THE TEMPORAL ANALYSIS OF ENGURI DAM DATASETS

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Abstract: *In this research, the results of the analysis of time intervals (waiting times) between events in the seismic catalog around the area of Enguri Dam and foundation displacement data sets were investigated. A statistical approach based on calculating time series helps us to determine the dynamic picture of the research area. Here we have used different nonlinear analysis methods: DFA (Detrend Fluctuation Analysis), and MF-DFA (Multifractal Detrend Fluctuation Analysis). The research aim is to investigate the dynamics of time distribution characteristics of Enguri dam seismic and foundation displacement*

Key Words: *Enguri Dam, nonlinear analysis, displacement, waiting time*

Introduction. It is well known that Enguri High Dam is one of the highest active dams in the world, it was built in the 1970s, in the canyon of river Enguri (West Georgia). The dam was built in the seismic active region and as many years of observation have shown, it causes tectonic and geotectonic processes during the filling-emptying of the reservoir. The dam is one of the most important and interesting subjects of scientific research. The observations of ongoing processes at the base of the Enguri Dam started in 1974. In the moments of filling-loading the reservoir, we observed movement at the base (deformation), which became the subject of very interesting research. It was found that in active periods seismicity is induced by the reservoir [1-6].

At the same time in our research, we will use seismic and other features of Enguri dam. In the frame of the research, we will investigate time intervals (waiting times) between Enguri dam seismic and foundation displacement. Modern methods of time distribution research based on traditional nonlinear concepts will be used.

Methods. In the present research, we analyzed the time interval (waiting times) between earthquakes $\Delta t = t(i+1) - t(i)$ in the seismic catalog of Enguri Dam and foundation displacement data. Nonlinear analysis has been carried out on seismic data at a 100 km radius of Enguri Dam for 1974-2017 years and foundation data for 1974-2020 years.

Long-term correlations of time series we estimated by DFA (Detrend Fluctuation Analysis), and MF-DFA (Multifractal Detrend Fluctuation Analysis) methods.

In time series analysis, detrended fluctuation analysis (DFA) is a method for determining the statistical self-similarity of the part of the system DFA scaling parameter includes full information about the correlation of time series and determines long-term correlations in non-stationary time series [7,8].

Multifractal Detrended Fluctuation Analysis (MFDFA) is a nonlinear method to investigate the long-term correlations of the power law of non-stationary time series. The MFDFA is an extension of the DFA method to detect correlations and multifractal characteristics in non-stationary time series data. The multifractal spectrum shows the variation in the dynamical structure of time series data [9,10].

Results and discussion. Nonlinear DFA analysis of time interval (waiting times) of seismic data area around 100 km of Enguri dam for 1974-2017 and foundation displacement data for 1974-2020 was carried out. The results of DFA analysis of seismic catalogs and displacement, show the long-range correlation of scaling features, changes in dynamical structures, and the regularity of the system. DFA analysis was carried out for polynomial fitting p=2, 3, 4 (see Fig. 1-Fig. 2).

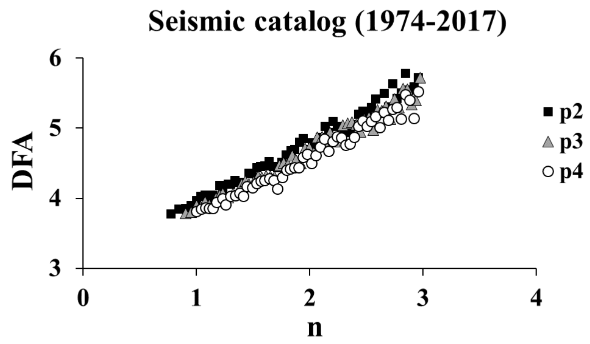

Fig. 1. DFA analysis of seismic data area around 100 km of Enguri dam for 1974-2017.

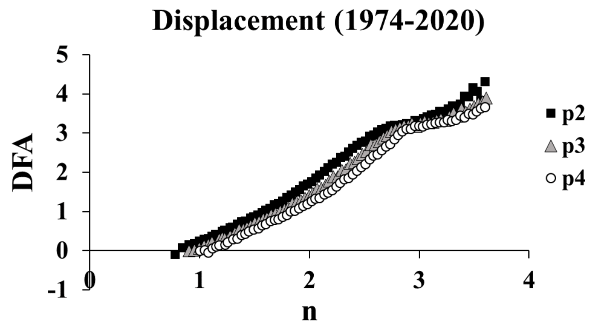

Fig. 2. DFA analysis of Enguri dam foundation displacement for 1974-2020.

From the DFA analysis of Enguri dam data sets, we can see how the structure of the dynamics changes with increasing polynomial approximation, order is disrupted, and mutual correlation weakens.

Multifractal Detrended Fluctuation Analysis (MFDFA) of long-term correlations of the power law of non-stationary of seismic data area around 100 km of Enguri dam for 1974-2017 and foundation displacement data for 1974-2020 was carried out. The variation of the multifractal spectrum was carried out for polynomial fitting p=2 (see Fig. 3-Fig. 4).

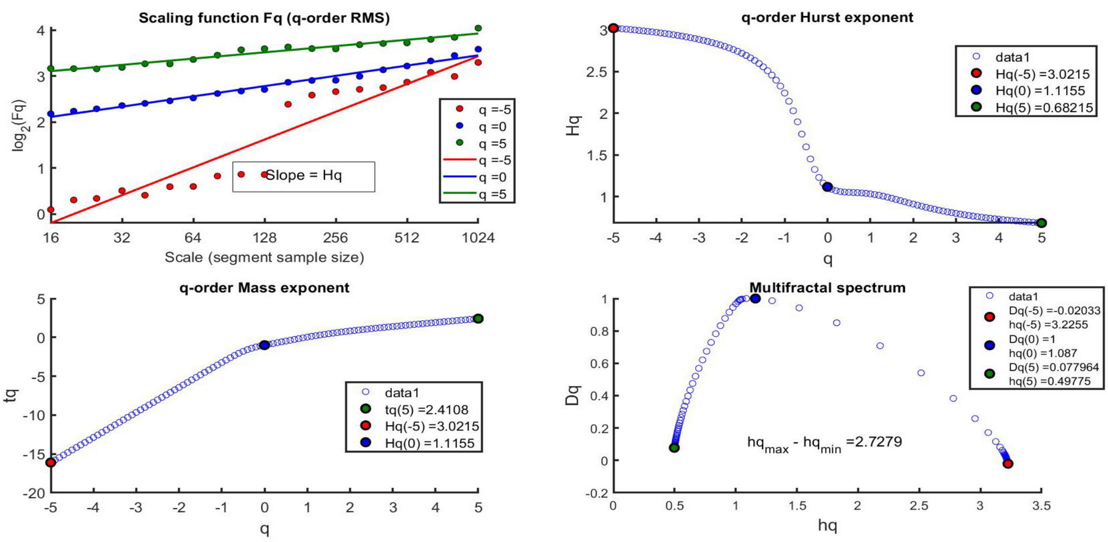

Fig. 3. MFDFA analysis of seismic data area around 100 km of Enguri dam for 1974-2017. % output variable: Hq: q-order Hurst exponent, Fq: q-order scaling function, tq: q-order mass exponent, Dq: q-order dimension.

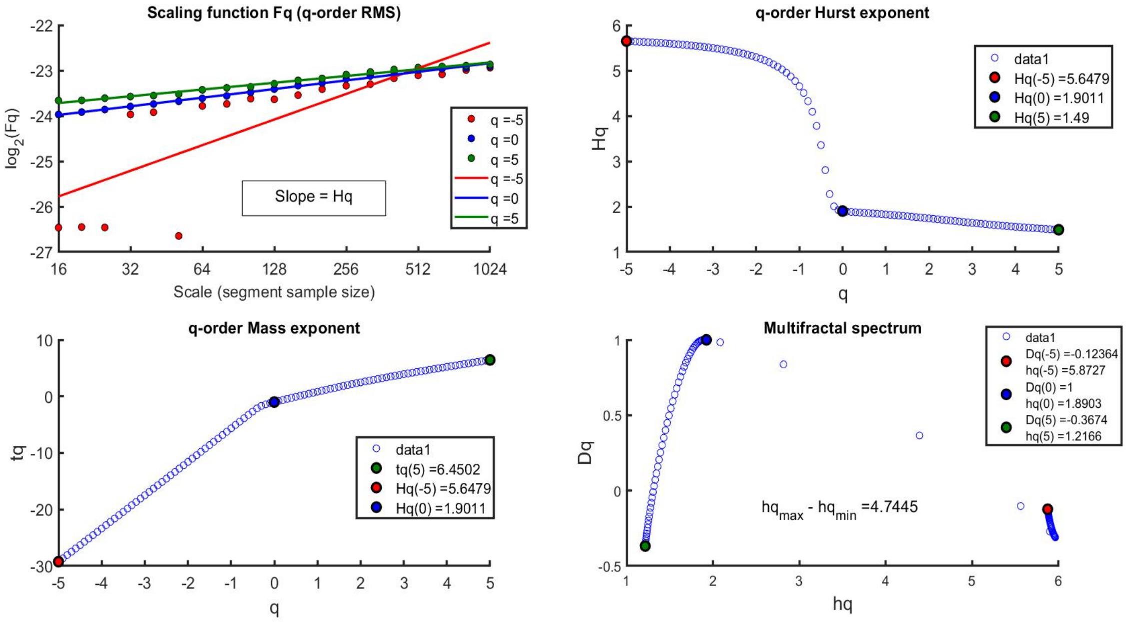

Fig. 4. MFDFA analysis of Enguri dam foundation displacement for 1974-2020. % output variable: Hq: q-order Hurst exponent, Fq: q-order scaling function, tq: q-order mass exponent, Dq: q-order dimension.

From Fig.3-Fig.4 we can see the scaling functions Fq with corresponding regression slopes Hq, which are depend on q-order Hurst exponent The scaling functions Fq and regression slope Hq are q-independent. The q-order Hurst exponent Hq for the time series is multifractal. MFDFA analysis consists of several steps: to first convert Hq to the q-order mass exponent (tq) and thereafter convert tq to the q-order singularity exponent (HQ) and q-order singularity dimension Dq; The plot of hq versus Dq shows us multifractal spectrum.

Conclusion. The time interval (waiting time) of seismic data area around 100 km of Enguri dam and foundation displacement have been analyzed. Results were observed for the 1974-2017 and 1974-2020 period. For nonlinear analysis, DFA and MFDFA analysis. The results, obtained by our analysis can be important in the investigation of Enguri dam behavior and show the normalizing process of a complex system by dynamical method. The analysis of the dynamics of displacement/seismicity time series of Enguri Dam and the surrounding area allows us to establish the pattern of nonlinear dynamics in the normal regime, as well as detect the significant deviations from it

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