Bristol® ControlWave® EFM

Power System Sizing

In order to minimize the costs of power system components—the battery and solar panel—Emerson Process Management has designed a number of power saving measures into Bristol® ControlWave® EFM.

Not only have we used the latest in low power electronics technology, we have also designed-in sleep modes and other methods, which allow the application programmer as well as the user to minimize current draw.

Users will appreciate that they need not skimp on functionality to conserve power. For example, ControlWave EFM will supervise a four-run M&R station or a well site with a current draw that is no more than 15 mA at 12 Vdc—and that includes power to three, external transmitters, Emerson 3808 MVT's, using RS 485.

Realistically, however, most ControlWave EFM applications will also operate process I/O devices as well as an internal radio for wide area SCADA network communication. Thus, current draw could range anywhere between 7.2 mA and approximately 137 mA.

To cover this full range of configurations, including live radio communication and I/O loop power, Emerson has done all the engineering work and has simplified the power system sizing process. For practically all applications, ControlWave EFM integrates a 12 Vdc solar power system that provides reliable operation. This system includes a 33 Amp-hour (AH) battery and 30 watt solar panel.

This power system provides plenty of autonomous time and practically zero drop-out probability so users can be fully confident in it reliable operation.

Users of Emerson's Bristol TeleFlow flow computers should take special note that many of the power saving operations featured in ControlWave EFM differ from those in TeleFlow. For example, there is

no "wake-up" mode, in which the CPU runs at maximum power. Therefore, there are no circumstances, such as leaving the PC cable connected, which keep the CPU in a full-power mode and, thus, drain the battery much faster than the design allows.

ControlWave EFM users will also appreciate that using AGA8 Detail does not have the major effect it has on less capable processors. Our power system loading no longer even considers the compressibility method because the difference is no more than 0.2 mA!

Overview Of Power System Loading

To determine the sizing information regarding the battery and solar panel, you must first calculate the current draw.

Once you know the current draw, you can quickly determine the autonomous time for the battery and the charging current required from the solar panel—and, therefore, the size of the solar panel in terms of watts.

The autonomous time tells you how long the battery will run the equipment if there is no charging source. This figure is very important to the power system design because it accounts for two risks:

Weather—the dreaded succession of cloudy days during which the solar panel does not charge the battery. In some areas, the concern is also that the solar panel is covered by snow. This means that the battery must have enough energy to run the equipment without the support of a charging source.

Solar panel failures—If the solar panel is damaged or otherwise fails, the autonomous time tells you how long you have to get out to the site and replace it!

It is up to the user to determine the required autonomous time. Our experience tells us that, due primarily to weather, an autonomous time of 10 days is reasonable.

Battery Sizing

Since we designed-in one battery selection, 33 AH, the autonomous time calculation will simply indicate whether this internal battery is sufficient. Otherwise, an external source is necessary.

In summary, the procedure that follows encompasses three steps:

1. Determine the current draw in mA.
2. Determine the autonomous time provided by the 33 AH battery (and whether or not that is acceptable).
3. Determine the minimum required charging current, which, in turn, tells us the minimum required solar panel rating in terms of watts.

Step 1: Determining Current Draw

In this step, you simply need to add up the current draw for all the hardware components in the ControlWave EFM. Please bear with the lengthy section, here, because it covers everything. The process, itself, consists only of simple addition.

Important: It is always best to err on the conservative side when it comes to power estimates. Fractions should be rounded up and estimates of duty cycling should favor longer “on” times.

Factors that affect current draw are as follows:

- CPU and application program loading
- Serial Port Drivers
- 3808 MVT Transmitters
- Modems and Radios
- I/O and Loop Power

CPU and Application Program Loading

While the ControlWave Micro Ethernet CPU runs on 100 mA at 12 Vdc, the ControlWave EFM 33MHz CPU typically operates well below 10 mA!

Most important is that the 33 MHz CPU is in a sleep mode when idle. Executing the standard application program typically takes 16 ms per second, which allows most of the electronics to sleep for the other 984 ms per second.

To size the load of the CPU (including the System Controller, chassis and LCD), please use the following current draw information at 12 Vdc:

- Base current draw using the 33 MHz CPU, including the integral MVT and display/keypad with the standard application program operating a single run: 7.2 mA
- Base current draw using the 150 MHz, Ethernet CPU and including the integral MVT and display/keypad with the standard application program operating a single run is 102 mA

- Additional load per run (to account for the additional CPU execution time): 0.4 mA
- Estimate for additional user application code for anything that is beyond the standard application program, per I/O card: 1.0 mA
- Example: Standard application load with three runs enabled: 7.2 + 0.4 * 2 additional runs = 8.0 mA

Serial Port Drivers

ControlWave EFM conserves power by turning RS 232 and RS 485 drivers off when not in use. Users should estimate how busy the ports are and add the following figures (at 12 Vdc):

- Not busy: 0.0 mA
- RS 485 very busy: 1.0 mA per port
- RS 232 very busy: 2.0 mA per port

Roughly, “not busy” normally describes COM1, the local PC port, which, most of the time, is not in use. “Very busy” describes COM3 if it is communicating via Modbus with an ultrasonic meter and uploading a list once per second.

COM2, the network port, is normally one extreme or the other. If polling is done hourly, it is not busy. If polling is done once every few seconds and long lists are uploaded each poll, that is very busy.

Power For Bristol 3808 MVT Transmitters

Emerson’s Bristol 3808 MVT transmitters are extremely power-efficient and allow expansion to four meter runs or monitoring of well site processes with very little current draw. Each transmitter uses less than 2 mA. To calculate current draw for systems in which the ControlWave EFM provides power to the transmitters, please use the following:

- 2.0 mA per transmitter
- 0.4 mA, one time, for the RS 485 port (please use this figure instead of the 1 mA figure listed under “Serial Port Drivers”)
- Example: two 3808 MVT transmitters: 2.0 mA * 2 transmitters + 0.4 = 4.4 mA

Modems and Radios

Relative to all other components in ControlWave EFM, modems and radios are very large current consumers. Therefore, managing their operations can make a major difference in the size and cost of the power system components.

Managing operations means taking advantage of the software provisions in ControlWave EFM that allow the modem or radio to be kept either powered-down or in its sleep mode the maximum amount of time.

Power to the OEM modem and radios, which are installed on the Comm Expansion Module, can be software-controlled. The standard application program uses this software control, for which user configuration is available via the web-style PC menu pages. This type of control is almost identical to that used by the *TeleFlow.*

Unlike *TeleFlow*, however, ControlWave EFM does not use an AUX power control for the standard model radios but rather uses serial port control via the DTR signal. This control allows the standard radio to enter its sleep mode rather than fully powering-down.

Duty cycle assignments are very flexible. The user can specify and schedule on time/off time as well as a cycle period.

While the range of duty cycling times is very broad, real-world operations almost always fall into one of the following three, general categories, slow duty cycle, fast (or quarter) duty cycle and constant on.

Slow Duty Cycle – For networks, which call for communication only once during a long period such as an hour or a day, the radio can operate in sleep mode (or powered-down for OEM radios) most of the time and “wake up” for a very brief time, e.g. 10 – 20 seconds, so it can receive and respond to a poll.

By operating the radio receiver and transmitter for the minimum time, the overall power consumption is not significantly higher than it is in sleep mode, e.g. 8 mA.

“Slow duty cycle” operation maximizes autonomous time and allows flow computers to operate with the smallest batteries and solar panels. The only disadvantage is that operators do not have access to live information at any time but, rather, have to wait until the next scheduled poll.

The ControlWave EFM power system is actually over-sized for slow duty cycle operation and much capacity is available for additional communication ports and I/O loop power.

Constant-on Operation – This is the other extreme with severe consequences to the power system. A single-run base unit with a licensed UHF radio constantly on represents the extreme case for the 33 AH battery. In most cases using the radio constantly on, an external power source is recommended.

“Constant-on” operation means that the radio power is always on and, most of the time, is consuming the specified “receive mode” current, e.g. 125 mA. That’s almost ten times higher than the base flow computer with slow duty cycle!

The advantage of this mode of operation is that the communication network allows access to alarms and other live site information at any time.

Fast Duty Cycle otherwise known as “Quarter Duty Cycle” – This mode of operation is an excellent compromise between the two methods mentioned, previously.

It allows access via the network at any time but also significantly conserves power. *Note that the ControlWave EFM power systems have been sized with quarter duty cycle operation in mind.*

Licensed UHF radios can be operated on a quarter duty cycle over a period as short as 2 seconds (over which the radio is on for ½ second). SCADA host PC’s using Emerson’s Bristol OpenBSI Harvester can be configured to poll flow computers that are operating in fast duty cycle mode. The PC will send a series of poll messages that ensure the flow computer receives one when it is “awake.”

Spread spectrum radios must be turned on for a longer time to allow synchronizing on the network. This time varies by model. Please consult the specifications for the particular radio you are using. For spread spectrum networks, a 15-second on-time on a one-minute period is a feasible, quarter duty cycle strategy.

MDS Transnet 900 Sleep Mode

A new feature of the MDS Transnet 900, spread spectrum radio is a sleep mode, which effectively provides operation that is similar to Fast Duty Cycle. In this mode, the radio powers off for approximately 80% of the hops. The user enables sleep mode during configuration of the radio.

Average current draw in this mode is 15 mA. This current draw assumes operation approximating twice per hour. The benefit is, like Fast Duty Cycle, the flow computer can be accessed at any time over the network. The delay time in responding to a poll will be no more than three seconds.

Radio Operation Examples

Current Draw (at 13.8 Vdc) for a one-watt, spread spectrum radio is exemplified by the MDS TransNet 900 and MDS TransNet OEM Radio, both of which have the same specifications:

- Receive: 115 mA
- Transmit: 510 mA
- Sleep: 8 mA

The MDS models 4710 and 9710 are examples of licensed, UHF radios with 5-watt ratings (current draw figures are at 13.8 Vdc):

- Receive: 125 mA
- Transmit: 2000 mA
- Sleep: 15 mA

Slow Duty Cycle Licensed Radio

To estimate power for slow duty cycle operation of a licensed radio over an hour, a conservative estimate would include a receive on-time of 30 seconds and a transmit on-time of 2 seconds. The 2-second figure for transmit on-time is appropriate from our experience with EFM systems (please contact our technical support people if your system transmits long lists every few seconds because the transmitter will be on a significantly longer time).

Factored over the hour, power is calculated as follows:

- Factor the 15 mA sleep current over the entire hour = 15 mA
- Factor the receive current as 125 mA * 30 seconds / 3600 seconds = about 1 mA
- Factor the transmit current as 2000 mA * 2 seconds / 3600 seconds = about 1 mA
- Add the three together: 15 + 1 + 1 = 17 mA

Since the cycle repeats every hour, the 17 mA figure is the average, or effective, current draw of the radio, just as though the radio were constantly consuming 17 mA.

Note that running the radio receiver and transmitter for short durations so infrequently makes their contributions almost insignificant (about 1 mA in each case)!

Fast Duty Cycle Licensed Radio

To estimate the power for quarter duty cycle, you need to estimate how often the radio will transmit. Since a remote radio will normally transmit only when it responds to a poll, you can use the network polling interval to estimate how often the radio transmits.

Assuming that the radio transmits every five minutes (ie. 300 seconds), calculations are as follows:

- Sleep current factor: 15 mA * 3 / 4 = about 11 mA (ie. the radio is asleep ¾ of the time)
- Receive current factor: 125 mA * 1 / 4 = about 31 mA
- Transmit current factor: 2000 mA * 2 / 300 = about 13 mA
- Total = 54 mA; you might add 1 mA since we rounded-down in all three calculations, above = 55 mA

Fast Duty Cycle Spread Spectrum Radio

For a spread spectrum radio, calculations are similar. For example, operating the TransNet 900 on a quarter duty cycle, with assumptions otherwise similar to those made for the licensed radio, calls for the following calculations:

- Sleep current factor: 8 mA * 3 / 4 = 6 mA
- Receive current factor: 115 mA * 1 / 4 = about 29 mA
- Transmit current factor: 510 mA * 2 / 300 = about 3 mA
- Total = 38 mA

Important Note on OEM Radios

For the OEM version of the spread spectrum radio, please note that power is turned off rather than operating the radio in sleep mode. Total current will, therefore, be lower.

Constant On – Licensed Radio

If the radio is kept on constantly, then a power estimate must factor the receive current plus the transmit current. For example, if the transmitter is operated every five minutes, calculations for a licensed radio are as follows:

- For the receive current factor, simply use the specified 125 mA
- Transmit current factor: 2000 mA * 2 / 300 = about 13 mA
- Total = 138 mA

Constant On Spread Spectrum Radio

Calculations for a spread spectrum radio are as follows:

- Receive current factor: 115 mA
- Transmit current factor: 510 mA * 2 / 300 = about 3 mA
- Total = 118 mA

I/O and Loop Power

In ControlWave Micro, we have designed-in a number of features, which allow users to operate measurement & control loops without the inordinate demand I/O commonly imposes on the power system.

ControlWave Micro I/O cards, as used in ControlWave EFM, feature very low power consumption. Often, much of the circuitry is powered-down while the CPU is idle.

For most analog and digital I/O, low-current or voltage operation modes are also available to conserve power that is used to operate loops.

Users are still cautioned that supplying loop power could overload the power system (that is, from an autonomous time point-of-view)! Use of low-power, voltage transmitters rather than those that operate on 4 – 20 mA loops makes a significant difference.

While our I/O power specifications are rather extensive, users can avoid the tedium of adding many figures together by applying a few good, conservative shortcuts. Mainly, the user should estimate, for each I/O module, the base current draw plus the worst-case loop current draw.

Also, please remember that loop power for analog I/O is stated as though it is supplied from an external source. However, that loop power could very well originate from the ControlWave EFM power source. The user must be particularly careful if 4 – 20 mA loop power is provided by the internal battery but via the 21V dc/dc power supply. That's because input current will be about double the output current (40 mA at 12 Vdc to power 20 mA at 21.4 Vdc).

I/O Examples

On one extreme is operation of a Mixed Digital Input/Output module. Users should assume all I/O is turned on. We suggest the low current mode, for which the specification statement is as follows:

- 4.4mA @ 3.3Vdc: 12 DIs ON @ 66uA, CLK active

Note that DO loop current, which could be as much as 100 mA each, is not included. If you know that current will not be supplied by the battery, you can take the 4.4 mA figure, listed above, and divide it by 3 to account for the load at 12 Vdc vs. 3.3 Vdc (this also accounts for the efficiency factor in the dc/dc conversion). This equates to about 1.5 mA and you can round up to a figure of 2 mA.

Loop Power with 21 Vdc Supply

In another application example, which represents the other extreme, assume the user is operating a Mixed Analog Input/Output module and the battery must also supply current to two, 4 – 20 mA loops.

Let's further assume that the transmitters are not Bristol Babcock's but another manufacturer's and they require a power source that is higher than the nominal 12 Vdc.

In this case, you must account for the load using the 21 V dc/dc power supply as well as the base load for the board. When operating a 4 – 20 mA loop, we normally assume that the maximum current for each loop will actually be 24 mA.

- Base load: 5 mA at 3.3 Vdc = about 2 mA (rounding up) at 12 Vdc
- Loop current load: 2 loops * 24 mA each * factor of 2 for dc/dc conversion = 96 mA

The total, just for the analog I/O, is 98 mA, which is very significant.

Step 2: Calculating the Autonomous Time for the Battery

To determine the autonomous time for the battery in days, follow this simple procedure:

First, convert the battery's Amp-hour (AH) rating to Amp-days by dividing by 24, ie. 33 / 24 = 1.375.

Then, divide that figure by the total current draw, noting that it should be expressed in Amps rather than mA.

Example 1: Single run base unit with quarter duty cycle spread spectrum radio:

- Current draw = 7 mA base + 38 mA radio = 45 mA, or 0.045 Amp.
- Autonomous time = 1.375 / 0.045 = about 31 days

Example 2: Single run base unit with quarter duty cycle licensed radio:

- Current draw = 7 mA base + 55 mA radio = 62 mA, or 0.062 Amp.
- Autonomous time = 1.375 / 0.062 = about 22 days

For single-run applications using quarter duty cycle radio operation, ControlWave EFM clearly provides ample autonomous time.

The next examples address the target applications for ControlWave EFM, those that use I/O and multivariable transmitters via RS 485.

Example 3: Four-run meter station with Discrete I/O for run switching and spread spectrum radio on quarter duty cycle—this configuration uses three, external 3808 MVT transmitters and one Mixed Digital I/O card:

- Current draw = 7 mA base + 38 mA radio + 2 mA * 3 transmitters + 0.4 for RS 485 port driver operation + 0.4 mA * 3 additional runs + 2 mA for the Mixed Digital I/O card = 55 mA.
- Autonomous time = 1.375 / 0.055 = about 25 days

Example 4: Same as above but with a licensed radio on quarter duty cycle:

- Current draw = 72 mA
- Autonomous time = 19 days

You can see that the four-run application does not present much of a significant additional load and autonomous time is still ample.

Since the standard application program supports a Mixed I/O card in slot 4, let's look at two configurations, which use that I/O.

Example 5: Four-run meter station, same as Example 3 except that the Mixed I/O card is used and three transmitters with voltage signals (e.g. Emerson's Bristol model 2808) are interfaced. In this example, the ControlWave EFM supplies the power to the transmitters:

- For current draw, use 55 mA from Example 3 (noting that 2 mA base current load is the same for both I/O cards) + 9.2 mA full voltage for each transmitter * 3 = 83 mA
- Autonomous time = 16.5 days

Example 6: Same as above but with a licensed radio on quarter duty cycle:

- Current draw = 100 mA
- Autonomous time = 13 ¾ days

Example 7: Adding operation of the analog output and supplying power to a 4 – 20 mA loop but, very importantly, running from the 12 Vdc provided by the battery, adds 24.3 mA to the Example 6:

- Current draw = 125 mA
- Autonomous time = 11 days

You can see that we are approaching the 10-day, minimum recommended autonomous time and surely realize that a total current draw of 137 mA results in just that figure.

A good example addition to the previous configuration is the Comm Expansion Module. Using this option in Slot 3 along with the Mixed I/O card in slot 4 and using COM3 for 3808 MVT transmitters comprises a good configuration of the standard application program.

COM4, which is on the Comm Expansion Module, could be used to interface a chromatograph.

Example 8: Addition of the Comm Expansion Module (2 mA base) plus operation of any or all ports in a very busy mode (2 mA each port) still results in current draw that is, at most, 137 mA and autonomous time is 10 days.

Finally, let's look at two unusual examples of "low power" systems and see how ControlWave EFM accommodates them.

Example 9: Single run base unit with licensed radio operating on constantly:

- Current draw = 7 mA + 138 mA = 145 mA
- Autonomous time = 9.5 days

You can see from the above that the ControlWave EFM power system is feasible if the user accepts a slightly lower-than-recommended 9 ½ day autonomous time. Note that, for a spread spectrum radio operating constantly on, the autonomous time is over 10 days.

Example 10: Single run base unit with spread spectrum radio on quarter duty cycle with the Mixed I/O card and supplying loop power to two 4 – 20 mA loops via the 21 V dc/dc power supply:

- Current draw = 7 mA base + 38 mA radio + 2 mA Mixed I/O + 2 loops * 2 (efficiency factor for 21 Vdc power supply) * 24 mA = 143 mA
- Autonomous time = 9.6 days

Again, the autonomous time is slightly below the 10-day recommendation. However, in this case, the user could choose to operate the radio on a slower duty cycle and conserve power.

Important Note On Battery Rating and Lifetime

While TeleFlow users might remember that we used to de-rate the battery AH rating by a factor of 0.5, experience tells us that we no longer need to do that.

Today's lead acid cell batteries continue to meet their AH ratings, even under temperature conditions. However, operation at temperatures toward the limits of the range will significantly reduce the lifetime of the battery. Please refer to the battery data sheet for specifics.

Therefore, instead of attempting to devise a very conservative autonomous time, we advise users to think, instead, in terms of the battery lifetime. While the battery lifetime expectation is normally five years, it could be reduced to as little as two years if operated at the extremes of the temperature range.

Users who still desire to be conservative in sizing the battery can apply a 20% loading factor by multiplying the total current draw by 1.2 and using the result in the autonomous time calculation (that's the same as dividing the Amp-hour rating by 1.2).

This practice will provide the same result as the solar/battery power system sizing procedures that are commonly used in the industry. Note that our solar panel sizing procedure, in the next step, always applies the 1.2 loading factor.

Step 3: Determining The Solar Panel Size

Solar panels are selected in terms of the current they supply at the charging voltage. Ideally, all that current is stored as energy in the battery and can be directly related to the flow computer load on the battery, e.g. if the solar panel supplies 100 mA and the flow computer uses 100 mA, the battery is not discharged at all. Of course, factors must be applied to account for the less-than-ideal, real world operating conditions.

The major sizing factor is that the panel provides current only when the sun is shining, a fraction of each day. The amount of "sun-hours/day" you can expect depends on the location. "Sun-hours/day" is technically known as "insolation" and is measured in units of kilowatt-hours/m2/day. Since the solar constant at the earth's surface is approximately 1 kilowatt/m2, these units are often referred to as equivalent (peak) sun hours.

To determine the sun-hours/day for a location, users can consult an "insolation" map or consult various web sites, which allow entry of latitude and longitude. Go to www.bristolbabcock.com/products/solar_insulation_maps.htm to view a basic solar map. Simply click on visible blocks to view closer detail.*

The resulting insolation figure is normally for the month in the year with the lowest solar energy received.

At a location rated at 6 sun-hours/day, the solar panel provides its rated current for one quarter (24 hours/6 hours) of the day. Therefore, the solar panel current must be de-rated to one quarter of the specified current.

Then, another factor must be applied to account for the fact that the current provided by the solar panel must charge up the battery as well as operate the flow computer hardware. For the 33 AH battery, a factor of 1.2 times the current draw is a good, minimum overhead figure for charging purposes.

Important Note On Solar Panel De-rating

TeleFlow users should note that we no longer derate solar panel performance by a factor of 0.5. Solar panels actually operate well under less-than ideal conditions such as bright overcast, mixed sun & clouds and with a film of dirt or dust covering the panel.

We still recommend that you select a solar panel that provides, at minimum, the 1.2 factor, mentioned above, to account for charging current. Note also that the 33 AH battery can be charged with a much higher current, so extra current capacity in the hundreds of mA is feasible.

Users concerned about solar panel failures (or theft) should consider using a higher autonomous time requirement for the battery. This would allow more time to react to the failure and replace the solar panel.

Note that panels are specified in watts, which should be comparable to the rated current multiplied by the charging voltage. However, we have seen some variance and recommend you use the current rating rather than the watt specification.

In Summary, Sizing The Solar Panel Consists Of The Following Steps:

1. Start with the current load from the battery autonomous time procedure.
2. Look up the sun-hours/day figure for the location (reference the world map).
3. Multiply the current load by 24, then divide by the sun-hour/day figure.
4. Multiply by a factor of 1.2. The result is a current figure, factored for the amount of sunlight, battery charging and zero drop-out probability.
5. Compare this figure with solar panels you are considering. The panel must simply have a specified charging current that is equal to or greater than the figure you calculated.

Let's Size The Solar Panel For A Few Of The Examples Used, Earlier, To Determine The Autonomous Time For The Battery.

Example 1: This configuration is the same as that used in Example 7 for the battery. If this system is to be installed in Mumbai, India, San Antonio, Texas, or Oklahoma City (which are all rated at 4 sun-hours per day), the solar panel requirement is calculated as follows:

- Current requirement: 127 mA * 24 * 1.2/ 4 sun-hours per day = 914 mA
- Appropriate solar panel: The 30 Watt solar panel provides 1.78 A (or 1780 mA).

In this case, the 30 watt panel provides an extra 866 mA that is well beyond that recommended for charging. Having about an Amp available for that purpose will guarantee a much shorter charging time.

Example 2: Same configuration as above but in a 2 sun-hours per day location such as Edmonton, Alberta, Canada:

- Current requirement: 127 mA * 24 * 1.2/ 2 = 1829 mA

Note that the 30 Watt solar panel is very close to this current requirement and would be feasible in the application.

When Do You Choose The 40 Watt Panel?

You can take the trend from Example 1 and Example 2 further and see that locations receiving less than 2 sun-hours/day will need the 40 watt panel. Users in such "low sun" areas probably do not even consider solar power but should re-consider.

Looking back at Example 2, a good reason to select the 40 watt panel is that the user desires the higher capacity, 2370 mA, in order to charge the battery more quickly.

* The solar maps at the Emerson Process Management site originated from Solarex, which now BP Solar, and were provided to Emerson courtesy of Southwest Photovoltaic (PV) Systems, Tomball, Texas, www.southwestpv.com

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