Disturbance Recognition through Subspaces

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# Project objective

Automatic and fast events recognition algorithm is important to enhance the wide-area situational awareness of power system and prevent cascading failures. Model-based methods often require complex modeling of power grid and accurate parameter estimation, data-driven methods without power system modeling are more attractive, considering the denser coverage of phase measurement units (PMU). The existing data-driven methods have the following limitations: (1) Most are offline algorithm; (2) Require complex training models and long time period of datasets; (3) large size of storage; (4) High sampling rate based on the measurements of frequency disturbance recorder.

The goal of our method is to develop a method based on PMU data to identify and locate different types of events efficiently in real time and with a small storage requirement.

# Problem Formulation

Given PMU measurements of multiple buses across time , where is the number of measurements at one time and is the number of time steps, the best rank-r approximation is, where is the rank of , are composed of left and right singular vectors and span the column and row subspaces of respectively, denotes conjugate transpose and is the corresponding singular values. We want to utilize these subspaces to characterize the dynamics of power system after events, and then compare these subspaces to identify and locate events efficiently and effectively.

# Main Idea

The main idea of our online identification method, as shown in Figure.1, is to construct a dictionary of row subspace of historical PMU data offline, and then identify the event type by calculating subspace angles between the dictionary and the row subspace of new coming PMU data. Subspace angle is a measure of the subspace similarity, and a small subspace angle reflects a high similarity.



Figure 1 Dictionary construction from historical datasets and real-time data identification through the subspace comparison

# Technical Implementation

## Construct the dictionary offline

We use the training datasets of four types of events, line trip, generator trip, three phase short circuits and load changes events, in the IEEE 68-bus power system to produce a dictionary offline and upload it before identifying the type of events. This dictionary is stored in the matrix ‘Dictionary’. There are total 49 subspaces, each of which has the dimension 34 by 6. In our dictionary, the type of first 12 subspaces are line trip, 13 to 19 are generator trip, 20 to 42 are three phase short circuits and the remain are load change.

## Event identification

With the dictionary constructed, we want to identify the type of events or disturbances. We upload 12 testing datasets including: 3 generator trip events, 3 three phase short circuit events, 3 load change events and 3 line trip events. The identifying process include the following steps, and they are carried out by function **‘Event\_Identification’**:

1. Data processing: we select about one second of the testing data after events occurrence, subtract their mean value of each bus, and obtain matrix ‘ ’ ;
2. Compute the subspace of each : we employ singular value decomposition (SVD) method to obtain the subspace V of X, and the rank ‘k1’ of each subspace is determined by two parameters ‘thres=0.99’ and ‘gap=10’ such that only the dominants of the row subspace are maintained;
3. The subspaces are compared by subspace angle, defined in equation (1), this is implemented in function ‘**angle0**’:
   * Where ) measures the subspace angle spanned by respectively; are the rank of the corresponding subspace;
   * When subspaces are the same and when orthogonal ;
   * When two subspaces have different ranks, the maximum one is chosen as their common rank, and most matrices V have rank less than 6.
4. Calculate the subspace angles between the ‘V’ of each testing dataset and the subspaces in the dictionary. The subspace in the dictionary corresponding to the minimum subspace angle with ‘V’ has the same type with the testing dataset and thus determines the type of the event;

Finally, the user can choose the index (from 0 to 11) of the testing datasets and we can output the type of the event, the voltage magnitudes of 68 buses, and the dominant subspace or the singular vectors of this dataset.