Optimized Design of Diesel Generators Based Chilled Water Cooling System for Intelligent Hospitals and Hotels

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Abstract*: For the intelligent applications like Hotels and Hospitals, there is requirement of efficient chilled water system in terms of energy consumption reduction, cost minimization, reduction in Carbon Dioxide (CO_2) emissions. As the loads in hotels and applications increases, the performances of water cooling systems becomes the worst that leads to excessive consumption of energy and emission of CO_2, thus it needs the efficient load management strategies as well. In this paper, we first analysed the challenges of energy and CO_2 efficiency of water cooling system in the intelligent hospitals and hotels from systematic point of view and then introduced the effective scheduling strategies for both hotel and hospitals. Further, the key focus in this paper is to design water cooling system using the diesel generators by considering the real time applications hospitals and hotels. Since the coolant temperature is having the significant effects on the performance of cooling engine and the CO_2 emissions, therefore we introduced the diesel generators with coolant system to investigate such effects. For the cold water supply load management, we designed the Particle Swarm Optimization (PSO) based scheduling strategy at last. This paper exhibits the plan and its simulation results that analysed in terms of ESR (Energy Saving Ratio), CSR (Cost Saving Ratio), and CRR (Carbon dioxide Reduction Ratio) for the Internal Combustion Engine (ICE) capacity on heating and cooling systems.

Keywords: Energy consumption, chilled water system, carbon dioxide, cooling, heating, diesel, temperature, radiator.

I. INTRODUCTION

Since from the last two decades, the intelligent hospitals and hotels were the result of high advancements in the 21th century. It is a reconciliation system of data innovation, programmed control, ergonomics, management, engineering, and so on. As we probably aware, the power use of structures is around 1/3 of the firm energy utilizes in a nation [1]. The expense of movement and the leading body of dexterous structures can be decreased clearly in light of the fact that it is conceivable to monitor and control the offices of a shrewd structure naturally. There are climate control systems as well as water cooling systems in any cutting edge structures [2], which can make the earth progressively agreeable and increasingly effective for individual's living and working. Such systems are usually called as HVAC technology. The Warming, ventilation, and cooling (air conditioning) is the innovation of indoor and vehicular natural solace. It will probably give thermal solace and adequate indoor air quality. Air conditioning system configuration is a sub discipline of mechanical engineering, in view of the standards of thermodynamics, liquid mechanics and warmth move [3]. Some of the time "Refrigeration" is added to the field's condensing, as HVAC&R or HVACR or "ventilation" is dropped, as in HACR (as in the assignment of HACR-appraised circuit breakers). HVACR is a significant piece of private structures. For example, single family homes, condo structures, inns and senior living offices, medium to enormous mechanical and business places like high rises and emergency clinics and vehicles like auto, trains, submarines etc. The power utilization of HVACR is about over half of the complete power utilization in hotels and hospitals as well as it lead to CO_2 emission [4]. The water cooling system is one of the integral parts of HVACR technology which is widely used in intelligent buildings like hospitals and hotels. Thus the design of water cooling system for hotels and hospitals is having the impact of CO_2 emissions and higher energy consumption which leads the increased costs. On the other side it is an accepted fact that modern energy carriers are essential for human development and prosperity and fossil fuels have played an important role in shaping modern society [5]. But the depletion of these fossil reserves has now emerged as a challenge to entire humanity from environmental as well as energy security perspective. Ongoing assessment from the Intergovernmental Panel on Climate Change brings forth ample evidence of adverse impact of indiscriminate fossil energy use [6] [7]. Energy security that is energy access to communities and nations at affordable price is at risk as never before. Increasing prices of coal, oil and natural gas in spite of extensive exploration efforts has raised legitimate concerns as regards their availability in near future. Denial of this energy access may mean adverse impact on poverty reduction efforts. At national level, this might mean increasing fiscal deficit to finance energy bill for energy importing nations. It is therefore in researcher's interest to use the fossil fuel resources wisely in applications like chilled water systems [8].

Fossil diesel is broadly utilized in an assortment of uses, including transportation, joined warmth and power age, industry and water system. Thus, it is an enormous supporter of worldwide ozone depleting substance emissions and along these lines there is need to locate a practical elective fuel. Usage of bio fuels as an optional gas

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have been around 1850's, and early automobiles, for instance, the 'Area Model T' become from the start needed to hold running on ethanol. Nevertheless, pursuits inside the bio fuels enterprise commenced to ascend after two universal wars and the oil emergency at some point of the past due 1900's. The use of high-quality bio fuels has been researched, as there would be prolonged fees inside the sustenance enterprise, in particular in making international locations [5]. Sensible 2nd length bio fuels conveyed from non-sustenance substances may be applied as a decisions in place of diesel within the Weight Start (CI) engines; engine execution what is extra, fumes unfold results changed depending on the form of bio fuels and engines used. Bio fuels could alter about eighty% of the closeness cycle ozone hurting substance discharges by way of overriding fossil diesel use in within expending engines [6]. Engine modifications, as an example, development of weight volume, injector geometry, chamber and chamber materials, and twofold fuelling structures are bolstered for adjusting waste chose pyrolysis oils use in the engines. Several other research works reported that investigate the bio fuels performances, however there is single study that presents the investigation of fossil diesel based water cooling system for the efficient energy management, cost management and CO_2 emissions by considering the hotels and hospitals load.

In this paper, we concentrated on the plan of diesel liquid based water cooling system by considering the applications of hotels and hospitals. We believe that use of Diesel Generators (DGs) on a very basic level work into the similar at small load far from their best productivity focuses [9]. We proposed the integrated process control scheme that improves the energy efficiency and reduced CO_2 emissions for chilled water cooling system with affordable costs. We design and analyse the water cooling engine model with respect to the key parameters such as ESR, CSR, and CRR for both cooling and heating systems. In section II, the brief review of related works in cooling systems and their optimizations has been done. In section III, the overview of water cooling system, its requirements, design and components with present solution has been presented. In section IV, the methods and materials are discussed. In segment V, re-enactment results are introduced. In area VI, conclusion and future work is discussed.

II. RELATED WORK

Earlier many strategies introduced for the design of water cooling systems and their effects on performances. Since from last decade some systematic studies presented that design and analyze the effects of water cooling systems. This section presents the review of such methods reported in last decade.

In [10], the setup approach for a fluid cooling framework proposed. They deliberate the fluid cooling framework making use of the micro channel heat sink, fluid siphon, and warmth rejecter for PC packages with high CPU manipulate. In [11] model-primarily based eager control (MPC) technique to building cooling structures with heat imperativeness accumulating exhibited. Makers focused on the structures top geared up with a water tank used for viably looking after cool water conveyed by a headway of chillers. They at ease up models of chillers, cooling towers, warm tanks, and systems were made and encouraged from the start, and afterward chilling gadget interest is proposed making use of MPC to ideally save the nice and cosy imperativeness within the tank by using smart facts of structure loads and cools. In [12], the examination on dynamic water cooling framework presented. They in the beginning processed the setbacks of the twists and compensating defend utilising electromagnetic research, at that point temporary three-D obliged fragment warm assessment became accomplished for each the stator and rotor. Finally a working cooling framework has been organized and re-ordered for offsetting the sultriest spot temperature of the turns at a given degree. In [13], creators offered the enhancement of a solitary level brushless DC engine (BLDCM) via substituting a commercial enterprise single-stage BLDCM for siphon software that allows you to acceptably enhance its productivity with appreciate to the important execution of an engine for siphon frameworks. They applied the Genetic Algorithm (GA) for enhancement procedure in water cooling framework.

In [14], some other investigation the cooling framework was offered. They dependent the 3-D multi-cloth technological know-how computational version for a creamer questioning photovoltaic/heat (HCPV/T) water professional. The gatherer includes a sun fuelled concentrator, forty silicon cells related in plan, and a multichannel fluid cooling shape with warmth healing limit. In [15], as of late warm investigation of the Integrated Gate-Commutated Thrusters (IGCTs) water-cooled warm temperature sink for the SSCB surveyed for the cadenced improvement of 7.Five kA depicted. They offered the 2 plans of the IGCT water-cooled warmth sink dependent on S-type fluid chamber and the Archimedes winding fluid chamber for the SSCB for the steadfast idea of the paralleled affiliation IGCTs.

Further we reviewed some optimization based approach for the water cooling systems in [16]-[24]. In [16], the conventional approach for the direct water cooling system presented, however many shortcomings reported with this approach.

In [17], author proposed the improved genetic algorithm to optimize scheduling scheme to address the load management and efficient of water cooling system. The calculation results demonstrate that the structure energy utilization can be diminished by about 7.4 %. In [18], effect of coolant system on fuel consumption rate is studied to enhance the thermal efficiency of gasoline engines. They tried to control the cooling water flow in order to find the optimized flow system in cold start condition. In [19], optimized Component Cooling Water System design proposed which meets the system prerequisites and flawlessly moves the warmth created in Tokomak, segments of associate & supporting structures to HRS. They depicted the difficulties experienced during the fundamental structure and portray the development of a suitable improved HRS plan

arrangement which is fit for dismissing the warmth to the air and keeping up the bowl temperature inside endorsed limit.

In [20], author used the concentrator photovoltaic's (CPVs) to sort out the extraction of light vitality and warm vitality. They proposed the water cooling framework which gives compelling cooling by flowing virus water to remove heat in the photovoltaics. In [21], author focused on easy to use enhancement apparatus for direct water cooling game-plan of a ground-breaking module which is starting cooling structure maker to see the upgraded arrangement relying upon client burden profiles and accessible pump power. In [22], recent work that proposed optimized plan strategy for ship ocean water cooling framework can comprehend energy-saving and emanation decline. By considering the water temperature and thermal load, they introduced optimized design. In [23], customary water tower streamlining plan enhancement for the present utilized cooling tower is a sort of advancement proposed, which is additional items in the present structure. In [24], another recent optimization based approach for the central cooling system proposed. In [25], author focused on the impact of various cooling frameworks and working parameters of the SI motor on their motor execution and discharge properties. A working coolant control (ACC) similarly as of motor warm administration has been perceived utilizing a variable-speed electrical pump, and a variable-position savvy valve which is managing liquid stream rate scattering between radiator & its reroute line to all the more likely direct heat dismissal.

In [26], authors recently investigated the impacts of cooling water temperature and vapour transmission properties of a CI motor worked with bio fuel mix. They made the Jatropha-alcohol mixes and physical and concoction properties of these mixes were estimated. The properties were broke down and thought about against one another, with diesel as the benchmark.

All above works mainly focused on the design and analysis of cooling systems for the water in many ways. There were some optimization techniques also introduced to effectively management loads in intelligent buildings so that energy consumption, CO_2 emissions, and cost reduction is achieved. The work present in this paper is differing from above cases as we mainly focused on designing the diesel generator based water cooling system and its analysis in terms of energy efficiency, CO_2 emission, and cost factors.

III. WATER COOLING DESIGN

In general any cooling system provided in ICE due the reasons like:

1. The temperature of the debilitating gases in the motor chamber comes to up to 1500 to 2000°C, which is over the solidifying clarification behind the material of the chamber body and pioneer of the motor. (Platinum, a metal which has one of the most raised dissolving centers, relaxes at 1750°C, iron at 1530°C and aluminum at 657°C.) Therefore, if the glow isn't dissipated, it would achieve the failure of the chamber material.
2. Due to high temperatures, the film of the lubing up oil will get oxidized, in like way making carbon stores externally. This will acknowledge chamber seizure.
3. Due to overheating, immense temperature partitions may instigate a mutilation of the engine parts considering the warm loads set up. This makes it basic for the temperature mix to be kept to a base.
4. Higher temperatures other than cut down the volumetric adequacy of the engine.
5. Accordingly the fit cooling structure required in ICE. There are two prime needs of gainful cooling framework.

Consequently the productive cooling framework required in ICE. There are two prime needs of productive cooling framework, for example,

1. It must be fit for expelling just about 30% of the warmth created in the burning chamber. A lot of evacuation of warmth brings down the warm proficiency of the motor.
2. It should expel heat at a quick rate when the motor is hot. During the turning over of the motor, the cooling ought to be extremely moderate with the goal that the diverse working parts arrive at their working temperatures in a brief span.

Cooling System Configuration: Each generator set manufacturer offers different crops for planning cooling framework. The two most common types of cooling frameworks are the Shutter Circle and the Open Circle Framework. Shut circle framework fuses the cooling pumps, coolant fans and radiator (s) on the slide across the board unit. What is more, there is marketing for compartments and trailer picks. Ethylene glycol based coolant is rotated through the cooling framework parts. There are basic cool framework arrangements as follow**:**

Single Pump Single Loop (SPSL) – SPSL frameworks are normal in littler to average size generator elements. Tasks for this framework are as per the following:

- Engine begins, direct drive siphon is driven & fan grip is pivoting.
- Engine comes to at working temperature, coolant indoor regulator opens and fan grasp locks in.
- Ethylene glycol coolant is provided to motor square and chamber head inside segments, for example, oil cooler & intercooler.
- Using radiator Air has been pulled.
- Return coolant stream is coordinated to radiator.

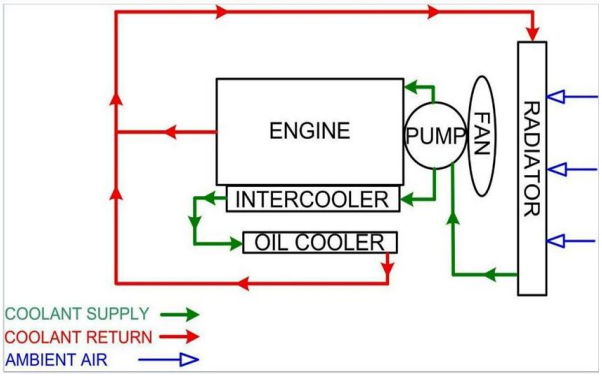

Fig.1. SPSL design for diesel engine based water cooling system

Twofold Pump Double Loop (DPLP) – DPLP cooling framework arrangements are ordinary to giant mills and whilst a generator is located in a high encompassing temperature air. Tasks for this framework are as in step with the subsequent:

- Engine starts off evolved, direct force siphon is pushed and fan grasp is pivoting.
- Engine arrives at working temperature, coolant indoor regulator opens and fan grip locks in.
- One siphon courses ethylene glycol coolant to motor square and chamber head.
- Remaining siphon guides ethylene glycol coolant to internal segments, as an example, oil cooler and intercooler.
- Air is pulled thru the radiator.
- Return coolant move is coordinated to the character radiators.

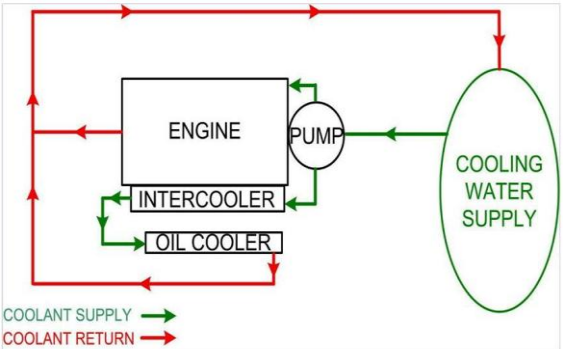

Fig.2. DPLP design for diesel engine based water cooling system

The components used in above designs are elaborated beneath. Each generator application can have an exceptional cooling system configuration. Below is a fashionable list of additives:

- Coolant pump – Contingent upon motor length, belt or rigging pushed. Flows coolant all through cooling framework.
- Radiator – Can be unmarried or twin radiator shape. Utilizing radiators to don't forget two circle framework takes under consideration extra noteworthy cooling capacity.
- Fan – Can be belt or direct force. Belt driven programs can utilize a fan clasp to keep in mind as required fan commitment.
- Engine Oil Cooler – Coolant furnished to vessel. Vessel has a heap of cylinders that is soaking wet in coolant. Oil moves via cylinder group and is cooled via encompassing coolant.
- Intercooler – Coolant is provided to a cylinder and stability percent. Cylinder and blade organization is located in a vessel. Wind currents thru vessel and is cooled by cylinder and blade percent.

Louvers – Used in overhang and portable units to enable air to circulate to the radiator from environment. Control frameworks can take into consideration complete open or full close. Propelled control frameworks can think about louver to open as a lot as required for premium pastime.

IV. MATERIAL AND METHODS

As per the aim of this paper, we present the water cooling motor framework utilizing the diesel generator as fluid system in order to improve the performance of ESR, CSR, and CRR. Figure 3 shows the system model which is designed using the custom thermal liquid blocks. In this model the fixed displacement pump drives the water via the cooling system according the load variations in hotels and hospitals. To reduce the CO_2 emission and temperature, the water coolant used which absorbed the engine heat and decadent via the radiator. The role of thermostat is to monitor the temperature of system dynamically and according to the load. The threshold approach used to diverts the flow towards the radiator by the thermostat block. If the engine temperature more than the threshold value, thermostat delegates the monitoring task to the radiator. The diesel generator block and radiator are the modifications of pipe block. The component of this cooling system demonstrates the liquid internal volume to model the influences of dynamic compressibility and ICE thermal capacity through the equations of mass and energy conservation. We set the properties of temperature and pressure to high in order to apply the initial conditions for the liquid state.

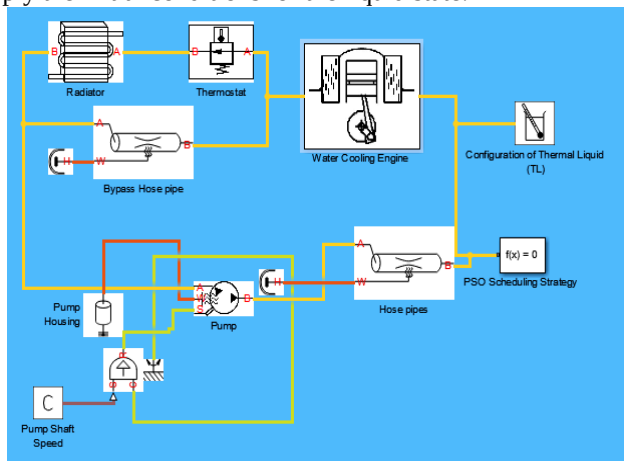

Fig.3. Design of water cooling system

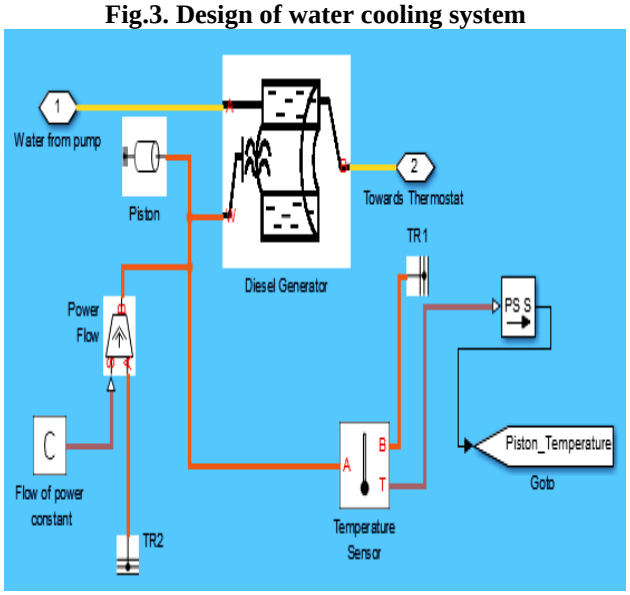

Fig.4. Water cooling engine subsystem

Figure 4 shows the subsystem of main design for the block of water cooling engine in which

the input from the pump is passed through the diesel generator for the cooling. The outcome may pass towards the thermostat to monitor the temperature of cooling engine. The parameters for the diesel generator are described in table 2 for the different capacity variations with their cost. Thus the selection of appropriate diesel generator is based on the requirement of hotels and hospitals. For this work, we assumed the 200 kVA Capacity diesel generator.

Table I: Configuration parameters of diesel generator

Capacity kVA	**180**	**200**	**225**	**250**
Fuel consumption in kg/h	29.9	31.5	35	40
Exhaust gas flow rate in kg/min	14.6	14.7	15	15
Coolant flow rate lpm	200	250	300	350
Coolant temperature difference in degree Celsius	5	5	5	5
Cost (INR)	11,0 0,000	12,0 0,000	12,5 0,000	13,00, 000

The diesel generator parameters including its capacity, fuel consumption, fumes gas temperature, fumes gas stream rate and coolant temperature are taken from the supplier‘s specification sheet. These parameters were used to arrive at the actual heat recovery potential and actual heat input for the vapour absorption machines (VAM).

Apart from the above design we used the optimum booking strategy of the virus water supply to achieve the load balancing and energy efficiency for hospitals and hotels. In literature server techniques introduced for the energy saving, but many of them based on working experiences of operators. Thus the automated and dynamic solution required to adjust the cold water flow as per the demands and engine behaviour. We used the optimization technique called the particle swarm optimization (PSO) to make the decisions on scheduling. The PSO designed such a way that chillers of water cooling system work automatically in distributed ways to achieve the load balancing and system efficiency. In short, in this paper we used the PSO to solve the problem of optimum scheduling problem of chillers in above designed water cooling system. Figure 5 demonstrates working of PSO based water chillers scheduling.

The computation and evaluation of each particle performed by the setting the objective function $f(X,Z)$ where *X* speaks to the present condition of chillers c at time t and Z speaks to the beginning/ceasing condition of chillers c at time t. At that point the optimum planning issue of chillers can be delineated as

$$\min f(X,Z):$$
$$Q(X) \leq 0,$$
$$R(X,Z) \leq 0,$$
$$U(Z) \leq 0,$$
$$M(X,Z) \leq 0 \quad (1)$$

Where, $f(X,Z)$ is the hard and fast cost of the framework; *Q(X)* is the necessities of defilement load of the structure; *R(X, Z)* is the explanation behind concealment of the pace of chillers; *U(Z)* is the cut-off of the huge heaps of starting/ending of chillers; *M(X, Z)* addresses various limitations. Thus the particle with minimum value of $f(X,Z)$ is selected as the current best solution. The process is continues until the convergence criteria met.

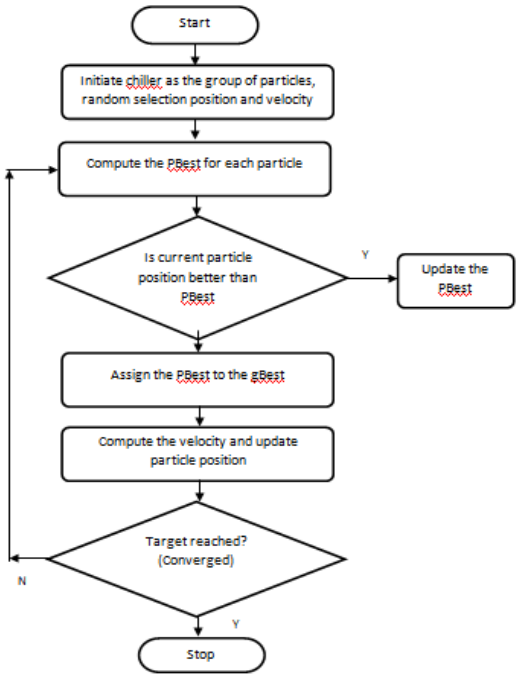

Fig.5. PSO based scheduling technique of the cold water supply

V. SIMULATION RESULTS

In this paper, the water cooling system simulated using the MATLAB Simulink toolbox. The cooling water load was estimated from the assumed data of hospitals and hotels. The loads which are to be met even during load shedding hours were identified. This means these loads need to be met by diesel generator with or without waste heat recovery. Based on this, diesel generator was selected for standalone. The hospital/ lodging load can be dispersed as warming, cooling and electrical load. In this work, we focused on water cooling load and heating load as the system designed mainly for the water cooling using the diesel generator. Warming burden contains the high temperature water prerequisites for washing. High temperature water should be provided toward the beginning of the day. Figure 6 shows the original water cooling and heating load during the scheduled hours (1-24) estimated without using the scheduling strategy. Also the figure 8 shows the energy consumption ratio for the same workload during that period. However after applying the proposed model using the PSO based scheduling strategy the energy consumption performance reduced significantly as demonstrated in

figure 8.

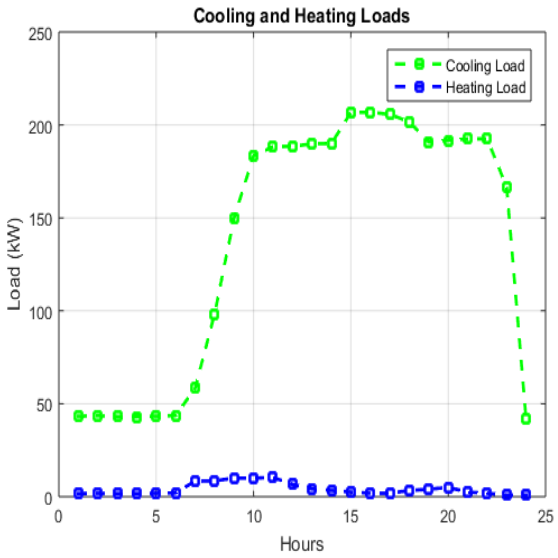

Fig.6. Estimated load for heating and cooling operations during 24 hours of day

As observed in figure 6, the cooling water load is higher than the hot water load; hence it is required to manage such loads to minimize the energy consumption. The energy consumption ratio is showing in figure 7 without applying the proposed scheduling strategy designed in this paper for the load management. The energy consumption is computed by considering other loads also such as lightning, pumping, max etc.

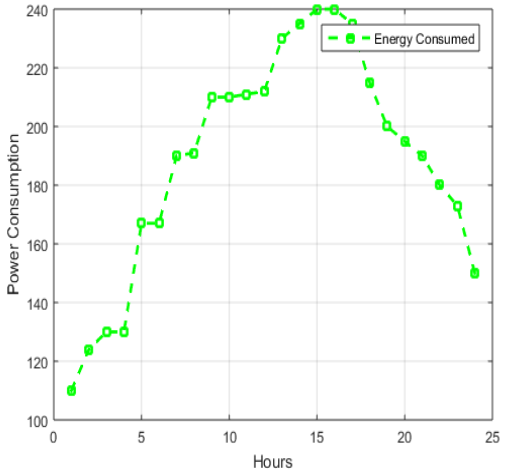

Fig.7. Energy consumption performance before applying scheduling strategy

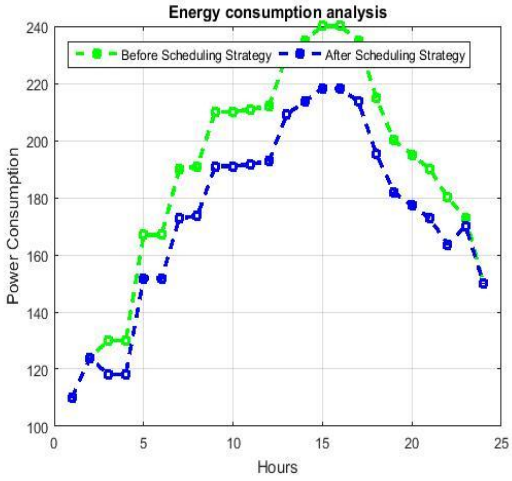

Fig.8. Energy consumption performance after applying scheduling strategy

Using this strategy, the effect of increasing load suppressed on the energy consumption performance has been studied. The cooling water load effectively scheduled to minimize the energy consumption performance. The outcome in figure 8 demonstrates the effect of applying the PSO based cooling water scheduling strategy. The energy consumption is minimized significantly during the peak hours in day as the proposed PSO based approach selects the optimum solution to reduce the total cost by considering the energy consumption and other parameters discussed in above section. Table 2 summarized the average results of before and after the applying the scheduling strategy. From the table first it is observed that some loads like pumping, and autoclave can be managed by scheduling strategy, hence the difference of load estimation after applying the strategy is shown. This means that these loads met when the grid supply is available. On other side, we noticed the overall energy consumption performance of day which shows that approximately 42 KW of energy is saved by using the proposed water cooling design along with scheduling strategy.

Table II: Average performances in kW

	Heating	**Cooling**	**Overall**
Load (before)	4.02	137.63	250.16
Energy consumption (before)	4.01	131.34	214.51
Energy consumption (after)	3.45	111.31	**173.676**

The reduction in energy ultimately reduces the cost and carbon dioxide as well. The Reduction leads the approximate 8% cost reduction for the hotels and hospitals. Finally, we estimated the performances of ESR, CSR, and CRR with varying capacity of ICE in table 3

(figure 9) and table 4 (figure 10) for cooling and heating respectively. The ratio is computed based on the energy consumption reduction achieved in the proposed designed mode.

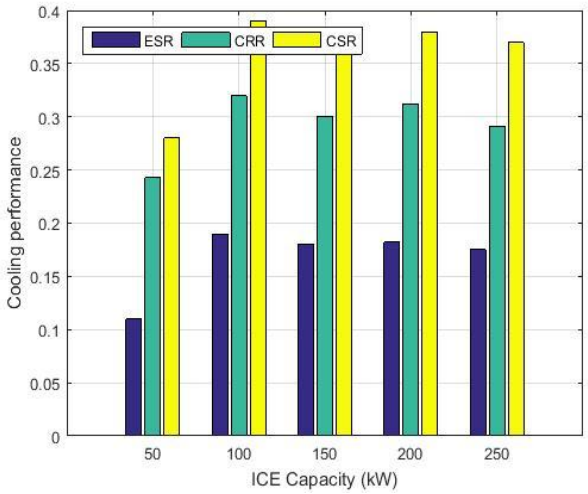

Fig.9. ICE capacity effects analysis on cooling

Table III: Influence of ICE capacity on cooling performance

Capacity (kW)	ESR	CSR	CRR
50	0.11	0.28	0.243
100	0.19	0.39	0.32
150	0.18	0.38	0.3
200	0.182	0.38	0.312
250	0.175	0.37	0.291

Table IV: Influence of ICE capacity on heating performance

Capacity (kW)	ESR	CSR	CRR
50	0.16	0.28	0.25
100	0.24	0.45	0.37
150	0.23	0.34	0.35
200	0.22	0.34	0.362
250	0.22	0.43	0.341

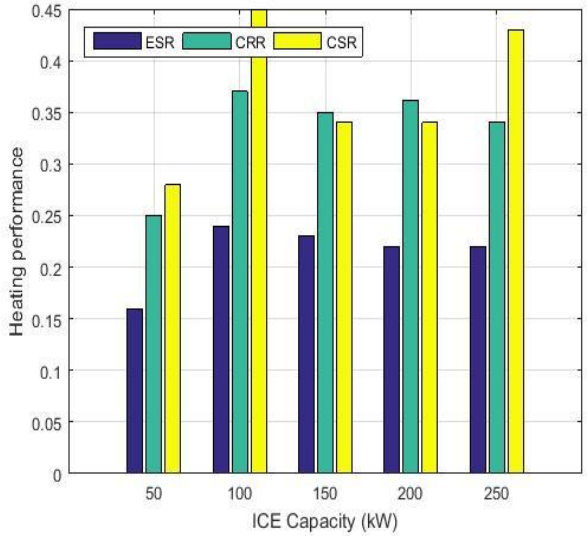

Fig.10. ICE capacity effects analysis on heating

As observed in tables 3 and 4 the influences of ICE capacity on warming and cooling demonstrate the comparable pattern. The framework execution improves unmistakably as far as possible is under 100 kW. For ICE limit in excess of 100 kW, the structure execution changes to some degree with the point of confinement. The presentation extending is recognized by the electric viability developing. The proposed designed model for the diesel generator based water cooling using the scheduling strategy achieved the optimization in energy, cost and CO_2 emissions.

VI. CONCLUSION

This research presented water cooling method design using the diesel generator and cooling water scheduling strategy by using the PSO method. The model is designed and simulated using the MATLAB. The simulation results obtained to justify the impact of diesel generator and scheduling strategy on the energy efficiency, cost efficiency and CO_2 emissions. The result shows the optimizations in terms of ESR, CSR, and CRR. For the future work, we further aim to optimize the available performances using the concept of tri-generation systems.

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