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Thermodynamic analysis of ORC based thermal power plant for performance improvement-A review

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Abstract

Nowadays organic Rankine cycle (ORC) become important technology for recovering waste heat, heat from renewable heat source for improving thermal performances. This technology manly used for low temperature and low grade energy resource. The main objective of this review to integrate ORC with different already working thermal power plant such as combined gas-steam power plant, solar integrated combined cycle, solid oxide fuel cell, geothermal, biomass or combination of these (hybrid power plant) plants for using as heat source to ORC. Further comparative performance analysis to be done between two of these cycles and also effect of ORC on already working thermal cycles to be investigated.
Keywords: Organic Rankine Cycle, Thermal power plant, Thermodynamic analysis.

1. Introduction

There are number of solar, biomass, geothermal integrated combined cycles are being used in the entire world and there are many projects are processing. These have several advantages as compared to solar thermal power plants, because these give higher conversion solar efficiency and it have very low investment cost. Many entrepreneurs and owners are ready to invest the many due to it low risk associated with the smaller plants as compared to the solar thermal power plants. Organic fluids are advantageous in comparison to water, when the maximum temperature is low and/or the power plant is small. At low temperatures, organic fluids lead to higher cycle efficiency than water. and organic fluids are preferred in small plants, since fluid mechanics leads to high turbine efficiency also in partial load, which is the main reason to use ORC for biomass application. Another advantage of ORC in small plants is a legal and economic one. Water shows good efficiency at high pressure requiring increased safety measures which are not economically feasible for small plants.

1.1 Organic Rankine cycle (ORC)

Organic Rankine cycles have gotten more consideration amid the most recent decade. This cycle takes after the crucial principles of regular Rankine cycles working with steam in like manner plants however has a few points of interest over steam Rankine cycle which made it prevalent. Firstly this cycle can work on low pressures and temperatures in comparison to the conventional Rankine cycle and reveals a better result than steam Rankine cycle especially from low grade heat sources because it has working fluids include such as variety of HCs and other refrigerants what's more, as per scope of open heat source pressure and temperatures, different outputs can be obtained by using useful working fluids, secondly, it can also work without multi-stage turbines and feed-water heaters and that thing makes it simple. Although this, solar parabolic collectors are a tremendous source of heat energy but these have low grade thermal energy. Because of this, these solar collectors give only some KWs to some mega watts of power generation mainly near factories and rural areas to generate own electricity consumption without the necessity for connection to grid that may be costly. Disadvantages of solar ORCs are comparatively high costs and low thermal efficiency (10 to 25 %according to working fluids and working conditions) mainly because of low HTF (Heat transfer fluids) temperature in solar collector.

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1.2 Working fluids selection for ORC

As described those are before, the organic fluid works in ORC cycles are classified into HCs and refrigerants, some of dry liquids which mean they have a positive slope T-S graph in the immersion vapor area. This makes it reasonable for some organic liquids to works legitimately without superheating to an extraordinary possibility and make no harm turbine. It has been appeared in this review, an examination of various dry organic liquids with or without superheating and recuperations has been done to reveal the difference in cycle effectiveness and execution of the system that encourages us to settle on a choice to pick the system condition as indicated by our requirements. The organic fluids used in ORC can be categorized into three groups of wet, dry and isentropic fluids. The dry fluids have disadvantages of reduction of net work due to superheated vapor at turbine exit and wet fluids of the moisture content at turbine inlet, so isentropic fluids are to be preferred. For demonstration of dry, isentropic and wet organic fluids HFE7000,R123 and Ammonia respectively are shown on TS diagram[71].

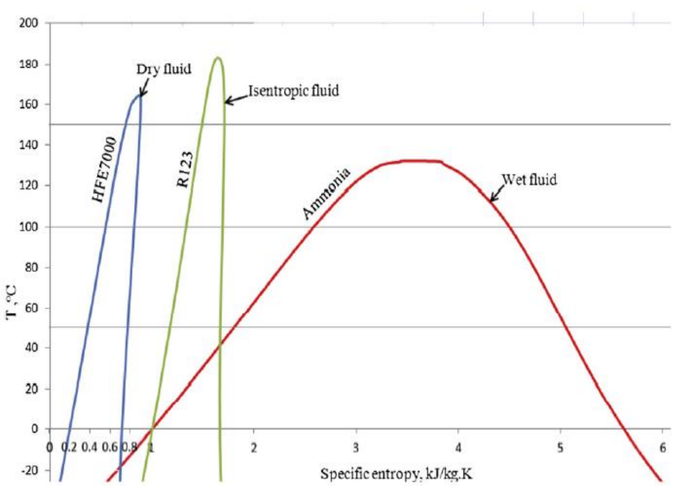

Figure 1: Three types of working fluid dry, isentropic and wet (data from EES)

In this study the main purpose is also selection of working fluid which is give the

- Maximum exergetic and the first law efficiency.
- Low global warming potential and the zero ozone depletion potential.
- And give lower exergy destruction in the each component.

1.3 Soar thermal power cycle based on ORC

This heat source is nothing simple solar parabolic through solar collector (PTSC). From PTSC the heat is taken by the ORC evaporator working fluid is heated in evaporator and converted in to the hot vapor this vapor goes to the expander and this heat energy converted in to the rotation of expander. Instead of the flat plate heat collector there concentrated parabolic heat collector can be used .The economizer works as a heat exchanger which preheats the organic fluid (liquid) to get the temperature to the saturation temperature (boiling point), that liquid to be supplied to a thick-walled boiler drum. That drum is installed where finned evaporator tubes is located that circulate heated organic fluid. The solar radiation incident on to the evaporator tubes and the heat is being absorbed and then the vapor is being created of in the tubes.

1.4 Combined cycle power plant

Combined cycle power plants have as of late gotten significant consideration because of their nearly high energy efficiencies, low poisonous waste and ozone depleting substance releases, and operational suppleness. A typical gas –steam combined cycle power plant is the cycle, which is comprised of a gas cycle (topping cycle) and a steam turbine cycle (bottoming cycle) coupled through a Heat recovery steam generator (HRSG).The utilization of energy is discovered wherever in an assortment of uses from warming and cooling to atomic power plants. For a considerable length of time, the reaction to the constantly developing requirement for electric era limit was to manufacture another steam power plant, one not altogether different from the past one. Other ORC based thermal cycle can be significant effects on power generation and cooling simultaneously with different heat source by recovering waste heat or using heat from the renewable energy source following ORC based combined cycle proposed for utilization maximum renewable heat source.

1.5 Combined cycles gas turbines and two ORCs

Combined cycles proposed comprising recuperated, intercooled and reheat gas turbines and two ORCs (recuperated ICRHGT-ORCs) to recover waste heat from the intercooler and the exhaust of recuperated gas turbine. Three existing gas turbines were performed as the topping cycles with appropriate modifications. Thermodynamic analyses were performed to study the effects of parameters including evaporator temperatures and degrees of superheat at the ORC turbine inlet on the combined cycle performance.[72

1.6 Combined gas turbine, ORC cycle and absorption refrigeration

In this proposed system the after combustion process, produced flue gas expands in the turbine and generates power. Turbine outlet stream still has some high quality energy which could be further used. To recover this energy, a vapor generator is used to produce superheated steam for organic Rankine turbine. The vapor generator constitutes of an economizer, an evaporator and a superheater. After expansion in turbine, turbine outlet stream condenses in condenser and then is pumped again to the vapor generator. Since ORC turbine outlet temperature is high, a recuperator is placed prior to the condenser to boost the efficiency of the plant and reduce the condenser load simultaneously. Further ORC can be added with different configuration with existing system [73].

1.7 The combined ORC and biogas boiler and PTC heating water circuits

The system consists of a biogas boiler system and a simple solar PTC cogeneration, both using the feed water as heat transfer fluid. The biogas boiler heating circuit includes a pump, a boiler and an evaporator. The basic components of ORC system include a pump, an expander, a condenser and an evaporator. The whole system has two independent circuits which have their own heat exchangers, where energy is transferred from the heat source to the working fluid. The pressurized working fluid flows into evaporator and is heated into saturated vapor by the hot water from PTC and biogas boiler .After reaching the maximum evaporation temperature, the saturated vapor will flow into the expander to generate mechanical power.Therefor with the application of ORC with dual heat source performance can be improved [74].

1.8 Combined geothermal driven dual fluid ORC

The main purpose of this system is to produce power from the geothermal water as a heat source. A dual fluid ORC consists of nine different parts: a high pressure evaporator, a high pressure preheated, a low pressure evaporator , a low pressure preheated, a high pressure turbine, a low pressure turbine, a condenser, a high pressure feed pump and a low pressure feed pump. The working fluid of high pressure ORC preheats and enters the at the saturated liquid condition. Having passed the, the working fluid enters the as saturated vapor and the exit flow heats the organic fluid of low pressure ORC. Heated low pressure working fluid flows to the LPT at the saturated vapor condition where it expands and produces power. The expanded working fluid at the LPT enters the condenser and cools down to condenser temperature. exit geothermal fluid preheats the low pressure organic fluid in the high pressure preheater and then heated fluid flows to the low pressure preheater. Therefor by integration of ORC thermal performances can be increased to some extent [75].

1.9 Combined ejector and refrigeration system

The proposed cycle combines the organic Rankine cycle and the ejector refrigeration cycle. It can be used as an independent cycle powered by the low temperature sources, such as solar energy, geothermal energy, or as a bottom cycle of the conventional power plant for the recovery of low temperature waste heat. A program will be developed to calculate the performance of the combined cycle [76].

Ref No		Journal/ Institution	Year	Work Done	Future Scope
[1]	Kelly et al.	Solar energy	2001	demonstrated that the most efficient way for converting solar thermal energy into electricity is to withdraw feed water from the heat recovery steam generator (HRSG)downstream of the last economizer, to produce high pressure saturated steam and to return the steam to the HRSG for superheating and reheating	Regeneration with inter cooling in gas turbine can be done for improvement of efficiencies (exergetic and energetic) and cost analysis can also be done.
[2]	Ling et al	Applied Energy	2012	proposed a model for a typical parabolic trough solar thermal power generation system with Organic Rankine Cycle (PT-SEGS–ORC) was built within the transient energy simulation package TRNSYS. They found that the heat loss of the solar collector increases sharply with the increase in Pinter at beginning and then reaches to an approximately constant value.	Solar heliostats can be used for maximum inlet temperature to the inlet of the gas turbine, for performance improvement
[3]	Gang et al.	Applied Thermal Engineering	2010	proposed the innovative configuration of low temperature solar thermal electricity generation with regenerative Organic Rankine Cycle (ORC) mainly consisting of small concentration ratio compound parabolic concentrators (CPC) and the regenerative ORC. The effects of regenerative cycle on the collector, ORC, and overall electricity efficiency are then analyzed. T	Thermal performance can also be increased by regeneration with solar reheating . in terms of exergetic efficiency, energetic efficiency and power output in orc.
[4]	Manolakos D et al	Applied Thermal Engineering	2013	proposed co-generation system producing electricity and fresh water by a solar field driven supercritical organic Rankine cycle (SORC) coupled with desalination. The proposed system can use parabolic trough solar collectors (among other options) to produce 700 kW thermal energy with temperatures up to 400°C at peak conditions.	Exergoenvironmental (exergy –environment) analysis can be done to know impact of different organic fluids which was taken this work.
[5]	Nafey et al			carried out design and performance analysis using MatLab/SimuLink computational environment. The cycle consists of thermal solar collectors (Flat Plate Solar Collector (FPC), or Parabolic Trough Collector (PTC), or Compound Parabolic Concentrator (CPC)) for heat input, expansion turbine for work output, condenser unit for heat rejection, pump unit, and Reverse Osmosis (RO) unit. the rate of exergy destruction.	Exergoeconomic analysis to done for knowing impact of different inlet condition on cost.
[6]	Sharif et al	Renewable Energy	2010	Carried out thermo-economic analysis of PTSC integrated with an ORC and a multi-effect distillation. Two scenarios of generation were considered in their study: the first one was with only water production and the second one was with both power and water production. The comparison is implemented according to the operation of Parabolic Trough Collector (PTC) with toluene organic oil and water working fluids. Therminol-VP1 Heat Transfer Oil (HTO) is considered for indirect vapor generation operation	For large power production and the large water distillation solar power may be used as a high temperature heat source. and comparison with simple parabolic trough collector may be done.

				across the solar field and evaporator heat exchanger. The comparisons are manipulated according to100 m^3/day of distillate product as a case study. As a result, only desalination technique is considered more attractive than desalination and power technique due to higher gain ratio and lower solar field area needed.	
[7,8]	Torres et al.	Energy conversion	2010	Conducted thermodynamic analysis of thermal system which consists of an ORC, a PTSC, and an RO (Reverse Osmosis). Initially they analyzed the system assuming only water production through RO then they extended their study to include both electrical and water production the main objective of their study was to examine the effect of different organic fluids on the aperture area of the PTSC	Effect of variable irradiation can be seen on power and distilled water production.
[9,10]	Al-Sulaiman et al.	Solar Energy	2012	Proposed the energetic performance analysis of PTSC integrated with an ORC in which the waste heat from the ORC is used for cogeneration was conducted. It was found that there was an energy efficiency improvement, when regenerations was used, from 15% to 94% (utilization efficiency). On the other hand using exergy analysis it is found that there was an exergetic efficiency improvement from 8% to 20% when regenerations is used as compared to only power generation.	Different renewable heat source may be proposed for this working system to use waste heat and these heat can be compared for choosing waste heat source for this system.
[11]	Al-Sulaiman	Energy	2013	carried out solar field sizing and overall performance analysis of different vapor cycles. The systems considered are parabolic trough solar collectors integrated with either a binary vapor cycle or a steam Rankine cycle (SRC). The binary vapor cycle consists of an SRC as a topping cycle and an organic Rankine cycle(ORC) as a bottoming cycle. selection of best working fluids is investigated.	Other ecofriendly working fluids (R12345ze,R245fa R410a etc.) may be considered for bottoming cycle.
[12]	Al-Sulaiman	Applied Energy	2013	Carried out detailed exergy analysis of thermal power system driven by parabolic trough solar collectors (PTSCs). The power is produced using either a steam Rankine cycle (SRC) or a combined cycle, in which the SRC is the topping cycle and an organic Rankine cycle (ORC) is the bottoming cycle.	Fresnel's mirror solar collector may be used for more power production than proposed system. Effect of whether conditions may be considered on performance of system.
[13]	MiladAshouri et al	MDPI Basel Switzerland		carried out analysis of a photovoltaic through collector (PTC) integrated with an organic Rankine cycle (ORC) for small scale electricity generation near Tehran. The system includes a solar field, a storage tank, and a small scale ORC engine. A comparison of different working fluids is presented and results shows that Benzene has the best performance among fluids butane, n-pentane, is pentane, R123 and R245fa for the system conditions described.	Dual cycle organic Rankine cycle may be proposed in this system for more utilization of heat coming out from the condenser of the high temperature cycle.

[14]	Popov	Elsevier LTD	2013	Proposed a concept for innovative hybridization of gas turbine combined cycle plant and solar power system. This conceptual plant is named as Solar Assisted Combined Cycle, as the solar energy is indirectly involved in power generation. The proposed solar hybridization can be accomplished in two ways. The first solar assisted option introduces mechanical chillers for a complete cooling of gas turbine inlet air.	In this proposed system, inlet air cooling may done by integration of organic Rankine cycle or hybrid inlet air cooling may be done (ORC –VARS)
[15]	Wang et al	Solar Energy	2013	Analyzed a 1.6 kW solar ORC using a rolling piston expander. An overall efficiency of 4.2% was obtained with evacuated tube collectors and 3.2% with flat-plate collectors. The difference in terms of efficiency was explained by lower collector efficiency (71% for the evacuated tube vs. 55% for the plate technology) and lower collection temperature	This system may further modified by integration of cascade ORC for power production KW to MW .Efficiency can also be improved.
[16]	Quoilin et al	Solar Energy	2017	Carried out thermodynamic modeling of a proposed small scale PTSC integrated with an ORC for power production, and presented an optimization and sizing procedure of heat exchangers in a small scale solar driven ORC by pinch and pressure drop and optimized, it was found that an overall electrical efficiency between 7% and 8% reached.. The comparison between working fluids showed that the most efficient fluid is Solkatherm. R245fa also shows a good efficiency and has the advantage of requiring much smaller equipment.	Other high temperature heat transfer may be used for improving performance of proposed system. Solar power may used for high power application.
[17]	Madejar et al.	Applied Energy	2017	presents the quasi-steady state simulation of a regenerative organic Rankine cycle (ORC) integrated in a passenger vessel, over a standard round trip. He used experimental data like exhausts temperature, engine speed and electricity demand on board for simulation purpose and to estimate the average net power production of the ship over a round trip. Finally he conclude that The maximum net power production of the ORC during the round trip was estimated to supply approximately 22% of the total power demand on board. The results showed potential for ORC as a solution for the maritime transport sector to accomplish the new and more restrictive regulations on emissions, and to reduce the total fuel consumption	This integrated regenerative ORC system may be used for recovering heat from other vehicle for power production.

[18]	Warren et al.	Journal Of Energy Storage	2017	Proposes enhancement of power generation unit-organic Rankine cycle (ORC) system through the electric energy storage and proposes the use of an electric energy storage (EES) device in conjunction with a PGU-ORC. The idea is to use the energy stored by EES at different times of the day so that continuous operation of the PGU is not required. The potential of the proposed PGU-ORC-EES system is assessed by evaluating the performance in terms of operational cost, primary energy consumption (PEC) and concluded that the potential of a PGU-ORC-EES system to reduce the operational cost,.	Further ORC system may be modified for performance improvement and exergoeconomic analysis can be done for evaluating cost of proposed system.
[19]	Jubori et al.	Applied Energy	2017	[l]proposed Modeling and parametric analysis of small-scale axial and radial outflow turbines for Organic Rankine Cycle applications using a range of organic working fluids (R141b, R245fa, R365mfc, isobutene and n–pentane). And he conclude that the efficiency of axial small scale turbine is better than radial out flow turbine .axial turbine have efficiency 82.5% and power output 15.15kw.and on other hand the efficiency of radial outflow efficiency is 79.05% and power output is 13.625kw with n-pentane as the working fluid in both cases. The maximum cycle thermal efficiency was 11.74% and 10.25% for axial and radial-outflow turbine respectively with n-pentane as the working fluid and a heat source temperature of 87 ^{0}C	In this study low temperature heat source is used but heat source may be used as the high temperature application in proposed ORC system and different working fluids can be selected for proposed system.
[20]	Hsieh et la.	Applied Thermal Engineering	2017	Design and preliminary results of a 20-kW trans critical organic Rankine cycle with a screw expander for low-grade waste heat recovery. they examine a trans critical Rankine cycle with screw expander with R218 as the working fluid in both sub critical and super critical state of working fluid Finally they concluded the efficiency of the expander and the working fluid pump is peak at peak pressure. The output power was not significantly affected by heat source temperature but thermal efficiency slightly decreased by increasing heat source temperatures The present TRC system successfully converted the low-grade heat into approximately 20 kW of power. The thermal efficiency of the TRC system was 5.7%, 5.38%, and 5.28% for the heat source temperatures 90, 95, and 100^{o}C, respectively, with the VFD at 50 Hz.	Toluene may be used for medium temperature 150 ^{0}C -250 ^{0}C heat sources if ORC system is modified

[21]	Junqi et la.	Applied Thermal Engineering	2017	lproposed Experimental investigation on heat transfer characteristics of plat heat exchanger applied in organic Rankine cycle (ORC) .and experimentally study the single phase and boiling heat transfer characteristics' of three types of working fluids on plate types of heat exchangers surface. These three working fluid are water and 50%coolant and R 245fa.and heat transfer dimensionless empirical equations for three types of working fluids are provided. Finally he obtained evaporation heat transfer empirical equation for the organic fluid R245fa is given with the mean absolute error9.97%which prevents 90% data with error less than ±20%.	In this study only three working fluids are considered. There number of working fluids can be investigated for this ORC system.
[22]	Jubori et la	Energy Conversion And Management	2017	Proposed Three dimensional optimization of small-scale axial turbine for low temperature heat source driven organic Rankine cycle Advances in optimization techniques can be used to enhance the performance of turbines in various applications. However, limited work has been reported on using such optimization techniques to develop small-scale turbines for organic Rankine cycles. This paper investigates the use of multi-objective genetic algorithm to optimize the stage geometry of a small-axial subsonic turbine. And he concluded that using working fluid R123 for a turbine with mean diameter of 70 mm, the maximum isentropic efficiency was about 88% and power output of 6.3 kW leading to cycle thermal efficiency of 10.5% showing an enhancement of 14.08% compared to the baseline design	Exergy and economic analysis of modified ORC can be investigated for cost associated with each component of system.
[23]	Michos et al	Energy Conversion And Management	2017	Proposed the backpressure effect of an Organic Rankine Cycle (ORC) evaporator on the exhaust line of a turbocharged, V12 heavy duty diesel engine, for typical marine and power generation applications has been investigated using the commercial software Ricardo WAVE. Three different state-of-the art turbo charging strategies are assessed in order to counterbalance the increased pumping losses of the engine due to the boiler installation: fixed turbine, Waste-Gate (WG) and Variable Geometry Turbine (VGT). At the same time, the And he concluded that engine side point of view, a VGT turbocharger is the most favorable solution to withstand increased backpressure, while, regarding the ORC side, between the considered fluids and layouts, acetone and a recuperated cycle show the most promising performance.	Dual stage ORC system can be integrated in proposed system for improving performance. Inlet heat source can be geothermal energy and exergy analysis can be investigated for exergy destruction .

[24]	Su et al.	Energy Conversion And Management	2017	Developed a performance evaluation model of Organic Rankine Cycle for working fluids based on the group contribution method An Organic Rankine Cycle (ORC) model is presented in his paper to easily, quickly, and inexpensively evaluate the performance potentials of various working fluids The relative errors of thermodynamic properties and cycle parameters are less than 10% for most of working fluids. He concluded that the proposed model can estimate the ORC characteristics of any pure working fluid only based on its molecular structure. Thus, a large amount of working fluids formed by the combination of groups can be directly screened by this model, and the optimal working fluids can be identified for engineering field.	Exergoeconomic and environment analysis may be done for investigating the effects of different working fluids on environment and the cost of working fluids.
[25]	Mago et al	Energy Conversion And Management	2017	Evaluates the potential carbon dioxide emissions reduction from the implementation of electric energy storage to a combined power generation unit and an organic Rankine cycle relative to a conventional system that uses utility gas for heating and utility electricity for electricity needs. Conclusion indicate that carbon dioxide emission reductions from the operation of the proposed system are directly correlated to the ratio of the carbon dioxide emission conversion factor for electricity to that of the fuel. Finally, it is shown that by using carbon emissions cap and trade programs, it is possible to establish a frame of reference to compare operational cost gains with carbon dioxide emission reductions/gains.	Other NOx and Sox emission can also be investigated .And effect of these emission on the environment can also be investigated Emission GHs from the the system can be reduced by integration of solar operated ORC.
[26]	Kim et al.	Energy Conversion And Management	2017	Developed an off-design analysis model for the ORC which is driven by waste heat or residual heat from a combined cycle cogeneration plant. The applied heat sources are the exhaust gas from the heat recovery steam generator (Case 1) and waste heat from a heat storage unit (Case 2). Optimal design points of the ORC were selected based on the design heat source condition of each case. Then, the available ORC power output for each case was predicted using actual long-term plant operation data and a validated off-design analysis model. The ORC capacity of Case 2 was almost two times larger than that of Case 1.	Thermal performance of this combined cycle system can be improved by the integration ORC by applying inlet air cooling or combined with vapor absorption system. Exergoeconomic analysis can be done for investigating cost of per component to decide the electrical cost.
[27]	Rahbar et al.	Energy Conversion And Management	2017	reviewed only organic Rankine cycle for small scale application .Study literature review .Finally find that organic Rankine cycle technology is applicable for small scale experiment.	

[28]	Sun et al.	Energy Conversion And Management	2017	Proposed exergy efficiency analysis of ORC (Organic Rankine Cycle) and ORC based combined cycles driven by low temperature. and did that the ORC system driven by industrial low-temperature waste heat was analyzed and optimized. The impacts of the operational parameters, including evaporation temperature, condensation temperature, and degree of superheat, on the thermodynamic performances of ORC system were conducted. In addition, the ORC-based cycles, combined with the Absorption Refrigeration Cycle (ARC) and the Ejector Refrigeration Cycle (ERC), were investigated to recover waste heat from low temperature flue gas. Finally concluded that The exergy efficiency of both systems decreases with the increase of the evaporation temperature of the ORC..	In this ORC based combined cycle there another ORC can be coupled with it for recovering the waste from coolant from intercooler for improving performance of existing cycle.
[29]	Cao et al.	Energy Conversion And Management	2017	Done Comparative analysis on off-design performance of a gas turbine and ORC combined cycle under different operation approaches having different input variable and results are obtained by using the modified sliding pressure operation (MSPO). He concluded that the sliding pressure operation had an optimal sliding condition to make the GT-ORC combined cycle have the best off-design performance. This condition was a fixed superheat degree of 0.1 K for organic vapor.Therefore, the MSPO might be more suitable for the off-design operation of the GT-ORC combined cycle. Finally, the sensitivity analysis indicated that the MSPO was more favorable for the GT-ORC combined cycle to reduce the influence of ambient temperature.	In this system two or three pressure heat recovery steam generator can be used for the more power production. Analysis can be done for investigating the approach and pinch point.
[30]	Xu et al.	Energy Conversion and Management	2017	proposed the Novel experimental research on the compression process in organic Rankine cycle (ORC).and made A small-scale ORC system is built in the present work to test the performance of a diaphragm pump, and the working fluids of R245fa, R123, R152a and R600a are tested under various conditions. The isentropic efficiencies of diaphragm pump for compressing those working fluids are between 57.22% and 93.51%.Concluded that the Circulating pump is the major power-consuming component in ORC system, but only very few studies are made to study its performance. The working fluids of R245fa, R123, R152a and R600a are used to test the performance of diaphragm pump, and the isentropic efficiencies for compressing different working fluids under various conditions are obtained	ORC driven pump can be used in the system for improving efficiency of the system.

[31]	Chen et al.	Energy conversion and Management	2017	proposed a novel cascade organic Rankine cycle (ORC) system for waste heat recovery of truck diesel engines. confluent cascade expansion ORC (CCE-ORC) system for engine waste heat recovery, which has simpler architecture, a smaller volume and higher efficiency compared with conventional dual-loop ORC systems. He concluded that the there is system proposed for using waste heat from the truck diesel a engine in single loop .this system used only the single working fluid. Working fluid is used is cyclopentane. and it increased thermal efficiency to some extent 45.3% to 49.5%.at minimum specific fuel consumption.	This dual loop ORC system can be used for other heat source for waste heat recovery for better performance. Instead of cyclopentane other ecofriendly working fluid can be used.
[32]	Luo at al·	Applied Energy	2017	developed a mathematical model for designing of liquid surface condenser for organic Rankine cycle. He collected different variables for designing purpose and the modeling equations contains both type of variables discrete and continuous variables .continuous variables contains the length of condenser pressure drop, fluid velocity ,air velocity ,heat transfer coefficient outlet temperature. Finally he concluded that this proposed mathematical model is suitable for low temperature heat sources organic Rankine cycle. And successfully applied for design optimization for liquid surface condenser (LSC).	Similar mathematical model can be developed for the liquid jet condenser for the steam Rankine cycle for high temperature heat source energy.
[33]	Panesar et al.	Applied Energy	2017	l proposed An innovative Organic Rankine Cycle system for integrated cooling and heat recovery to recover exhaust heat and coolant heat a cascade system is employed. This system has two fluid that one of them is the water and second one is R245fa and combine cycle is used for improvement break thermal efficiency almost 1.8%. After doing that research work he concluded that the use of exhaust and coolant heat to be most beneficial across the all engine works .its uses one different amount of heat second one is differ quality of heat it compete the single loop ORC system.	There other ecofriendly refrigerant can be used for bottoming cycle to investigate impact on thermal performances
[34]	Wu et la·	Applied Energy	2017	proposed optimization and financial analysis of an organic Rankine cycle cooling system driven by facade integrated with ORC and VCC..He concluded that façade integrated ETC-ORC-VCC system for a typical office building in a tropical climate was optimized to maximize the electricity savings from the ORC separately. In the financial point of view depends on heat exchanger area but when applied more number of plate it increases the overall cost.	Instead of the vapor compression refrigeration system, there vapor absorption system can be used for cooling purpose.

[35]	Kim et al.	Applied Energy	2017	developed a model of Parametric study and performance evaluation of an organic Rankine cycle (ORC) system using low-grade heat temperatures below 80 ºC. In this model they uses the low grade heat source at 80ºC with cycle power at 10kw undertaken to analyze the performance and efficiency .it uses the R245fa as working fluid for system. Finally he concluded that small scale low grade heat source system efficiency is increased by increasing the heat source temperature and system able to generate 300kw power and 3.6% efficiency. using a heat source at 80c..	Exergoeconomic analysis can also be done for the proposed system to investigate irreversibility and the cost of the each component in order to decide the cost of electricity.
[36]	Ziviani et al.	Applied Energy	2017	Optimizes the performance of small-scale organic Rankine cycle that utilizes a single-screw expander. With this model they used the three off shelf component a liquid receiver. Three plate heat exchanger a multi-stage centrifugal pump and a single-screw compressor adapted to operate as an expander and ORC system is used the 11kw power. They two working fluids first one is R245fa and other one is SES36. He concluded that in the case of SES36 both the expander efficiency and system performance were maximized for a pressure ratio between 7 and 9. In the case of R245fa, while the system efficiency achieved values similar to SES36 but the expander maximum isentropic efficiency was 17% lower.	This similar thermodynamic can be done for the scroll expander and compressor in order to improve the performances.
[37]	Li et al.	Applied Energy	2017	Proposed Performance analysis of organic Rankine cycles using R600/R601a mixtures with liquid-separated condensation. He used working fluid as azotrops R600/R601a . he used liquid separated condenser . Finally concluded that The liquid-separated condensation can increase the average condensation heat transfer coefficient by 23.8% and reduce the condenser heat transfer area by 44.1% compared to the conventional condensation.	Exergy analysis can also be done to investigate the irreversibility of each component.
[38]	Song et al.	Applied Thermal Engineering	2017	Proposed the Performance estimation of Tesla turbine applied in small scale Organic Rankine Cycle (ORC) system the performance of tesla turbine is evaluated with help of different operating conditions and operating parameters .and the model is used to predict the efficiency of tesla turbine for use of small scale organic Rankine cycle. Thermodynamic analysis of the ORC system with different organic working fluids and under various operating conditions is conducted. Finally he concluded that the tesla turbine is effective for small scale organic Rankine cycle because ORC system generate effective power output.	This same system can also be applied for the combined gas turbine cycle for recovering waste heat from the exhaust of the HRSG. And instead of the tesla turbine analysis can also be done for the other turbine for small scale power production.

[39]	Dong et al	Applied Thermal Engineering	2017	Analyzed the supercritical organic Rankine cycle and the Radial Turbine design for high temperature applications. Thermodynamic design of the supercritical organic Rankine cycle (SORC) and the aerodynamic design of its radial turbine for high temperature application And he concluded that The total to static efficiency of the SORC radial turbine is 80.84% at the nominal condition with the pressure ratio of 6.86 and the rotational speed of 23,000 rpm. The proposed radial turbine could effectively handle a relatively large variation of the pressure ratio with slight performance degradation at the nominal rotational speed.	Effect of the varying speed of expander and pressure ratio on system performance can be seen. Best operating speed for this radial expander can be found.
[40]	Hu et al	Applied Thermal Engineering	2017	·Proposed Effects of evaporator superheat on system operation stability of an organic Rankine cycle. He analyzed the effect of evaporator super heat with R245fa as working fluid. The experimental apparatus used in this research is an installed 500W ORC system integrated with a plate evaporator and a shell-and-tube evaporator in parallel results that the super heat at evaporator's outlet is main parameter for system performance and stability of the system. the relationship of the vapor dryness, the entrainment quality fraction, and the superheat was analyzed	In this model only R245fa is used as working fluid further this study may done for different working fluids and then the effect of super heat at outlet of the evaporator can be done. Further comparison between two effect can be done to chose the better option.
[41]	Ustaoglu et al.	Applied Thermal Engineering	2017	In this study, the energetic and exergetic performance analysis of a rotary kiln and cooling section in a cement factory using wet method was carried out based on the actual operational data. The energy and 2nd law efficiencies of the wet type rotary kiln are about 46% and 35%, respectively. The results showed that a great amount of heat energy of 30.5MW is exhausted from the chimney of rotary kiln. In order to evaluate recovery capacity of exhausted gas, Organic Rankine Cycle was considered and its energetic and exergetic performance were evaluated for isentropic and dry type fluids for different conditions. Isentropic fluid. He concluded that the R245a gives better performance than other dry fluid R600a. The exergy destruction rates in heat exchanger and evaporator are about 80% of the total exergy destruction	Further exergoeconomic analysis can also be done in order to decide the cost of electricity.
[42]	Wang et al.	Applied Thermal Engineering	2017	Multi-objective optimization and grey relational analysis on configurations of organic Rankine cycle Concerning the comprehensive performance of organic Rankine cycle (ORC), comparisons and optimizations on 3 different configurations of ORC (basic, regenerative and extractive ORCs) are investigated and different operating conditions are used as input parameter. He concluded that best organic Rankine cycle performs well another than three system in	In this proposed ORC system further working fluid selection may be carried out in order to choose the best working fluid for the deferent heat source temperature application.

				terms of thermodynamic and economic performance using R245fa as working fluid	
[43]	Zhonglu He et al.	Applied Thermal Engineering	2017	proposed the Thermodynamic analysis of a low temperature organic Rankine cycle power plant operating at off-design conditions. He used the screw expander and simulation is ny different working fluids This work was purposed to assess the ORC system and get the performance map at off-design operating conditions in a typical year from the view of the first and the second law of thermodynamics.	Further thermal performance can be improved by integration of ORC as a another low temperature cycle.
[44]	Yang et al.	Applied Thermal Engineering	2017	Proposed the Experimental investigation on a 3 kW organic Rankine cycle for low grade waste heat under different operation parameters. In this 3kw organic Rankine cycle is used having R245fa as working fluid. And the expander is used is the hermetic type. The effects of pressure drop, degree of superheating and condenser temperature on system overall performance are examined. He concluded that pressure drop is high impact system efficiency power output. Pressure drop in condenser have more impact on electrical power and the thermal efficiency of ORC system.	Further Exergoeconomic analysis can also be done in order to see the cost associated with each component. Also different working fluid may be select in different range of the temperature application.
[45]	Kaviri et al.	Energy Conversion And Management	2013	From the point of view of optimization methodology, there are many types of analyses. In this work, the review will highlight most common methodology: the exergy destruction method, and the efficiency improvement method.	Exergoenviroment analysis can also be done in order to investigate the impact on environment.
[46]	B.J Huang et al	International Journal of Refrigeration	2001	Proposed a combined cycle refrigeration system (CCRS) that comprises conventional refrigeration and air-conditioning system using mechanical compressor (RAC/MC) and an ejector cooling system (EJC).	Exergy analysis can also be done and simultaneously find the losses in components due to irreversibility.
[47]	E. Mincius et al	Applied Thermal Engineering	2003	Proposed combined power plants based on gas turbine or internal combustion engine with absorption chilling machine. A thermodynamic analysis has been performed for the case of this system with an absorption chilling machine.	There are some others Environmental friendly refrigerants which can also be used for such a system.
[48]	J. Herna et al	Applied Energy	2003	Proposed new processes focused towards a more efficient use of energy, is nowadays highly desirable. In this paper, the design of a system of tri--generation is presented as an alternative way of improved energy use in cogeneration systems.	The heat leaving the compressor can be utilized for power production as well as heating purposes.
[49]	E.T. Calva et al	Applied Thermal Engineering	2005	Focuses on tri-generation schemes where a gas turbine is used as a prime mover for power production and cooling is generated by a typical compression–refrigeration system.	Combined cycle efficiency can be improved by ORC for inlet air cooling decreasing exergy losses and effect of recompression is important from the research point of view.

[50]	Ahmad Oudha et al	International Journal of Exergy	2005	Calculated components exergetic loses by operating at constant evaporating temperature of -30^{0}C and condensation temperatures of 30^{0}C, 40^{0}C, 50^{0}C and 60^{0}C with two natural substitutes of HCFC22, namely propane (R-290) and ammonia (R-717) as working fluids.	Performance of such a vapor absorption refrigeration system can be enhanced by ORC Also optimizing design characteristics and fluids inlet conditions and temperature.
[51]	Akhlesh Arora et al	International Journal of Refrigeration	2008	Proposed a detailed exergy analysis of an actual vapor compression refrigeration (VCR) cycle. A computational model was developed for computing coefficient of performance (COP), exergy destruction, exergetic efficiency and efficiency defects for R-502, R-404A, and R-507A.	There are some other important factors that may be analyzed i.e. temperature, pressure, refrigerants used, and effectiveness for such a system.
[52]	Yinghai Xie et al	International Journal of Refrigeration and Air-Conditioning,	2008	presented a performance study on a low-temperature absorption–compression cascade refrigeration system (LACRS), In the system, low-grade heat of AS is used to sub- cool the CS, which can obtain cold energy at −100 °C.	Effect of inlet pressure of the fluid on the performance also an important operating parameter, which is used to analyze the optimum working pressure range.
[53]	A. Lazzarettoa.	Energy	2008	Proposed a systematic and general methodology for defining and calculating exergetic efficiencies and exergy related costs in thermal systems. Thus, a direct link between the definitions of fuel and product for a component and the corresponding costing equations is established.	Exergy destruction is mainly due to heat exchanger and evaporator. Therefore performance is majorly dependent upon the design conditions under which all these components show better exergy performance.
[54]	Wang. Y et al	Applied Energy	2008	Proposed a combined power and refrigeration cycle which combines the Rankine cycle and the absorption refrigeration cycle. This combined cycle uses a binary ammonia–water mixture as the working fluid and produces both power output and refrigeration output simultaneously with only one heat source.	Exergoeconomic analysis and optimization can also be performed for such a system.
[55]	R.Yapicia	International Journal of Refrigeration	2008	Studied the performance of the ejector refrigeration system using ejectors with cylindrical mixing chamber at operating conditions with choking in the mixing chamber. The performance of the constructed system is determined by using six configurations of ejector and R-123 as working fluid in the system.	Volume concentration and mass flow rate at which refrigerants are flowing through the absorber and generator has an ability to alter the performance of the cascading refrigeration system. Also cascading ORC can be done with this system.
[56]	Y. Dai et al	Applied Thermal Engineering	2009	Proposed a new combined power and refrigeration cycle, which combines the Rankine cycle and the ejector refrigeration cycle. The results show that the biggest exergy loss due to the irreversibility occurs in heat addition processes, and the ejector causes the next largest exergy loss.	How much extent exergy related cost techniques affects to efficiency of such a thermal system.
[57]	J. Wang et al	International Journal of Refrigeration	2009	Proposed a new combined power and refrigeration cycle for the cogeneration, which combines the Rankine cycle and the ejector refrigeration cycle by adding an extraction turbine between heat recovery vapor generator (HRVG) and ejector.	Supercritical ORC has a potential to generate the more electricity than subcritical ORC.

[58]	U. Dai et al	Applied Thermal Engineering	2009	Proposed a new combined power and refrigeration cycle, which combines the Rankine cycle and the ejector refrigeration cycle. This combined cycle produces both power output and refrigeration output simultaneously.	Exergy analysis and advance exergy analysis may be performed. Find out which component having the largest exergetic loss due to irreversibility.
[59]	I. Chaer et al	Applied Energy	2009	Proposed a triple cycle combined system was set up in the laboratory to investigate the system performance and application feasibility. The rig was composed of three modules, a power component containing a micro turbine, a refrigeration unit consisting of an absorption chiller with gas pipe connection, and a supermarket section containing a display cabinet.	Supercritical ORC has a potential to works on comparatively lower temperature than that of Rankine cycle.
[60]	A. Khaliq et al	International Journal of Refrigeration	2009	Proposed a conceptual combined gas and steam cycle system is proposed based on the conventional gas turbine cycle for the high temperature heat addition while adopting the heat recovery steam generator for process heat and vapor absorption refrigeration for the cold production.	With integrated ORC exergy(specially chemical exergy) and environ performance of this system can be done in order to calculate best combustion fuel.
[61]	F.A. Al-Sulaiman et al	International Journal of Hydrogen Energy	2010	Studied energy analysis of a tri-generation plant based on solid oxide fuel cell (SOFC) and organic Rankine cycle (ORC) is conducted. The physical and thermodynamic elements of the plant include an SOFC, an ORC, a heat exchanger for the heating process and a single-effect absorption chiller for cooling.	ORC with dual stage can be used in order to investigate the
[62]	R.P Marquesa et al	Energy and Buildings	2010	Proposed a novel heat power and refrigeration system for application of energy technologies which simultaneously produces heat, refrigeration and electricity. An expression for the calculation of the thermodynamic performance of this system is presented.	There are some others working fluids may be used that can have comparatively lesser exergetic loss through an ejector. Ejector can also be driven by modified ORC.
[63]	K.C. Kavvadias et al	Energy Conversion and Management	2010	Focuses on the problem of optimal design of CHP system plants and discusses the factors that affect the operation and the feasibility of investment. The effect of various operation parameters and energy tariffs structures are studied	Parabolic trough collector can be integrated to organic Rankine cycle(ORC) to generate power to drive desalination process and study can extend up to the evaluation of performance optimized in this combination by the different fluids.
[64]	B. Zheng et al	Solar Energy	2010	Proposed a cycle combines the organic Rankine cycle and the ejector refrigeration cycle. The ejector is driven by the exhausts from the turbine to produce power and refrigeration simultaneously.	Results can be optimized by using water intercooler and flash chamber incorporating with such an existing cycle. In addition thermo economic analysis can be used to find out the cost comes to produce the cooling effect.
[65]	H. Vidal	Applied Thermal Engineering	2010	Performed a double stage solar ejector cooling cycle is using the TRNSYS-EES simulation tool and the typical meteorological year file containing the weather data of Florianopolis, Brazil.	There are some other refrigerants like R152a, R-717, R-1234yf, R-507a may be effectively used and produces higher COP.

[66]	Alireza Javanshir et al	Energy	2018	Thermodynamic analysis and optimization of the power block of concentrated solar power (CSP) plants. Single and combined power cycles such as regenerative steam Rankine cycle with reheat (RSRC), organic Rankine cycle (ORC), combined Rankine/ORC cycle, regenerative Brayton cycle (RBC), regenerative Brayton cycle with recompression (RBCR), and combined Brayton/ORC cycle were compared.	Further in this cycle another regenrative Brayton cycle integrated with ORC can be compared with exiting Six power cycle.
[67]	Meeta Sharma et al	Journal Of Ambient Energy	2018	In the present study, a dual-pressure heat recovery steam generator (HRSG) used in a gas/steam combined cycle power plant is investigated. This paper presents exergy and economic analysis of a dual-pressure HRSG	In this proposed system ORC can be integrated in order to improve the thermal performance.
[68]	Alok K. Mahapatra et al	Applied thermal Engineering	2018	perform an exergetic evaluation of a gas-steam combined cycle power utility that is integrated with vapor absorption inlet air cooling system. Effect of several thermodynamic parameters on component-level and total exergy destruction are discussed.	Inlet air cooling for the proposed gas combined cycle can done by taking heat from intercooler Through ORC and result can be compared with existing system.
[69]	N.H Mohd Idrus et al	Renewable Energy	2018	Proposed a new Rankine power cycle utilizing a combination of ocean thermal energy and geothermal waste Energy is proposed and thus called a GeOTEC (Geo-Ocean Thermal Energy Conversion) power cycle/plant. The potential geothermal waste heat, which exists in the form of raw hot natural gas is continuously pumped from a shallow water Malaysia-Thailand Joint Authority (MTJA) gas production platform, and the supply data is estimated based on the output of the platform.	This combined OTEC and geothermal energy can be used as heat source to the small scale power production by ORC.
[70]	Guoquan Qiu et al	Energy Conversion And Management	2018	Proposed this work is to present a hybrid Organic Rankine Cycle (ORC) driven by solar energy and waste heat. Parabolic trough collectors coupled to a storage tank feed the heat recovery system which also utilizes waste heat of low-grade temperature (150 °C – 300 °C). Four different working fluids (toluene, cyclohexane, MDM and n-pentane) are examined in the regenerative ORC	This ORC can also be hybridized by the solar and waste heat from exhaust engines for improving performance

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