IOP Conf. Series: Earth and Environmental Science **132** (2018) 012009 doi:10.1088/1755-1315/132/1/012009

An Extreme Meteorological Events Analysis For Nuclear Power Plant (NPP) Siting Project at Bangka Island, Indonesia

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Abstract. The potential sources of meteorological phenomena in Nuclear Power Plant (NPP) area of interest are identified and the extreme values of the possible resulting hazards associated which such phenomena are evaluated to derive the appropriate design bases for the NPP. The appropriate design bases shall be determined according to the Nuclear Energy Regulatory Agency (Bapeten) applicable regulations, which presently do not indicate quantitative criteria for purposes of determining the design bases for meteorological hazards. These meteorological investigations are also carried out to evaluate the regional and site specific meteorological parameters which affect the transport and dispersion of radioactive effluents on the environment of the region around the NPP site. The meteorological hazards are to be monitored and assessed periodically over the lifetime of the plant to ensure that consistency with the design assumptions is maintained throughout the full lifetime of the facility.

Keywords : meteorological, nuclear power plant, hazards.

1. Introduction

Nuclear installations must be operated safely, securely and reliably to meet the requirements and safety criteria since the early stages of siting, design, construction, and even activities in the previous stage to the operational stage and also safety when handling and during decommissioning and radioactive waste management. According to the guidelines on siting guide: site selection and evaluation criteria for an early site permit application, that the siting, design, construction, operation and decommissioning are the five major stages that need to be considered in the installation of nuclear power plants. The site evaluation program consists of provisions and activities to be implemented for the evaluation and characterization of the site to ensure the fulfillment of all the requirements. Furthermore, every nuclear power plant is also necessary to formulate a comprehensive emergency plan that will help ensure public safety. This plan should provide appropriate measures, by way of security measures, for implementation at the specified time so that the radiation exposure to members of the general public will remain in the level of intervention (Bapeten , 2014; Batan, 2014; Bishnoi et al., 2005; and EPRI, 2002).

Meteorological phenomena may cause danger either singly or in combination, which may affect the safety of nuclear installations. Thus, evaluation of the nuclear installation site for the meteorological aspects referred to in Bapeten (2014) about the site evaluation for the nuclear installation meteorological aspects, which include: (a) monitoring and data collection as well as meteorological information; (B) Evaluation of meteorological hazards; and (c) determination of the basic parameters of the design for the meteorological aspects. Meteorological measurements in the vicinity of a nuclear power plant are needed to assess the dispersion of the releases of radioactive materials in the atmosphere. One purpose of this paper is to examine the potential of meteorological hazards that can hinder the process of installation and construction of nuclear power plants. Monitoring and data collection as well as meteorological information referred to in points (a) includes: a. The collection of data and meteorological information from outside of site locations (off site); and b. Monitoring and gathering meteorological data at the site locations (on site). Meteorological hazard evaluation referred to in points (b) includes: a. Value extreme meteorological parameters; and b. Extreme weather phenomena. Meanwhile, the determination of the basic parameters of the design for the meteorological aspects referred to in points (c) includes: a. Value extreme meteorological parameters; and b. Extreme weather phenomena (see Bapeten , 2014; CNSC, 2008 and Roshan et.al., 2006).
There were four meteorological variables which need to be addressed for meteorological hazard. Those four variables are air temperature, wind speed, precipitation (liquid equivalent) and snowpack. It also needs to analyse hazardous, rarely occurring meteorological phenomena such as lightning, tropical cyclones, typhoons, hurricanes, tornadoes and waterspout. Lightning was a common event in the Indonesian region, including Bangka, due to high convective activity in this region, but typhoons, hurricanes, and tornadoes almost never happen in this region. No record has ever been found about the occurrence of such phenomena. Water spouts is also a rare phenomenon, but it was likely to occur in this region (IAEA, 2011). The objective of this paper is to present all results of the studies, assessments and investigations in relation to the meteorological hazards assessment and dispersion characteristics. Furthermore, the scope of this paper covers the description of the tasks and the results obtained in relation to the meteorological aspects regarding to the assessment of meteorological hazards for the design of the Nuclear Power Plant at the West Bangka area of interest.

2. Methodology

The study area located in West Bangka area of interest in Indonesia (see Figure 1). For assessing the extreme values of meteorological variables and rarely occurring hazardous meteorological phenomena as well as for determining the specific characteristics of the site that affect the transport and dispersion of radioactive effluents to the environment, specific and detailed information should be collected. The meteorological instruments (on site) were already installed on the tower and on meteorological instrument park and full operation since 1 January 2012. In detail, the meteorological instruments and the sensors arrangement are presented in Table 1. Meteorological data available from the site consist of wind (speed and direction) and air temperature at four heights, i.e. 10, 40, 60, and 80 m; air pressure and relative humidity at one height i.e. 10 m. Other data available are precipitation and solar radiation. All data are stored in a data logger and transmitted to a personal computer every one hour where the data are stored.

An off site meteorological data obtained by formal and non-formal meteorological stations. Indonesian Agency for Meteorology Climatology and Geophysics (BMKG) is the formal meteorological stations associated to the World Meteorological Organization (WMO) and reporting all meteorological data such as precipitation, air temperature, air pressure, wind, relative humidity etc. (BMKG, 2010). Non-formal meteorological stations operated by Agriculture Department and only reporting precipitation data. These meteorological stations used for the baseline analysis are listed in Table 2 along with their distance from West Bangka (WB) area of interest, time period and consistency of data record. Meteorological hazards are associated with extreme meteorological conditions and with rarely occurring hazardous meteorological phenomena.

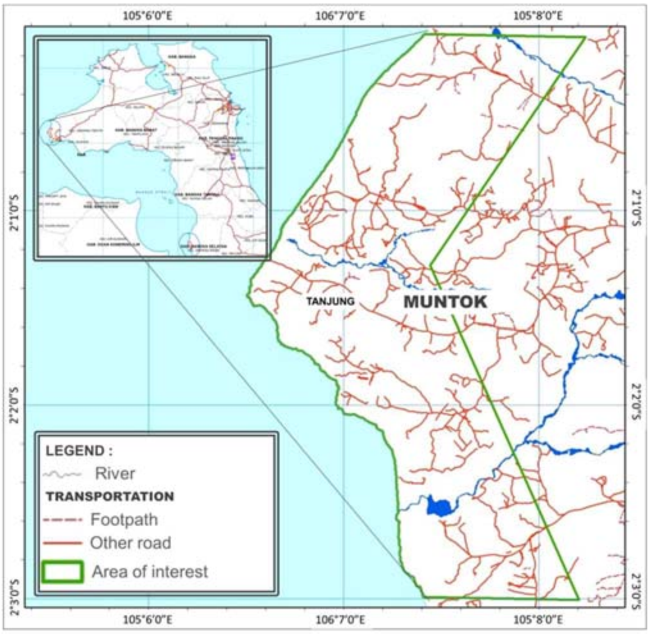

Figure 1. Location of West Bangka Area of Interest.

The meteorological hazards as well as treated in the IAEA Safety Guide are those caused by external events i.e. unconnected events with the operation of a facility or the conduct of an activity that could have an effect on the safety of the facility or activity. Methods for the assessment of hazards are often divided into two broad approaches: deterministic methods and probabilistic methods. When a statistical analysis is performed, it is typically based on time series analysis and synthesis. It is assumed that the series represents both deterministic components and an unknown number of random components, and that the random components are reasonably independent. Using these methods, gaps and missing data and outliers of the available data set should be adequately taken into account. Data analysis including tabulation of the primary and secondary meteorological data, short and long-term, both of on sites or even off sites. These tabulations are made into yearly, monthly, daily and hourly. Missing data analysis being concerned since in-situ measurements or reanalysis and satellite data provides inconsistency.

Table 1. List of the instruments installed on the West Bangka area of interest.

No.	Name of Instruments	Placement	Utility	Qty. (pc)	Status
1	Anemometer	10, 40, 60, 80 m	Wind speed and direction measurement	4	ok
2	Wind Vane	10, 40, 60, 80 m	Wind speed and direction measurement	4	ok
3	Humidity Temperature sensor with weather & Radiation S.	10 m	Multi measurement	1	ok
4	Anemometer Young propeller	10, 40, 60, 80m	Wind speed and direction measurement	4	ok
5	Solar Panel ET Module	1.5 m	Generate solar power	1	ok
6	Solar Powered Warning (lamp)	80 m	Power indicator	1	ok
7	Lighting Arrester	83 m	Prevent power line interruptions by lightning	1	ok
8	Tipping Bucket Rain Gauge	1 m	Precipitation measurement	1	ok
9	Pyrometer	1.5 m	Radiation measurement	1	ok
10	Data logger	4 m	Record data	1	ok
11	Temperature Sensor	10 m	Temperature measurement	1	ok
12	Barometric Pressure sensor	4 m (in cabinet)	Pressure measurement	1	ok
13	Net radiometer	1.5 m	Radiation measurement	1	ok
14	Lighting sensor	1.5 m	Lightning Measurement (Cloud to Ground)	1	ok
15	Air pressure sensor	1.5 m	Pressure measurement	1	ok
16	Solar Panel ET Module	1.5 m	Generate solar power	1	ok
17	Tipping Bucket Rain Gauge	1 m	Precipitation measurement	1	ok
18	Pyranometer	1.5 m	Radiation measurement	1	ok
19	Net radiometer	1.5 m	Radiation measurement	1	ok

Table 2. Summary of meteorological stations in the regional of the NPP study area.

Station name	Coordinates		Distance (km) from WB	Period	Consistency**
	Lat.	Lon.			
Pangkalpinang	2°10'0.1"S	106°7'59.9"E	114	1980-2012	Good
Palembang	2°54'0.0"S	104°42'0.0"E	109	2002-2012	Good
Klapa*	1°53'17.70"S	105°38'47.61"E	60	1971-2000	Poor
Muntok*	2°01'23.03"S	105°14'26.94"E	14	1971-2000	Poor
Pemali*	1°55'50.16"S	106°00'20.48"E	99	1971-2000	Poor
Sungai Liat*	1°52'32.91"S	106°05'40.03"E	110	1971-2000	Poor
Belinyu*	1°38'13.60"S	105°49'48.88"E	89	1971-2000	Poor

*Non-formal station
** Calculated by total data availability

3. Results and Discussion

3.1. Extreme Meteorological Events

Extreme winds, air temperature and precipitation were studied. A minimum of a 30-year data set of on-site measurements is necessary to perform an extreme value analysis. Where a 30-year dataset was not available, it was possible to interpolating data using regression analysis in order to create a minimum 30-year dataset. Given that the West Bangka areas of interest measurements do not cover a 30-year period, this became a necessary calculation before being able to perform the extreme value analysis. Pangkalpinang was used as nearby meteorological station data to develop a long-term analytical data set for the West Bangka areas of interest. The values presented in this section are independent of the possible variations due to climate change.

3.1.1 Wind speed. A 30-year data set was created by correlating the existing of data on site to 30-year data from Pangkalpinang station, the nearest meteorological station with a similar climatology that recorded sustained wind speeds for that period. An extreme value analysis was then performed on this new 30-year data set in the West Bangka areas of interest. The results of this statistical analysis are predictions of maximum values for a set period in the future. A return period of 2, 5, 10, 25, 50, and 100 years is the most interest as it encompasses the entire lifecycle of the plant. Standard deviation is quoted as a measure of uncertainty in the calculation and all subsequent extreme value analysis. This exercise was done for the10 m heights (see Table 3) and also summarized of maximum wind speed (see Table 4) :

Table 3. Extreme Value Predictions for 10 m of Wind speed at the West Bangka areas of interest.

No.	Return Period (years)	Wind speed (m/s)
1	2	28
2	5	30
3	10	32
4	25	33
5	100	35

Table 4. Summary of Maximum of Wind Speed at the West Bangka areas of interest.

No.	Date	Wind (m/s)
1	12 Januari 2012	16.9
2	18 Februari 2012	15.8
3	20 March 2012	17.1
4	01 April 2012	15.5
5	08 May 2012	16.3
6	09 June 2012	19.2
7	26 July 2012	12.5
8	05 August 2012	12.5
9	02 September 2012	12.4

3.1.2. Air temperature. Similar to the wind speed data, a few of temperature measurements are only available at the South Bangka areas of interest. A regression analysis was done with the Pangkalpinang station, the nearest meteorological station with a similar climatology that recorded sustained air temperature for that period.These analysis was done as seen in Table 5 below. For the analysis of maximum temperature >32.2 °C and summary of maximum air temperature described in Figure 2 and Table 6 respectively.

Table 5. Extreme Value Predictions for Air Temperature at the West Bangka areas of interest.

No.	Return Period (years)	Air Temperature (^{0}C)
1	2	32.2
2	5	32.3
3	10	32.4
4	25	32.8
5	100	34.6

Table 6. Summary of Maximum of Air Temperature at the West Bangka areas of interest.

No.	Date	Temperature (°C)
1	15 January 2012	30.7
2	25 February 2012	30.5
3	10 March 2012	30.5
4	23 April 2012	32.6
5	17 May 2012	33.0
6	04 June 2012	32.6
7	21 July 2012	32.0
8	12 August 2012	32.7
9	23 September 2012	33.0

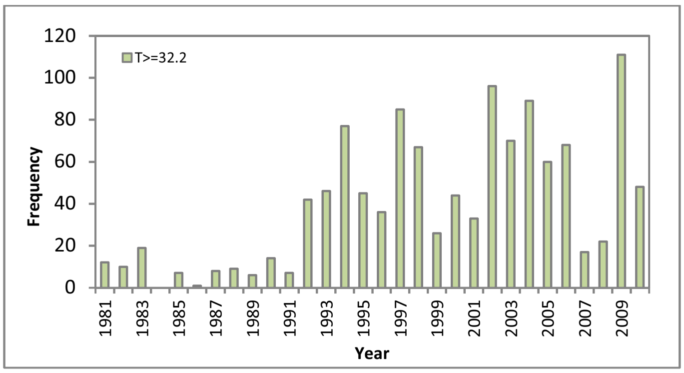

Figure 2. A 30-year of maximum temperature with a threshold 32.2 °C.

3.1.3. Precipitation.. While a few of precipitation measurements available at the West Bangka areas of interest, Pangkalpinang station are the nearest meteorological station with a similar climatology that recorded sustained precipitation for that period.

Table 7. Extreme Value Predictions for Precipitation at the West Bangka areas of interest

No.	Return Period (years)	Precipitation (mm/hr.)
1	2	104
2	5	132
3	10	150
4	25	171
5	100	210

Figure 3 below show the frequency of the precipitation with a >50 mm of threshold, with a total frequency during the years 1981-2010 are 263 and exist for every year. From the total of frequency as a cumulative, the probability occurrence of precipitation>50 mm/day calculated and shown as well as in Figure 4 which is more than 14% lie on January and April; at least 10% on November, December and March. Summary of maximum precipitation described in Table 8 below.

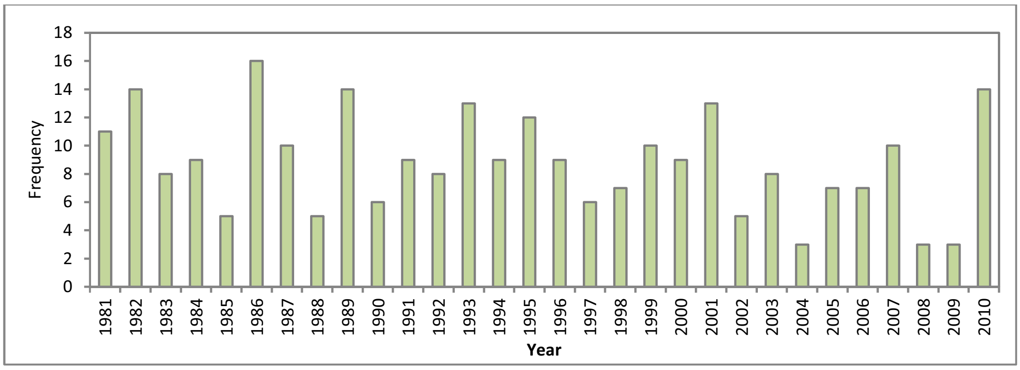

Figure 3. 30-year frequency of precipitation with a >50 mm/day of threshold.

Table 8. Summary of Maximum of Precipitation at the West Bangka areas of interest.

No.	Date	Precipitation
1	20 January 2012	28.8
2	26 February 2012	76.1
3	15 March 2012	93
4	24 April 2012	16.9
5	23 May 2012	31.5
6	16 July 2012	15.1

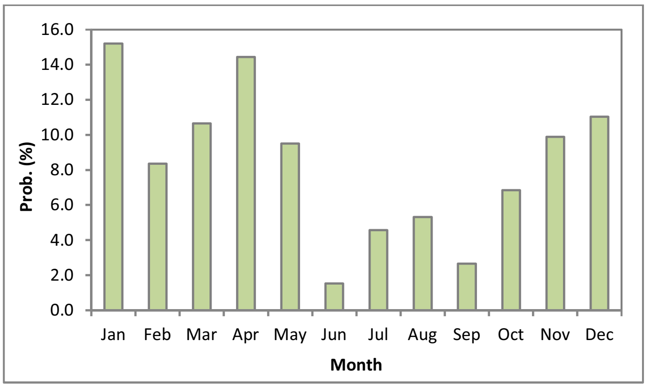

Figure 4. The probability occurrences of precipitation with a >50 mm/day of threshold.

3.2. Interpretation of Design Basis Parameter

The proposed design basis value for meteorological parameters with an interim interpretation at West Bangka area of interest are established as follows, if a return period of 100 years is adopted:

Wind Speed at H = 10 m	35.0 m/s
Air Temperature at H = 10 m	34.6 ^{0}C
Precipitation	210 mm/day.

Concerning the proposed design basis value, the following point should be noted:

The proposed design basis value is established by applying of Pangkalpinang meteorological station as data reference, because meteorological data at West Bangka area of interest is only one (1) year at this moment. it is however recommended that the design basis values for West Bangka area of interest should finally be re-evaluated and established based on the long-term meteorological data at the site itself.

4. Conclusions

The potential sources of meteorological phenomena in West Bangka area of interest are identified and the extreme values of the possible resulting hazards associated which such phenomena are evaluated to derive the appropriate design basis for the nuclear power plant. The appropriate design bases shall be determined according to the Bapeten applicable regulations, which presently do not indicate quantitative criteria for purposes of determining the design bases for meteorological hazards. These meteorological investigations are also carried out to evaluate the regional and site specific meteorological parameters which affect the transport and dispersion of radioactive effluents in the environment of the region around the nuclear power plant site. The meteorological hazards are to be monitored and assessed periodically over the lifetime of the plant to ensure that consistency with the design assumptions is maintained throughout the full lifetime of the facility. For all such purposes indicated above, the recommendations and guidelines from IAEA Safety Guide SSG-18 "Meteorology and Hydrology Hazards in Site Evaluation for Nuclear Installation", were applied. The proposed design basis value for meteorological parameters with an interim interpretation at Bangka area of interest are established as follows, if a return period of 100 years is adopted: wind speed at height 10 m are 35.0 m/s; air temperature at height 2 m are 34.6 °C; and rainfall are 210 mm/day. Concerning the proposed design basis value, the following point should be noted: The proposed design basis value is established by applying Pangkalpinang meteorological station as data of reference, because meteorological data at site area of interest less than 2 years at this moment. it is however recommended that the design basis values for site area of interest should finally be re-evaluated and established based on the long-term meteorological data at the site itself.

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