Field implementation of virtual flow computer systems for fiscal measurement and allocation calculations on the Centrica Energy Upstream offshore production facilities in the Netherlands

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1. Summary

Since 2010 all fiscal and non-fiscal streams flow measurement and allocation calculations on the operated Centrica Energy Upstream (CEU) offshore facilities in the Dutch continental shelf of the North Sea are implemented by the virtual flow computer (VFC) based systems.The VFC systems on the offshore facilities of the CEUs assets operate in a fully redundant hot standby configuration handling 10 complete metering streams on the recently commissioned F3FA asset to a total of 47 streams with more than 400 hundred continuously sampled signals from the field instrumentation and demanding allocation calculations carried out in real time on the J6A Greater Markham Area (GMA) asset.
The transition from a conventional flow computer system to the VFC system was performed on the J6A offshore facility operating as a production hub for both mature and newly developed assets within the CEU operated GMA. The existing duty and standby systems were replaced by the VFC. The substitution of the old system was accomplished in 12 working days on site while keeping the platform production undisturbed during the live changeover activities. The adoption of the VFC technology on J6A installation resulted in the implementation of the same type of a measurement and supervisory system on the new F3FA installation commissioned in 2011.

The VFC system offers a high degree of integration with numerous advantages such as centralized calculations, use of the real time fluid properties and composition determination (from flash calculations), faster cycle times, clear visualization of the calculation procedures (VFC graphic application interface) and upgrade flexibility.
There are a number of field examples where a VFC system has been used to handle utility streams and non-fiscal measurements. This is the first time it has been implemented on the CEU operated installations for the fiscal flow measurements of natural gas and condensate with the sales allocation, including that for third parties streams. The successful implementation and demonstrated adherence to the applicable standards and requirements of the authorities led to adoption of the VFC as a future standard for all existing and future assets in the Netherlands.

2. Introduction to Centrica's practices at the operated assets in the Netherlands

The Markham field, operated by Centrica Production Nederland BV, is located in the Southern North Sea straddling the border between the Dutch and the UK sectors. This area is referred to as the Greater Markham Area (GMA). GMA is operated by Centrica with partners including Dyas, EBN, Total E&P Nederland, Total E&P UK, RWE, Sojitz and Nuon. The J6A offshore platform is the GMA hub for the natural gas and condensate export via the West Gas Transport pipeline (WGT), operated by Wintershall Noordzee B.V, with landfall at Den Helder in the Netherlands The wet natural gas from the GMA is processed on the J6A installation to the export specification, and allocated to individual fields and to each partner. The GMA production structure is displayed on the schematic below.

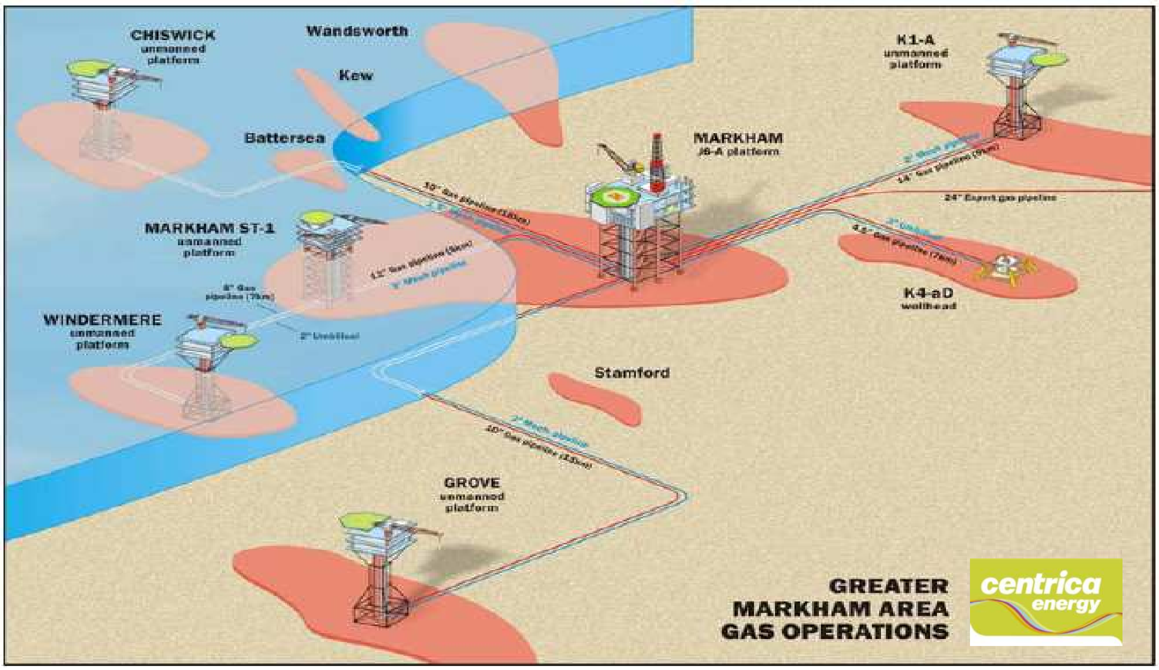

Figure 1 The Greater Markham Area and the J6A – Centrica operated fields

Production from GMA fields flowing via J6A into the WGT pipeline is sold via a number of individual sales agreement contracts. In addition, Markham and all other field import streams arriving to J6A are regarded as direct input streams into the WGT pipeline. This requirement, along with the diversified gas sales schemes, significantly adds up to the complexity of the flow measurement, operations and allocation calculations done on the J6A platform. The essential allocation principle here is that all measured flows must be corrected at J6A export conditions in order to establish the actual contribution of each of the wells/fields into the WGT pipeline. When the export flow is known for each import stream, the J6A platform fuel and vent gas are allocated to each stream based on its contribution in total production, while the compression fuel gas deductions are allocated to those streams using compression. To reconcile individually determined flows with the total export, each party's flow is proportioned to the fiscally measured export total. This represents a minor correction, and ensures that the individual flows are normalized to export production rates. The reported J6A allocation figures to each field are reconciled by the WGT sales allocation procedure on the hourly bases and monthly basis. The flow diagram of the Markham and third party metering system is displayed in Figure 2.

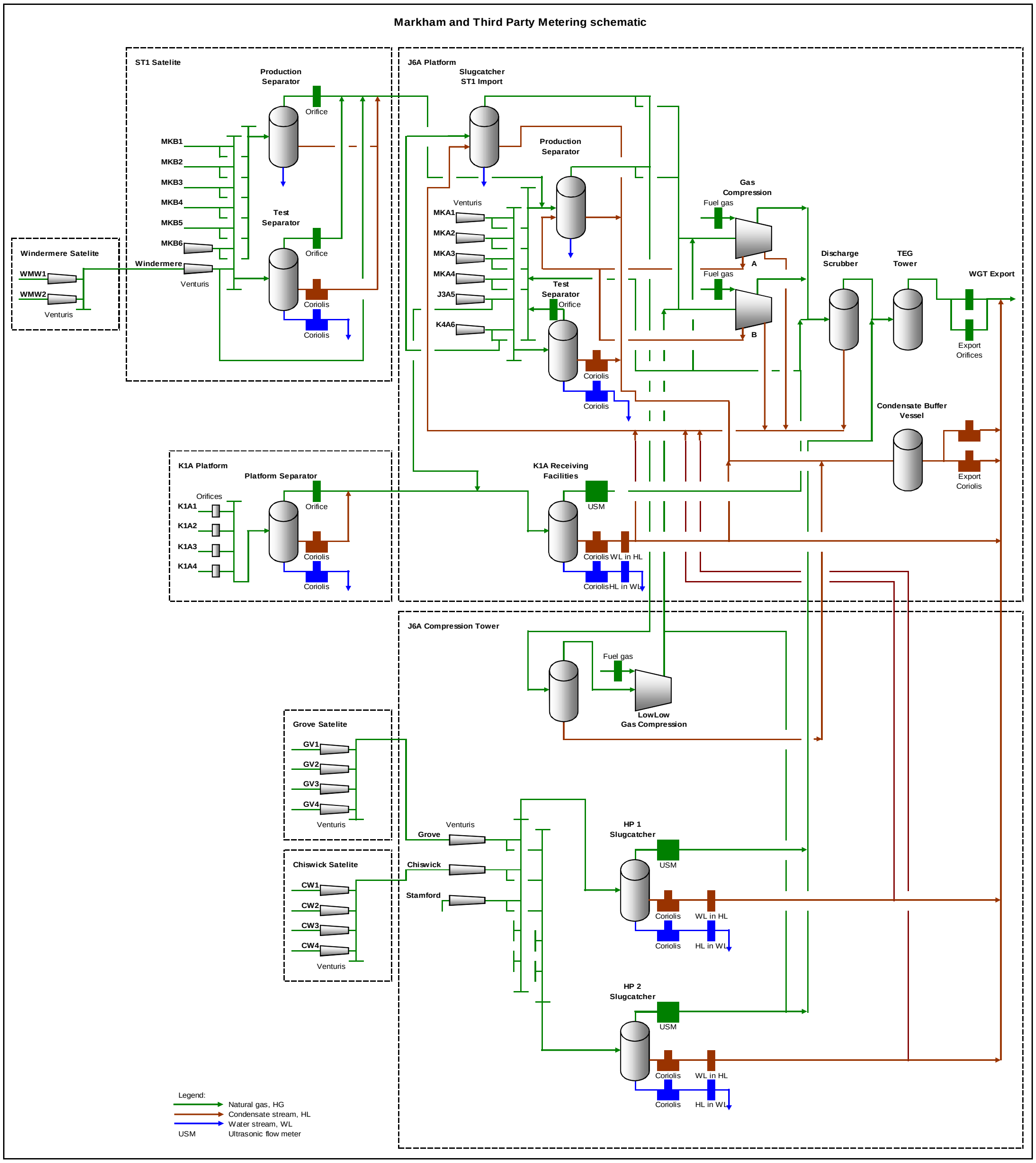

Figure 2 The J6A flow measurement diagram

The Windermere is unmanned satellite platform which produces the natural gas from two wells, measured by wet gas venturi tube flow meters (non-fiscal) prior to export to the ST-1platfrom. Total Windermere import flow is measured on the ST1 by means of a dedicated fiscal venturi flow meter.

The ST-1 unmanned platform, receives the natural gas from Windermere and the Markham B1-B6 wells. The ST-1 is equipped with a production and a test separator used for the venturi calibrations. There are no dedicated venturi flow meters for the individual B1 to B5 well flow lines as opposed to well line B6 and Windermere. The Markham well

B1 – B5 gas flow is calculated based on the well performance derived from the well tests using the test separator. The B6 venturi is validated / calibrated against the test separator gas and liquid flow measurements. The test separator output is measured using the orifice for gas, and Coriolis flow meters for water and condensate. The test separator input can be connected to any of the ST-1 wells, or the Windermere flow line.

The K1A platform is a third party unmanned satellite, with four wells. After the K1A production separator, gas and condensate flow into the K1A export pipeline to J6A. On the J6A, downstream a dedicated slug catcher, a fiscal ultrasonic flow meter measures the incoming gas from the K1A platform. The K1A condensate and water streams are measured by Coriolis flow meters. The K1A condensate can be directly exported if the pressure is sufficiently higher than the WGT pipeline export pressure. The K1A gas flow could bypass the J6A process installation and tie in just before the export meter, provided compression is not needed.

Grove is another unmanned satellite platform tied in to the J6A. Five Grove wells produce the gas measured directly to the J6A as there are no gas treatment facilities on the satellite. The import wet gas flow from each well on Grove is measured by a venturi. The comingled gas from Grove wells is measured by a fiscal grade venturi on the J6A Compression Tower (J6A-CT), and separated in one of the slug catchers, HP1 or HP2. Where an ultrasonic flow meter is used for gas measurement, condensate and water flows are measured by Coriolis flow meters. The Grove condensate from the HP1 or the HP2 slug catcher train can be directly exported if the pressure is sufficiently higher than the WGT pipeline export pressure.

Chiswick is an unmanned satellite platform tied in to the J6A in 2007. There are four wells on Chiswick, and similarly to Grove, the wells produce directly to a 10 inch export sub-sea pipeline to J6A as there are no facilities on board for the gas treatment. The commingled gas from Chiswick wells is measured by a fiscal grade venturi on the J6A and separated from liquids in one of the slug catchers, HP1 or HP2. The Chiswick condensate from the HP1, or the HP2 slug catcher train, can be directly exported if the pressure is sufficiently higher than the WGT pipeline export pressure.

Stamford is a sub-sea well completion added as an import stream to the J6A in 2008. There is a dedicated venturi flow measurement on the J6A, and the gas can be diverted to either of the slug catchers, HP1 or HP2.

The J6A platform also receives the flows directly from four Markham wells, A1-A4 wells, and two third party wells J3aC, and K4aD. The Markham field flow is established as the sum of the mass flows from the individual Markham A and B wells, measured on the J6A and ST-1 respectively. All Markham wells import flows are measured using a dedicated fiscal grade venture flow meters. The platform has a test separator fitted with an orifice plate measurement for the gas, Coriolis flow meters for water and condensate.
The J6A fuel gas used for compression and power generation, and the vent gas are measured by orifice plate type flow meters.

Gas export measurement is by two high accuracy ultrasonic flow meters arranged in parallel duty and stand-by meter runs. The condensate export is measured by two Coriolis flow meters, as well arranged in a parallel duty and stand-by meter runs configuration.

3. Flow measurement system on the J6A – Greater Markham Area production hub

The architecture of the flow measurement system on the J6A prior to the change in 2010 is given in Figure 3.

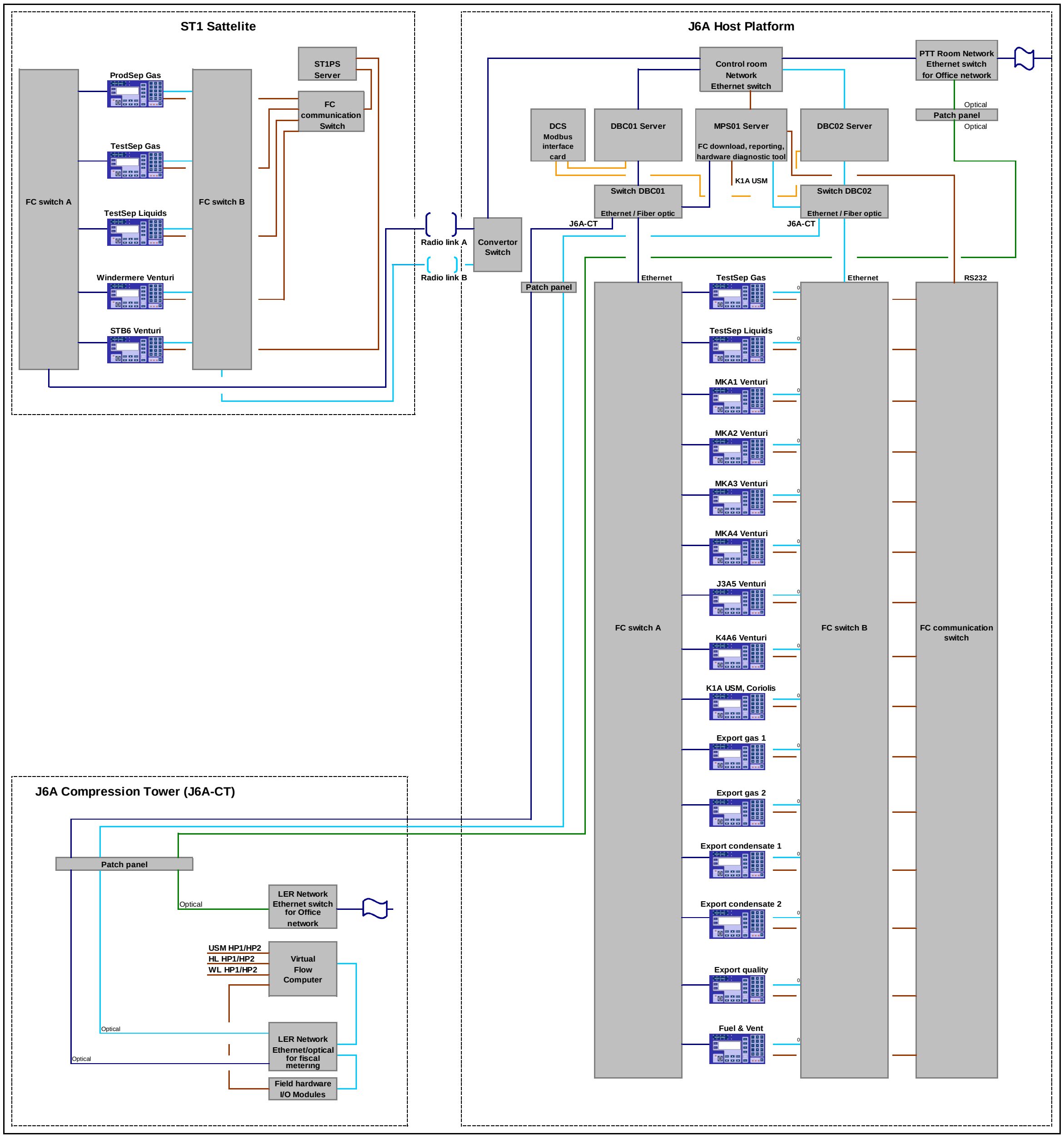

Figure 3 The J6A flow measurement computer and supervisory system before the change

The flow computers used are Solartron type FC 55 computers which were installed in 1996. The three integral parts of the J6A metering system are:

1) The ST-1 metering system component consisting of five flow computers of FC 55 type, redundant flow computer switch modules (A and B) linked to the redundant Data Base Computers (supervisory DBC01 and DBC02 servers) on the J6A via radio link, and local Supervisory Computer (SC) for downloads of the flow computer applications,

2) The J6A host platform has fifteen flow computers, redundant flow computer switch modules (A and B), redundant hot standby DBC01 and DBC02 servers linked to the Office Network (Ethernet), DCS, Markham Production Server (MPS) – used to generate and send the production reports , for flow computer configuration download and Ethernet / fiber optic switches. As the FC 55 flow computer was already considered obsolescent technology with the post sales support becoming increasingly difficult, it was decided to build the J6A-CT flow measurement system around a VFC technology.

3) The J6A Compression Tower (J6A-CT) metering system module consisting of one Virtual Flow Computer (VFC), I/O module, linked to the DBC01 and DBC02 servers on J6A, and to the Office Network (Ethernet).The J6A-CT was installed in order to increase the J6A total compression capacity, and to receive new import streams initially coming from Grove and Chiswick satellites and later from Stamford sub-sea completion as well. Next to the well lines the J6A-CT accommodated two slug catchers where each could be used as a test separator for the dedicated Grove, Chiswick and Stamford venturi calibration. This amounted to 6 additional main flow measurement streams (see Figure 2), plus the utility streams measurements (e.g. fuel gas for the new compressor and methanol and corrosion inhibitor injection) to be added to the existing metering system three were handled as direct fiscal exports into the WGT pipeline.

The VFC selected for the J6A-CT was a PIP 9 type embedded industrial computer (with a 1 GHz processor and 512 MB system memory) which used the type of application builder able to create flow computer applications similar to those programmed in the FC 55 flow computers, therefore ensuring a full compatibility with the running system on J6A. The J6A-CT VFC computer had MS-Windows based system with, in total 5 flow computer applications corresponding to new main flow measurement lines. Compared to previously used FC 55, the VFC was equivalent to five FC 55 computers plus the utility streams, which were managed within the same main five VFC applications addressed as “Grove”, “Chiswick”, “Stamford”, “Slug01” and “Slug02”. The analogue input field measurements (e.g. line temperature, pressure, differential pressure) were communicated to the VFC via I/O module. The mass flow from Coriolis flow, or flow from ultrasonic gas flow meters were communicated directly to the VFC as a serial signal. The J6A-CT VFC incorporated calculation blocks (e.g. ISO 5167, ISO 12213, ISO 6976 etc.) officially approved by the Dutch national metrology authority, the NMi (Nederlandse Meetinstituut), assuring that the calculations are carrier out according to applicable standards and WGT transportation agreement requirements. Over the time the VFC on J6A-CT showed good performance with regard to available computational power, stability and reliability with zero failures.

As the overall J6A flow measurement and mass balancing apportionment calculations of flows back from the main J6A export became more demanding, the good performance of the J6A-CT VFC was contrasted by the FC 55 starting to experience difficulties with the flow calculations and communication (especially those on unmanned ST-1 satellite), which lead to production reporting errors and increased work load to perform the corrections. For example, a flow computer would experience a break in communication, idle due to insufficient computational power (due to the required shorter cycle time to complete the calculations), or fail to restore the calculation correctly after a power cut. Incorrect production figures on one flow computer would compromise the entire allocation procedure as the daily totals would appear incomplete leading to the J6A export calculation and production allocation errors. In such cases the intervention from the Metering Department and personnel offshore would be necessitated in order to restore the proper operation of the affected flow computer and recalculated the production and sales figures.

Soon, it became evident that there was a good chance that the system performance and reliability might be adversely affected and deviate more frequently than acceptable from those required for a fiscal metering system. The age of the system, the rapidly decreasing reliability followed by the additional complexity and diminishing support service and spare parts availability, and announcement from the manufacturer of production phase out of FC 55 made the flow computer replacement inevitable.

The subjects of modification were the fifteen J6A flow computers, I/O module and fiscal metering supervisory computers. The primary and secondary field flow measurement equipment remained on their positions as before i.e. venturi, orifice plates, ultrasonic and Coriolis flow meters etc., but all pressure, temperature, and differential pressure transmitters on host J6A platform were set to communicate a digital, HART, output signal. The I/O module installed on the J6A-CT remained in place receiving the analogue and digital field signals from the compression tower measurement lines. The transmitters of several J6A Coriolis flow meters were modernized, too by exchanging the transmitter head electronics with modern processors. The change of the J6A flow metering system involved the replacement of all FC 55 flow computers on J6A by two redundant new generation VFCs , as well as the DBC01, DBC02 and MPS servers due for replacement every 4 years to ensure reliability.The new VFCs installed on the industrial grade HP Proliant DL 360 server computers (the same type as new DBCs and MPS servers), which incorporate the NMi approved calculation blocks similarly to the VFC predecessor on J6A-CT from 2006, reflects a state-of-art technology and have an ample computing power – a fast and configurable calculation cycle time of minimum 1 second are available, compared to 5-20 seconds by the former system.

Greatly enhanced computational power enables online gas properties and flash calculations (formerly data was derived using polynomial curve fit table calculations) providing a better representation of the J6A export gas mixture composition and allocation calculations. A third party flash calculations package is appended to the VFC applications in a form of subroutine using the advanced Redlich-Kwong-Soave (RKSA) equation of state. The reservoir composition of an import stream is used in the on-line flash calculations with actual line pressure and temperature to determine the current gas mixture properties. The flash calculations are triggered when a set deviation in pressure or temperature is reached (e.g. 2°C and / or 0.5 bar), this to limit processor usage of the virtual flow computer. When it is possible to have more than one import stream flowing through the same test separator / slug catcher, each with a different reservoir compositions, the imbedded active logic in the VFC performs the identification of which of the streams / reservoir compositions are connected depending on the import valves positions. With the lined-up stream / reservoir composition and the actual line pressure and temperature at slug catcher or test separator conditions, the flashed composition is calculated. If more than one stream is at the same time online, the mixed composition is calculated with fluid properties of that particular mixture. The calculated properties are downloaded to the specific VFC block for the calculation of the flow rates and totals. Details of the gas composition are held within the database computers and are periodically updated.

Further, a benefit of reduction in the measurement uncertainty due to the usage of direct digital signal should be mentioned as well – formerly the field data was based on analogue signals, received by a FC input card which converted the analogue signal into a digital signal used by the FC with the unavoidable additional card and signal conversion uncertainty. A screenshot of the actual J6A "Export_J6A" VFC application interface is given below in figure 4. As previously mentioned, the featured VFC calculation building blocks are NMi certified.

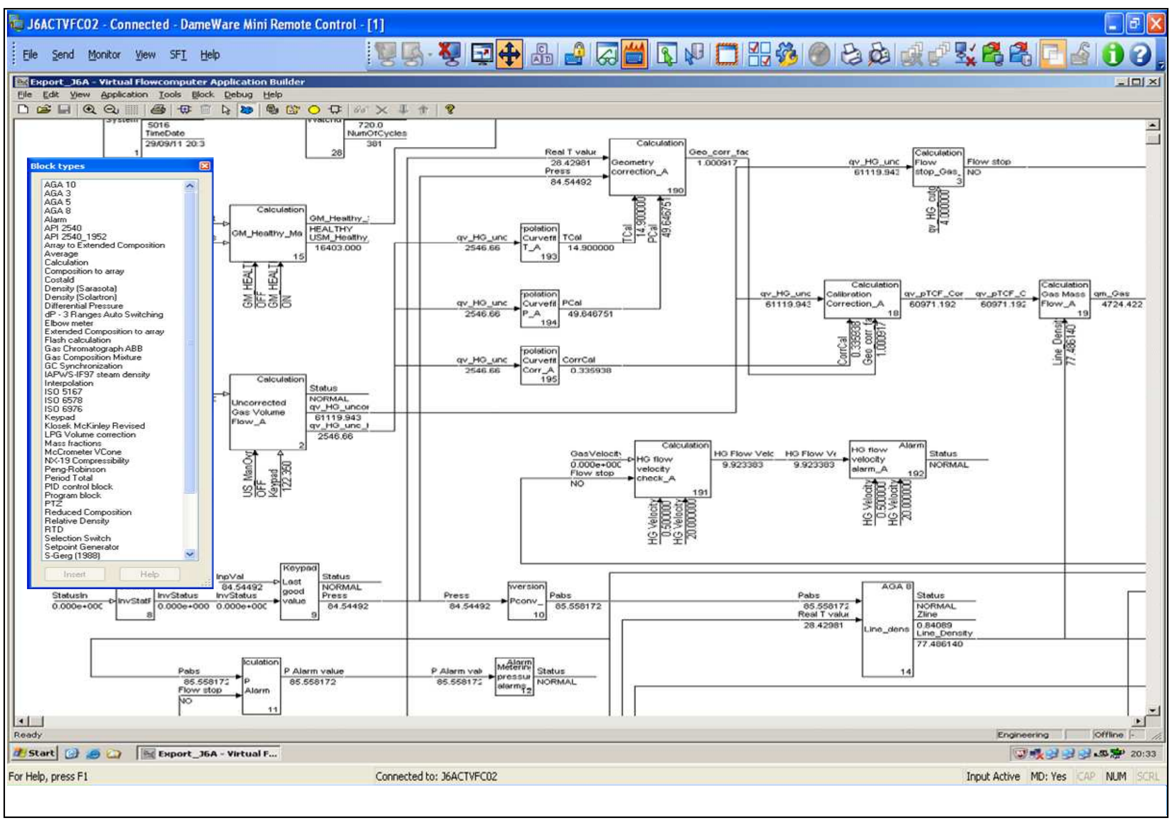

Figure 4 Screenshot of the VFC application builder and actual "Export_J6A" application; on the left hand side is a prompt window for the VFC block selection with a long list of available building blocks

The system is MS-windows based, meaning the replacement in a case of failure shall be swift and without problems using the backup flow computer applications and configurations files. To build a new VFC application is a matter of selection of the calculation blocks, their configuration to perform particular operation (e.g. input block of the raw field values, AGA 8 block, interpolation or totalisation block) and configuration of the VFC drivers to communicate via OPC with the I/O module on one side, and with the DBC interface software on the other side which regards the VFC as the service.

Time synchronization using the internet atomic time clock via office domain controller ensures that VFCs run with exactly the same time with DBC01, DBC02 and MPS, which is essential for the calculation of hourly and daily flow totals and summations. The VFCs send flow calculation figures to DBCs in 2 second cycles and time synchronization between VFCs and DBCs is important in order to ensure the stable calculation of hourly and daily production totals. These VFCs are easily configurable and capable of handling all current streams, while still leaving the capacity for addition of new streams in the future, or for modification of the existing applications with a broad range of additional monitoring, trending and alarming features. The achieved degree of integration is very high with all VFC applications (each application is the equivalent of a multi-stream conventional flow computer) and calculations performed by one computer, that is, two computers with increased availability and reliability as the J6A VFC is truly redundant running in a hot-stand mode with no failures by so far.

The J6A metering system consists of two database computers DBC01 and DBC02 on the top level of the system architecture connected to the dedicated virtual flow computers VFC01 and VFC02 respectively. Each data base computer collects and stores fiscal data and system events / alarms in its own database, and functions independently from another one in a truly hot-stand-by redundant configuration regarding the data collection and storage. The two DBCs also serve as a primary interface to the metering system. The data base computers are connected to the Markham Production Server (MPS) which collects metering data from the ‘Duty’ database computers and generates daily production files and reports.

All essential production and allocation figures are communicated to onshore database of the office server (permanent historical and back up record) via the office network with the access guarded by a firewall preventing any unauthorized access. The DBCs, VFCs and MPS are additionally secured for the authorized access by means of login usernames and passwords of several levels, e.g. operator engineer – administrator just list the number of levels as descriptions are not required. The possibility of remote connection from a dedicated computer enables the authorized personnel to directly access the J6A flow metering system for monitoring purposes, or if required, to provide an immediate support for corrective maintenance or assistance. Additionally one report printer offshore is connected to the metering network via the print server service.

Two virtual flow computers VFC01 and VFC02 obtain analogue and digital field signals via I/O modules (e.g. P, T, dP, etc.) as well as serial signals through serial signal convertors from certain number of the field instrumentation (e.g. ultrasonic meters,

Coriolis meters and DCS). In case of unlikely failure of the Duty DBC, or VFC, the operator has the possibility to automatically switch the Standby database computer to Duty.
The J6A DCS utilises a redundant serial link to communicate with both database computers. The metering system exchanges some specific data with the DCS, i.e. metering system receives relevant field signals (e.g. valve open/closed statuses, well and down-hole, etc) and data from the satellite platforms (e.g. ST-1, K1A, Grove, Windermere, Chiswick) and sends the both data and calculation results back to the J6A DCS.

The data base computers and virtual flow computers were moved from the J6A Central Control Room (CCR) to a local electrical room (LER) on the J6A Compression Tower, and communicate with the metering equipment on the J6A and in CCR via Ethernet / fiber optic connection. The reason for such a move was to abate the noise in the J6A produced by 5 industrial server computers and additional fans, in that case, required to be installed in the cabinet for cooling.
The components of J6A metering system and their functionality can be summarized as in the table below.

System component	Quantity	Brief description of functionality
Database computer (DBC01/DBC02)	2 off	Communication link between all flow computers for measured data, calculated data, events and alarms, communication link with the DCS system and link to the Office LAN, a human machine interface for the operators, data logging to maintain a historical record of the received data stored onto the local, redundant, hard disk.
Virtual flow computer (VFC01/VFC02)	2 off	Receives field metering input signals via I/O modules, performs fluid properties and flow calculations and corrections, calculates flow totals, runs the J6A allocation calculation procedure
Markham production server (MPS01)	1 off	Collects metering data from the ‘Duty’ database computers, generates daily production report files and sends them via email internally and externally, provides the interface for data exchange between the J6A metering system and WGT pipeline operator’s center
J6A DCS	1 off	By means of redundant serial links, the metering system exchanges some specific data with the DCS – local field signals from the satellite platforms are communicated via DCS to the metering system
ST-1 flow computer	5 off	FC55 flow computers with simplified functionality used as remote I/O stations to gateway the ST-1 field signals to the virtual flow computers on the J6A
ST1PS server	1 off	Local supervisory PC type computer on the ST-1 with limited functionality, used for the visualization of the ST-1 metering streams and for flow computer downloads

Table 1 Overview of the J6A metering system components and functionalities

Owing to the new metering set up, the functionality of the ST-1 flow computers have been altered and simplified in order to decrease the calculation load. At present, these flow computers do not perform any flow calculations, but just gateway the ST-1 field signals to the redundant VFC connected to the database computers on the J6A through a dual radio link. The “stripped” ST-1 flow computers were tested as the field I/O units. Therefore, a new I/O module was not installed on the unmanned ST-1 satellite, which steadily approaches its end of production life as the replacement would introduce additional costs, as well as technical and logistical challenges.

The architecture of the new VFC based flow measurement system on the J6A in use since April 2010 is given in Figure 5.

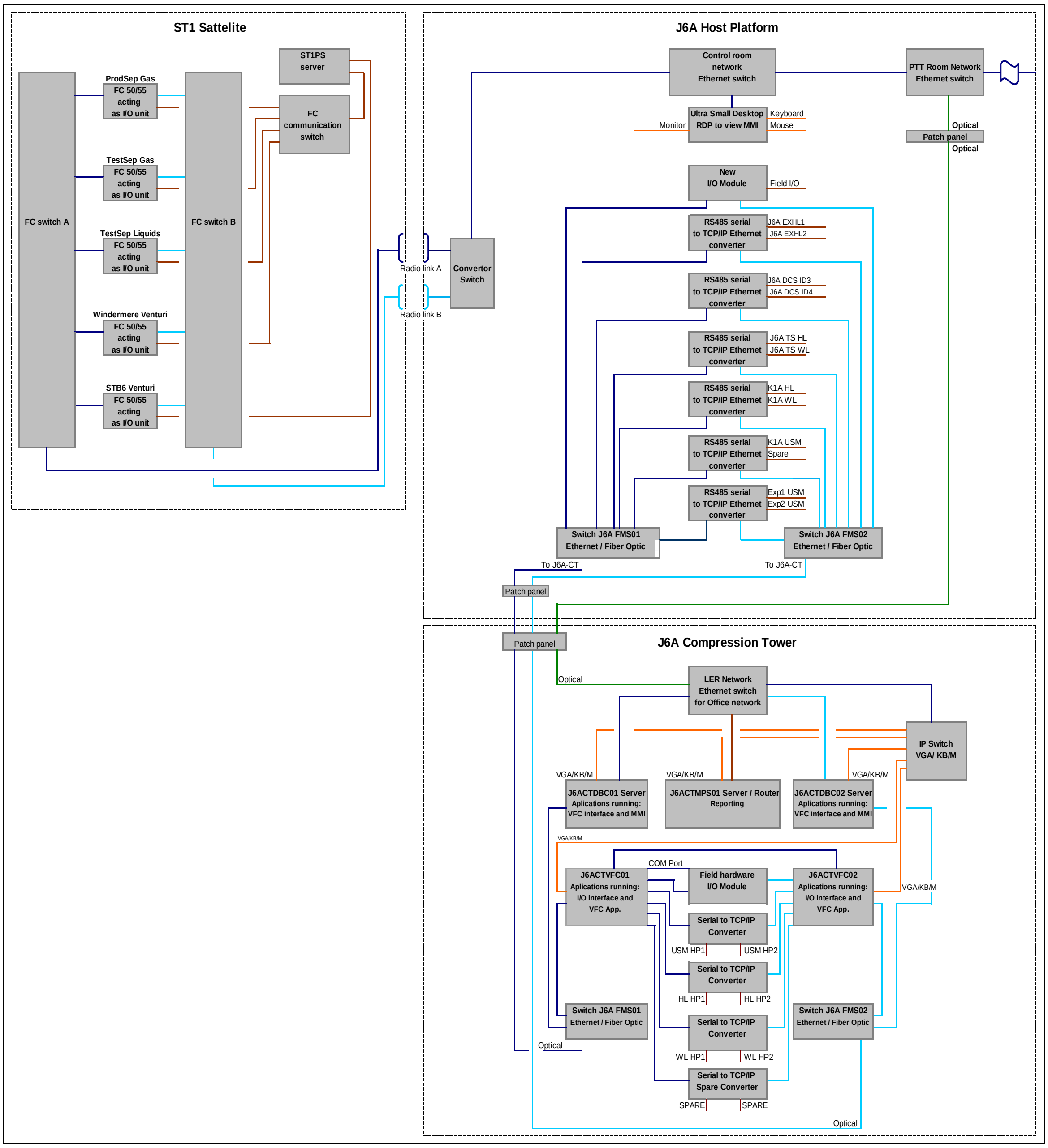

Figure 5 The J6A new flow measurement computer and supervisory system after the change in 2010

Following the success of the new J6A VFC computer system, the same concept was adopted as basis of the design for the flow measurement system on CEU's new offshore installation F3FA. The F3FA is normally manned platform within the Dutch F3 sector of the North Sea some 230 km north of Den Helder tied in via the 20 inch branch pipeline, operated by Wintershall, to the NOGAT pipeline operated by the Gas de France. The F3FA installation produces natural gas from the F3FA field, currently, one well (FA-A1) with ability to accommodate future wells. The received hydrocarbon well head gas is measured by a venturi flow meter complete with set of differential pressure, pressure and temperature instrumentation. The fluid flowing through the FA-A1 venturi (import) is saturated hydrocarbon gas with a quantity of dispersed liquid, including a small quantity of produced water. The import flow is directed to a separator where the gas is separated from the liquid phase. The gas is, dried and the fuel gas is subtracted prior the gas is measured by the export metering station. The F3FA can produce natural gas either on free flow, or on compression depending on the available well head production pressure. The F3FA gas export metering station comprises of two meter runs in a duty-spare configuration, each equipped with an ultrasonic flow meter, and instrumentation for the line pressure and temperature measurement and the single gas quality module, which features an automatic gas sampler and dew point measurement unit. The separated condensate is pressurized to export pipeline pressure and is measured by Coriolis mass flow meter in duty-spare configuration. The import and export measurement data are transferred to the F3FA supervisory system.

The simplified F3FA flow diagram and the flow measurement system schematic are given in the Figure 6.

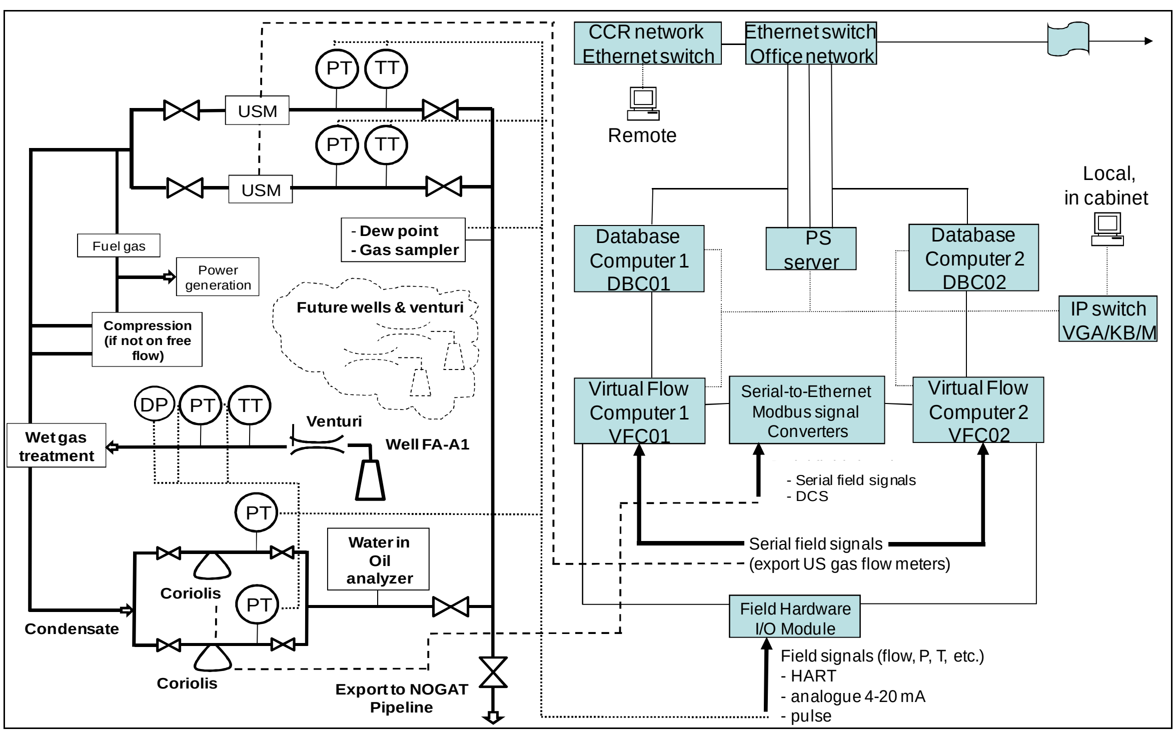

Figure 6 The F3FA flow measurement diagram and supervisory system

Similarly to the J6A system, the F3FA flow measurement system consists of two database computers, DBC01 and DBC02, highest in the system architecture hierarchy, each collecting and storing fiscal and allocation calculation results, fiscal data and system events and alarms in its own database. The DBCs function independently one from another in a truly redundant configuration regarding the data collection and storage. The data base computers are connected to the F3FAmetering production server PS, which collects metering data from the selectable 'Duty' database computer and distributes the real time data to the NOGAT operator and generates daily production reports stored in historian data base of the office production server.

The DBCs have a full Man-Machine Interface for all available equipment and serve as a primary interface to the metering system. The communication with the metering systems is realized through the local TCP / IP metering network. The access to DBCs, VFCs and MPS is regulated by "guest", "operator", "engineer" and "administrator" levels of authorization. In the same fashion as with J6A asset, the communication with the office production server, and remote access to the supervisory system from the office or elsewhere is only from the dedicated company's computers assigned to production support personnel e.g. flow metering engineer.

The DBC01 and DBC02 are connected to the dedicated virtual flow computers VFC01 and VFC02 respectively, providing for physically two systems running in a hot-standby arrangement. For the F3FA data base computers, as well as for PS, ProLiant DL360 HP type serves were installed, the same as used on the J6A. The flow calculations are performed by the VFCs installed on the Moxa DA-682 rack mounted type imbedded computers, which obtain field signals via I/O modules (e.g. P, T, dP, etc.). On the F3FA the advantage is given from design stage to digital field inputs, e.g. HART pressure and temperature signal, while analogue or pulse field input signals were kept by only few devices where really necessary such are gas dew point meter or gas automatic sample grabber. The signal from export gas ultrasonic flow meters is communicated directly to the VFCs by means of a serial signal via serial input card of the VFCs.

Following the practice on the J6A, the F3FA VFCs incorporate the NMi approved calculation blocks, have sufficient computational power, easy to configurable, with capacity for the addition of new streams, or for modification of the existing applications. The same Moxa imbedded computer was initially installed on the J6A as a platform for virtual flow computer applications, but turned that, even the extended system memory to a maximum of 1GB for this type of imbedded computer (standard 512 MB) was insufficient to cope with calculation and communication for that many streams as present on the J6A, and were replace by the current ProLiant DL360 HP server computers with adequate memory capacity and computation power.

4. The J6A changeover project – transition to a fully VFC based system

The subject of modification on the J6A was fiscal metering supervisory and flow computer system, while the flow measurement field equipment remains unaltered e.g. pressure / temperature transmitters, venturi, orifice plates, ultrasonic and Coriolis flow meters. The functionality of the old system was entirely preserved with a noticeable increase of additional computation power and flexibility.

The new VFC flow metering system was integrated and commissioned during the J6A continual operation without production stops or disturbances. During the changeover, the J6A flow metering system redundancy was temporarily lost as the modification was carried out on one system at the time while the other had to handle the platform production. The actual production was running on the old configuration (FC 55 computers) of system 1 with DBC01 set as DUTY only, while the modification was carried out on the system 2 (DBC02, VFC02). When the new system 2 was fully installed, it was tested with the real production online figures and compared with the old system 1 still running on the old DBC1. After successful validation and verification of the data, which are now coming through the new system, the new DBC2 was set as DUTY while the old DBC1 was subjected to changeover. When the DBC1 upgrade was done, the J6A metering system regained the full redundancy in new configuration, see Figure 3 and 5 for reference.

The input signals from the field instrumentation were made available and communicated through the Ethernet TCP/IP on the Metering Network. This feature required the use of HART signals from the field instrumentation, that is, temperature and pressure transmitters, while for the communication of field serial link, the serial-to-Ethernet Modbus signal converters were installed used e.g. ultrasonic and Coriolis flow meters as shown on the schematic below in Figure 7.

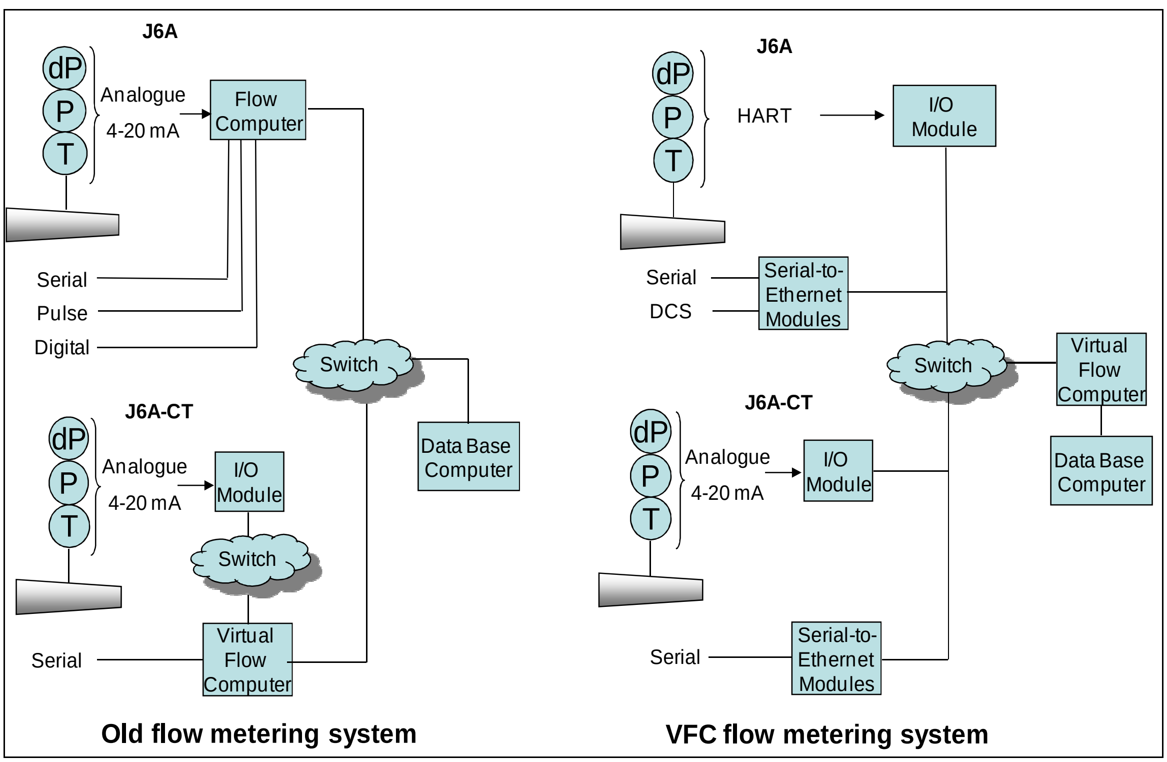

Figure 7 Change of the J6A field instrumentation input signal and configuration

A change of design on the existing installation, or introduction of a new measurement technology which may affect the J6A operation and its input into the pipeline, is subject to a formal review and approval of the Technical Committee set up by delegates of the WGT pipeline operator and the party responsible for the WGT sales allocations and reconciliations. With regard to that, several meetings were organized with representatives from Wintershall Noordzee BV and NAM BV (Shell), both members of the WGT technical committee. The applicability of the new J6A VFC concept for the fiscal and technical GMA streams was presented during these sessions, and the compliance with relevant standards and requirements of the technical addendum of the WGT Transportation Agreement for flow measurement systems was successfully demonstrated. The result was the approval for use of the system for intended purpose. The type approval for the VFC could not have been obtained as the VFC is not a classic flow computer with strictly defined hardware and modules, but it is rather a software platform installed on a variety of generic, good quality, industrial computers with customized flow calculations and interface to other elements of the supervisory system to suit the actual flow measurement application. The VFC applications are, however, built from blocks which comprise the calculations according to internationally accepted standards and recommendations e.g. ISO, AGA, API, NX-19, PTZ, S-Gerg etc, which are NMi approved for the type of VFC used on J6A and F3FA platforms – for the F3FA the same approach was taken with regard to the NOGAT pipeline operator and NOGAT flow measurement technical requirements (e.g. reliability, accuracy, integrity), while the system was approved by Gaz de France Suez BV and Wintershall Noordzee BV.

The modification project on site took place in controlled steps with each step completed before the next step could take place in order to maintain the integrity of the fiscal measurement system, and to avoid production data loss during the live system changeover. The changeover project execution onsite was organized in the following sequence:

- Prior to arrival of the upgrade team, the backup of all system configuration files, applications and records was made. Further, mechanical installation of the new server cabinet and the core processors preparation for installation in the field was done before arrival of the upgrade team.

- Installation of components in the new server cabinet J6A-CT, day 1 on site – The old PIP 9 VFC in the existing cabinet had to be connected to the network via new Ethernet switches in the new cabinet in order to simultaneously enable data transfer to the system 2 (stand by) which was undergoing the change and the old duty system 1. Once the new switches were ready the old one was removed. This period was kept as short as possible and no fiscal data was lost.

- Installation of the swing frame with the new J6A I/O module (PLC) and installation of the new MTL barriers, day 2 and 3 on site – The new PLC and the barriers with digital and analogue outputs for field signals were installed in the J6A metering cabinet in the CCR. The new barriers with two outputs were installed for one by one flow measurement stream i.e. import, test separator, fuel gas and export streams in order to enable field input to both old duty system 1 and new system 2.

The old FC 55 computers had to be reconfigured one at the time of the each stream being worked on to receive the input signals from the new PLC. After this step the old system 1 the new system 2 was running in parallel with all J6A transmitters connected to the new PLC.

- Installation of the serial-to-Ethernet modules and I/O module on J6A-CT, day 4 on site – The communication signal of flow meters on J6A-CT (ultrasonic and Coriolis) was changed from serial to TCP / IP Ethernet. Due to change of the protocol of serial devices from "modbus serial" to "modbus TCP/IP" and change in the modbus addresses of the I/O module, the field communication from J6A-CT was shortly disconnected from the metering system as the VFC interface software had to be updated for the new configuration.

- Setup communication with ST1, day 4 on site – The communication with the ST1 flow computers was tested. Before testing the communication between the new system 2, VFC02 and ST1, the old standby system must have been shutdown. Upon completion of this changeover step, the ST-1 was communicating to the still duty old system and new system 2, there was no old standby system anymore.

- Preparation to compare old vs. new system, day 5 on site – Before the old and new system could be compared the following serial communication was enabled: J6A export condensate stream 2 switched from Hart (Triloop) to serial, K1A gas ultrasonic and liquid Coriolis flow meters from pulse to serial RS 485, and the DCS communication.

- Testing old against the new system simultaneously, day 5 on site – At this point the old and new systems were running simultaneously. Only the serial communication of the J6A Coriolis flow meter was not yet connected to the new system. At this point it was possible to compare the old and new system. This was a hold point: before the work was continued it had to be ensured that new system worked properly.

- Coriolis flow meters RFT exchange with the core processors and other serial communication J6A, day 6 on site – After this step the old duty metering system 1 was not in use anymore and the new system 2 was fully operational. The J6A condensate was exported through the export Coriolis flow meter of export stream 2 in order to finalize the change to serial signal for the export stream 1 Coriolis. The J6A test separator Coriolis flow meters signal were changed to serial RS485 signal, too and the DCS serial communication enabled for new system 1.

- Download new applications ST1 flow computers, day 6/7 on site – The communication between new VFCs on J6ACT and the ST-1 flow computers was completed. In this step new flow computer applications were downloaded to the ST1 FC 55 flow computers. After this step the new VFCs received status and input signal values from each of the ST-1 FC 55 computers, which acted only as a remote I/O station without other functionality.

- Remove the old duty system and setup the new duty system to the network and clean up / arrange the cabinets, day 7/8 on site – The unused components were removed out of the cabinets and the metering cabinets in J6A CCR and J6A-CT LER re-arranged to accommodate new metering system. The J6A flow measurements and allocations were conducted by the new duty system 2, while the new standby system 1was fully operational.

- Test the system, day 8 – Both duty and stand by systems 1 and 2 were checked on proper functioning and performance of the new configuration. During the testing, although the system was fully functional, the problems were observed with regard to the performance of the embedded computers. The embedded VFC was found much less responsive in the real environment than during the simulations in laboratory. An attempt to perform an on line the change or even to navigate through the running VFC application would often lead to application crash or communication breakup.

In order to obtain the more stable and reliable system, it was decided to replace the embedded computers with servers types computers, the same as used for the DBC computers (HP ProlLiant DL360). The new servers were purchased very quickly, and 4 weeks after the completion of the embedded VFC installation the second offshore visit was arranged followed by the onsite work carried out in the same sequential fashion with precisely defined order:

- Prior to the start of embedded VFC exchanged work, backup of all currently used system configuration settings and records were generated.

- Replacement of virtual flow computer embedded VFC02, day 1 (including the previous visit 9th working day on site) – In this step the embedded VFC02 was replaced for a server type computer. The running standby VFC02 was switched off and removed from the new J6A-CT cabinet. On that day, the J6A flow metering system was reporting from system 1, and due to the work on system 2 there was no backup system.

- Replacement of virtual flow computer embedded VFC01, day 2 (10th working day on site including the previous visit) – The second embedded VFC computer JVFC01 was replaced by a server computer. Production and reporting was done from the system 2 set as duty at 06:00 h in order to have a complete production day figures consistently recorded in one computer data base. There was no redundancy during this exchange step as work was carried on system 1.

- Installation of the new circuit breakers for backup power supply to the server cabinet, day 3 (11th working day on site including the previous visit) –A backup power was enabled for the new metering cabinet in the LER on J6A-CT connected to the platform essential power supply to guaranty that in case of the platform power cut, servers VFCs and DBCs would remain powered sufficiently long to avoid abrupt termination of applications. New circuits breakers for new VFC servers and power supply were installed with a caution to avoid a trip of the 24 VDC power supply as the exchange was taking place on the live system during normal platform operation.

- Final touchups, day 4 (12^{th} working day on site including the previous visit) – Configuration of the backup I/O module cards, update of the VFC to I/O module software interface, metering cabinets cleaned up and neatly arranged (e.g. wiring, terminal strips, various modules.

5. Lessons learned and conclusion

The VFC concept presents transition from a classic hardware type flow computer commonly encountered in the oil and gas industry, to a dedicated software platform with dedicated flow calculations with clear health diagnostics indication and flexible interface and high level of integration realized by setting the system together with the with DBC and MPS supervisory computers, DCS, field signals via Ethernet links offshore and onshore via office LAN, and with local and remote access for the authorized personnel. The VFC calculation algorithms are readily configurable and modifiable if necessary, the existing application can be easily extended, or a new one created if a new stream is added on line – similarly the application can be reduced or removed if a well or stream stopped producing. The VFC installed on computers of compact design showed on the example of J6A as efficient concept for the offshore installations suitable for the great number of streams: it is just one flow computer license in place of 256 classic single stream computers capable of handling of thousands of field signal inputs within one unit. with a cycle time set to 2 seconds at 20% of the VFC CPU usage during normal production, and not more than 50% CPU load during large scale upsets.

The VFC paired with a flash calculation module delivers a fast cycle calculations of fluid composition at many different process conditions: it is required only to add another flash calculation block in the VFC application a new set of conditions. The calculated natural gas composition enables calculation of the velocity of sound (VOS) for that particular stream in the VFC block AGA10 and comparison with the measured VOS by ultrasonic flow meter. This validation is set up on the J6A for the HP1 and HP2 slug catchers on J6A-CT and for J6A export gas (see Figure 2); the match of VOS reported on these positions is normally better than 0.15% (the AGA10 recommendation limit is VOS difference by 0.3%) testifying the good measurement and reservoir recombination practices in the online flash calculations & VFC calculations, measurement practices provide a very accurate match of the gas mixture composition between the calculated VOS of the gas mixture and measured VOS by one of the US flow meters.

The demonstrated insufficient computational power of the initially installed imbedded VFC01/02 and therefore their introduced instability, could possibly compromise the integrity of the fiscal flow measurement system and its performance according to the requirements. This stressed once again a proven fact that often laboratory simulations do not reflect the situation in real environment, here for the J6A that meant the integration of the new software and hardware into the existing system operating for nearly 20 years. Lead by this example, for the similar systems planned to be installed on the installations handling a large number of flow measurement stream, or needing to perform a comprehensive allocation calculations, a powerful server computers would be recommended with sufficient system memory and computational headroom. It should be as well mentioned that implementation of the VFC on systems such are J6A or F3FA is not really a "plug-and-play" solution, and requires decent degree of system knowledge and understanding of the system, its components and their interaction with the actual production and allocation process in order to get the best out of it. On its side this would implicate a necessity for the general and more specific training required for inexperienced personnel.

Further, for the modification projects carried out on remote offshore installations a good work planning, understanding of the system and cooperation with a third party vendors / contractors and onsite supervision are essential. During the changeover project the Metering Dept. personnel worked closely with the system integrator, acting proactively on devising the solutions and implementation maintaining a very good control over the project. The result was that the whole changeover project was completed on site in 8 plus 4 days without a need to stop the normal operation and production, yielding at the end a fully operational flow measurement system operating according to specifications and expectations.

The VFC is a viable technique suitable for diverse technical and fiscal flow measurement systems, and could be advantageous technique for large and rather complex metering systems involving quality checks, real time calculation, production and sales allocations to own and third party assets – platform gas vs. onshore processing plant and gas at "export flange" conditions can be calculated and matched next to each other which enhances the production control and facilitate the steering to meet the hourly / daily nominations.

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.