Hybridization of Conventional Thermal Power Plant Based on Solar Aided Power Generation (SAPG).

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Abstract : Our aim of research work is to find out the technical, environmental and economic aspects of integrating the PTC with the feed water heater in an 210 MW Amarkantak Thermal Power Plant located in Chachai (MP).The integration of the Parabolic Trough Collector with the feed water heater for heating the feed water by solar energy and replacing the bled-off steam will result in improvement in the performance of existing power plant and it helps in reduction of fuel consumption and hence the resultant pollutants including GHG emission will be reduced. System Advisory Model (SAM) software which is developed by National Renewable Energy Laboratory is used as simulation tool to find out the aperture area of the required solar field and to predict the performance of solar system at that location. Various thermodynamic basic relations, energy and mass balances are used to simulate the main components of the Rankine cycle existing power plant. Different scenarios of FWH replacement option with PTC are discussed and their effect on various parameters is presented. Due to the integration the efficiency of the existing power plant increased by 6 % due to increase in turbine work output by 42 % as a result of increased steam flow rate in latter stages of the turbine. As we have replaced the bled-off steam by PTC to heat the feed water by solar energy the saved steam will expand in latter stages of turbine such as IP & LP and hence produces more power. The integration of PTC with feed water heater shows the positive effect on the environment as the GHG emission avoided is approximately 73800 ton CO_2 annually. The economic analysis of such integration of PTC is performed and it is found out that the payback period for all replacement option lies between 9 to 11 years.

Keywords: Thermal power plant, CSP, Parabolic Trough Collector, GHG Emission.

I. INTRODUCTION :

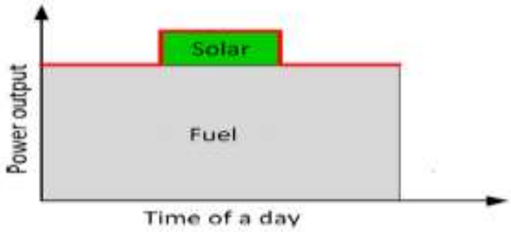
In this research work we have hybridized the existing conventional thermal power plant of 210MW named Amarkantak Thermal Power Plant of MPPGCL situated in Chachai (M.P). Hybridization is done by using solar thermal energy for feed water heating by using Concentrated Solar Power (CSP) technology and replace the bled-off steam by CSP technology in regenerative rankine power cycle. In conventional power plant this bled off steam from the turbine is normally used to preheat the feed water entering the boiler, it has the effect of increasing the thermal efficiency of the cycle but at the cost of reducing the power output of the turbine due to reduced mass flow rate. This hybridization process is known as Solar Aided Power Generation (SAPG).

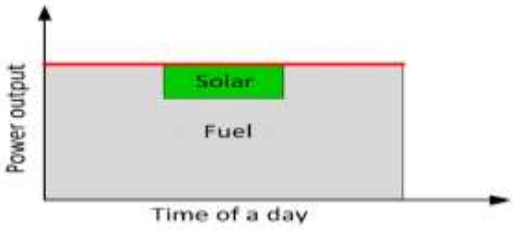
Hence in SAPG technology we use the solar energy to heat the feed water. Hence it helps to increase the thermal efficiency of the cycle. At the same time the more steam which is saved will expand in the turbine. Hence it will be able to generate more power.

The SAPG actually uses the two important points of two mature technologies, firstly traditional regenerative rankine cycle with relatively higher efficiency and secondly, solar heating at relatively low temperature range[1].

In SAPG technology, two different operation mode exist " Power Boosting Mode" and " Fuel Saving Mode". The "Power Boosting Mode" is to use the saved steam generate additional power while consuming the same amount of fuel. Alternatively "Fuel Saving Mode" reduces the amount of fuel to the boiler while maintaining the same generation output capacity, resulting in a proportional reduction of CO_2 emission[2].

Our aim of research work is to find out the technical, environmental and economic aspects of integrating the PTC with the feed water heater in an 210 MW Amarkantak Thermal Power Plant located in Chachai (MP).The integration of the Parabolic Trough Collector with the feed water heater for heating the feed water by solar energy and replacing the bled-off steam will result in improvement in the performance of existing power plant and it helps in reduction of fuel consumption and hence the resultant pollutants including GHG emission will be reduced.





(a)Power Boosting Mode (b)Fuel Saving Mode

Fig 1:The alternative " power boosting" and "fuel saving" modes of operation in a SAPG Plant.

Earlier the work of hybridization of solar thermal energy with rankine cycle started with Zoschak and Wu [1975] studied seven ways of integrating solar thermal energy to the steam rankine cycle .They used Solar Central Receiver (SCR) as the CSP technology. Their results shows that the integrating solar energy with the conventional thermal power plant is best with combination of water evaporation and superheating [3]. Pai [1991] combine the Solar Central Receiver (SCR) with a 210 MW thermal power plant as adding heat exchanger before feed water heaters. His result of study showed that during the time of using solar energy for feed water heating, 24.5% of fuel consumption is saved when feed water is heated to a temperature of 241^0C [4.]Ying and Hu [1999] studied rankine cycle with solar reheating. They obtained optimal thermal efficiencies and exergetic of combined system of power cycle and solar collector, optimal saturation temperature in the boiler and optimum temperature of fluid entering the solar field. They found that the integration of solar energy and reheating and regeneration is the best state for solar thermal hybrid configuration for power generation at average temperature [5].Gupta & Kaushik [2009, 2010] studied the exergy characteristics for different components of DSG solar heat power plant. In this system steam generated by PTC is combined with steam generated in boiler and enters into steam turbine. They found out that heating feed water using solar energy is more economical than using the same solar energy in single solar power plants units. Their paper is based on exergy concept for the utilization of solar energy in rankine cycle. It has been find out that using solar energy for feed water heating reduce the exergy loss in FWH and develop more work than developed by Solar Thermal Power Plants. It is found out that the work increases in case of low pressure heaters [6,7].Yan [2010] found out that the replacement of bled-off steam for high pressure feed water heater with the solar heat is the most efficient SAPG configuration [8]. Hu [2010] studied the advantages of Solar Aided Power Generation (SAPG) concept using THERMOSOLV software. They proved that energy and exergy efficiency can be improved by using solar energy to replace the extracted steam for feed water heating [9].Suresh [2010] analyzed energy, exergy, economic and environmental effects of integrating solar energy to feed water preheating using Cycle Tempo software in ordinary as well as critical conditions. They used Parabolic Trough Collector (PTC) as CSP technology for heating feed water. They showed by replacing turbine extract steam, it is possible to reduce fuel consumption by 5-6% [10]. Popov [2011] modeled three repowering states for a 130 MW steam cycle power plant. It was found that the best repowering is replacing high pressure feed water heater by solar field [11]. Reddy [2012] analyzed using integrating solar energy for feed water heating in a conventional power plant. They used CLFR for using solar energy for heating feed water. They have concluded that when heat need by all high and low pressure feed water heaters is supplied by solar heat, power output of hybrid power plant is increased by 20% [12].Peng [2014**]** studied the thermodynamic performance of SAPG system and concluded that exergy destruction is lower in SAPG as compared to stand alone solar thermal power plants [13] **.**Qin [2017] studied the impact of the two different operation strategies for non displaced feed water heaters on plant's performance. They performed a case study on 300 MW thermal power plant, in which the extraction steam to high pressure heater is replaced by solar thermal energy. They concluded that the plant adopting the constant temperature strategy is better than constant mass flow strategy. But adopting the constant mass flow strategy can achieve better performance [14].

II.RESEARCH METHODOLOGY:

In this research work we hybridized the conventional thermal power plant by integrating the Parabolic Trough Collector with the Feed Water Heaters (FWHs) to substitute for steam extraction from the steam turbine. Such integration of new technology will lead to improve the performance of existing power plant and reduce its fuel consumption and consequently the resultant pollution emissions will be reduced.

In this paper the plant in which the study is performed is Amarkantak Thermal Power. It is located near Amlai station on Bilaspur -Katni section of South East central railway zone. It is situated at Anuppur district of Madhya Pradesh, India. The power plant is one of coal based power plant of Madhya Pradesh Power Generating Company Limited (MPPGCL).It has an installed capacity of 210MW.It is commissioned on August 2008.The water for the plant for cooling purpose and for steam formation has been taken from the nearby Sutna Nala dam which is constructed on the sone river and spread across 700 acres (2.8 km^2).The coal for the plant has been obtained by rail from the mines of South Eastern Coalfields Limited(SECL). The employed thermal cycle is a standard regenerative rankine cycle in which the boiler feed water heating system consists of 2 high pressure heater,1 open feed water heaters (Deaerator) and 3 low pressure heater. Fig. 2 shows the original heat and mass balance and flow diagram for this unit, with the coal as fuel. The design point energy and mass balances are presented for each component, which represent the base case in the current study i.e. before integrating the proposed CSP system.

In this study the integration of CSP system with FWHs is considered and nine different options of replacing FWHs are presented and discussed as follows:

1. Feedwater heater No.1(one high pressure FWH)
2. Feedwater heater No.1 and No. 2(two high pressure FWHs)
3. Feedwater heater No.1 to No. 3(two high pressure FWHs and one open FWH)
4. Feedwater heater No.1 to No. 4(two high pressure FWHs, one open FWH and one low pressure FWH)
5. Feedwater heater No.3 to No. 6(one open FWH and three low pressure FWHs)
6. Feedwater heater No. 4 and No. 5(two low pressure FWHs)
7. Feedwater heater No.5 and No. 6(two low pressure FWHs)
8. Feedwater heater no. 6(One low pressure FWH)
9. All feedwater heater (six FWHs)

First of all we calculate the power output and the efficiency of the hybrid power plant for each replacement option by applying energy and mass balance equation. After that the simulation of CSP technology for each replacement option is conducted by using the System Advisory Model (SAM) software, which is developed by National Renewable Energy Laboratory (NREL) of USA, to study and analyse the performance of CSP as part of hybrid solar rankine cycle.

In SAM software we have to provide the latitude and longitude of the site of the plant .Then the weather files of that location can be downloaded from the software. These files helps to tell us about the solar energy source and weather condition on sites such as hourly values of solar radiation and weather data. Weather parameters include GNI, DNI, dry/wet ambient temperature, relative humidity, atmospheric temperature, wind speed as summarized in table 1 for the selected location. These files are used by SAM software for simulation of CSP system. The DNI employed in this study is shown in figure 3.

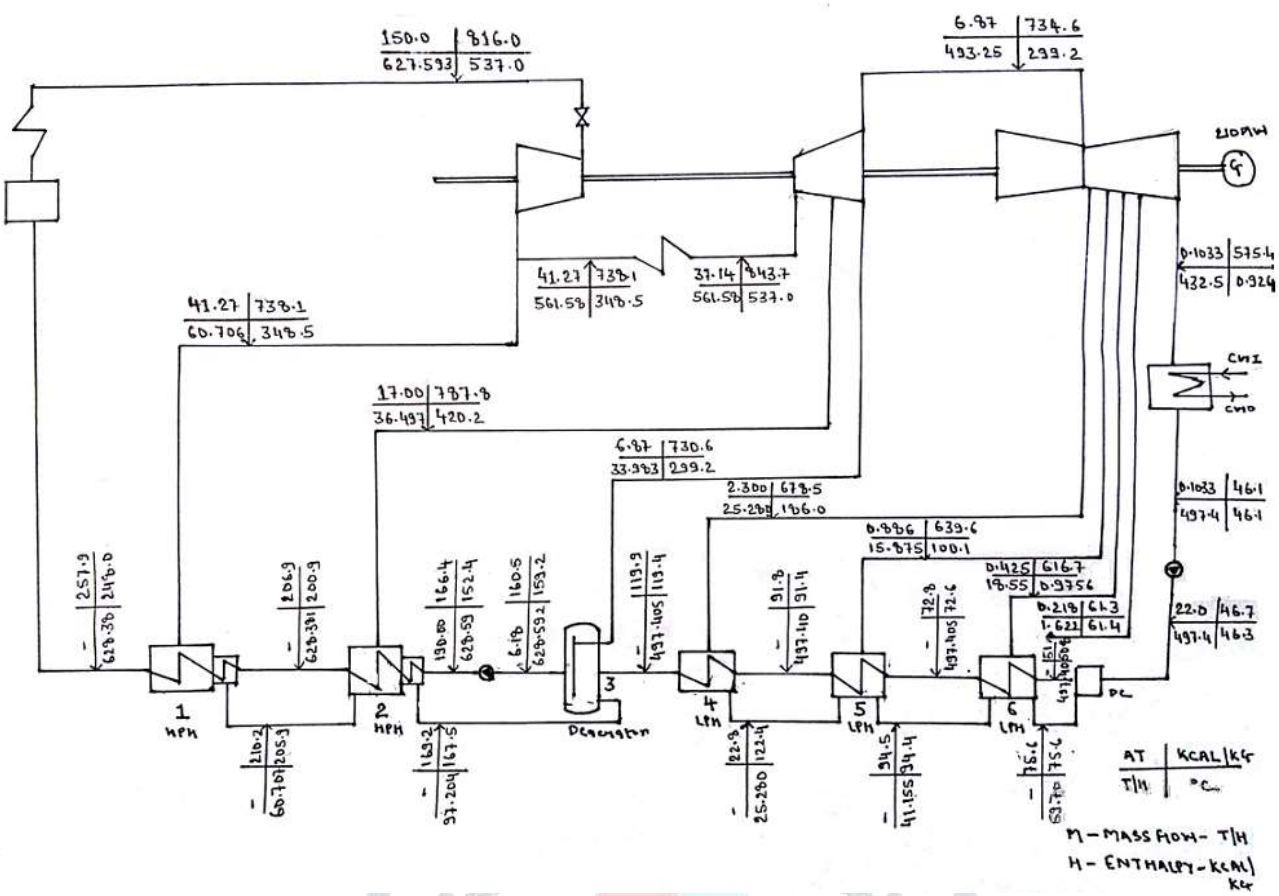
The input parameters for simulation with SAM for all proposed options are given in table 2 each option is taken as separate case in order to calculate the optimal area required for the PTC solar field. This helps to find out the best and optimal performance with feasible initial cost. The aperture area depends on required thermal capacity, DNI, ambient temperature and solar multiple.

The basic assumptions used in this study are:

(1)The average DNI at the selected site is 750 W/m^2.

(2)Ambient temperature is 26.4^0C.

(3)Wind velocity is 1.5 m/s.



SOURCE-ATPS MPPGCL 210MW MANUAL

Fig.2: Heat balance and flow diagram for the 210 MW Amarkantak Thermal Power Plant.

The objective of our research work is concluded as follow:

- To calculate the generation capacity and efficiency of power plants for all replacement options of FWH and find out the best replacement option.
- To find out the aperture area of PTC for all replacement option using SAM software.
- To do the economic analysis of all replacement option. It means to calculate the total cost of all replacement option and to calculate the payback period for all replacement option.
- To do environmental analysis. To find out the amount of CO2 emissions avoided annually and consequently the cost of CO_2 emissions avoided annually as per carbon trading. Again calculate the SPBP including the cost of CO_2 emissions avoided and the fuel cost saved annually.

Table 1: Solar & weather data for Plant location.

State, City	Madhya Pradesh, Chachai
Country	India
Time Zone	GMT 5.5
Data Source	NSRDB
Latitude	24.15^0N
Longitude	81.35^0E
GNI (kWh/m^2/day)	5.36
DNI (kWh/m^2/day)	4.33
DHI (kWh/m^2/day)	2.33
Average Temperature (^{0}C)	26.4
Average Wind Speed (m/s)	1.5 m/s

Table 2: Parameters for different FWHs replacement options.

Replacement Option		Mass Flow Rate(ton/hr)		Thermal Energy Rate(Kcal/hr)	Thermal Energy (MW)	Water/Steam Inlet Temp(^{0}C)	Water/Steam Outlet Temp(^{0}C)	Water/Steam Inlet Pressure(bar)
FWH #1		60.707		31167697.6	36.248	346.6	205.9	99.21
FWH #1+2	#1	60.707	97.204	61644176.1	71.688	346.6	205.6	99.21
	#2	36.497				419.6	167.5	16.15
FWH #1+2+3	#1	60.707	131.167	83102412.9	96.643	346.6	205.6	99.21
	#2	36.497				419.6	167.5	16.15
	#3	33.963				293.8	159.2	8.99
FWH #1+2+3+4	#1	60.707	156.447	97079493.4	112.90	346.6	205.6	99.21
	#2	36.497				419.6	167.5	16.15
	#3	33.963				293.8	159.2	8.99
	#4	25.280				185.8	122.4	2.185
FWH #3+4+5+6	#3	33.963	93.672	55724467.25	64.807	293.8	159.2	8.99
	#4	25.280				185.8	122.4	2.185
	#5	15.875				99.8	94.4	0.849
	#6	18.554				0.3766	75.6	0.409
FWH #4+5	#4	25.280	41.155	23422801.45	27.240	185.8	122.4	2.185
	#5	15.875				99.8	94.4	0.849
FWH #5+6	#5	15.875	34.429	20289149.95	23.596	99.8	94.4	0.849
	#6	18.554				0.3766	75.6	0.409
FWH #6		18.554	18.554	10843429	12.610	0.3766	75.6	0.409
All FWH's		190.876		117368643.4	136.499	346.6	75.6	0.40-99.21

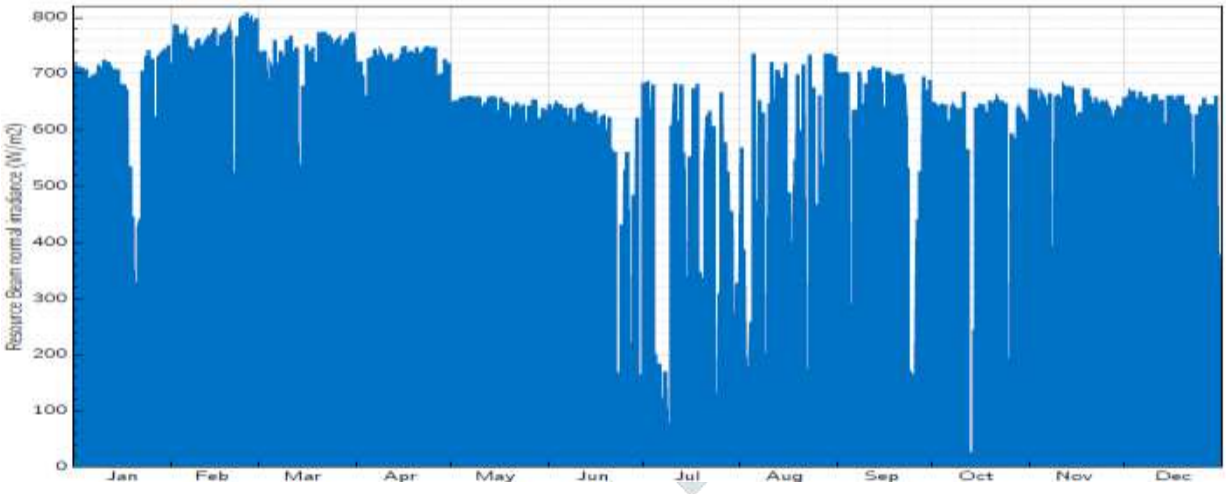


Fig.3: Resource Beam Normal Irradiance (DNI) in Chachai around the year.

The research methodology is explained in the following steps,.

1. Energy and Mass Balance.

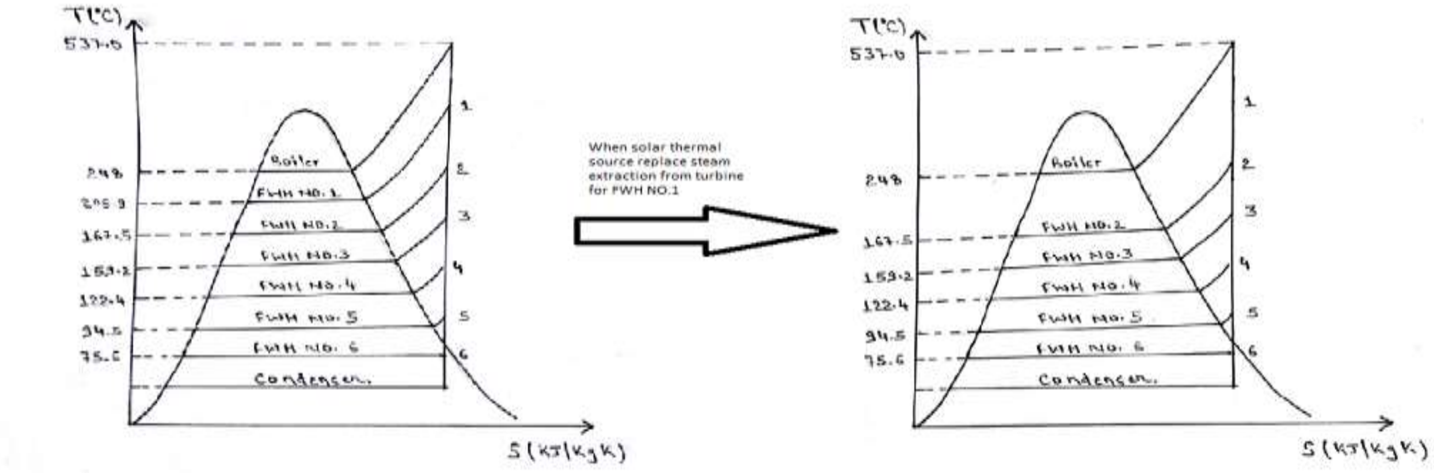


Fig .4: Replacement of FWH No.1 on T-s diagram

In this we first integrate the FWH NO.1 with PTC to generate the required heat which is previously obtained from the bled steam. Such heat supplied from solar energy would eliminate steam extraction from the steam turbine, as a result more steam mass flow and expand in next stages of the turbine. Finally this will produce more network output to the generator if the SAPG system is operating on power boosting mode.

The effect of first replacement (FWH NO.1) on the T-s diagram is shown in fig.4. It is shown from the figure that steam at point 1 is not extracted from the turbine. Since the required heat is produced by PTC system. By applying energy and mass balances the effect on different cycle parameters ($W_{turbine}$, W_{pump}, $Q_{condenser}$ etc) is determined and the final efficiency (η) of the steam cycle can be estimated.(Table 3)

The replacement of FWH No.1 showed positive result on the turbine's output. The turbine output increased by 20.88 MW and cycle's efficiency by 2.8%.Similar procedure is followed for rest of the replacement option. (see fig.5& 6)

Table 3: Main Performance Indicators For all Studied options.

Replacement Option	Saved Steam(ton/hr)	FWHs Thermal Energy Rate(Kcal/hr)	$W_{turbine}$ (MW)	$Q_{condenser}$ (MW)	W_{pump} (MW)	Efficiency (η %)
Base Case	0	-	213.67	306.19	4.31	34.81%
FWH #1	60.707	31167697.6	234.55	343.56	4.72	37.60%
FWH #1+2	97.204	61644176.1	244.023	366.02	4.98	39.20%
FWH #1+2+3	131.167	83102412.9	247.409	386.93	5.21	39.75%
FWH #1+2+3+4	156.447	97079493.4	250.44	402.59	5.38	40.24%
FWH #3+4+5+6	93.672	55724467.25	223.469	363.85	4.95	35.90%
FWH #4+5	41.155	23422801.45	215.409	331.52	4.59	34.61%
FWH #5+6	34.429	20289149.95	217.674	327.38	4.54	34.97%
FWH #6	18.554	10843429	216.489	317.61	4.44	34.78%
ALL FWHs	190.876	117368643.4	256.112	423.68	5.62	41.15%

2. Solar Field required for each replacement option.

The solar field aperture area for PTC system was found out by using SAM software. The PTC aperture area should be able to developed the heat which is equal to the heat transferred by bled steam before replacement. The inlet temperature of steam to feedwater before integration should be equal to the outlet temperature of HTF (Heat Transfer Fluid) of PTC system .Similarly outlet temperature of steam from feedwater before replacement becomes equal to inlet temperature of HTF of PTC. In SAM software for finding the aperture area we need to provide five input parameters namely Design point DNI ,target solar multiple, target receiver thermal power, loop inlet HTF temp & loop outlet HTF temperature. Design point DNI at the location assumed is 750 W/m^2, rest of the input parameters are obtained from table 2 except solar multiple. Solar multiple is defined as the ratio between the thermal power produced by solar field at the design point and the thermal power required by power block at nominal condition. The SM value is usually determined by experience. For finding out the effects of solar multiple we have calculated the required solar field aperture area for the replacement option FWH #1+2+3+4.Different trials were carried out by changing the SM value between 1.5 and 2.75 with a step of 0.25.Results obtained are summarized in table 4.Similar procedure is adopted for all studied option.

Table 4: Simulation results of FWH#1+2+3+4 with various SM values

Input Parameters			Output of PTC		
Solar Multiple(SM)	Required thermal power output(MW)	Steam output/Input temp(^{0}C)	Solar Field Aperture Area (m^2)	Active Hours (hour)	Out of Service Days. (Days)
1.50	112.90	419.6/122.4	210560	1511.839	176
1.75			246280	1598.974	166
2.00			281060	1644.717	160
2.25			315840	1637.510	161
2.50			351560	1237.398	211
2.75			386340	852.214	259

Note: Active hours is out of 8760 hours & out of service days (out of 365 days) is calculated by assuming solar energy is available for 8 hrs in a day.

3.Economic Analysis.

There is very less information available about the cost breakdown of CSP systems. The only dependable sources from which the cost Breakdown of CSP system is available from World Bank Report 2011, which included the investment cost of different subsystems of Anasol-1 plant in Spain [15] and The cost model developed by the National Renewable Energy Laboratory (NREL), for use with NREL's System Advisory Model (SAM)[16].Based on the reports, estimates of capital and running costs factors of the proposed PTC system are summarized in table 5.

Based on basic assumptions provided in table 5, the total capital cost of PTC system needed for the replacement option FWH #1+2+3+4 with different SM is calculated in table 6. This could provide an initial projection of cost related to integrating a CSP system with an existing steam power unit.

In table 8, we have calculated the simple payback period for option FWH #1+2+3+4 by taking the value of calorific value of coal 4860 kcal/kg and cost of coal is Rs.1925/ton. Same procedure is adopted for all replacement option taking also different SM values. It was found that Simple Payback Period for any replacement option range between 10 to 14 years.

Table 5:.Estimated capital & running cost factors for proposed PTC system.

Parameter	Cost Factor
Direct Capital Cost	
Site Improvement(US$/$m^2$)	10.0
Solar Field(US$/$m^2$)	400.0
HTF System(US$/$m^2$)	5.0
Contingency (% of total direct cost)	3%
Indirect Capital Cost	
Engineering, procurement and construction(% of total direct cost)	10%
Annual Running Cost	
O & M(labor and material)(US $/kW-year	12.0

Table 6: Total Capital cost of PTC for option FWH #1+2+3+4

Parameters	Cost (US $)					
	SM=1.5 Area=210560	SM=1.75 Area=246280	SM=2.00 Area=281060	SM=2.25 Area=315840	SM=2.50 Area=351560	SM=2.75 Area=386340

Direct Capital Cost						
Site Improvement	2105600	2462800	2810600	3158400	3515600	3863400
Solar Field	84224000	98512000	112424000	126336000	140624000	154536000
HTF System	1052800	1231400	1405300	1579200	1757800	1931700
Contingency	262472	3066186	3499197	3932208	4376922	4809933
Indirect Capital Cost						
EPC Contract	9000387.2	10527238.6	12013909.7	13500580.8	15027432.2	16514103.3
Total	99004259.2	115799624.6	132153006.7	148506388.8	165301754.2	181655136.3
Total (in Rs)	6500619659	7603403351	8677166420	9750929489	1.085371318×10^{10}	1.192747625×10^{10}

4. Green House Gas Emissions.

The new CSP integration with existing steam plant saved energy, represented by the amount of fuel (coal) needed to generate steam. Consequently there is net reduction of pollutant gases including GHG emissions. The amount of avoided GHG emissions represented by CO_2 equivalent was calculated using an emission factor of 96100 kg CO_2/TJ or 96.1 tonCO_2/TJ(assumed sub-Bituminous coal is used)[17].Cost reduction of such project could be achieved through financing from grants and/ or CO_2 emission trading. Based on European Emission Trading Scheme(EU-ETS) each ton of CO_2 avoided could be sold in the international market for approximately 26 US $[18].When such cost is taken into consideration and added to fuel savings ,then SPBP is reduced by about 12%.The formula used to calculate the avoided GHG emissions is given by,

$$\text{Emissions}_{GHG,\ fuel} = \text{Fuel Consumption}_{fuel} \times \text{Emission Factor}$$

Where,

$\text{Emissions}_{GHG,\ Fuel}$=Emissions of a given GHG by type of fuel (Kg GHG)

$\text{Fuel Consumption}_{Fuel}$=Amount of fuel combusted (TJ)

$\text{Emission Factors}_{,\ Fuel}$=Default emission factor of a given GHG by type of fuel (kg CO_2/TJ)

Table 7 shows the % change in the value of payback period for replacement option FWH #1+2+3+4 after considering the cost of CO_2 emissions avoided and Fig .8 shows the comparison of calculated SPBP before and after considering CO_2 emission.

Table 7: Cost analysis of SPBP for replacement option FWH #1+2+3+4 after considering CO_2 emissions.

SM	Capital Cost(Rs.)	Thermal Energy Saved(kcal/yr)	CO_2 emission avoided per year(ton CO_2)	Cost of CO_2 avoided sold (Rs/year)	Previous SPBP	Latest SPBP	% Change in SPBP
1.50	6500619659	1.4676×10^{11}	59052.322	100811762	8.86	7.7	12.5%
1.75	7603403351	1.552×10^{11}	62455.813	106622066	9.80	8.6	12.2%
2.00	8677166420	1.596×10^{11}	64242.656	109672492.6	10.91	9.5	12.8%
2.25	9750929489	1.589×10^{11}	63961.01	109191677.8	12.27	10.79	11.5%
2.50	1.085371318×10^{10}	1.201×10^{11}	48332.833	82511879.97	18.08	15.90	11.6%
2.75	1.192747625×10^{10}	8.273×10^{10}	7950.545	13572852.74	28.88	27.94	2.9%

III. RESULTS & CONCLUSION:

1. Energy and Mass Balance.

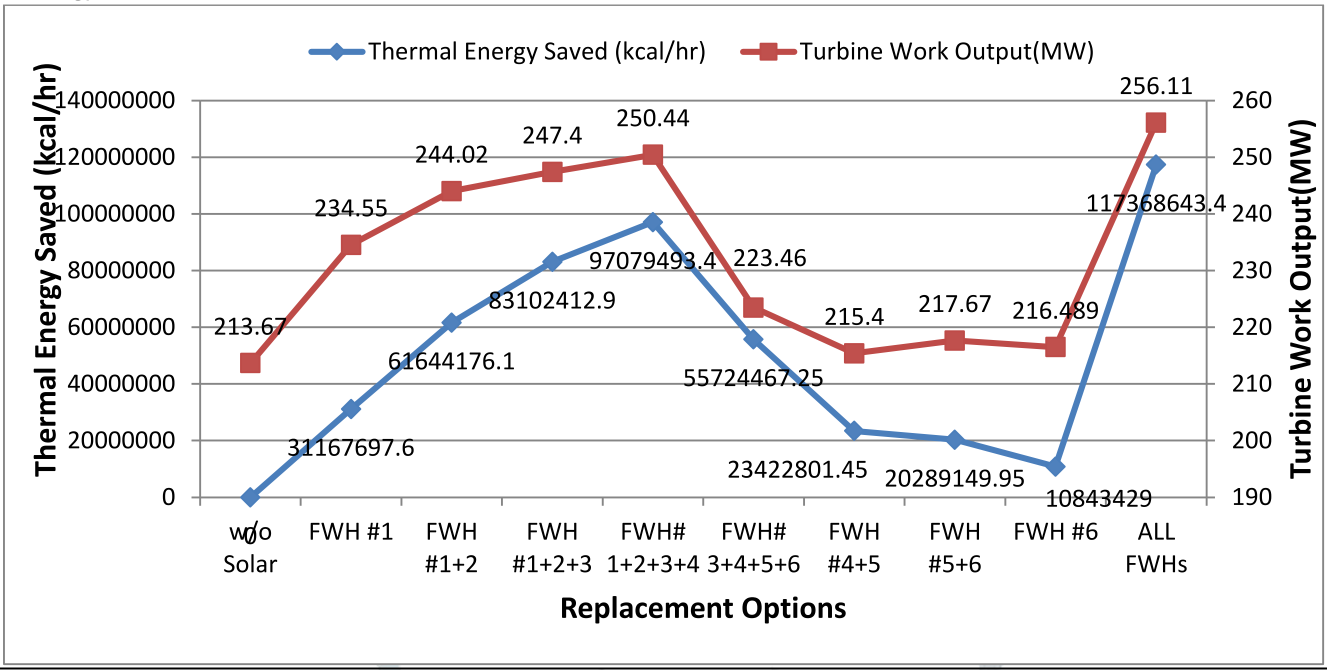


Fig. 5: Saved thermal energy and turbine work output for various replacement options of FWHs.

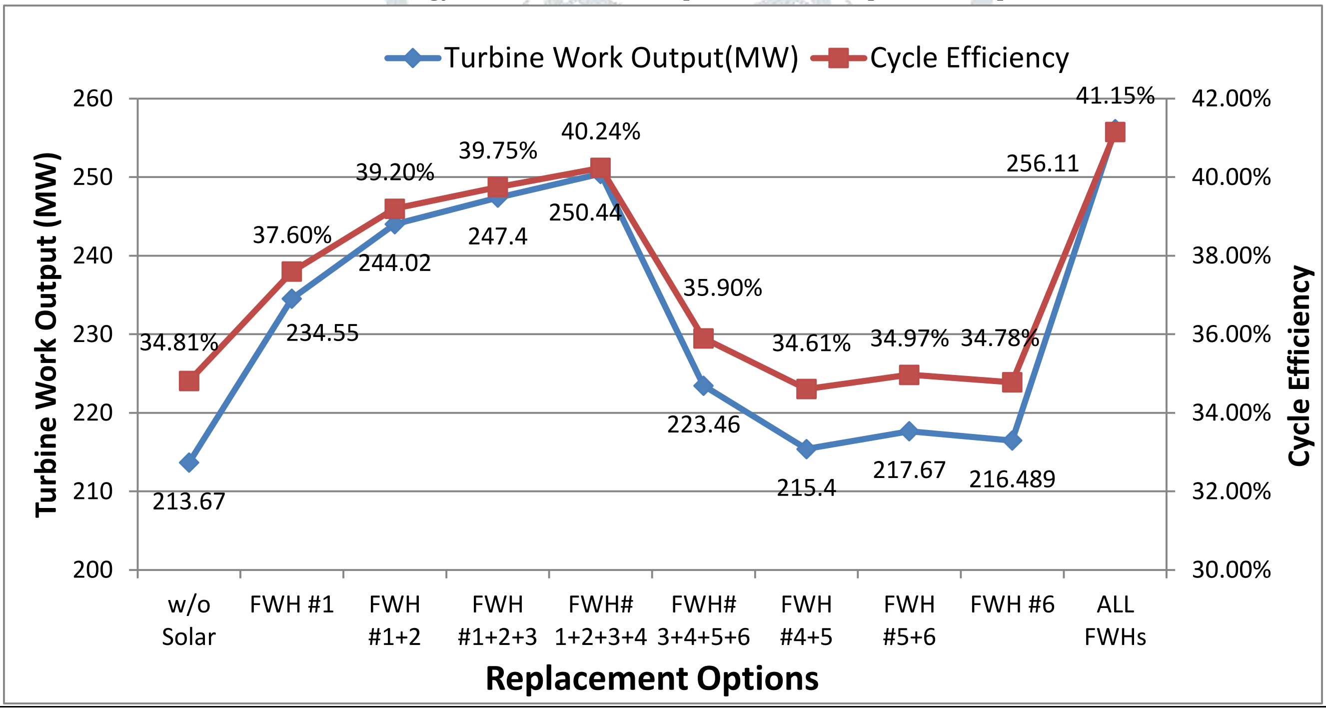


Fig. 6: Steam turbine work output and cycle efficiency for various replacement options of FWHs.

From the fig.5 & 6, it is cleared that the two replacement options are best. The replacement option FWH #1+2+3+4 is the best because it increases power output by 36.77 MW and cycle efficiency by 5.5%.Another best option is replacing all FWHs it increases power output by 42

MW and cycle efficiency by 6%. It should be noted that out of two best replacement option (i.e. FWH #1+2+3+4 & All FWHs) replacing all feed water heaters has two main disadvantages. First of all by replacing All FWHs the turbine power output increase by 6 MW & cycle efficiency increase by 0.5% when compared with replacement option FWH #1+2+3+4 but the mass flow rate of steam entering the turbine increases by 34 ton/hr. Hence such high mass flow of steam causes overloading of the latter stages of turbine especially the LP turbine stages.

Second disadvantage of replacing all FWH's is that for replacing all FWHs to generate the required heat by PTC the PTC area must be large. Hence it increases the cost of the project.

Hence the best replacement option is FWH #1+2+3+4.

2. Solar Field Required For Each Replacement Option.

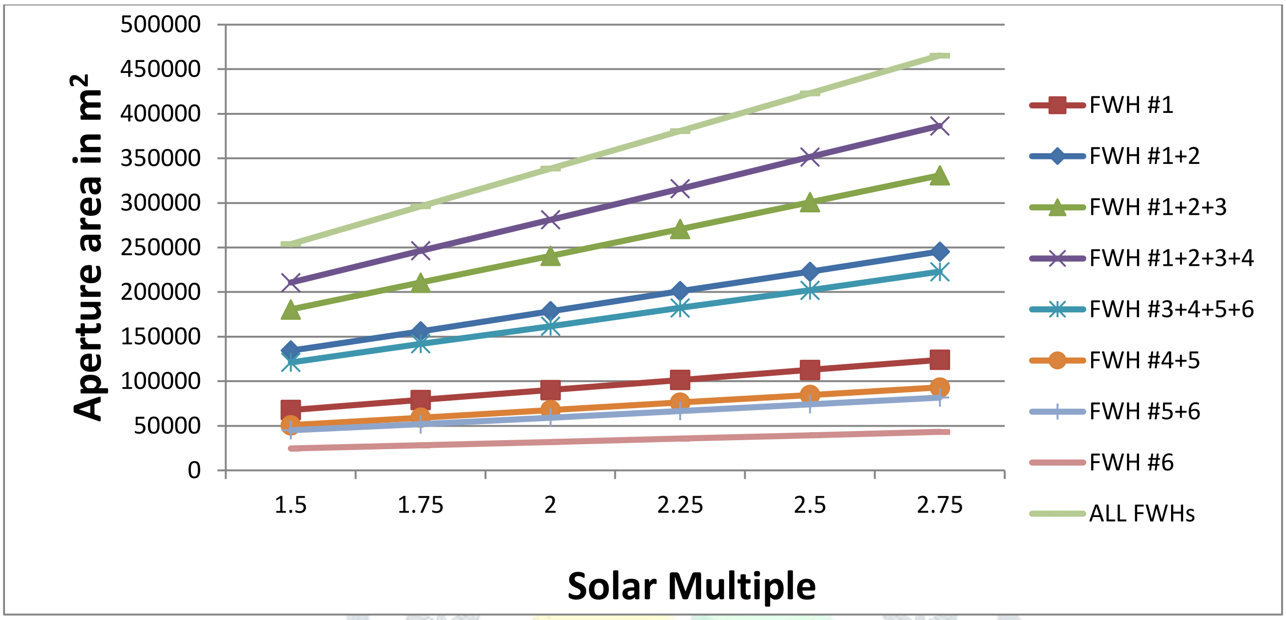


Fig. 7: Relationship between solar multiple and solar field aperture area.

The following result is obtained from the graph.

1 .Solar field aperture area is directly proportional to solar multiple for all studied options.(as shown in fig.7)

2. In case of FWH #1+2+3+4 as solar multiple increases from 1.50 to 2 solar active hours increases and out of service days decreases with further increase in solar multiple active hours decreases to a very low value and out of service days increases very high. Hence there is a need to find out optimum value of SM value.

3 .Solar multiple must not be too large because large sizes of solar field would achieve a worst return on their investment because solar thermal energy over nominal level would be wasted. Similarly it should not be very small because high investment will get nothing in return due to reduced solar power output.

4. .The optimum SM value selected is 1.5 to ensure that the system will work all over the year at its rated capacity.

3. Economic Analysis.

Table 8: Simple Payback Period for replacement option FWH #1+2+3+4

SM	Aperture Area(m^2)	Capital Cost(Rs.)	Unit Energy Cost(Rs/kWh)	Actual Active Hours(hour)	Thermal Energy Saved(kcal/yr)	Fuel Saving Cost(Rs./yr)	Simple Payback Period (year)
1.50	210560	6500619659	674998520.3	1511.839	1.467685642×10^{11}	58133639.11	8.86
1.75	246280	7603403351	713901849.7	1598.974	1.552275859×10^{11}	61484177.54	9.80
2.00	281060	8677166420	731538777	1644.717	1.596682931×10^{11}	63243099.63	10.91
2.25	315840	9750929489	731107249	1637.510	1.589686412×10^{11}	62965974.14	12.27
2.50	351560	1.085371318×10^{10}	552467316.2	1237.398	1.20125971×10^{11}	47580760.12	18.08
2.75	386340	1.192747625×10^{10}	380144453.4	852.214	8.273250339×10^{10}	32769561.53	28.88

It is found out that the simple payback period for the project is between 9-10 years.

4. Green House Gas Emissions.

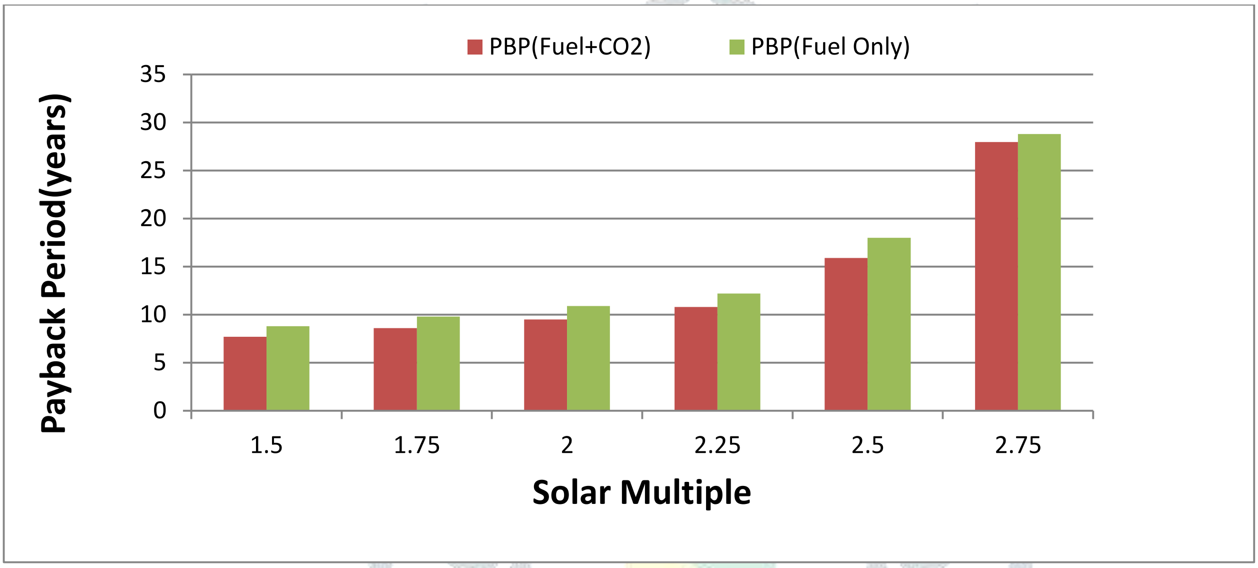


Fig.8: Calculated SPBP for replacement option FWH #1+2+3+4

Based on European Emission Trading Scheme(EU-ETS) each ton of CO_2 avoided could be sold in the international market for approximately 26 US $.When such cost is taken into consideration and added to fuel savings ,then SPBP is reduced by about 12%.

IV.CONCLUSION:

In this research work integration of PTC with feed water heater in 210MW power plant is done which is used to heat the feed water and replace the bled off steam from the steam turbine. Technical, economical end environmental analyses were conducted with different scenarios of such integration. The introduced system increases the efficiency of plant by 6.34% due to increase turbine work output by 42.44 MW as a result of replacing bled off steam more steam expands in latter stages of turbine. The economics of such system with different scenarios of the system were studied. It was found that the payback period of such integration is found to be 9 to 11 years for different replacement option. The integration of CSP has positive result on environment since 73769.534 ton CO_2 emissions could be avoided for replacing All FWH and 59052.322 ton CO_2 could be avoided for replacement option FWH#1+2+3+4.

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