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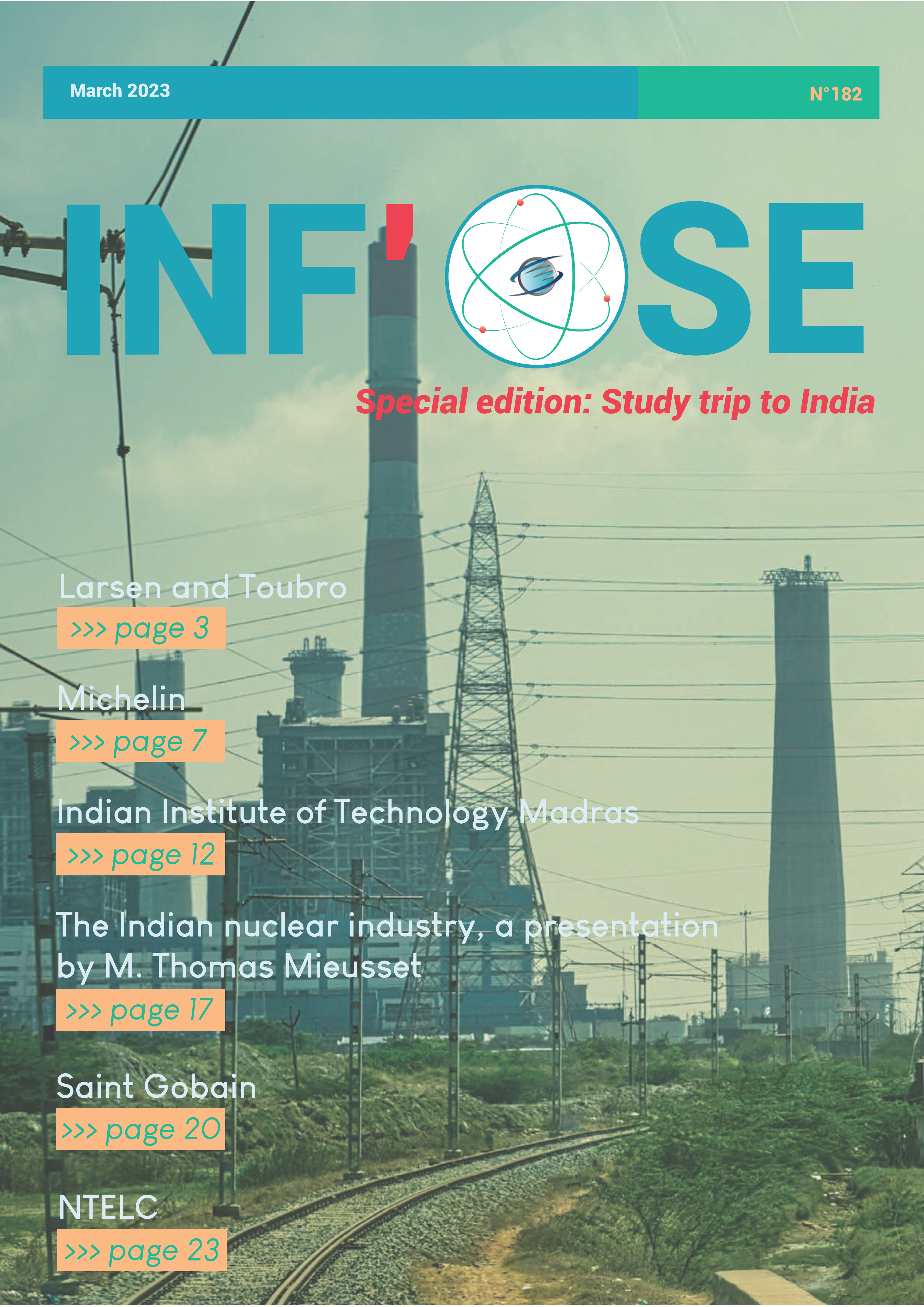
INF'OSE

Special edition: Study trip to India



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EDITOR'S NOTE

Dear readers,

With the end of the academic year comes the traditional trip abroad for the OSE Master students. This time, we went to India and particularly between Chennai and Pondicherry. This was an opportunity to familiarize ourselves with a culture and an energy system almost diametrically opposed to ours.

Indeed, coal occupies the majority of the electricity mix (52% in 2022), but also of the energy mix (over 55% in 2021).

But France and India have one major point in common: they are both powers that have decided to develop nuclear energy. Their respective strategies differ greatly.

This trip would not have been possible without the help, involvement and contacts of many people: Mr. Xavier de Mortreuil, attaché for science and academic cooperation at the French embassy in Bengalore and Mr. Thomas Mieusset, nuclear advisor at the French embassy in New Delhi; Mr. Bertrand Bonhomme of Michelin and Mr. Mario Olivier of Saint-Gobain. Thank you all for allowing us to make such visits.

In this 182nd edition of the Inf'OSE, we retrace what we learned from these industrial visits. We would like to thank the teams from Larsen & Toubro, Michelin, the Indian Institute of Technology, Saint-Gobain and NTELC for welcoming us and answering our many questions. Thanks again to Mr. Thomas Mieusset for meeting us and accompanying us during part of this trip.

Finally, we would like to thank Gilles, Alice, Amel and all the other people in charge of the organization of this trip, including our local responsible travel agency BB voyage (https://indexperience.fr/bb-voyage/) carried by Véronique and Raghu, who guided us with Jay. This experience will keep a special place in our memories and we are very grateful for all that we learned from it.

Have a good read

The Inf'OSE team

LARSEN AND TOUBRO – FEBRUARY 27TH

L&T Group, L&T Construction and L&T Valves general presentation

Reading time: 6 min

On Monday, February 27th, at 9 am in the meeting room of our hotel, we had the privilege of hosting representatives (insert names) from the company L&T (Larsen & Toubro). The presentation began with a brief introduction of the company, which is one of the largest engineering and construction conglomerates in India. The presentation focused on L&T's activities in the fields of construction, with a particular emphasis on nuclear projects, engineering, energy, and defense.

The L&T representatives then presented some of the major projects undertaken by the company, including nuclear projects such as the construction of the first 700 MWe pressurized heavy water reactor (PHWR) of national design for the Kakrapar 3 nuclear power plant. They also presented the construction of the Statue of Unity, which is the tallest statue in the world at 182m. Among the achievements of L&T's heavy engineering division is the design and fabrication of the world's heaviest LC-Max reactors. These reactors weigh 2,313 tonnes each and will convert the heaviest oils into high-quality BS-VI diesel.

The company representatives then explained the energy mix installed in India in 2022, which amounts to around 412 GW, mainly composed of fossil sources at 57% of total power, renewable energies at 41%, and nuclear power at 2%. They then presented a forecast of the capacity needed for the country's development in 2030, estimated at 755 GW, and how L&T will contribute through its projects to maintaining energy security and developing the necessary infrastructure to achieve it.

The presentation also focused on the scenarios for the development of the nuclear sector in India, which aims to increase the number of reactors in operation from 23 with a total capacity of 7,430 MW in 2022 to 55 reactors with a total

Figure 1: The world's heaviest LC-Max reactors

capacity of 22,480 MW in 2032, representing a 300% growth by then.

To achieve these results, India plans to develop its nuclear industry in 3 phases. The first, which is well advanced today, involves installing LWR (light water reactor) and PHWR (pressurized heavy water reactor) reactors that convert uranium, enriched for the former and natural for the latter, into plutonium-239. The formed plutonium will then be mixed with reprocessed uranium to produce MOX (mixed oxide fuel), which will serve as fuel for fast-breeder reactors (FBRs). This is the second development phase for which a first reactor of this type is currently under construction. The idea will be to use these FBRs to produce uranium-233 (U233) by transmuting thorium, which will be inserted in the core of non-combustible rods. Finally, the produced U233 must be used for the third and final phase of the Indian nuclear program in order to power thorium reactors. India, with significant reserves of this element, will be able to reduce its dependence on fuel imports in this ultimate step.

Today, L&T has end-to-end capabilities to develop nuclear reactors. From engineering (reactor design) to construction (main plant, electricity, instrumentation) and procurement (valves…). These capabilities allow L&T to reach 100% market share for LWR and 67% for PHWR.

The presentation concluded with a question-and-answer session, during which the MS OSE students sometimes asked technical and strategic questions about the company's projects, international expansion, and the opportunities for nuclear development in India. The company representatives answered enthusiastically and shared their perceptions without hesitation.

Training centre

We were fortunate enough to visit, on the afternoon of February 27th, a training center for underprivileged youth run by L&T. The company, for its various activities, needs to acquire a skilled workforce that can be sent to various construction sites across the entire Indian territory. To meet this need and at the same time help the poorest populations in the country, L&T has decided to set up 8 training centers to develop the necessary skills.

Figure 2: Main training building

It is important to note that the students are not paid during the training, however, the training is free, without commitment, and the students are provided with food and lodging. Following this training, students are offered a job in the company but are not obligated.

The center we visited trains workers in almost all areas of construction, including, but not limited to, plumbing, HVAC, low-voltage electricity, and civil engineering. The various courses offered by this center, which last between two to three months, produce a total of between 500 and 1000 new skilled workers each year.

5 LARSEN AND TOUBRO – FEBRUARY 27TH

An interesting feature of these training centers is the adaptation of teaching methods that have been made to ensure good transmission of information. The Indian constitution recognizes 22 regional languages. However, especially in certain disadvantaged environments, students may only speak a regional language. Thus, a series of videos available in several languages are provided to the students. In addition, each instructor speaks multiple languages.

The training is 80% practical work and 20% theory. The emphasis on practical work goes hand in hand with the application of learning through repetition. The trainers explained to us that the repetition of tasks is the key to good learning, so each important task is performed 5 times to allow for true mastery of the concepts. Throughout the training, students will have daily tests. Finally, the trainers emphasized two points that are particularly highlighted during the training: safety and the use of new technologies.

Thus, this training makes sense for the company by providing a trained workforce to meet its exact needs and at the same time offers an opportunity for people living in disadvantaged environments to develop their skills and, above all, to obtain a job offer once the training is completed.

L&T Valves factory

Following our visit to the training center, we also toured an L&T Valves Limited factory located 2 hours west of Chennai by car. L&T Valves Limited is a Larsen & Toubro group company specializing in valve production.

The factory we visited was established in 1997 and spans 33 km across 5 buildings. With over 600 employees, it operates 6 days a week with at least 2 shifts per day, producing over 6,000 valves per month. The valve manufacturing process is divided into several stages. First, operators machine the raw parts, after which the valves are assembled and tested. Finally, depending on the customer's request, the parts are painted.

The machine tools allow for a precision of up to 100 μm on the machining of parts. L&T Valve offers a wide range of valves from a few centimeters to the size of a human, which can take more than 2 months of work. Their clients are international companies from various fields, such as Saudi Aramco in the oil industry or other players in the Indian nuclear industry, providing valves to the parent company Larsen & Toubro.

Figure 3 : presentation of the practical work areas

Figure 4 : presentation room for working techniques

Inside the factory, there is a laboratory where numerous tests are carried out on the various components. L&T Valve teams are intended for all types of processes, so they must be tested in extreme cold conditions for the transport of liquid nitrogen, but also in heat. Thus, fire simulations are carried out where the valve is exposed to extreme heat.

In addition, the company also performs seismic tests. Finally, more traditional tests are also carried out, such as on the permeability of the valves or the wear of the shaft. These tests are carried out for each series of valves. This quality is also reflected in the API 603 (American Petroleum Institute) certificate, which guarantees resistance to valve corrosion. Finally, verification of each valve is also carried out before the shipment of each valve to check for any cracks using an ultrasonic and water test.

Throughout the process, the parts are traced with barcodes, and an RFID chip is installed on each completed valve.

We thank them very much for their warm welcome, the time they spent with us to show us around the factory and the premises, especially S. Ravi Sankar and M.S. Rajarama. It was an enriching experience for all of us.

Alan JULIEN, Achraf AMRANI, Paul FAYEL, Charles DESTOMBES

MICHELIN – FEBRUARY 28TH

General

Reading time: 8 min

Michelin, a French company specializing in the manufacture of tires, has a production plant in Chennai, India. The imposing site is called UCH for simply "Usine de Chennaï". It was built in 2013 in an Industrial Park developed by the Government of Tamil Nadu State. Florent Chaussade has been the plant manager since October 1, 2022. He worked at Michelin for 21 years; before India, he lived in Thailand for 6 years. The machines in the plant were designed locally by the specialized engineering team called "ME".

Michelin's strategy in India is based on three concepts forming the "3P" strategy:

- People: Employees are very important to Michelin's strategy. For example, ensuring safety is paramount. Site ergonomics is also an important issue the plant is still trying to improve. Of the 900 employees in the complex, 100 are women and 6 are people with disabilities. The latter work in operator positions and perform the same tasks as other employees. In addition, 14% of the employees come from local communities (within a 7km radius of the plant), which helps to support them. The company also has a high retention rate with, for example, 75% of the operators having more than 4 years of seniority in the factory. Finally, supporting employees also involves ensuring their good mobility: 85% of employees come to the plant by buses provided by Michelin.

- Planet: The UCH site is committed to sustainable development by trying to reduce its environmental impact. For example, it has a pond that collects rainwater and reuses it on the site. In 2022, 76% of the water demand was met by rainwater. Between 2015 and today, UCH has reduced its water consumption by 69% and does not discharge any liquid waste outside, which means that all the water used in the plant remains in the plant. Regarding energy, the site has solar panels on the roofs of the buildings. These panels do not belong to them, they are under a PPA contract. They cover 11% of the site's consumption. The plant is also supplied by a solar power plant outside the site which covers 27% of the needs. UCH has reduced its energy consumption by 45% since 2015.

- Profit: UCH sells its production in India and abroad. It has a capacity of 700,000 tires per year.

In line with this strategy, the plant has set targets for the year 2023. Compared to 2022, it intends to:

- Increase actions in favour of disabled people as well as the share of women

- Increase exports significantly.

- Improve industrial performance by reducing production costs.

- Reduce energy consumption by 25% through resource optimization, the use of heat pumps, team awareness, and other energy efficiency projects.

- Double the proportion of low-carbon energy used.
- Reduce solvent consumption.
- Eliminate the use of phytosanitary products.

Energy

Michelin joined the Road to Net Zero Cooperation during COP26 and has set a target of net zero emissions by 2050. Eswaramoorthy Ralasamy, Energy coordinator, and Mohamed Hasan, Energy utility manager, explained how UCH manages its energy consumption and its environmental consequences.

First of all, it is worth welcoming the progress made by UCH. By 2022, the site had reduced its CO_2 emissions by 50% for scopes 1 and 2 compared to 2010, and by 15% for scope 3 compared to 2018. Overall, this represents a 22% reduction between 2022 and 2015 for a 46% increase in production. Similarly, UCH is aiming for 40% sustainable materials by 2050 and is developing industrial recycling processes. All this is part of the 4R Strategy: reduce, reuse, recycle, and renew. It applies to the site itself as well as to products leaving the factory.

About improving energy management, Michelin has identified two levers: energy efficiency and production emission factors.

Figure 1: photos taken during the visit

The measures Michelin has taken and planned to act on the first lever mainly concern better management practices for heating, ventilation, and air conditioning (HVAC) systems, chillers, and lighting, as well as digitalization.

To operate on the second lever, Michelin has joined RE100, a consortium of companies that are committed to sourcing 100% renewable electricity as soon as possible. These commitments are accompanied by ambitions to reduce energy demand, produce renewable energy, and reforest.

Training centre

At UCH, 2.5% of employee working time is dedicated to training. This implies better energy management practices through team empowerment. The training centre we visited is identical to the one in Clermont-Ferrand. It consists of 4 workshops:

- The maintenance workshop, where employees are trained in assembly and disassembly processes.
- The hydraulics and pneumatics workshop, where the emphasis on leakage saves energy.
- The automation workshop, which is equipped with unique Rockwell test walls.
- The electrical training facility, which has virtual reality high voltage training.

After training, employees are directly operational in the factory. This center is a real asset for UCH, which has a turnover rate of only 6% per year, compared with around 50% in this sector in India.

Tree plantation

To conclude our morning visits, Florent Chaussade and his teams took us to the tree plantation that borders the factory. Indeed, the State of Tamil Nadu requires industries to reforest part of the area around their facilities.

Michelin has chosen to use the Miyawaki method, i.e. to plant the trees very densely and to select species adapted to the environment. The UCH also has a medicinal herb garden. As part of the company's social responsibility measures, employees can bring their children to the garden to teach them about plants.

Industrial buildings

In the afternoon, we had the opportunity to visit the industrial buildings housing the tyre manufacturing line.

The Michelin plant in Chennai is divided into several segments called "shops". A tyre is made up of a succession of layers of material, mainly rubber based. The different parts of the tyre are not subjected to the same stresses and are therefore of a different composition.

The industrial process starts in the "Z shop" - or mixing shop - where the raw materials are transformed into thin rubber skin. To do this, rubber is first mixed with oil, silicates, and other materials and then kneaded once in rollers at a temperature of 170°C. Then a second kneading is done at 70-80°C to homogenize it. The result is a mass of about 450 kg called "sausage". This is then laminated to form a strip of standardized

Figure 2: photos taken at the tree plantation

skin, coated with anti-adhesive, and stored in roll form for at least 8 hours before being used in the following workshops. The Z shop has a production capacity of 157 t/day. It is also equipped with many sensors allowing one to follow the whole process from a control room in real time.

In the next step, a part of the rolls previously produced is sent to the PK shop to form tissues which will be used to ensure the resistance of the tyre afterward. For this purpose, the rolls are kneaded again at a temperature of 60-90°C and then laminated into thin rubber layers. The tissues are then formed by inserting a thin tin mesh between two layers of rubber. The resulting product has a thickness between 0.6 and 1.5 mm.

Finally, the tyres' assembly, control, and storage are done in the last workshop (PL shop). Five steps are carried out in series. The first one is a parallel preparation of the beads (conical or flat depending on the tyre) and the rubber layers that will constitute the tread. The latter is produced from the rollers from the Z shop.

The second step consists of assembling the different elements (two beads, a superposition of tissues from the PK shop, and the rubber band for the tread) to form the tyre. For the tyre to keep its shape and have adequate mechanical properties, it is then subjected to a curing process. This is one of the most sensitive stages from an industrial point of view and Michelin is careful to keep it secret.

Once the tyres leave the ovens, they are inspected as a final step before they can be marketed. All tyres are inspected visually and by touch. Some are randomly selected and inspected by non-destructive testing (X-ray, ultrasound) or destructive testing (destruction of the tyre to check its composition). Tyres with minor defects are sent to a repair line while tyres that are too degraded are discarded and the rest are sent for marketing.

Control and quality are keys in the plant, as Michelin wants to maintain its status as a premium brand. The various automatic processes are monitored by numerous sensors (temperature, pressure, size, speed).

Michelin's Chennai plant is expected to continue to increase its production rate in the coming years, with one objective: to be a top player in the Indian market.

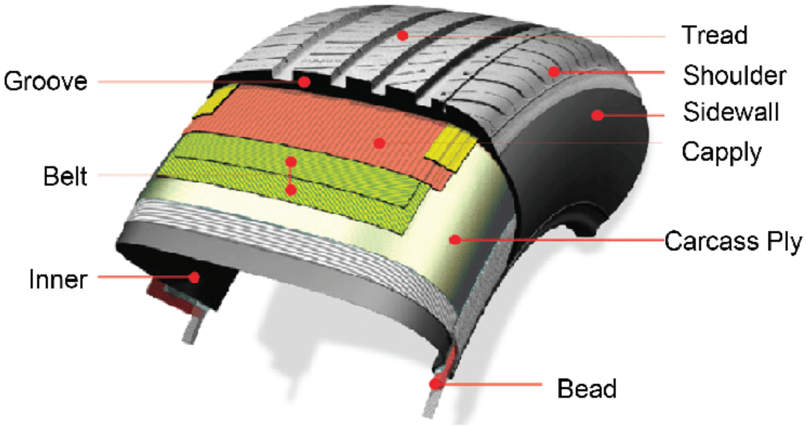

Figure 3: Diagram of a tyre

We would like to thank all the people who accompanied us during this very interesting visit and first of all Florent Chaussade, factory director, for the perfect organization of this visit, his availability, his experience and his wide knowledge of Michelin's activities.

Alexandre CASTANIÉ, Marie CODET, Rémi FALLON, Damien BOUVIER

INDIAN INSTITUTE OF TECHNOLOGY (IIT) MADRAS – MARCH 1ST & 2ND

Reading time: 8 min

One of the greatest interests of traveling is confronting another culture suggesting different ways of eating, dressing, and learning. It is even more enriching to have the opportunity to meet teachers as well as students who are studying similar topics to ours and observe their way of approaching them.

This article relates to our visit to the Indian Institute of Technology Madras that took place in the middle of our trip to India. We would like to thank the entire administrative team of IIT, as well as the professors, PhD students and students who made this visit possible.

IIT campus

Following our visit to Michelin, our trip continued with a return to Chennai, where we had the privilege of being welcomed by the Indian Institute of Technology Madras (IIT Madras).

During this day, we attended different presentations given by the directing staff of IIT. Besides, we had brief exchanges and discussions with students from IIT Madras to discuss some of their work.

We started our visit to laboratories with a visit to the power electronics laboratory. This laboratory is headed by Dr. Arun who supervised a group of students including doctoral candidates and master's students. Dr. Arun gave us a presentation about power electronics implemented in AC microgrids and different issues related to batteries.

Figure 1: Exchange between OSE students and Dr. Arun's research team.

Regarding AC microgrids, Dr. Arun focused on control aspects to be considered in the research work carried out by his team.

INDIAN INSTITUTE OF TECHNOLOGY (IIT) MADRAS – MARCH 1ST & 2ND

Figure 2: Group photo in front of the IIT

The issues of frequency and voltage, essential within the microgrids, but also equally indispensable when it comes to periodically connecting these same networks to a centralized network, were also addressed. Dr. Arun finally highlighted the different tests carried out by his team, including those consisting of using different types of converters to optimize the control of alternating current and to carry out fault detection operations within microgrids.

Other applications carried out by the same team were also presented to us, concerning "Wireless charging" of batteries. These preliminary works aim to develop the charging of electric vehicles at specific locations in the future. If the research is still in its early stages, promising initial results had already been obtained, such as an efficiency rate of 95% concerning the charging of first batteries at moderate distances of only half a meter. This research is based on the fundamental principles of materials and electromagnetic fields already used for mobile phone charging technologies.

Then, we had the opportunity to meet the director of the IIT Madras Campus Mr. KAMAKOTI, and his deputy. During this meeting, the director highlighted the multidisciplinary as well as the excellence of IIT Madras. He also emphasized the growing international reputation of the school and its campus. In fact, the institute had various laboratories working on a wide range of subjects such as fluid mechanics, chemistry, and computer science.

Figure 3: Exchange of gifts between Gilles and Mr. Kamanoti

After a traditional buffet offered by IIT, we visited the fluid mechanic's laboratory to see numerous pieces of equipment. Firstly, there was a steam expander of a Wankel-type engine that can be used in the industrial sector to produce electricity with an efficiency of 91%.

Moreover, they presented us with a machine that can remove the heat of fluids while relying on magneto-calorific effects. This machine cools fluids by reducing the entropy of magnetic fields and has the advantage of using no refrigerant or compression systems.

Furthermore, they presented us with optical devices for the measurement of sulfur and nitrogen oxides. In addition, they showed us their research about global models for batteries using data-driven modeling techniques to evaluate the battery's performance. Other methods exist for battery performance evaluation, namely parametric optimization by experiments and physics models for batteries. However, these two methods are more complex, expensive, and time intensive.

Then, we visited the chemical engineering laboratory. In this laboratory, Ph.D. students are working on two main subjects. The first one is the green corridors which aim to study the performances of different types of batteries for the needs of the flexibility of micro-grids that can be coupled with solar panels. The types of batteries used are zinc, Li-ion, and lead. And the second subject is the analysis of the impact of intermittent renewable energies on the performance of electrolyzes as well as the study of the technical-economic feasibility of H2 long-duration storage.

The day concluded with a presentation by Dr. Satyanarayanan Seshadri. He explained his work in the applied mechanics department as well as his prominent role in the energy consortium of IIT Madras. Within this consortium, there is various research carried out including storage, energy conversion, and heat recovery in industrial processes, but also micro-grids or photo and electrochemical energy. This consortium contributes to the synergy between different laboratories of the university, and it's also involved in issues related to climate change and its challenges for a country like India.

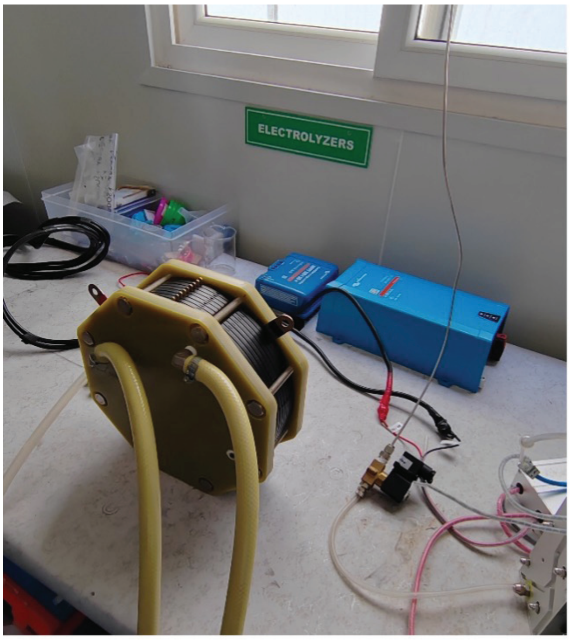

Figure 4: Electrolyser

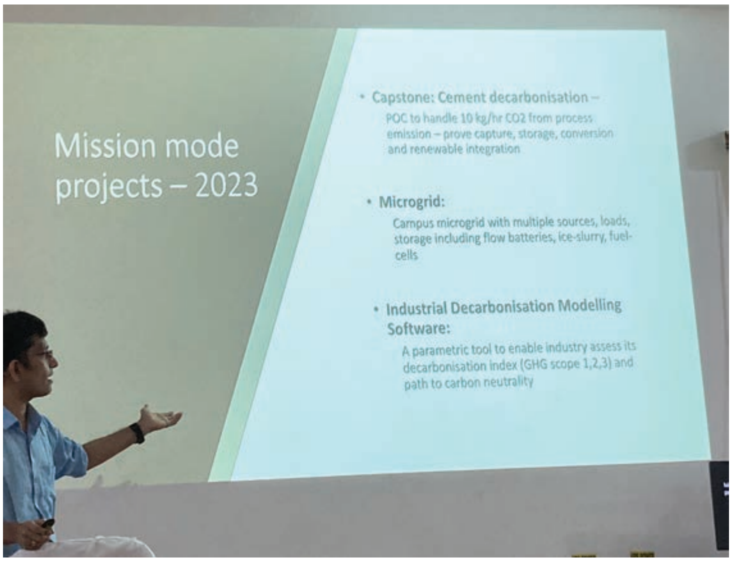

Figure 5: Presentation by Dr. Satyanarayanan Seshadri

MS OSE's talks

As part of their annual theme on nuclear energy, MS OSE students delivered two talks to the Indo-German Centre for Sustainability students. Here are the talks' abstracts.

The place of nuclear energy in a low-carbon electricity mix

One of the most effective methods of tackling climate change is to decrease the use of fossil fuels. Electrifying usages combined with the deployment of low-carbon electricity sources is a strategy that has been chosen by many countries, including France and most of Europe.

Nuclear energy today is the second most common way of producing low-carbon electricity in the world, and the first in Europe. Solar energy and wind turbines, both of which are fast-growing alternative energy sources, are two of the other most used low-carbon electricity production methods. Efficiently managing the interaction between these low-carbon electricity sources in the electric grid is necessary. This conference focused on the interactions and potential issues of nuclear power in a low-carbon electricity mix.

After a brief state the art of nuclear technology development in the world, the presentation targeted the advantages and limits of the use of nuclear energy in the management of an electric grid. The future of electric grid management and the impact of nuclear energy using different electric mix prospective scenarios have been discussed.

Assessing nuclear power acceptability

While we are living in a climate crisis, global electricity demand is rising. The energy sector is the biggest greenhouse gas emitter and nuclear power has the potential to reduce its carbon intensity.

According to statistics, nuclear energy is safe, and efficient, and emits little carbon. However, acceptability varies greatly among countries and remains a limiting factor for its development. Mixing statistical and sociological studies carried out in several countries, we have identified the main concerns about nuclear energy and what causes them.

Safety and environmental impacts are found to be people's main concerns. These stem from a variety of factors including accidents, information access, public inclusion in the debate, cultural values…

Fear is not to be brushed off because of its irrationality. It must be addressed by governments looking to develop their nuclear power industry. Communication methods to promote nuclear power should be adapted to sociocultural and individual requirements.

This morning concluded with a question and answer session with the audience, which was an opportunity to share a fruitful exchange with the students and the professor present. We thank them warmly for their listening and their keen interest in our subject.

Nathan BLISCAUX, Ouarda BOUKYOUD, Soundous OUZAKRI, Nikolaos PAPASTEFANAKIS

THE NUCLEAR SECTOR, PRESENTATION BY MR. THOMAS MIEUSSET – MARCH 2ND

Reading time: 5 min

As part of our trip to India, we had the opportunity to meet Mr. Thomas Mieusset, nuclear advisor at the French embassy in India. We thank him warmly for having traveled so far to meet us. During his presentation, He provided us with insights into India's current situation regarding civil nuclear energy and its prospects.

India, with a relatively low GDP, has seen its population steadily increase over the years and is grappling with a significant rise in its CO2 emissions. In 2020, coal accounted for 72% of the country's electricity production and 44% of its primary energy consumption.

Furthermore, coal remains the primary source of employment for many Indians, making the topic of energy transition a sensitive issue to tackle among the population. However, during COP26 Indian Prime Minister Narendra Modi announced the country's commitment to a long-term decarbonization project, to achieve net-zero emissions by 2070. His carbon neutrality strategy is based on the development of renewable energy and nuclear power.

Despite this, India has a long history in the nuclear industry and has been implementing a nuclear program since the 1950s, based on three distinct phases:

- The development of pressurized heavy water reactors (PHWR).
- The development of fast neutron reactors (FBR).
- The development of advanced heavy water reactors (AHWR) that use thorium as the main fuel.

India's grand vision is to shift its primary focus to thorium as a fuel source, as the nation boasts substantial reserves of this element within its soil. With a dearth of uranium resources, India aspires to break free from any potential dependence on other nations for its nuclear program.

The fundamental characteristic of this civil nuclear program is to focus on the closed fuel cycle. In the first stage, the use of heavy water reactors enables the reprocessing of spent fuel to accumulate the required plutonium for the FBRs. During the second phase, the fast neutron reactors will convert thorium into uranium 233. This uranium 233 will be utilized in the final phase for the advanced heavy water reactors that function with both thorium and uranium 233. This cycle that tends to close will thereby optimize resources and minimize the volume of ultimate waste.

Currently, India has 23 pressurized heavy water reactors in operation, with a total capacity of 7.48 GW, while 10 reactors with a combined capacity of 8 GW are under construction and 10 more with a total capacity of 7 GW are sanctioned. Initially, India had set a goal of launching one reactor per year to achieve a total capacity of 22.5 GW by 2030.

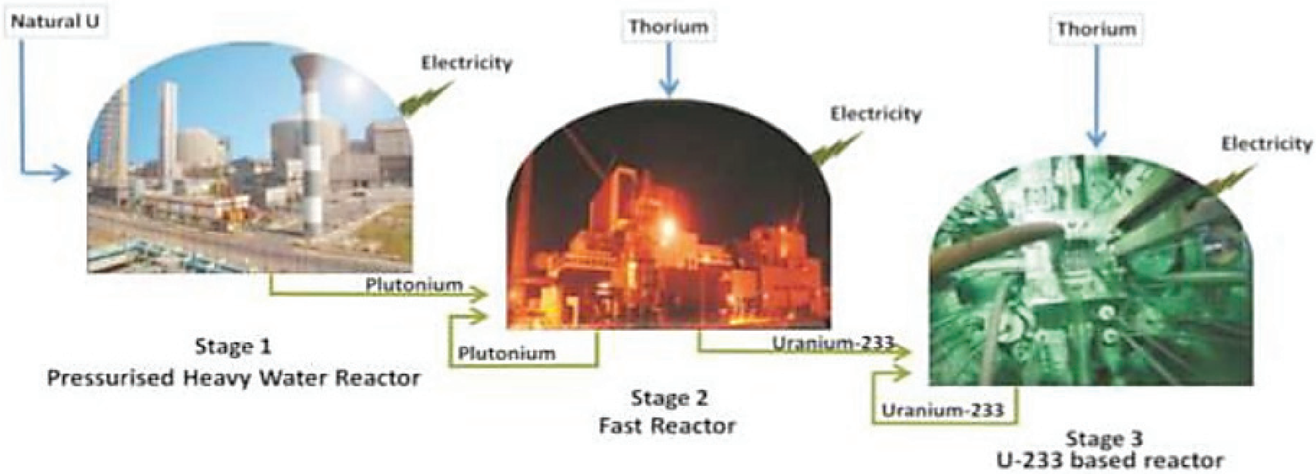

Figure 1: The 3 phases of the Indian civil nuclear program

India has good diplomatic relations with most of the major powers in the world, and the Russian nuclear industry has a strong presence in the country. As evidence of this, four of the currently under-construction reactors are being built by the Russian state-owned company Rosatom, and the fuel being used is also sourced from Russia. At present, there are ongoing bilateral negotiations between the Nuclear Power Corporation of India Limited2 (NPCIL), France, the United States, and Russia regarding the provision of new reactors.

The project to launch six RNRs, which was initiated in 2003 to be operational by the end of 2023 or early 2024, is experiencing delays. This can be attributed in part to the lack of expertise of the new operator, the complexity of the technology, and the delay in the launch of the demonstrator. It is worth noting that India's objective regarding this technology is not to position itself as a global exporter of know-how, but rather to harness its potential to meet its own energy needs.

As India sets its sights on achieving the third phase of its program for the development of Advanced Heavy Water Reactors (AHWR), the country is currently undertaking preliminary work on both molten salt and high-temperature reactors.

The Indian government, through the National Thermal Power Corporation (NTPC), as well as other emerging players, are showing interest in small-scale modular reactors (SMRs) due to their low investment requirements and simplicity. This technology has the potential to accelerate the development of the nuclear power sector and replace thermal power plants. Moreover, SMRs can be interfaced with other sectors such as the production of decarbonized hydrogen, making it a promising option for India's energy needs.

At present, it seems there is no national dialogue centred around public acceptance of nuclear energy development in India. With nuclear power accounting for only 2% of installed capacity, the topic fails to garner significant public attention. As the government looks to increase nuclear power's share in the energy mix, efforts to improve public awareness and acceptance have been initiated.

While opposition to the construction of new nuclear facilities has been voiced at the local level, it is important to note that such concerns are not unique to nuclear power projects and do not necessarily reflect a widespread public distrust of the technology.

Finally, realizing that they missed out on the photovoltaic market lead, India aims to become a global hub for the production, usage, and export of hydrogen. The goal is to make India energy independent and decarbonize its major economic sectors. To achieve carbon neutrality by 2070, the country's future energy outlook is turning towards hydrogen, an ambitious solar development program, and the expansion of the nuclear power plant fleet (PHWR, RNR, REP, SMR) to achieve an installed capacity of around 24 GWe by 2030.

Caroline SCHOER, Anas BEN TAHER

SAINT GOBAIN – MARCH 2ND

We continue our journey by visiting the Saint Gobain factory, in the city of Sriperumbudur, near Chennai.

Reading time: 6 min

We would like to thank all the people who made this visit possible and especially to Mr. Venkat Murugan, director of the factory, for the perfect organization of this visit. Thank you for organizing this exchange and for taking the time to explain to us with passion the different processes of your factory.

The company was created in 1665 under the reign of King Louis XIV to manufacture the mirrors for the Palace of Versailles and its logo was inspired by the bridge of the village Pont-à-Mousson. It came to India in 1997 with factories in Sriperumbudur that started in 2000, Jhagadia, and Bhiwadi. The plant is equipped with three production lines and has the largest flat glass production line in the world. With its laboratories and 3,700 researchers, a quarter of the products sold by Saint Gobain did not exist five years ago.

The company also has ambitious climate objectives, such as reducing its energy consumption by 15% and its CO2 emissions by 20%. The aim is to anticipate climate risks and develop a low-carbon economy. To achieve this, the company's objectives are based on the United Nations' sustainable development goals. From a social point of view, the company has 85 initiatives and more than 33,000 beneficiaries, including financial support for families, but also offers qualifications and jobs to local populations.

One example is the "Gift for Education" program, with 208 young people have completed the program and 340 having the opportunity to follow it.

To reduce its environmental footprint, the glass industry has two main drivers for CO2 emissions: raw materials (28%) and energy use (67%). To this end, Saint Gobain's research laboratories are looking into alternatives. The use of recycled cullet, or new raw materials, which emit less or no CO2 during chemical transformation. For the energy used, hopes are turning to hydrogen and the production of green electricity via electricity purchase contracts.

Another important lever is the use of glass. Not all uses require the same types of glass and treatments. Choosing the right type of glass for the right use is important to avoid additional manufacturing processes. The Sriperumbudur factory has installed photovoltaic panels on its roof for a total capacity of 3.5 MW and it recovers the heat resulting from the fusion of the raw materials which allows it to generate 1.2 MW of electricity.

We had the chance to visit the plant's flat glass workshop, dedicated to the production of glass for the automotive industry. The production is almost autonomous, and the staff is qualified to maintain the line. First, raw materials such as cullet, sand, soda ash, dolomite and calcite are fed into a melter at 1600°C. It is here that the heat produced is used to generate electricity through a waste heat recovery system.

Figure 1: Saint Gobain factory visit: injection of raw materials

Once melted and freed from its gaseous bubbles, the liquid glass acquired from the mixing of the raw materials enters a float bath containing molten tin. The glass with its less dense composition than tin will float on the metal forming a ribbon of thickness ranging from 1.8 mm to 12 mm depending on the flow speed. At the exit of the float bath, the temperature is about 600°C; the glass is sufficiently rigid, and the throughput is about 750 tons of glass per day.

The furnace control unit uses machine learning and simulations with digital twins to control the level of tin in the float line. The glass is then cleaned, goes through several processing steps, and can eventually be painted.

As for the treatment process, the glass goes through vacuum chambers (10-7 atm), and thin layers of one-hundredth of a hair thickness of argon and oxygen are deposited. To cut the glass, a mark is made with a diamond so that a simple pressure on the glass allows it to be cut it perfectly. In case of a defect, the glass is sent to a manual cutting line to recover the maximum possible standard surface.

Finally, a non-destructive test is performed using a spectrometer to check the brightness and colour of the glass. The control instruments are calibrated in a laboratory, which allows for minimizing the uncertainties in the measurements. These processes take more than a week and there are more than a hundred instruments to be calibrated with international standards. The lenses are then arranged vertically by robots and transported to the storage areas by the operators with their electric forklift trucks.

The three production lines have a throughput of 750, 850, and 950 tons of final product per day, respectively, and the entire process takes about 72 hours from raw material insertion to lens storage. Most of the production of this plant is reserved for India and only 12% is exported.

SAINT GOBAIN – MARCH 2ND

To conclude our visit, we went to the 3-hectare (7.5 acres) forest of Saint Gobain with five kilometers of the pathway. Previously, an open dump was in place of this forest. The forest was planted according to the Miyakawi method; the principle is to plant about 3 trees per square meter, of different varieties, adapted to the climate, and selected not to attract too many monkeys or other animals.

Again, a big thank you to all the members of the Saint Gobain team for their welcome: Venkat Murugan, Pugalenthi M, Shreya V, Karthick Ravichandran, Ramya S, Karthik J, Karthika T, Srinivasan K, Saravanan K, Kannadasan K, Mahaboob Subani, Nivedha N, Muthurajalingam G, Silambarasan U, Devaraj N, Soundarya Saravanan, PrasanthKumar N, Amit Mahajan, Sivakumar K, Yuvaraja T, Ravi D, Saranyamala T, Kirithikadhevi RM, Kathiresan M, Saju K C, Ramachandran P, Prasanna R, Sathish R, Balaniranjan Kumaar, Saravanakumar S.

Figure 2: Saint Gobain forest visit

Valentin LASSAIGNE, Daniel-René NKOUNCHOU SOMO, Caroline SCHROER

NTELC – MARCH 3RD

Reading time: 5 min

During our trip to India, we visited the Vallur coal-fired power plant, located north of Chennai. This visit was organized by NTECL (NTPC Tamil Nadu Energy Company Limited), a merger of two electricity production companies: NTPC (National Thermal Power Corporation), a national public enterprise, and Tamil Nadu Generation and Distribution Company.

During the visit, we had the pleasure of discovering the various activities carried out on this approximately 4.5 km site: electricity production and transformation, a high-voltage electrical isolation substation, as well as two seawater desalination processes.

Presentation of the company and the power plant

The NTPC group has an installed capacity of 72 GW, composed of 80% coal-fired power plants, representing approximately 18% of the total installed capacity in India. These 72 GW are distributed across 88 stations, and 34 are under construction to add 19 GW. The growth of electricity production capacity is therefore extremely rapid (327 GW installed in India in 2017 and 410 GW in 2022), and NTPC plays a very important role in this evolution. The rest of the group's electricity mix is evenly divided between gas/liquid fuel and renewable energies (hydroelectric, solar, etc.).

NTPC aims for carbon neutrality by 2050, relying on several decarbonization levers such as (green) hydrogen, carbon capture, and biomass.

What did we see?

Electricity generation

Regarding our visit, the power plant we visited that day consisted of three generators of 500 MW each, for a total capacity of 1.5 GW, with an efficiency of about 35% and a load factor of 65%.

About 7.5 Mt of coal is consumed each year to power the three sets of 500 MW turbines. These three sets each consists of 3 turbines arranged in series (9 turbines in total): a high-pressure turbine (HPT), an intermediate-pressure turbine (IPT), and a low-pressure turbine (LPT).

This configuration allows for better efficiency compared to a single large turbine thanks to the enthalpy increase of the steam between the HPT and the IPT via an exchanger that heats the fluid with heat from the boiler. Additionally, this choice saves space. We also had the chance to see the control room where operators regulate the power generated based on information sent by the power grid operator: demand from the grid and supply from the power plant (in 15-minute intervals) and grid frequency.

Transformation and Isolation Substation

At the plant's output, the voltage is 21 kV. Transformation substations are located at the foot of the production building to raise the voltage to 400 kV. A few hundred meters away, the site has an electrical isolation substation that aims to measure the electrical characteristics of the lines (voltages, currents) and disconnect the power plant if necessary. As this substation is located on the ground, it is necessary to insulate the very high-voltage lines to protect the operators present in the building. To do this, the lines pass through tubes in which gas (SF6) acts as an insulator.

Desalination

In addition to electricity production, the site has two seawater desalination plants that collect seawater through 4.5 km of pipelines. The first process is based on a succession of steps: successive filtration and reverse osmosis with membranes. The second desalination process uses thermal solar collectors to cause the evaporation of salt water (80°C under low pressure) to separate the elements. This second process is a pilot project started at the end of 2020 and produces 120 tons of drinking water per day, used for bottled water consumption.

The site thus produces 13,000 m3 of water per day. The boilers used for electricity production consume 1,500 m3 per day.

Chemical tests

Finally, we visited the chemical testing laboratories for quality control of the various elements consumed on the site: coal, water, oil, and gas.

We would like to warmly thank all the people who made this visit possible.

Yasser KANNAS et Vadim RICHON