Integration in conventional coal fired power plants: the easiest and logical way for the development of Concentrated Solar Power in India

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During coming years, India is going to witness a huge economical growth. This growth is having a very deep impact in the energy needs. Probably the most important energy to be available for this development is the electricity.

Nowadays the installed power generating capacity in India is around 160 GWe. From this amount almost 53% comes from coal fired plants (85GW). Also, for 2031-2032, the Integrated Energy Policy of India has foreseen an installed capacity of about 778 GWe (386% increase!), mainly with fossil fuels and specifically coal. It will be illogical to think about India power sector future, in the short and mid term, without coal and sub and supercritical coal fired plants.

Though India has huge coal reserves, the sustainability principle and environmental and climate change policies should press to give more efficiency and renewable approach to this enormous amount of power to be installed.

On the other hand, the dispatchability and availability of electrical energy is a must, taking into account that future of the economic development will be dependent on this production of electricity.

At this moment the contribution of solar energy within the spectrum of power production in India is negligible. Even, after the first phase of Jawahar Lal Nehru National Solar Mission (JNNSM) the contribution will not be more than testimonial. For that reason, it is essential to find a good solution to achieve the entire goal at once: Whole power availability and dispatchability with the highest possible contribution of renewable energy in the Indian generation spectrum.

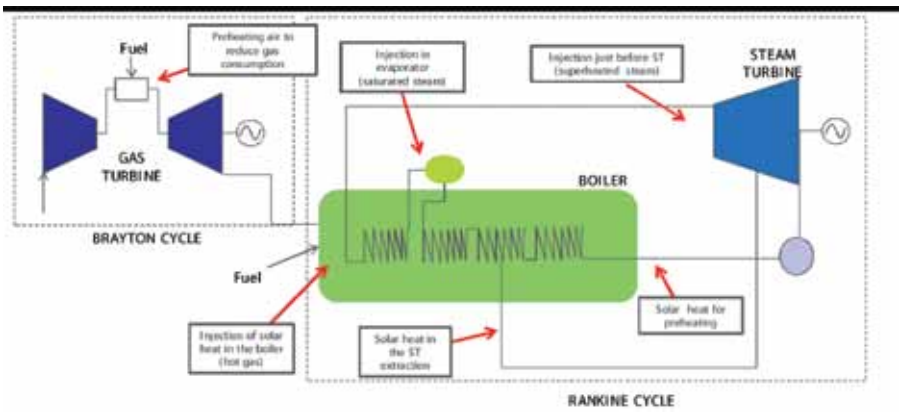

Figure 1. Integration types in Brayton, Rankine and Combined Cycles.

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Other important factors to be considered are the ideal position of India within the Sunbelt with part of the best areas in the world in terms of Direct Normal Irradiation (DNI) and huge acreages of land to be used for solar power generation purposes.

Around the world, there are already several "integrated" plants in commercial operation, combining the conventional power generation from fossil fuels and the solar power generation, which have been built in different locations between 2007 and 2011: Ain Beni Mathar (Morocco), Hassi R'mel (Algeria), Kuraymat (Egypt), Martin Energy Center (Florida-USA), Agua Prieta (Mexico, under construction).

Joining all these ideas, it is possible, and almost obvious, to think that integration should be the more logical and natural solution for the solar power generation development in India. This article deals with this option and how the integration can emphasize the contribution of solar energy integration in existing and new power plants in India and it could be a feasible way to enhance the solar generation in the country and a very effective energy efficiency measure.

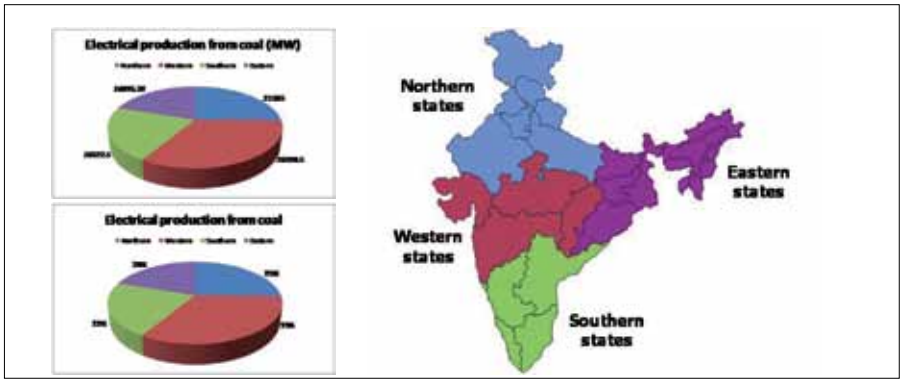

Figure 2. Electrical production from coal. Geographical distribution in India.

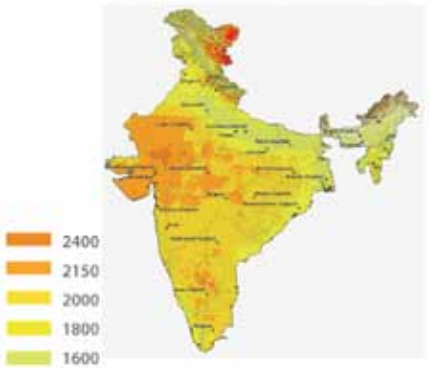

Figure 3. DNI geographical distribution in India

Solar-conventional integration

In the last few years, several theoretical and practical studies have been carried out to define different ways of integration between conventional and solar power production. These ways have been studied both for standalone Rankine cycles (like coal fired plants) and for combined cycles. In the Figure 1 is shown a general conceptual scheme of different kind of integration considering the several places where the solar heat could be "integrated" into the conventional cycle.

These kinds of integration can be classified from the point of view of easiness to be fitted in the power plant and they can be divided in the following types:

- Hybridization: intrinsically inserted into the process. These should come implemented from the original design because several equipment designs are conditioned for them.
- Externally add-on to the process. These can be implemented in existing plants because they do not affect main equipments design.

Both types are applicable in India generation range, depending on the phase when the process is going to be implemented. For existing plants, of course, the externally add-ons are technically more easily feasible.

Regarding the solar technologies to be used, almost all integration types could be implemented with parabolic trough (oil based or DSG), Fresnel technology or Central Receiver System.

Making a brief comparison between integrated plants and stand alone solar plants it is easy to find the following advantages:

- Much less investment because most of the main equipments are included and shared with the conventional plant: steam turbine, cooling system, condenser system, electrical system, etc.
- Dispatchability: The electrical power is always available, during daylight it comes, in part, from the sun, but during night time or transients the conventional part remains in operation, so there is no discontinuity or lack of supply.
- No need of storage: The storage is conceived to provide dispatchability, but in this case the conventional part gives it.
- Increasing power or fuel saving: there are two possibilities in the integration, to design it for increasing the power, if equipments allow it or for substituting part of fuel consumption with solar energy contribution.
- Better performance for equipments in long term: Due to the continuous operation of main equipments of the plant, the daily starts and stops of the plant get avoided, which otherwise are very harmful for equipments.
- Grid connection solved: When the integration is carried out within an existing plant all problems related with grid connection are already resolved.
- Competitive LEC: Besides the lower investment, the cost of maintenance is also less because this cost is shared with the whole plant one.

ALMOST ALL INTEGRATION TYPES COULD BE IMPLEMENTED WITH PARABOLIC TROUGH (OIL BASED OR DSG), FRESNEL TECHNOLOGY OR CENTRAL RECEIVER SYSTEM

India scenario

Some authors have developed very interesting articles about specific solar thermal aided in coal fired power plant. One interesting article, written by K.S. Reddy et al (2010), includes a very deep 4-E analysis of power gains using solar energy into subcritical and supercritical coal fired plants. As main conclusion, an important fuel consumption reduction and CO_2 emissions reduction are achieved.

Far away of that objective, this paper does not deal to demonstrate strictly the power gain including solar add-on, which is depending on the plant configuration and the integration nature. Here, the solar energy addition is considered as a whole, taking into account an average performance, giving more importance to the DNI value analysis in different Indian locations and highlighting the significance and links between this DNI and coal fired plant generation in the country.

Considering the whole spectrum of Indian power generation from coal fired plant, in Figure 2 is shown the geographical distribution of this electrical generation.

As it has been commented before, the solar resource in India is also very high in great part of the country. Figure 3 depicts the DNI map from NREL showing the different DNI values within the Indian Territory.

Best DNI areas lie in Northern, Western and Southern states. Western ones enjoy a DNI close to 2400 kWh/m^2 year, which is an excellent value for solar plants performance.

Joining of two geographical distributions has been elaborated graphically in the Figure 4, from where it is possible to obtain some conclusions as under:

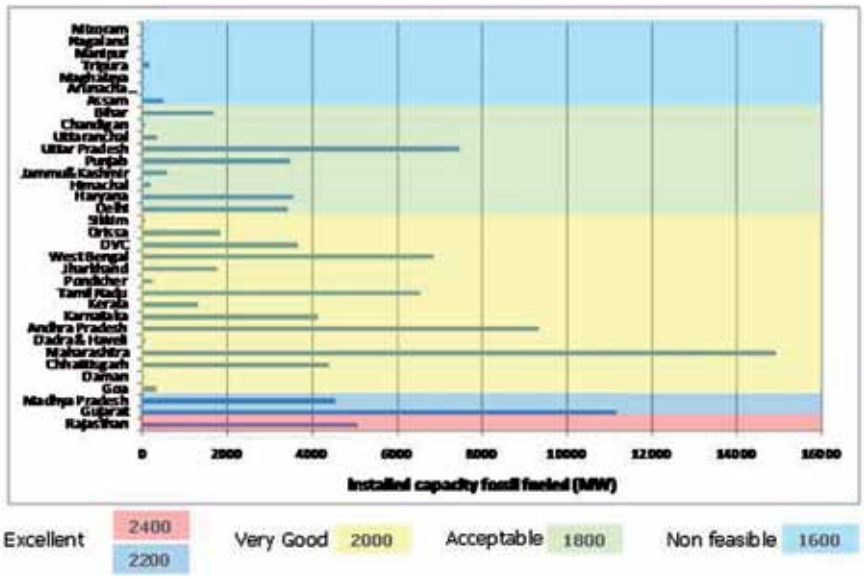

Figure 4. DNI-Power generation in India.

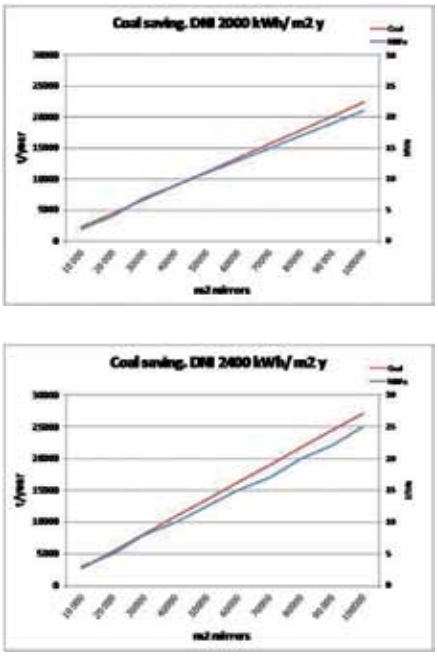

Figure 5. Coal saving and power generating capacity with solar add-on..

- Considering the 8 main states in power generation capacity from coal, 7 of them have excellent or very good DNI.
- States with lowest DNI, & hence less feasible for solar power plant, have insignificant coal based power generation.
- For more than 95% of power generation capacity locations, the solar plants appear to be highly feasible considering the DNI.

Gains with solar add-on in coal fired power plant

Modelling a general solar field and taking into account the following hypothesis:

- Average performance for a solar technology: "Sun to steam"
- Nominal optical parameters in the solar device
- Average performance for the Rankine cycle: "Steam to electricity"
- The average coal LHV in India

it is possible to generate for different DNI values, the amount of fuel saved per year vis-a-vis mirrors surface area. Figure 5 shows this graphic from where it is easy to conclude:

- With a moderate solar field size, it is possible to obtain an important solar power generation capacity.
- The coal saving amount is linear with the solar device surface area.
- Above all, it is a matter of economical balance to determine the feasibility for installing such solar device, even without a supporting feed-in tariff or any other incentive.

IN COMING 20 YEARS THE AVAILABILITY OF POWER MUST INCREASE SERIOUSLY TO FACE THE INDUSTRIAL AND SOCIAL DEVELOPMENT OF THE COUNTRY

As an exercise, analysing a virtual scenario where existing coal fired plant in Northern and Western States were provided with a solar device, it is possible to obtain around 500 MW from Solar power with the basis that 1% (as average) of power source from coal is substituted by solar energy in all the plants.

Conclusions

After the reflections realised in this article we can obtain a wide range of conclusions, both technical and economical.

India has a very important conventional power production from different sources, with special importance of coal fired plants. In coming 20 years the availability of power must increase seriously to face the industrial and social development of the country.

THE HYBRIDATION HAS A LOWER COST OF INVESTMENT THAN STAND ALONE SOLAR PLANTS, DUE TO THE SHARING OF MAIN EQUIPMENTS THAT ARE ALREADY CONSIDERED WITHIN THE WHOLE CONVENTIONAL POWER PLANT

Also India has globally a very high DNI, and the areas with higher DNI match up with high coal fired production capacity.

The integration of solar energy into conventional power plant is a very good option to reduce environmental effects, for increasing the renewable and solar quota in the energy market and for improving the economical benefit of the production by saving tonnes of coal consumption.

The hybridation also has a lower cost of investment than stand alone solar plants, due to the sharing of main equipments that are already considered within the whole conventional power plant (steam turbine, cooling system, condenser system, electrical system, etc...).

Thus, the cost of this solar energy is much cheaper and could permit to develop, at good price, new plants and, at same time, to improve progressively the state of the art, the technological knowledge in order to decrease quickly the investment cost of solar plant aiming to become competitive to the conventional ones in a shorter span of time.

So, as general conclusion, the integration of solar energy into conventional power plants is a very good alternative for developing solar power production in India.