SOLAR PRDS : A CONCEPT OF HYBRIDIZATION OF SOLAR POWER WITH THERMAL POWER

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ABSTRACT

Electricity sector in India had an installed capacity of 307.28 GW as of 31 October 2016 with thermal contributing to about 69 %. The Indian power sector is undergoing a significant change Sustained economic growth continues to drive electricity demand in India. The Government of India's focus on attaining '**Power for all'** has accelerated capacity addition in the country. As per the CEA estimates, power demand in India will grow at ~ 7.5% CAGR during 2009-19. This rapid growth in fossil fuel based generating capacity in the last few decades has exerted considerable pressure on the shrinking natural resources and environment.

Therefore, Renewable energy sources will play a crucial role in the energy security of the country and sustaining the growth. However, generation from the renewable sources poses their own challenges. Since their availability varies over time, forecasting the output gets difficult. The energy source is renewable, but the land required for installation of the generating equipment is limited. With high rate of population and industrial growth, land shall soon become a bottleneck in the way of meeting the growing demand.

Hybrid solar thermal installations have the potential to overcome these challenges. They promise a higher efficiency, a stable output. In addition to this hybridized solar energy with thermal power plants that run on coal reduces consumption of coal in and in turn their carbon footprints will reduce and will also increase the efficiency of the plant. Moreover the major hurdle of land requirement for solar panel installation will be solved as power plants are having ample space.

This paper focuses on the technical, economical and operational advantages of a using solar energy for producing steam for Auxiliary PRDS. As we know that various auxiliary of power plant requires steam during unit startup, normal running and shutdown such as Turbine sealing, Fuel oil atomizing, Soot blowing, VAM etc. this steam is supplied at 13-15 ksc and 200-250c. This steam is usually extracted from CRH and MS line. Both the sources of steam are high energy steam which is then throttled to low quality steam. Thus if we are using solar energy to produce this steam not only we would be saving coal but also our MWe would also increase, increasing our efficiency and saving our natural resources and money.

NTPC with its environment vision statement, "Going Higher on Generation, lowering Green House Gas Intensity" can use this concept to fulfill the vision." Also NTPC with its plan to become 128 GW company by 2032 is going to have many new units which will be using auxiliary boiler during the initial commissioning phase for steam requirement which require huge investment (1.5 crores) and also uses costly fuel (LDO) therefore contributing to pollution and after unit commissioning tend to become scrap. This concept of Solar PRDS is going to be a boon as it will not only save money but can be utilized forever and will also help in reducing emission thus our commitment of protecting the fragile ecology as well as ensuring a sustainable growth of power would be fulfilled The report below shows the details as how with the help of CSP technology steam required for the auxiliary system will be produced along with economical feasibility of the concept for Sipat project .

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INDIAN POWER SECTOR

Electricity sector in India had an installed capacity of 307.28 GW as of 31 October 2016. Renewable power plants constituted 28.9% of total installed capacity and thermal contributing to about 69 %. During the fiscal year 2014-15, the per capita electricity generation in India was 1,010 kWh. Despite the growth, the power consumption is much lower than other BRIC countries like China (2150 Kwh), Brazil (2100 Kwh) and Russia (6000 Kwh)2 , suggesting a large unmet/latent demand in the country.

The InternationalEnergy Agency estimates India will add between 600 GW to 1,200 GW of additional new power generation capacity before 2050(refer fig 1). The Indian power sector is undergoing a significant change Sustained economic growth continues to drive electricity demand in India. The Government of India's focus on attaining '**Power for all'** has accelerated capacity addition in the country.

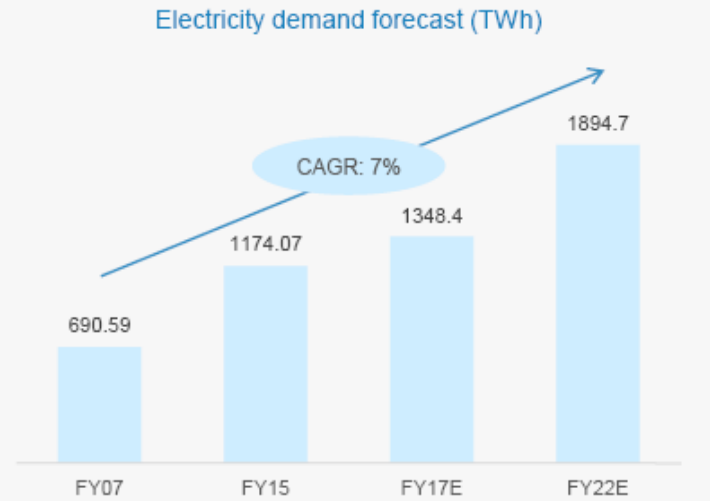

Figure 1

Source: International Energy Agency (IEA), CEA, Demand estimates based on IEA forecasts, TechSci Research
Notes: TWh - Terawatt Hour,
CAGR - Compounded Annual Growth Rate
E- Estimated

The Indian power sector has an investment potential of Rs 15 trillion in the next 4–5 years.. Power sector in India is at a crucial juncture today, with several large investments being undertaken by public and private sector players, promising a significant transformation of the sector. The sector is witnessing a fundamental shift that is opening up new business opportunities for the industry. At the same time, the competition for scarce resources is expected to intensify and support enablers in terms of logistics, T&D, equipment supply will be stretched to the fullest. The emerging dynamics of the Indian power market would require industry players to realign their strategies and operating models. The focus would need to be both on project execution as well as efficient operations.

The economy aspiring to grow at much higher rates in the future, and pollution levels reaching critical limits, Renewable energy sources will play a crucial role in the energy security of the country and sustaining the growth (refer fig 2)

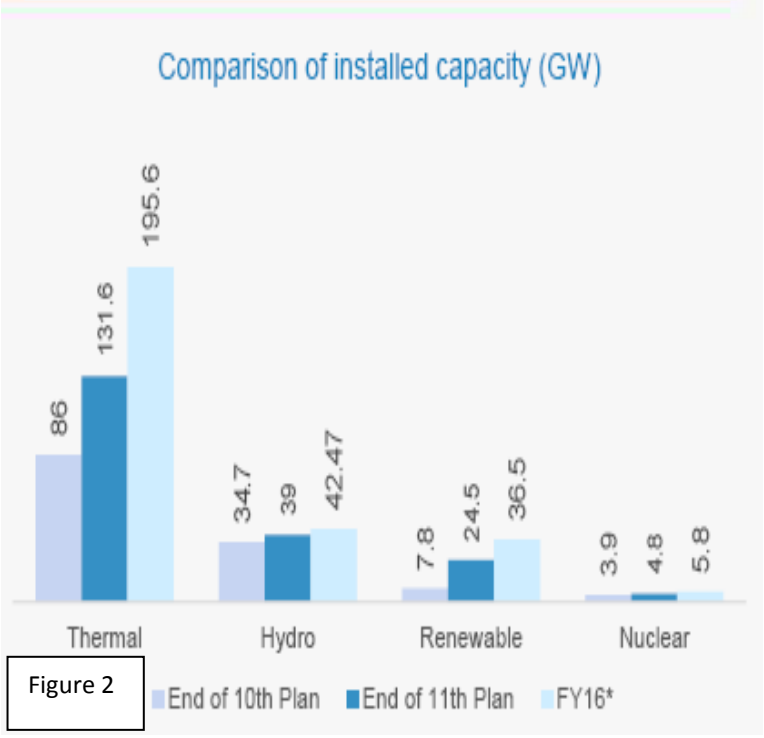

Figure 2

RENEWABLE ENERGY IN INDIA

Renewable energy in India comes under the purview of the Ministry of New and Renewable Energy (MNRE). Newer renewable electricity sources are targeted to grow massively by 2022, including a more than doubling of India's large wind power capacity and an almost 15 fold increase in solar power from April 2016 levels. 63% of the renewable power came from wind, while solar contributed nearly 16%.

Among the various renewable energy sources solar energy is most suitable for India because of its location between the Tropic of Cancer and the Equator, India has an average annual temperature that ranges from 25°C – 27.5 °C. This means that India has huge solar potential.

India is endowed with vast solar energy. With about 300 clear, sunny days in a year, The solar radiation of about 5,000 trillion kWh per year is incident over its land mass. With average daily solar power potential of 0.25 kWh per m^2 of used land area and with the available commercially technologies this exceeds the possible energy output of all fossil fuel energy reserves in India. As of 31 August 2016, the installed capacity was 8.1 GW.

However, generation from the renewable sources poses their own challenges. Unlike generation from fossil fuel-fired power plants or hydropower with storage, which may be ramped up or down to match demand, the output from sources likes solar and wind is linked to the availability of the resource. Since their availability varies over time, forecasting the output gets difficult. The energy source is renewable, but the land required for installation of the generating equipment is limited. As per reports Installation of solar power plants require nearly 2.4 hectares (0.024 km^2) land per MW capacity which is similar to coal-fired power plants when life cycle coal mining, consumptive water storage & ash disposal areas are also accounted and hydro power plants when submergence area of water reservoir is also accounted. Therefore land shall soon become a bottleneck in the way of meeting the growing demand with high rate of population and industrial growth.

Hybrid solar thermal installations have the potential to overcome these challenges. They offer the following advantages

- Hybrid plants can achieve higher efficiencies than standalone CSP plants
- Incorporating the solar thermal into an power plant saves on additional costs of a turbine and generator
- Daily start-up and shutdown energy losses can be eliminated
- Additional operational and maintenance (O&M) costs incurred for a solar addition are also lower compared to that of standalone solar plant.
- There are inherent advantages of reducing carbon dioxide emissions
- Output is stable therefore grid integration will be easy
- Higher land utilization is possible as power plant has ample spaces to install solar panels

NTPC PERSPECTIVE

Harmony between man and environment is the essence of healthy life and growth. Therefore, maintenance of ecological balance and a pristine environment has been of utmost importance to the Union Ministry of Power. NTPC being the leading organization under the ministry in the areas of power generation, has been taking various measures for mitigation of environment pollution due to power generation.

"Going Higher on Generation, lowering Green House Gas Intensity" is NTPC vision statement for environment

With a plan to become a 128 GW company by 2032 integration of its thermal power plant with solar energy would help to fulfill its vision and would also help in surviving the competitive market with higher efficiency , decreased heat rate and with environmental norms becoming stringent solar hybrid plant will emerge as a solution.

There are following options to utilize the energy of the solar power like

- Using the PV technology for it townships, auxiliary etc.
- Solar heat to power the conventional steam power cycle
- Using low grade power cycle like kalina cycle

In this paper we have considered the solution of using the heating power of the solar energy by using the Concentrated Solar power (CSP) technology for producing steam which can be used in the cycle for reducing the use of fossil fuel and enhancing the efficiency of the power plant

CSP TECHNOLOGY

Solar energy received at the earth's surface is of dispersed in the atmosphere. To attain higher temperatures, i.e. higher efficiency, the dispersed solar energy needs to be concentrated. Concentration can be achieved by reflecting the solar energy falling on a large reflective surface, called collector, and focusing it onto a smaller area, called receiver. The working fluid is passed through the receiver to absorb the concentrated solar heat. The working fluid can be Water, Thermal fluids, or Air/Gas. Currently four CSP technologies available are in the market for commercial use. These are Parabolic Trough, Linear Fresnel Reflector, Parabolic Dish and Central Receiver Tower – with Parabolic Trough being the most prevalent.

CSP has advantages compared to photovoltaic as it can readily incorporate thermal energy storage and/or hybridization to provide dispatchable power. The use of relatively 'low tech' manufacturing methods for solar collector fields, together with the use of available steam turbine technologies, makes the prospect of CSP capacity quite feasible to get rapidly scaled up.

USE OF THE TECHNOLOGY

Thus by using parabolic trough (CSP) technology the steam so produced can be directly used in the power cycle to gain additional MWe. But the quantum of solar steam starts from zero hits the peak around noon and once again goes back to zero after sun set. Integration of this variable solar steam quantity with the main steam and continuously modulating the fuel input will require sophisticated controls which are not proven till date.

Also the other option is to Generation of steam in solar thermal block & replacing extraction steam of HP / LP heater: it can be used to preheat feed water in LP & HP heaters. Under this option, extraction steam is partly or fully replaced with solar steam. The saved extraction steam is expanded in the turbine to generate some more electricity. However seamless integration of solar steam with extraction steam and development of suitable 'controls' are the main difficulties also this can pose problem in turbine balancing.

The third option which is considered as the best method in this paper is to use the steam so produced from CSP technology for steam for Auxiliary PRDS. As we know that various auxiliary of power plant requires steam during unit startup, normal running and shutdown requires steam for Turbine sealing, Fuel

Oil Atomizing, Soot Blowing, VAM etc. This steam is supplied at 13-15 Ksc and 200-250 C. This steam is usually extracted from CRH and MS line both the sources of steam are high energy steam which is then throttled to low quality steam thus loosing it energy. thus if we are using solar energy to produce this steam not only we would be saving coal but also our MWe would also increase, increasing our efficiency and saving our natural resources and thus saving money. Also as this steam do not participate in the cycle thus control and integration of the system will be easy.

CASE STUDY OF NTPC SIPAT

NTPC after gaining expertise in operation and management of 200 MW and 500 MW Units installed at different Stations all over the country had looked ahead for higher capacity Unit sizes with super critical steam parameters for higher efficiencies and for associated environmental gain with Sipat being the first of them presently Sipat having 3*660mwe unit of supercritical technology and 2*500 units. Situated in Bilaspur (C.G) is having huge potential of using solar energy as the plant fall in the radiation zone of 5.5 to 5 kwh/m2/day zone (Refer Fig 3) and with 300 sunny days is also having ample space for installation of the solar parabolic troughs.

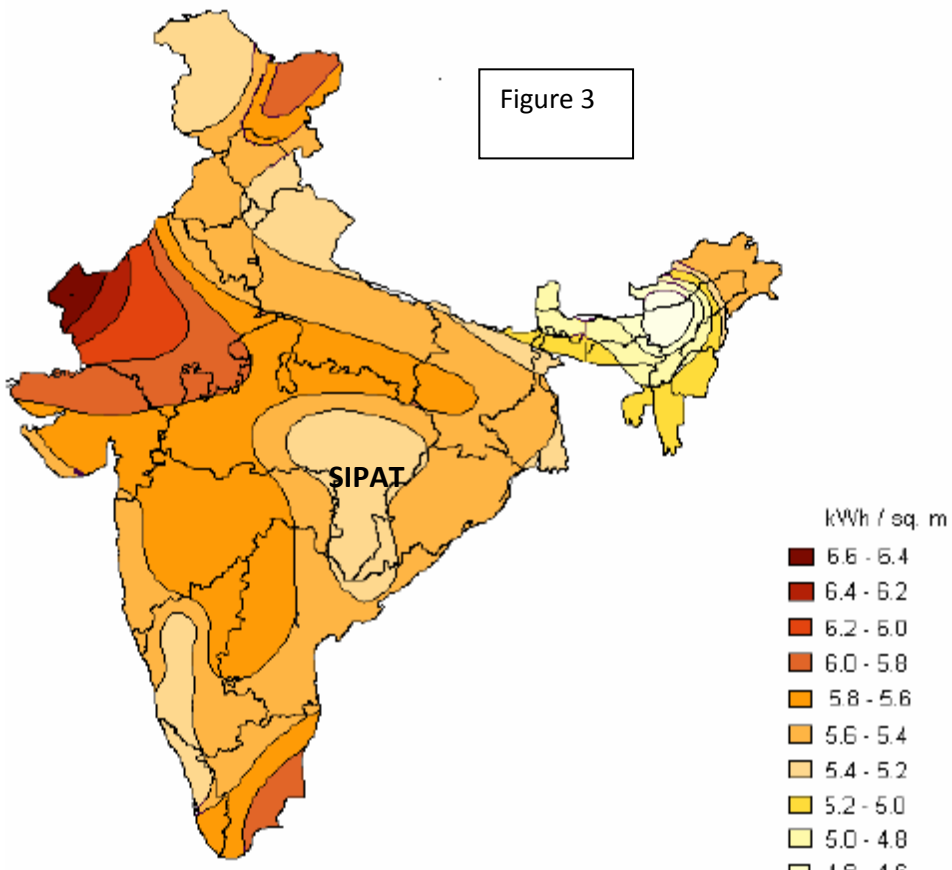

Figure 3

SOURCE: IMD DATABASE

Presently the station is having 15 Ksc Auxiliary PRDS header with temperature maintaining between 200 to 250 c. this steam is presently extracted from CRH line and Main Steam line the average consumption of about 30 t/hr which is mainly consumed by the VAM system and HFO heating(Refer Fig 4). The consumption of auxiliary steam goes up to 100 t/hr during unit startup & shutdown. This high quality of

steam produced by the boiler instead of expanding in the turbine and producing power is used in auxiliary system thus wasting the valuable fuel. Thus by the use of CSP technology solar energy would be used to produce this steam also there would be backup of the conventional MS & CRH system (Refer figure 5).

The benefit of this proposed project is discussed below:

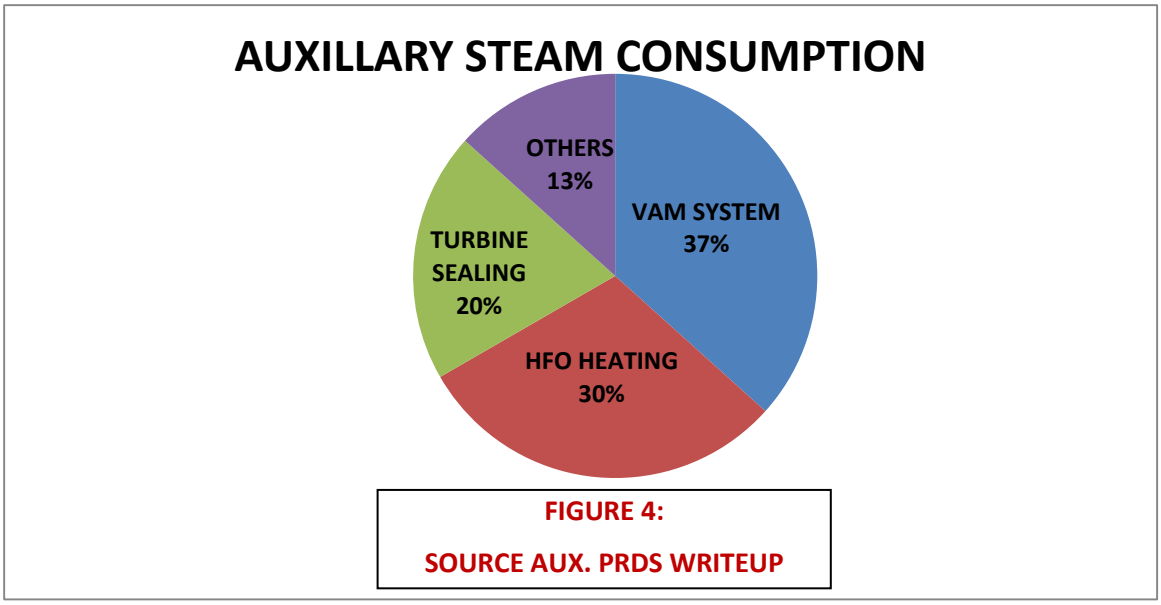

FIGURE 4:

SOURCE AUX. PRDS WRITEUP

COST ANALYSIS

- Total steam produced by Parabolic Solar Convertors = 30 T/hr
- Assuming that for 300 days in a year parabolic mirrors generate steam for 8 hrs a day.(considering that there is no storage system)
- Even if we are taking steam only from CRH this 30 T/hr of steam would produce = 6.5MW/hr
- For these 300*8 i.e. 2400 hrs , total energy saved in a year would be = 15600MW/year
- **Thus extra energy which we will be able to produce by the turbine with this increased flow in a year would be = 15.6 mu**
- Average fuel cost of Sipat at present is around 1.5 Rs/ unit
- **Thus extra amount which we would save in fuel =2.34 Crores**
- also in this calculation we have not considered the loss due to throttling which occurs as

  1. If CRH steam is used inlet condition is 48 Ksc and 297c while pressure and temperature in APRDS is 15 Ksc and 250 c thus from the steam table we are losing around **2 kcal/kg** of steam (from steam table)

  2. This loss increases if we are using MS line with inlet condition of 247 ksc and 538 c with same outlet condition we are losing around **100 kcal/kg** thus showing huge loss.

  Thus this kcal/kg of steam will get convert in kwh thus decreasing the heat rate.

Now taking into the account the investment which we have to put

- Steam consumption = 30t/hr
- This steam will be produced from 16 sq.m. which is most common commercially available parabolic plates with each one producing = 40 kg of steam
- Therefore total number of panel required will be = 750 panel
- Each panel cost =18.5 Lakh

  (average cost of 24 panel quoted 45 Lakh under JNNM-1 for 1 ton steam)
- **Therefore cost of total panels will be = 13.8 Crores**
- **Thus with saving in fuel cost of Rs 2.34crore/year payback will be = 5.8 yrs**
- This is very feasible and the payback period is going to come down due to reduction in the cost of technology which is mainly due to "The analysis of costs shows major cost component of the system is the structural frame and there are chances to reduce costs to Rs.5000 / m2 for the 50 - 100 m2 model due to use of alternative material for the structural frame, low engineering costs and spare fabrication facilities available at competitive prices." As quoted in Maharashtra energy development agency website.
- Also with increasing fuel cost and scarcity of coal the fuel coat is definitely going to rise thus further reducing the payback period.

Space above service building for solar panel installation

Also this is only in terms of money now we will analyze the environmental impact

From above we will be generating 15.6 mu with the same coal firing in the boiler thus taking the design specific coal of 0.6 total fuel we will save = 9360 T of coal /year

- Now 1kg of carbon produces 3.6 kg of CO_2
- **Thus Solar PRDS concept will reduce the CO_2 emission by = 11700 Ton/ year**
- With this there will be reduction in other emission and Ash also
- Thus we will be able to give a better world to our future generation

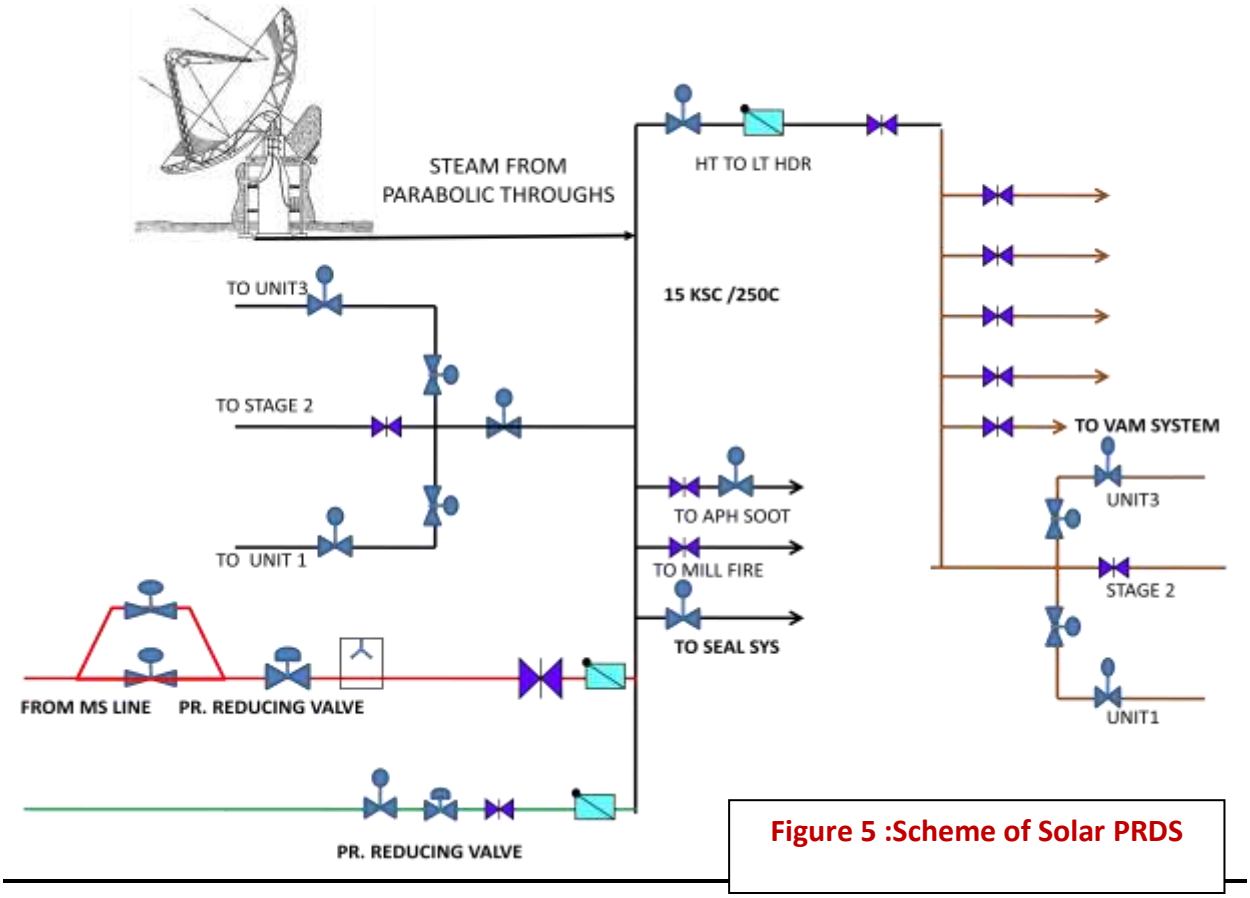

Figure 5 :Scheme of Solar PRDS

CONCLUSION

- With rapid growth of the country electricity demand & output both will increase due to scarcity of fuel and stringent environmental norms convention fossil plant has to realign themselves with new technology to meet the challenges.
- Renewable energy demand will also increase but the stability of output, efficiency, cost of generation, land utilization etc. are few major factors which play a major role in deciding the proportions of renewable energy mix in the grid.
- Therefore hybrid solar system has to be developed which will have in overcoming these challenges with this concept of Solar PRDS we will be able to hybridized solar and thermal energy with both economical and environmental benefit
- Also NTPC with its plan of becoming 128 GW company is having many new projects in pipeline which will be installing costly Aux. boiler firing costly LDO. Solar PRDS would be a profitable investment as it would be in use throughout the life of the plant.
- Thus NTPC will be able to fulfil it mission of **"PROVIDE RELIABLE POWER AND RELATED SOLUTIONS IN AN ECONOMICAL, EFFICIENT AND ENVIRONMENT FRIENDLY MANNER, DRIVEN BY INNOVATION AND AGILITY."**

About Authors :

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