Meteorological monitoring system for NPP "Kozloduy"

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Abstract

This work presents the features of the system providing meteorological monitoring of the Bulgarian NPP "Kozloduy". It discusses the choice of representative for the particular region sites for location of meteorological stations, characteristics of measurement and telecommunication means, structure and operative algorithms of the system as a whole and use of diffusion atmospheric models. Spatial variation of wind characteristics over the Kozloduy region is demonstrated, showing the necessity to preprocess meteorological data when using Gaussian diffusion model.

1. Introduction

Yet in normal operation Nuclear Power Plants (NPP) release differing by kind and composition pollutants which, although in quantities considerably lower than the maximum admissible concentration (MAC), should be monitored. In case of accident the amount of released radionuclides could considerably exceed MAC. Measuring only radioactive substances' concentration and deposition at certain points of the region merely gives a snapshot of the situation. It couldn't give any suggestion for pollution spatial characteristics, not to mention its time variations. It is because there is no information about the condition of the environment in which pollution takes place – Earth atmosphere. Such approach doesn't yield good results in obtaining realistic assessment of NPP impact on the environment. For these considerations, International Atomic Energy Agency (IAEA) imposed the requirement for obligatory equipment of NPP with meteorological monitoring systems. Nowadays these are automated systems for meteorological monitoring (ASMM), operating on-line. Such ASMM shall provide the measurement of the basic metrological parameters, pollution fields modeling, assessment of concentrations and depositions of pollutants of different kind, and forecasting of their time and spatial variation. Here the ASMM of operating NPP "Kozloduy" will be described. The system is designed by the National Institute of Hydrology and Meteorology with the Bulgarian Academy of Sciences and produced by the Consortium "MS&E" – Bulgaria. ASMM meets the Safety Standards Series requirements of International Atomic Energy Agency (IAEA) and those of the national Nuclear Regulatory Agency..

2. Automated meteorological monitoring system for NPP Kozloduy.

ASMM for NPP Kozloduy meets all requirements of the existing national and international regulations, that is:

- ♦ provides, in normal operation and in accident, real-time weather data, for:
  - wind speed and direction at 10 m height, averaged for 10 min period;
  - precipitation intensity and amount;
  - variance of wind direction;
  - Pasquill stability categories;
  - air temperature and relative humidity;
  - atmospheric pressure.
- ♦ provides, in case of accident in NPP Kozloduy, real-time data for:
  - atmospheric mixing layer height over the station area;
  - main flow velocity and direction.

- archives and stores on technical carrier whole meteorological information for NPP Kozloduy site for the entire period of its operation;
- has reliably verified numerical dispersion model for calculation of diffusion in the atmosphere of radioactive substances, concentrations, depositions, and doses in NPP zones of responsibility;
- ASMM is protected, maintained and serviced, and calibrated within the regulated terms; it provides at least 90% of annual data.

2.1. Accounting for terrain influence when determining the number and location of measuring devices

ASMM for NPP Kozloduy is designed in 1992 and implemented in 1995. The choice of the number and location of measuring instruments takes into account terrain features, the requirements of reliable digital information transfer via VHF radio channel and existing infrastructure. Three automated meteorological stations ***MS&E-3RD*** (AMS) are located at three sites, typical for the area:

- AMS1 is located on the plateau south of NPP Kozloduy, elevated +90 m compared to NPP site. This place is typical for the greater part of the area around NPP Kozloduy;
- AMS2 is located in the low part, close to the Danube river and is 15 m lower of the NPP site. This AMS is representative of the wind in case of calm weather over the region, as it registers the channel effect of the big river;
- AMS3 is situated in the area where rivers Skat and Ogosta flow into the Danube and is elevated by +20 m over the NOO site. This AMS registers the effect of the two deep river beds on the wind..

This siting of AMS allows correct wind field retrieval over the whole monitored area, on data from the three local measurements. Besides the standard meteorological variables - air temperature, relative humidity, wind velocity and direction, precipitation amount and intensity, AMS ***MS&E-3RD*** determine also Pasquill stability category, using the method of horizontal wind direction variance.

Automated system for aerological sounding (ASAS) is used to obtain necessary data for main flow direction and speed and mixing layer height. ASAS is situated to the west of NPP Kozloduy, accounting for the prevailing flow in the region. Digital DFM-98 radiosondes with GPS positioning and GK90C ground station are employed. A model is integrated to ASAS for automated determination of main flow speed and direction and mixing layer height according to the obtained air temperature, relative humidity, and wind vertical profiles. ASAS is integrated informationally in ASMM and its data are automatically included into the common radio exchange. Location of measuring instruments is shown in Fig. 1.

2.2. Choice of appropriate dispersion model

Major requirements to dispersion models for assessment of radioactive substance transport in the atmosphere are formulated in IAEA normative documents and WMO regulations concerning meteorological aspects at normal run of the NPP and at emergency state.The are:

- To allow assessment of the short-term (a few hours) normalized concentrations and depositions, as well as the probability of occurrence of high values and pollution levels;
- To allow assessment of long-term (a year or more) summary (time integrated) normalized concentrations and depositions;
- To account for the change of source effective height due to the difference between the temperature of released gases or aerosols and environmental air, as well as the flow variation due to the presence of obstacles like buildings and other structures;

When describing released radionuclides, besides transport and diffusion processes, have to account for the following accompanying ones:

Figure 1.Location of measuring instruments of ASMM – NPP Kozloduy

- Radioactive decay and daughter products;
- Wet deposition:
    - In-cloud rain or snow;
    - Aerosol wash-out by the sub-cloud precipitation;
    - Aerosol capture in fog;
- Dry deposition;
- aerosol deposition or gravitational precipitation (of particles with dimension greater than 10 μm);
- Capture of aerosols and adsorption of gases in the presence of obstacles to the wind;
- Formation of aerosols;
- Accounting for resuspension by the Earth surface.

♦ The used mathematical models for the atmosphere dispersion shall be selected in compliance with the requirements of the study purposes, hopefully taking into account also the peculiaririrs of the source location.

It is important to know the limitations of the corresponding model, as in different applications depending on the task and the results looked for, the appropriate model could be selected. E.g., actually the most used models for assessment of the dose load to distances up to 10 km from the source, are Gaussian models. In some specific situations, e.g. complex orography, littoral zones and large rivers, very high chimneys, accounting for mesoscale transformations, etc., Gaussian models are not suitable. Then the more complex Eulerian and Lagrangian models are used.

ASMM of Kozloduy NPP still uses the numerical realization of a classical Gaussian for the doze load assessment.

In 2005 integration of a version of EMAP model (Eulerian Model for Air Pollution) / Syrakov (2002)/ is to be integrated. This is an Eulerian dispersion 3-D model for assessment of radionuclide concentration and deposition in the NPP Kozloduy, in normal and in possible accident state. The model uses Cartesian coordinate system with uniform discretization along the horizontal axis and non-uniform one along the vertical one. Horizontal coordinate surfaces which follow the terrain shape are denser near the Earth surface and become rarer with height, which corresponds to the characteristic profiles of meteorological elements in the atmospheric boundary layer – rapid changes at the ground and more smooth in height.

Diffusion schemes in EMAP are different. An explicit "open boundary" scheme is applied along the horizontal axis. Along the vertical one an implicit scheme with open upper boundary is used. The reason to apply implicit scheme is the non-uniformity of the network along the vertical. At the lower boundary a Neuman boundary condition is set, reflecting the process of dry deposition of pollutants when interacting with the Earth's surface. The wet deposition in EMAP is taken into account by a formula, similar to this for radioactive decay. Instead of half-life period (more precisely its reciprocal value) the exponent uses a coefficient consisting of the product of the rain intensity and the so called "wash-out" coefficient, dependent on the type of pollutant and the type of precipitation intensity as well..

The version used in ASMM of NPP Kozloduy differs from Syrakov D. (1997) by the addition of pre-processing for the wind and precipitation and obtaining assessments of doze loads as output. EMAP is verified in the framework of the ETEX experiment and in two intercallibrations carried out by the Meteorological Synthesizing Centre-East of EMEP in 1997 и 2000.

2.3. Functional scheme of ASMM in NPP Kozloduy

The means for ground meteorological measurements AMS1, AMS2 and AMS3 operate on-line and are connected in a common network.. ASAS operates only in accident state. The overall management of the measurement of vertical profiles of meteorological elements, archiving of row data and automatic running of the meteorological models for determination of mixing layer height and the velocity and direction of the main flow is performed by the ASAS computer. On turning on ASAS is automatically recognized and integrated into ASAS.

The principal meteorological computer is situated in the environment control center, It is provided with special software for management of operating mode of the devices for measurement, control and diagnostics of the ASMM operation, controlling of telecommunications, data visualization and archiving. Meteorological models for preprocessing of meteorological elements are also installed on this computer. The specialized software should automate to the highest degree all processes of data acquisition, screening, processing and submission of results, as the NPP operating staff usually possesses basic training in meteorology. Therefore, all necessary knowledge should be algorithmized and set up in this specialized software. .

Wind preprocessing is required because diffusion models operate with generalized wind data at the emission point. In case of a complex relief like at NPP Kozloduy, wind parameters at the site area often are different. Figures 2, 3 and 4 show the wind rose for speed (in m/s) for the three AMS on 23.11.2003.

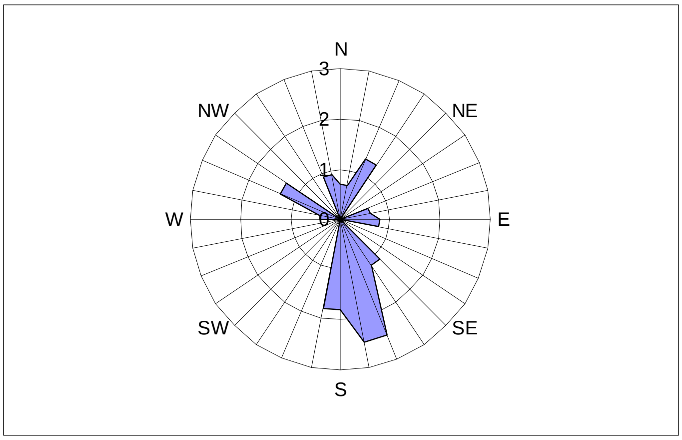

Fig.2 Wind rose plot for speed on 23.11.2003 at AMS1.

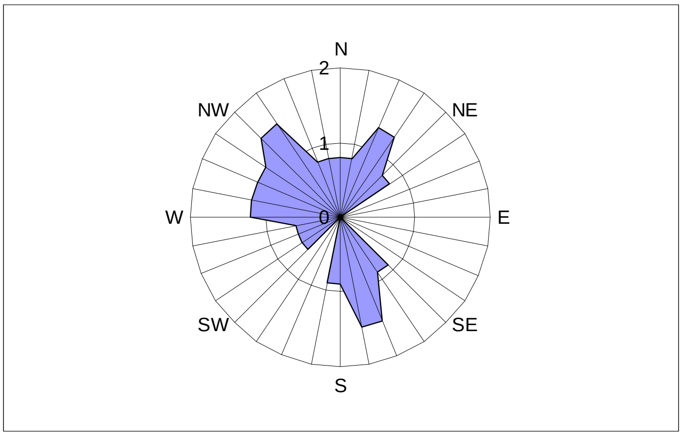

Fig.3 Wind rose plot for speed on 23.11.2003 at AMS2.

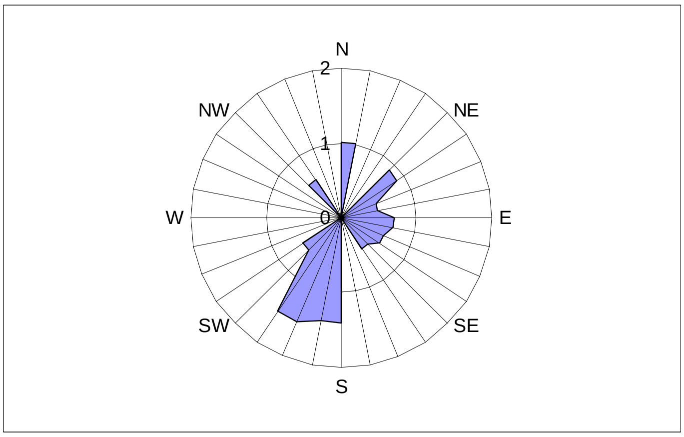

Fig.4 Wind rose plot for speed on 23.11.2003 at AMS3.

Differences in wind characteristics in the three measuring sites are a function, simultaneously depending on wind velocity and its direction. The preprocessing is based on empirical statistical model which transforms wind data from the three points into a generalized for the region value, used by diffusion models.

The situation concerning precipitation is analogous. Here main spatial differences are related to the precipitation type – continuous or shower and thus basic predictors in the statistical model are precipitation intensity and the spatial differences of its amount.

Additionally a second meteorological computer is installed in the Accident Control Centre taking control of ASMM in case of accident. Connection between ASMM measuring devices and the main meteorological computer is via UHF channel, and between the two meteorological computers at NPP Kozloduy – via internal network.

General functional scheme of ASMM – NPP Kozloduy is shown in Fig. 5.

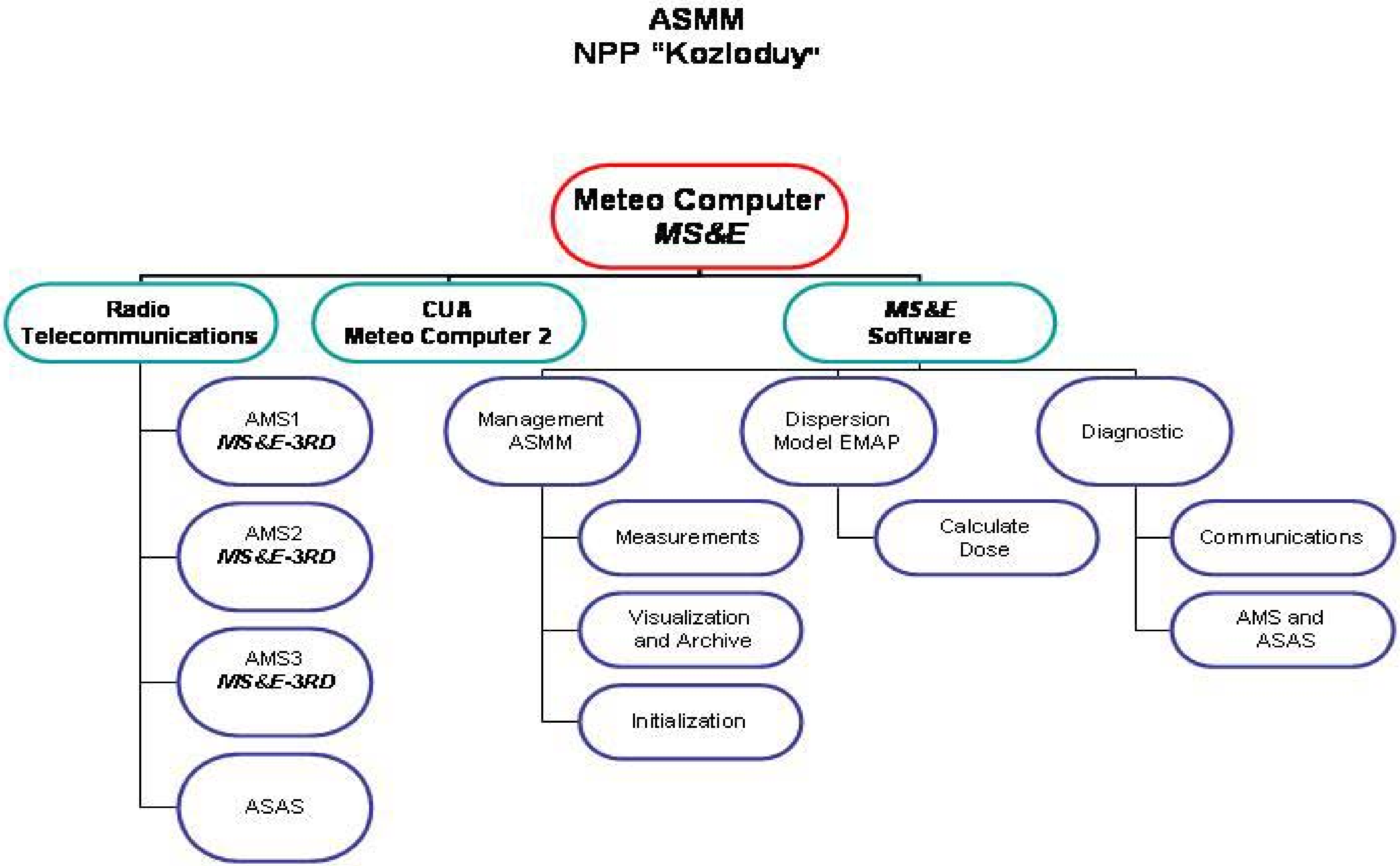

Figure 5. Functional scheme of ASMM in NPP Kozloduy

Conclusion

Many-sided aspects of a well-run up-to-date NPP meteorological monitoring system are shown. The need for a preliminary micrometeorological study is indicated, aimed at determining the smallest number of measurement means and their installation at proper sites in the monitored region, so that to retrieve with maximum reliability the fields of the meteorological elements. Selection of appropriate means of measurement and their management and information integration. Selection of appropriate dispersion model adequate to the conditions in the monitored region and development of empirical meteorological models for wind and precipitation data preprocessing. Creation of appropriate communication environment, adequate to NPP operation in normal and in accident state. Development of applied meteorological software, automating to the highest degree the entire process of acquisition, processing and visualization of meteorological information, in order that operating personnel could take the necessary decision.

All this is demonstrated on a particular automated meteorological monitoring system –of the Bulgarian NPP "Kozloduy", and shows the complexity of the meteorological task to design and develop such a system

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