A Review of Solar Powered Steam Piston Engine Technology: Its' Application to Concentrated Solar Power Plants

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Abstract- Solar energy is an incredible resource, but one of its weak points is the affordability and affordable storage options. Almost all the power plant station in the world today uses turbine steam engine to run and turn generator to produce electricity and the most power use to generate electricity is fossil fuels, which emit carbon dioxide and other pollution. More importantly, fossil fuel will eventually run out.

According to the statistics released by World Health Organization (WHO), direct and indirect effects of climate change leads to the death of 160,000 people in a year and the rate is estimated to be doubled by 2020. In order to make the development of our civilization sustainable and cause less harm in the environment, the worlds are looking for new source of substitute clean energy. In order to make this solar energy sustainable, affordable and also environment impact by reducing the noise pollution, solar steam engine has to come in and play a role in the solar power plant, for the production of electricity to be cheap. This research is a review of solar steam engine generator technology and how it can be applied to concentrated solar power plant.

1 INTRODUCTION

Consider the steam engine as an alternative source of powering a generator in a power plans stations. A steam engine is a heat engine that performs mechanical work using steam as its working fluid, In order to generate heat that will create a steam as the working fluid for power plant. Nowadays there are several major directions for solar technology development. E.g. photovoltaic systems, concentrated photovoltaic systems, concentrated solar power. This study will be focusing on using concentrated solar power design to generate heat that will power the steam engine performance. By applying the solar steam engine in a solar power plant station, this generator work by focusing a large surface of sunlight into a smaller area of PV or a thermal receiver of CSP (Concentrated solar power) which are parabolic tough, disc or tower and the energy in the sunlight concentrated, produce vast quantities of heat. This heat is converted into mechanical energy by boiling water in a boiler furnace at a high temperature degree to create a steam which is use to turn the steam engine and the steam engine will power the electric motor or generator that is directly connected to the grid and electricity is produce.

2.0 OVERVIEW OF STEAM ENGINE WITH PARABOLIC TROUGH

Considering the energy demand in world today and its affordability is at high side which makes the accessibility of electricity very low in the world. According to world energy council 2014 update, it was estimated that 1.3 billion people are without access to electricity in the world and 87% of these people live in rural areas [5, 13].

In order to improved the accessibility of electricity in the world through parabolic trough, is by applying old technology of solar energy storage which uses steam piston engine and pressure vessels to accumulate and store the energy for use when the sunlight is down and when the demand is high.

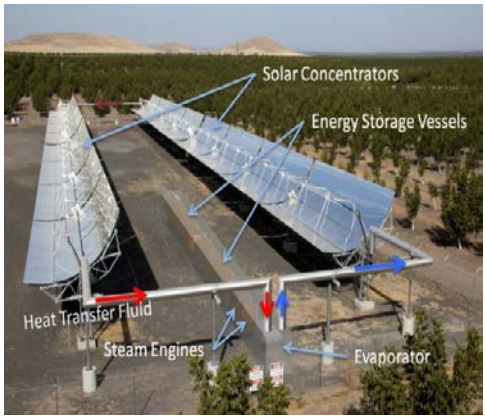

Figure: 1 schematic diagram of a parabolic steam engine power plant with energy storagr vessel [18]

The steam engine is an external combustion engine, [3] which work by separate the working fluid from the combustion products. Non-combustion heat sources such as geothermal energy, solar power or nuclear power energy may be used. The ideal thermodynamic cycle that was used to analyze process is called the Rankine process or rankine cycle. In the process, the fluid or water is heated and transforms into steam within a boiler operating at a high pressure. When expanded through pistons, mechanical work is done. The reduced-

pressure steam is then condensed and pumped back into the boiler.

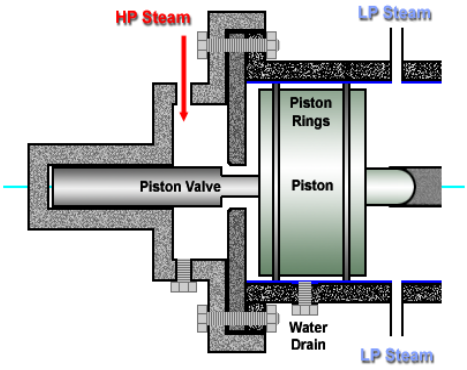

Figure 2: schematic diagram of a piston steam engine [18]

Parabolic tough technology is one of the best technologies and most efficient in concentrate solar power plants in the world. Parabolic trough is a solar collector which is parabolic in shape and straight in one dimension and curve. Considering the solar steam engine for operation with working fluid also know as thermal oil which move through an absorb tube. The heat is use to produce steam in order to run the steam engine

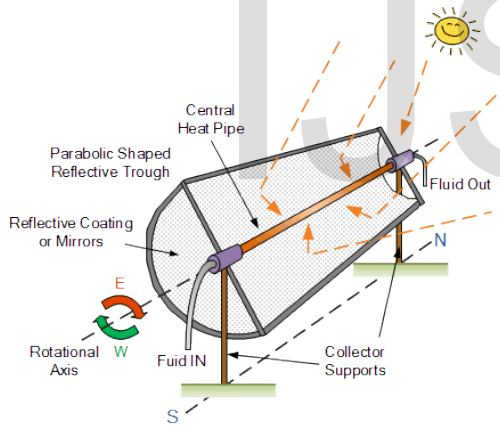

Figure 3: schematic diagram of a parabolic trough [18]

2.1 ADVANTAGE AND DISADVANTAGE OF STEAM ENGINE

- ✓ Steam engine can run in a very low pressure and it can also run in any position like an electric motor
- ✓ Steam engine cost little to build and its lubrication requirement is about zero percentage
- ✓ Steam engine are particular suitable of running power plant station 24 hours a day regardless of location, weather or daylight
- ✓ Steam engine has no construction cost, tower, roof panel and it also have long life with low maintainers
- ✓ It has no backup power require as it for wind and solar system
- ✓ There is no transmission requirement during operation
- ✓ Steam engine has no noise or environment impact associated with steam power
- ✓ One of the disadvantages of steam engine is the efficiency. It is low and steam engine efficiency cannot reach more than 30%. Meaning that 100% steam enters but less than 30% utilized.
- ✓ The other problem is obviously it needs plenty of fossil fuel in order to create steam for the engine. And fossil fuel will deplete soon if they is no alternative.

3.0 BRIEF HISTORY OF STEAM ENGINE

Steam engine has been in existing since years back and using boiling water to produce mechanical motion goes back over 2000 years, although early devices were not practical. The first recorded of steam engine was done in the 1606 by a Spanish inventor; Jerónimo de Ayanz. [15, 16] And In 1698 Thomas Savery produce a steam pump that used steam in direct contact with the water being pumped. And also in 1712 Thomas Newcomen's atmospheric engine was the first commercial true steam engine using a piston, and was used for pumping in a mine, in the same year 1712 [14]. In 1781 James Watt produced continuous rotary motion for a steam engine that. [1, 2] Watt's ten-horsepower engines enabled a wide range of manufacturing machinery to be powered. The stationary steam engine was a key component of the Industrial replacement, allowing factories to locate where water power was unavailable.

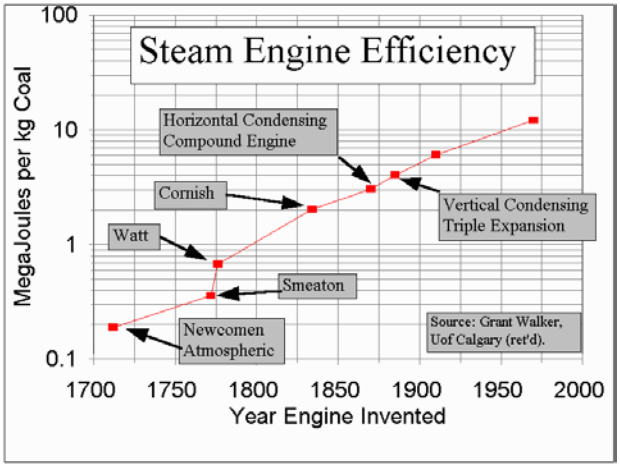

Figure 4: schematic chart of steam engine efficincy and the year invented [18]

Reciprocating piston type steam engines remained the dominant source of power until the early 20th century, when design of electric motors was improved and internal combustion engines gradually resulted in the replacement of reciprocating (piston) steam engines for commercial use, and the dominant of steam turbines in power generation.[4] the majority of worldwide electricity generated are produced by steam turbine engines, the "steam age" is continuing with energy levels far beyond those of the turn of the 19th century.

3.1 EFFICINCY OF STREAM ENGINE

The efficiency of an engine can be calculated by dividing the energy output of mechanical work which the engine produces by the energy input to the engine by the burning of fuel. For the greatest efficiency, steam engines should be operated at the highest steam temperature possible i.e. superheated steam, and distribute the waste heat at the lowest temperature possible. A steam engine drawing steam into the atmosphere will typically have an efficiency (including the boiler) in the range of 1-10%, but with the addition of multiple expansion and a condenser, with a high steam temperature and pressure, it may have a high improvement, within the regime of 10-20%, and very rarely slightly higher and in teams of efficient Carnot cycle is more efficient in heat engine. (That means no heat engine can be more efficient than that of Carnot cycle), in which heat flow from a high temperature reservoir to the low level temperature side and the efficiency depends on the temperature difference. Internal combustion engines are primarily heat engines, in which their theoretical efficiency can be calculated by idealized thermodynamic cycles. The efficiency of a theoretical period cannot exceed that of the Carnot cycle and the efficiency is determine by the difference between the lower and upper operating temperatures of the engine.

Most steel engines have a thermodynamic limit of 37 %. Even when there is turbochargers and stock efficiency assist, most engines retain an average efficiency of about 18 %-20 %[6] Rocket engine efficiencies are much better, up to 70 %, because they operate at very high temperatures and pressures and can have very high expansion ratios.[7] Electric motors are much better, within the range of 85 -90 % efficiency or more, but they work with an external power source (often another heat engine at a power plant subject to similar thermodynamic efficiency limits).

3.2 EFFICINCY OF PARABOLIC TROUGH

A Parabolic trough concentration is about 1/3 of a theoretical maximum for the same angle of acceptance, that is, for the same overall tolerances of the system to all kinds of errors,. The theoretical maximum is better achieved with more elaborate concentrators based on primary/secondary designs using nonimaging optics [8, 9] which may nearly double the concentration of conventional parabolic troughs [10] and are used to improve practical designs such as those with fixed receivers [11] Thermal efficiency ranges from 60-80%. Considering the total efficiency from collector to grid, (i.e. Electrical Output Power) is about 15%, less than Stirling dish concentrators [12].

4.0 COST OF CONSTRUCTION

Cost of designing a piston solar steam engine require low capitail and the operation cost with parabolic trough technololgy also require low maintainers and doesn't require fuel and this is a plus in the operating cost. With storage in the operating system couples concentrated solar with steam engines and an integrated storage system using an insulated pressure vessel to deliver cost-effective solar energy 24 hours a day[17]. According to Terrajoule website, by end of 2015, they will be a system at which a peak watt price of $1.50 to $2.00 per watt will be comparable to the price for a photovoltaic system of the same capacity (depending on a number of variables in each system) [17]. This means that a price of net electrical storage capacity can be less than $100 per kWh, which is just a small amount compare to a battery storage system.

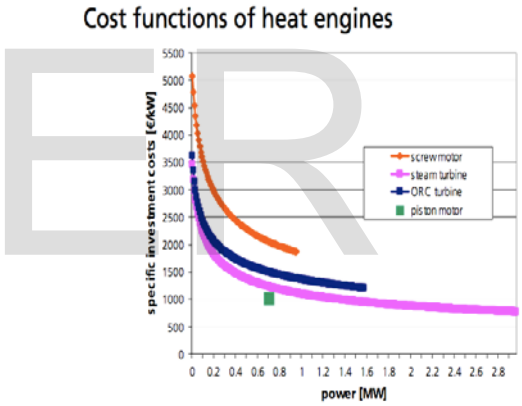

Figure 4: schematic chart of a cost function of heat engine [18]

5.0 Conclusion

In the world today there are many steam engines that are operating but we just have few concentrated solar piston power plant and one of these plant was carry out by Terrajoule clean energy Company. And to make electricity cheap, affordable and accessible in every way in the world is to apply the old technology and development of steam engine (piston) to the solar world.

Finally, solar steam piston engine is very important in generating electricity and to solar power plants operation system, because almost all power plants in the world, uses steam turbine engine as a means of running the generator for the plants. The low efficiency of this technology is a major issue and also a setback for this technology and this has drop it purposely compare to steam turbine engine

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