PGESCo

Engineering Magazine

2020 ENR TOP 225 DESIGN FIRMS

PGESCo Listing in the top 225 ENR Design Firms 2020....p4

Issue 34
Septemper, 2020

Editor's Note..

For the last 8 years, PGESCo Engineering Magazine were issued under the guidance and assistance of Engineer Magdy Mahmoud until he retired and left PGESCo last month. This issue #34 is issued under the direction of Engineer Soliman Abdel Hamid as Engineering Director. The Magazine Editorial board welcome Eng. Soliman and continue to work with him as usual.

In page 4 we **are proud to announce PGESCo listing in the Engineering news record list of the Top 225 International Design Firms, year 2020.**

The first article in this issue by **Eng. Khaled Reda** titled "**Zero Liquid Discharge (ZLD) Waste Water Treatment Technology and System Basic Components."** In this article Khaled explains Zero liquid discharge which is an expanding water treatment philosophy in which wastewater is purified and recycled, leaving little to no effluent remaining when the process is complete.

The second article by **Eng. Ahmed Abd Elfattah Ali** is a review of "**Water Intake Filtration System**" in this article Ahmed explains how the Raw, process or cooling water must be cleaned before use. He also explain how the environment balance to protect aquatic living organisms from being impacted is considered.

The third issue by **Eng**. **Mohamed Elseify** titled "**The first utility scale PV plant Benban Solar Complex & the Grid Code "** explains how with Renewable Energy Sources gaining a lot of attention in Egypt & worldwide recently, Grid codes is developed to meet the new technology & high level of participation of renewable in the grid. When it comes to solar energy development & growth, significant part of the process is related to the inverter that was he tried to explain.

Dr. Mohamed ElBanhawy.

In This Issue

The Magazine Cover about

THE FIRST UTILITY SCALE PV PLANT BENBAN SOLAR COMPLEX & THE GRID CODE **>>>>**

***We** are proud to announce PGESCo listing in the Engineering news record list of the Top 225 International Design Firms, year 2020*

Engineering News-Record (ENR) the industry's leading publication, compiled the rankings based on companies' 2019 international revenues.

We thank our business partners and Clients in their trust and take this moment to thank all PGESCo team for there commitment and efforts in meeting our Client requirement and supporting the sustainability vision.

Zero Liquid Discharge (ZLD) Waste Water Treatment Technology and System Basic Components

Article By : Khaled Reda

1. Introduction

The industrial involvement with brine is twofold. Many industrial processes require water which they contaminate and releasing it may cause irreversible damages to the local environment.

Zero liquid discharge is an expanding water treatment philosophy in which wastewater is purified and recycled, leaving little to no effluent remaining when the process is complete. Although the treatment requirements will largely depend on the application, ZLD often includes reverse osmosis, ultrafiltration, evaporation and various other membrane technologies.

In some countries due to heavy contamination of local waters by industrial wastewater strict regulations were put that makes ZLD necessary in order to ensure the future of their environment and water resources. In other countries, the drive towards zero ZLD has been applied due to the high costs of wastewater disposal at inland facilities.

2. Advantages of ZLD

ZLD can also be used to recover valuable resources from the wastewater which can be sold or reused in the industrial process. Some examples are as follows,

- Generation of valuable potassium sulphate (K_2SO_4) fertilizer from a salt mine
- Concentration of caustic soda (NaOH) to 50 and 99% purity
- Recovery of pure, saleable sodium sulphate ($NaSO_4$) from a battery manufacturing facility
- Reduction of coal mine wastewater treatment costs by recovering pure sodium chloride (NaCl) which can be sold as road salt
- Lithium (Li) has been found in USA oil field brines at almost the same level as South American salars
- Gypsum ($CaSO_4.2H_2O$) can be recovered from mine water and flue gas desalinization (FGD) wastewater, which can then be sold to use in drywall manufacturing

Other advantages to the application of ZLD are:

- Decreased volume of wastewater lowers the costs of waste management.
- Recycling water on site thus decreasing the need for water intake and meeting with treatment needs.
- Reduce the truck transportation costs for off-site disposal and the related environmental risks.

3. ZLD applications

There is a wide diversity of sources for discharge flow streams that include:

- Cooling tower blowdown in heavy industry and power plants
- Ion exchange regenerative streams particularly in food and beverage processing
- Flue gas desulfurization, wet wastewater stream
- Municipal potable water systems, wastewater streams
- Process water reuse from agricultural, industrial and municipal streams
- Various industrial wastewater streams from the textile, coal-to-chemical, food and dairy or battery industries

4. ZLD Determining Factors

The most important factors that determine the ZLD design depend on,

1. The specific contaminants in the discharge stream
2. The volume of the dissolved material
3. The required design flow rate

Fig.1 The contaminants of concern are presented in the below table [1]

Sodium (Na^+)	TDS/TSS	Phosphate (PO_4^{3-})	Strontium (S^{2+})	Sulfate (SO_4^{2-})
Potassium (K^+)	COD/TOC/BOD	Ammonia (NH_3)	Oil & Grease	Fluoride (F^-)
Calcium (Ca^{2+})	pH	Boron (B^+)	Barium (Ba^{2+})	Nitrate (NO_3^-)
Magnesium (Mg^{2+})	Chloride (Cl^-)	Alkalinity	Silica	-

These parameters need to be accurately measured before requesting a quote in order so as to get an accurate estimation of the system's cost. If the feed is prone to changes in flow and the concentration of the contaminants, inlet buffering tanks regulate the peaks.

5. Basic Components of ZLD treatment system

Though the exact components of a ZLD treatment system will vary, a basic ZLD treatment system typically includes some types of [6].

⇒ **Clarifier and/or reactor:**
To precipitate out metals, hardness, and silica

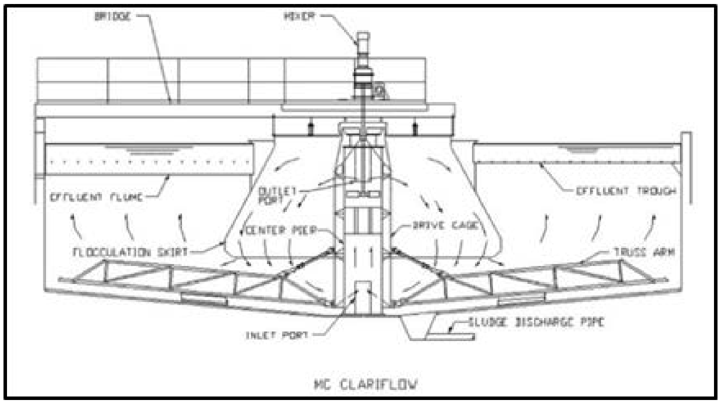

Fig.2 Circular clarifier configuration [2]

⇒ **Filter press:**
To concentrate secondary solid waste after pre-treatment or alongside an evaporator

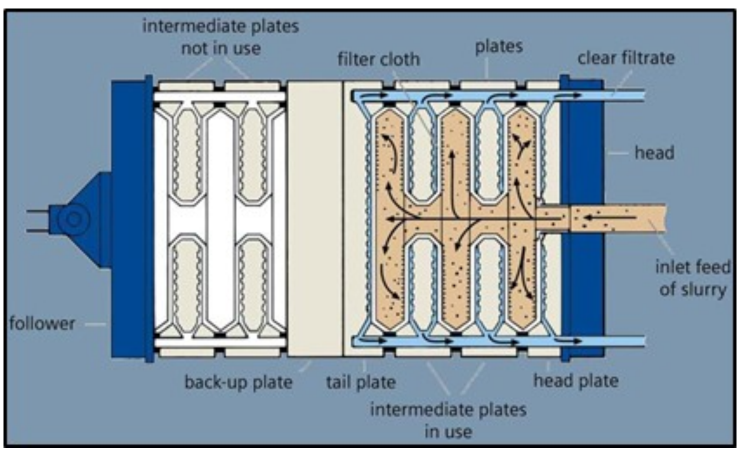

Fig.3 Filter Press Configuration [3]

⇒ **Ultrafiltration (UF):**
To remove all the leftover trace amounts of suspended solids and prevent fouling, scaling, and/or corrosion down the line of treatment

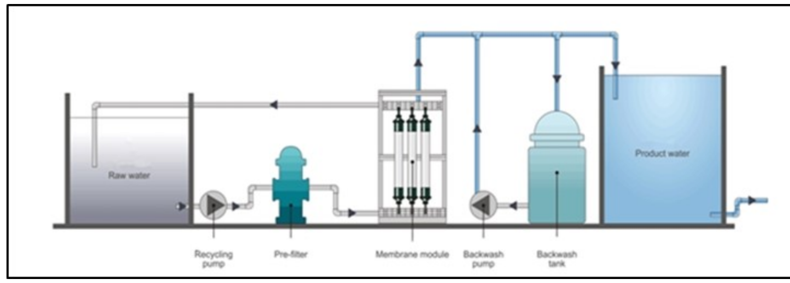

Fig.4 Simplified UF Process schematic [4]

⇒ **Reverse osmosis (RO):**
To remove the bulk of dissolved solids from the water stream in the primary phases of Concentration

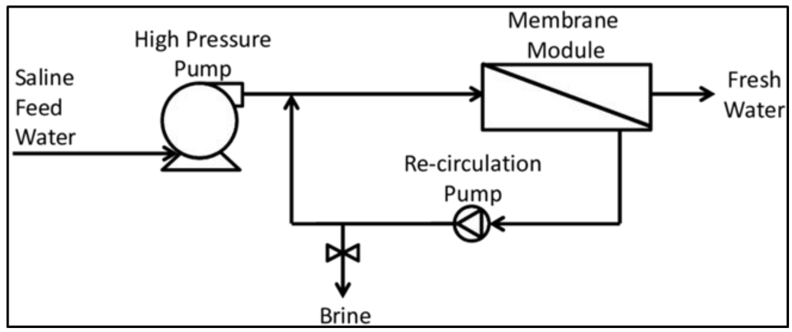

Fig.5 Simplified Schematic design of RO system [5]

⇒ **Chemical feed:**
To help facilitate the precipitation, flocculation, or co-agulation of any metals and suspended solids

⇒ **Evaporator:**
For vaporizing excess water in the final phases of waste concentration before crystallizer.

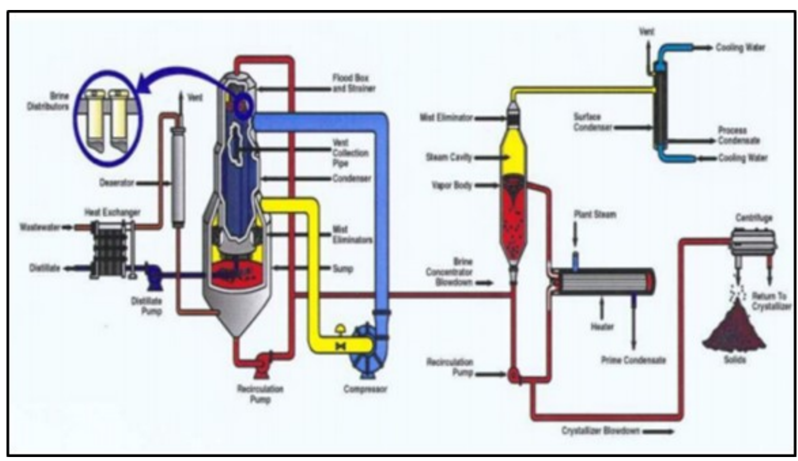

Fig.6 Evaporator/Crystallizer Basic Components [7]

⇒ **Crystallizer:**
To boil off any remaining liquid, leaving you with a dry, solid cake for disposal

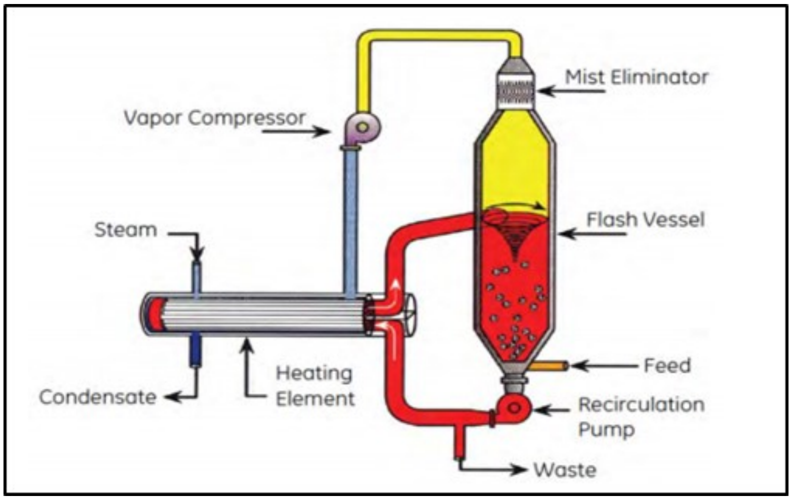

Fig.7 Crystallizer Basic Components [8]

6. Conclusion

Depending on the needs of the plant and process, these standard components are usually adequate, however, if the plant requires a system that provides a bit more customization, there might be some features or technologies needed to add on. Because of the broad range of industries that use ZLD and the various waste streams produced, ZLD is a highly custom process and these add-ons will depend on the facility's individual needs.

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WATER INTAKE FILTRATION SYSTEMS

Article By : Ahmed Abd Elfattah Ali

A Review of Water Intake Filtration Systems

Raw water, process or cooling water must be cleaned before use. Furthermore, each plant's facilities vary in their requirements. Environmentally-friendly solutions are used in both open surface water and submerged passive water intakes to deliver debris-free water; for example, cooling water at power plants, process water at industrial sites, raw water at potable water plants, desalination plants and irrigation plants. On the other hand, Latest technologies in washing systems have considered the environment balance to protect aquatic living organisms from being impacted.

We can see in figure 1: General Arrangement for Intake Water Filtration System commonly used in any process

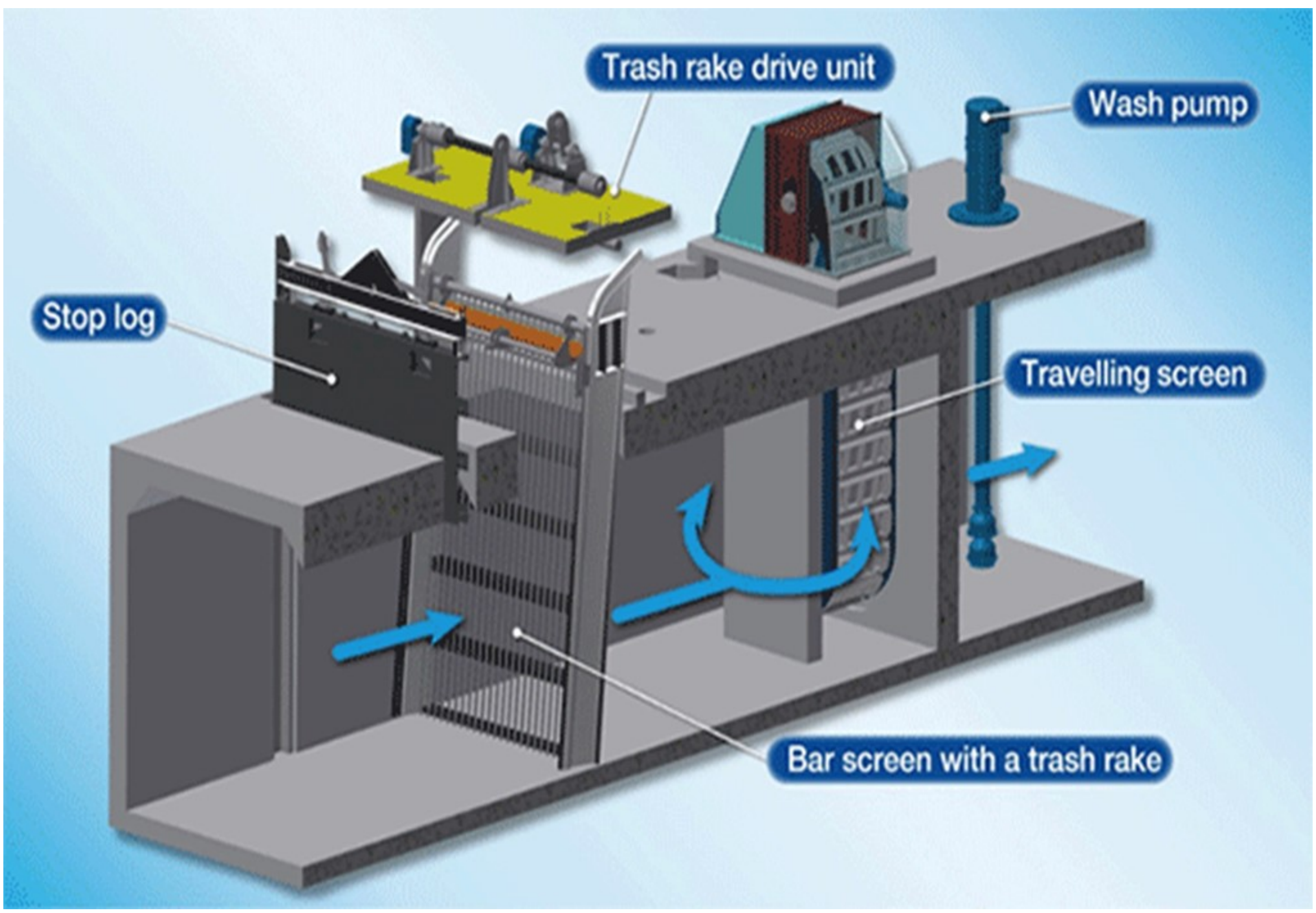

Figure One: General Arrangement for Intake Water Filtration System Components.

Here we can briefly describe and give simple information about each system component related to water intake filtration system.

1. **Dredging system**
2. **Stop gates**
3. **Bar screens**
4. **Trash rakes**
5. **Traveling Water screens**
6. **Wash pump**

1. Dredging system

Dredging is an important waterway maintenance step, which is probably its most important application. By removing the accumulated debris, dredging can restore the waterway to its original depth and condition. Dredging also removes dead vegetation, pollutants, and trash that have been gathered in these areas.

We can see in figure 2: General Arrangement for Dredger

Figure Two: general arrangement for Dredger.

2. Stop logs

Throughout the water intake and conditioning stages in cooling water at power plants, process water at industrial sites, raw water at potable water plants, desalination plants and irrigation plants, we find that during the operation of the equipment there is a need either to seal the channels or to temporarily stop the flow of water. This is the main purpose for the STOP LOG or STOP GATES.

We can see in figure 3: Stop Logs/Gates General Arrangement

Figure Three: General Arrangement for stop logs/gates.

3. Bar screens

A bar screen is a mechanical filter which is a Preliminary fixed screens used to remove medium or large-size debris, It is part of the primary filtration flow and typically is the first, or preliminary, level of filtration, being installed at the influent to a power plant or _a treatment plant. Bar Screens typically consist of a series of vertical steel bars evenly spaced between.

A screen is a device with openings, generally of a uniform size, that is basically used to retain and extract solids found in the influent water from rivers and seas into power plants, treatment plants or desalination plants. The principle role of screening is to remove coarse particles and solids from the flow stream that could:

1. Damage subsequent process equipment.
2. Reduce overall treatment system reliability and effectiveness.
3. Contaminate waterways.

The screening element may consist of parallel bars, rods or wires, wire mesh, or perforated plate, and the openings may be of any shape, but generally are circular or rectangular slots. A screen composed of parallel bars or rods is often called a ''Bar Rack'' or a “Coarse Screen” and is used for removal of coarse solids. The materials removed by these devices are known as “screenings”.

Hand cleaned coarse screens: used for applications where the flow is not more than 5000 m^3/day.

Mechanical cleaned coarse screens: used for applications where the flow is more than 5000 m^3/day.

Figure. Four: General Arrangement for Bar Screen.

4. Trash rakes

Trash rakes are heavy devices that are used to remove the large pieces of debris retained at bar screens at hydropower facilities. Most of trash rakes are designed with long arms that can reach into the bottom of the basin, which in turns move upwards across the screen, picking up pieces of debris along the way.

Some trash rakes simply drop off the debris collected on a nearby deck so it can be manually removed by workers at the facility. Other types of trash rake are selected to pick the debris and carry them away from the deck and to drop them into a bin designated for this type of wastes.

There are two main categories of trash rakes:

1. ***Cable operated rakes.***
2. ***Hydraulically operated rakes.***

Cable operated rake system consists of a cable winch and rake arm. The rake arm scrapes across the screen to remove large pieces of debris, which are then deposited in a dumpster.

The Catronic Series trash rack sits on the deck located above the screens. It can be used as a stationary unit that cleans a single screen or as a moving unit that is capable of cleaning multiple screens.

Another cable operated rake system is the Monorail Series trash rake. Instead of sitting on the deck, this type of trash rake moves back and forth along a monorail structure that is built above the screens. Because it moves along the monorail, this trash rake can be used to clean multiple screens within the same layout area. One benefit of the Monorail Series trash rake that is required in multiple applications and is found to be appealing to different users, is that it does not take up space on the deck whereas the Catronic Series trash rake does.

Yet, Both of these systems use low maintenance energy efficient equipment that can easily be repaired and cleaned away from the water that is being treated. The install for these raking systems is easy, too. This means that facilities can install either one of these systems without having to replace their existing screens or make any other modifications.

The automated hydraulic Trash Rack Cleaner can be of the mono-arm or double-arm type, with single-stage extensible units. It is used to remove the material captured by the grills in intake facilities, always allowing the maximum flow of water to the pumps, turbines or plant. The cleaning action is carried out by the rake, which opens and moves to the lowest point of the grill, then rises back up against it, intercepting and removing the solids retained up to the highest discharge point, where Conveyor Belts are ready to operate continuously and in coordination with the Trash Rack Cleaner.

Figure. Five A: General Arrangement for trash rake.

Figure. Five B: General Arrangement for trash rake.

5. Traveling Water screens

The function of the traveling water intake screen is to prevent (debris/contaminants) from entering into the intake bays and damaging the mechanical equipment in water intake like pumps. Traveling water screen is powered by an electrical motor coupled to a fluid drive, gear reducer “if applicable” and chain drive assembly mounted near top of the screen.

Debris is collected and retained on the inlet side of the screen and carried upward. Traveling screens are equipped with a spray wash system that consists of a single or double row of venture type spray nozzles threaded to a spray pipe to provide complete spray coverage along the screen width that wash the debris off the screen into a trash trough that discharge back into the water source. Spray nozzles are backed up by a screen wash pumping system.

Most traveling screens are designed to protect the plant of the industrial water user but not fish and other aquatic organisms. Fish protection technologies have been invested in the industry of traveling water screens to reduce the impact on the rivers, waters and seas. Special designs with a shape of buckets have been considered to gently elevate the fish to the head section assisted by a low pressure water spray, the fish are smoothly discharged into a return trough independent of the debris to get returned to the water source.

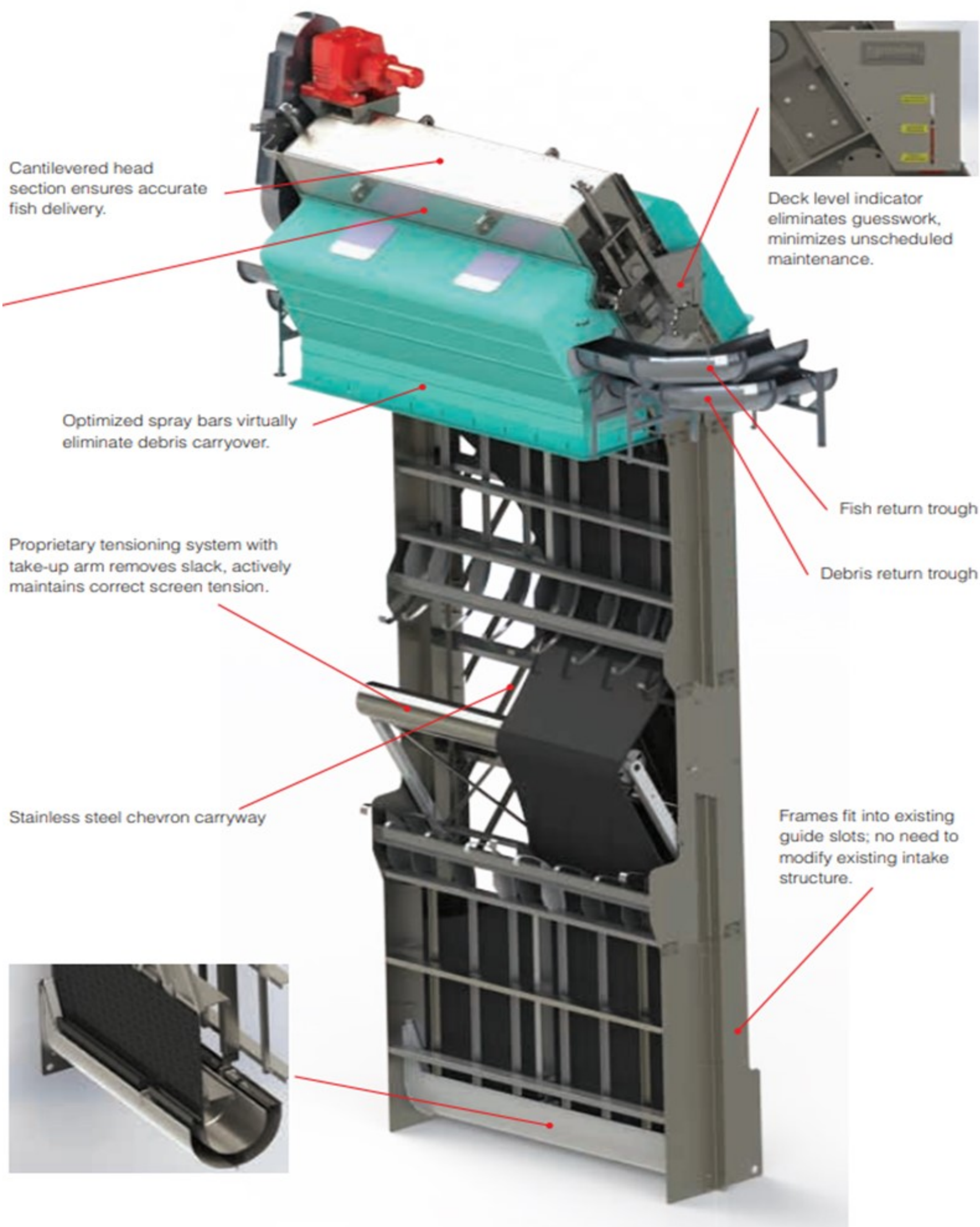

Figure. Six: General Arrangement for traveling screens.

Traveling Water Screen Types.

1) Traveling water Band Screen type.

The travelling band screen is a self-cleaning screen with millimetric mesh apertures that removes all types of debris from the water to be screened in order to protect the downstream industrial applications equipment from being obstructed (heat exchangers, drinking water and desalination plants, chemical and LNG plants, irrigation networks, etc.).

Types of traveling water band screen inlet water flow direction

a. Direct flow

- Uniform flow pattern through the screen.
- Minimal head loss.
- Foot shaft with sprockets for providing positive chain trays engagement.

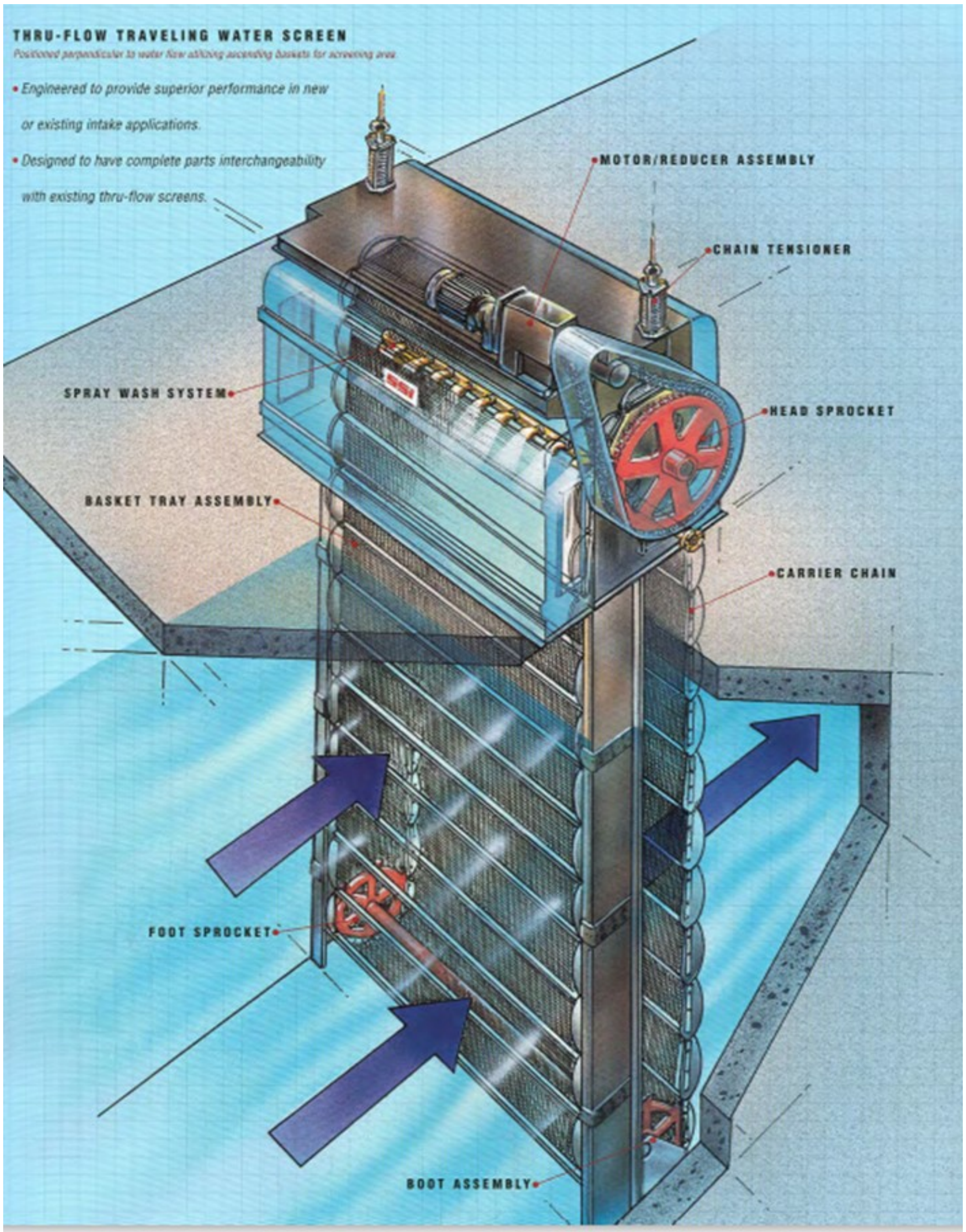

Figure. Seven A: Traveling Water Band Screen - Direct (Thru) Flow.

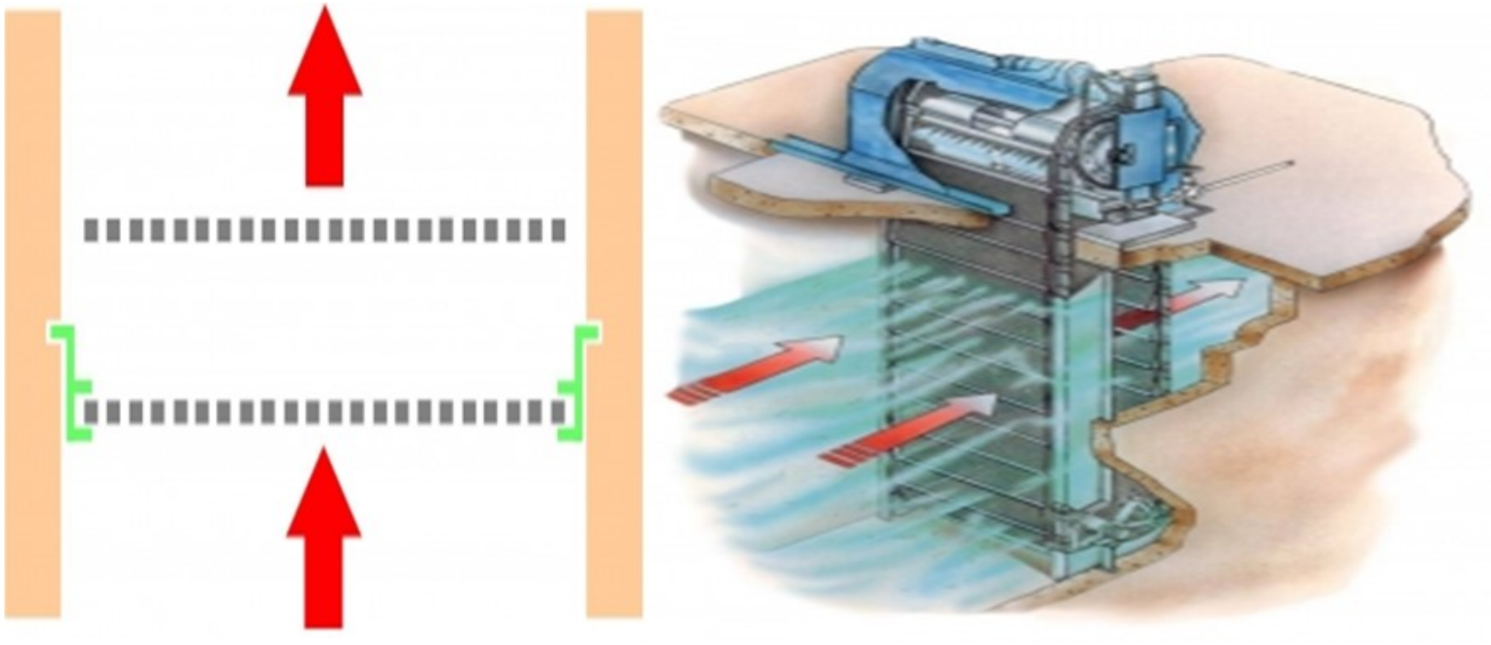

Figure. Seven B: Traveling Water Band Screen - Direct (Thru) Flow.

b. Dual flow

- Double entry-single exit flow pattern eliminates debris carryover.
- Utilizes both the ascending and descending sides of the screen for a large screening area.

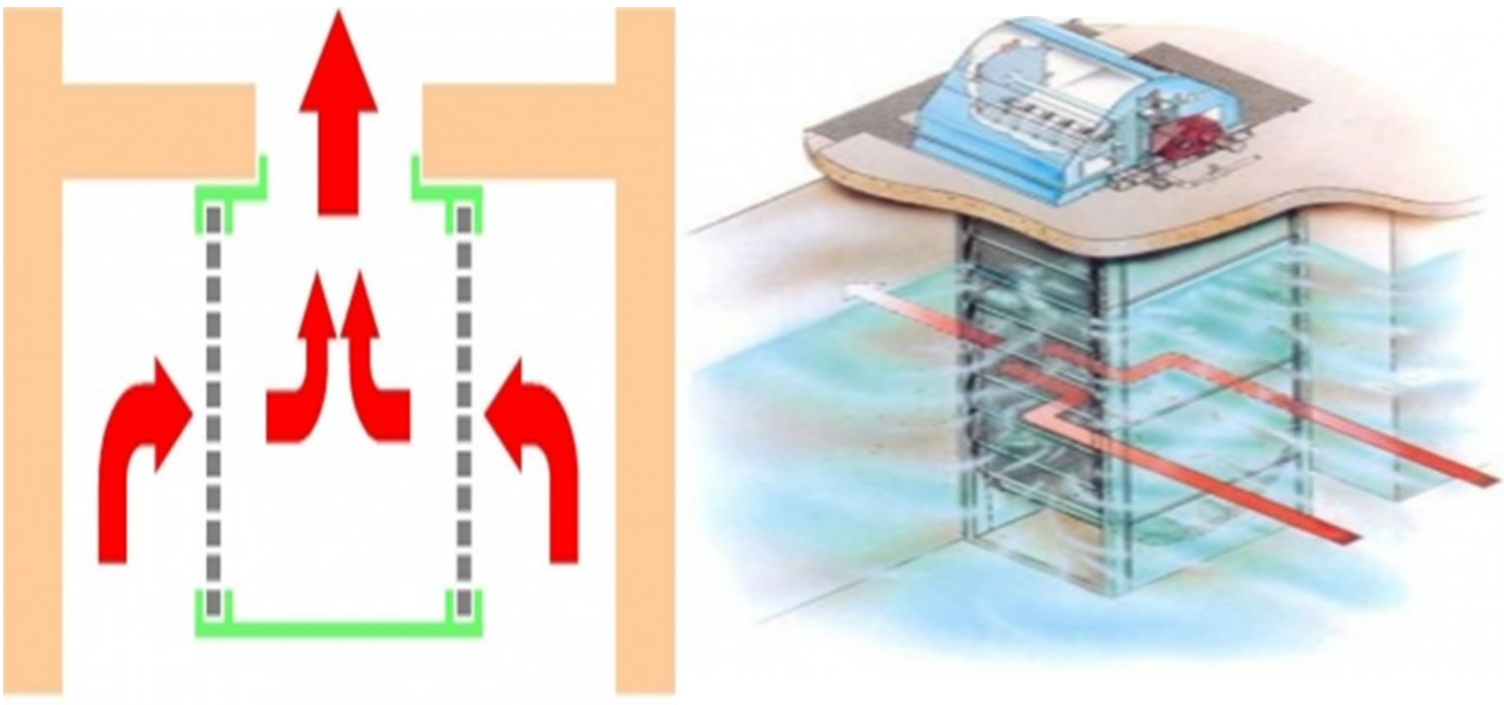

Figure. Eight: Traveling Water Band Screen - Dual Flow.

c. Centre flow

- Single entry double exit eliminates debris carryover.
- Minimal framework required.

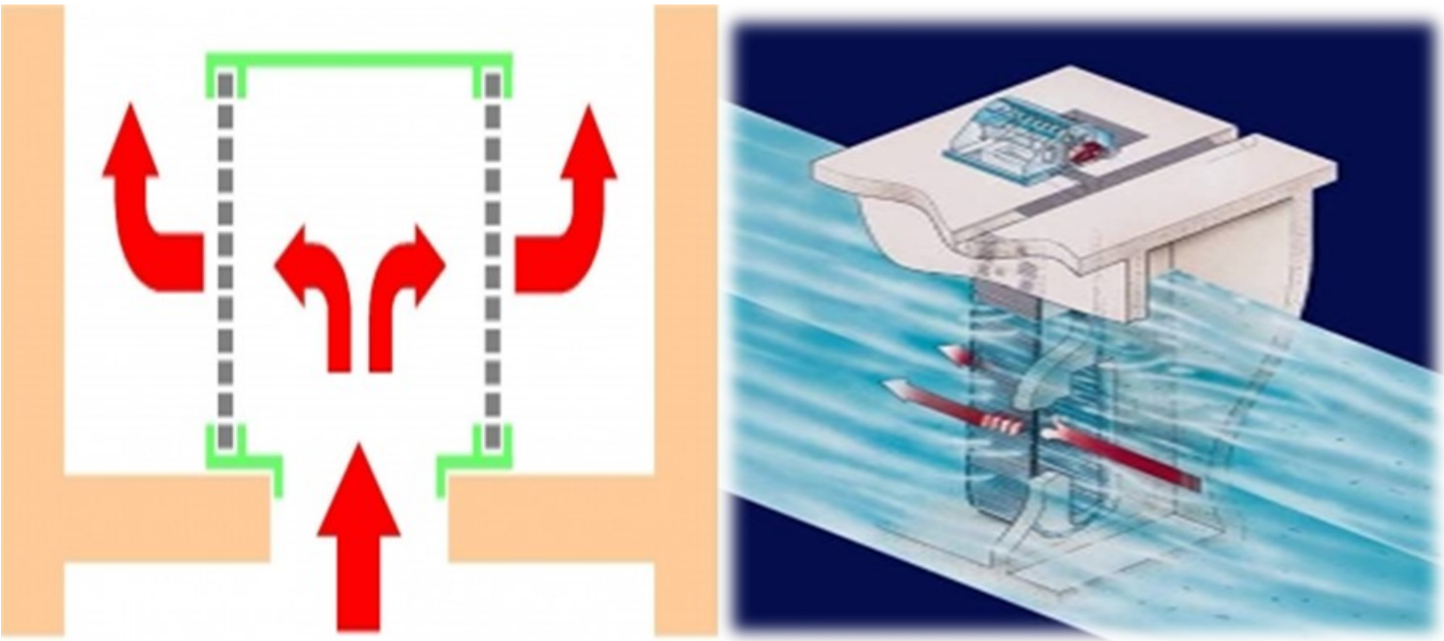

Figure Nine: Traveling Water Band Screen - Central Flow.

2) Traveling Water Drum Screen type.

Drum screen type is mainly used for medium and large capacity plants; the drum screen is a self-cleaning millimetric mesh aperture screen. It is the most reliable type of rotating screen as it has only one moving part: the drum motor.

Fully automatic, capable of the very largest flow rates (up to 35 m^3/sec), the drum screen is installed in a concrete chamber.

It is installed in power stations, LNG and petrochemical plants, desalination plants, drinking water and irrigation plants.

Figure. Ten: Traveling Water Drum Screen type.

Types of traveling water drum screen flow patterns

a. From the outside towards the inside

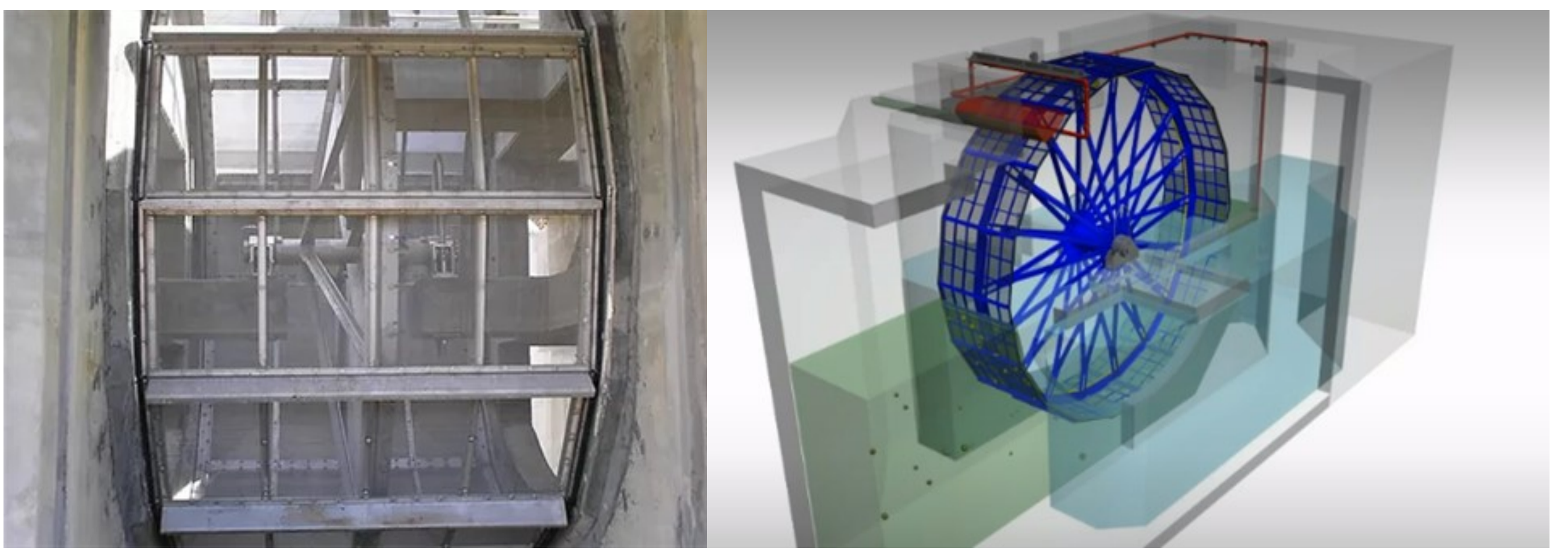

Figure. Eleven: Traveling Water Drum Screen type "Out to In"

b. From the inside towards the outside

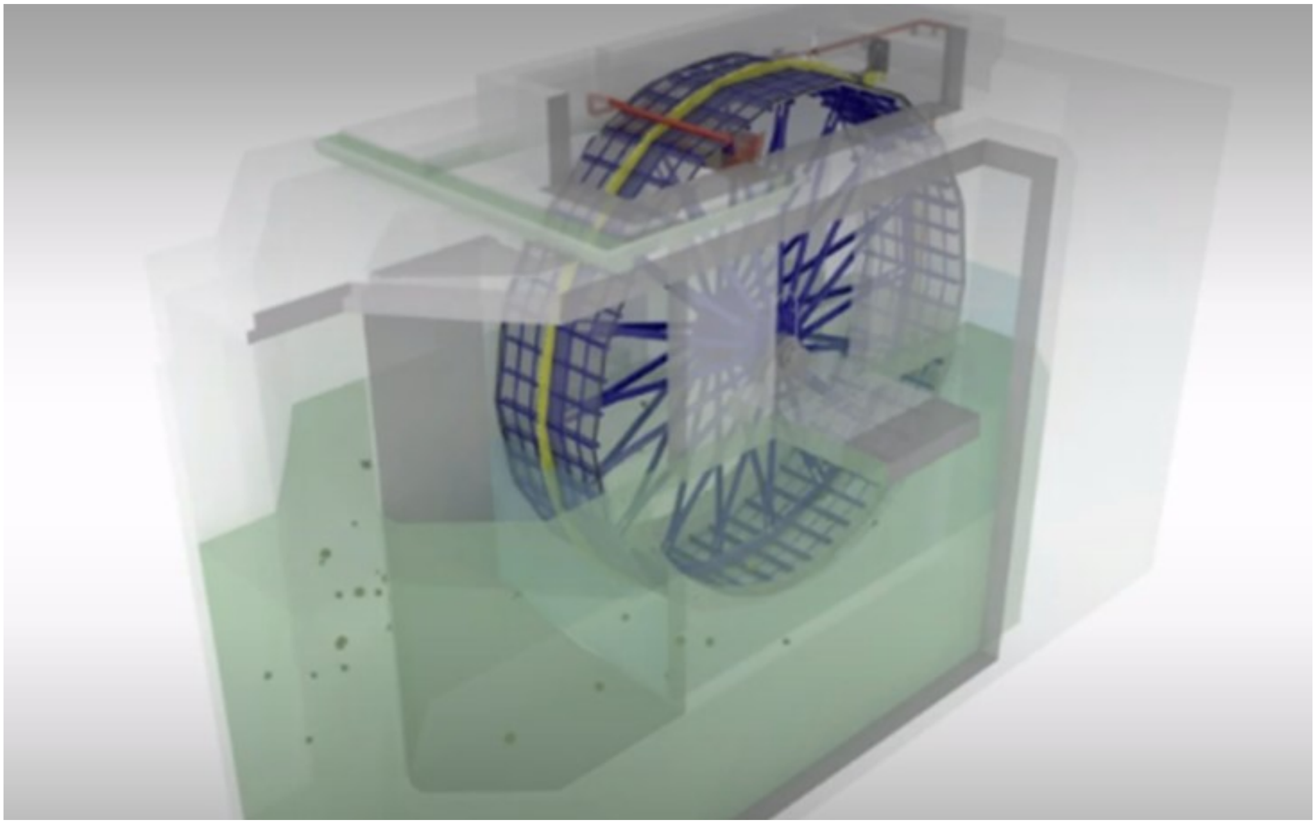

Figure. Twelve: Traveling Water Drum Screen type "In to Out"

6. Wash spray pump

Screened Intake water is passing through the traveling water screen. The debris retained, on the other hand, is collected on the outer surface of the screen meshes. Traveling screen needs reliable washing system which is initiated once the screens are obstructed by debris. Debris is removed through back washing by the spray water system.
Screen washing is achieved using vertical pumps, equipped with electrical motors located outdoors in the intake pump bay. High efficiency spray system is sized and designed to periodically wash travelling screens for debris removal. Pumps are associated with self-cleaning strainers that filter the spray water after pumping. Water sprays shall not operate until the differential head across screen reaches a preset limit and hence the wash pump will be initiated. At higher preset differential head encountered on screens, the screen will operate at fast speed.
Strainers are interconnected with differential pressure system that controls the strainer differential pressure, that transmits back the differential pressure to the screen washing and spray system control panel. If the strainer differential pressure is raised, a cleaning order will be sent from the strainer control box to the backwash motor actuated valves to be opened and a strainer backwash cleaning cycle will be done to ensure clean spray water system.

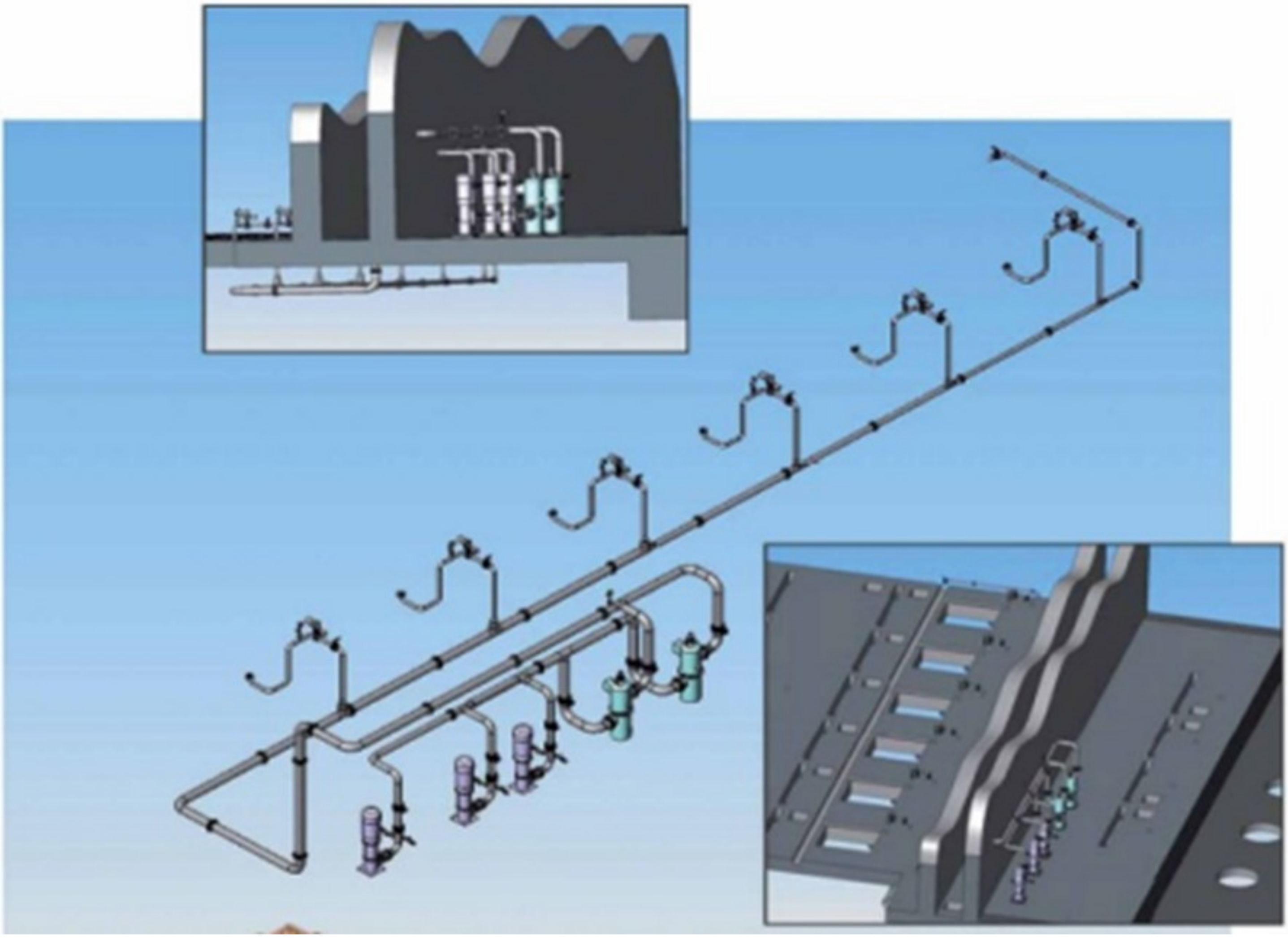

Figure. Thirteen: Traveling Water Wash Spray System.

Conclusion

We tried in this article to give more insights in a simple way, about the basic considerations adopted in filtering water intake systems. Cleaning systems have to fulfill reliably the requirements, depending on their source (i.e. rivers, lakes or the sea), and the type of industrial plant in which they will be used.

The market is always trying to meet challenges faced, thanks to a variety of flexible solutions and the implementation of the latest manufacturing technology, which have been briefly presented in this article. New screening techniques may have to be developed or older systems improved to provide environmental protection and good operational performance.

Construction considerations and operational experience of different water intake system components are discussed. It is recommended that these options offer potential cost savings over the life of a plant and be environmentally acceptable as well. Components should be tested to determine their potential suitability for a commercial and operational point of view. The various traveling water screen options are presently used at large different facilities and must have an extensive operational history.

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THE FIRST UTILITY SCALE PV PLANT BENBAN SOLAR COMPLEX & THE GRID CODE

Article By : Mohamed Elseify

1. Introduction

By the end of 2019, Egypt had effectively strengthened the contribution of the renewable energy sources into the grid. Benban Solar Complex is the first utility scale solar photovoltaic plant in Egypt with total capacity of 1.8 GW. The Eastern Sahara sun's development scheme led by the International Finance Company (IFC) with the World Bank, the Multilateral Investment Guarantee Agency (MIGA) & the Egyptian Government (3), with loans exceeded 3 billion USD (4), is an important fragment of Egypt's huge plan to meet 20 per cent of its electricity demand through renewable energy sources by 2022 & double it to 45 per cent by 2035 (4).

Benban Solar Complex is 37,200,000 m^2 land divided into 41 plots, 32 developers, containing 4 substations connecting the solar park to the extra high voltage network 220-kilovolt (kV), a control center & approximately $7.2x10^6$ photovoltaic panels which make the park visible from space as a big ocean of photovoltaics (3). "See Figures 1, 2 and 3"

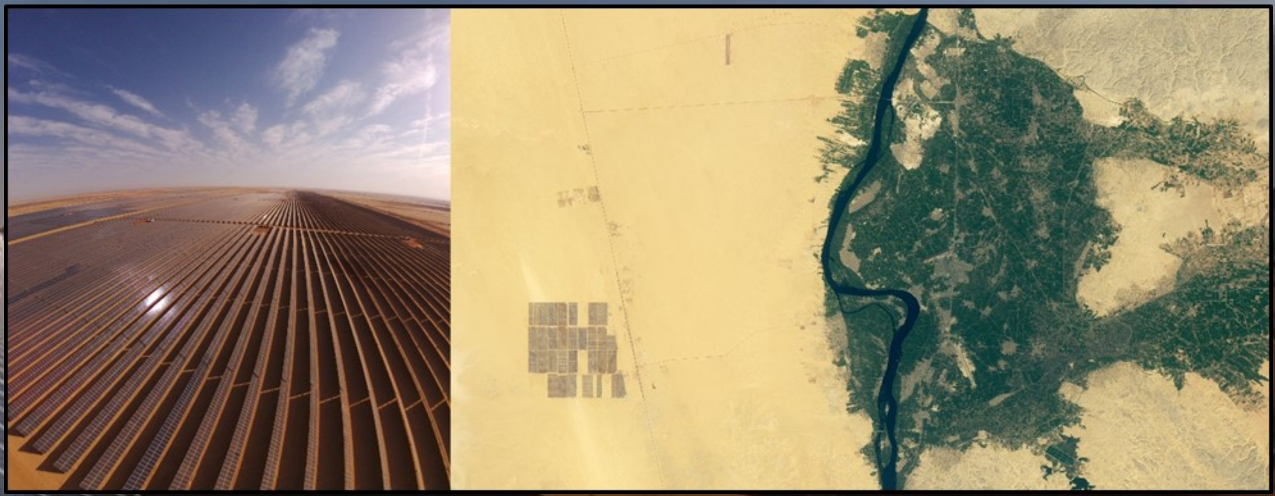


Figure 1 - Alcazar Energy Plant (1) & Figure 2 - Benban Solar Complex by Operational Land Imager (2)

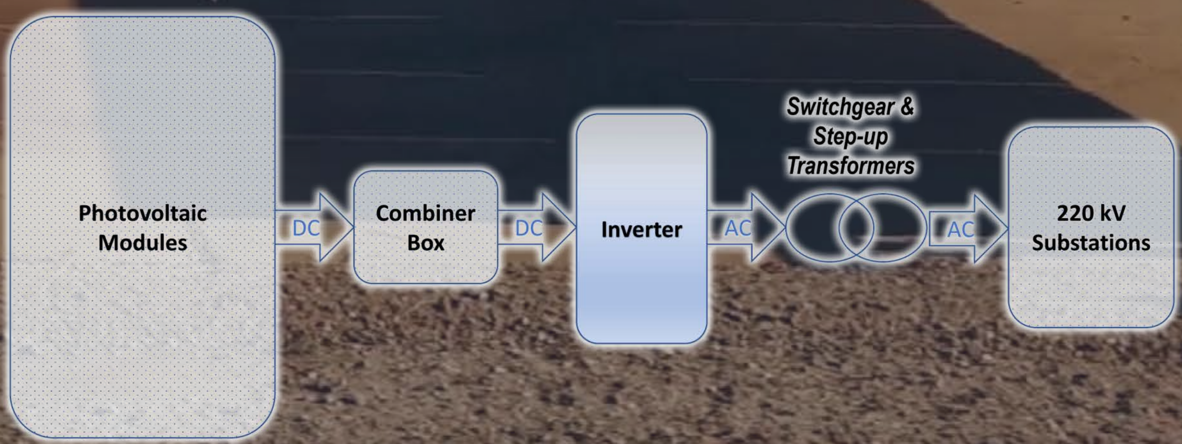


Figure 3 - Typical Photovoltaic (PV) system architecture in Benban Solar (5)

In the past, the majority of the generation of renewable energy was connected to the medium voltage network, these renewables were treated, according to the related grid codes, as loads that should be disconnected from the grid as soon as possible during disturbances (6).

Currently, due to the fast-growing contribution of renewable energy in to the grid "see Figure 4", additional roles to renewable energy is being imposed. The role of renewables now is not only to participate in power generation, but also to offer ancillary services to ensure the electrical grid's quality & reliability (6).

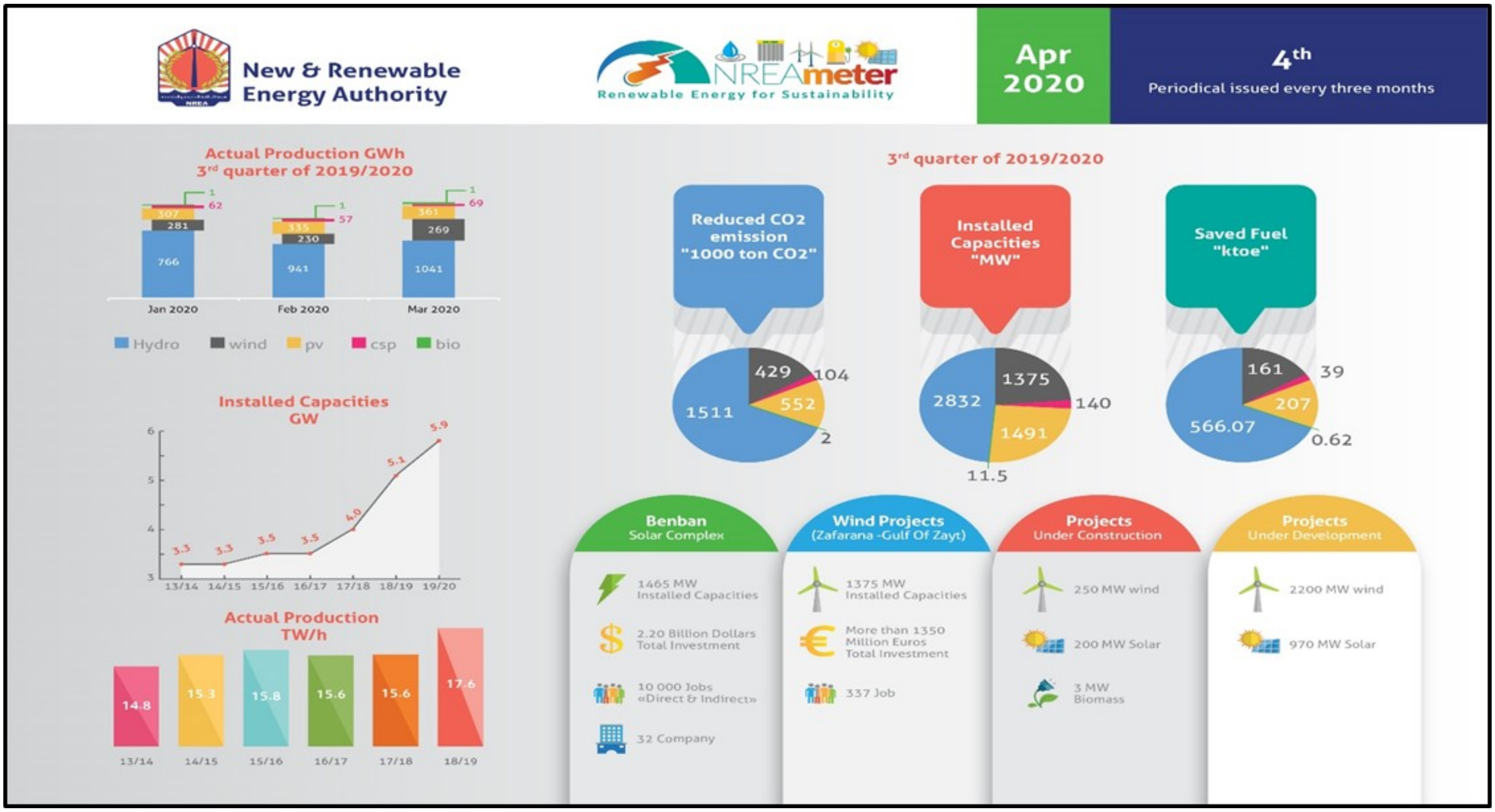


Figure 4 - New Renewable Energy Authority (NREA) April 2020 Report (4)

In the following paragraphs, we shall illustrate few examples of the ancillary services that are required in a utility scale photovoltaic power plant such as Benban Solar Complex in terms of grid operational ranges & features.

2. Photovoltaic & Grid Code Requirements:

The Egyptian Electric Utility and Consumer Protection Regulatory Agency (EgyptERA) issued two codes regarding the connection of photovoltaic power plants to the grid to guarantee reliability & quality of the grid, simultaneously complying with other compulsory codes e.g. the Egyptian Transmission Grid Code & the Egyptian Distribution Network Code, as following:

- "Solar Energy Plants Grid Connection Code (SEPGCC)" for:
  - ◊ Medium Size Solar Plants (MSSP) (500kW-20MW)
  - ◊ Large Size Solar Plants (LSSP) (≥20MW).
- "Technical Requirements for Connecting Small Scale PV (ssPV) Systems to Low Voltage Distribution Networks" for:
  - ◊ Small Scale PV (ssPV) (>500kW).

The responsible component in a typical PV system for providing ancillary services to the grid is the inverter.

The inverter is static power converter device that converts Direct Current (DC) electricity into Alternating Current (AC) electricity (7). This equipment converts the DC generated energy from the Photovoltaic modules into a suitable form of energy & is responsible for Maximum Power Point Tracking (MPPT), and meeting grid operational ranges & features.

According to the SEPGCC, the following functions are required by the solar plant's inverter, to support the grid quality & reliability:

- Grid operational ranges:
  - ◊ Voltage Range
  - ◊ Frequency Range

- Grid operational features:
  - ◊ Active power control
  - ◊ Reactive power control
  - ◊ Fault ride through

As an example, according to "1500V 2.5/3MW PV Power Container", one of the inverters used in Benban Solar Complex in Al Tawakol Photovoltaic Power Plant plot 42-4 (20MWp) & ACWA Benban 1 plot 43-4 (67.5 MWp), the inverter is described as "Utility interactive" (8) for having several functions that meet the grid operational requirements. "See Figure 5"

Utility Interactive

- Active power continuously adjustable
- Reactive power control with power factor from -0.9 to +0.9
- Give reactive power compensation to the grid at night according to directive
- Comprehensive grid management functions including complete dynamic grid support

Figure 5 - Snapshot from the datasheet of 1500V 2.5/3MW PV Power Container (8)

2.1. Voltage Ranges:

In the event of grid's voltage deviation from its tolerable range, the plant's inverter shall continue to generate the actual active power as specified by Table 1**.** The actual active power is "the amount of active power that the Solar Plant could produce based on current solar irradiance and ambient temperature conditions." (9).

Voltage Range	Time Period for Operation
85 – 110 %	Unlimited Operation
110 – 115 %	30 minutes maximum then disconnect in case of time limit exceeded

Table 1 - Minimum Operation Time Periods (9)

2.2. Frequency Ranges:

During grid frequency deviations, the inverter shall perform according the grid frequency value "see Figure 6". Depending the on the frequency deviations from 50 Hz, the inverter shall support the grid for a period time either by ceasing to energize or reducing the active power with definite steps (9).

The concept is illustrated in the following paragraphs.

2.3. Active Power Control:

During frequency deviations, the disconnection of LSSP may create severe grid instability due to the impact of unbalance between demand & supply.

In the events of frequency decreasing from its normal value (50 Hz), this means that the demand is larger than the electrical supply, the disconnection of LSSP (≥20MW) may weaken the grid stability due the loss of huge percentage power, and therefore the inverter should support the grid by maintaining the continuous power generation.

In contrast, when the frequency increase from its normal value, it means that the grid supplying excess power to a lesser demand, consequently the inverter should reduce its active power generation.

The curtailment process of the active power shall in steps of 10%/min-rate each.

According to the grid parameters; voltage, frequency & time ranges, the solar plant shall continue generating active power to the grid. "See Figures 6 and 7"

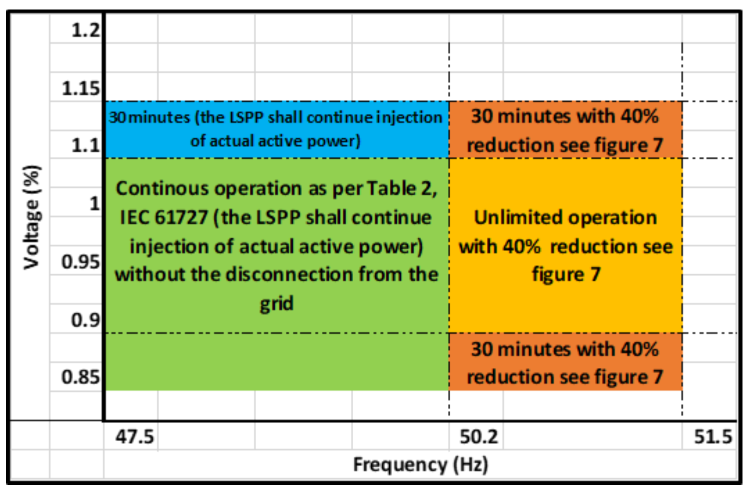


Figure 6 -Requirements on the output power of the solar plant in case of grid frequency and grid voltage variations (9)

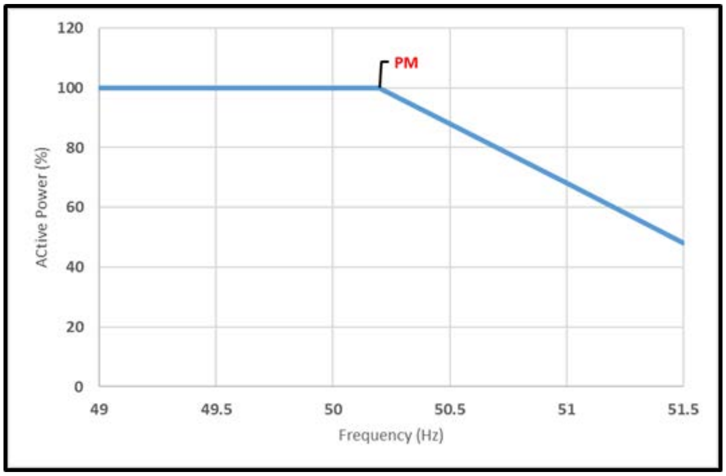


Figure 7 - Active Power Reduction due to over frequency (where PM is the actual power before frequency exceeds the threshold set point 50.2 Hz) (9)

In case the frequency increases or decreases even more the LSPP shall cease to energize the grid. The inverter shall only be reconnected to the grid if the frequency & the voltage at the Point of grid connection are within the limits stated in Table 2 (9).

Grid's Parameter	Minimum Value	Maximum Value
Frequency (Hz)	48 Hz	51 Hz
Voltage (V)	90 %	110 %

Table 2 - Solar Plant Start up Ranges (9)

2.4. Reactive Power Control:

Aforementioned that the growing contribution of renewable energy sources to the grid imposed additional roles for the renewables, one of such roles is the reactive power control. Although ssPVs are not required to inject any reactive power into the distribution network (10), it's required by the MSSP & LSSP to support the grid by controlling the reactive power at the Point of Common Coupling (PCC) to maintain grid's voltage stability (6).

In case the solar plant generate power at unity power factor (no reactive power – only active power), it's acceptable to small sized plants due to its negligible impact on the grid, however for MSPP & LSPP, due to their significant share of power in the grid, it's obligatory to inject reactive power related to several parameters e.g. voltage, active power output. Such obligation is to maintain a balanced power factor in the grid.

Consequently, it's required by the LSPP to control the reactive power in a range of 0.95 lagging to 0.95 leading at maximum active power according to PQ Capability curve as per nation's grid code "see Figure 8".

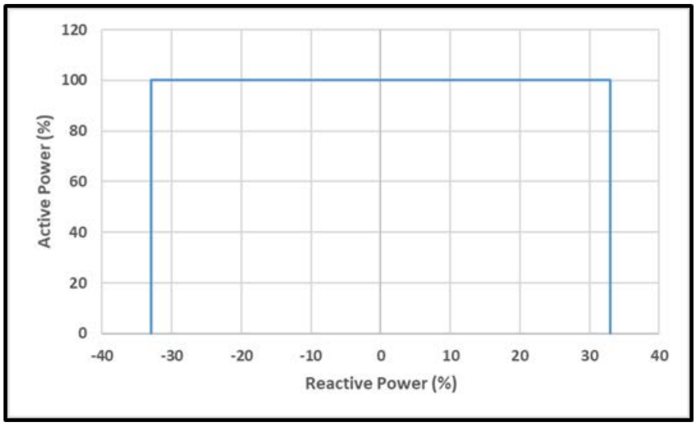


Figure 8 - PQ Diagram for LSSP

For LSPP, even at zero active power output (e.g. during the night), reactive power injection may be required & to meet such requirement the inverter shall operate VAR mode – Q on Demand or we can utilize capacitors or reactor banks (9).

2.5. Fault ride through

The Fault ride through function is used to cope with voltage sags or swells "see Figure 9" & ride through grid's fault. It describes the inverter's ability to stay connected to support the grid for a period of time during disturbances to mitigate any chain reaction resulting from the tripping of large energy generation sources from the grid.

It is classified into two types based on voltage as following:

- Low Voltage Ride Through (LVRT) dealing with voltage sags in the grid by injecting capacitive reactive current (11)
- High Voltage Ride Through (HVRT) dealing with voltage swells in the grid by inject inductive reactive current (11)

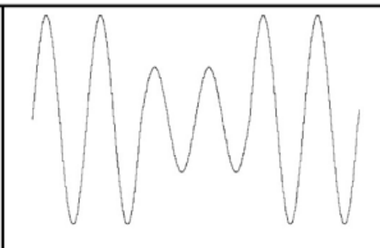
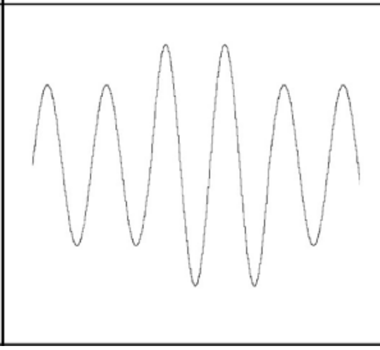
Disturbance		Origin	Consequences
Voltage sag, undervoltage 2.2		Short circuits in the network grid. Start up of large motors.	Disconnection of sensitive loads. Fail functions.
Voltage swells. Overvoltages 2.3		Earth fault on another phase. Shut down of large loads. Lightning strike on network structure. Incorrect setting in substations.	Disconnection of equipment may harm equipment with inadequate design margins.

Figure 9 - Voltage's Sag & Swells Waveforms (12)

According to SEPGCC, solar plants have to deal with voltage dips with different scenarios (LVRT) depending on phase to phase voltage percentage & type of faults according to Figure 10

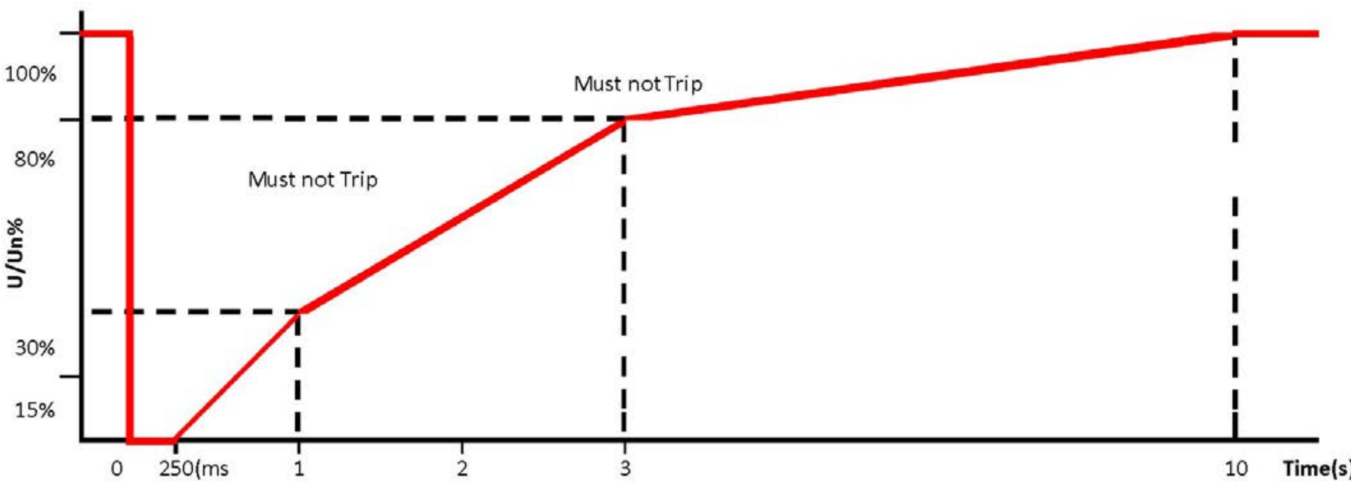


Figure 10 - Low voltage ride through profile for a solar plant (9)

I. The phase to phase voltage percentage is below the curve, then the inverter must disconnect from the grid.
II. The phase to phase voltage percentage is above the curve & the fault is unsymmetrical, the inverter must not inject any reactive current.
III. The phase to phase voltage percentage is above the curve & the fault is symmetrical, the solar plant is required to supply capacitive current, after 250 ms from the fault until fault clearance, the amount of the current shall be defined by Figure 11, Equations 1 & 2 (9).

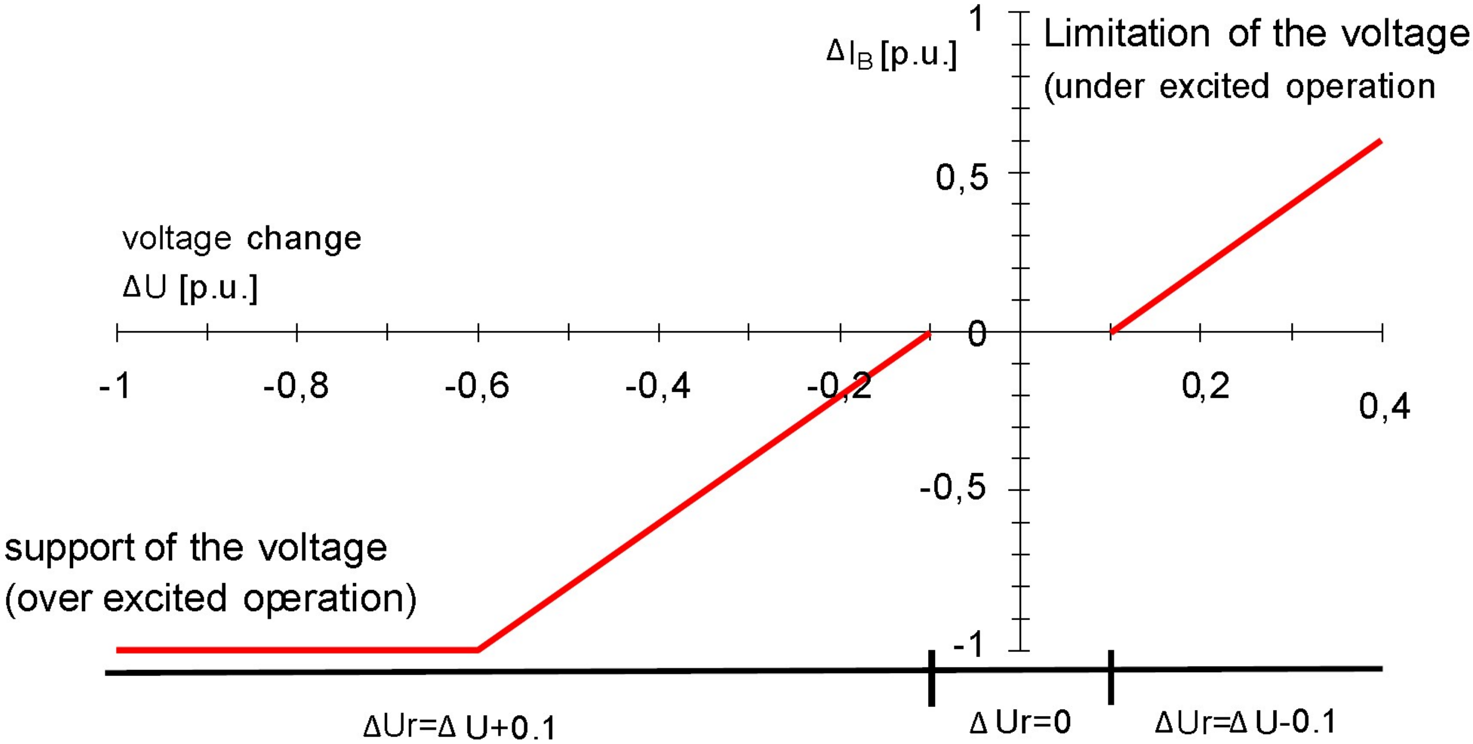


Figure 11 - Requirement of reactive current injection during the fault (k = 2) (9)

Equation 1: $$\frac{\Delta I_B}{I_N} = k \times \frac{\Delta U_r}{U_N}$$

Equation 2: $$\Delta U = U - U_0$$

ΔI_B :The required reactive current during the fault

I_N :The rated current

k :Adjustable factor from 0 to 4

ΔU_r :The relevant voltage change during fault

U_N :The rated voltage

ΔU :Voltage change “see Figure 11 x-axis”

U :The voltage during fault

U_0 :The pre-fault voltage

Such feature in the inverter maintain the voltage level at tolerable range & prevent further deterioration at the grid from widespread loss of generation.

3. Summary:

The development of ancillary services of renewables is merely dependent on the contribution of renewable energy sources in the grid.

With Renewable Energy Sources gaining a lot of attention in Egypt & worldwide recently, Grid codes shall be developed to meet the new technology & high level of participation of renewable in the grid.

When it comes to solar energy development & growth, significant part of the process is related to the inverter.

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