SUMMARY OF OUR GOOSE MESSAGE VS. HARDWIRE PERFORMANCE TEST

Key Conclusions

> Using GOOSE to replace hardwired connections is a viable option if the proper design and device selection is done.

> Given our performance results using hardwired inputs, we recommend taking additional care in the selection of your GOOSE publishing unit.

> Not all devices are the same! We had a large variance in our test results using both the hardwired and GOOSE solutions. Vendor and vendor device model selection is very important.

> In reviewing the raw data comparisons, some devices consistently performed poorly and some performed very well. The average GOOSE transmission time was 4.3 ms. The average difference between the raw time stamp data for a hardwire and GOOSE was a 6.9 ms lag for the GOOSE targets. The difference in these two numbers is due to the input detection time differences seen by the various devices.

Welcome to the Q1 2015 edition of the NexStation Lab Report.

For the past three quarters, we have been performing in-depth testing to determine end-to-end information transfer times using IEC 61850 GOOSE messages in a multi-vendor system. This quarter, we focused on comparing GOOSE messaging to a baseline hardwired solution. We share our results below.

For the non-technical reader: The left-hand sidebar provides a summary of our results, while the report below describes the technical details, including our goals, the test setup, the execution and the results.

GOOSE Response Test III – GOOSE Message vs. Hardwire Performance

OVERVIEW

This test connects a common event to different devices that are configured to use IEC 61850 GOOSE messaging. Each of the devices is connected to the same GPS clock using an IRIG-B connection to update its internal clock. A single event is generated from both opening and closing a common latching interpose relay providing a 130 VDC wetting source to physical inputs on the devices.

One of the devices—in this case, V1M1—was selected to publish a GOOSE message when it detected a change of state on the physical input connected to the interpose relay. All other devices used in this test subscribe to the GOOSE message published by V1M1.

This setup allows us to look at the time tags generated from the single event by both the hardwire input and the subscribed GOOSE message. All of the devices have an internal target that indicates the change of state from both sources. These internal targets can be used to initiate additional functions within the devices. Our test stopped at this point where the first internal target change of state was captured and time tagged.

The naming convention used for the devices in our test identifies the vendor with a “V” in the name using an indexed number for each vendor. We did have different device models from the same vendor that were identified by using an “M” in the name and an indexed number for each of the separate device models from the same vendor.

GOALS

- Determine the end-to-end IEC 61850 GOOSE message information transfer times when compared to a hardwired solution.
- Identify key items in system documentation, testing tools and procedures that are important in testing GOOSE message performance.

TESTING SETUP

NETWORK

A very simple 100 Mbit Ethernet network was set up for this test using a single NIC connection from each of the devices to the network. All but two of the devices were connected to the same Ethernet switch with the remaining two connected to a separate switch. The two Ethernet switches had a truck connection between them to allow for traffic flow between them. A single VLAN was used for all traffic, and no additional network loading was injected into the system.

TIME SYNCHRONIZATION

A single GPS clock time source was used to output a demodulated IRIG-B signal that was connected to each of the devices used in this test. Each device was configured to use the IRIG-B signal as its primary source for internal time synchronization.

HARDWIRE

A single latching interpose relay supervised a 130 VDC wetting connection to physical inputs on all of the devices used in this test. Each device’s internal target, associated with the input, was used to detect the change of state for the connected physical input. The input target was placed in each device’s internal sequence of events recorder for time tagging.

GOOSE

A single device, V1M1, was chosen to publish a GOOSE message that contains the same event information the device detected from its physical input. The remaining

SOLICITING YOUR INPUT:
We value your feedback and welcome input. Send your testing ideas to: solson@powereng.com

Disclaimer
This report is meant for informational purposes only. POWER Engineers, Inc. cannot be held responsible for readers' interpretation or use of this information. No endorsement of products or vendors is intended or implied. Trademarks and brands noted herein are the property of their respective owners.

To receive a PDF copy of this newsletter quarterly, please send an email to solson@powereng.com or call 406-237-2000 and ask for Scott Olson.

devices used in the test were configured to subscribe to the V1M1 published GOOSE message. Each device's internal target was used to detect change of state for the incoming event from the subscribed GOOSE message. The input target was placed in each device's internal sequence of events recorder for time tagging.

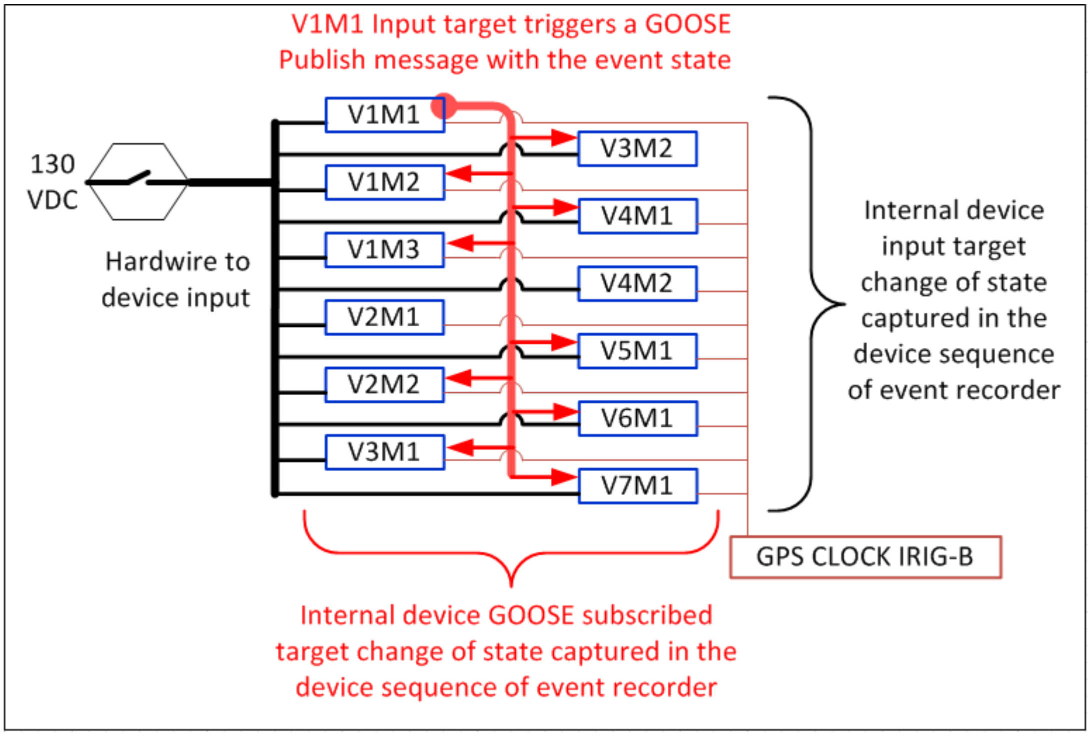

Figure 1: The figure above shows the complete system setup and lists all of the devices used in our testing by their coded names. The figure shows the physical input event trigger to all of the devices along with the IRIG-B connection for time synchronization. The red line indicates a connection to the Ethernet network with the V1M1 device publishing the GOOSE message that contains the input change of state information. This was accomplished by creating a simple logic formula within the device that causes the value of the physical input to equal the GOOSE message dataset target. All other devices in the test setup subscribe to the V1M1 GOOSE message, receiving the same event information as they do from their physical input.

EXECUTION

We first checked the internal device diagnostics to verify that the internal clock on each device was being updated by the IRIG-B connection. We ran a few cycles of the event trigger and verified that both the hardwired and GOOSE target change of state was seen in all the devices' event recorders with a reasonable time tag.

Our final test generated a total of 20 data points for each device by closing and opening the latching interpose relay 10 times. We found that the V1M1 internal target time tag and published GOOSE output target always had the same time stamp. This was expected, given the process time required by the device to perform the logic is much faster than a millisecond. This also gave us a common starting point to compare the response times between a hardwire input and the GOOSE message data exchange. Once the hardwired input target is recognized by the device, it can be used to trigger other functions within the device. This same philosophy applies to the subscribed GOOSE input target after it is received from the V1M1 published GOOSE message.

During each triggered event, the hardwired input target and the subscribed GOOSE message device's incoming GOOSE target time stamps, mirroring the event state, were recorded. This gave us the time stamp of a target from each of the two information transfer methods.

From our preliminary testing, we initially saw some unexpected results. Some of the device time tags came in at tens of milliseconds off the expected margin. Our investigation found that firmware had to be changed for a few of the devices and default configuration parameters required changes.

After a few months of investigation and working with vendors, all of these problems were resolved and our preliminary test results were within a reasonable margin.

TEST RESULTS

Before we analyzed the difference between the two methods of information transfer, we took an individual look at each of the two methods: hardwire and GOOSE. The data was normalized by removing the most significant value, leaving only the data to the right of the decimal point. This was done to make it easier to perform an analysis across all the test runs.

The following outlines how we used the data to answer a few questions:

HARDWIRED INPUTS

How does the hardwired input target time tag data look relative to each other?

Our plan was to check device data from the same vendor and all devices from all vendors.

We performed the following calculations:

- We took the standard deviation for each of the 20 test runs for only devices from the same vendor
- For each of the 20 test runs we calculated the range of the time tag data using:
  [Max value – Min value]
- We calculated averages for the standard deviation and the range of data across all 20 test runs

How did the input target time tags of the devices compare to our base unit, V1M1?

We performed the following calculations:

- For each of the 20 test runs:
  [Device V1M1 input target time tag (ms)] - [Device V#M# input target time tag (ms)]
- For each of the 20 test runs: standard deviation and mean values
- Average standard deviation and average across all 20 test runs

SUBSCRIBED GOOSE MESSAGE INPUT DATA

What was the time delay between when the base unit, V1M1, published the GOOSE message and when the GOOSE subscribers received the information for internal use?

For this test we used V1M1 as the sole GOOSE publisher of the input change of state; therefore, we used its internal GOOSE output target time stamp as the start time for the message. We performed the following calculations:

- For each of the 20 test runs:
  *[Device V1M1 GOOSE input target time tag (ms)] - [Device V*M* GOOSE receive input target time tag (ms)]*
- For each of the 20 test runs: standard deviation and average, excluding the V1M1 data.
- Average standard deviation and average across all 20 test runs.

DIFFERENCE CALCULATIONS

For each of the device test runs, how much did the physical input target time tag differ from the subscribed GOOSE receive target time tag?

We performed the following calculations:

- For each device data entry, over all 20 test runs:
  [Device V#M# hardwired input target time tag (ms)] - [Device V#M# GOOSE receive input target time tag (ms)], excluding the V1M1 data
- For each of the 20 test runs: standard deviation and average, excluding the V1M1 data
- Average standard deviation and average across all 20 test runs

HARDWIRED INPUT RESULTS

When looking at the hardwired input results, we did have a few surprises. We would expect that the hardwired physical inputs to the devices would have time stamps that are close to one millisecond apart. They didn't, and the first clue as to why is found in the device documentation. Our devices scanned their physical input from a half millisecond to plus two milliseconds between the various vendors and models within a single vendor's offering.

This introduced some error in our testing because not all of the devices see the event at the same time. However, this reflects the reality of a hardwired solution. In a multi-vendor or multi-vendor model or both, implementations using a hardwired solution do not guarantee that all devices will be able to react to a change of state at the same time. We also have to consider that the V1M1 device will not publish the state change in the GOOSE message until it recognizes a change for its input.

Selecting different devices to publish the GOOSE message will change the results of the test. We will investigate this in future testing.

How does the input target time tag data look relative to each other? How did the input time tags of the devices compare to our base unit, V1M1, limited to only the vendor models?

Vendor	Average standard deviation between devices	Average range, Max-Min, between devices
V1	1.53 ms	3.00 ms
V2	0.07 ms	0.10 ms
V3	0.74 ms	1.05 ms
V4	0.95 ms	1.35 ms

The above table lists the mean value and max-min range of the time tag data to illustrate the difference in the same event hardwired time tag between device models of the same vendor.

Note that only V1 through V4 had multiple model devices in the test. The data used to calculate the results shown in the above table used all 20 samples from our test data. It is interesting to note the differences between vendors' device models. The data shows that some vendor devices had a very low standard deviation and range while others had very large differences.

The data shown below was taken from all devices over all 20 test runs, not limiting the calculation to like vendors. The standard deviation, max value, min value and calculated range were found for each of the test runs.

We then took the average across all 20 samples for the standard deviation and range shown below:

- 2.47 ms – Average standard deviation
- 8.25 ms – Average range [Max value – Min value]

This data shows us that there is a large standard deviation and max-min range between all the devices in our test in detecting an event using a hardwired solution.

How did the input time tags of the devices compare to our base unit, V1M1, using the entire dataset?

Figure 2 (below) shows how much the individual device's physical input target time stamps differed from V1M1.

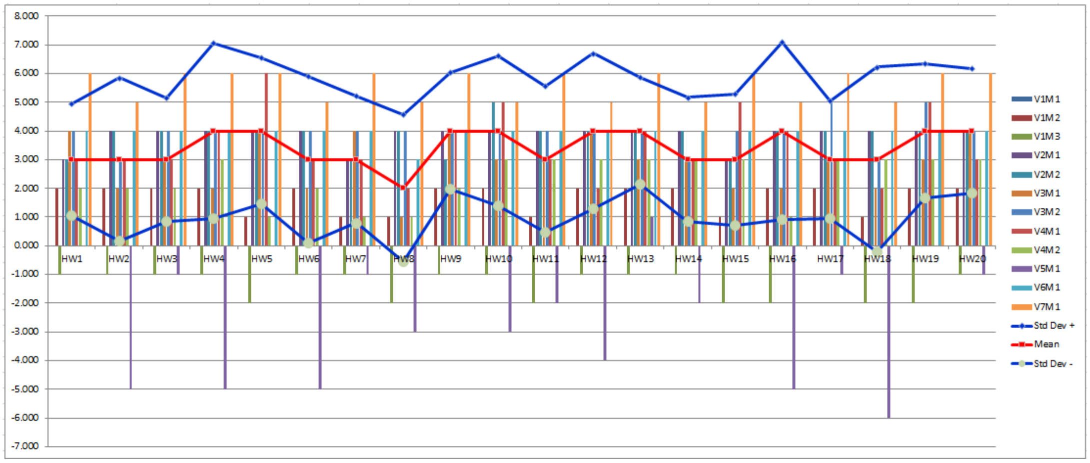

Figure 2: The graph above shows the results for each of the 20 samples, along with the mean and +/- standard deviation for all of the hardwired input time tag differences. Note that some devices lagged the V1M1 time stamp and some led the time stamp, producing an average mean value of 3.4 ms with a standard deviation of 2.46 ms

GOOSE

We used the V1M1 GOOSE output target time stamp, used in the published GOOSE dataset as the base to compare all other device GOOSE subscription target transmit times. The GOOSE target in this dataset has the same value and time stamp as the V1M1 physical input target.

The table at right shows the difference in the subscribed GOOSE input target time stamps and the V1M1 GOOSE output target time stamp between device models of the same vendor. This table lists the mean value of the time tag data using all 20 samples.

Vendor	Mean GOOSE receive target time tag difference between device models and the V1M1 time tag
V1	4.50 ms
V2	1.50 ms
V3	2.50 ms
V4	2.50 ms
V5	5.35 ms
V6	4.70 ms
V7	4.85 ms

Similar to the hardwired data, only V1 through V4 had multiple model devices in the test, we also added the single device vendor data to the table. This shows the same large variation between vendors and between vendors' device models.

Figure 3 (below) shows the individual device test results for each of the 20 samples, along with the mean and standard deviation for that sample set.

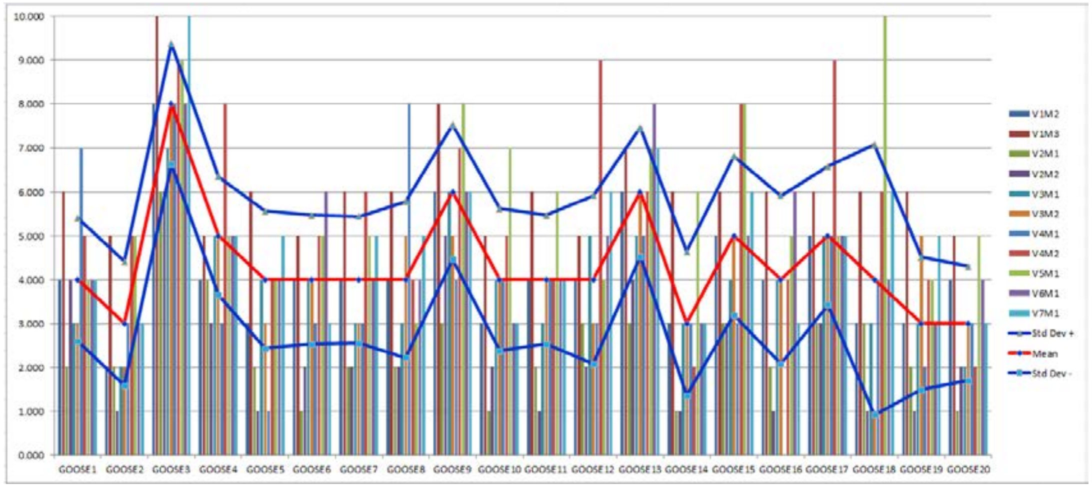

Figure 3: This graph shows the difference in the time stamp for the GOOSE publish target event from V1M1 as compared to the other devices subscribed to the GOOSE event target. The 20 samples produced an overall average of 4.33 ms, a mean of 4.35 ms and an overall standard deviation of 1.63 ms.

HARDWIRED VS. GOOSE INFORMATION EXCHANGE COMPARISON

When we take the hardwired time stamp values minus the GOOSE input time stamp values, we end up with some surprising results.

The following table compares the results above by vendor. The last column, "Mean Hardwired vs. GOOSE Difference (ms)," shows the calculated difference between hardwired and GOOSE. We see that there are no consistent results between hardwire and GOOSE differences.

Some vendor devices showed a positive time tag difference, while others showed a negative difference.

Vendor	Mean hardwired time tag difference between device models (ms)	Mean GOOSE receive target time tag difference between device models (ms)	Mean Hardwired vs. GOOSE Difference (ms)
V1	1.5	4.50	-3.00
V2	3.85	1.50	2.35
V3	3.425	2.50	0.93
V4	2.925	2.50	0.43
V5	2.25	5.35	-3.10
V6	3.95	4.70	-0.75
V7	5.6	4.85	0.75

Figure 4 (next page) shows the raw data time difference between the hardwired target and GOOSE receive target time stamps.

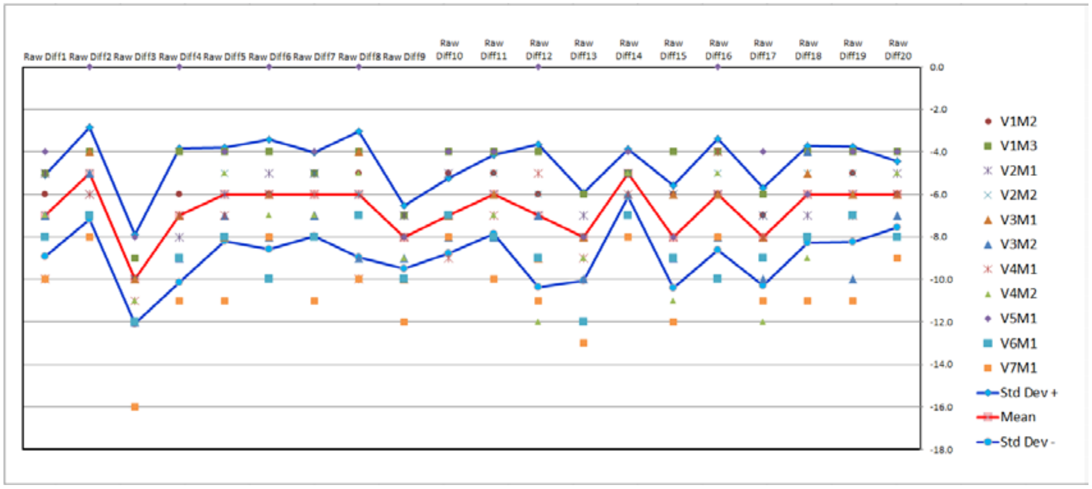

Figure 4: This graph shows the raw data time difference between the hardwired target and GOOSE receive target time stamps. The V1M1 GOOSE target is the publish target that has the same time stamp as the hardwired target. It is not included in this graph.

SUMMARY

When beginning this test, we assumed that the hardwired data transfer would be very consistent between the devices and that a clear time lag would show in the GOOSE data transfer. This was not the case; we found good and bad performance for both the hardwired and the GOOSE information transfer solutions.

As a result, we determined that choosing which device publishes the GOOSE message will greatly affect the outcome of the test results. For this test report, we only used a single device to publish the message. Our next report will not only expand the participating devices and vendors, but also use each one as the GOOSE publishing device.The following points summarize our report:

- Given our performance results using hardwired inputs, we recommend taking additional care in the selection of your GOOSE publishing unit.
- Not all devices are the same! We had a large variance in our test results using both the hardwired and GOOSE solutions. Vendor and vendor device model selection is very important.
- In reviewing the raw data comparisons, some devices consistently performed poorly and some performed very well. The average GOOSE transmission time was 4.3 ms. The average differences between the raw time stamp data for hardwire and GOOSE was a 6.9 ms lag for the GOOSE targets. The difference in these two numbers is due to the input detection time differences seen by the various devices.
- The results indicate that using GOOSE to replace hardwired connections is a viable option if the proper design and device selection is done.

POWER
ENGINEERS