BASIC APPLICATION OF FLOW COMPUTERS AND TELEMETRY SYSTEMS

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Introduction & History

Prior to the evolution of flow computers being commonly used in the measurement of hydrocarbons, most telemetry systems were used to collect control information and real time data and provide control commands to a Remote Terminal Unit at major pump and compressor stations. Most of the local metering was being handled by chart recorders and local data collection by operations. These charts and reports were sent to a central facility where the information was used to provide custody transfer reports and or operations reports. Most of the commonly used chart recorders used the standard circular chart format and were mostly pneumatic devices. The collection of the circular charts and the processing of the information to provide billing information was a cumbersome and costly task. The measurement departments often had to deal with discrepancies in data and information that was often months old. There was a strong need for collecting real time information for metering and custody transfer. Although there were telemetry systems in place, collecting real time information and getting this information to a central office was not easily accomplished with the types of SCADA systems in place. Most of the early RTU/SCADA systems were used for control purposes, such as start/stop, open/close and alarm reporting. Some units did have analog signal capabilities, and could be used to download remote setpoints and collect valve positions etc.

This was all about to change with the advent of the microprocessor. In the early seventies, the advent of microprocessor systems allowed for the development of intelligent controls such as the PLC, DCS and also EFM devices to name a few. By the mid seventies, microprocessor systems were being implemented in RTU designs as well, thus allowing remote controls utilizing advanced communication protocols, such as HDLC, ModBus, TiWay, etc.

Flow Computers have long been used as the 'cash register' for both Hydrocarbon liquid & gas measurement. One of the first microprocessor based flow computers was the 7900 series introduced by Solartron back in 1975 and whilst the functionality of these early flow computers was limited, their primary function has remained the same for the last 30 years or more; to accurately compute the amount of gas or liquid that has flowed through the associated flow meter(s).This 'amount' may be expressed in terms of actual volume but is usually required to be calculated in either standard volume (expressed at a given temperature and pressure such as 14.696 psi_a and 60^oF or 1013.25 $mBar_{abs}$ & 15^oC), mass or energy, while adhering to the required National & International Standards

The essential inputs to the flow computer are typically flow (volume or mass), pressure, temperature and often density or fluid composition. The essential outputs are the afore mentioned flow totals, which traditionally would be printed in a daily report at a local printer attached to the Flow Computer, along with any alarms & events in order to produce an audit trail.

But throughout the last 30 years flow computer manufacturers have invested significant man years of effort into developing new features and functionality. While some of this development has gone into ensuring that the flow computer's algorithms comply with the latest standards from bodies such as American Gas Association (AGA), American Petroleum Institute (API), Gas Processors Association (GPA), International Standards Organization (ISO) and International Organization of Legal Metrology (OIML). The majority of work has typically been employed to make their flow computer products provide greater functionality, which in turn should simplify the metering operation, help reduce costs and make the data more reliable and accurate as well as easier to access. This paper attempts to cover just some of the additional functions that are available from many of today's modern flow computers that just may make your life easier going forward.

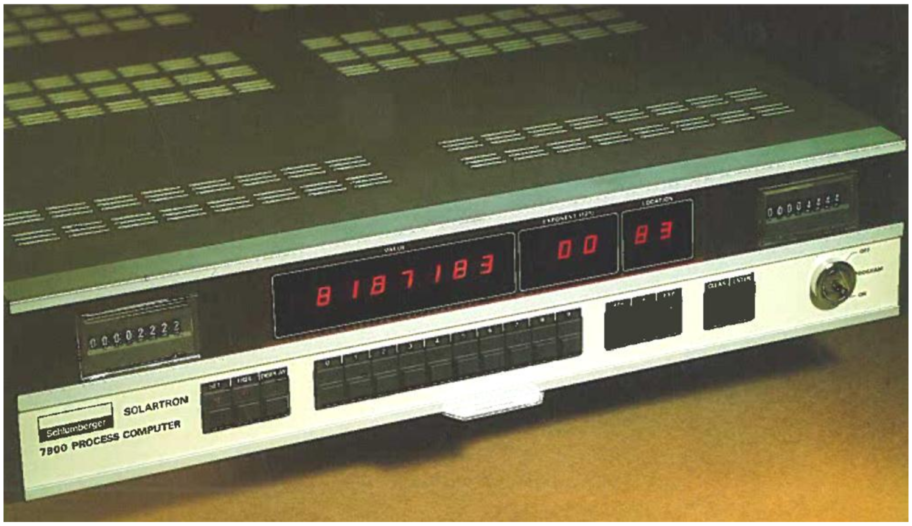


Figure 1. An early flow computer - Solartron 7900, circa 1975

Multi-Function Devices Evolve

As the flow computer industry evolves, so does the PLC marketplace along with process control systems and of course major developments in RTU technology and communications. In the mid-1980's through the 1990's, the universal multi-function controllers begin to appear. Many of the PLC's of the 1980's began to have process control capabilities. These functions, such as PID (regulatory) control and floating point math functions gave the early PLC systems the ability to perform basic flow calculations, along with regulating valve controls. The issue was the programming language, ladder logic, which was not accepted by most measurement engineers.

Many RTU's systems had communication capabilities, and could also perform basic I/O functions such as On/Off control, timers, counters and basic math functions. The development of low power microprocessor RTU systems, which could be powered by solar cell/battery systems, opened up a whole new market for RTU systems in the early 1990's.

Flow Computers could not only perform advanced flow calculations and reports but basic on/off control functionality. The key RTU function was advanced protocols and communication functions.

The addition of IEC-61131 standard programming capabilities for the newer flow computers in the mid 1990's truly was the development of a **Multi-Function control platform.**

Redundancy, Single Steam vs. Multi Stream

One of the most significant recent changes relates to the use of single stream and multi stream flow computers and the way they are employed, which can have a significant impact on the operation and redundancy of the metering system. Below is a brief comparison of single stream & multi stream flow computers and redundancy.

Single stream flow computers

A single stream flow computer, is a flow computer that is connected to just a single meter stream (meter run), so that a metering station with three meter streams would require three single stream flow computers. For liquids applications that require a prover to be present at the station, a 4^{th} flow computer would normally be required.

The diagram in Figure 4 below shows a metering station with 3 gas streams and each stream has its own dedicated single stream flow computer. There is also a dual redundant Ethernet communications link to a metering supervisory computer. The supervisory computer must be capable of implementing the switch over of a failed flow computer to a back up unit. Many single stream computers have the capability to perform basic control functions locally. This is often implemented during proving applications for liquid applications. The key functionality of having dual Ethernet communication ports and a switched Ethernet network offers a level of redundancy or hot back up for critical applications.

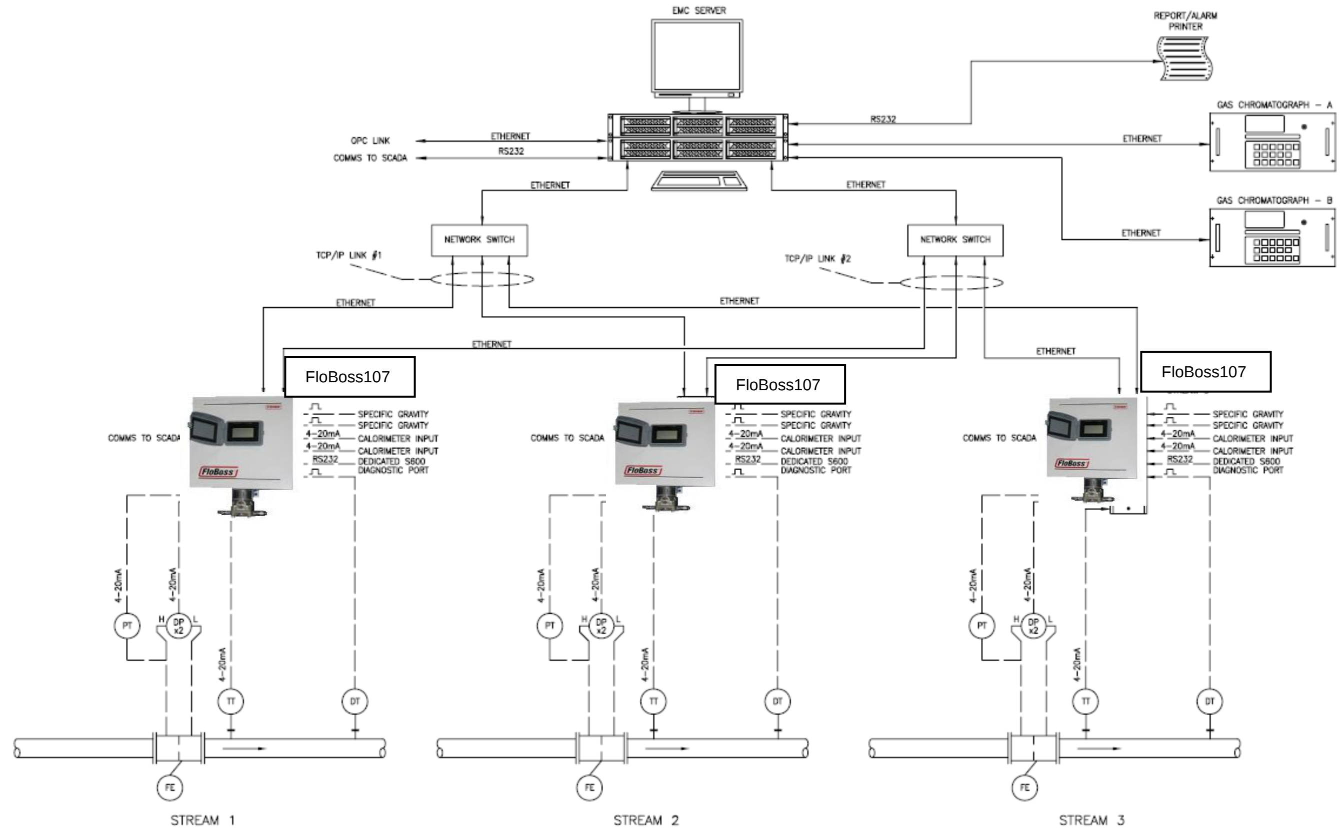


Figure 2. Typical single stream flow computer implementation.

The principal advantage of single stream flow computers is the redundancy that they offer. The above metering station on a transmission pipeline was designed to have 3 streams (meter runs). Normally design would be that each of the meter streams would be able to meter at least one half of the maximum station flow rate. In this way if the metering station was operating at its maximum flow rate, it could be measured with 2 streams running and the 3rd stream could be in standby. So if one of the flow computers or one of the meter runs employed were to have a failure for whatever reason, the 3rd stream could be bought online to replace the stream with the failed instrumentation/flow computer. This would then allow the problem with the failed stream to be investigated and in the case of a failed flow computer, the flow computer could be repaired or replaced with a unit from stores, but only after it had had the correct configuration down loaded.

In some areas, such as Europe, it has been traditional to only allow the use of single stream flow computers. This is particularly common on fiscal or custody transfer applications, where legislation has often prohibited the use of multi stream flow computers due to redundancy concerns.

The use of single stream flow computers has been good engineering practice, especially in critical transmission pipelines and custody transfer applications. The reliability of early microprocessor based flow computers, using through-hole component technology, was not as good as that of today's machines utilizing more reliable surface mount components. Single stream computers provided the required redundancy, with minimal down time in the event of a failure, that critical measurement applications required to ensure that uninterrupted flow metering could continue with little or no missed measurements.

It is worth remembering that when single stream flow computers are used, each flow computer can only see what is happening on its own metering stream. It is unaware of what is happening on the other streams, so the metering supervisory system needs to be responsible for all station functionality. In this situation many of the available features within today's flow computers are left stranded and cannot be utilized to provide operational benefits.

Multi stream flow computers

In other areas, particularly outside of the more conservative European markets, multi stream flow computers have been used for 10 to 15 years, but not necessarily on critical transmission pipelines or fiscal custody transfer duties, due to redundancy implications and the need to ensure uninterrupted flow measurement.

Figure 3. Typical multi-stream flow computer with both gas and liquid measurement capabilities

In the example below in Fig. 4, with a 3 stream metering station, if a multi stream flow computer were used it would receive the outputs from all flow meters, pressure & temperature transmitters from each of the 3 meter streams, as well as any density measurement (and associated pressure and temperature), water cut or gas composition that may be measured at the header/quality loop.

Multi-Stream flow computers typically have additional communication capabilities, as well as more memory and computing power to implement advanced features not available in single run devices. This would allow a multi-functional unit to perform many functions normally performed by a local computer system today such as in Fig. 2 above. The decision has to be made on what functionality is required at the multi-function platform. In those applications requiring lots of communications up to host SCADA systems, or advanced reporting and or historical database functions, with advanced control capabilities, such as a hot back up switching algorithm, perhaps a local computer system is justified. However, for most applications at metering stations, the modern Multi-Function controller functionality may be adequate.

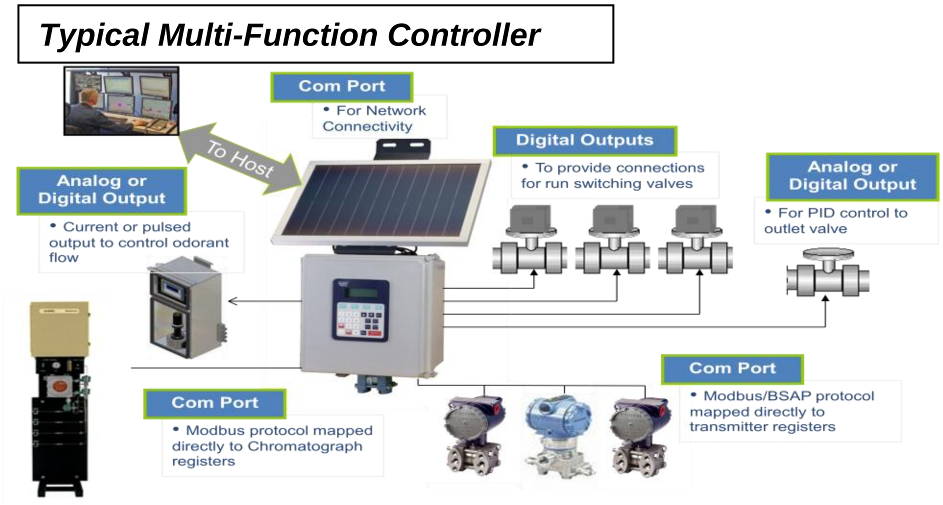


Figure 4. A typical 3 stream flow computer configuration

One of the benefits of the multi stream approach is that one multi stream flow computer can see all of the metering runs and station control functions. Therefore one Multi-Function Controller can calculate the flow rate across the complete metering station as well as control the number of meter streams in use at any one time to ensure optimum use of the streams. The single flow computer can control all of the valves on a single metering station as well as providing flow totals for the run, and a daily report is available to SCADA. Most of this functionality is available as standard from most multi stream flow computers. There are numerous other benefits of using multi stream, multi-functional controllers including;

Features of a modern *EFM with Process Automation Benefits :*

- ✓ *Package design*
- ✓ *Transducer integration*
- ✓ *Communication integration-serial and Ethernet*
- ✓ *Power system sizing-solar/battery*
- ✓ *Application programming-IEC-61131 compliant (process language, FB's,relay logic, etc.)*
- ✓ *HMI configuration – local display*
- ✓ *Hazardous area approvals*

While there are many advantages of using multi stream flow computers, there remains one principal disadvantage, which is that you have 'all your eggs in one basket'; your total metering capability resides in one solitary Multi-Function controller. Should the controller fail you would lose all metering and control capability, which is often an unacceptable risk.

So what do you do when faced with the following choices ????;

1. An optimized redundant solution but with the additional cost and system complexity of using many single stream flow computers.

<u>OR</u>

2. Multi stream ,multi function controllers to optimize you overall system but with the increased risk from a single point of failure.

This can be a difficult decision, if continuous measurement is critical. Many would err on the side of caution and go for single stream flow computers, but there is another way.

<u>Hot Duty-Standby</u>

Hot Duty-Standby is a method used on multi stream metering stations where operators wish to take advantage of using multi functional controllers, while still maintaining the need for full redundancy of the metering station. The Hot Duty-Standby arrangement uses two multi stream flow computers working together to provide redundant metering for typically between 2 to 8 meter streams. The two identical multi functional controllers are mounted in the same panel/cabinet and both machines have the same program and configuration loaded in their memories. Each one receives all the flow, pressure, temperature, density etc. signals from all the flow meters and transmitters on every meter run on the metering skid. Dual Ethernet I/O systems allow for real time switching between I/O systems if needed.

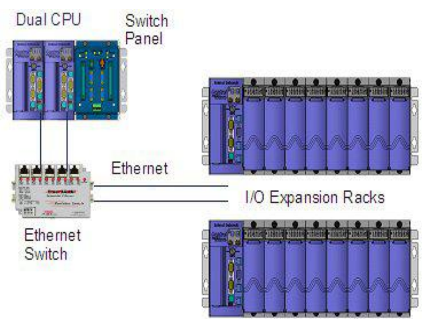


Figure 2. A typical Hot Duty Standby arrangement

<u>Redundant Process Control and Communications</u>

•Dual CPUs Multi-Function Controllers with dual Power Supplies

•Automatic Failure Detection

•Automatic Switchover to Hot Standby Controller

•High Reliability/Availability of system

•No Single Point of Failure

•Communication Channel Switching

•Alarm and Historical Data Backup

•No programming required for redundancy data transfer

•Upgrade programs on the fly

In the event of a failure of the duty controller, alarms are raised, a 'handover' takes place and the standby computer automatically becomes the new duty controller. The accuracy and integrity of the flow data is maintained without 'losing' any flow. Synchronization of data between the two machines is crucial for successful operation. The duty computer must periodically update key operational data, such as new Meter Factors, K-factors, batch stack data, etc. in the Standby computer. This is carried out via a Peer-Peer communications link between the two computers and automatic synchronization of the two machines takes place at start-up and at user defined intervals throughout operation. This system will provide a bumpless transfer of control if any subsystem fails during operation. This is an important feature if a complete station is controlled and all measurements are handled by a single system.

Hot Duty-Standby is not without its challenges, for example when sharing the signals from HART transmitters between the two flow computers, the flow computers need to be able to work together as 'secondary' masters. The requirement to drive flow control valves from the duty machine would normally require some external logic to ensure that the outputs from the standby and the duty do not both end up at the control valve at the same time. However with experience these challenges are easily overcome allowing increased use of hot duty-standby flow computer systems worldwide.

Hot duty-standby capability can make the metering challenge a little easier, as you have good redundancy capacity and are also able to utilize today's multi stream flow computers to optimize your overall metering system. The arrangement is efficient, accurate, and for metering systems with multiple meter runs, highly cost-effective. In practice most operators feel that the sweet spot for costs for a single pair of hot duty-standby flow computers is somewhere between 4 & 8 streams, since more than this number is seen as putting all of your eggs in two baskets, which is too risky for many operating environments.

Data Access & Security

With all of the information from the metering station now in a pair of multi stream flow computers, it is important to be able to access this data reliably and efficiently.

Most flow computers have provided Modbus communications via serial ports for some time. These serial ports have traditionally been used to; obtain data from Gas Chromatographs, print various reports and provide access to a Metering Supervisory SCADA system. But with multi stream flow computers now containing data for perhaps 6 or 8 streams as well as the total station reports, etc., the volume of data held has increased to up to 10 times that previously present in a single stream flow computer.

Over the last 10 years we have seen a significant increase in the use of 'Intelligent' Coriolis & ultrasonic flow meters for metering both oil and gas, because of the operational benefits that they can give over the traditional orifice plate, turbine or positive displacement meters. This has resulted in the demand for more and more communications ports to communicate with these 'intelligent' flow meters. Not only does the communications capability provide more accurate data for metering purposes, but the flow computers can also access the increasing amount of diagnostic data available from these smart devices. Standard practice is to communicate to the flow meters in point to point communication to aid redundancy, rather than using multi-drop mode. The result is that intelligent meters not only add to the quantity and accuracy of data available but also add to the number of communication ports required on each flow computer. When you combine the need to have a peer-peer communications link, between the duty and the standby flow computers, the user needs to have dedicated communication sports for each intelligent flowmeter, it means that providing 3 or even 5 communications ports on each flow computer is often not enough.

To address this issue, manufacturers now provide not only increased number of serial ports, but high speed Ethernet ports as well.

To increase the efficiency of the additional communications traffic, most flow computers now support a configurable Modbus map, rather than a fixed Modbus map. This allows system integrators the flexibility required to control the grouping & positioning of different data types within the Modbus map. This technique allows for the optimization of communications, and reduces the unnecessary traffic in the system.

Security and auditing trails have always been a priority for metering engineers and global events over the last 10 years have understandably lead to increased security concerns, particularly when Ethernet communication is utilized. Many flow computers today make use of the leading-edge security that is currently available with Ethernet systems. This additional security is particularly important for users who want to make use of flow computers with a built in web server to facilitate remote monitoring, communications and remote diagnostics.

What can we expect in the future.

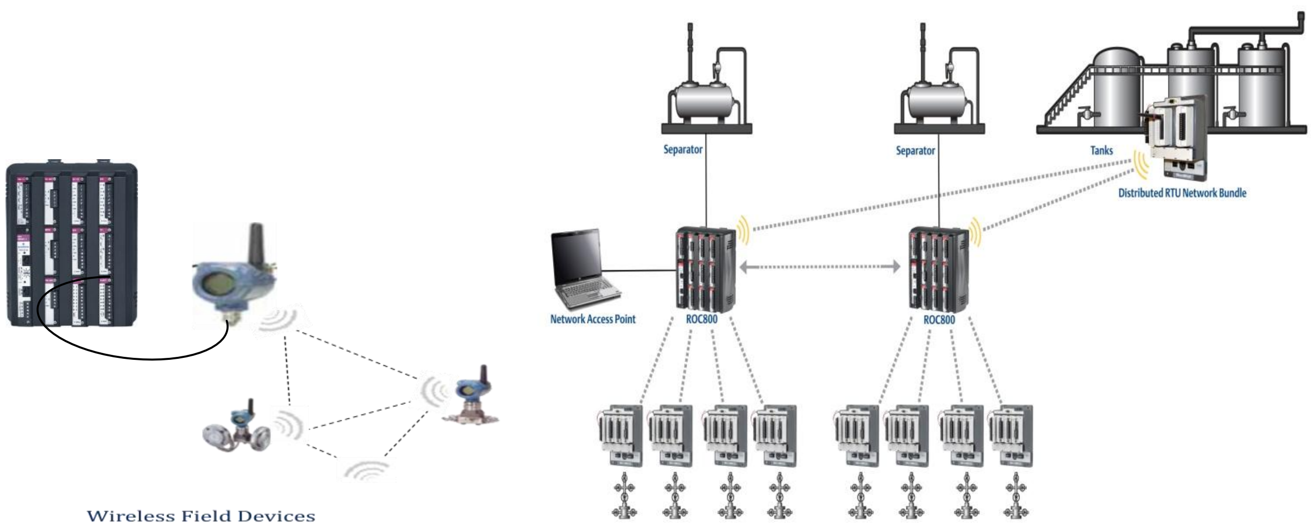
Look for increased communications capability with the advances in Ethernet networks. Not only will you see advanced features in interfacing controls and measurement devices in a tightly integrated network, but look for the implementation of Ethernet features in distributed I/O platforms. Ethernet networks can be used to interface almost any device, since it can be configured to support many standard and proprietary protocols. In fact, with some work, a single Ethernet backbone network can operate with multiple protocols simultaneously using tunneling capabilities of TCP/IP.

With the enhancements in communications bandwidth, speed, and functionality, Multi-Function Controllers (MFC's), can perform diagnostics on I/O devices and intelligent transmitters without any loss in control performance. With standard transmitter accuracy typically around .25% for 4-20ma loops, digital transmitters can offer accuracy at .10% or better. Quite often, the limiting factor is the sensing device itself, as some process transmitters offer 14 and even 16 bit A/D converters. Not only can modern transmitters offer greater accuracy, but they are more stable and repeatable. This all adds up to a more accurate metering system, as pressure, DP, and temperature coupled with MFC's with IEEE 754-2008 double precision (64-bit) floating point math capabilities, offer accuracy not realized in previous multi-function deigns, whether they be EFM, PLC's, or RTU's.

Expect to see local control networks, with built in redundancy, allowing single run computers to communicate directly with smart sensors and other single run devices. With local sensors networked, we can envision stand alone control platforms at each meter run, communicating over a high speed network to other similar devices and with a link to a local station control platform residing in a multi-function controller. This type network could become "self healing" if a failure should happen in a critical piece of equipment.

Don't overlook the advances offered in wireless technologies. Today's mesh networked sensors and transmitters, coupled with actuators and valve operators make the networked controls system a reality.

New advances in wireless communications in single run and multi-run flow computers will allow flow computers and multi function controllers to communicate with each other in the very near future (see diagram below).



Smart Wireless Field Link

Conclusion

The above is a small sample of some of the recent advances in functionality that are now available in today's flow computers and MFC's(multi-functional controllers). However these changes have the potential to change the way metering and control systems are designed and operated, plus increasing the reliability, safety and the security of the system. It is recommend that when looking at new facilities or upgrading existing ones that you do your homework and find out what functionality is available and whether these features can help your operations reduce your costs, reduce your metering uncertainty, minimize your down time and reduce your overall risk.