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Research Article

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Dakhla Desalination Plant Using Renewable Energy

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ABSTRACT
This paper concerns the project of desalination in Dakhla region in the south of Morocco; the project involves the construction of a Sea Water Desalination Complex that comprises four categories of components:

- An industrial seawater desalination unit with a production capacity of 113376 m3/d of desalinated water intended for irrigation and potable water, located on the southern slope of the Skiymate estuarine Guelta, above the upper submergence level of this Guelta in the north at 130 Km of Dakhla.
- A wind farm (PE) to supply energy to the plant and its annexes, as well as to the irrigation facilities,
- Water distribution networks (irrigation and drinking water) and electrical power.
- An irrigated perimeter of 5000 hectares.

The Dakhla Seawater Desalination Complex project comprises several components:
A desalination Plant Comprising

- a seawater collection and pumping basin,
- a seawater desalination plant (building with internal equipment),
- 2 desalinated water storage tanks for agricultural use (2 x 87,000 m³),
- 2 desalinated water storage tanks for drinking water requirements (2 x 2,500 m³).

- underwater and underground pipelines: one to convey oceanic water from the open sea intake to the plant, and the other to transport the brine from desalination operations.
- an underground land pipeline between the seawater collection and pumping basin and the desalination plant.
- a small-scale wind farm (12 wind turbines, 60 MW), which will serve as a source of energy for the project and the exceeding delivered to the ONEE,
- a transformer station to supply power to a local grid.
- a network of underground power cables between the turbines and the substation.
- two overhead power cables, one between the substation and the plant, and the other between the substation and the ONEE network
- a network of access tracks (and roads) to the various project components.
- This project is supported by an agreement called the Public Private Partnership (PPP) between the ministry of agriculture and a Nareva- Engie group. The project is under construction.

Keywords: Desalination, Irrigation, Renewable Energy, Water Supply

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Introduction

The Province of Dakhla-Oued Eddahab is known for its agricultural potential, particularly in the production of early crops. However, the area is subject to an increasing pressure on the underground water resources, which are considered fossil and renewable.

Today, this is reflected in a decline in the level of the Dakhla ground water resource, by the salinization of it, which is a threat to the development of agriculture.

Faced with this situation, the Ministry of Agriculture, Maritime Fishing, Rural Development and Water and Forests, has entrusted private operators with the mission of co-financing, designing, building and managing a desalination unit, a wind farm and an irrigation infrastructure in the project perimeter, and this in the best technical, economic and financial conditions.

The project aims to achieve a desalination unit for the irrigation of 5,000 ha of arable farmland. These lands will be exploited by investors and young entrepreneurs of the Dakhla region. This will occur within the framework of PPP contracts around agricultural lands launched by the Agency for Agricultural Development [1].

Figure 1: Localization of the project

General Considerations

The present technical specification concerns a seawater reverse osmosis plant under built in Dakhla, province, a part of Dakhla-Oued Eddahab region, the Southern Part of Morocco.

Final capacity of the Plant shall be 113376 m3/day for irrigation and potable water.

The Owner is a project company formed by ENGIE and NAREVA. The Off taker is the Moroccan
« Ministry of agriculture, fishing and Rural development water and forest. (MAPMDREF) under the PPP procedure.

The intent of this specification is to define the scope of Works and activities to be undertaken under an Engineering Procurement and Construction (EPC) term sheet to procure for the Owner a modern, functional, well-designed Plant meeting the performance requirements and being capable of continuous, efficient and reliable operation of the Plant with minimum maintenance. The overall plant and individual systems and equipment supplied by the Contractor have been performed by proven, robust and reliable design with appropriate levels of redundancy and factors of safety built-in and incorporate protective systems and devices.

It is not the intent of this specification to define all details of design and construction of the complete Works. However, it shall be recognized that the whole of the Works shall conform in all respects to high standards of engineering, design and workmanship, be in accordance with Good Industry Practices and shall be capable of performing in continuous commercial operation with very high availability whilst meeting the Contractor's guarantees and complying with all environmental and statutory regulations.

No defects, errors or omissions in this document in relation to any design, specification or method set out herein shall relieve the Contractor from his responsibility to provide a fully operational Plant capable of delivering the defined capacities over the specified range of operating conditions [2].

Plant Configuration

The Plant consists of one Desalination Plant to produce irrigation and potable water from seawater. The total (irrigation + potable) water net capacity, measured at the outlet of the remineralization plant, shall be 113376 m3/day: 86900 m3/day for irrigation and 26476 m3/day for potable water.

The pumping station and the Desalination Plant shall be installed on the seashore at 100 m from the shoreline. Two irrigation storage basins (capacity of each basin: 87 000 m^3) as well as two potable water reservoirs (capacity of each reservoir: 8 500 m^3) both installed at the Desalination Plant outlet are part of the scope of supply.

Electrical power to the Desalination Plant will be provided by a local substation 33 kV connected to a wind farm and to the national grid 225 kV.

Sea Water Intake and Pumping Station

A submerged intake tower is installed at about 15 m CM (CD) depth in the sea. The tower position shall be such that the seawater will be taken at a depth of approximately -10 m CM relative to minimum sea level (ZH). According to the bathymetry campaign realized by the Owner, these depths will be achieved at about 450 m from the shoreline (0 CM).

The intake tower initially planned to be made of concrete is a metallic structure with cathodic protection to avoid corrosion by seawater.

From the intake tower a pipe is conducted, by gravity, seawater to the intake basin and the pumping station located on the coast at 100 m from the shoreline [3].

Outfall to Sea

An outfall pit is installed 100 m from the shoreline. An undersea pipe will be conducting the brine at about 650 m from the shoreline where a diffuser will be installed.

Water Quality Considerations

The plant is designed to operate normally meeting the required potable and irrigation water quality with the following sea water characteristics:

- pH: between 7.2 and 8.3
- Temperature: between 14 and 24°C
- TSS: maximum: 25 mg/l
- TDS: Between 36 and 42 g/l
- Ca: 673 mg/l
- Mg: 1400 mg/l
- Na: 11600 mg/l
- K: 400 mg/l
- B: 5,65 mg/l
- HCO_3: 135 mg/l
- Cl: 22700 mg/l
- SO_4: 3500 mg/l
- NO_3: 0.84 mg/l
- SiO_2: 0.6 mg/l

The Plant shall be able to produce potable and irrigation water at the required net capacity in the following sea water conditions:

- Temperature: 14°C
- Salinity: 40,5 gr/l
- Aging: 5 years operation (3 years average RO membranes age)

The required net capacity is measured at the Plant outlet and is therefore the plant production reduced by the internal demand of the Plant Desalination (process demand and personnel demand) [4].

Desalination Plant
The desalination systems (pre-treatment, UF racks, RO racks, remineralization and auxiliaries) shall be located at 100 m from the shoreline; its elevation will be approximately + 20 m NGM.

The plant Desalination Contains the Following Items
- Sea water intake tower
- Sodium hypochlorite shock dosing system at the intake tower,
- Pipeline delivering seawater from the intake tower to the pumping station by gravity,
- Screening system: bar screen and travelling screen,
- 6 pumps of seawater to deliver seawater from the pumping station to the treatment process

Pre-Treatment Plan Including the Following Sections
- 5 Mechanical filters
- pH correction by sulfuric acid,
- Ferric chloride as coagulant
- 17 trains of Ultrafiltration system: DuPont™ IntegraTec™ MB 80 TR, 128 membranes by train,
- De-chlorination system
- Antiscalent dosing treatment

Water Quality Pretreated Must Have the Following Caracteritics Before Ro
- SDI<3
- Turbidity < 0,3 NTU

5 Trains of Single RO Desalination System with the Following Components
- One high pressure pump, one ERD booster pump and relevant energy recovery system for each train.
- 229 Pressure tube, each tube is filled with 7 membranes from LG Chem: model LG SW 440 GR G2
- Membranes fresh water flushing system.
- Membranes chemical cleaning system
- Remineralization system includes CO2 injections and limestone filters with limestone loading facility.

Irrigation and Potable Water Storages
Two Irrigation basins and two potable water reservoirs will be constructed just next to the Desalination Plant.

The irrigation water storage is formed by dikes (earth dikes + tightness + geo- membrane protection).

Each reservoir has a net capacity of 87 000 m³. The following concrete structures are included:
- Water inlet
- Water outlet
- Overflow
- An outlet draining system

Two potable water storage with a rectangular closed potable water reservoirs (net capacity: 8 500 m³) and constructed with reinforced concrete.

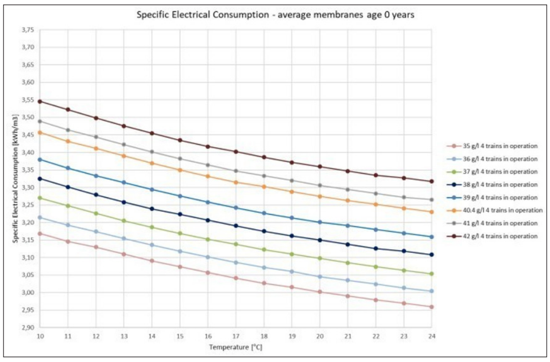
Irrigation and Potable Water Quality
Potable water produced by the desalination plant shall comply with the following specifications and guidelines:
- Compliant with the Moroccan regulation for potable water
- Most recent WHO recommandations
- Boron < 1 ppm
- TH between 8 and 12 °F (1,6 - 2,4 meq/l)
- TAC > 8 °F (1,6 meq/l)
- LSI between 0,1 and 0,3
- TDS < 500 ppm
- Turbidity (at outlet remineralization): max 1 NTU
- The potable water production about 26476 m³/day

Water for Irrigation Produced by the Desalination Plant Shall Comply with the Following Specifications
- Compliant with the Moroccan regulations for irrigation water
- Boron < 1 ppm
- TAC > 4 °F (0,8 meq/l)
- Sodium < 120 mg/l
- SAR lower or equal to 6
- Turbidity (at outlet remineralization) max 1 NTU
- The Irrigation water production will be 86900 m3/day

Energy Consumption
The energy consumption that must be guaranteed during the test performance for the first start of the plant is 3.14 kwh/m3 at the condition specified in the reference conditions that are temperature 14°C and TDS 36g/l.

If the conditions measured during the Performance Test are different from the Reference Conditions (temperature 14°C and TDS 36 g/l), the following correction curves will be used to correct the measured performances related only to Specific Electrical Consumption [5].

The others guarantee they do not need any corrections.



Due to the difference between the value of the TAC for irrigation and for potable water (0,8 meq/l versus 1,6 meq/l) the flow intended for irrigation water is divided into 2 parts, one part is bypassed, and another is remineralizer across calcite bed and the 2 flows are mixed.

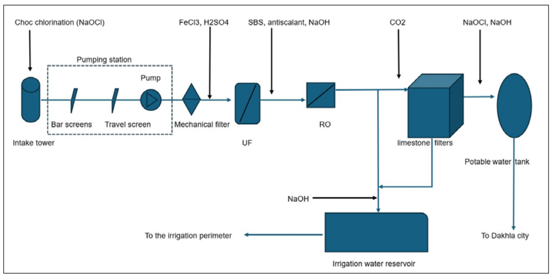


Figure 2: General design of the process

Control System

The Desalination Plant shall be equipped with a Distributed Control System (DCS). The Plant shall include one control room equipped with the daily control and operation of the Desalination Plant and the provisions for:

- the supervision and control of the Windfarm.
- the supervision and the control of the HV switchyard and.
- the supervision of the Irrigation pumping station (including water meters).

The plant will be equipped with online analytical instruments for controlling the quality of water at each step of the process of treatment and all the results will be followed from the room control. Each step of treatment is monitored and an indicative parameter fixed to avoid a bad quality of produced water that will be rejected to discharge pit [6].

All effluent (reject from RO, water from flushing, back washing, CIP) will be neutralized by a necessary chemical product before rejection to the sea outfall equipped with a diffuser at 650m from the plant.

The degree of automation will be such that the normal operation of the Plant can be performed from the control room, without operator intervention in the field.

The control and instrumentation (electrical and process) design shall be done in such a way:

- To start/stop the Desalination Plant in a "fully automatic mode" at any time.
- To allow in the future, the implementation of EMS software.

Full control of the Plant shall be achieved by DCS operator screens in the Control Room. Control of auxiliary packages, such as emergency diesel generating set, compressed air plant, shall be integrated with the DCS through PLC and serial communication to ensure operation from the DCS consoles with an optimum number of global commands, without altering the reliability level of the whole automation system.

The degree of redundancy will be such that no single failure of a DCS component may jeopardize the operation of the Plant. Particularly, no single I & C failure shall:

- Cause any danger to personnel and the Plant.
- Invalidate protection by inhibiting a trip.
- Shut down more than one Major Equipment item.
- Simultaneously trip a Plant item and invalidate its auto-change-over; and affect more than one control area.

To obtain high availability of the Plant, the central control system also requires high availability. This will be achieved by using a redundant design respectively single fault tolerant design for the centralized components, that may affect large parts of the Plant operation such as data bus, control processors, operator control stations, hot stand-by power supply, etc. Under no circumstances shall a single failure lead to an outage of the complete control system.

This philosophy will also apply to significant "Black box" sub-system controllers. In addition, important sensors, which might affect the Plant availability in case of malfunction, should be provided in a redundant configuration (e.g. in 2 out of 2 or 2 out of 3), too.

A consistent control philosophy will apply throughout the Plant and will be implemented in terms of a range of equipment exhibiting a minimum diversity of type and manufacturers. The objective is to standardize all measurement and control equipment throughout the Plant to rationalize operation, maintenance and reduce spare parts holding.

As a rule, measuring points and measuring equipment for interlocking and protection purposes will be separate and not combined with measuring equipment for monitoring or automatic control equipment, except they are designed in a redundant configuration (2 out of 2 or 2 out of 3 voting). For flow measurement one common primary element can be used. Signals to be processed in several systems will be repeated and mutually decoupled to avoid interaction.

The process requires an evaluation to determine the appropriate Independent Protection Layers (IPL) to control hazards. Safety Instrumented Systems are intended to provide protection for people, property and the environment against deviations in the processes.

The plant also will have a laboratory equipped with analysis instruments and capable of performing analysis necessary for the control process in addition to the online control performed by instruments.

The laboratory performs also water sampling for analysis for specific analysis at external laboratory that must be accredited according to ISO 17025.

Results and Discussions

The DAKHLA region is Morocco's gateway to West Africa and sub-Saharan Africa. This region is known for the lack of surface water and the poor quality of groundwater.

The region and particularly the city of DAKHLA (its bay) is known for its tourist attraction, particularly for the water sports, surfing and windsurfing.

The new port of Dakhla under construction is Morocco's new showcase vis-à-vis the countries of West Africa and the Sahel countries for import and export!

To develop agriculture with high added value in the region and to make it more attractive, a desalination plant is being built with the aim of irrigating 5000 hectares of arable land intended for young promoters.

The water produced by the desalination plant will also be used to reinforce and secure the supply of drinking water to the town of DAKHLA and the entire region and particularly for the agglomeration of BIR ANZARANE.

The environmental aspect was taken into consideration during the study and the realization of the project, and particularly the discharges of the brine in the sea.

To save the project and make it more profitable, the production of the necessary energy for the operation of the project will be produced by a wind turbine, 12 in total producing 60 megawatts; the surplus energy produced is injected into the ONEE network.

The project is carried out within the framework of Public-Private Partnership, which is a mode of cooperation, and financing that has been successful in other similar projects in Morocco.

This flagship project, which includes a desalination plant, a wind farm and an irrigated area, is an example of a sustainable development project integrating environmental protection, renewable energy and youth employment.

The public-private partnership method of financing infrastructure projects is a new method of financing that overcomes liquidity difficulties while allowing technology transfer.

This project is part of the Green Generation program launched by the Ministry of Agriculture but also as part of the national water program in Morocco which aims to reach one billion m^3/year of desalinated water by 2050.

Finally, the project makes the Dakhla region even more attractive to investors.

Conclusion

The Dakhla Desalination Plant is the second project intended for irrigation by desalination according to the green generation program after the project achieved at CHTOUKA near Agadir. This project is a part National Program of Water (PNE 2020-2050) encouraging desalination projects to secure and ensure water for irrigation and potable water.

The project also ensures and secures the supply of potable water for Dakhla city and the entire area for its region.

The project is a sustainable project, by using renewable energy, participle to the protection of the environment by reducing CO2 emissions

The project participles in the development of the region by creating jobs and business for young entrepreneurs from the region.

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