CONSTRUCTION OF THE ISCC KURAYMAT

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1 Introduction

The Integrated Solar Combined Cycle Power Plant (ISCC) Kuraymat is located about 87 km South of Cairo, Egypt on the eastern side of the river Nile. The ISCC Kuraymat is a first of its kind construction of a combined cycle power plant with solar generated steam input.

The plant is owned by the **New and Renewable Energy Authority (NREA)** of the **Ministry of Energy** of Egypt. The **Global Environmental Facility (GEF)** of **World Bank** has contributed a grant of 49 M$ towards the incremental cost of solar electricity generation. The remaining foreign currency portion of the investment cost is financed by **JBIC (Japan Bank for International Cooperation)**. NREA is financing the local currency portion of the investment.

The complete ISCC Project is implemented in four (4) contract lots:

- **One Contract Lot for Solar Island** as contract for engineering, procurement, construction, commissioning and five (2) years operation and maintenance (EPC cum O&M), being executed by **Orascom Industries** of Egypt with a subcontract to **Flagsol** (a subsidiary of **Solar Millennium AG**) of Germany.

  The Solar Island consists of a parabolic trough solar field, the heat transfer fluid (HTF) system up to the HTF inlet and outlet flanges of the Solar Heat Exchangers, associated control systems and control and service buildings. The contract includes 160 SKAL-ET collectors arranged in 40 loops. The Contractor for Solar Island guarantees the supply of solar heat to the solar heat exchangers as a function of direct normal irradiation (DNI) and incident angle of the sun.
- **One Contract Lot for Combined Cycle Island** as contract for engineering, procurement, construction, commissioning and extended two (2) year warranty period, being executed by **Iberdrola** of Spain.

  The Combined Cycle Island consists of one gas turbine, one heat recovery steam generator (HRSG), one steam turbine, solar heat exchangers plus all associated control and balance of plant equipment and installations.

  The Contractor for Combined Cycle Island guarantees the generation of electricity and the heat rate as a function of ambient temperature and supply of solar heat from the Solar Island.
- **One Contract Lot for the engineering of the complete ISCC**, being executed by **Fichtner Solar GmbH** of Germany.

  The engineering included the initial studies, the technical design, the preparation of specifications and contract documents, evaluation of the bids from potential EPC Contractors as well as the contract negotiations up to "Contracts ready to be signed". Thereafter Fichtner Solar has been assigned the complete project construction management (design review and construction supervision and two years warranty period support).
- **One Contract Lot for Combined Cycle Island as O&M contract** for five (5) year operation and maintenance.

The scope split between the Solar Island and the Combined Cycle Island of the project is shown in Figure 3-1. The thermodynamic interface between Solar Island and Combined Cycle Island is the HTF inlet and outlet flanges of the solar heat exchanger. The Solar heat exchangers are in scope of the Combined Cycle Island Contractor.
The ISCC Kuraymat power plant is under construction since January 2008. Start of commercial operation is scheduled for October 2010.

2 History

After discussion on ISCC technology the World Bank in 1999 decided to sponsor four ISCC projects, respectively one in Egypt, Morocco, India and Mexico by a grant of 50 Million USD each. The planning and engineering for the Kuraymat project in Egypt was awarded to Fichtner Solar in 2001.
Fichtner Solar prepared the Technical Design Report, Specifications and Tender Documents for a turn-key ISCC plant. In 2004 the original planning was modified and it was decided to tender the plant in two lots (Solar Island and Combined Cycle Island). Fichtner Solar was awarded with the preparation of Specifications and Tender Documents for these two lots. During that period Fichtner Solar also prequalified and short listed potential bidders. The shortlisted bidders submitted their proposals and after evaluation and contract negotiation the EPC contracts were awarded to Iberdrola with Mitsui for the Combined Cycle Island and Orascom with Flagsol for the Solar Island in October 2007.
At the same time Fichtner Solar won the contract for project construction management.

3 Technical Concept

In reference day mode conditions of **700 W/m^2 direct normal irradiation at solar noon of 21 March and 20 °C ambient temperature** the Solar Island will generate about **50 MJ/s** of solar heat at a temperature of 393°C; this enables the ISCC to generate **125.7 MWe** of net electric power output. Without solar heat the plant will generate **103.8 MWe** of net electric power output. The difference between reference day mode and night mode operation is 21.9 MWe; thereof 2.7 MWe are accounted to the part load losses of the steam turbine and 19.2 MWe are accounted to the true (exergetic) solar generation. The plant's general concept is depicted in Figure 3-1

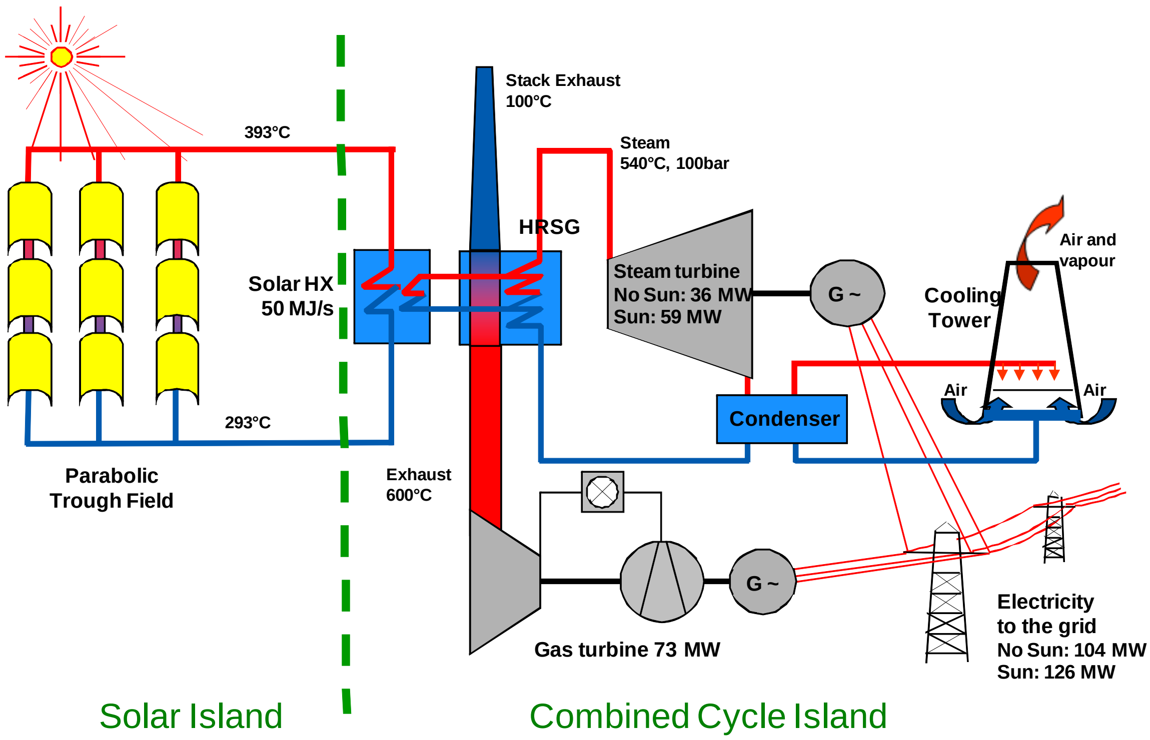

Figure 3-1 Scope Split and General Concept of the ISCC Kuraymat

Table 1 shows the technical key data for the ISCC Kuraymat according to the EPC contract and the latest construction design. The design thermal power of the Solar Island will be reached for DNI values between 700 and 800 Watt/m² depending on incident angle and status of the solar field (Number of loops in operation, tracking accuracy, mirror reflectivity etc.).

Key Technical Data		
	Unit	**Value**
Solar Field total Aperture Area	m²	130800
Number of Collectors	N°	160
Number of Collector Loops	N°	40
Design Irradiation	W/m²	700
Solar Field Design Thermal Power at Reference Conditions	MJ/s	50
Hot Leg HTF Temperature	°C	393
Cold Leg HTF Temperature	°C	293
Gas Turbine Generator Rated Power Output	MWe	74,4
Steam Turbine Generator Rated Power Output	MWe	59,5

Table 1 Key Technical Data

4 Construction Site and Plant Arrangement

The ISCC Kuraymat construction site is located at 29° 16' 45,81'' North and 31° 15' 9,43'' East approximately 87 km south of the city centre of Cairo. The site is located on a plateau about 49 m above the shore line of river Nile. Elevations of the site are between 55 m and 66 m above sea level. North of the areal a gas pipeline, which will supply natural gas to the project, is passing. The construction site is also passed by a 500 kV power line in the North and a double 220 kV power line in the South East. Further in the South East the existing Kuraymat combined cycle power stations are located. In the South cultivated land is neighboring the plant site and in the East a small Wadi is bordering.
Figure 4-1 shall give an overview on the arrangement of the plant at Kuraymat. Coming from Cairo heading towards the plant on the access road, first the non-plant building area is passed on the right. It will contain offices, a fire fighting station, workshops and warehouses. The plant itself is accessed over the ring road from the north. The figure shows the power block area in the North surrounded by the solar field areas 1, 2, 3 and 4. Some of the balance of plant (BOP) installations of the Combined Cycle Island are located outside of the power block in the North of the plant. These are for example the sedimentation and effluent basins, the natural gas station and the switchyard.

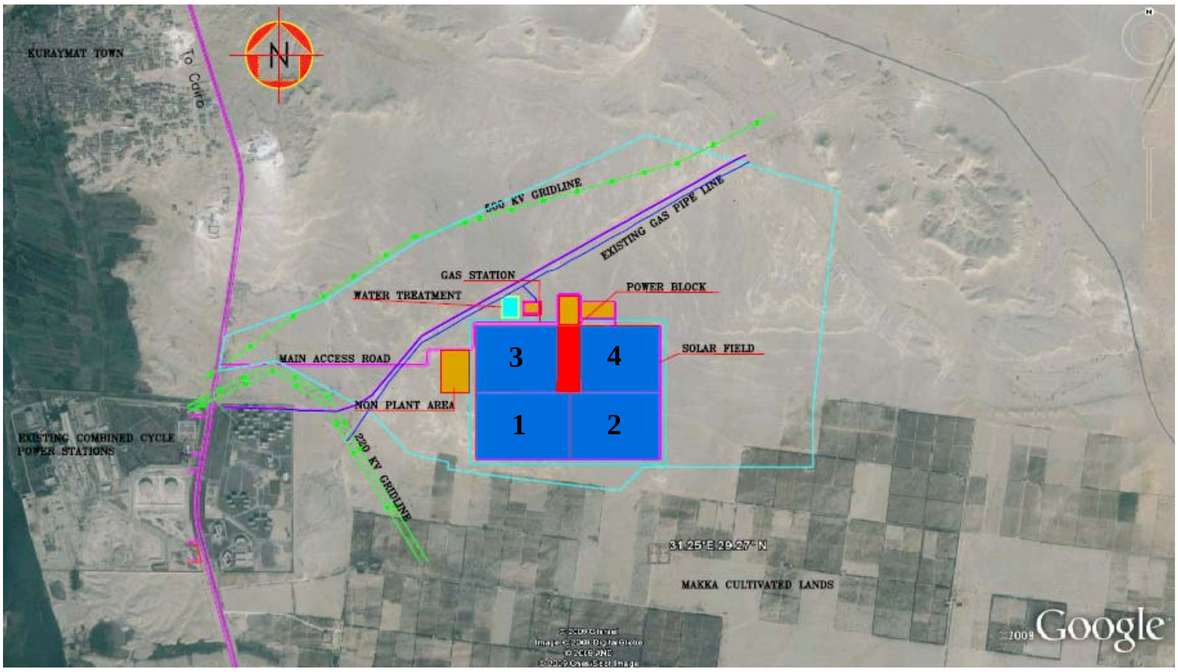

Figure 4-1 Plant Overview

5 Design

5.1 Solar Island

Windbreakers

Of special importance in the solar field design has been the reduction of wind loads. For that purpose a 6.50 meter high pillar reinforced wind breaker wall from locally manufactured bricks has been designed for the East and the West boundary of the solar field. The original windbreaker design had foreseen a wind fence from wire, later Orascom proposed to construct the windbreaker from bricks, which is locally manufactured material.

Pylon Foundations

The soil in the solar field area has a very rocky layer at the top. Pylon foundations have been designed accordingly in rather broadly based flat design. The pylon foundations require excavations of about 2 meters depth on a square of 2.5x2.5 meters. Pylon foundations are individually designed for end pylons, drive pylons, middle and shared pylons as well as in reinforced design for the outer areas of the field, where higher wind loads are expected.

Collector

The parabolic trough collector design being installed is based on the SKAL-ET 150. The collectors exposed to higher wind loads due to their position in the outer rows of the solar field are of reinforced design. The SKAL-ET collector is designed to be assembled in an assembly hall close to the site from pre-fabricated low cost steel structure that can be manufactured locally all over the world. The pre-fabricated welded steel parts of torque box frames and plates, cantilever arms and HCE supports are delivered locally by a sub supplier and assembled by Orascom at the site. The assembly which is technically advised by Flagsol is organized in one line using three jigs, arm jig for assembly of cantilever arms, box jig for assembly of the torque box and SCE jig for final assembly of all pre-assembled parts. Quality control of the assembled SCE steel structure is done on a photogrammetric measuring station. Final steps in the assembly hall are mirror mounting and SCE balancing.

The collector design uses four different pylon designs, end pylon, middle pylon, drive pylon and shared pylon. Similar to the collector steel structure and the pylon foundation the pylons are designed as reinforced or regular according to the position in the solar field. Solar mirrors for the ISCC Kuraymat are supplied by FLABEG in 4 millimeters and 5 millimeters thickness. Absorber tubes installed at the plant are SCHOTT PTR® 70.

HTF System

The HTF system is designed for a HTF mass flow of Solutia's VP1 of 250 kg/s at 100% load. The solar field is divided by a main header which leaves the power block area at the southern end, splits into an East and a West section and separates the solar field into a northern collector loops area with the power block in the middle and a southern collector loops area. The northern part comprises 18 loops of four collectors per loop, nine at each side of the power block and the southern part 22 loops, leaving space for four spare loops. The HTF is pumped into the solar field by 3x50% HTF main pumps, the HTF flow is separated by control valves between the East and the West section, HTF flow through the loops is controlled per individual adjusting valves. The HTF system of the ISCC Kuraymat will include an ullage and reclamation system with one ullage vessel, one ullage drain vessel, one reclamation flash vessel and one reclamation drain vessel, all equipment with the required coolers and pumps. Furthermore the HTF system with include one expansion vessel, a HTF filter and a freeze protection unit with natural gas fired freeze protection heater and freeze protection pumps.

5.2 Combined Cycle Island

Power Block Arrangement

The power block area is located in the middle of the northern part of the solar field with collector loops in the East and the West. Auxiliary plant equipment such as water treatment and gas station are located in the North of the plant outside the power block area.

Gas Turbine

The plant will include one GE type MS 6111 FA gas turbine with generator of rated electric power output of 74 MWe at 20°C ambient dry bulb temperature. The gas turbine will combust about 4.7 kg of natural gas per second and therefore require about 200 kg of combustion air per second.

HRSG

At rated conditions of gas turbine full load operation the heat recovery steam generator will receive about 206 kg/s flue gas from the gas turbine at temperatures of about 600°C. The flue gas leaves the HRSG at about 100°C.

The HRSG steam system design includes two low pressure economizer, low pressure evaporator, low pressure steam drum and low pressure super-heater for feed off the steam turbine low pressure section, three high pressure economizer, high pressure evaporator, high pressure steam drum and two high pressure super-heater for feed of the high pressure section of the steam turbine. The HRSG is designed and delivered by NEM of the Netherlands. The solar generated steam will be injected into the high pressure steam drum at about 80 bar pressure.

Solar Steam Generator

Enthalpy received with the HTF from the solar field is used for steam generation in two trains each consisting of one tube and shell economizer and one evaporator, also in tube and shell design. Steam is slightly superheated and fed into the high pressure steam drum.

Steam Turbine

The ISCC Kuraymat will include a Siemens SST 900 series single casing, horizontally split condensing type steam turbine with generator. At rated conditions of gas turbine and HRSG full load operation, solar heat input of 50 MJ/s and 20°C ambient dry bulb temperature the steam turbine generator output will be 59.5 MWe. The turbine will have a high pressure section that receives steam from the high pressure super-heaters and a low pressure section that receives steam from the low pressure super-heaters and the high pressure turbine section. Electric power output of the steam turbine according to solar heat input is depicted in Figure 5-1.

Cooling System

Exhaust steam will be condensed by a horizontal tube and shell type condenser. Cooling of the condenser will be by five cellular type evaporative coolers. Cooling water range will be 6°C.

Water Supply System

About 300 m³/h of raw water will be pumped to the plant from an intake station at the Nile, and treated by clarification, filtration and ion exchange. The cooling towers will use clarified water, closed cycle cooling water make-up, steam cycle make up and mirror washing water will be from de-mineralized water. The plant will include a water treatment plant which treats blow down before discharge to the Nile.

Electrical System and Power Evacuation

Power generation voltage level at steam turbine generator and gas turbine generator will be 11 kV, power evacuation voltage level is 66 kV, station loads will be fed from 6.6 kV medium voltage switchgear.

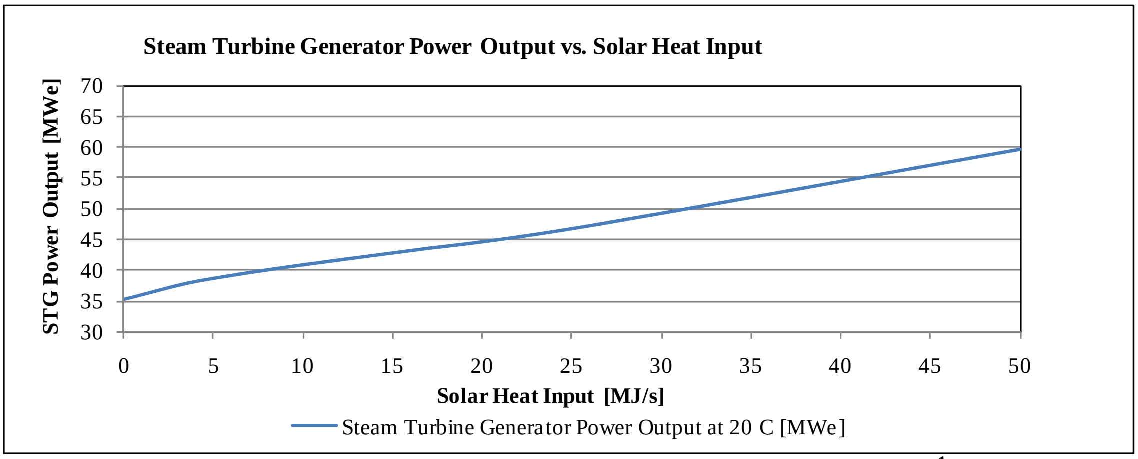

Figure 5-1 Steam Turbine Generator Output vs. Solar Heat Input[1]

[1] Gas Turbine Generator Output constant at 74.1 MWe

6 Construction Works Progress

As of July 2009 the following work progress has been recorded at the site:

6.1 Solar Island

Solar Field Earth Works
In Area 1, 2, 3 and 4 all solar field earth works, including leveling, excavations and, backfilling have been completed.
Collector Foundations
Collector foundations have been completed for the entire solar field.
Pylons
Collector pylon installation in area 1 and 3 is completed and in area 2 work is in progress, about 70% overall completion of pylon installation has been achieved.
Collector Installation
In area 1 and 3 collector installation has been completed, in area 2 work is in progress, about 55% overall completion has been achieved.
HTF System
Header piping fundaments are completed and installation of HTF piping has started. For the HTF building concrete works have been completed and finishing is in progress.

In Figure 6-1 the work progress for civil works, is depicted. The first picture top left shows area 4, where earth works and foundations have been completed recently and works for the east side windbreaker are to be finished. The picture at the top right shows a close up of the windbreaker. The picture down left shows a completed pylon foundation before final backfilling and the picture down right shows the HTF concrete building which will contain most of the solar field control equipment as well as the electrical systems for the solar field and HTF system.

Figure 6-1 Progress of Solar Island Civil Works

Photos comprised in Figure 6-2 shall give a review on the collector installation progress at the site. The picture top left shows collector area 2, where collector installation is in progress. The picture up right sows the preparations for header pipe welding and installation in area 1. The picture down left shows the completed collector area 3, the picture down right again shows area 2 where collector installation is in progress.

Figure 6-2 Collector Installation Progress

6.2 Combined Cycle Island

Civil

Non-Plant Area and BOP

Work shops and stores in the BOP area have been completed to 90 %. Fire station is completed to about 70 % and the electrical building of the non plant area is in progress. External pipe lines from/to Nile to the interface point with the power block are under construction. The effluent pipe from the Power Block to Nile as well as the raw water supply pipe are under construction and finished to about 30%. Underground Systems including the raw water pipe inside power block and the effluent pipe inside the power block are completed to 95 %. Fire-fighting equipment installation inside power block is in progress and completed to about 60 %. Drainage systems including rain water drainage, non-oily drainage, steam turbine building drainage and oily drainage are completed to about 70%. The gas pipeline from gas station to gas turbine is under construction and the section inside the power block has been completed to about 70%.

Power Block Area

Civil works for the electrical and control building are in progress and completed to about 80%, internal works and cabling have started, so far no functional equipment has been installed. In the gas turbine area civil works are almost completed with about 90%.

Civil works for the boiler unit, the steam turbine building, the steam turbine condenser, cooling water pumps housing, and cooling towers have been completed.

Further civil works for cooling water pipes from/to condenser, de-mineralized water plant, water treatment area, feed water tank, main transformer for steam turbine and gas turbine, condensate tank, main pipe rack, service water tank, effluent basin, switchyard, control building and raw water basin have been completed to about 60 to 80%.

Mechanical

Gas Turbine (GT)

About 90% of the GT equipment has been delivered to the site.

Steam turbine/condenser

The condenser has been delivered to the site.

Cooling tower

About 10% of the mechanical cooling tower structure has been completed and the glass reinforced epoxy cooling water pipe from and to the condenser almost has been completed.

Solar Steam Generators

The solar steam generator units, including two pre-heaters and two evaporators have been delivered to the site.

Pictures comprised in Figure 6-3 shall give a review of the civil and mechanical works progress of the Combined Cycle. The picture up left shows one delivered solar steam generator on the left and one pre-heater on the right. The picture up right shows the steam turbine housing and fundament on the left and the gas turbine on the right, in the back collector area 1 and 3. The picture down left shows the 66 KV switchyard and the picture down right again shows the pre-heaters of solar steam generator units, in the back the associated racks and further in the back the cooling tower steel structure which is under construction.

Figure 6-3 Civil and Mechanical Works Progress of Combined Cycle