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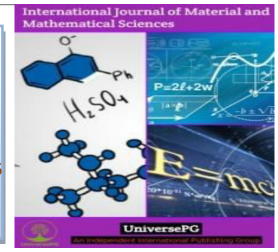

Efficient Water Management and Selection of Cooling System for Future NPP in Bangladesh

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ABSTRACT

Water withdrawal today presents a vital issue for Bangladesh to build a new nuclear power plant (NPP) as the country has a deficit in its water resources. It is an issue that may create conflict among the socio-economic activities that require and depend on the water like agriculture that mostly depends on river and ground water. Very recently nuclear power has come into focus during debates on energy generation, often in relation to wider issues such as global warming and climate change. According to Power System Master Plan (PSMP) 2016 of the Government of Bangladesh, it is estimated that a capacity of 7200 MWe of electricity may be generated from nuclear power by 2041 (PSMP, 2016). The government of Bangladesh has already started the construction work of 2400 MWe Rooppur NPP and planning to construct more units of NPPs in the future to fulfill the planning of PSMP 2016. Usually, water is used as a coolant for most of the commercial NPP designed in the present world. In this paper, a study has been performed about the estimation of both the needs for cooling water and other essential systems for a future NPP in Bangladesh using IAEA's Water Management Program (WAMP). Moreover, the selection of cooling systems by evaluating three different criteria: water resource, environment, and economics, has also been performed during this study.

Keyword: Cooling system of NPP, IAEA, Water Management Program (WAMP), NPP, and Bangladesh.

INTRODUCTION:

Water management is an important topic for countries like Bangladesh considering building new NPPs. Good water management addresses the issue of securing water for NPPs at various stages: construction and flushing, cold and hot testing, the condenser cooling operation including the primary coolant make-up system, as well as the safety inventory and release from radioactive liquid waste treatment structure (Moss *et al*., 1998). In all stages of construction, operation and maintenance of any NPP, efficient water management is needed. Water use involves two processes that can occur separately or simultaneously: water consumption and water withdrawal.

Water consumption occurs when water either ceases to exist as a liquid, through evaporation (direct evaporation in a cooling tower or increased surface evaporation from the source due to the elevated temperature) or when water is degraded through contamination so that it is not fit to be returned directly to its original source.

Withdrawal water means water is removed from a source. It may have consumed and not returned to its origin. The difference between water consumption and water withdrawal is important to any discussion about water use. Normally open loop cooling systems may withdraw significantly more water than recirculating cooling towers, but consume substantially less (Baker, 1988). Other systems may withdraw no water at all, but still consume water, as in reservoir evaporation at a hydroelectric power plant. However, when making such comparisons, differences in cooling water temperature as well as the thermal efficiency of the power plant must be kept in mind.

Water requirements for NPPs may vary, based on the cooling system they involve, the thermal efficiency of the NPP, the need for service water, safety and non-safety system designs, as well as the waste disposal techniques (Hasan *et al*., 2020; Mathey, 1990). Selection of site is also a very important parameter in terms of availability of cooling water as well as appropriate atmospheric conditions. These parameters will higher plant efficiencies at lower water withdrawal rates.

Water is required mainly for cooling of NPPs. It is compulsory to carefully choose and design cooling system for NPP. There is a number of cooling processes that can reduce the water consumption rapidly. Cooling water requirements of NPPs exceed the conventional fossil fuel power stations on an average by 20-25 percent (Khamis and Kavvadias, 2012). Most of the existing NPPs have lower thermal efficiency which is responsible for this as they operate with lower steam pressures and temperatures. These parameters can be varied very slightly as of the limits forced by the common use of zircaloy as a material for fuel cladding and thermal hydraulic considerations [6]. Another limiting condition is the manufacturing capabilities of the main reactor heavy components.

Different methods of cooling used for NPP/Technologies available for cooling systems

Power plants require dependable access to large amounts of water, mainly for cooling. Normally NPPs use water for cooling in two ways: 1) convey heat to the steam turbines from the reactor core 2) remove and reject excess heat from the internal steam circuit.

If the power plant is next to a large natural water body (Like sea, big river or large inland water body) then the cooling may be achieved simply with a once-through cooling system, where large amounts of water are circulated through the condensers and discharged back into water body with less amount of withdrawn.

If such water body does not exist nearby, the cooling may have carried out by passing water throughout the condenser unit and then through a cooling tower, where an up breeze of air through water droplets cools the water. Normally an on-site water body may be good enough for this.

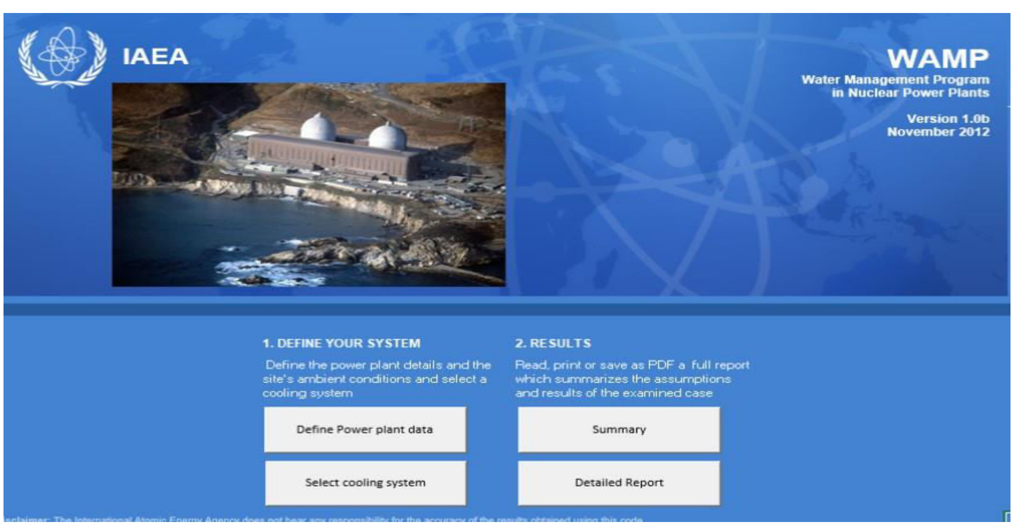

Fig 1: WAMP user interface.

Table 1: Distribution of cooling systems in current operating NPPs

Once-through cooling	Closed cycle	Sea/Lake/ River water	Cooling tower
45%	15%	14%	26%

METHODOLOGY:

Water Management Program (WAMP) is used for this study. The IAEA has developed and released the WAMP, which is freely available to all Member States which may be used for the estimation of water needs in NPPs especially for water cooled NPPs. The program estimates both the needs for cooling water and other essential systems.

Following flow chart shows a brief idea about different cooling types available presently -

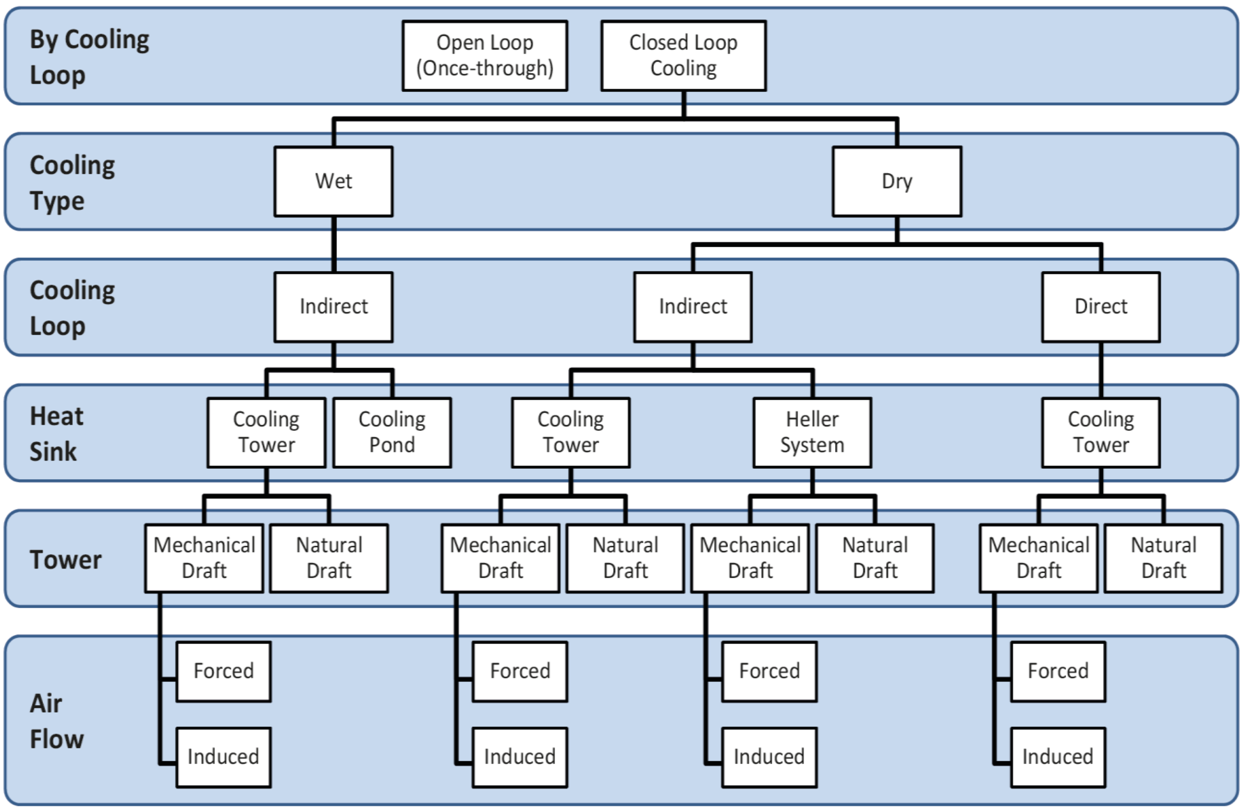

Fig 2: Different types of cooling system.

Study of cooling system for the proposed site

For the proposed site, the following NPP parameters have been chosen, considering that Bangladesh is going to construct large size NPP in future. Parameters chosen are shown on **Table 2**.

Table 2: Assumed Power Plant Specifications and Site conditions

Power Plant Specifications	
Type	Light Water Reactor
Reactor electric capacity	1199 MWe
Reactor thermal capacity	3600 MWth
Reference efficiency	33%
Rejected heat	2380 MWth
Coolant flow rate through reactor	23.88 m^3/s

Site conditions	
Location	River/Inland
Dry bulb temperature	28 °C
Wet bulb Temperature	23.6 °C
Relative Humidity	70%
Surface water temperature	25 °C
River flow	95 m3/s
Average wind velocity	3.05 m3/s

After considering the above mentioned specification, the cooling water requirements were calculated using WAMP software. The results are tabulated below:

Table 3: Simulation result for water withdrawal and water consumption for different cooling systems

Cooling System Type	Water Withdrawal (m^3/s)	Water Consumption (m^3/s)
Once Through	58.12	0.79
Once Through (Cooling Pond)	58.12	0.79
Close Loop with Cooling Pond	0.67	0.45
Wet Cooling (Mechanical Draft)	1.54	1.05
Wet Cooling (Natural Draft)	1.58	1.13
Hybrid Plume Abatement	1.57	1.07

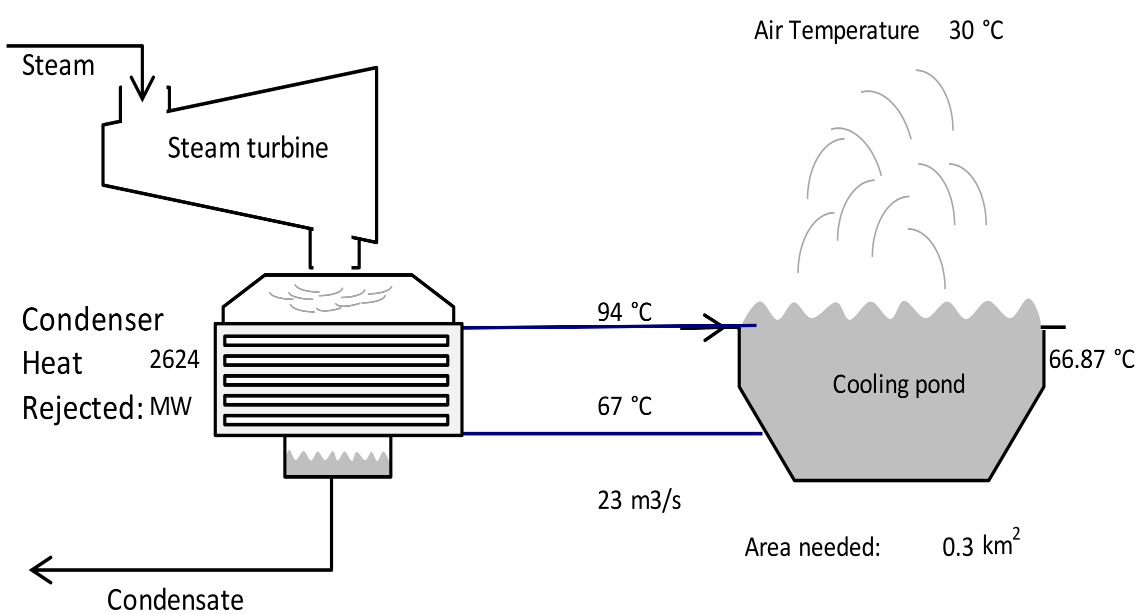

Fig 3: Close Loop cooling system with cooling Pond simulation result.

It is found that once through cooling system required highest amount of water for cooling and close loop with cooling pond required lowest amount of water.

Table 4: Cost estimation for cooling systems

Cooling System Type	Capital Cost (M$)	Operating Cost (M$/Yr)
Once Through	Base Cost	Base Cost
Once Through (Cooling Pond)	0.00	Base Cost
Close Loop with Cooling Pond	84.4	Base Cost
Wet Cooling (Mechanical Draft)	47.2	15.5
Wet Cooling (Natural Draft)	82.7	5.4
Dry Cooling(Air Condenser)	135.9	30.3
Hybrid Plume Abatement	129.9	21.3

Table 5: Environmental impact of different cooling systems

Environmental Impact / Cooling System Type	Visual Impact	Plume	Thermal Pollution	Air Pollution
Once Through			√	
Once Through (Cooling Pond)	√			
Close Loop with Cooling Pond	√			
Wet Cooling (Mechanical Draft)	√	√	√	
Wet Cooling (Natural Draft)	√	√	√	
Dry Cooling (Air Condenser)	√			√
Hybrid Plume Abatement	√		√	√

Table 4 shows the capital and operation cost of different cooling system analyzed by WAMP software.

Table 5 shows the environmental impacts (Visual Impact, Plume, Thermal Pollution, Air Pollutions etc.) of different cooling systems

RESULTS AND DISCUSSION:

To dissipate the rejected heat (2380 MW_t) from the reactor, flow rate of coolant at the condenser side should be 23 m^3/s or more. From the simulation result obtained from WAMP, it is found that close loop cooling system with cooling Pond can ensure 23 m^3/s coolant flow rate at the condenser side. This system has the lowest water withdrawal and water consum-ption rate (0.67 m^3/s and 0.45 m^3/s respect-ively) in comparison with the other systems.

This system has a higher establishment cost in compare with wet cool system but it has no operating cost at all (only base cost). The system has almost no environmental impact and very much favorable for a country like Bangladesh. So; close loop cooling system with cooling pond may be a good option for future NPP in Bangladesh with respect to the selected site conditions.

CONCLUSION:

As a new comer country in the field of nuclear power plant, Bangladesh need to consider the environmental impact as well as the cost effectiveness of the cooling system for NPPs. By considering both criteria it can be said that close loop cooling system with cooling pond can be a good option for future NPP in Bangladesh.

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CONFLICT OF INTERESTS:

The authors declare no conflicts of interest.

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