IN INDIAN REAL TIME ONLINE DECISION SUPPORT SYSTEM (IRODOS)

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INTRODUCTION

Multi-level safety features are an inherent characteristic of nuclear technology and these are necessary to:

- Prevent an accident from occurring in the first place.
- Limit its magnitude in the unlikely event of an accident.
- Limit the consequences of the accident itself, in case it takes place.

In keeping with the traditional emphasis on safety, nuclear technologists were prompted by the Chernobyl accident (1986), to consider the consequences of accidents Beyond the Design Basis Accident (BDBA) scenarios, despite the fact, that the probability of such an occurrence was considered extremely low. These consequences, though highly unlikely, necessitate additional measures to protect the public from possible adverse radiological impact and it is in this context, that there is need for drawing up emergency preparedness plan for such contingencies.

The foremost part of a nuclear emergency planning are:

- An early prediction or assessment of the extent and significance of any accidental release of radioactivity to the environment.
- Rapid and continuous assessment of the accident.

The current emergency plans prepared and approved for practice in Indian Nuclear Power Plants (NPPs), fully depend on environmental radiation monitoring. This, along with prevailing site specific meteorological conditions are used, at deciding the areas / sectors effected for implementing countermeasures like iodine prophylaxis, sheltering, temporary relocation, evacuation etc.

This approach may have limited application in case of a BDBA scenario, wherein a long term release of the activity is anticipated, leading to change in effected sectors with time, due to change in meteorological conditions (specially the wind direction). Additionally, any countermeasure will require a certain duration (time lag) before it is being implemented, requiring an advance prediction of the sectors effected. Also, in case of a temporary relocation, it is important that during the transit period, the public should not be crossing the sectors having high radioactivity during their movement/ transport, thereby requiring the best escape route prediction, leading to minimum exposure.
to public, during such type of eventualities.

Keeping in view these limitations / requirements, a real time online nuclear emergency response system, with 72 hours meteorological and radiological forecasts, for off-site nuclear emergency under the frame work of “Indian Real time Online Decision Support System “IRODOS”, for Nuclear Power Plants (NPPs) has been designed and developed, which takes care of the predictive requirement for emergency planning.

It is an inter-divisional programme of the Health, Safety and Environment Group, BARC.

**SALIENT FEATURES OF IRODOS**

- This is a decision support system, to handle an offsite nuclear emergency, arising out of an unlikely event of a nuclear accident.
- It is a system similar to an operational European emergency response system RODOS.
- This system shows a 72 hr weather and radiological forecast at any instant of time.
- The system is designed for fixed sites (i.e. taking care of topography and local characteristics).
- The 72 hr weather forecast with an hourly resolution for this region, in a 10 km x 10 km, is provided by the National Centre for Medium Range Weather Forecasting (NCMRWF), Noida. This NWP (Numerical Weather Prediction) is updated every 24 hours.
- The NWP is used by RIMPUFF (Riso Mesoscale Puff Model) and predicts the atmospheric concentration, ground deposition, the atmospheric activity, below plume activity, deposited activity etc. on a 1 km x 1 km resolution, for various radionuclides (64). Finer grid resolution is achieved by mass consistency interpolation technique.
- These concentrations are used by a radiological dose code, COSYMA (Code SYstem from Maria) to predict the dose received by human population (public). This takes into account, the inhalation dose, plume dose, dose due to deposited activity etc.
- These doses based on the avertable dose concept are utilized in forecasting optimum counter measures like iodine prophylaxis, Sheltering, areas requiring Evacuation on a GIS (Geographical Information System).
- GIS shows the area, villages, cities etc. on which countermeasures are to be applied.
- Query specific population in a particular area, nearest Public Health Care Centres, nearest rallying point (collection centre), sheltering locations etc. are also provided to the user in the GIS.
- GIS also shows the logistics available like transportation, manpower, availability of iodine tablets etc. to carry out the countermeasures.
- The system shows the optimum transportation route to be followed, in order to have minimum exposure to radiological activity, during the implementation of countermeasures.
- In the day-to-day operation, a hypothetical, Beyond Design Based Accident (BDBA) scenario (NORMAL MODE) with high activity release is simulated, so that, all modules are activated at any instant of time. Information on the likely areas to be affected, areas requiring monitoring etc. in case of an accident are thus available to the user, at any instant of time.
- In case of a real emergency, which is detected by the field Environmental Radiation Monitors (ERMs), placed in the form of two rings, the system switches over to an EMERGENCY MODE from the NORMAL operating mode. Visual changes in the GIS display, along with alarm sound systems are activated, for alerting the operators.
- The ERMs are stand-alone solar power-based GM detectors with GSM communication devices.
- Based on the ERMs readings, the system calculates the likely source term using inverse calculation
and the actual meteorological conditions of the site.

- The realtime weather conditions are monitored using the Automatic Weather Stations (AWS) supplied by ISRO. The AWS are solar powered and data transmission is through satellite.

- The concentrations and dose fields calculated in the NORMAL mode are either downscaled or upscaled, for initial phase action in the EMERGENCY mode. The entire calculations are re-run to simulate the scenario using the estimated release rate, for later phase EMERGENCY actions.

- Since a practical duration is required in a real world, the advanced radiological forecast and advanced counter measures predicted by the IRODOS system, will be very useful, to the Emergency Response Team handling the crisis.

A flow sheet of the IRODOS system is shown in Fig. 1.

NUMERICAL WEATHER PREDICTION

The system in its present form gets 72 hours forecasted meteorological data [Numerical Weather Prediction (NWP)] from mesoscale weather forecast model MM5, operational at NCMRWF, Noida. The NWP is available in grid size of 10 km x 10 km over the horizontal domain of 150 km x 150 km with NPP at the centre and covering a vertical height of about 15 km.

ATMOSPHERIC TRANSPORT MODELLING

The NWP data is used in driving the atmospheric contaminant dispersion model, a model based on the concepts of RIMPUFF, to simulate the transport and deposition of various radionuclides in case of an accident at NPP, with output in a grid size of 1 km x 1 km and a time resolution of 1 hour upto a radial distance of 75 km from the reactor centre.

RADIOLOGICAL DOSE MODELLING

The dispersion model results are utilized in calculating the radiological doses, received by the population, through various intake pathways, using COSYMA code. Optimum countermeasures, based on IAEA's avertable dose concept are also predicted using this code.

NORMAL AND EMERGENCY OPERATION

The system in its normal operation runs with a high release term (possibilistic source term), to simulate a Beyond Design Based Accident (BDBA) scenario, with all countermeasure options activated. An accident / event is sensed by the IRODOS system using the reactor (NPP) status sensors and / or from the field environmental radiation monitors, located around each
The environmental radiation monitoring network planned in the form of two rings (one at 500 m and another at 1600 m) around each of the NPPs to sense an accident is shown in Fig. 2.

The indigenously developed solar powered environmental radiation monitor to be used in the above network, is also shown in Fig. 2. Data from these monitors is continuously received and updated at the IRODOS centre, using GSM-based wireless data communication devices, inbuilt in this system.

Once an event/accident is sensed, IRODOS system switches over to an emergency mode. In this mode, it calculates the likely source term based on the ring monitors (inverse calculations) or from the NPP status data and using the real-time weather data from AWS. The atmospheric concentration and dose contours are updated, based on this source term for early phase action. The entire dispersion and dose calculation with the new source term is activated along with the estimation of optimum countermeasures, for later phase decisions.

In IRODOS, there are two approaches for estimating source term

- First is by using pre-release estimates (anticipated from nuclear power corporations Centralised Operating Plant Information System; COPIS), which are based on actual NPP process status (if available) and based on postulated accident scenarios.
- Second is by using post release estimates based on the gamma dose rate measurements of the installed online environmental radiation monitors.

The main assumptions used, in estimating the source term using the second approach is that, the integrity of the containment would remain intact, however, the release may occur through stack or through leakages at the ground level or both.

Measured dose rate $D_w$ recorded at receptor (500 m or 1600 m) can be represented by

$$D_w = \sum_j \frac{Q_j \times DRF_{ijk}}{Q_{ik}}$$

where ‘i’ is the index for weather category, ‘j’ is the index for height of release, ‘k’ is the index for receptor location, $Q_j$ is the quantity of radionuclide released at height j and ‘DRF’ represents Dose Response Function for respective i, j and k for unit activity (from a possible mixture of radionuclides).

Using the above relation and an iterative inverse approach, a time-dependent source term ($Q_j$) along with likely radionuclide spectrum is estimated.

**GEOGRAPHICAL INFORMATION SYSTEM (GIS)**

The atmospheric concentration, deposition and radiological doses are displayed on a GIS platform. The various database (layers) available in GIS include city and village boundaries, hospitals, schools, police...
and fire stations, sheltering and rallying points, vegetation cover and live stocks, transportation, logistics available, road network etc. Figs. 3 and 4 show a typical concentration output and counter measures predicted for a hypothetical release at NAPS, Narora for visualization and for action to be taken by decision makers.

IMPLEMENTATION

The first prototype system developed under this programme for NAPS, Narora, is operational at the Emergency Response Centre of BARC, Mumbai for the last two years and the demonstration version at NAPS, Narora is operational since the last six months. It is planned to deploy these systems in a phased manner at various NPPs of the Nuclear Power Corporation of India Limited (NPCIL).

ACKNOWLEDGEMENT

The project is a coordinated effort of various divisions of Health, Safety & Environment Group (HS&EG) of Bhabha Atomic Research Centre (BARC), Mumbai, India. Authors duly acknowledge the guidance and motivation provided by Mr. H.S. Kushwaha, Director, HS&EG; Dr. A.K. Ghosh, Head, RSD, Mr. M.L. Joshi, Head, HPD; Dr. D.N. Sharma, Head, RSSD; Mr. V.D. Puranik, Head, EAD and Dr. Pradeep Kumar, Head, ERSM. The efforts and support extended by Ms. P. Indumati of EAD; Dr. D. Dutta and Ms. S. Chitra of HPD; Mr. V.M. Shanware, Mr. P.K. Sharma and Mr. B. Ghosh of RSD; Mr. Rajvir Singh of RSSD and the continued operational support from Computer Division, BARC; NPCIL Mumbai; NCMRWF, NOIDA; ISRO, Bangalore; SAC, Ahmedabad; NRSA, Hyderabad and RRSSC, Nagpur is duly acknowledged.