

Research Article

SCADA System for the Modeling and Optimization of Oil Collecting Pipeline Network: A Case Study of Hassi Messaoud Oilfield

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Abstract: This study aims are data acquisition, control and online modeling of an oil collection pipeline network using a SCADA «Supervisory Control and Data Acquisition» system, allowing the optimization of this network in real time by creating more exact models of onsite facilities. Indeed, fast development of computing systems makes obsolete usage of old systems for which maintenance became more and more expensive and their performances don't comply any more with modern company operations. SCADA system is a telemetry and control system adapted for particular requirements of an oilfield management. Thanks to its different functions, we take advantage of this system to solve production problems especially those related to oil collecting pipeline network. In fact this network is confronted to some problems, in particular pressure losses which has significant effect on the production. This problem can be taken under control by the awareness of pipeline network operation and all its process data (especially junctions) in real time. This will allow online creation of representative and accurate computerized models for the oil collecting pipeline network including producing wells, collecting pipelines, manifolds and others facilities.

Keywords: Oil collection network modeling, oilfield pipeline network, pressure losses, SCADA system, telemetry

INTRODUCTION

Techniques used right now to manage, control and maintain oilfield wells, became more and more expensive on one hand and on the other hand performances of these techniques, in front of fast development of computing systems, doesn't meet any more with the requirements of modern company operations. More than this, supplied data are neither complete, nor precise to allow technicians quick intervention in order to correct onsite possible problem.

It is thus, on one hand an issue of renovation and on the other hand with the aim of optimizing the management of the installations (wells, manifolds and satellite centers), that large oilfields (like Hassi Messaoud one) has been equipped by a very powerful supervision and acquisition SCADA system. This system has for role to collect all the data in real time from field, thanks to a telemetry network working in the UHF (Ultra High Frequency) radio band. This SCADA system allows putting in connection, by a pyramidal structure, a vast network of oil wells with data acquisition units which their role is to record, process and broadcast the information.

The production of an oilfield depends on petrophysics parameters of the producing layer and the subsurface operating parameters. The good knowledge of these parameters allows choosing better subsurface installation and well size the oil collection network which connects the well with a manifold or with a separation station passing through several junctions. Oilfield pipeline network for oil collection may contain several junctions which connect two production pipes of two or several wells.

The variation of wells production parameters further to the oilfield operation in addition to the dilapidated pipeline network, these factors can negatively influence the field production. Oil wells could have fast increase of the GOR (Gas Oil Ratio) and of the pipe pressure, whereas their systems of collection stay without change. This situation requires fast actions on all the collection network process to re-configure it according to the current and projected potential of the field (Aouadj, 2003).

MATERIALS AND METHODS

Hassi Messaoud oilfield contains more than 1000 wells among which 750 are producing oil wells, the

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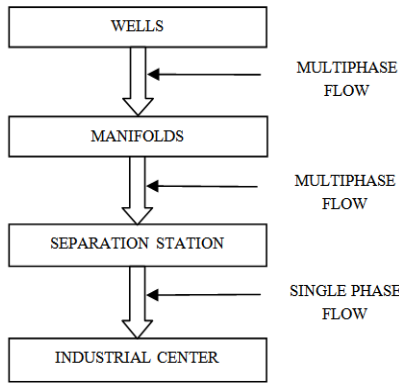


Fig. 1: Flow types in oil collection network

others are either closed, or gas and water injectors for underground pressure preservation.

Production of the producing wells is collected towards three processing centers: CIS (Centre Industriel Sud: Industrial South Center), CIN (Centre Industriel Nord: Industrial North Center) and recently UTBS (Unité de Traitement de Brut Sud: Crude oil Processing South Unit). Crude oil is collected to these centers by means of a pipeline collection network with a length of about 4500 km.

Hassi Messaoud oilfield consists of two different fields:

- North field
- South field

Every field consists of the following process installations:

- Oil producing wells
- Water and gas injectors wells
- Manifolds and gas lift stations
- (06) South satellite separation stations
- (08) North satellite separation stations
- Industrial processing centers: South and North

The oil collection network is composed by pipelines of various diameters, intended to convey hydrocarbons of the field towards industrial centers via manifolds and satellite stations (Fig. 1). The transport of these hydrocarbons is made by two types of flow:

- Single phase flow
- Multiphase flow

Generally pipelines of diameters 3", 4", 6" and 8" are used for the single phase flows, the big diameters are used for the multiphase ones.

According to the producing wells position, the Hassi Messaoud pipeline collection network is divided in two parts North and South. These networks contains the following manifolds and satellite stations (Aissani, 2012):

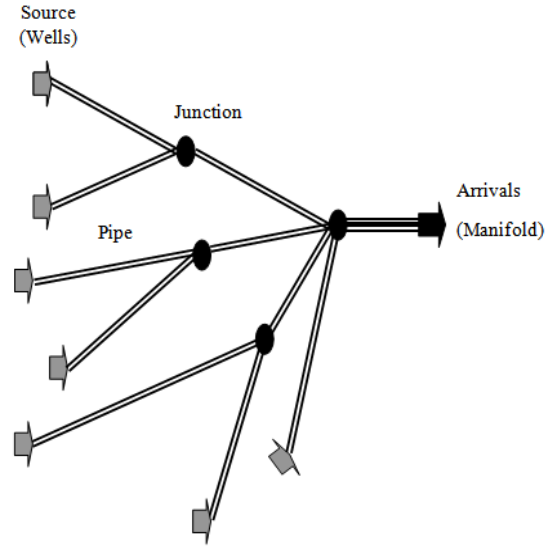


Fig. 2: Example of links by collectors

- Manifolds which are directly Connected to the North or South center (CIN or CIS)
- Satellite stations with different configurations:
 - **One manifold and one separator:** Oil and gas separated in these stations are conveyed to a second separation before being pumped towards the center, the gas is compressed before its expedition
- One manifold, one separator and two immersed pumps with one in service and the other on stand-by
- An entry manifold, two production separators, test separator, centrifugal pumps and one or two compressors

Due to the large scale of the field, Hassi Messaoud collection network uses the method of links by collectors (Fig. 2) which is characterized by the choice of one or several onsite groupings where reach individual pipes of wells.

Problems on the oil collection network: The main problem which has an effect on the oil collection network is the increase of the pressure losses which is due to the production braking by the presence of bottlenecks in the network. This increase of the pressure losses has a considerable effect on field production.

In all flow types, the equation of pressure loss consists of three terms (Fig. 3):

- The elevation factor or static factor
- The friction factor
- The acceleration factor

Such as: Total pressure losses = pressure losses by friction + pressure losses by elevation + pressure losses by acceleration.

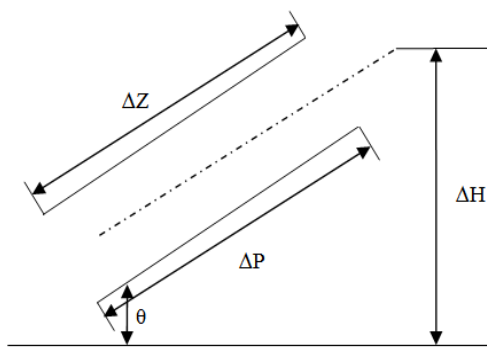


Fig. 3: Inclined pipeline section example
 ΔP : Pressure loss; ΔZ : Section length; ΔH : Elevation;
 θ : Inclination

Besides the problem of pressure losses, Hassi Messaoud oil collection network also is affected by the problem of leaks which are due to internal and external pipelines corrosion due to the water settling in lower part of pipes.

Pressure losses causes: The production braking in Hassi Messaoud oil collection network is essentially due to:

- The increase of pressure at manifolds, due to a blocking or an under sizing of collectors
- Considerable interferences of junction connected wells due to the increase of the GOR or the oil flow
- The degradation of pipelines flow properties

Problem resolution: The problem of pressure losses increase in the collection network can be mastered by the functioning state knowledge of this network and all its data. It can be made by real time follow-up of all production chain parameters (from wells up to the processing centers). These real time acquired parameters, are also going to allow creating exact and precise computing models of the collection network. These models are going to be very useful for future modifications and simulations.

Oilfield network collection modeling: The main objective of this effort consists in creating an exact and precise computerized model of the productive wells, collection lines (pipelines), manifolds and satellite separation installations associated with the Hassi Messaoud oil collection. Once created, this model can serve to optimize the current production of the field and to predict the effects of future changes on the oil, gas and water flows according to production forecasts. Besides, this model can be used to develop directives and procedures for the inclusion of new wells, lines of collection and future satellite separation installations.

It consists in collecting enough data in order to calculate flow between wells and manifolds and to supply pressure data at the extremities of pipelines.

These data should be used as input data to hydraulic model of the computerized field, obtained by of the PIPEPHASE SimSci software. The results of the computer calculations can be compared to the pressures measured on the field, after performing reasonable adjustment in the limits of variables accuracy and correlations. Once this hydraulic model developed and compared to the data obtained from the field, it can be used as a simulation program tool for the future change effects on the flow rates, gas-oil reports, line dimensions, etc. Previously, a team from the oil collection department at Sonatrach-DP has been assigned a task of collecting data from operating wells of Hassi Messaoud North and South fields. The selected wells and all the manifolds were controlled by means of digital manometers recorders during periods of 24 h or more (Zeddami, 1998). Other wells in operation were watched during periods of approximately 10 min, upstream and downstream to the wellhead choke (when available). Thus, this method of collecting data represent time lost and delayed data.

Modeling principle: The modeling is performed thanks to a simulator called "PIPEPHASE" and must follow the following steps (Bevil, 2001):

- Introduction of the network collection data and the current production
- Calculation of the pressure losses
- Comparison of measured and calculated pressure losses
- Model adjustment by eliminating the differences between the measured and calculated pressure losses

The principle of calculation is based on nodes and pipes system. The nodes are designated by the sources of flow (wells) and connection points (junctions) and the pipes by the portions between the nodes.

Before beginning the study of a given problem it is necessary to collect all needed data. Thus, the team from oil collection department must make on field visits to bring up pressures and temperatures measures, in addition they should also contact various departments to have actual wells states and collect the latest flow rates and GOR (Gas Oil Ratio) of producing wells, which ultimately constitutes a loss of time and delayed information.

Pressure losses computing: The PIPEPHASE is a simulation program that predicts pressure and temperatures states of studied wells, pipes and other linear networked configurations of pipes, wells, pumps, compressors, separators and other facilities. The PIPEPHASE can handle single phase flows (liquid or gas) as it can handle the multiphase mixtures of gas or liquid (Bevil, 2001). There are two main calculation modules in PIPEPHASE, namely, Single-Link and Network.

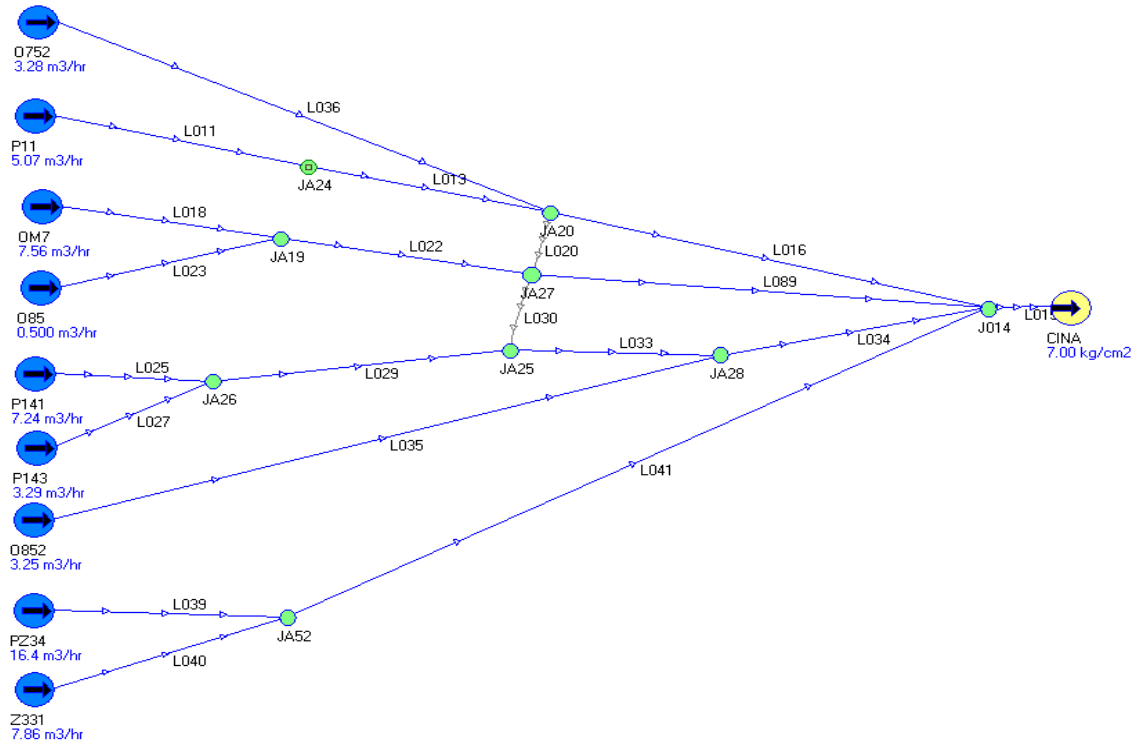


Fig. 4: CIN oil collection network model (plot with PIPEPHASE)

To calculate the pressure losses with PIPEPHASE between an input (source) and one output (arrival), it is necessary to set the flow rate or pressure at the entry and estimate it at the output. The estimated parameter will be calculated by PIPEPHASE.

Pressure losses calculation procedure: The pressure losses computing procedure is based on the following steps (Simulation Sciences Inc., 1993; Bevil, 2001):

- Sources (wells) and Sinks (arrivals: Manifolds, Junctions, Separators) positioning and then link them by Links (pipes)
- Insert necessary data for each part of the network: (Fig. 4)
 - Sources (wells):
 - Name of the source
 - P_{pipe} : Estimated pipe Pressure (measured on field)
 - Q_o : Fixed oil flow
 - GOR ("Gas Oil Ratio" Q_{gas}/Q_{oil})
 - T_t : Well head temperature
 - % eau: Water proportion
 - Sinks (JCT: Junction, MFD: ManiFold, SEP: SEPARATOR):
 - Q_o : Total estimated oil flow;
 - $P_{arrival}$: Arrival fixed Pressures (junction Pressure « P_{jct} », manifold Pressure « P_{mfd} », separator Pressure « P_{sep} »);
 - $T_{arrival}$: Arrival Temperatures
 - Links (pipes):

- Length;
- Diameter;
- Ambient Temperature
- Elevation
- Roughness and flow efficiency
- Correlation Type (B.B.M.«Beggs/Brill/Moody» and D.E. «Dukler/Eaton/flannigan»)
- In Hassi Messaoud oilfield we use D.E. correlation which is based on the «flow efficiency» pipe characteristic

- After the software «Run», we must compare calculated pressure losses with the measured ones in order to estimate the typical deviation, if the difference between the two pressure losses is negligible (<10%) the model is representative, otherwise, it must be adjusted by changing few data of pipes for which deviation of the pressure losses exceeds 10%, the modified data could be
 - The estimated oil flow " Q_o " of sources from which the model doesn't converge, with a modification of $\pm 10\%$
 - The flow efficiency, it is initially set to 100% and then it is decreased until the calculated values converge to the measured ones
 - The correlation type

RESULTS AND DISCUSSION

Pressure losses calculation results: Usually, the measured pressure losses are greater than the calculated

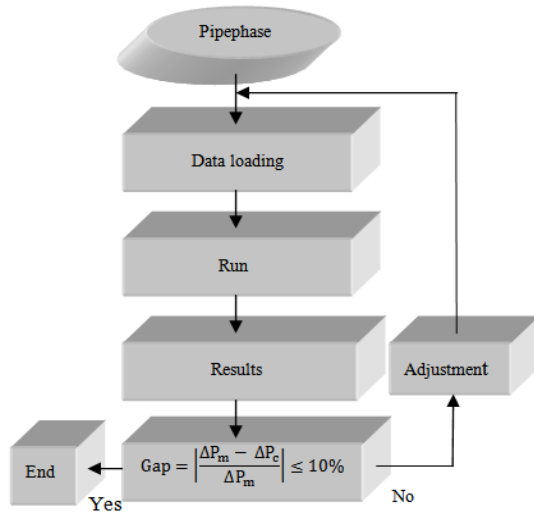


Fig. 5: Model adjustment procedure

ones. The causes of these discrepancies can be explained differently:

- Deposits inside the pipes
- Corrosion
- Inaccuracy of the flow rate values

To build a model, we reduce this gap by adjusting some parameters. Due to the absence of some production data (especially junction’s data) of the pipeline network, we can’t calculate pressure losses for every single line of pipe.

Model adjustment: The adjustment (Fig. 5) is to find a referential model that reflects the current state of the collection network (Zeddami, 1998) with the latest wells production and pressures. We should adjust a model when there is a large gap between the measured and calculated pressure losses. The adjustment of our model is assumed acceptable when the difference does not exceed 10%:

$$\text{Gap} = \left| \frac{\Delta P_m - \Delta P_c}{\Delta P_m} \right| \leq 10\% \tag{1}$$

where,

ΔP_m : Measured pressure losses

ΔP_c : Calculated pressure losses

When the difference is greater than 50%, we must first change the pipe roughness and the flow efficiency. Once the gap becomes less than 50%, we modify the pipe diameter up to convergence.

Adjustment results (Table 1 and Fig. 6):

- After adjustment, the pressure losses are closer.
- The convergence of pressure losses caused the diameter change of (05) five pipeline sections.
- The parameters obtained after the adjustment do not represent the current settings of the network, the fact that there is a lack of data which does not allow the accurate calculation of pressure losses. Therefore, this model does not really represent the real model.

Benefits of using a SCADA system for pipeline network modeling: According to the results of the studied example, we can deduce that the production parameters values obtained after the adjustment doesn’t converge to the onsite values unless we were in possession of the production parameters of the whole collection network (particularly junctions parameters). This would allow us to know the real pressure losses on each part of the collection network and consequently better locate the problems and have a valid model.

In order to make this study to be even more efficient, we suggested to deport a terminal to the oil collection department office, this will help engineers (especially those responsible for the modeling) to monitor operation and modeling of Hassi Messaoud oilfield pipeline network in real time. This can be

Table 1: Pressure losses calculation example before and after adjustment

Parameters	Before adjustment					After adjustment		
	Pp _m bar	Pp _c bar	ΔP _m bar	ΔP _c bar	Gap (%)	Pp _c bar	ΔP _c bar	Gap (%)
Wells								
OMO 752	13.5	13.58	3.0	3.08	2.66	13.58	3.08	5.50
OMP 11	12.5	12.39	2.0	1.89	5.50	12.39	1.89	2.66
OM 7	12.6	10.76	2.1	0.26	87.60	12.45	1.95	7.14
OMO 85	10.8	10.53	0.3	0.03	90.00	10.78	0.28	6.66
OMP 141	11.0	11.10	0.5	0.60	20.00	10.98	0.48	4.00
OMP 143	13.1	11.01	2.6	0.51	80.40	12.87	2.37	8.84
OMO 852	11.5	11.40	1.0	0.90	10.00	11.40	0.90	10.00
OMPZ 34	11.2	10.95	0.7	0.45	34.00	11.16	0.66	5.71
OMPZ 331	13.0	10.71	2.5	0.21	90.40	12.86	2.36	5.50

Pp_m: Measured pipe pressure; ΔP_m: Measured pressure losses = Pp_m-P_{mfd}; Pp_c: Calculated pipe pressure; ΔP_c: Calculated pressure losses = Pp_c - P_{mfd}; P_{mfd} = 10.5 bar: CIN manifold arrivals pressure

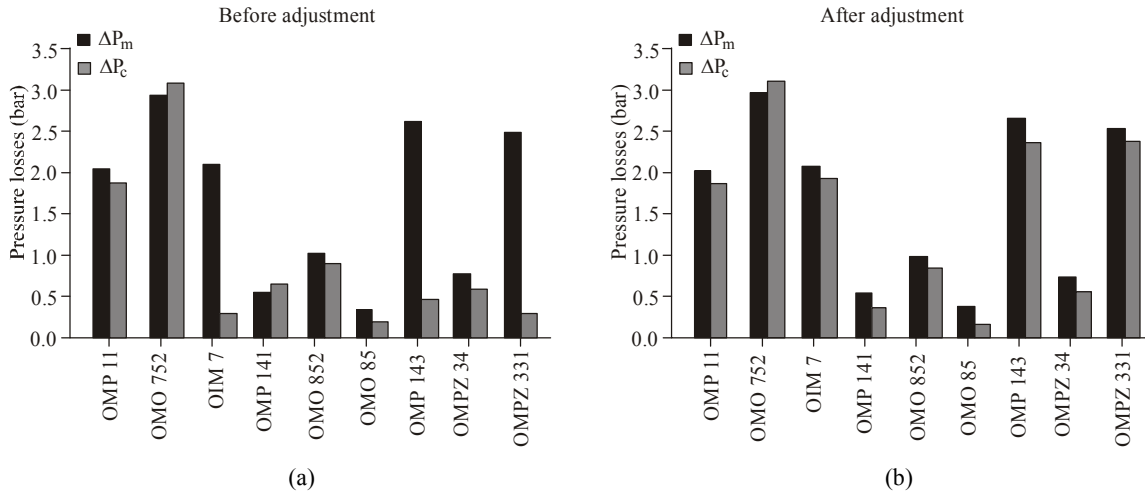


Fig. 6: Pressure losses before and after adjustment

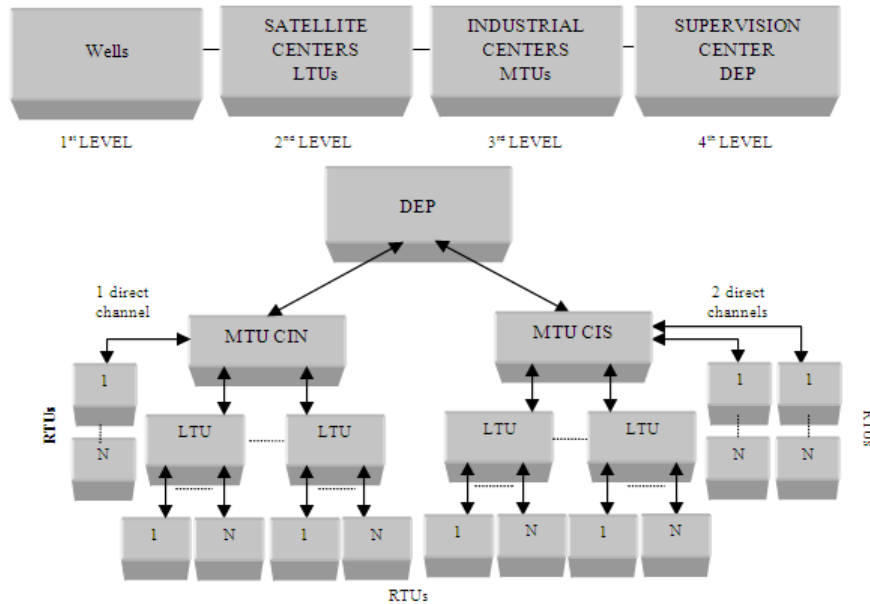


Fig. 7: The design of SCADA system installed for Hassi Messaoud oilfield

done by the creation of a V-LAN (Baraka, 1999) by using a new mask of IP network addresses.

The production data acquisition of the network collection, from an end-to-end, using a SCADA system will allow having more accurate model and therefore to approach more and more to the real network existing onsite and so we will have to compare pressure losses (and not only pressures) calculated with those measured per kilometer with accuracy:

$$\frac{\Delta P_c}{Km} / \frac{\Delta P_m}{Km}$$

$\frac{\Delta P_c}{Km}$: Pressure losses calculated per kilometer

$\frac{\Delta P_m}{Km}$: Pressure losses calculated per kilometer

This will allow an optimal results prediction of changes made on the field.

Oilfield SCADA system design: As used in Hassi Messaoud oilfield, the SCADA system general architecture is divided into four levels, with a master-slave communication philosophy (Fig. 7) (Aouadj, 2003).

First level: It corresponds to wells which are equipped with RTU (Remote Terminal Unit). This is the acquisition unit located at on each well site.

Second level: It corresponds to the satellite centers which are equipped by LTU (Local Terminal Unit). It is a data hub and also plays an intermediary role between wells and the industrial center.



Fig. 8: Onsite RTU equipment

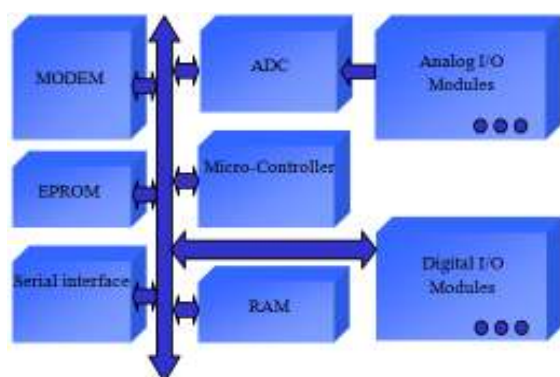


Fig. 9: RTU data acquisition blocks

ADC: Analog to digital converter; EPROM: Internal memory containing resident program that performs the functions of the RTU; RAM: Cache memory containing intermediate data; MODEM: Integrated in the communication module

Third level: It corresponds to the North and South industrial centers which are both equipped with MTU (Master Terminal Unit). It is here that arrive and where are processed all the data from LTUs.

Fourth level: It corresponds to the supervision center DEP (Division Engineering and Production), it is responsible for the collection of all Hassi Messaoud oil field information throughout the two industrial centers North and South.

We can divide equipments of the SCADA system in two blocks:

- Well site SCADA equipment
- Control rooms SCADA equipment

Well site SCADA equipments:

Transmitters: Transmitters are intelligent sensors used for the physical acquisition of field data (analog such as: wellhead Pressure and Temperature, digital such as: wells shutdown valve state) by issuing an electrical signal of 4 to 20 mA. They are powered (24 v) by a photovoltaic power supply (Nuovo Pignone DSA, 1998).

RTU « Remote Terminal Unit »: RTU is an intelligent and independent data acquisition station that allows processing the acquired data (Fig. 8). The field data acquisition passes through the blocks illustrated on (Fig. 9) (Microwave Data Systems, 1994).

RTU power supply system: All RTUs at the level of wells (Aouadj, 2003), manifolds and others field installations have been equipped with a solar energy system composed of (Fig. 10).

Photovoltaic solar panels: Each solar panel is composed of two photovoltaic modules and each module is composed of 36 serial connected cells. Each module has the following characteristics:

- Voltage: 12 v
- Maximum power: 75 w
- Open circuit voltage Voc: 7 v
- Closed circuit current Icc: 4, 8 A

Batteries: The batteries used are stationary type without maintenance. On each RTU we can find two serial connected batteries and each of them is composed of 6 serial connected cells. Each battery has a nominal capacity of 12 v and a power of 105 Amp/h (Ampere/Hour), the two serial connected batteries provide a voltage of 24 v. The life duration of these batteries, up to 80% of their capacity, is 500 cycles which is equivalent to 13 years of operation.

Charge regulator: Charge regulating system (Siemens, 1997) is an element of the photovoltaic system which

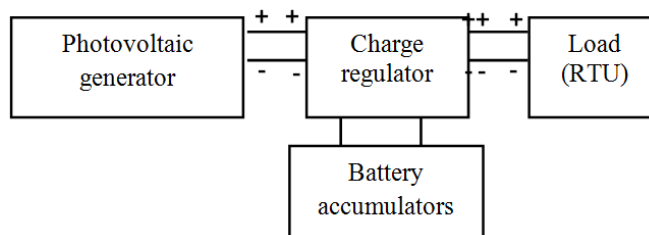


Fig. 10: Block diagram of a photovoltaic installation

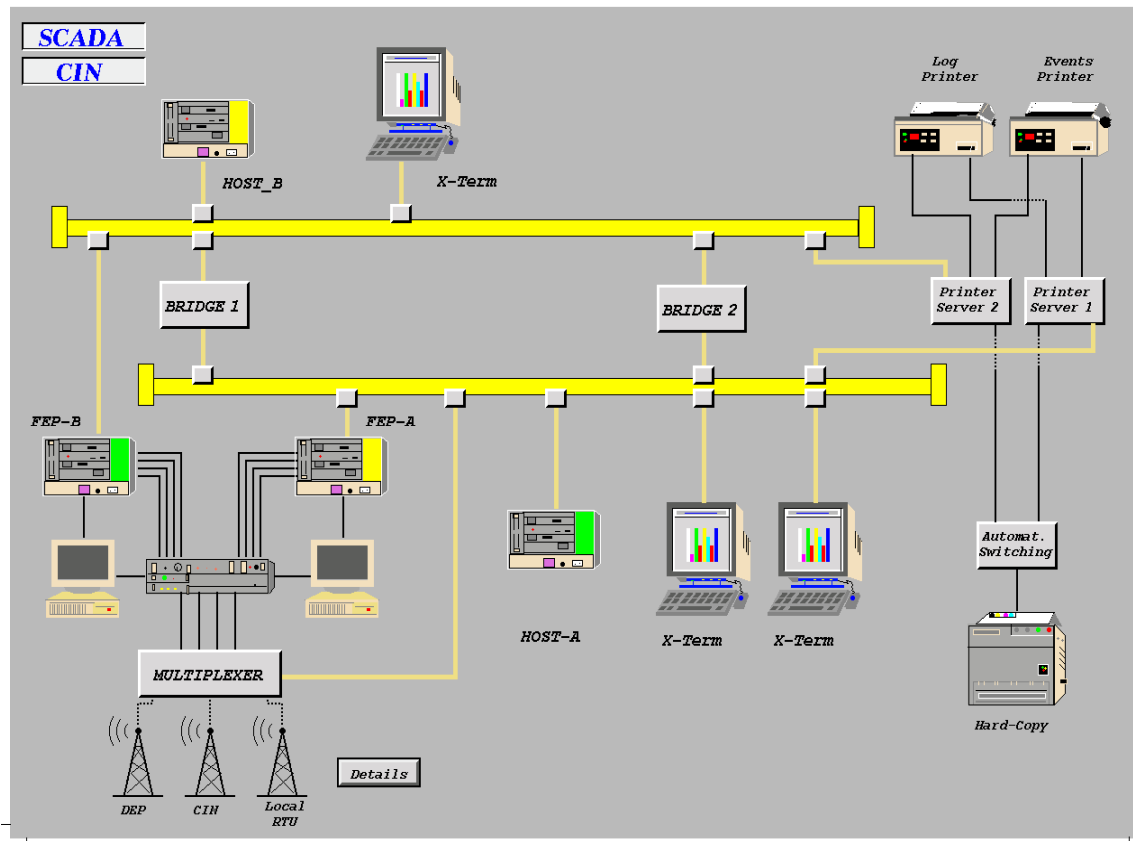


Fig. 11: MTU representation of the CIN industrial center on the SCADA system

aims to check the charge and the discharge of the battery in order to maximize its life duration. We will maintain the voltage by element of battery between 11 v and 14, 4 v for a 12 v battery. The charge regulator is an RTU module used will monitor the state of charge (SOC: State of Charge) of the battery, the charging process defines the cases in which different elements of the RTU are operating or not.

SCADA equipments in control rooms: L.T.U. « Local Terminal Unit »: It is a processing and monitoring station of local data of the satellite center and wells data which are assigned to this center. Main tasks of this unit are:

- **Perform a dual function:** Acquiring RTUs data and responds to queries coming from the MTUs
- Has a local integrated RTU reserved for local data acquisition of the satellite center
- Allows the transmission of data with two types of radios
- Point-to-multipoint for communications with the RTUs (Lakehal, 2001)
- Point-to-point for communications with the MTUs

M.T.U. « Master Terminal Unit »: This is the master station of the system (Fig. 11) also called Host that

allows the processing and the representation of data received from the LTUs and RTUs. Its main tasks are:

- Allows on one hand the reception of field data (measurements, alarms etc.) and on the other hand sends commands toward both LTUs and RTUs
- Manage the local area network LAN Ethernet
- Performs the data transmission with two types of radios
- Point-to-multipoint for communication with the RTUs and the LTUs
- Point to Point in HF (High Frequencies) band (900 MHz) for communications with the DEP center (Lakehal, 2001)

Supervision center D.E.P. «Direction of Engineering and Production»: All data relating to all wells and to all facilities of Hassi Messaoud field are collected at this center (Fig. 12). It is mainly characterized by:

- The data doesn't arrive directly from wells, but rather from the industrial centers through the HF connections
- Two redundant Hosts or MTUs with hardware configuration identical to those at the industrial centers

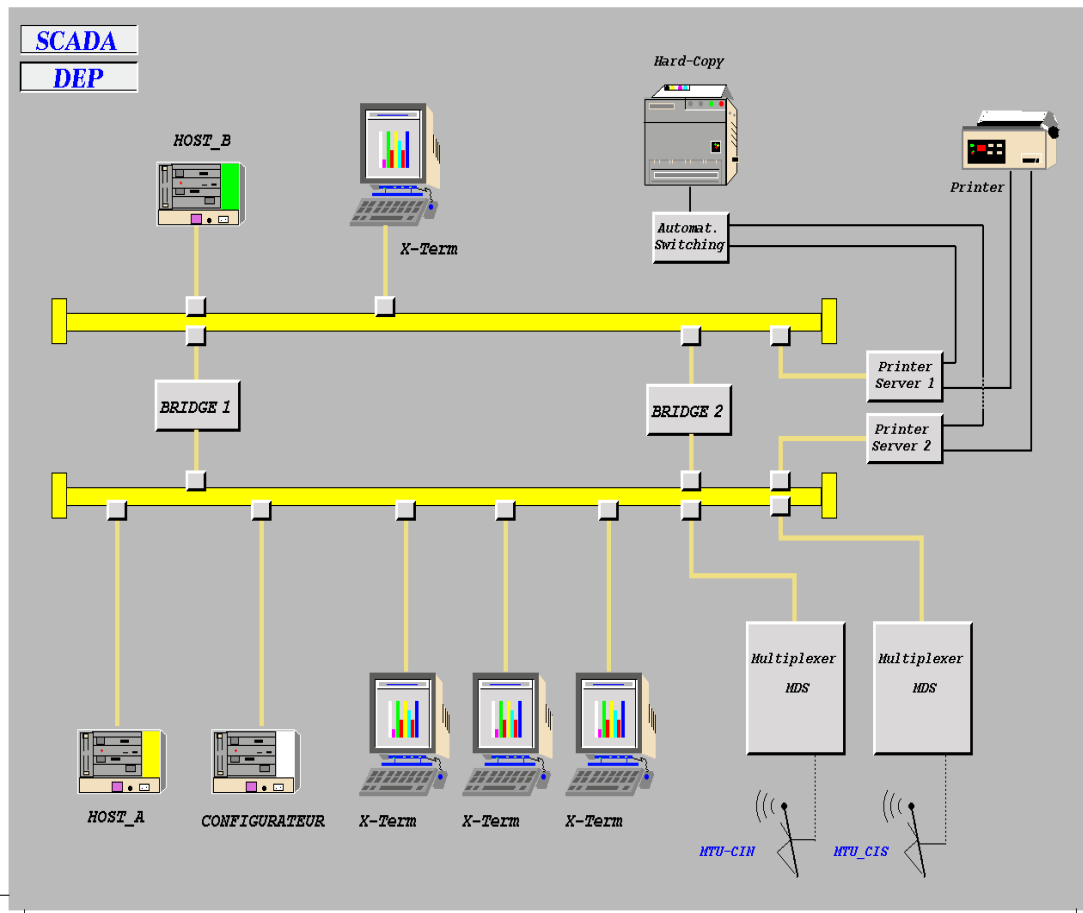


Fig. 12: DEP supervision station representation on the SCADA system

- A configurator which is used for the SCADA system database configuration and initialization
- The vital elements of the center are redundant this provides more security and high availability

Pipeline network data acquisition by SCADA system: For the data acquisition by the SCADA system, we proceed by the following steps:

- Field instrumentation equipment sizing (transmitters, RTUs, etc.)
- On field electrical energy system sizing
- Radio propagation analysis
- System database configuration

Sizing of on field telemetry equipments: For this phase, it was essentially to size the following equipments (Table 2):

- **Transmitters:** The type (parameter "pressure or temperature", range, calibration) and the number (parameters) regarding to the installation on field (well, junction, manifold or other)
- **RTUs:** The type (size the acquisition cards, Zener barriers "intrinsic protection") (Hutcheon, 1990)

Electrical energy system sizing:

- The Radio

Emission mode: The radio is usually in emission mode during 3 h/day, it consumes 3 A at a voltage of 12 v, which gives a consumption of:

$$3A \times 12v \times 3H = 108 WH \text{ (Watt/Hour)}$$

Reception mode: The radio is usually in reception mode during 21 h/day; in this case it consumes a current of 0.065 A at 12 v which gives a consumption of:

$$0.065A \times 12v \times 21H = 16.4 WH$$

The 24/12 v converter losses: The 24/12 v converter losses are estimated to 13.8 WH.

The RTU: The RTU consumption is 6WH, under a voltage of 24 v, this will gives a daily consumption of:

$$24H \times 6W = 144 WH$$

Table 2: On field instruments sizing example

Well : SOPWGL RTU type: C		Barriers number de A.I. = 04	Barriers number D.I. = 01	Relay number = 01
Parameters	Designation	Range		
1	PT 1	Well head pressure transmitter	0-250 bar	
2	PT 2	Producing line pressure transmitter	0-100 bar	
3	PT 3	7" annular pressure transmitter	0-350 bar	
4	PT 4	9" 5/8 annular pressure transmitter	0-300 bar	
5	PT 5	GL injection pressure transmitter	0-300 bar	
6	PT 6	Pump suction pressure transmitter	0-20 bar	
7	PT 7	Pump discharge pressure transmitter	0-250 bar	
8	PT 8	Gas lift pressure transmitter	0-300 bar	
9	FT 1	Gas lift flow transmitter	0-1000 mb	
10	TT 1	Gas lift temperature transmitter	-10-100°C	
11	TT 2	Well head temperature transmitter	0-100°C	
12	SDV	Well shutdown valve command		

SOPWGL: Saline oil producing well with gas lift; A.I.: Analog input; D.I.: Digital input; PT: Pressure transmitter; TT: Temperature transmitter; FT: Flow transmitter; SDV: Shutdown valve

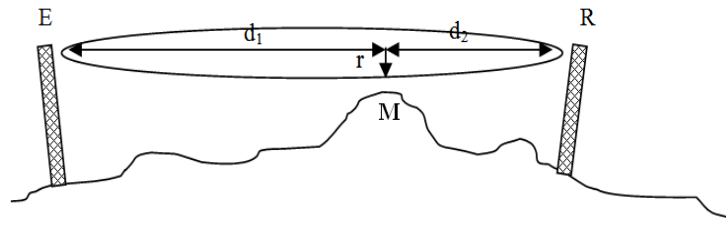


Fig. 13: Fresnel ellipsoid

The transmitters: Every transmitter has a consumption of 0.9 W/24 h.

Example: Saline Oil Producing Well with Gas Lift (SOPWGL).

A SOPWGL wells are equipped with 11 transmitters (PT, TT and FT) which gives a consumption of:

$$0.9W \times 24v \times 11 = 237.6 WH$$

Therefore SOPWGL wells telemetry installation will have an absorbed power of:

$$108 + 16.4 + 13.8 + 144 + 237.6 = 519.8 WH$$

Under 24 v voltage, we will have an absorbed hour current (Amperes-Hour: AH) of:

$$\frac{519.8 WH}{24 v} = 21.65 AH$$

With a nominal capacity of 12 v and a power of 105 AH, battery life will be:

$$\frac{105 AH}{21.65 AH} = 4.85 days$$

From the sizing of the electrical energy system, we obtain 4 days battery life autonomy.

Radio propagation analysis:

Transmitting antennas heights calculation: The determination of the towers heights has been performed in order to have a good radio clearance (Fresnel Zone) (Combes, 1988; Brault and Piat, 1997).

The plot of 1st Fresnel ellipsoid: We have calculated the radius of the ellipsoid for each point of the transmission link path by applying the formula of calculation which gives the radius of the ellipsoid at the topographic relief point (Fig. 13).

The plot of the transmission link is to determine the heights of the on field radio stations and Central radio Stations in the Industrial Centers (CIS and CIN) control rooms, taking in consideration the radio clearance necessary to a good spread:

$$r_i = \sqrt{\frac{d_1 d_2}{(d_1 + d_2)}} \lambda \tag{2}$$

where,

- r_i : Fresnel ellipsoid radius at a point i of the path
- d_1 : Distance of the point from the transmitter
- d_2 : Distance of the point from the receiver
- λ : Transmission wave length

All this requires topographic data of field installations (wells, junctions, manifolds, etc.) including:

- Topographic coordinates (X, Y, Z)
- Obstacles heights

- And distances

Radio link budget calculations:

Calculation of the power received on a hop: The power received on a hop (Zidane, 1997) is given by the following equation:

$$P_r(dB) = P_e + G_e + G_r - A_{br} - A_f - A_{fs} \quad (3)$$

where,

- P_e : Emitted power
- P_r : Received power
- G_e : Emitting antenna Gain
- G_r : Receiving antenna Gain
- A_{br} : Branching losses
- A_f : Feeders Attenuation (cable losses)
- A_{fs} : Free space Attenuation

Noise power calculation:

$$N = 10 \log(kTB F_N) \quad (4)$$

where,

- N = Receiver Noise power
- k = $1,38 \cdot 10^{-23}$ J/°K: Boltzmann constant
- B = 10 MHz: bandwidth frequency
- T = 20°C (293, 15°K): Ambient temperature
- F_N = Receiver noise factor

Then, it was necessary to determine the main characteristics necessary for the establishment of the transmission link report, such as:

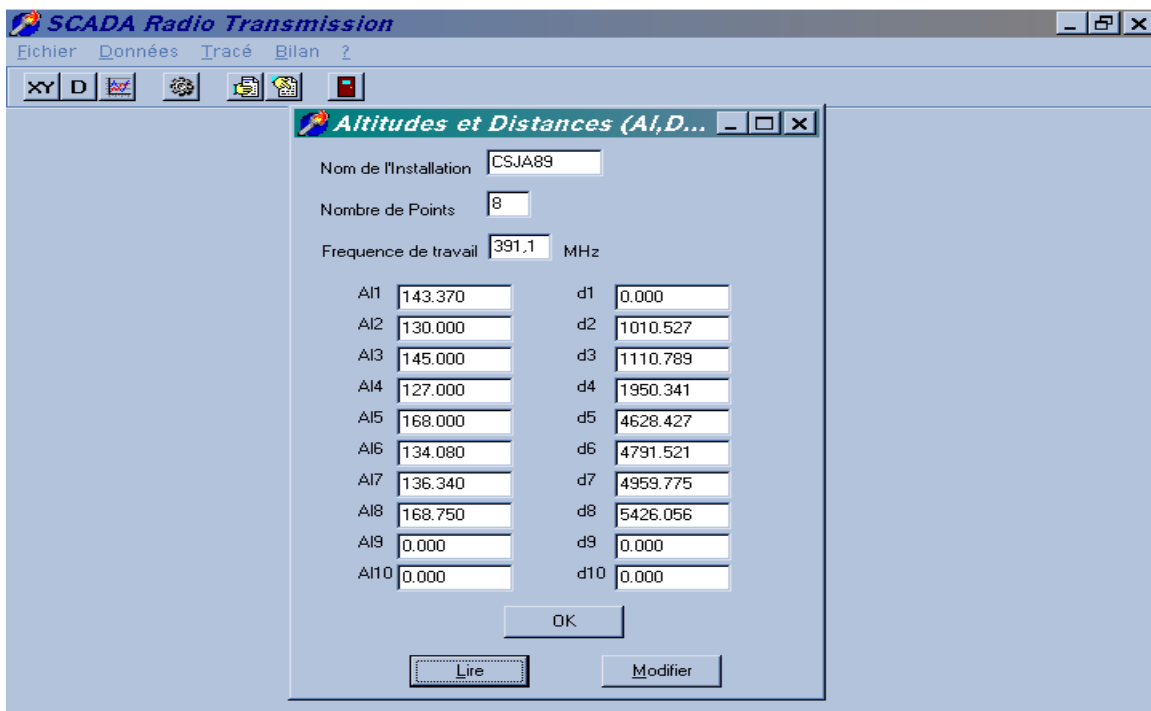
- The data characteristics of the transmission equipment
- And the different attenuations of the signal

Note: A digital radio transmission can be considered as functional (Rossi, 1998) if the received signal level is higher than or equal to the threshold (-110 dB), if the level is at the threshold, the link is considered to be cut off.

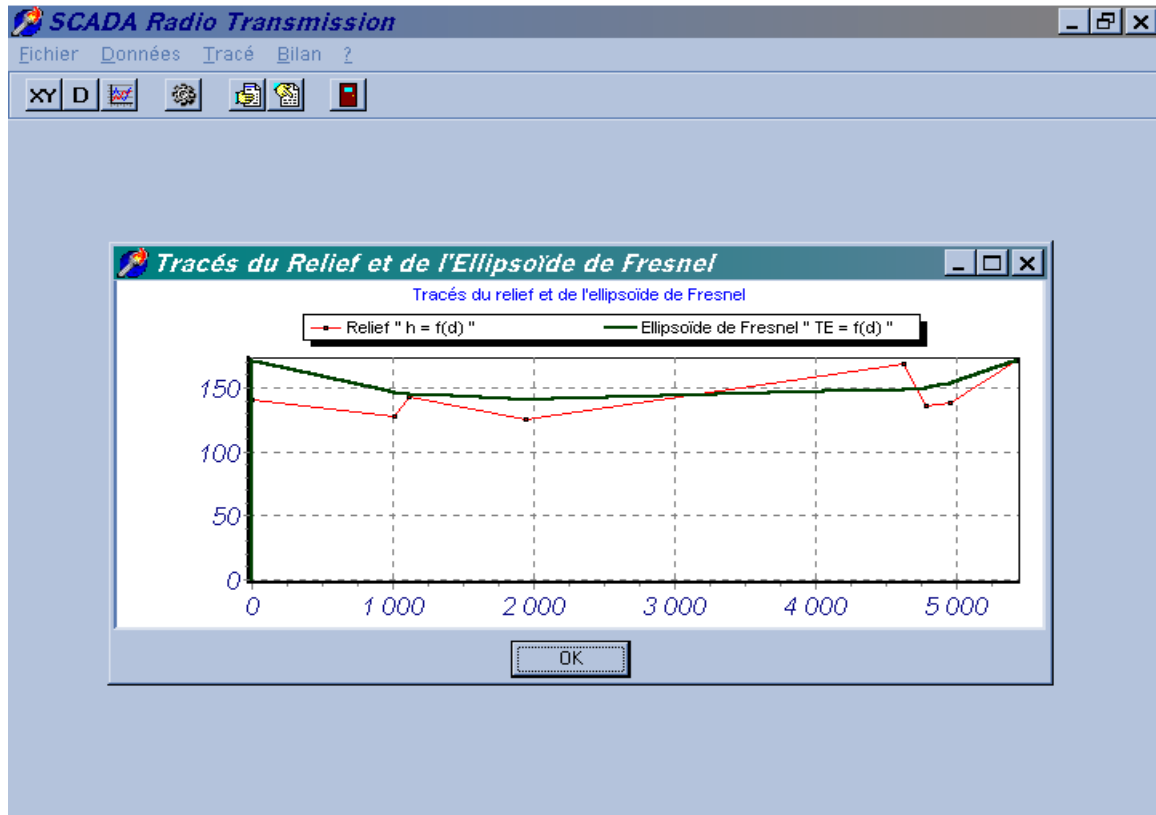
Software for the radio propagation analysis: To perform the analysis of the radio propagation, we have designed software which we called "SCADA Radio Transmission". The software role is to:

- 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.
- In addition, this software allows the adjustment of the pylons heights in order to rectify any diffraction, due to bad visibility hop. Thus, we will save valuable time, as well as a precision traces on the graph of the link profile.

Calculations data: We used the geographical data of Hassi Messaoud area as well as the characteristics data



(a)
799



(b)

Fig. 14: Radio propagation analysis software (a) topographic data (Al, d) window, (b) Fresnel ellipsoid trace display window

of the transmission equipment, based respectively on the topographic map of the Hassi Messaoud region and Foxboro SCADA telemetry project documentation (Rossi, 1998).

Geographic data of Hassi Messaoud region:

- **X, Y:** Are the geographic coordinates of a point on the road network map of Hassi Messaoud field.
- **Al:** Is the Altitude of a point on the topographic map above sea level.

Software description: The software program we designed has been produced under the object oriented Pascal compiler (Borland Delphi) (Belaid and Bardou, 2001). It is presented as follows:

- A main menu which includes all the features of the software
- A window «Coordonnées (x, y)» (coordinates (x, y)) which allows to insert the geographical coordinates (x, y)
- A window «Altitudes and Distances (Al, D)» (Fig. 14a) which allows to insert altitudes and positions of the points corresponding to the coordinates (x, y)

- A window of graphs «Tracés du relief et de l'Ellipsoïde de Fresnel» (Fig. 14b) (Traces of land and the ellipsoid of Fresnel) which allows to view the following plots of the link:
 - Profile of land relief
 - Fresnel ellipsoid
- A window «Données Caractéristiques du Matériel» (Characteristics data of the Hardware) in order to insert characteristics data of the transmission equipment
- A window «Bilan de Liaison» (Radio link budget) which allows to view the results of the transmission link budget with the heights of the emitting (RTU) and receiving (LTU) towers
- Finally, a window «Correction des hauteurs de Pylônes» (Towers heights Adjustment) which allows inserting height correction of the receiving tower

On (Table 3a and b) are presented radio propagation analysis results of RTUs installed for the studied oil collection network.

SCADA database configuration: The «P6009 Configurator» is the tool used to access to the database source. It allows all database management functions,

Table 3: Radio propagation analysis results

(a)							
LTU (CIN)	X		818375.00		Y		138000.00
	Height a.s.l. (m)		156.55		Transmission frequency (MHz)		391.00
	Tower height (m)		30		Factor k		1.33
RTU	X	Y	Height (m)	Distance (m)	Obstacle height (m)	Obstacle distance (m)	Tower height (m)
CNJA 24	820000.00	136320.00	135	7910.8	165	2300.0	3.4
CNJA 26	820800.00	135440.00	165	3396.0	162	1903.2	21.4
CNJA 19	820500.25	136249.83	162	3038.0	170	2650.1	19.7
CNJA 20, 25, 27	819999.81	136250.11	155	2387.0	156	2000.0	0.9
CNJA 28	819513.25	137920.81	162	1200.0	160	907.7	4.0
CNJA 52	822500.19	134400.00	168	5276.8	162	3780.0	2.8
OMO 752	818400.00	136960.00	145	1200.0	160	1000.0	1.1
OMPZ 331	822800.00	134000.00	168	5956.8	162	4460.0	17.6
OMPZ 34	823360.00	135200.00	168	6356.8	171	1696.8	1.2

(b)							
Transmitter power (P_e)	30 dB			Received threshold level (P_{thres})	-110 dBm		
Cable attenuation	4.660 dB/100 m			Cable attenuation	4.66 dB/100 m		
Cable losses (A_f)	5.592 dB	120 m		Receiving antenna gain (G_r)	10 dB		
Branching losses (A_{br})	3 dB						
Emitting antenna gain (G_e)	10 dB						
RTU	Distance (m)	Free space attenuation (A_{fs}) (dB)	Cable length (m)	Cable losses (A_f) (dB)	Received RF signal (P_r) (dBm)	Margin on RX threshold ($P_r - P_{thres}$) (dB)	
CNJA 24	7910.8	91.65	3.4	0.14	-46.21	23.83	
CNJA 26	3400.0	95.22	21.4	1.11	-50.62	59.37	
CNJA 19	3038.0	93.07	19.7	0.91	-48.39	61.60	
CNJA 20, 25, 27	2387.0	91.84	0.9	0.04	-46.28	63.71	
CNJA 28	1200.0	86.06	4.0	0.18	-44.83	40.17	
CNJA 52	5276.8	98.92	2.8	0.13	-57.64	27.36	
OMO 752	1200.0	84.62	1.1	0.05	-39.07	70.92	
OMPZ 331	5956.8	98.66	17.6	0.82	-53.88	56.11	
OMPZ 34	6356.8	100.39	1.2	0.41	-54.84	55.15	

a.s.l.: Above sea level; Factor k: Land profile between two fixed points based earth radius $R = kR_0$ (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

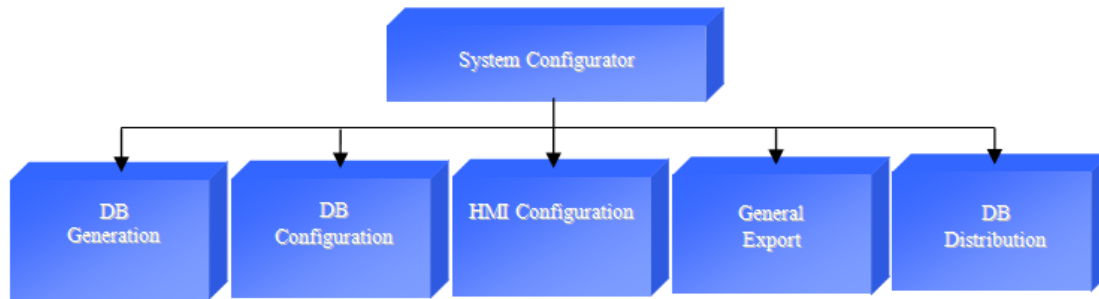


Fig. 15: SCADA database configuration phases

such as: links, Creating, Viewing and editing items (i.e., Node, transmission channel, RTU, analog variable, digital variable, legal situation, etc., (Trai, 1998).

The main functions of the configurator (Fig. 15) are:

- **Generation:** Generating SCADA Tags (identifiers) of configured facilities
- **Database configuration:** Configuring entities of the system such as: RTUs, analog variables, etc
- **HMI environment configuration:** Graphically represent the data of field installations
- **General export (compilation):** Compilation of all the system databases

Table 4: SCADA database configuration phases for a junction from the oilfield pipeline network

- **Database distribution:** Database source distributing on system nodes in an object form

Junction configuration example:

- On the entities table of node hmcinfl, the choice of channels table list of this node allows to view the corresponding entities (Table 4a).
- The selection of a communication channel such as for example «C00N», displays the table of RTUs connected to CIN with their entities (Table 4b). The creation of a new RTU «N_CNJA20» displays a grid of input which will allow to define different parameters such as: Tag, address, configuration of

(a) Channels table of node hmcinfl and the related entities

Channel tag	Entities
C00N	RTU
OMN77	
OMP53	
OMO13	
OMO35	
OMJ82	
OMP57	
OML75	
OMP73	

(b) Table of RTU assigned to the channel C00N and the relating entities

RTU tag	Entities
N_OM7	Analog input
N_OML11	Digital input
N_OML301	Command
.	.
.	.
N_CIN	
N_OMO752	
N_OMPZ331	
N_OMPZ34	
N_CNJA20	

(c) Table of analog variables configured for the junction CNJA20

Analog tag	Entities
N_CNJA20_PT701	Junction pressure
N_CNJA20_TT701	Junction temperature
N_CNJA20_HTR	High voltage reference
N_CNJA20_BTR	Low voltage reference
N_CNJA20_VB	Battery voltage
N_CNJA20_VPS	Solar panels voltage
N_CNJA20_CB	Battery amperage
N_CNJA20_TIS	RTU shelter inside temperature

(d) Table of the digital variable configured for the junction CNJA20

Digital tag	Description
N_CNJA20_SD	Shelter door

acquisition cards (analog and digital) and the assignment of the acquired parameters.

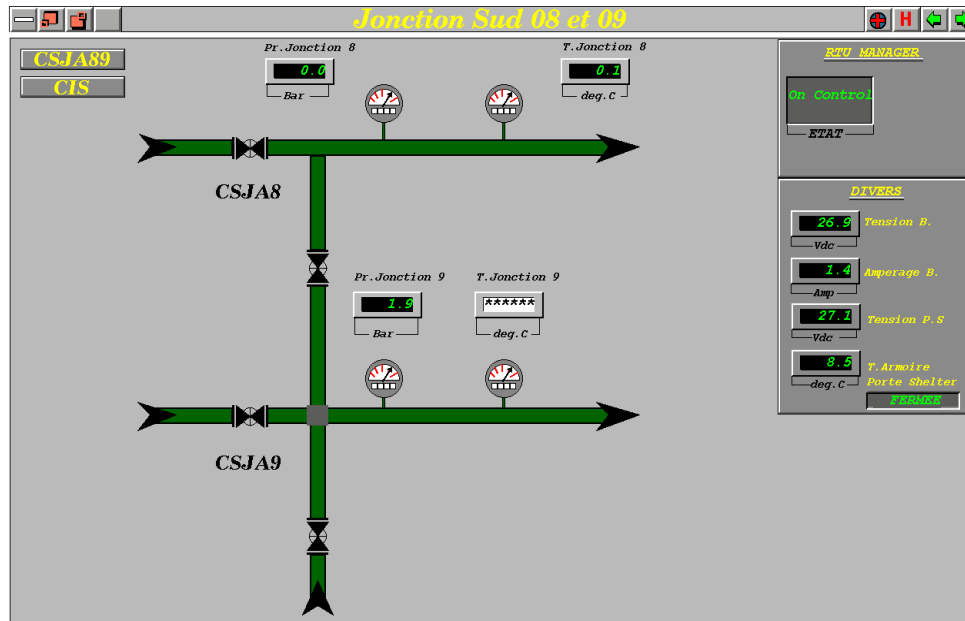
- Selecting one entity on the RTU table of entities: for example Analog input, allows viewing the table of all the junction CNJA20 variables (Table 4c).
- The consultation, modification or creation of an analog point, displays the corresponding input grid (example N_CNJA20_PT701) which allows defining: Tag name, address on the acquisition card, range of variation, alarm thresholds and other. Idem for the Digital input entity, for our case (the junction CNJA20) it is only the parameter N_CNJA20_SD which determines the opening or closing of RTU shelter door (Table 4d).

Once the configuration of the database made, we proceeded to the operation of Export (single or global) which allows the generation of the object database in the system configuration workstation.

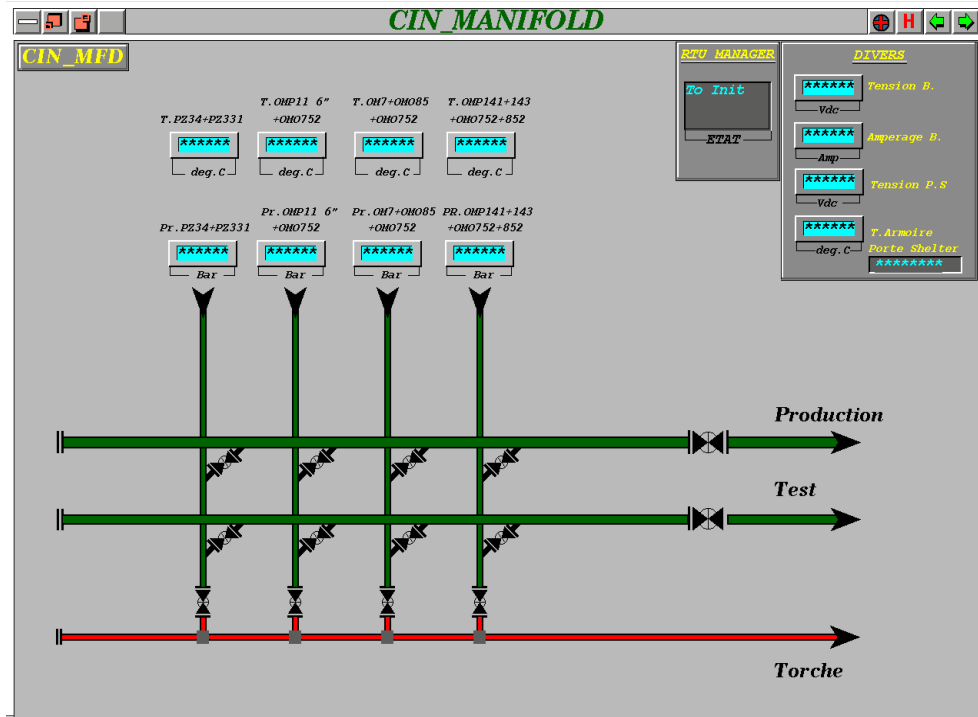
On Fig. 16 are presented two samples SCADA HMI pages configured for two facilities from the studied pipeline oil collecting network. The RTUs onsite distribution used for data acquisition of this sample network is shown on (Fig. 17).

CONCLUSION

New technologies offer multiple benefits that guarantee particularly rapid return on investment and excellent quantitatively and qualitatively results. The possibility of modernizing the businesses is valid by steps, by the choice of scalable platforms and variable architectures which allow implementing an entire control processing system (Aouadj *et al.*, 2012) starting



(a)



(b)

Fig. 16: Synoptic Pages configured on SCADA for a few facilities of the studied pipeline oilfield network (a) synoptic of two junctions CSJA 08 and 09, (b) synoptic of CIN center manifold arrivals

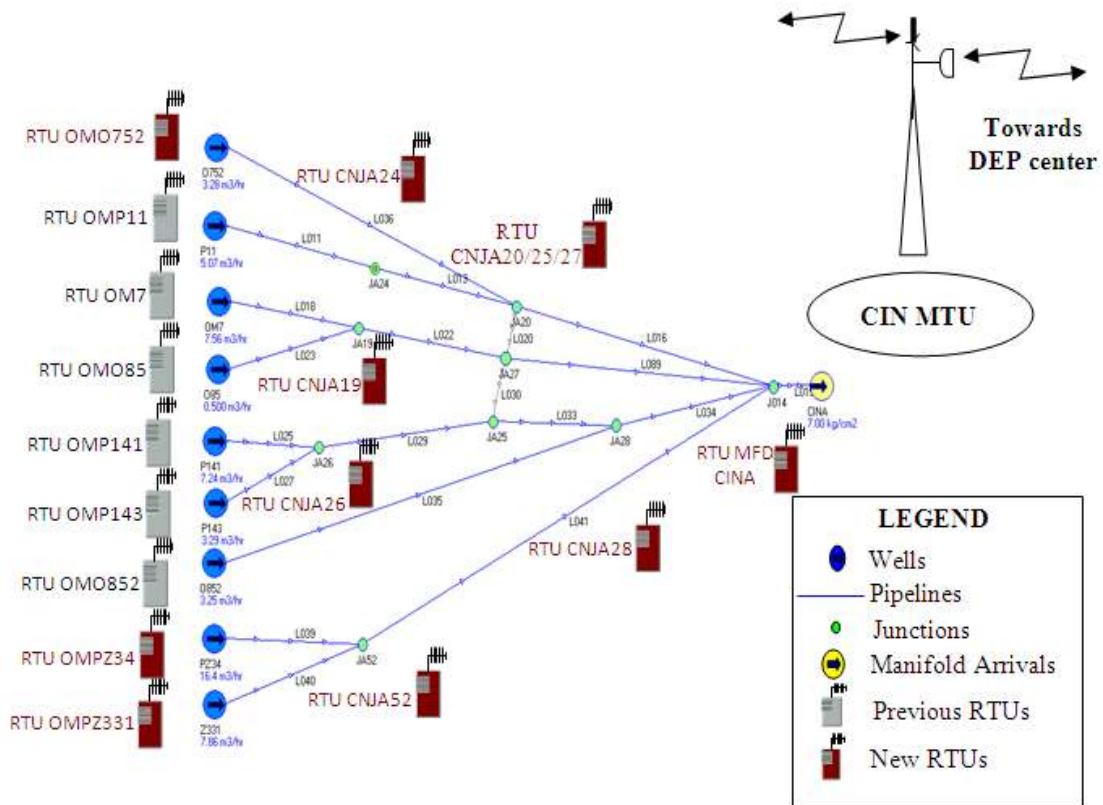


Fig. 17: Onsite RTUs distribution

with a few equipments and expand it according to process requirements and budget availability.

We have proposed through this study a method of operating a SCADA system which will allow the following benefits:

- Create more accurate models and therefore to approach more and more to the real network existing on field and so we will have to compare the pressure losses (and not the pressures) calculated by software (PIPEPHASE) in those measured on field. Then, predict in the optimum way the results of changes made on pipeline network process.
- Have control on the pressure losses which will allow a significant improvement of the production.
- Ensure in real time a rigorous monitoring of an oilfield pipeline network operation from end-to-end (from wells to the oil treatment centers).
- Improve working conditions and limit interventions time.
- The implementation of a software analysis of radio propagation for adding future new facilities.

Also, compared to the method based on electronic recorders used no longer, the proposed method allows a regular performance monitoring of an entire production line in the pipeline network with a lower cost.

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