# Neural Approaches to Blind Separation and Cumulant Analysis and Its Application to Diagnostics of Nuclear Power Plants

**Alexei Ourmanov**
Institute of Physics and Power Engineering
Bondarenko sq. 1
Obninsk, Kaluga region, 249020, Russia
urmanov@ippe.obninsk.com

The problem concerned is to explore the possibility of using artificial intelligence techniques, namely neural networks, and design the appropriate neural network-based algorithm to detect signals of interest from multi-channel data recordings. The problem finds application in diagnostic systems of nuclear power plant with liquid-metal fast breeder. The idea of a whole approach is to make an adaptive diagnostic system of acoustic monitoring of a steam generator unit. The system is based on neural network feature extraction and pattern recognition of multi-channel acoustic signals generated by a steam generator unit. In the background noise environment the diagnostic system must detect water leaks in sodium which may occur in the steam generator unit under monitoring.

Unfortunately traditional linear techniques fail to solve the problem with extreme low signal to noise ratio that is the case in the application described above. The power spectra of acoustic background noise signal and leak signal are completely overlapped and there is no possibility to separate or extract signals used only second-order techniques which are based on auto- and cross-correlation.

Neural networks turn to be powerful tools in modeling underlying phenomena that are responsible for generation of real signals. Due to significantly nonlinear structure and adaptive learning behavior neural networks become very attractive and promising in solving such problems as described. Recently there appeared a new technique for multi-channel signal separation referred as Blind Source Separation (BSS) or Independent Component Analysis (ICA) treating original source signals as independent components which are then observed mixed in the multi-channel recordings. The aim is to combine the powerful of neural networks and the methods of blind separation to solve the problem of signal extraction with low signal to noise ratio and overlapped power spectra.



To apply BSS technique it is necessary to be sure that signals under consideration possess meaningful higher order statistics, namely cumulants of order higher than second, what leads to a problem of reliable estimation of cumulants from given data. The cumulant analysis of signals corresponds with the analysis of density distributions of the signals to make a decision whether signals have non-gaussian distribution density. Non-gaussianity of signals is the main feature signals must possess for one to apply ICA technique. In frequency domain ICA approach assumes to use higher-order spectra. Unfortunately classical approaches to BSS can not be applied to real data due to fairly simple mixture model and conditions imposed on signals. It is a task to explore new BSS techniques including delays in signals and possible convolutions with media.

An important aspect of problem to be considered is to extent the BSS technique on the case with a prior information available. In diagnostic systems for signal detection in noisy environment, as a rule, at least one source is known. The group of independent sources, which form the background noise component, is always known in such problems. More precisely there is information about all statistical characteristics of background noise signals, as there is a lot of background noise recordings provided to solve the problem of detection a signal of interest. In contrast to that there is no information about a signal to be detected before the "fault" appears. So the separation becomes not strictly blind. This circumstance makes the problem easier in some sense. The main difficult being arisen while working with real data is that due to unknown source signals it is difficult to interpret the obtained independent signals. Thus, forcing the known component to be as one of the output signals other outputs may be interpreted as signals being sought and further analyzed.

According to the problem stated, available to-date BSS techniques, and necessity of investigations and improvements of existing techniques a work plan had been drawn up and a certain progress in research has been achieved.