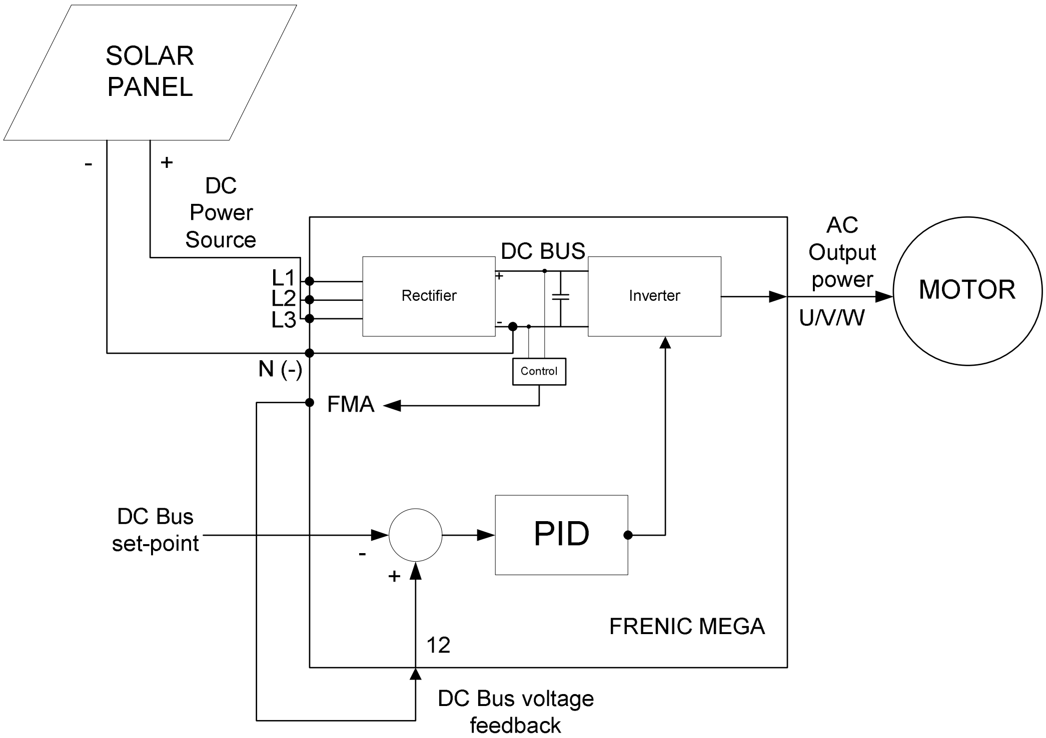

Figure 1. Conceptual diagram.

2. Application implementation.

The idea of this application is to use the PID as an adaptive system for controlling the pump speed depending on the inverter DC bus voltage.
The set value of the PID (in this application the set point is given by the keypad) is a voltage slightly higher than the Undervoltage level of the inverter (the PID set point must be around 200 VDC in 200 VAC series inverter and it must be around 400 VDC in 400 VAC series). The feedback is the real DC bus voltage.

To obtain the feedback signal, analog output (FM1) is used, set as proportional to the DC bus voltage (F31=9) and connected to the PID feedback by means of analog input (12). Therefore this analog input must be configured as the feedback of the PID (E61=5). To adapt the units of the PID, the suggested values for function E40 are 500.0 VDC for 200 VAC series and 1000.0 VDC for 400 VAC series.

The PID structure is set as inverse operation (J01=2) because the frequency must increase as long as the PID feedback is greater than the PID set point. This is because -as long as the real DC bus voltage is higher than the set point- the output frequency can increase to pump more quantity of water.

3. Connection set up diagram.

The connection diagram in figure 2 shows the connection set up.

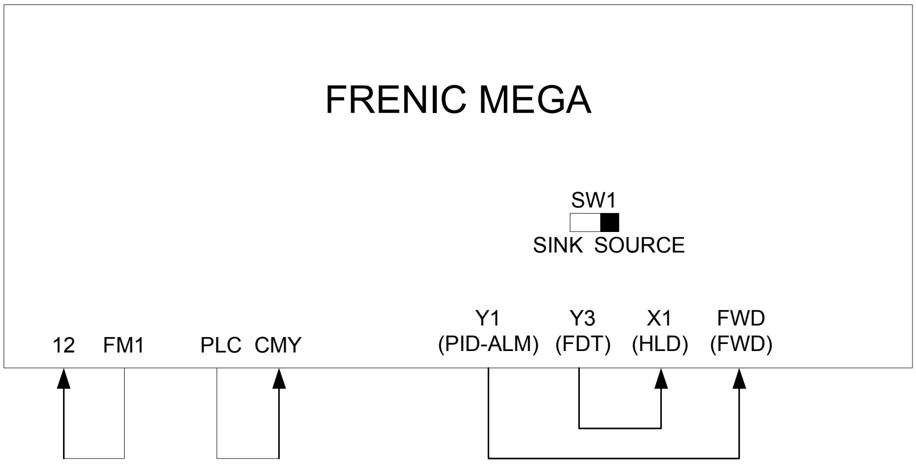

Figure 2. Connection set up diagram.

In this example:

1) Analog input 12 signal is used as the PID feedback, which indicates the DC bus voltage level. In order to get a signal proportional to the DC bus voltage is necessary to use FM1 output (F31=9).

2) The inverter receives the RUN (forward) command by means of an output of the FRENIC MEGA given by itself. The RUN command is given when the feedback reaches a certain value. Below a certain level of DC bus voltage is not worth to RUN the inverter, because this means that there is not enough irradiation (power) to start the pump. To solve this matter PID-ALM (E20=42) is used; when the target level of feedback is reached (J12) this function becomes ON and starts the inverter.

3) The inverter HOLDS the RUN state by means of FDT function. Once the inverter is in RUN state, the frequency increases at the output. Therefore in order to hold the RUN state FDT function is used. The frequency level to HOLD the RUN state is set up by means of parameters E31 and E32. The aim of using FDT function is only to hold RUN state of the inverter when it is possible to achieve a minimum frequency without dropping fast the voltage of the Solar Panel. In case of Voltage of Solar Panel drops fast once the inverter has started and FDT level of frequency is not reached is not worth enough to try to hold the RUN state.

4. Starting the RUN state of the pump.

The RUN command is given by means of an output of the FRENIC MEGA itself. The inverter starts running when the value of the PID feedback (proportional to DC bus and proportional to the voltage of the solar panels) reaches the level of PID-ALM (adjustable by means of parameter J12).

Once the inverter is in RUN state and the speed (and consequently the current of the motor) increases, the amount of voltage decreases and the signal of RUN (PID-ALM) information disappears. Therefore a HOLD signal must be used in order to keep the RUN state although the signal PID-ALM has been turned OFF.

It is possible to use the FDT function for creating the HOLD of the RUN state. The idea is to set FDT to a level of frequency by means of functions E31 (level) and E32 (hysteresis) so that when this frequency is reached is high enough to hold the RUN state.

5. Stopping the pump.

The pump must stop for different reasons and these cases must be analyzed separately.

Due to the working point of the pump

When the working point of the pump (output frequency of the inverter) is below the working point recommended by the pump builder ("useful" or minimum speed for creating differential of pressure at the output of the pump) the inverter must STOP. Normally in water pumps the speed of the pump must be higher than a certain level. If the speed of the pump is lower than this level, the pump only moves the water inside it without pumping it to the output, without creating an increase of pressure between the pump inlet and outlet.

Three parameters are involved in this matter:

1) The minimum frequency of the pump must be set using parameter J15 (stop for slow frequency).
2) Time J16 for stopping that the output frequency keeps lower than J15. The inverter must stop when the output frequency of the inverter is lower that J15 during the time set in J16 (latency time).
3) Start frequency J17 after stopping for slow flow rate. If the PID output frequency (set point frequency) is higher than J17 the inverter will start again.

When the irradiation decrease fast.

When the irradiation decreases fast the output of the inverter should decrease fast in order to prevent that the inverter stops. For this reason the deceleration time of the inverter should be fast (F08=0.5 s) compared with the acceleration time (F07=30.0 s). The acceleration time should be slow in order to prevent the inverter DC bus voltage reaching the Undervoltage level due to a fast drop of the solar panels voltage.

NOTE: If response of PID is not fast enough for avoiding Undervoltage level, it is recommended to wait 10 minutes after the DC link bus has been reestablished before restarting inverter operation. Otherwise, expected inverter lifetime could be reduced due to stress on the DC Bus charging circuit.

6. Inverter set up.

The following table describes the function settings that differ from factory defaults.

Function	Value	Description
F02	1	RUN command from input terminals
F03	60.0 Hz	Maximum frequency. Must be set up depending on the motor characteristics.
F07	30.0 s	Acceleration time
F08	0.5 s	Deceleration time
F14	5	Restart at the start frequency without Undervoltage alarm
F15	60.0 s	Frequency limiter high. Must be set up depending on the motor characteristics.
F16	XX.X Hz Initially 0.00	Frequency limiter low. Must be set up depending on the pump characteristics.
F31	9	FM1 output is DC link voltage
E01	6	Digital input X1 as HOLD (3 wire operation)
E20	PID-ALM (42)	Digital output Y1 programmed to PID-ALM
E31	5.0 Hz	Frequency detection LEVEL
E32	3.0 Hz	Frequency detection HYSTERESIS
E40	500.0 (-2) 1000.0 (-4)	PID display coefficient A= 500 or 1000 depending on the series of the inverter -2 or -4 respectively
E61	5	Analog input 12 as PID feedback
H06	1	Cooling fan OFF enabled
H72	0	Disable main power loss detection
J01	2	PID enable, inverse operation
J03	X.XX Initially 0.5	P Gain (PID). Must be set up
J04	X.XX Initially 0.2	I Gain (PID). Must be set up
J11	0	PID Alarm Absolute-value
J12	XX Initially 45 % (-2) 50 % (-4)	Level of PID-Alarm equals of level of DC voltage for starting to pump. Must be set up
J57	XX% Initially 50 % (-2) 45 % (-4)	PID set point 250 VDC in case of 200 VAC series, J57=50. Must be set up. PID set point 450 VDC in case of 400 VAC series, J57=45. Must be set up.
J15	XX Hz	Stop frequency for slow flow rate. Must be set up depending on the pump characteristics.
J16	XX s	Latency time of the stop frequency for slow flow rate. Must be set up depending on the pump characteristics.
J17	XX Hz	Starting frequency after stopping for slow flow rate. Must be set up depending on the pump characteristics.

It is important to note that the motor related functions must also be set accordingly to the application.

The PID gains could be different than suggested (perhaps it is needed to make the PID faster, increasing J04, decreasing J05 and even using derivative term J06 with a low value).

Acceleration and deceleration times could be different as well (normally the deceleration time will be reduced in order to react faster in front of changes of solar irradiation for avoiding Undervoltage level).

The PID set point could be different in order to avoid Undervoltage level. The PID set point must be a value that, with maximum irradiation, generates a PID output corresponding to the fastest possible frequency that avoids hitting the Undervoltage level.

7. Conclusion.

This application note shows that PID in inverse operation combined with other several functions of FRENIC MEGA can be used for solar pumping.

8. Document history.

Version	Changes applied	Date	Written	Checked	Approved
1.0.0	First	04/08/2011	D.Bedford		
1.0.1	Logo changed	11/08/2011	D.Bedford		
1.0.2	Small changes and text modifications	16/08/2011	S.Ureña	D.Bedford	D.Bedford
1.0.3	Corrections in chapter 6. Reference to Low voltage alarm removed. Reset circuit removed.	11/01/2012	D.Bedford	S.Ureña	D.Bedford
1.0.4	Corrected input connection Figure1 Note about waiting time added	21/03/2014	JM Ibáñez	J. Català	J. Català