An Efficient Solar Thermal Power Plant.

Shirsendu Das
National Institute of Technology, Agartala
Dr. Arjun Kr. De
Assistant Professor TIT Narsingarh

Abstract - ***Solar energy is the main source of energy. All other energies have been derived from solar energy. Solar energy use to produce electricity. With the help of photo voltaic cell we can directly convert solar energy into electrical energy. Another mode is solar thermal power plant. In solar plant solar energy is utilized to heat up water to convert steam. Then this steam is used to run steam power plant. But efficiency is not enough & net output also very low. Here I have introduced a method by which efficiency of solar thermal plant can be increased.***

1. INTRODUCTION

If a close cycle gas turbine plant is used in place of steam power plant that time efficiency of the plant will increase coz there is no pumping loss. Without using water glycol mixer if we use carbon dioxide gas as working fluid then heat absorption by the fluid will increase. So power output will increase. .

2. MAIN PARTS OF THE PLANT

a. Concentrated Solar collectors:- Central Solar Receiver Power station should construct so concentrate solar energy of a large are towards the heating chamber with the help of large numbers of solar reflectors.

b. Heating Chamber:- wall of the heating chamber should make with such types of materials (Copper, silver etc) which can easily absorb concentrated solar heat incidence on it.

C. Reflectors:- Reflectors should have high reflectivity. So glass mirror made with low iron contents is used. Now a day plastics (Acrylic) & polymethyl methacrylate is also used.

d. Turbine:- turbine is a part where heated gases will expands & produce shaft power & it is utilized to run generator to produce electricity.

e. Condenser:- A water cooling condenser will use to condense gases released from turbine.

3. PRESENT SOLAR THERMAL PLANTS

In case of today's plants working fluids are water & plant pattern is steam turbine based. A circulator pump also uses to circulate water from turbine to reservoir. The pump fed by the turbine. Today's plants based on Ranking Thermodynamic cycle & parts are- solar collector, storage, turbine, condenser & pump. But predicted plant is close cycle gas based plant working on Brayton cycle.

4. Advantages of using Co_2 as working fluid

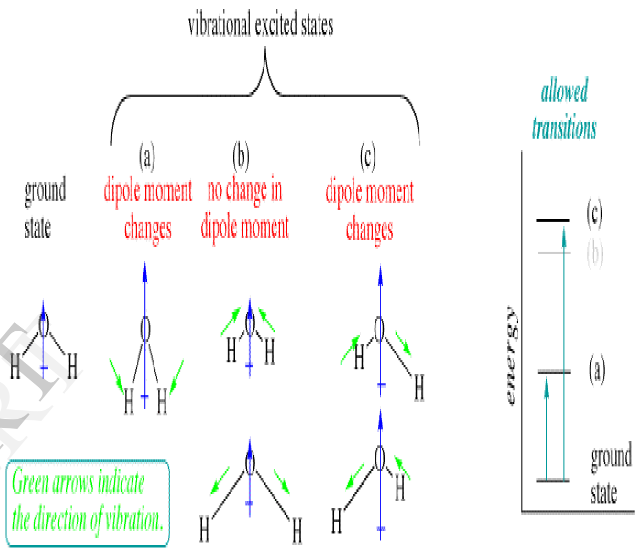

Fig-1

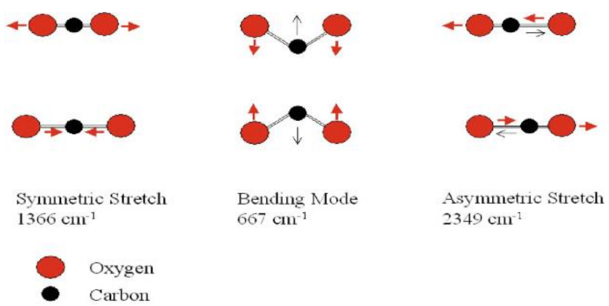

Fig-2

Water molecule has V- shape structure. Any molecule can absorb energy (heat) then dipole moments will change. From fig-1 is clear that there are two changes in dipole moment due to contentious vibration of structure. So water molecule can absorbed heat due to 2 changes in dipole moment. But in case of Co_2 structure is linear. In the fig-1 vibration of Co_2 is given & observed that due to the Co_2 vibration some structures with molecular dipole can produce & vibration of Co_2 molecule is more than H_2O. So Co_2 can absorb more heat than H_2O.

5. COMPARISON OF STEAM & GAS BASED PLANT

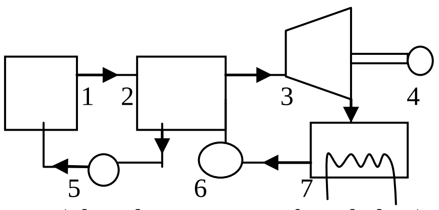

Fig-3(Flow diagram Steam based plant)
(1-Solar heat collector, 2- Boiler, 3- Steam Turbine, 4- Generator, 5 & 6- Pump, 7- Condenser)

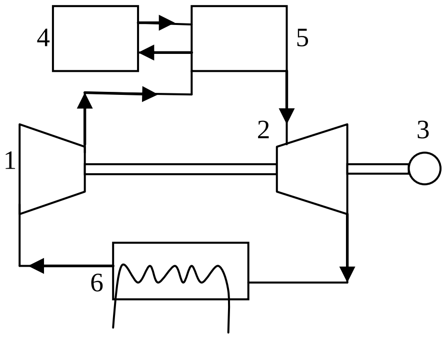

Fig-4(Flow diagram of Gas based Plant)
(1-Compressor, 2- Turbine, 3- Generator, 4- Solar collector, 5- Heating Chamber, 6- Condenser)

In gas based plant gas is compressed before heating. It increases both the pressure & temperature of gas. Then gas is heated in heating chamber. The heated gas expands in turbine & produces shaft power. Then again condense before fed into compressor inlet.

$$Efficiency\ of\ any\ plant = \frac{W_{net}}{Q}$$

$$Q = Heat\ supply.$$

Water takes a remarkable amount of time to convert into steam. But Co_2 can quickly absorbs the heat. So if fix volume of water & gas is employ in two different plants water takes more amount of heat than gas. So for same net work a steam plant will be less efficient. Normally a steam based plant has more thermal efficiency than open cycle gas turbine plant. But in case of close cycle plant gas based plant is more efficient.

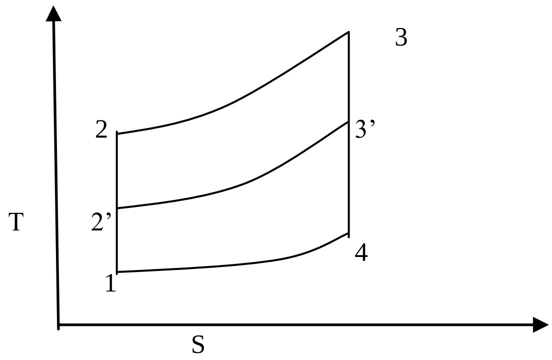

Fig-5

In given T-S (Temperature- Entropy) diagram 1-2'-3'-4 represents steam based cycle & 1-2-3-4 represents gas based cycle.

1-2= compression process in compressor. For per unit mass of gas enthalpy after compression= $C_p(T_2-T_1)$

1-2'= Pumping process of condensed water. Basically enthalpy does not increase in remarkable amount after pumping. Here, enthalpy after pumping= $C_p(T'_2-T_1)$
But in real practice $(T_2-T_1)>>(T'_2-T_1)$

During the heating process Co_2 can absorbs more heat than water/ steam. So $T_3>T'_3$. So maximum cycle temperature is more in case of gas based plant than steam based plant.

3-4= expansion in gas turbine. Work output from gas turbine= $C_p(T_3-T_4)$.

3'-4= expansion in steam turbine. Work output from steam turbine= $C_p(T'_3-T_4)$.

So, work output from gas based plant> steam based plant.
Now, net work of steam based plant=Turbine work- pump work.

$$=C_p[(T'_3-T_4)-(T'_2-T_1)]$$

Net work of gas based plant= $C_p[(T_3-T_4)-(T_2-T_1)]$.

So, net work in gas based plant> steam based plant. We can produce more electricity from GAS BASED.

3. Mechanical advantage
Above mentioned prove is based on thermodynamic aspect. But practically temperature does not increase in remarkable amount after pumping. Negligible or very low temperature will increase. On the other hand pumping of water against gravity required remarkable amount of energy. But in case of gas no external force is require for circulation. If same amount of effort, which is using in pumping of water, is utilized to compress gas, a remarkable temperature of gas can be increased. So for a same pumping & compressing effort a gas based plant is more efficient than steam based plant.

4. Reduction Of Compressor Effort

Compressor effort can reduce keeping the output same by using EPICYCLIC GEAT TRAIN in between turbine & compressor. Because this type of gear train can produce more r.p.m in output shaft than input shaft. So desired output can achieve by utilizing less turbine effort. Therefore net output will increase.

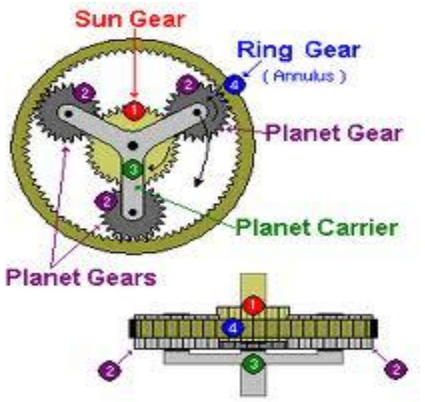

Fig-6

Due to use of this type of gear for fix turbine effort we can more compressor work. But neat work of the plant will remain same. On the other hand turbine inlet temperature will increase due to increase in compressor work. As the turbine inlet temperature increases, the thermal efficiency increases with the other variables being held constant. It is observed that if inlet temperature rapidly increases from lower value the thermal efficiency first increases but after reaching max value it decreases. But for higher values of inlet temperature curves are flatter. So epicyclic train will use to increase the temperature up to optimum limit corresponding to max efficiency & reduce power consumption by compressor so that net work of plant can increase.

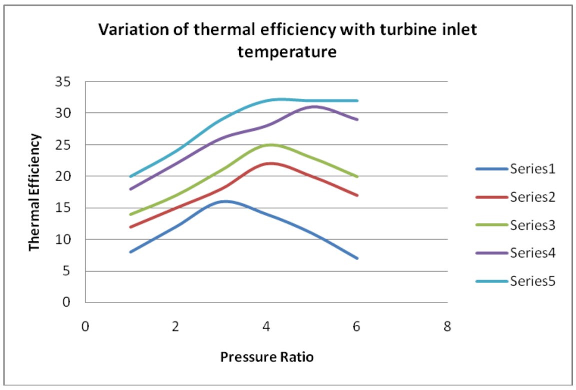

Fig-7(Series 5-320^0 C, Series4-410^{0}C, Series3-500^{0}C, Series2-590^{0}C,Series1-620^{0}C).

5. Effect of reduction on efficiency

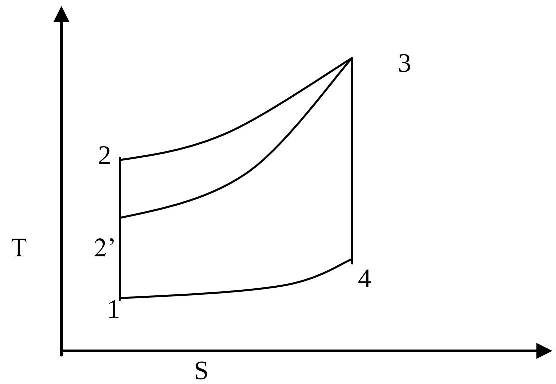

Fig-8

Let, T_2= optimum temperature at compressor exit corresponding to maximum efficiency.

T_1= Compressor inlet temperature.

Work output from compressor (W_{Co})= $C_p(T_2-T_1)$

Work input of compressor (W_{Ci})=$C_P(T'_2-T_1)$

Turbine work output(W_T)= $C_P(T_3-T_4)$

1-2-3-4= Gas turbine cycle without epicyclic gear train in between turbine & compressor.

1-2'-3-4= Gas turbine cycle with epicyclic gear train.

Net work of plant without gear train=$C_P[(T_3-T_4)-(T_2-T_1)]$

Net work with gear train= $C_p[(T_3-T_4)-(T'_2-T_1)]$

So, net work with geat train> net work without gear train.

On the other hand area under T-S diagram represents the total heat absorb/ supply through out the cycle. Here, area under 1-2-3-4 is more than 1-2'-3-4. So heat supply in 1-2-3-4 is more than 1-2'-3-4.

$$Efficiency\ of\ any\ plant = \frac{W_{net}}{Q}$$

Therefore, a plant with Epicyclic Gear Train is more efficient than normal gas based plant with same compressor inlet, turbine inlet & outlet temperature.

6. Advantages of gas based plant over steam based plant

1. No water feed system is required in gas based plants.
2. Less amount of components are there in gas based plant than steam based plant & there is no need of boiler.
3. Lower specific weight & size / KW of power generation.
4. The initial cost & operating cost is lower than steam based power plant.
5. If steam based plant is used as solar thermal plant, it take more time to start. Because water takes more time to absorb heat & convert into steam. But on the other hand carbon dioxide can catch heat faster than water. A steam based solar plant will take 2-3 hours of a day to start but a gas based plant will start faster than it.
6. Maintenance cost is less than a steam based plant.
7. It operates with very low operating pressure.

CONCLUSION

Maximum amount of electrical power is generated in gas, steam & nuclear based plants. But all these plants have harmful impact on environment. So it is very much essential to produce electricity using Renewable Sources of energy. Solar thermal plant has great significance in present stage. But steam based plant takes more time to start due to slow absorption of heat by water. It is proved in this paper that a gas based (carbon dioxide) close cycle plant with Epicyclic Gear Train in between turbine & compressor is used net power & efficiency both will increase than steam based plant with same compressor & turbine inlet temperature.

ACKNOWLEDGEMENT

The authors wish to thank Mss. Ekta Deb (Executive Engineer of OTPC) for her helps & supports in this work.

REFERENCES

1. Shirsendu Das "A cooling system to increase the efficiency of a gas turbine plant" 'International Journal of Engineering Trends & Technology' Vol-4, Issue-7, July-2013.
2. V. Siva Reddy, S.C. Kaushik, K.R. Ranjan, S.K. Tyagi" State-of-the-art of Solar thermal power plant—A review"*"Renewable and Sustainable Energy Reviews*" *Volume 27, November 2013, Pages 258-273*
3. A. Frein, M. Calderoni, M. Motta " Solar thermal plant Integration into an Industrial Process" *Energy Procedi*a' *Volume 48, 2014, Pages 1152-1163.*
4. Sarada Kuravi, Jamie Trahan, D. Yogi Goswami, Muhammad M. Rahman, Elias K. Stefanakos "Thermal energy storage technologies and systems for concentrating Solar power plant" '*Progress in Energy and Combustion Science*' *Volume 39, Issue 4, August 2013, Pages 285-319.*
5. Rocío Bayón, Esther Rojas"Advances function describing the behaviour of thermocline storage tank"*'International Journal of Heat and Mass Transfer*' *Volume 68, January 2014, Pages 641-648.*
6. M.S. Jamel, A. Abd Rahman, A.H. Shamsuddin "Advances in the integration of solar thermal energy with conventional and non-conventional power plant *Renewable and SustainableEnergyReviews, Volume20, April2013, Pages71-81.*