application
NOTE

Redundant Sump Pump Controller

Introduction

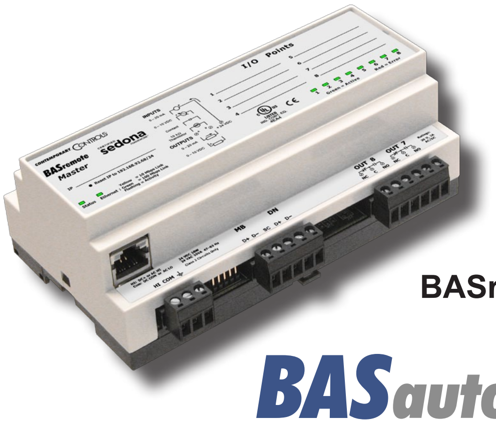
If your home is in a low-lying area prone to flooding and you have experienced a flooded basement more than once, you are acutely aware of redundant sump pump schemes. And if your area has overhead power lines, losing power in a storm is your worst nightmare. Installing a backed-up battery sump pump for emergencies is common, but they lack pumping power, need periodic exercising and lack energy capacity for long outages. Portable gasoline generators have more energy capacity but you must be home during a storm to start the generator. Probably the best solution is a natural gas-fired standby generator with an automatic transfer switch. Finally, add a second pump in your sump in case one fails.

The application note describes a redundant sump pump controller system that incorporates a BASremote BACnet controller executing Sedona Framework logic to run the redundant pumping application. Redundancy is stressed in different points of the design. Alarm and event messages are sent via email alerts. Remote access to the controller is accomplished by opening up ports on the homeowner's residential gateway. The two sump pumps are provided a lead-lag sequence to even out run times and to verify that each pump is operating properly.

Although this is a residential application, it shows the capabilities of the BASremote as a versatile BACnet/IP controller that is freely programmable using Sedona Framework and I/O expandable via a Modbus serial port. Its Ethernet port directly connects to the homeowner's residential gateway for sending out emails and for displaying its web pages.

Sequence of Operation

The Redundant Sump Pump Controller evens out the run time of two sump pumps located in a single well and guards against a single pump loss. Each ½ HP sump pump is self-contained with its own float switch. Each pump can draw up to 10 A and has its own dedicated 15 A branch circuit. Both plug into outlets controlled by the BASremote Sedona controller located in a control panel with interposing relays and control transformers. The two pumps are identical, but only one will cycle on a high level at a time because of the alternating action of two pump enabling relays. If a pump fails to respond to a high water condition, an external high-high level switch forces both enable relays to drop out — enabling both pumps and sending an alarm. Beyond reporting an alarm, the controller maintains cycle counts for each pump and monitors the status of the two AC branch circuits and the exercising of the 8 kVA standby generator. Remote Internet access to the BASremote is accomplished by port forwarding within the homeowner's IP router.



BASremote

Primary and Backup Power Sources

The residence is powered from a conventional 240 VAC 125 A utility service. There is a main distribution panel and a sub-distribution panel. The sub-distribution panel receives power from the utility company via the main distribution panel or from an 8 kVA Generac natural gas-fired standby generator through an automatic transfer switch. In the event of utility power loss, the switch

1. senses the loss,
2. confirms the standby generator has started,
3. confirms the generator is producing stable voltage, and
4. switches the sub-distribution panel to generator power.

The complete transfer time is approximately one minute. Because of limited generator power capability, only a few sub-distribution panel circuits are used for powering essential devices in the house — one of which is the sump pump.

An additional source of power is an automobile battery salvaged from a discarded Ace-in-a-Hole DC backup pump system. The old method used a 12 VDC pump as a backup sump pump but was abandoned because of the limited capability of the pump in a heavy rain when power loss is common, the need to manual exercise the pump to ensure its operation, and the limited power storage from a battery after a long outage. After experiencing a power outage of two straight days, the only feasible method to ensure continuous operation of a sump pump was a standby generator. However, the automobile battery offered one advantage — it could power the sump pump controller so that email alerts could be sent during the one-minute complete loss of mains power. The battery is in the old DC backup pump control enclosure and is recharged by the trickle-charger used with the old DC backup pump system.

Sump Pump Panel

A wall-mounted NEMA 1 sump pump panel was designed to be fed from two 120 VAC 20 A branch circuits using a common neutral. One circuit is from the main distribution panel and the other from the sub-distribution panel. The two legs (L1 and L2) are 180° out of phase so that the voltage across L1 and L2 is a nominal 240 VAC. Inside the panel is a ganged two-pole switch (fused at 15 A) which allows the panel to be completely disconnected from mains-power through a single switch de-activation. If utility power is lost, L1 and L2 will drop out. After standby power is stable, L2 will return. Once utility power is restored, L1 and L2 will return to normal utility power. The L1 circuit is intended for powering Pump 1 and the L2 circuit is intended for powering Pump 2. During a pumping cycle, only one pump runs — the controller alternately cycles each pump by determining which pump will lead the next cycle. The decision to use two power phases was to guard against a circuit breaker trip during normal operation. If either phase is lost, an email alert is sent. Unfortunately, it was not possible to derive both L1 and L2 from the sub-distribution panel due to a lack of a spare branch circuit. The dual loss of primary power and an L2 circuit breaker trip was deemed very unlikely.

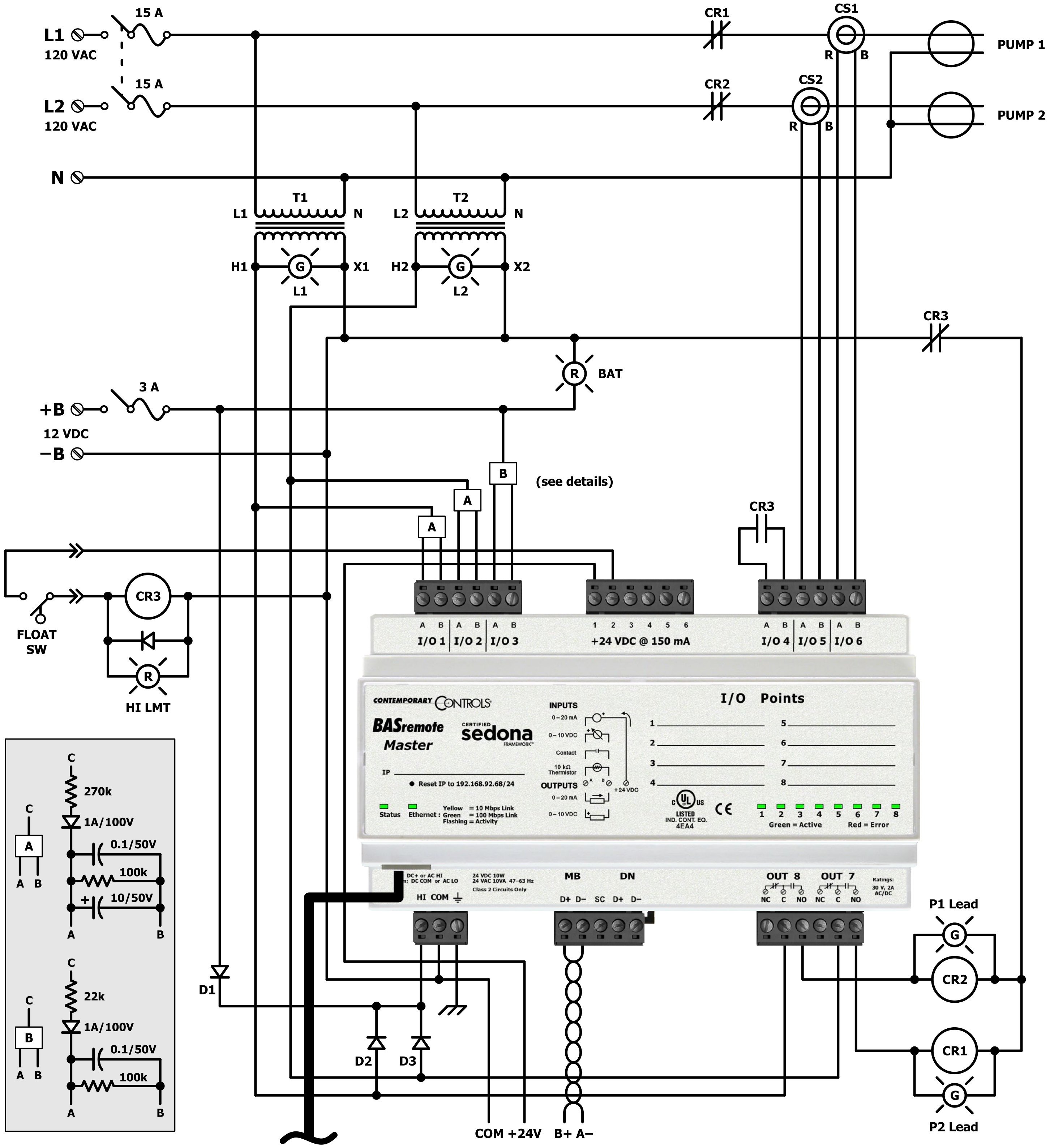
Each of two 24 VAC control transformers in the panel is powered by one circuit. Using diode isolation, the pump controller gets redundant power from three circuits:

1. control transformer from L1
2. control transformer from L2
3. the 12 VDC battery

Lights on the sump panel indicate the source of power. Although the BASremote — functioning as the pump controller — is rated at 24 VAC/VDC, its internal switching power supply will operate from a nominal 12 VDC source such as a battery. The power sources are monitored using three universal input/outputs on the BASremote (I/O1, I/O2 and I/O3) — each configured for 0–10 VDC analog inputs via a filter network. Details of the voltage divider filter networks are shown in Figure 1. For channels 1 and 2 — which are AC inputs — the filter outputs approximately 6 VDC via a half-wave rectified and filtered circuit. Channel 3 receives a 5 VDC signal using a simple voltage divider with a reverse-protection diode. These voltages are adequate for monitoring each source. In the Sedona logic, these three points are scaled to represent the approximate line voltage and DC battery voltage that they monitor. This is handy when determining the proper hysteresis trip points necessary when driving the Sedona logic.

Channels 5 and 6 connect to current transformers CS1 and CS2 that monitor current to the pumps plugged into to a duplex outlet. The two pumps are identical with integral float switches — so there is no way to know if they are active without measuring the current draw of each. These sensors are inexpensive two-wire analog sensors that convert current to voltage, but we are not interested in current draw — we only need to know when a pump is running. Channels 5 and 6 are configured for analog inputs and in the Sedona logic, Hysteresis components are used to convert the analog reading to digital — to indicate that a pump is running.

Redundant Sump Pump Controller



"A" and "B" Details

Ethernet CAT5 Cable

To BTR-MR-DI10

Figure 1 — Wiring Diagram

Because we only monitor that the pump is running, we cannot tell if a pump fails to run. The only way to detect a pump failure — such as a defective float switch — is to use another float switch as a high-level alarm. A single high-level float switch uses +24 VDC power from the BASremote to energize relay CR3. One contact from CR3 is feedback to channel 4 (configured as a binary input) to indicate a high-level condition.

Outputs 7 and 8 are attached to 24 VAC relays. Output 7 indicates that Pump 2 is to be the lead pump. Output 8 does the same for Pump 1. The pump controller will alternate the enabling and disabling of these relays in order to balance running time.

Crucial to the redundant pump application is to check the exercising of the standby generator which runs once a week for about ten minutes to charge its battery. This event is captured with an external BTR Modbus compatible 10-point input module. The BASremote supports Modbus so a device profile was created for this module and installed on the unit. Regardless of the state of the automatic transfer switch, when the standby generator runs an email is sent to the homeowner.

Finally, a CAT5 Ethernet cable attaches to the BASremote from a spare Ethernet port on the gateway that provides Internet access to the home. The sending of emails from the BASremote poses no problems, but to view the BASremote web pages remotely requires ports to be opened on the residential gateway.

Sedona Logic — Main Wire Sheet

On the main wire sheet are components for the six universal I/Os, one Modbus input and two relay outputs. From the BASremote main web page, all universal I/Os are configured as analog inputs except for I/O4 which is configured for a binary input. The two relay outputs are fixed requiring no configuration. Loaded in the BASremote is a Modbus device profile for a BTR MR-DI10 ten-point input module. Using Niagara Workbench, all input and output components must be configured for the channel assignments in Table 1.

L1Live and L2Live are Input components for the two 120 VAC legs of the incoming power through a filter network. Two Multiplier components boost the output of the input components to better reflect the actual line voltage by using the Constant called Lfactor. A Hysteresis component creates two trip points — one for the rising edge of the input voltage (100) and one for the failing edge (80). The line voltage must drop below 80 volts to indicate a phase fault. The fault condition will be maintained until the line voltages return to 100 V or more. The Battery voltage is similarly monitored using the Constant Bfactor.

Two Input components — P2Runs and P1Runs — sense if the pumps are active. Hysteresis components convert these analog signals into digital with two Count components accumulating the number of cycles run by

I/O Channel	Configured As	Channel Name	Sedona Tag
1	0–10 VDC	L1 Voltage	L1Live
2	0–10 VDC	L2 Voltage	L2Live
3	0–10 VDC	Battery Voltage	Battery
4	Binary Input	High level in sump	HiLevel
5	0–10 VDC	Pump 2 running	P2Runs
6	0–10 VDC	Pump 1 running	P1Runs
7	Relay Output	Pump 2 lead	P2Lead
8	Relay Output	Pump1 lead	P1Lead
1001	Binary Input	Standby generator on	StbyGen

Table 1 — I/O points are configured using web pages and Niagara Workbench.

each pump. A high-level float switch is inputted and tagged as HiLevel. The Modbus point StbyGen verifies a generator cycle — during a power outage or during the weekly exercising of the generator recharging its battery.

The remainder of the wire sheet has the two output components P2Lead and P1Lead — plus the two folders LeadLag and Alarms.

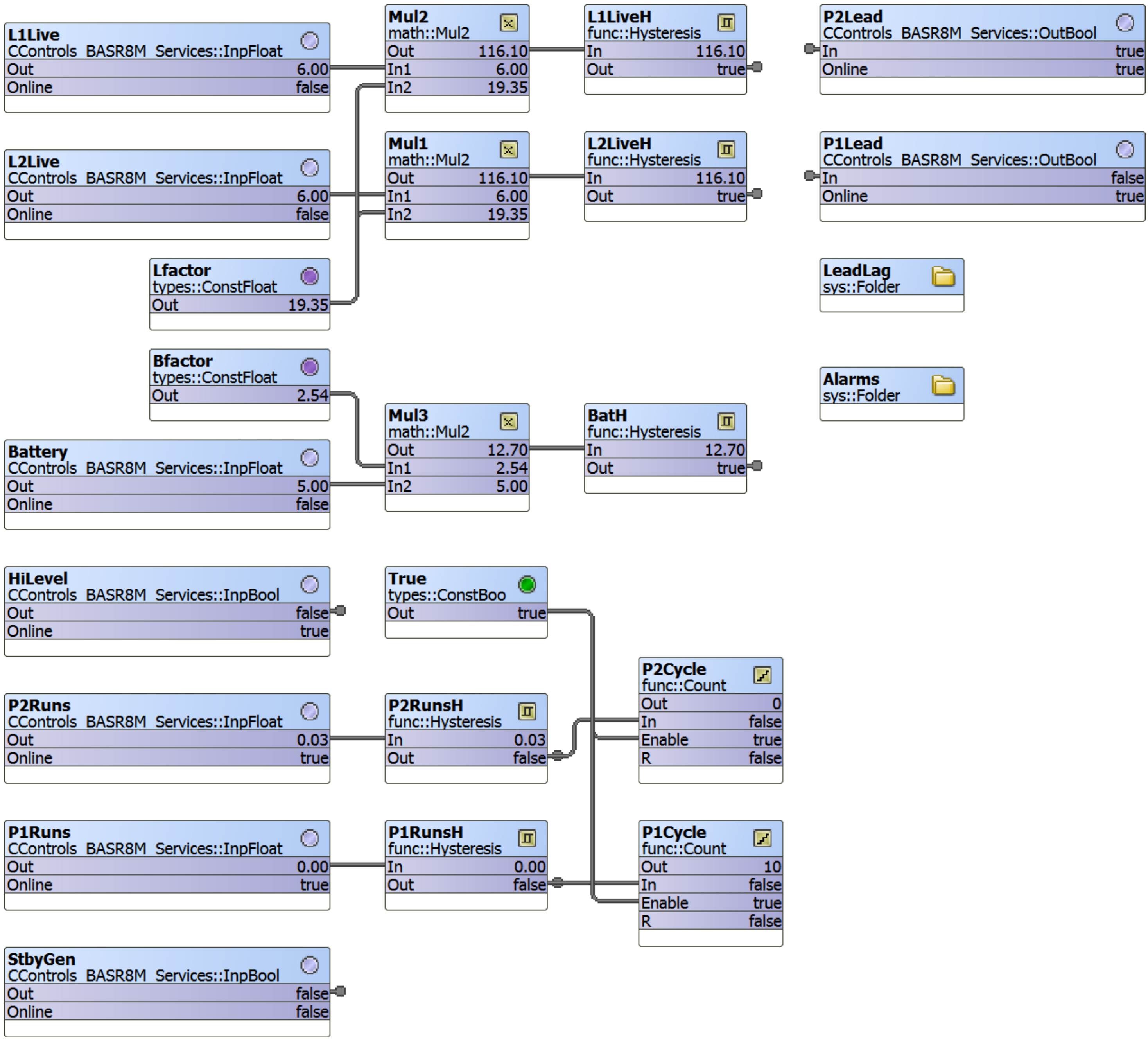


Figure 2 — Input and output components, signal conditioning, and two folders comprise the main wire sheet

LeadLag Folder

Although there are two pumps, only one should run at a time. Instead of designating one pump as the primary and one as the backup, it was decided to alternate which would lead a pumping operation (primary) and which would lag (secondary). Instead of alternating the lead assignment at the end of each pumping operation, the lead assignment remains with each pump for five consecutive cycles. Although the two pumps are identical, it is difficult to have their float switches cut out at low level at the very same time. The lead pump (as designated by the controller) could experience a short cycle if its float switch was still tripped from the previous cycle. By having the cycle counter (CycCtr) set to five, we are guaranteed at least four full cycles — even if a particular pump executes a short cycle when switched to a lead role. The risk of a short cycle turned out to be a minor concern.

Once a pump makes five consecutive cycles, counter ChgPump increments by one — thereby selecting the alternate pump as the lead pump which will cycle five times before the complete sequence repeats.

If power is lost on a particular phase due to an outage or a tripped circuit breaker, its corresponding pump will be locked out from being the lead pump — while enabling the alternate pump. For example, if L1 is lost, P1Lead is disabled and P2Lead is enabled — regardless of the ChgPump state. If a HiLevel is sensed, it could be due to a failed lead pump or the absence of both power phases. In this case, it is best to disable both P1Lead and P2Lead and hope power returns or the lag pump empties the sump.

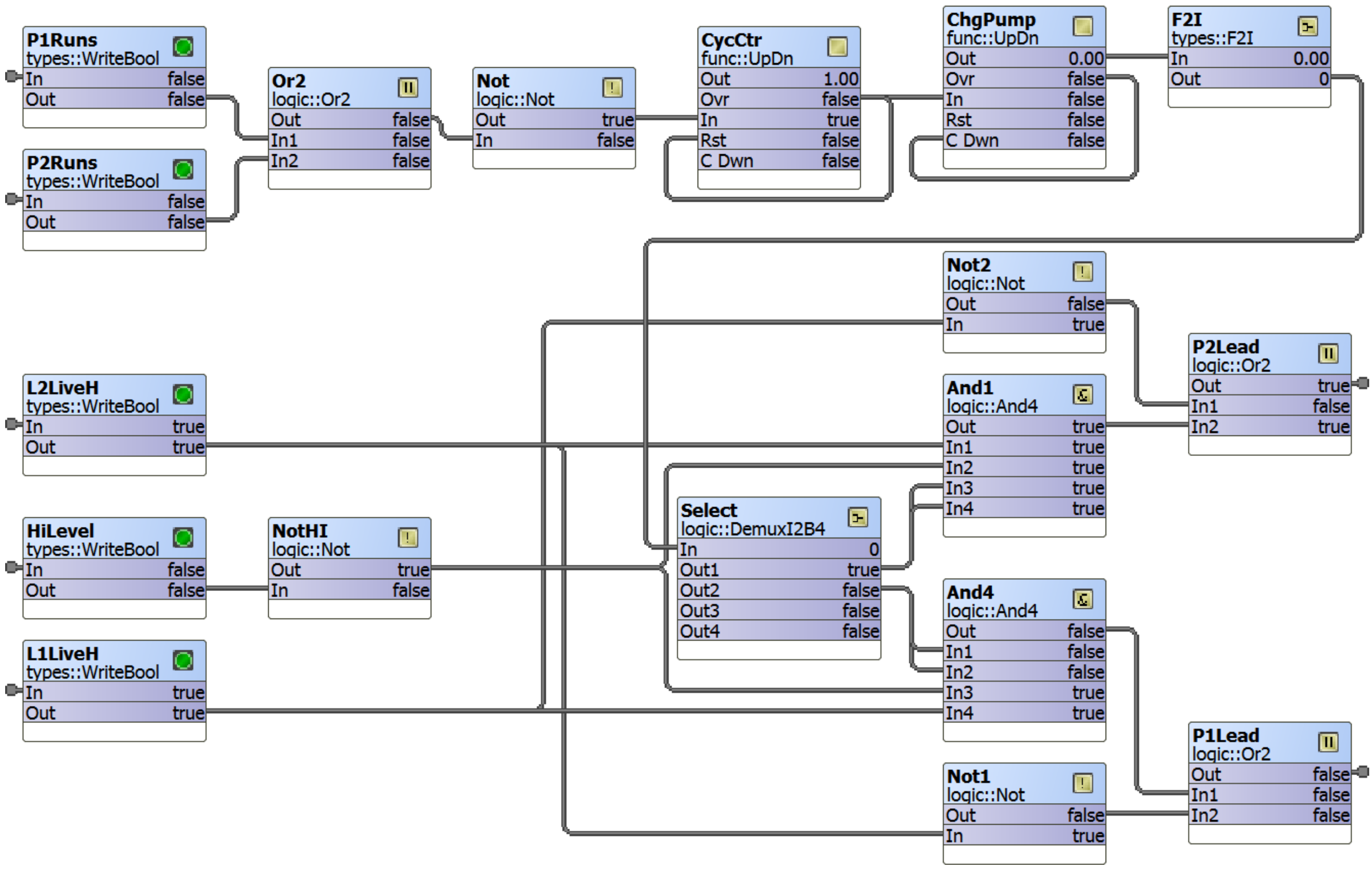


Figure 3 — Lead-lag logic is ignored during fault conditions to ensure that at least one pump will run.

Alarms Folder

The second folder on the main wire sheet is the alarms folder — where ten email alarm and event messages can be sent. Emails are first configured by clicking the Email button on the BASremote main page. Emails must first be configured with a secure email service such as hosted by Google or Yahoo. For Yahoo, in the Server field enter *smtp.mail.yahoo.com*. In the From field, enter your Yahoo email address. For the Port, type 587 and under Security choose SSL/TLS. Next, enter your email service credentials. Click Update to save your settings. Then confirm your email connection by clicking Test. You will be prompted to enter a destination email address to receive your test message. You can send to one or two addresses. Once they are entered, click OK and the test message will be sent.

After communication is verified, email messages are assigned sequentially — beginning with the number 1. Emails are triggered by alarm conditions or event conditions of interest. In this example, we want to know the state of five binary variables — L1Live, L2Live, Battery, HiLevel and SbyGen. Table 2 shows the email assignments to which the Sedona email components are configured. Again, Niagara Workbench is used. Notice there are both alarm/event and restore actions. Alarms and events are cleared automatically when the variable being monitored returns to its normal state. By monitoring both conditions for each variable of interest, we can determine duration of the alarm/event by the time stamp of the email messages.

For binary variables, it is only necessary to put the meaning of the alarm in the subject line of the email. However, the BASremote allows you to append a single analog value to the message. It was then decided to encode the five binary variables of interest using a B2F component so that the state of each of the five variables could be recorded in each message. This could be helpful when analysing a fault situation such as loss of power that will trigger several alarms and events. Table 3 can be used to determine the state of the five variables by looking at the variable sent in the body of the email. Also remember that emails do not need to be sent to the same recipient. Each email message is configured uniquely in terms of content and who is to be contacted.

Email ID	Sedona Tag	Description
1	L1Res	Sump Pump – L1 Power Restored
2	L1Loss	Sump Pump – L1 Power Loss
3	L2Res	Sump Pump – L2 Power Restored
4	L2Loss	Sump Pump – L2 Power Loss
5	BatRes	Sump Pump – Battery Power Restored
6	BatLoss	Sump Pump – Battery Power Loss
7	HiLvRs	Sump Pump – Sump Level Normal
8	HiLv	Sump Pump – Sump Level High
9	GenRan	Sump Pump – Standby Generator Running
10	GenStby	Sump Pump – Standby Generator Idle

Table 2 — A Sedona tag is helpful in determining the purpose of the email.

Var	Standby Gen.	L1 Present	L2 Present	Battery Pres.	High Level
31	Idle	Yes	Yes	Yes	No
30	Running	Yes	Yes	Yes	No
29	Idle	No	Yes	Yes	No
28	Running	No	Yes	Yes	No
27	Idle	Yes	No	Yes	No
26	Running	Yes	No	Yes	No
25	Idle	No	No	Yes	No
24	Running	No	No	Yes	No
23	Idle	Yes	Yes	No	No
22	Running	Yes	Yes	No	No
21	Idle	No	Yes	No	No
20	Running	No	Yes	No	No
19	Idle	Yes	No	No	No
18	Running	Yes	No	No	No
17	Idle	No	No	No	No
16	Running	No	No	No	No
15	Idle	Yes	Yes	Yes	Yes
14	Running	Yes	Yes	Yes	Yes
13	Idle	No	Yes	Yes	Yes
12	Running	No	Yes	Yes	Yes
11	Idle	Yes	No	Yes	Yes
10	Running	Yes	No	Yes	Yes
9	Idle	No	No	Yes	Yes
8	Running	No	No	Yes	Yes
7	Idle	Yes	Yes	No	Yes
6	Running	Yes	Yes	No	Yes
5	Idle	No	Yes	No	Yes
4	Running	No	Yes	No	Yes
3	Idle	Yes	No	No	Yes
2	Running	Yes	No	No	Yes
1	Idle	No	No	No	Yes
0	Running	No	No	No	Yes

Table 3 — By studying the value of the variable in the email, the state of all five variables can be determined.

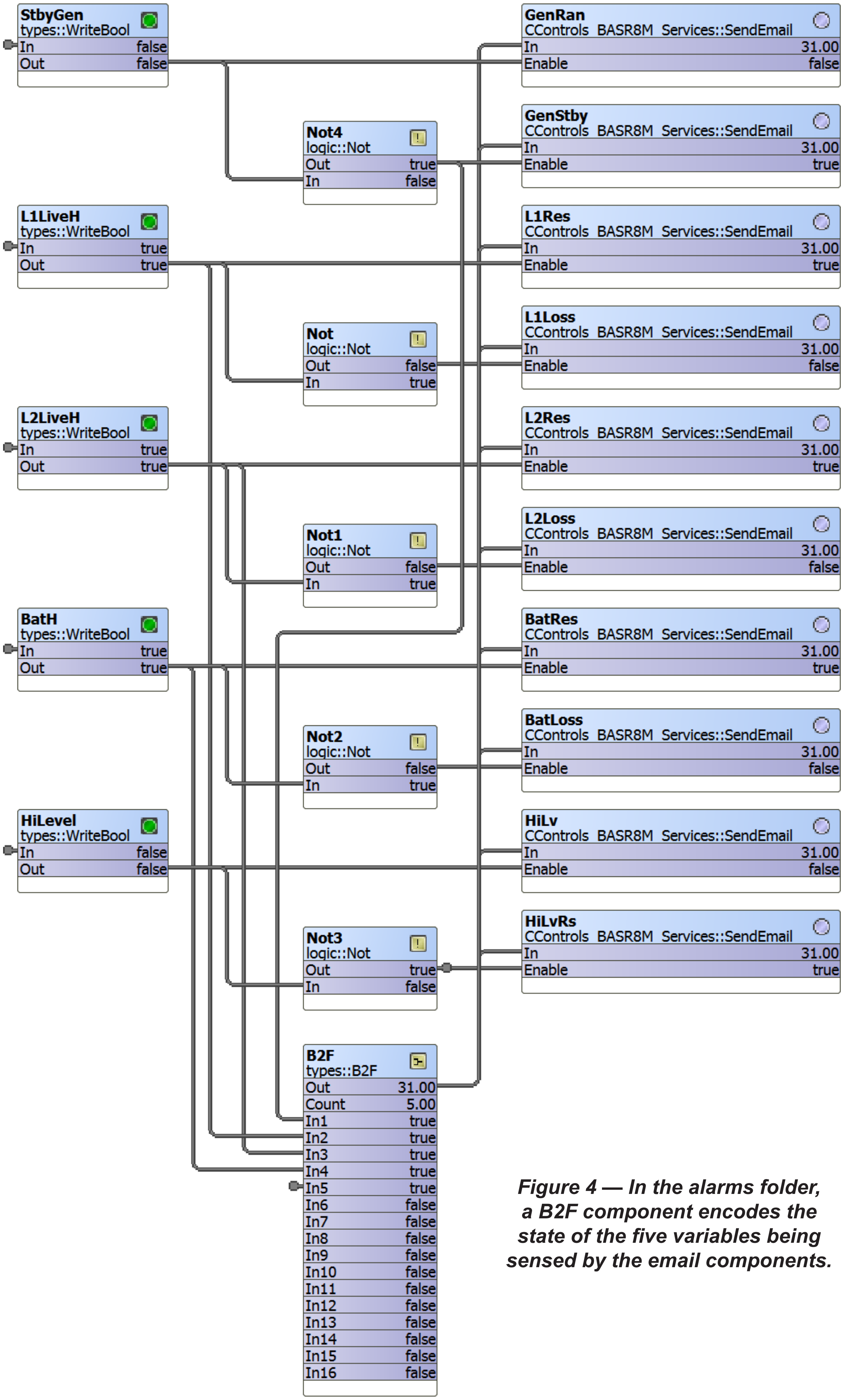


Figure 4 — In the alarms folder, a B2F component encodes the state of the five variables being sensed by the email components.

Figure 5 — A Generac 8 kVA natural gas-fired standby generator is the only source for backup power. Its weekly exercising is monitored by the BASremote.

Figure 6 — An automatic transfer switch feeds the smaller distribution panel when there is a loss of utility power. Only critical circuits are backed up which includes the sump pump.

Figure 7 — Two identical ½ HP pumps — each with its own check valve reside in the sump. These are consumer-grade pumps that can be easily replaced upon a failure. A high-level float switch was added to detect a failure of a pump to run.

Figure 8 — Wall-mounted sump pump panel with battery case nearby. Pumps plug into a duplex receptacle alternately switched by interposing relays. An Ethernet connection is made to the homeowner's residential gateway.

Remote Access

To read the BASremote web pages or the Sedona wire sheets remotely, TCP and UDP ports must be opened on the firewall of the homeowner's residential gateway. This is called port forwarding and three rules had to be entered to pass the following ports:

- Web page access .... port 80
- Java .... port 507
- Sedona .... port 1837

The BASremote was assigned a fixed IP LAN-side address that was appended to these rules. The homeowner did not have a dynamic DNS service, so the public IP address of the residence was used for remote access. Password protection was used to restrict access.

Both the residential gateway and the BASremote have battery-backed power sources so that emails can be sent and remote access is available — even if there is complete loss of mains power. In addition, the trickle charging of the BASremote's battery source and the charging of the residential gateway battery source are on a branch circuit served by the standby generator.

Figure 9 — BASremote mounted in the sump pump panel with interposing relays and redundant control transformers. When power is momentarily lost during the switch between utility power and standby generator, the automotive battery keeps the controller operational to send out email alarms.

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