A Study to Find out The Suitability of Nuclear Power Plant to Sri Lanka

R.L.T. Thisirini*, K.A.C. Udayakumar

Department of Electrical Engineering, The Open University of Sri Lanka, Nawala, Nugegoda, Sri Lanka.

*Corresponding Author: Email: thilokathisrini@gmail.com, Tele: +94711487063

Abstract *– Power plants with larger capacities should be introduced to the system to meet the future demand of the country. This paper discusses the possibility of introducing nuclear power plant (NPP) to meet this demand. Since the nuclear power plants are based load plants base load of a system should be sufficient to operate NPP. The paper analyses future demand of the country to see the feasibility of NPP to Sri Lankan power system. The paper also discusses different technologies for NPP and type of reactor that may be suitable for Sri Lanka. The paper analyzes the possible locations of NPP considering factors that are affected in deciding locations for NPP. The aspect of radioactive waste management which is one of critical aspects in NPP operation has been also discussed. The options available for the NPP to the exiting grid also are a part of this work.*

Keywords: *Nuclear power plant, base load power*

1 INTRODUCTION

Presently, nuclear energy contributes about 11% of electricity generation and more than four hundred nuclear reactors are being operated successfully in thirty-one countries around the world. Installation of a nuclear power plant to the Sri Lankan power system has been actively discussing for number of years. However, installation of NPP to Sri Lanka is still debating due to the factors including technical, environmental, economic, social and political.

Increase of population, living standard of the people, 100 % electrification, infrastructure development, and establishment of different types of industries lead to increase of electricity demand in the country. The country should have both short and long term generation plans to meet this demand. Future energy crisis in the country can be avoided only having a proper generation plan and its implantation.

At present, electricity demand is met by mixture of hydro, thermal (coal, gas turbine) diesel power plants together with certain percentage of electricity generation from non-conventional renewable energy (NCRE) sources (solar, wind). The economic viability of further addition of both coal and diesel power plants to the system in long term may become questionable due to depletion of fossil fuel and increase of their cost. In addition to this fossil fuel based power plants produce Green House Gases (GHG) such as Sulfur Dioxide (SO_2), Nitrogen Dioxide (NO_2) and Carbon Dioxide (CO_2). The emission of these GHS becomes a threat to the environment and causes global warming. Even though the regulations have been imposed to minimize the environmental impact, there are environmental issues in the area surrounding the existing coal power plant.

Larger portion of electricity generation of the country comes from the hydro power plants. Even though hydro power plants do not produce GHG the electricity generation highly depends on the weather conditions. During last few years the country has been experiencing energy deficit due to draught weather conditions. In addition to this the possibility of future construction of high capacity hydro power plants in the country is very minimum due to lack of locations with the capability of storage of water in large amount.

Utilization of NCRE for electricity generation has been increased significantly during last few decades. However, the electricity generation from both solar and wind is highly depending on climate condition. The unit capacity of these plants also is limited due to technical limitations. Macro systems like power systems needs power plants with larger capacity to maintain the stability of the system. On the other hand still the efficiency of these non-conventional power plants are low and their cost is high and therefore the unit cost of energy produced by the non-conventional power plants is of higher value. This means still the conventional power plants with higher capacity has an essential role to play in a power system.

With the increase of the demand and due to limitations and certain disadvantages of the currently used power plants, the NPP may be a good potential candidate to meet the future electricity demand of the country. The operation of NPP involves the emission of radioactive product and therefore safety and environmental issues play a crucial role on deciding the construction of nuclear power plant. This paper discusses type, capacity, location, type of the NPP and social and environmental issues related to the operation of NPP.

2 SYSTEM CAPACITY

By year 2034, thermal power capacity retirements will be 1023 MW and total installed capacity will be 8032 MW (without adding Non-Conventional Renewable Energy (NCRE) portion total capacity will be 6616 MW). The peak demand will be 5692 MW. NPP are considered as based load power plants. The installed capacity of NPP depends on the base load of the system load curve. This means there should be a sufficient amount of base load for the NPP. Presently base load of the demand curve is about 1100 MW. Considering the average growth rate 5.3% of the demand forecast, the base load demand can be estimated as 2600 MW in 2034. It is clear that more generating plants should introduced the system to cover this load (Ceylon Electricity Board, 2015). Figure 1 shows the contribution of different types of power plant to meet the predicted demand in year 2030.

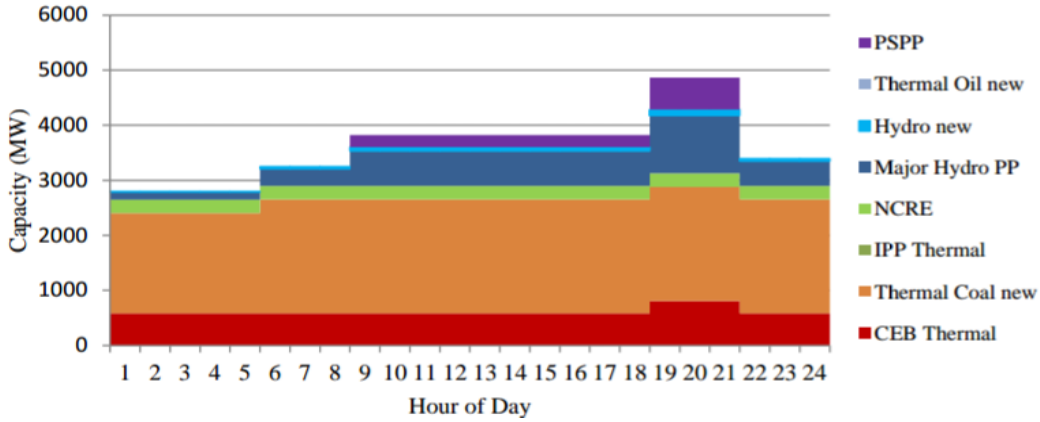

Figure 1: Capacity contribution from power plant in a day in March/April 2030 (Ceylon Electricity Board, 2015)

3 NPP CAPACITY

According to the largest unit index, capacity of the largest unit should be smaller than 900 MW by 2034, but there were number of suggestions for establishing coal power plants in Sri Lanka according to the CEB long term generation expansion plan. The capacities of the most plants are about 300 MW because it is a disadvantage to install larger capacity power plants in Sri Lanka even when considering the capacity. One of the major issues that need to be considered is the capacity of a nuclear power plant. The nuclear power plants are to cover the base load of the system. The reason is that the plants are not suitable for frequent starting or stopping. This means the capacity of a nuclear power plant should be less than the base load of the system. Since the base load of Sri Lankan system is not expected to be a very large one, the NPP capacity also should be a relatively smaller one.

Based on the capacity, nuclear reactors are grouped as smaller, medium and larger reactors. The reactors with electrical capacity of less than 300 MW or thermal capacity of less than 1000 MW are known as small size reactors. Small size reactors have several advantages compared to large size reactors. Constructions, land area, plant requirements and impacts (specially cooling water impacts) are less in small size reactors than medium or large size reactors. Considering the geographical area and the amount of the base load in the total load curve small size reactor is more suitable for the country. Handling of smaller capacity reactors is easier than handling the lager capacity reactors. Small size reactors are better matching of system demand growth and they have smaller unit capital cost.

4 NUCLEAR REACTOR

There are several reactor types is being used by several countries, such as Light Water Reactors (Pressurized Water Reactor and Boiling Water Reactor), Pressurized Heavy Water Reactor (PHWR), Advanced Gas Cooled Reactor, Graphite Moderate Light Water Reactor and Fast Breeder Reactor. Among these reactor types, PHWR scores higher mark because this reactor has several advantages than other reactor types.

4.1 Basic advantages of Pressurized Heavy Water Reactor

- Use natural Uranium (UO_2) as fuel, therefore fuel cost is less expensive and spent fuel can be store more compactly
- Ability to refuel while on load is a special feature, this increase duty cycle and capacity factor of the plant
- This reactor has indirect cycle, therefore no radioactivity involve in secondary cycle
- Reactor consists of full double containment design. It increases the safety
- Reactor vessel is not single vessel type, therefore transportation is easy
- This reactor consists of two independent shutdown systems
- Lay out of the plant is designed for twin unit modules, therefore some auxiliary systems can be shared by both units
- Reactor consists of several auxiliary systems and safety procedures

Mainly PHWR are operated in Canada (CANDU), India, and China. In India the first two units (Rajasthan Atomic Power Station units 1 & 2) were imported from Canada. They are based Douglas point. Due to the failures of these reactors India constructed standard Indian Pressurized Heavy Water Reactors (IPHWRs). They are based on CANDU technology. India has built 220 MW, 540 MW, 700 MW small and medium size reactors. Sri Lanka government has signed a nuclear corporation agreement with India in 2015 and also India is the nearest country to Sri Lanka. In India sixteen 220 MW IPHWR are successfully operated (Muktibodh, 2011). The plant layout of Indian PHWR has been developed on the basis of twin unit concept (Therefore total capacity of this plant is 440 MW).

5 IDENTIFICATION OF THE SUITABLE LOCATION FOR THE NUCLEAR POWER PLANT

Location of a nuclear power plant should be selected very carefully considering various aspects. Since the nuclear power plants deal with radioactive product the location should not be a living area. Even the place is far away from the living area the people in the region may dislike having a power plant in the area. A good example for this may be the objections from different societies within Sri Lanka for NPP in South India. The same can be expected when the power plant is proposed within the country.

The selected location also should be free from natural disaster such as earthquake, tsunami. The reason for the disaster of the Fukushima Daiichi nuclear power plant in Japan in 2011 was this type of natural disaster. Even though the hundred percent guarantees from the natural disasters cannot be given, the locations should be scientifically verified the probability of having disaster.

Radioactiveness of waste product of the nuclear reaction remain number of years, therefore, storage of the radioactive product also is an important aspect. In countries where the nuclear power plants are in operation this is done in number of ways such as near surface disposal and deep geological disposal, deep boreholes, Ocean floor disposal, etc. Considering above facts the plant location should be done very carefully. Some of the general factors are listed here.

5.1 General Factors

- Geology and Seismology - area should be free from geology and seismic hazardousness
- Tectonic structure - seismic hazard of Sri Lanka is very low because it does not lie near any of plate boundary
- Hydrology - A NPP requires reliable source of water for the cooling purposes and other plant requirements
- Demography - Low population area is most suitable
- Climatology - Coastal area Climatology is quite suitable for the plant
- Public acceptance - anti nuclear movement can be come as direct action groups, environmental professional organizations

The site survey was carried out in three steps. First the regional analysis was done by considering the general factors. Then potential sites were selected. Candidate sites were found out by screening potential sites according to the general factors and special factors. And according to the gathered data it was found out which candidate sites are most suitable to establish a nuclear power plant. Below is the list of 6 candidate sites which have been analyzed and explained. Table 1 shows potential suitable sites for the nuclear power plants.

Table 1: Candidate sites

Location	District	Area (km^2)	Population	Pop. density per km^2	Distance to pop. area (km)
Delft island	Jaffna	45	3.824	84.98	40
Lahugala	Ampara	815	8,914	10.94	15
Musalai	Mannar	475	8,119	17.09	21
Manthai west	Mannar	608	1,477,1	24.29	18
Vakarai	Batticaloa	584	2,153,7	36.57	21
Maritemepattu	Mulativu	600	2,897,3	49.29	20

5.2 Selected location

By considering sociable and environmental involvements, Delft Island is selected as most suitable location for the NPP, because those involvements can be less in this area than other selected areas. This island is 40km away from main land and this will be very useful to get public acceptance when considering protection zones around the plant. Delft island is famous for wild horses, heritage, agriculture (coconut) and tourism. This area consists of many fishing villages. Electricity scheme will not meet the requirement of 1082 families and frequent power disruptions. Houses are fenced by coral- stones piled up or by Palmyra leaves. This island is underdeveloped. Roads are not crowded. Population of this area is low and few number of families have to be relocated. And also small island around the delft island can be used for the plant purposes such as spent fuel disposal and store new fuel, etc. Inland water distribution is very low and fresh water for some areas are supplied by army from main land. But according to a research carried out by Jaffna university, they have found inland ponds, but those water sources will not enough for the plant requirements. Therefore desalination plant may be better solution for this problem.

Figure 2: Delft Island

6 ENVIRONMENTAL AND SOCIABLE IMPACTS

6.1 Impacts of land

Impacts on land used are mainly based on the exclusion boundaries of NPP. The people who live on these exclusion zones have to be relocated and the cultivation process must be shifted to another area owing to the boundaries even though the plant footprint is small. Some of lands are agricultural lands, therefore effects due to loss of those lands must be taken into account.

6.2 Impacts of the cooling water and waste water

Discharge cooling water that use in the power plant will increase the temperature of the sea water close to the discharge place (this used cooling water doesn't include any radioactivity), this slightly temperature increase of the sea water will not do any significant effect on fish mitigation. But turbidity due to construction activities may cause to fishery mitigation.

6.3 Impacts of radioactive and other emissions

All the emissions are released to the environment in control manner and after reduce to set limits, and also these emissions are so low (normal operation set limit 0.1 mSv/year).

6.4 Impacts of living condition and health

Someone just exposed to about 0.03 mSv of radiation living near a power plant for a day, and also of someone lived within 50 miles of a NPP, he would receive an average radiation does about 0.0001 mSv per year, normally the average person in US receive a 3 mSv per year (IAEA, 1996).

6.5 Impacts of landscape and cultural environment

This impact will be caused by heavy traffic required by the transport of large building parts and its requirements, new road connections and the improvement of current roads. All the selected areas are coastal areas and most of the areas are famous for tourism and holiday residues, but these industries will be no longer possible.

6.6 Impacts of the waste management and waste disposal

Nuclear waste disposal doesn't have any negative effect if it disposed properly. Nuclear waste is located in the storage place for many thousands of years until it is no longer radioactive and dangerous. However, there can be large impacts from nuclear waste disposal if the nuclear waste is improperly disposed. There is no easy or simple way to clean up spilled radioactive materials and also that area takes several years to ensure that it is safe to live or even visit again.

6.7 Impacts of the decommissioning of the power plant

The impacts of decommissioning of NPP remains low, there must be radiation protection to the people that participate in the decommissioning process. The generate waste during the demolition phase may be similar to the generated waste during the operation of the plant.

6.8 Impacts of people and society

Good social impacts and bad social impacts can be occurred due to NPP, because lots of labors are needed to the plant construction at the construction stage. Form the population details of the selected areas, the large potion has gone to the young age group. For an example, Employment for youth and means of livelihood are the major demands of Delft Island. Therefore these people will be able to get jobs owing to a NPP. Another important thing is the area will be well developed (new roads, ports, and buildings will be constructed). The bad impacts are causeless fear of people and negative attitude of societies against NPP.

6.9 Impacts of accident condition

International Atomic Energy Agency (IAEA) has defined that a NPP accident as an event that release radioactivity with significant consequences and including harmful does to human and soil contamination. Most of the people have a fear about the accidents of NPP, but Sri Lanka is an Island near to India and also the Kudankulam Nuclear Power Plant in Tamil Nadu is only 225 km away from Sri Lanka (Kalpitiya). Therefore Sri Lanka is already located at NPP region.

7 LIFE CYCLE COST (LCC) ANALYSIS OF NUCLEAR POWER PLANT AND COAL POWER PLANT

LCC assessment involves the estimation of major expected costs within the useful life of a power plant. This calculation allows comparison of different investment alternatives and thus enables determination of the most cost effective system.

Specific Life Cycle Cost = $\frac{P+Md}{8760.C.d}$ + f + m per kWh

where,

P - Capital cost including Interest During Construction (IDC) per kW

M -Fixed Operation & Maintenance (O & M) cost per kW

d -Present Value factor corresponding to the economic life of the plant

f - Fuel cost of a kWh of electricity generated

m- Variable maintenance cost per kWh of electricity generated

7.1 Life cycle cost of NPP and Coal Power Plant (CPP)

Table 2: Cost values of Plants

Cost	IPHWR – 220 MW (US$/kWh)	CPP (275 MW) (US$/kWh)
Capital cost (with fixed O & M cost)	0.02807	0.03762
Variable maintenance cost	0.00261	0.00349
Fuel cost	0.00518	0.02785
Life cycle cost	0.03586	0.06896
	5.49	10.5964

LCC of the Nuclear power plant and Coal power plant is 5.49 LKR/kWh and 10.5964 LKR/kWh respectively. The LCC of the Nuclear power plant is quite small than LCC of the Coal power plant. Here, environmental pollution control methods of the Coal power plant have not been considered.

Cost values of unit IV reactor of Kaiga Atomic Power Station were considered for this cost analysis. This plant was commissioned in 2010. But as an assumption authors have considered as this plant was started in the current year. And also cost data of Lakvijaya coal power plant project were used and as an assumption author has considered as this project also started in the current year.

8 NUCLEAR WASTE MANAGEMENT

Radioactive waste can be categorized according to its activity level and the radioactive half-life radionuclides it contains. The main types of waste are Low Level Waste (LLW), Intermediate Level Waste (ILW) and High Level Waste (HLW). The LLW is comprises paper, clothing, tools, gloves, plastic containers, etc. This LLW is not dangerous to handle but carefully disposed than normal garbage. The volume of LLW is 90% of the total volume of the waste but contains only 1% of the radioactivity (short lived radioactivity). This waste doesn't require any shielding during handling and transport. ILW is more radioactive than LLW. But generated heat (< 2 kW/m^3) is not rather high for design special storage or disposal. But this waste requires some shielding. This waste contains radioactive resin, chemical sludge, metal fuel cladding, and containment materials from reactor decommissioning. The volume of ILW is 7% of the total volume of the waste but contains only 4% of the radioactivity.

HLW is considered as the used fuel assemblies (spent fuel) taken out from the reactor during the refueling process and decommissioning of the plant. This waste contains highly radioactive radionuclides (long half-lives). The volume of HLW is 3% of the total volume of the waste but contains 95% of the radioactivity. The radioactivity level of fuel assembly has been analyzed as 92.5 TBq/kg and it takes 10 years (Spent fuel pool inside the fuel building) for drop to 14.8 TBq/kg, after 100 years radioactivity will be dropped to approximately 1.85 TBq/kg.

8.1 Nuclear waste disposal options

Various processes are used to treat Low and Intermediate Level Waste (LILW). The treatment process is depends on the nature and radioactive level of the waste. Most of the activity present in the form of Cesium (137Cs), Cobalt (60Co), Ruthenium (106Ru). The main focus of these processes is waste volume reduction. Commonly used LILW treatment processes are Chemical treatment process, Treatment using solar evaporation, Ion exchange and Treatment by membrane process. After the treatment process, the waste should be disposed. There are several ways to use for disposed LILW. Such as near surface disposal, sea dumping, incineration, etc. but sea dumping and incineration can cause large harm to environment. Therefore near surface disposal is acceptable. Near surface disposal is done at ground level, or in caverns below ground level (10 m depth). Ground level disposal is suitable for the Sri Lanka because capacity of the plant is not very high.

There are two main methods have been used for the HLW disposal. They are mined repositories and deep borehole. Mined repository is the oldest method of deep geological disposal and many countries have been using this method for dispose HLW. The depth of this disposal is between 250 m and 1000 m. Mined repository consists caverns or tunnels into that packaged waste would be placed. Multiple barriers should be applied for the fuel assembly for reducing the heat and radioactive products to the environment. For the digging of deep underground repository using standard mining or engineering (eg: under land or near shore), most suitable types are rock units without major underground water flow that are stable and safe. Potential host rocks are rock salt, clay/ argillaceous rock and crystalline rock. Rock salt is the most suitable because it has higher thermal conductivity and high resistance.

Deep borehole disposal method has been developed (but not implemented yet) in several countries. It is more protective concept than mined repository. But stored fuel cannot be reused again. Deep boreholes are narrow, vertical holes drilled deep (depth of up to about 5000 m) in to the earth. 400 steel canisters can be contained in a single borehole of disposal zone (each canister is 5 m long and one third to half meter in diameter). This is more effective method for low volume waste and this will be expensive for the large volume of waste. These boreholes can be drilled off shore as well as on shore in both crystalline and sedimentary host rocks.

Those methods are suitable for the HLW disposal in Sri Lanka. But deep borehole method is most suitable because capacity of the selected plant is not very high. Therefore waste will be less. But this deep borehole concept is still under development state. Most of the countries expect to replace mined repository disposal options to borehole disposal. By considering the protection to environment and people, deep borehole disposal scores high mark than mined repository disposal. Mined repository also better way to dispose HLW. But protection is less than deep borehole disposal.

8.2 Suitable site for the waste disposal

Site selection for the waste disposal should be done very carefully. There are some special factors to be considered before selecting a site for the disposal. These factors are free from earthquake threats, the area must be isolated area and underground water flow should be less, Low risk of flood and natural disasters, etc.

The selected location for the plant is Delft Island. This delft island is free from above factors. Total land area of the area is 45 km^2 and all the people should be relocated in another area. Therefore whole island can be used for the plant purposes (only 25 hectares are belongs for the plant footprint). Therefore some part of this island can be given for the waste disposal. The delft island consists of coastal vegetation, dry pasture land, managed home gardens, Palmyra wood land, thorn scrub jungle, and wet pasture land. Underground water distribution also less in this area. Mined repositories and deep borehole disposal can be implanted onshore, near shore or offshore. Therefore part of this island can be used for this purpose.

9 LOAD FLOW ANALYSIS

The load flow analysis was done by using PSS/E software. Transmission network of the upper part of country was taken for the analysis because selected location was Delft Island and the nearest grid was Chunnakam grid substation. Twelve of 132 kV grid substations (Chunnakam, Kilinochchi, Vavunia, Anuradhapura, Puttalam, Trincomalee, Habarana, Ukuwela, Kiribathkubura, and Kurunegala) and one 220 kV grid substation (New Anuradhapura) were added for this load flow analysis. The selected unit total capacity was 440 MW (2 x 220 MW PHWR). High power has to be transmitted through the cables (distance is 156 km to New Anuradhapura 220 kV grid substation). Therefore new transmission voltage was calculated using empirical formula of voltage selection. The selected transmission line voltage was 400 kV. Therefore new two 400 kV grid substations were implemented. Generation voltage of the plant is 12.5 kV, this voltage is step up to 400 kV and 132 kV through three winding transformer and 132 kV line was connected to 132 kV Chunnakam grid substation and Delft 400 kV switchyard was connected to the New Anuradhapura 400 kV grid substation (implemented).

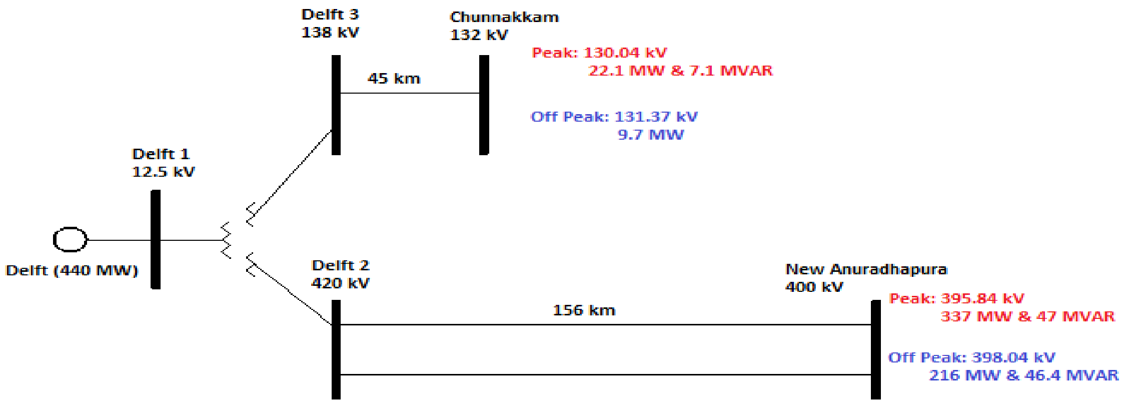

Figure 3: Transmission line connections to grids from Delft

10 CONCLUSION

NPP can be considered as one of potential candidate to meet the future based demand of the Sri Lankan power system.

A present the base load is not sufficient for the NPP, that is considered as base load power plant. However, according to the load growth there will be sufficient base load for NPP after ten to fifteen years. As per the literature review and the current practice of NPP in other countries smaller type reactor will be most suitable type of reactor for NPP in Sri Lanka.

Location of the NPP is one of the important aspect since general mass of the people do not accept the construction of a plant nearby. Considering this fact, the locating NPP within main island may face lot of opposition from the people and it might become a social and political issue. Therefore, one of the solution for this is to locate NPP in a small island in the norther sea of the country. The island can be isolated from the people by shifting residence of the island to some other places. The water requirement for the NPP can be met using desalination of sea water. According the land area of the island the part of the island can be utilized for the disposal of radioactive waste.

The analysis shows that capacity of the NPP is 440 MW and it is suggested to connect the NPP to the national grid by two lines: 132 kV at Chunaakam and 400 kV New Anuradhapura.

ACKNOWLEDGEMENTS

The authors greatly appreciate data given by Ceylon Electricity Board (CEB) for the details of long term generation expansion plan and current situation of electricity generation and demand of Sri Lanka.

REFERENCES

1. Banerjee, S., (2014), "Pressurized Heavy Water reactor", Bhabha Atomic Reaserch Center Mumbai.

2. Ceylon Electricity Board - Transmission and Generation Planning Branch, 2015, CEB Long term generation expansion plan 2015-2034.

3. Criteria for regulation of health and safety of Nuclear Power Plant Personal, the public and environment, (2011), [ebook] Atomic Energy Regulatory Board Mumbai

4. Goonatilake, A.S., Ekanayake, S., Kumara, T.P., Liyanapathirana, D., Occasional Papers of IUCN Sri Lanka, (2013). Sustainable Development of Delft Island: An ecological, socio-economic and archaeological assessment

5. IAEA Nuclear Energy Series, Managing Environmental Impact Assessment for Construction and Operation in New Nuclear Power Programmes. (2017). [ebook]

6. International Atomic Energy Association, 2015. Site survey and site selection for nuclear installations. [Online]. Available at: http://www-ns.iaea.org/standards

7. International Atomic Energy Association, 2016. Radioactive waste management.

8. Kaiga nuclear power plant project. (1974). [ebook]. Chapter 3. Available at: http://shodhganga.inflibnet.ac.in/bitstream/10603/94644/9/09_chapter%203.pdf

9. Managing Siting Activities for Nuclear Power Plants, (2017), IAEA Nuclear Energy Series, Available at : http://www-pub.iaea.org/MTCD/Publications/PDF/P1565_web.pdf

10. Muktibodh, U.C. (2011). Design, Safety & Operability Performance of 220MWe, 540MWe & 700MWe PHWR in India. [ebook] IAEA Headquarters,Vienna, Austria. pp.1-127.

11. Murray, R.L. (1986). 'Radioactive waste management and disposal', 74(4), IEEE.

12. Ramana, M.V., Antonette, D. and Reddy, A.K.N. (2014). "Economics of nuclear power from heavy water reactors", Available at: iei-asia.org.

13. Ranaveera, M. (2015). 'Nuclear technology for socio-economic development & electricity generation in Sri Lanka', Sri Lanka Atomic Energy Board.

14. Safety series No.115, 'International Basic Safety Standards for Protection Against Ionizing Radiation & for the safety of Radiation Sources', IAEA, 1996

15. Siyambalapitiya, T., Samaliarachchi, L.A., Nanthakumar, J. and Perera, N.G.S., (2002), Power System Planning – ECX 6332, Session [1-23].

16. Subki, M.H. (2015). Small Modular Reactor Designs and Technologies for Near term Deployment, Nuclear power technology development section- IAEA

17. Thakur, A., Jadhav, M., Chavan, N. and Ranveer, A. (2015). 'Radioactive waste management', *International Journal of Innovations in Engineering Research & Technology*, 2(5), pp. 4-9 [Online]. Available at: http://www.researchgate.net/publication/278683473

18. Venkatesh, S. and Gamage, P. (2015). Development of seismic hazard maps for Sri Lanka. [online] Available at: https://www.researchgate.net/publication/280382858_Development_of_seismic_hazard_maps_for_Sri_Lanka