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Design, Manufacturing & Testing of Captive Power Plant Using Liquid Coolant Jet

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Abstract: Captive Hydropower plant is the Low cost way to generate electricity present day. It is the best source of non-conventional energy. India is developing nation with the growth in population and upsurge in the utilization of electricity is tremendously increasing at an upsetting rate. The following paper explains an idea about efficient use of liquid coolant jet to generate electricity using an open loop coolant flow which gives most economical solution for provincial electrification purpose at Cummins PHP plant. This is achieved by allowing the liquid coolant jet to fall on low head open type water turbine coupled to alternator by means of gear pulley mechanism. The generated electrical energy is fed to lighting load. The working principle, functioning, design with calculations and applications along with future scope of captive power plant has been explained in this paper.

Keywords: Nozzle, Turbine, Alternator, Coolant Jet, Gear Pulley.

I. INTRODUCTION

Electricity generation using cogeneration captive power generation. Energy conservation is a few solutions to resolve this problem to some extent. Energy is most important and one of the biggest factor for Nation's economy. The need of electricity has been increased vastly at Industry level, Commercial level and Residential level. Electricity plays a role in Human development; it has to serve different purposes of human being (E.g.- Lighting, Refrigeration, Household and Industrial appliances). Technology has made the life very reliable and comfortable, but it results in higher consumption of the electricity.

While electricity generation is not able to cope up with the increased demand of electricity. Now, Private industries are taking care of saving an electricity as well as electricity bill by implementing various types of captive power plants. It directly gives benefits to industries and government by saving on fuel required to generate electricity since it has been seen from past decades that natural resources are getting drained very terribly.

Captive power plants are the power plants set by any person or group of industries to generate electricity for its own resource. It also includes power plant set up by an association or co-operative society. Captive power is the plant that generates required power by itself to the plants by using its own by-product for power generation. By-product can be anything like liquid coolant, water, bagasse, Heat.

II. WORKING OF CAPTIVE HYDROPOWER PLANT

A captive power plant is a facility that is dedicated for providing a localized source of power to an energy user. These are typically industrial facilities or large offices. The captive hydropower plant described here has used the liquid coolant of the assembly line of industry. The potential energy of liquid coolant is converted into kinetic energy by using convergent nozzle. The converted kinetic energy of liquid coolant is fed to low head open type water turbine which converts input into mechanical energy. The produced mechanical energy is given to alternator and alternator generates electricity, which is used further for Industrial lighting load.

III. CAPTIVE HYDROPOWER PLANT CLASSIFICATION

The Captive Hydropower Plant can be classified to two categories:- large hydropower plant and small hydropower plant. The categories vary depending on countries and norms they follow. The table below gives the classification of it.

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Type	Capacity
Large hydro power plant	Above 100 MW.
Medium hydro power plant	15 to 100 MW.
Small hydro power plant	1 to 15 MW.
Mini hydro power plant	Above 100 KW and below 1 MW
Micro hydro power plant	From 5KW to 100 KW
Pico hydro power plant	From a few hundred watts up to 5kW

Table1-Classification of Hydropower Plants

IV. PRINCIPLE OF PICO HYDRO POWER PLANT

The plant designed by us is a PICO hydro power plant. Generation of electricity from liquid coolant mainly depends upon head and flow of liquid coolant. Both must be required to be available for the generation of electricity. Liquid coolant at Cummins PHP plant is diverted from an assembly line towards the filtration plant and then through the nozzle and turbine. The pressure of liquid coolant at the end of coolant jet depends on vertical distance i.e. head. This pressurized liquid coolant creates force on turbine buckets and drives the turbine. The turbine coupled to an alternator then electricity is produces. Amount of electricity produced depends on quantity of flow of liquid coolant and available head at Cummins PHP site.

The electric power (theoretical) produced i.e. output at the given head corresponding to a input coolant is given by
$P = Q \times H \times e \times g$ in Kilowatts (kW)

Where,
P = Power output in KW.
H = Head available at site in meter.
Q = Flow in outlet pipe, in meter cube per second ($m3/s$)
e = Efficiency of the power plant considering total head loss and efficiency of the turbine and generator, expressed by a decimal (e.g. 85% efficiency= 0.85)
g = 9.81 (constant) is the product of density of water and acceleration due to gravity.

This available energy is converted into mechanical energy using hydro turbine.

V. LIQUID COOLANT FILTRATION PLANT AT SITE

Filtration plant basically for the reuse of liquid coolant, it filter outs chips and oil comes from assembly line of Cummins PHP. The dirty liquid coolant came from industry is fed into dirty tank through the outlet pipe having diameter of 600 mm. The dirty tank has magnetic conveyor inside it, which attracts the entire unwanted chip and throws out in a container.

The Procedure of Filtration Plant is explained below:
1. Contaminated coolant enters into the drag conveyer via a toughing system. The continuously operating conveyer removes the bulk of the cheap load.
2. Metal chips are stripped out by the filter element as the coolant passes through.
3. The suction which draws the coolant through the element holds these chips on the surface of the wedge wire screen.
4. As the chip cake builds on the wedge wire screen, so does the resistance to coolant flow. The resistance to flow is measured by the vacuum builds up until it reaches suction of the system pump.
5. A vacuum is builds up until it reaches a pre-set point(3mtr). Then the filter automatically indexes.
6. It should be noted that a 10% excess flow is generated by the system pump and allowed to weir into the generation tank of the filter unit. This maintains the level in the clean tank of the filter unit

Fig.1: Coolant Filtration Plant

VI. STUDY OF DISCHARGE

Cummins PHP has coolant filtration plant to supply liquid coolant to its high horsepower engine manufacturing assembly line. The capacity of coolant tank is 130000 litres. This coolant is filtered by three processes and circulated throughout the assembly line with the help of four 75HP motors which gives flow discharge of 11000 litres per minute. The available head due to the outlet pipe is of 1.5 meters from the top surface of the coolant tank.

Fig.2: Coolant Filtration Jet

VII. STUDY OF SELECTION OF NOZZLE

The nozzle is selected according to the required speed of turbine and the available flow rate. It must fit in the available space above the tank.

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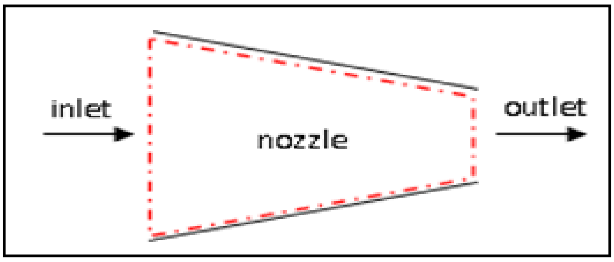

Fig.3: Convergent Nozzle

VIII. DESIGN RESULTS OF THE TURBINE

Design of Open Type Low Head Turbine

Input Parameters
Discharge = 7400 litres per minute (0.1258 m3/s)
Head = 1.5 meters (5 feet)

DESIGN PARAMETERS		PARAMETER OUTPUT	UNIT OF PARAMETERS
1)	Hydraulic Power	1.851	KW
2)	Velocity of Jet (V_1)	4.341	m/s
3)	Diameter of Jet (d)	196.092	mm
4)	Mass Flow Rate	183.19	Kg/sec
5)	Normal Force Exerted On Vanes	2.0834	m/s
6)	Normal Force	827.139	N
7)	Power Output	1.723	KW
8)	Hydraulic Efficiency	93.10	%

Table2- Design Results of the Turbine

IX. CALCULATIONS FOR THE SELECTION OF ALTERNATOR DESIGN

Assumptions:
1. Specific Electric Loading(ac) = 20000 to 40000 A/m
2. For Specific magnetic Loading (Bav) Air Gap Flux Density = 0.52 to 0.65 Wb/m^2
3. Winding Factor (Kw) = 0.995
4. Ratio L/t = 0.6 to 0.7
5. Synchronous speed = 1500 rpm
6. 10 KVA, 0.8 P.F

Solution:
1. Synchronous Speed $= 1500/60$
$= 25$ r. p. s
2. No. of poles $= 2 \times 50/25$
$= 4$
3. Average Flux Density = Bav $= 2/\pi \times 0.55$
$= 0.3501$ Wb/m^2
4. $C_0 = 11 \times Bav \times ac \times Kw \times 10^{-3}$

$= 11 \times 0.3501 \times 20000 \times 0.995 \times 10^{-3}$
$C_0 = 76.63$
5. $D^2L = Q_0/C_0 \times Ns$
$= 10/76.63 \times 25$
$D^2L = 5.2198 \times 10^{-3}$

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Taking,
$L/t = 0.65$
$L = 0.65\times(\pi/P)\times D$
$L = 0.510D$
$D^2L = 3.47\times10^{-3}$
$0.510\times D^3 = 3.47\times10^{-3}$
$D = 0.1894$ m
$L = 0.510\times0.1894$
$L = 0.0965$ m
$Kw = 0.995$

6. Peripheral Speed (Va) = $\pi \times D \times Ns$
$= \pi \times 0.1894 \times 25$
$= 14.875$ m/s
7. $Q_0 = 1.11 \times Bav \times ac \times Kw \times 10^{-3} \times Va \times 2 \times L/n_s$
$= 1.11 \times 0.3501 \times 20000 \times 0.995 \times 10^{-3} \times (14.875)2 \times 0.0965/25$
$= 6.604$ KVA
8. $Q_0 = 6.604\times0.8$
$= 5.28$ Kw

Electric Loading (ac)	Air Gap Density	Output Coefficient (C_0)	D^2L	Q_0 (KVA)	Q_0 (Kw)
20000	0.55	76.63	5.21×10-3	6.60	5.28
30000	0.55	115	3.47×10-3	9.95	7.96
38000	0.60	158.461	2.524×10-3	13.72	10.97

Table3- Varying Range of Power Output

X. Block Diagram

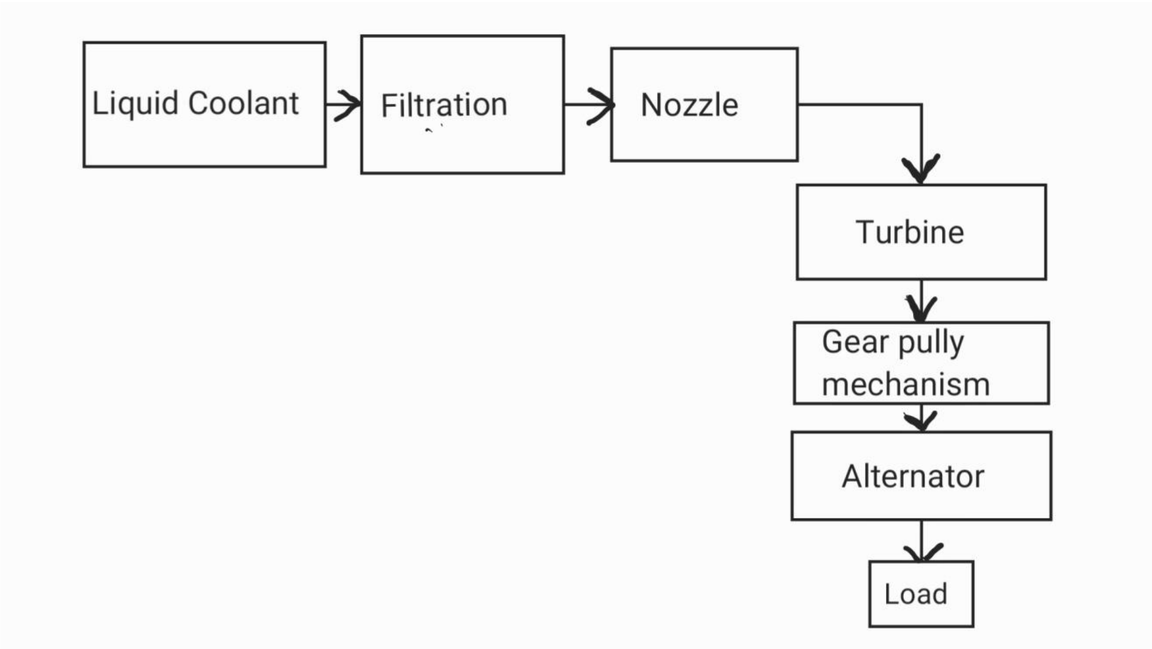

Fig.4: Captive power plant generation using liquid coolant jet

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XI. RESULTS

1.	Maximum Power which can be generated using maximum flow rate of coolant.				5kW
2.	Observation Table				
	Flow Rate	Speed of Alternator		Voltage	
	11000 Lps	1500 Rpm		230 Volts	
3.	After load connection				
	Voltage	Current	Speed	Frequency	
	220≈230 Volt	27.2 Amp	1450≈1500 Rpm	49≈51	
4.	Maximum load which can be supplied.				4kW

Table4- Result Table of Project

XII. COSTING OF PROJECT

1.	Turbine	RS. 41100/-
2.	Alternator	RS. 32000/-
3.	Nozzle	RS. 4300/-

Table5- Costing of Project

XIII. CONCLUSION

We conclude that low head open type Water wheel turbine is a best suitable and efficient option for head produced due to coolant jet.It is also helpful for head imparted by waste water in city area to produce electricity for small scale application. This paper reviews the Captive power generation from coolant jet. This paper can be a guideline for the developers in implementing captive hydro power plant for available low head of coolant jet.

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