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Study on Performance Enhancement of Solar Rankine Cooling System

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Abstract: ***Cooling sector is highly dominated by conventional vapour compression system which have negative effect on environment. The solar rankine cooling system which runs on renewable energy and with environmental working fluids. Solar rankine system consists of two cycles, one is power cycle and another is cooling cycle. Power cycle is either solar rankine cycle or organic rankine cycle(ORC) and cooling cycle is vapour cooling cycle(VCC). To optimize the system there are some modification discussed in this paper. Solar heat source are widely available, so solar energy as a heat source for generator is an good option. This paper covers the basic rankine cooling system and modification in rankine cooling system to enhance the performance of system. But this cooling system still needed lots of work and research to make it as an alternative to conventional cooling system.***
Keywords: Organic rankine cycle, vapour cooling cycle, solar energy.

I. INTRODUCTION

Solar rankine cooling system is a basic solar thermo-mechanical cooling system, which takes heat from the solar collector and convert it into mechanical work and this work is used to run vapour compression cycle[1]. Recently, research on solar rankine cooling system getting popularity because of use of working fluid in refrigeration which are environmentally friendly. The primary criteria for solar rankine system is choosing of working fluid[2]. Working fluid should have low cost, toxicity, specific volumes and have high efficiency. Due to introduction of organic rankine cycle, interest in rankine system is developed. With concentrated solar power, the size of thermal storage disposal is reduced.

These configurations are preferable choice because of high performance, reliable, and easy to use and low cost maintenance[3]. But issue regarding the optimum rankine cycle capacity is still open. Conventional method for refrigeration uses chlorofluorocarbons refrigerant which are responsible for ozone depletion. Solar energy can be used in place of refrigerant which causes negative effect on environment.

In solar power, concentrated solar power technology can be used to provide high temperature thermal energy. Parabolic trough collector system is best among concentrated solar power technology because of light weight, lower operating cost and higher efficiency[4]. Rankine solar cooling system is basically divided into two type of cycle, one is separate power and refrigeration cycle in which power generated in expander is used to compress the refrigerant in compressor of conventional vapour compression refrigeration cycle[5].

Other type of cycle used in solar rankine cooling system is using integrated power and refrigeration cycle in which single condenser is used to drive both the cycle. After the proposal of ORC-VCC concept Prigmore and Barber[6] tested the first prototype in which separate power and cooling cycles are used. Bu et al[7] uses both the cycles with same working third and R123 was regarded as good refrigerant for their system. Wang et al[8] used free piston expender compressor to join ORC and VCC system for easy mechanical design and to stop transmission loss. And this system achieved cooling temperature of 0^{o}C with thermal energy as low as 60^{o}C. Nan Zhang et al[9] investigated theoretically solar powered ORC-VCC cooling system working between temperature range -5^{o}C and 50^{o}C, and found suitable working fluid for their system is R600.

Aphornratana and Sriveerakul et al[10] proposed a model for single fluid ORC-VCC system in which single condenser is used between power and refrigeration cycle and called it novel configuration. Pieroban et al.[11] tried to find optional design for multi-objective optimization with genetic algorithm. Liu et al.[12] made waste heat recovery or generic model to avoid over or under expansion.

There are some other studies are done on ORC and VCC with separate cooling and power cycles with different working fluids to find desirable results[13,14,15,16,17]. Some other studies is also done using single working fluid for separate cooling cycles of ORC and VCC and found desirable combination for their system[18,19,20,21].

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II. BASIC SOLAR RANKINE REFRIGERATION CYCLE

Main function of solar rankine cooling system is take heat from solar energy and use it to run the vapour compression cooling system. The solar rankine cooling system is divided into two basic arrangements. In first configuration, there are two separate cycle one power and other for cooling and both are coupled by expander of rankine cycle(ORC) and compressor of vapour compression cycle. In power cycle, Working fluid in generator takes heat from the solar collector and convert into vapour then produce mechanical power in expander and after producing mechanical power vapour leaves the expander and enters condenser(fig 2). The mechanical power produce in expander is utilize by compressor of vapour compression cycle(VCC) to compress refrigerant. The cooling effect id produced in evaporator of vapour compression cycle.

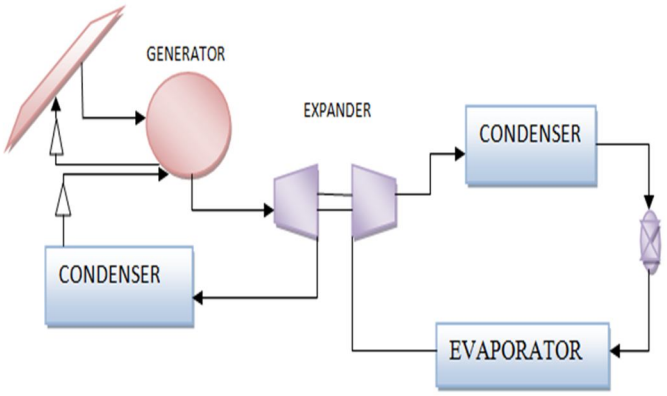

fig 1

The other configuration of rankine cooling system in which single condenser is used in the both the cycle(fig 2). In this configuration, to avoid problem during mixing and leakage problem same working fluid is used in both the cycle[22]. And it also reduces size of setup.

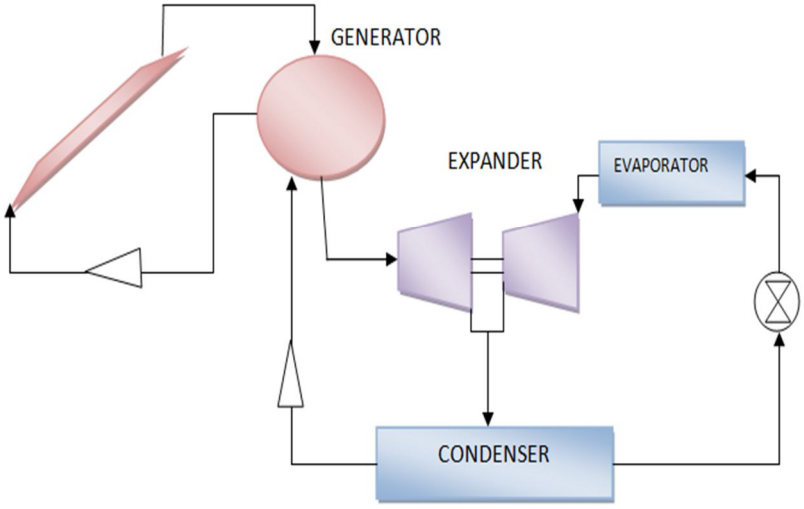

fig 2

III. PERFORMANCE ENHANCEMENT TECHNIQUES

To enhance the performance of solar rankine cooling system, several modification has done on basic rankine cooling system. The main purpose of adjustment is to increase the efficiency of system. The main parameter of rankine cooling cycle is selection of expander. For high boiling point working fluid and for high flow rates, turbine give good performance than positive displacement expander. For low heat source, free piston expander gives better result.

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As shown in fig 3, two cycle are introduced and regenerator is added into rankine cycle to decrease the load of generator. And by increasing the effectiveness of regenerator the C.O.P of system increase[23].

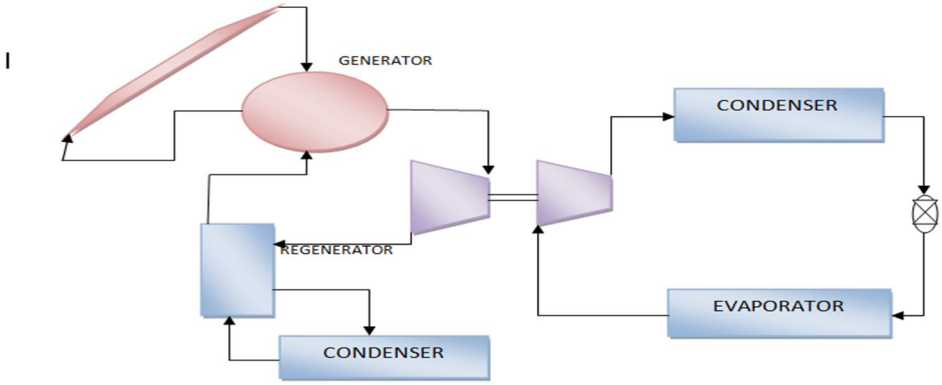

fig 3

A modification in rankine system, as shown in fig 4, which utilize renewable energy, a recuperator is used as a heat exchanger between rankine and vapour compression cycle and both the cycles run on same working fluid[24].

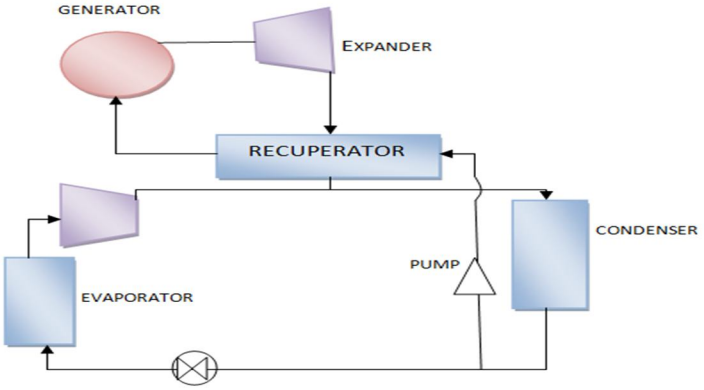

fig 4

Two sets of solar collector in single rankine cycle is shown in fig 5. In this configuration two separate temp achieved by working fluid in solar collector[25]. It consists of two expander, one expander is placed after second collector and second expander is placed is placed for working fluid leaving from first solar first solar collector through heat exchanger.

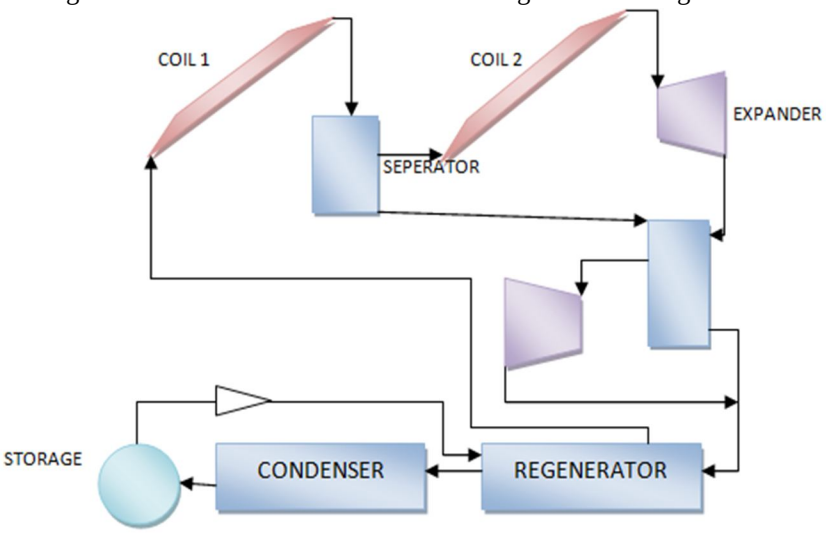

fig 5

Another configuration which consists of economizer, two compressor and two expander as shown in fig 6. This configuration uses single condenser and have high C.O.P but size of setup increases[26].

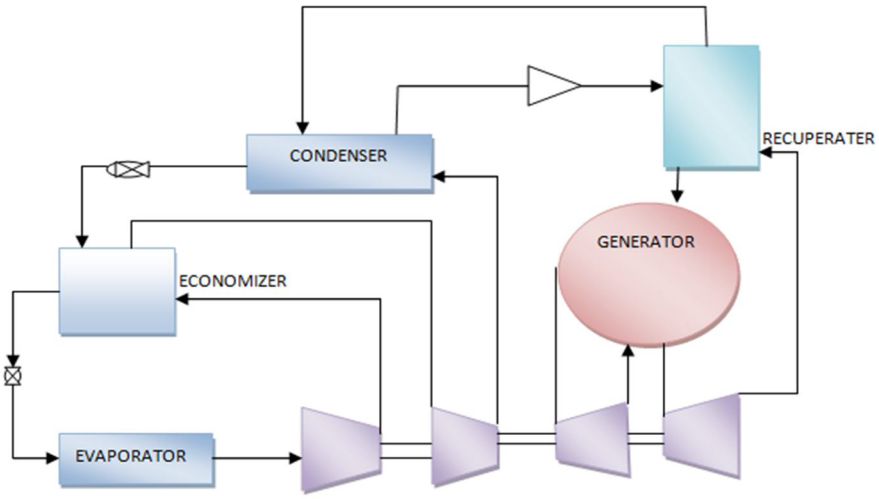

fig 6

IV. CONCLUSION

A system optimization of an solar rankine cooling system is discussed in this paper. Introducing regenerator before generator reduces the generator load. Turbine as a expander gives better results than positive displacement expander. The solar rankine cooling system is an alternative of conventional refrigeration system as it consumes low grade energy and delivers required cooling effect. Using single condenser for both the cycle reduces the size of setup and for that single working fluid is used to run both the cycle. Use of waste energy to heat up the working fluid coming from solar collector can increase the performance of system. optimum rankine cycle capacity is still an open issue.

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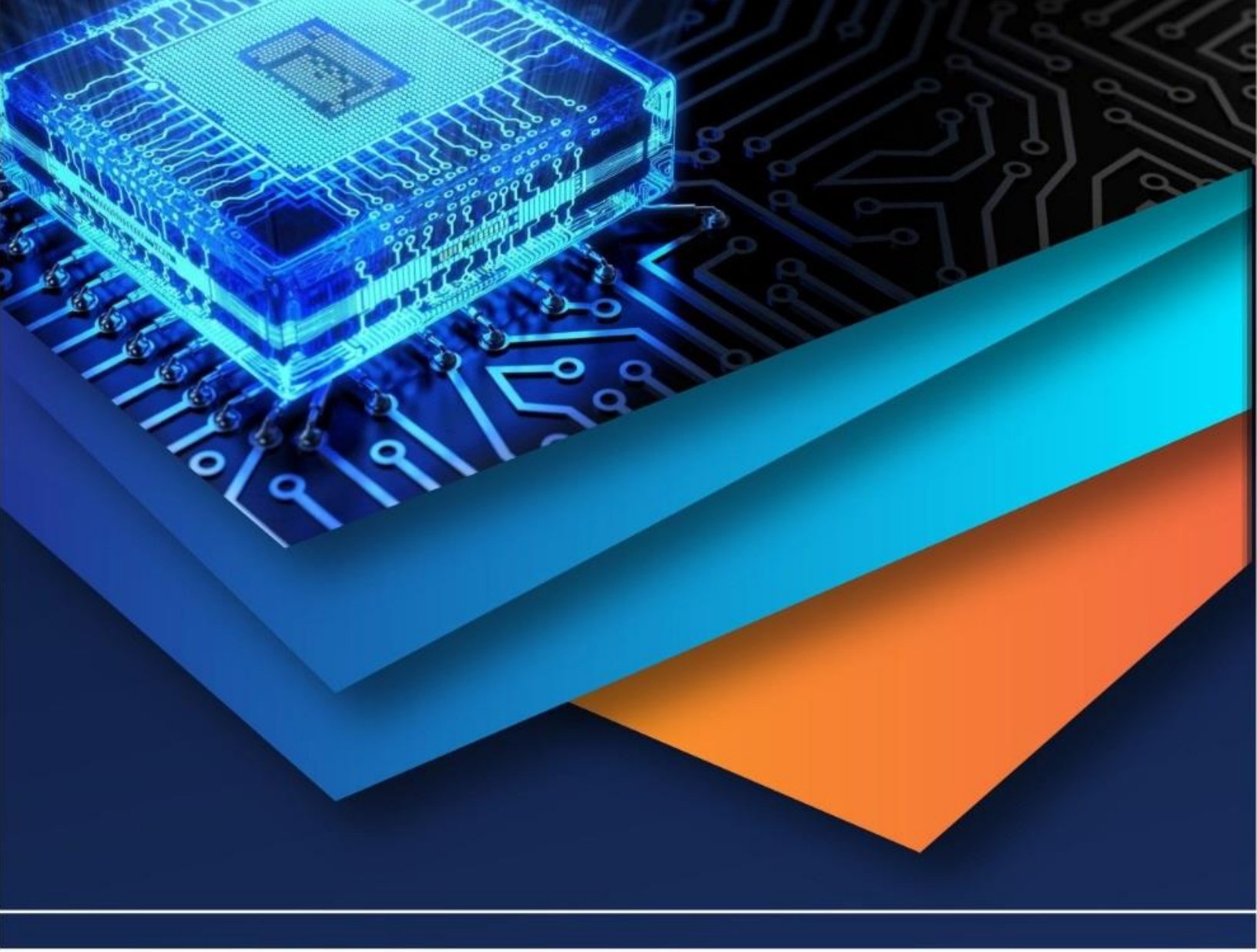

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