A TELEMETRY SYSTEM COMBINED WITH A CONTROL SYSTEM FOR REMOTE PROCESSES MONITORING

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***ABSTRACT**: Nowadays, different kinds of Industrial Control Systems (ICS) are used in heavy industries like oil and gas industry to monitor and control production and operation processes. In a same industrial plant, major engineering and design efforts are made during each system implementation, to comply with process requirements and features. Moreover, other efforts are made regarding to operation and maintenance issues due to diverse hardware and software architectures of such systems. This paper aim is to make a comparative study between most used control systems by highlighting their strengths and features, each according to its preferred domain of process control. Then to discuss how to develop a unified system that will have core features to monitor and control different kinds of processes. This approach is applied for the design of an oilfield telemetry project. The purpose is to propose technically optimized and cost-effective hardware and software solution.*

***KEYWORDS**: Industrial Control Systems (ICS); SCADA system; combined control approach; radio transmission; software development.*

1 INTRODUCTION

Heavy industries (like oil and gas industry) are very much linked to technological progress in electronics and information technologies; this has allowed a considerable evolution of production processes control. During the last two decades the design and development of personalized Industrial Control Systems (ICS) have appeared, according to the process control domain. Fire & Gas system, Burner Management System, Power Management System are sample examples of ICS commonly used in today's process industry. All of these control systems belongs to one of the main three ICS families: PLC, SCADA or DCS. Programmable Logic Controller (PLC) is still one of the most widely used control systems in oil and gas industry. As need to monitor and control more devices in the plant grew, the PLCs were distributed and the systems became more intelligent and smaller in size known as Distributed Control Systems (DCS). It uses a high-speed communications medium, such as Local Area Networks (LAN). A significant amount of closed loop control is present on the system. In front of these control systems (PLC and DCS) usually used within a more confined area, Supervisory Control And Data Acquisition (SCADA) system covers larger geographical areas. Usually associated with a telemetry system, it may rely on a variety of communication links. Closed loop control is not a high priority in this system [Eckley et al. 2014; Bailey et al. 2003].

The current trend is to include diverse production and operation processes on a same industrial plant. Then, to reach higher levels of safety and reliability it is very likely to find in the same control room several supervision workstations. Not only for redundancy purposes but because every workstation is dedicated for a different control system. This also requires diverse operators in front of every workstation where everyone must have necessary skills relating to a specific control system.

2 MATERIAL AND METHODS

2.1 Industrial Control Systems (ICS)

Industrial Control System includes several types of control systems, often found in the industrial sectors and critical infrastructures. ICS are typically found in heavy industries such as oil and gas, electrical, water and wastewater, chemical, transportation and pharmaceutical [Stouffer et al. 2015]. These control systems are very important to the operation of these infrastructures which are often highly interconnected and mutually dependent systems. Over the time several architectures have been implemented by the development and/or improvement of components and network connections typically found on each system. Today's implementations of ICS may be mixture that removes differences between two systems by including features of both of them.

While control systems used in process and manufacturing industries are very similar in operation, they are different in some aspects. One of the primary differences is that DCS or PLC-controlled subsystems are usually located within a more confined factory or plant area (ex. Power Generation Plant), when compared to geographically dispersed SCADA field sites (ex. oil and gas wells). DCS and PLC communications are usually performed using local area network (LAN) technologies that are typically more reliable and high speed compared to the long-distance communication systems used by SCADA systems. In fact, SCADA systems are specifically designed to handle long-distance communication challenges such as delays and data loss posed by the various communication media used. DCS and PLC systems usually employ greater degrees of closed loop control than SCADA systems because the control of industrial processes is typically more complicated than the supervisory control of distributed processes.

PLCs are computer-based robust devices that control industrial equipment and processes. While PLCs are control system components used throughout SCADA and DCS systems, they are often the primary components in smaller control system configurations used to provide operational control of discrete processes such as automobile assembly lines and power plant soot blower controls. PLCs are used extensively in almost all industrial processes [Stouffer et al. 2015].

Programmable logic controllers are essentially nothing more than special-purpose, industrial computers. As such, they are built far more ruggedly than an ordinary personal computer (PC), and designed to run extremely reliable operating system software. PLCs as a rule do not contain disk drives, cooling fans, or any other moving parts. This is an intentional design decision, intended to maximize the reliability of the hardware in harsh industrial environments where the PLC chassis may be subjected to temperature extremes, vibration, humidity, and airborne particulates (dust, fibers, and/or fumes).

DCS is a combination between local control simple loop concept and computer networks. DCS systems are used to improve process industry management with more safety and flexibility. They allow centralized management and supervision with distributed control. DCS are essentially based on a multi-loop network controllers and an HMI (Human Machine Interface) [Bahaz 2004].

DCS are used to control production for industries such as oil refineries and Power Generation Plants. A DCS uses a centralized supervisory control loop to supervise a group of localized controllers that share the overall tasks of carrying out an entire production process [Frazer 2001; Erickson and Hedrick 1999]. By modularizing the production system, a DCS reduces the impact of a single fault on the overall system. In many modern systems, the DCS is interfaced with the corporate network to give business operations a view of production.

Typically a DCS system is composed of several client servers; each server has a different interface according to its mission [Prasad, Jayaswal and Priye 2010; Tachi 2015].

The distinction between DCS and PLC technologies is fading; software tools have been developed for PLC enabling it to perform process control and DCS have adopted the sequence control techniques used with PLCs, including the adoption of the ladder logic notation [Walker 2012; Davis 1992]. The borderlines between PLC's and DCS's are now disappearing, therefore the choice of technology arguably is one of preference and at the end overall reliability is the main requirement for a process control system [Rameback 2003].

SCADA is the combination of telemetry and data acquisition. This means a system consisting of RTUs: Remote Terminal Units collecting field data connected back to a master station via a communications system. The master station displays the acquired data and also allows the operator to perform remote control tasks [Clarke et al. 2004].

SCADA systems are used to control dispersed assets where centralized data acquisition is as important as control [Boyer, 2010]. These systems are used in distribution systems such as water distribution and wastewater collection systems, oil and natural gas pipelines, electrical utility transmission and distribution systems, and rail and other public transportation systems.

There is a fair degree of confusion between the definition of SCADA systems and process control system. SCADA has the connotation of remote or distant operation. The inevitable question is how far "remote" is – typically this means over a distance such that the distance between the controlling location and the controlled location is such that direct-wire control is impractical (i.e. a communication link is a critical component of the system). PC-based SCADA enhanced the capability of PLC control systems enabling them to compete directly with DCS [Fauci 1997].

2.2 Case study: Oilfield wells data collection and monitoring project

The case study is an oilfield composed of (03) main processing facilities. A total of 63 oil producing wells are distributed over three field areas [Sonatrach NOC. 2019].

Oilfield data collection and monitoring of production wells parameters (oil producing parameters, gas lift volumes and flow, water supply and injection volumes, …) are recorded by using a 32 Bits microprocessor based electronic instruments that performs flow calculations, pressure and temperature measurements, and data archival with remote communications [Sonatrach NOC. 2005]. These autonomous instruments are designed for measurement and control applications mostly provided by the firmware and software configured:

- Flow calculations orifice meter (AGA3: American Gas Association committee report 3), rotary pistons or turbine (AGA7: American Gas Association committee report 7).
- Archive of historical data.
- Memory for alarms and events.

The existing DCS operates from (04) main control centers, each site has autonomous operation (DCS Level 2) in case of network is disconnected between one of the four main sites [Aouadj et al. 2022]. The system centralized server is provided for the time synchronization, backup and recovery, historical record, and remote monitoring. All based in Central Control Room (CCR). A diagram of a telemetry system combined with the DCS system is given on (Fig. 1).

The DCS has an open, modular and scalable architecture, with the ability to share data between applications using network high-speed non-proprietary protocols such as Ethernet with TCP / IP.

This DCS system has been designed under the following requirements:

- All control systems for the field devices are redundant.
- A single failure everywhere in the system doesn’t lead to a loss of control for the other loops.
- The redundant equipment is continuously monitored.
- The communication systems are redundant with separate cables.

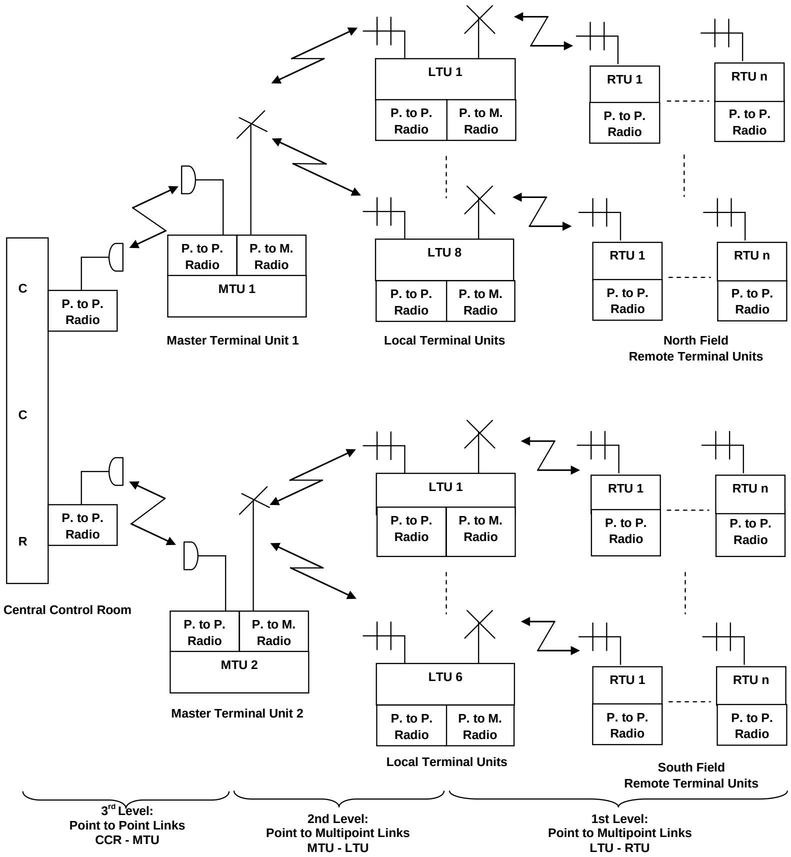

Fig. 1: Telemetry system diagram design (Oilfield wells monitoring).

3 RESULTS AND DISCUSSION

The project execution is based on the creation of a networked telemetry system which will provide data communication and transmission between the remote control instruments and the DCS control system.

3.1 Project development

In this part of the paper we will describe the main development steps of this project:

3.1.1 Project hardware development

The proposed telemetry system for linking remote control instruments to the DCS system is presented on (Fig. 2). The following is a brief description of telemetry system components. This part gives a brief description of the telemetry system components.

To allow remote control instruments data transmission, we have associated it with a radio transmission system which is composed of:

- RS 232 to Ethernet converter
- Wireless network bridge
- Radio dish (parabolic radio antenna)
- Photovoltaic Power Supply

The converter and the wireless bridge will be power supplied by a photovoltaic system, composed of one solar panel and two batteries.

To allow communication between the control system and the remote instruments, we have associated the DCS with a radio transmission system which is composed of:

- Radio dish
- Wireless network bridge

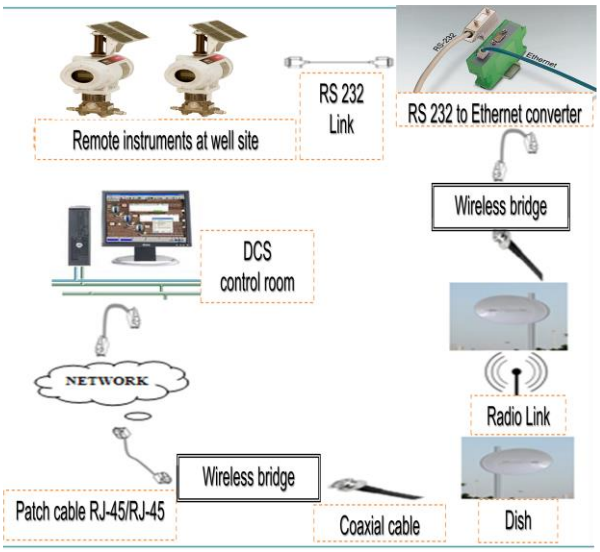

Fig. 2: Telemetry system.

The wireless bridge is connected directly to the switch of the DCS network cabinet, and then to be integrated in the network of the control system by an Ethernet cable.

Ethernet is now very well accepted in the industrial applications. However, controllers are often unable to communicate with these networks. The serial device server: RS 232 to Ethernet converter offers a solution that allows integration of serial interfaces in the 10/100 Base-TX industrial networks [Phoenix Contact 2009].

The data link between the converter and another component is performed using the RS-232 cable. The converter is equipped with a DCE (Data Communication Equipment).

Configuration, commissioning and diagnosis of this component can be made via the Web-Based-Management (WBM) using IP address with standard browsers without additional software, The "General setup" menu access is protected by a password.

On delivery or during a subsequent reset to the factory settings, the default IP parameters are:

IP Address: 192.168.231.254
Subnet mask: 255.255.255.0
Gateway: 0.0.0.0

Wireless network bridge configuration. This component is an outdoor unit compatible with 802.11b and 802.11g network norms. This component can play both roles: access point or bridge to provide wireless, high speed and economical network connections, between fixed and/or mobile clients [Cisco Systems 2002; Choi 2013].

In our project, it was required to raise a wireless network bridge link between oilfield wells and the DCS control room. We have started by creating network link which connects the wireless bridge to the LAN (Local Area Network) of the DCS system. Main terminal connection of this bridge was configured as "root" group and the secondary terminal connection as "Non-Root" group. The SSID (Service Set IDentifier) was then defined, for both sides of the link.

3.1.2 Radio propagation analysis

To perform the analysis of the radio propagation, we designed software which we called "SCADA Radio Transmission". The software role is to [Aouadj et al. 2017]:

- Determine the correct height of the towers by inserting the topographical data of the field, thus providing a radio clearance of the Fresnel first ellipsoid;
- Draw up, for the established link, a link budget including the received signal power

as well as the margin in relation to the reception threshold.

The (Fig. 3) represents « Radio link budget » window in which results of the transmission link budget are displayed with the heights of the emitting and receiving antennas towers.

On (Table 1) and (Table 2) are presented radio propagation analysis results between control system (LTU: Local Terminal Unit) and RTUs.

For radio link commissioning, we have performed operation check of the telemetry system configuration. From a PC on the primary bridge network connected to the DCS LAN via a switch, we have launched the ping command to the secondary bridge connected to the remote instrument via the converter.

3.1.3 Project software development

This is to verify that we can access the other secondary component of the remote group. The link commissioning tests have been carried out with success. This radio link using wireless network bridges enabled connecting remote sites of thirty kilometers far (line of sight).

This part explains software configuration steps using the following software:

- DCS software to create Tags and to configure the HMI.
- OPC (OPC: OLE for Process Control, OLE: Object Linking and Embedding) Server software to import Tags of the parameters saved in the remote instruments.
- DCS OPC Server software to import the created DCS Tags.
- OPC Data Manager Software to create Master-Slave relationships between the remote instruments OPC server and the DCS OPC server.

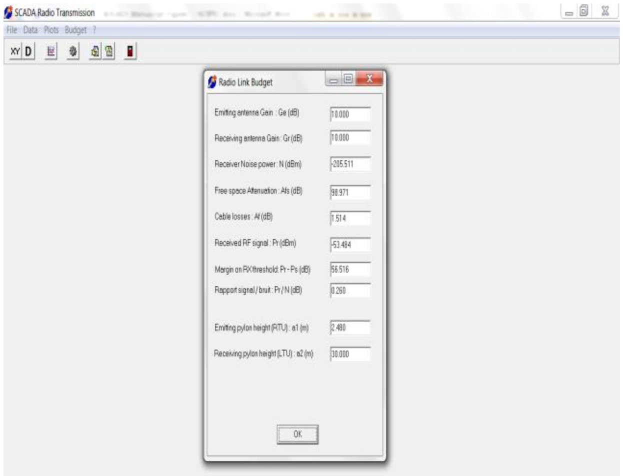

Fig. 3: Radio link budget results window.

After the hardware development we have started software configuration step; this will allow data transmission from the remote instruments up to the HMI control room (HMI: Human Machine Interface) of the DCS system. Software configuration steps are represented on Fig. 4:

- Using the OPC Server software, we have downloaded existing data from remote instruments.
- From these data we have created, using DCS software, the corresponding parameters Tags of the desired process parameters.
- Then, we have created Masters-Slaves relations between remote instruments OPC and DCS OPC software.
- The final step was the creation of the HMI interface to graphically represent all remote instruments parameters at the beginning of the configuration, then to be displayed and controlled by the operators in real time.

Table 1: Towers heights calculation results.

RTU	X	Y	Height (m)	Distance (m)	Obstacle height (m)	Obstacle distance(m)	Tower height (m)
CSJA 05	824320,00	128800,00	135	7049,5	165	2372	2,5
CSJA 04	823440,00	126800,00	135	5306,0	162	2594	0,8
CSJA 40	822109,13	125470,59	136	3631,3	169	665	1,8
CSJA 36	821184,00	125802,00	135	2836,3	140	1468	2,0
CSJA 34	823360,00	126885,00	150	5262,5	149	738	4,8
CSJA 06	823638,00	126977,00	136	5554,0	140	3001	3,8
CSJA 08,09	823605,00	126722,07	143	5426,1	168	4628	2,4

a.s.l.: above sea level; Factor k: Land profile between two fixed points based earth radius R = k x R_o (R: Radius of fictive earth; R_0 = 6400 km: real radius of earth); Using this fictive earth, associated to a rectilinear propagation; will simplify the study of radio transmission links.

Table 2: Radio link budget calculation results.

RTU	Distance (m)	Free space attenuation (Afs) (dB)	Cable length (m)	Cable losses (Af) (dB)	Received Signal (Pr) (dBm)	Margin on threshold (Pr – Pthres) (dB)
CSJA 05	7049,5	101,24	2,5	1,51	-55,76	54,24
CSJA 04	5306,0	98,77	0,8	1,36	-53,13	56,86
CSJA 40	3631,3	95,48	1,8	1,48	-49,96	60,03
CSJA 36	2836,3	93,33	2,0	1,49	-47,82	62,17
CSJA 34	5262,5	98,70	4,8	1,62	-53,33	56,67
CSJA 06	5554,0	99,17	3,8	1,58	-53,75	56,24
CSJA 08,09	5426,1	98,97	2,5	1,51	-53,48	56,51

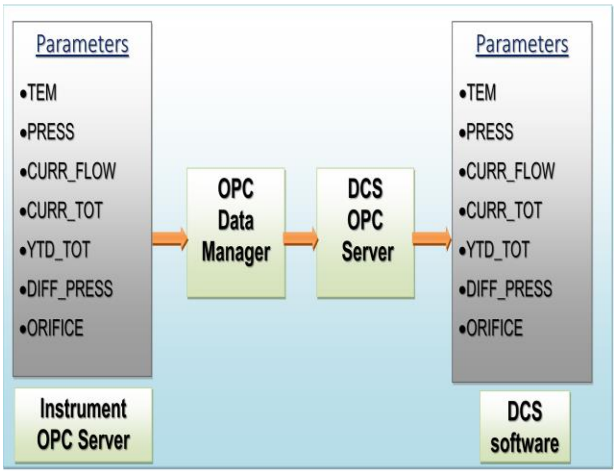

Fig. 4: Project software development steps.

On (Fig. 5) are represented installed RTUs for a sample wells from the studied oilfield.

3.2 Towards a SCADA system

The integration of remote control instruments in the DCS control system converges towards the creation of a unified DCS-SCADA control system. The idea is based on remotely acquire all data of oil collection network to the DCS control system, passing through a controller which plays as a gateway role.

The proposed system is composed of two levels:

Level I. It corresponds to the filed remote control instruments which they play the role of RTUs: Remote Terminal Units.

Level II. It corresponds to the intermediate point between the remote instruments and the control system. The proposed intermediate point is based on the installation of a controller, which is associated with the telemetry system described before.

All remote control instruments will be connected to the controller via network and then using the telemetry system connected to the controller, data can be transmitted to the DCS control.

4 CONCLUSION

New technologies offer multiple benefits which particularly guarantee fast return on investment, and excellent qualitative and quantitative results.

Industrial process modernization is valid by steps, by the choice of scalable platforms and reconfigurable architectures which allow implementing a full process control system, starting with few devices and extend to the cadence of needs and available budgets.

On the other hand, innovation rate of new technologies is such that we no longer know where stops the "old" and where begins the "new". This reflection on the integration of remote process control instruments in a DCS control system can therefore have only a provisional conclusion because each of the elements used in this project continue to progress continuously.

In this paper we proposed a method of using a DCS control system to monitor remote oil and gas wells particularly in large fields. This is important because we can save valuable time and money by using the same control system (DCS) for both: local central processing facilities and remote field process monitoring, this will significantly reduce operations costs. Over a case study, this approach has been applied in a pilot project (oilfield) to integrate remote instruments (used to acquire and control wells production parameters) in a DCS system. Project execution has been completed on both hardware and software parts, tests carried out were successful, which allow real time DCS supervision of all parameters acquired by the remote instruments. We proposed to extend this approach to all the other wells and remote processes of oil collection network which will constitute in final the creation of a unified DCS-SCADA control system.

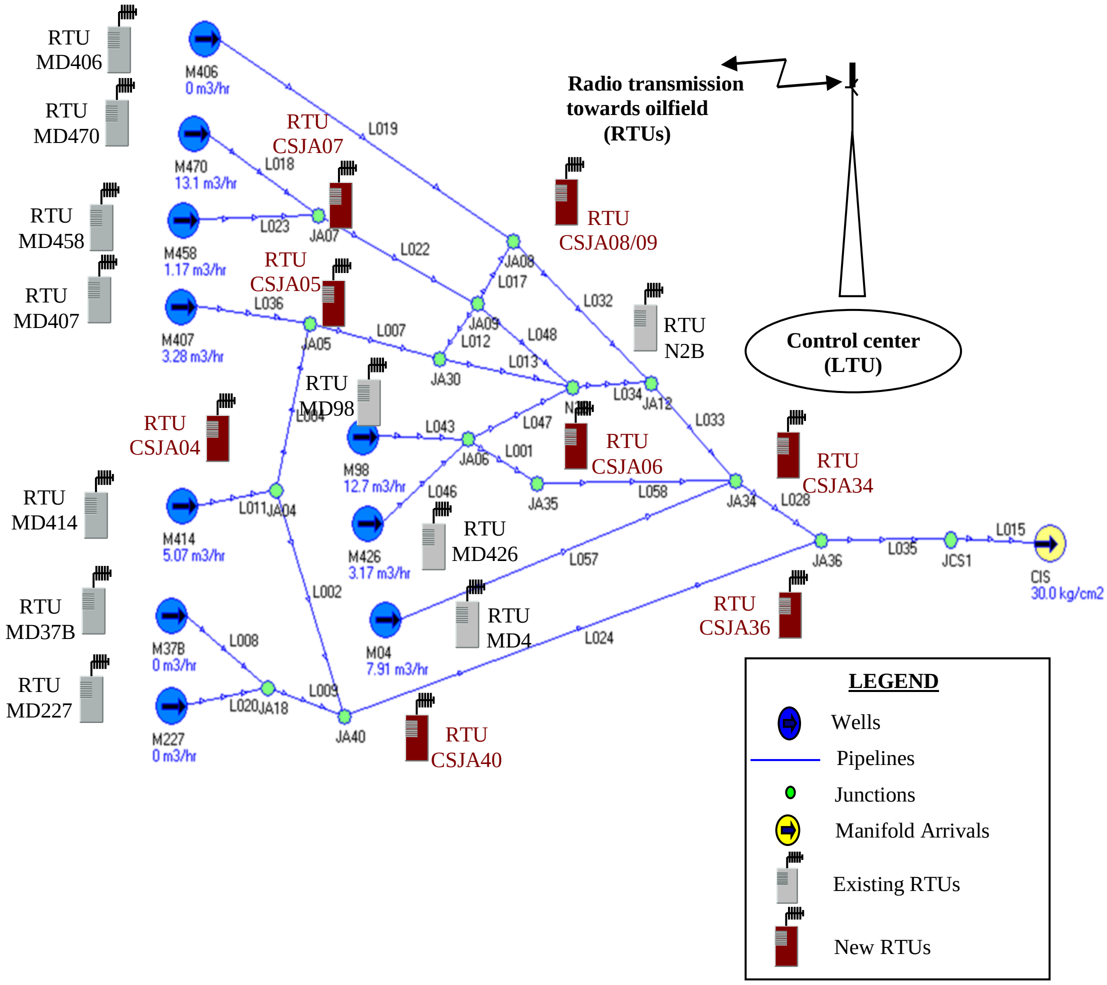

Fig. 5: Onsite distribution of telemetry equipments (RTUs).

By the consideration of new low-cost and wireless technological components, we target an innovative step forward in the feedback design of networked distributed systems by the development of unified Control, Computing and Communication (3C) aspects [Cardoso de Castro 2012]. We will emphasize wireless communications technologies with energy optimization (use of renewable photovoltaic energy).

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