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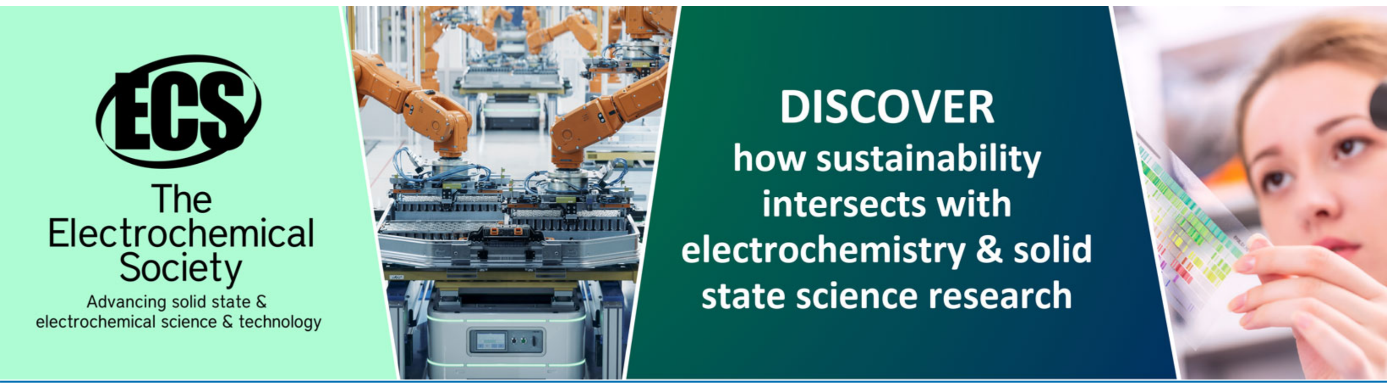

# Research on Detect of Power Quality Problems in DC Distribution Network

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**Abstract.** In recent years, sparseness-based representation methods have been studied in the field of signal processing. Among them, sparse decomposition based on Matching Pursuit is the most commonly used, but it is a NP difficult (Nondeterministic poly-nominal) problem essentially. The concept of infinity will increase the difficulty, affects its practicability. Aiming at the problem of the computational efficiency above, Matching Pursuit algorithm based on genetic algorithm is proposed to achieve sparse decomposition of signals. Then build a simulation model through MATLAB, simulate the actual DC distribution network, obtain power quality data, and use the algorithm proposed in this paper to verify, the results show that the algorithm is applied to the DC power distribution system power quality detection, in the realization of disturbance classification. At the same time, the characteristic parameters of the disturbance component can be obtained. This method not only can obtain the optimal atom with higher precision, but also can greatly reduce the calculation amount and improve the efficiency, which has certain practical value in engineering

## 1. Introduction

Because of the wide application of power electronic converters, sensitive loads and non-linear loads are increasing in the power grid; the form of load power consumption has gradually changed. Therefore, the concept of DC distribution network was proposed[2-3]. The flexible DC distribution system based on the voltage source converter (VSC) becomes a new trend in distribution field, due to its advantages of low loss, low cost, high efficiency and high reliability.

There are a large number of access points in the DC distribution network, including load access, distributed new energy access and AC grid access, which include different types of power electronic converter. The operation control of these devices or any non-ideal situations of access terminal will cause a series of power quality problems, such as voltage sag, voltage swell, ripple, short-term power failure, high-frequency oscillation disturbance and voltage flicker[4-5]. Therefore, the detection of DC power quality and the identification and classification of the time and severity of interference can help to assess and control power quality problems.

Disturbance detection methods of power quality signals in AC systems are maximum posterior probability, sparseness-based representation method, new norm method, empirical mode decomposition (EMD), Sub-frame decomposition (VMD) and mathematical tools (wavelet basis, frame, ICA). Common methods that can be used for the detection of electrical energy disturbance signals in DC systems are wavelet transform, Hilbert-Huang transform, mathematical morphology and etc. The above-mentioned detection methods have more research on detecting a single disturbance instead of complex disturbances. And the disturbance parameters obtained by these methods cannot describe the disturbance characteristics fully. In recent years, sparseness-based representation methods have been studied in the field of signal processing. The main idea of this method is to use time-frequency atoms (or called basic functions) with different waveform characteristics to construct a huge "dictionary", then use the Matching Pursuit algorithm to select the most suitable atoms from the signal waveform and in order to accurately express the signal with the least number of atoms. This method has good adaptability in the choice of base, which can greatly improve the convenience and flexibility of signal expression.

In this paper, based on the research results of topological structure, voltage level and load type of DC distribution network at home and abroad, to analyse common DC power quality issues. The Matching Pursuit algorithm based on genetic algorithm is used to search and extract the characteristic parameters of the DC system disturbance problem's signal. Use the parameter group involved in defining atoms as the parameter to be optimized. Using the feature of similarity between genetic algorithm populations can avoid the calculation of a considerable part of the fitness function in the process of Matching Pursuit; reduce the amount of calculation effectively. The feasibility and effectiveness of the algorithm will also be verified in MATLAB with low-voltage DC distribution network simulation examples.

## 2. Application of Matching Pursuit algorithm based on Genetic Algorithm in power quality detect

If $\varphi_k$ be a set of expansion functions in the signal space, then any signal can be expressed as a linear combination of $\varphi_k$.

$$f(n)=\sum_{k=1}^{M}a_k\varphi_k(n) \tag{1}$$

If the signal in equation (1) can be expressed with fewer expansion functions, and they are concisely, it means that these expansion functions contain the main component of that signal.

One of the most classic and commonly used methods in atomic sparse decomposition is the Matching Pursuit algorithm. If $f$ be the signal to be decomposed and its length is $L$. $D = \{g_\gamma\}$ is a redundant atom library for signal sparse decomposition, $g_\gamma$ is the atom (base) defined by parameter group $\gamma$, and $\Gamma$ is the set of parameter group $\gamma$. Its principle is to do the inner product operation of the signal $f$ and each basis function $g_\gamma$ in the redundant atom library, that is, the projection or the component of $f$ on each atom, and find the atom with the largest inner product as $g_{\gamma 0}$, in a physical sense, it is the base of the minimum angle between the signals $f$ in a bunch of atoms, which can be expressed as:

$$\left|\left\langle f,g_{r0}\right\rangle\right|=\sup_{r\in\Gamma}\left|\left\langle f,g_r\right\rangle\right| \tag{2}$$

Then the signal $f$ can be expressed as

$$f=\left|\left\langle f,g_{r0}\right\rangle\right|\cdot g_{r0}+R_f^1 \tag{3}$$

That $R_f^1$ is the initial residual component of the signal after once decomposition. Then replace the original signal with the initial residue, and continue to search for the atom with the most similar structure. The process is still to perform the inner product operation in the redundant atom library to find the basis function $g_{\gamma 1}$ with the largest inner product, and then the initial residual signal $R_f^1$ is divided into two parts:

$$R_f^1=\left|\left\langle R_f^1,g_{r1}\right\rangle\right|\cdot g_{r1}+R_f^2 \tag{4}$$

That $R_f^2$ is the residual component after second decomposition. Then continue the search process. After $k$ time's decomposition, the residual $R_f^k$ is expressed in a generalized form as:

$$R_f^k = \left|\left\langle R_f^k, g_{rk} \right\rangle\right| \cdot g_{rk} + R_f^{k+1} \left(k = 1, 2...\right) \quad (5)$$

Where $g_{\gamma k}$ is the best atom matched in each decomposition process, it satisfies:

$$\left\langle R_f^k, g_{rk} \right\rangle = \sup_{r\in\Gamma} \left\langle R_f^k, g_r \right\rangle \left(k = 1, 2...\right) \quad (6)$$

After $k$ time's decomposition, the signal $f$ can be expressed as:

$$f = \sum_{k=0}^{n-1} \left\langle R_f^k, g_{rk} \right\rangle g_{rk} + R_f^n \quad (7)$$

So when the length of the signal $f$ is limited, the residual component $R_f^n$ will decrease rapidly in an exponential form. When it is as small as the specified threshold, then $f$ can use linearly independent atoms to represent its component, relative to the signal length $L$, $k$ is a small number. This completes the adaptive and concise expression of the signal.

However, due to the greediness of the MP algorithm, each step must complete the projection calculation of the residual components of the signal or signal decomposition on each atom in the redundant library. The root cause of the large amount of computation for signal sparse decomposition is as required by equation (6). The inner product calculation to be performed at each step of decomposition, which is calculate in a high-dimensional space, it need performed iteratively.

In this article, we use a genetic algorithm based MP[9-10]. Genetic algorithm is a parameter optimization algorithm. When the object to be optimized provides upper and lower parameter limits and evaluation function criteria, the optimal result is usually obtained. The MP algorithm also provides the range of the parameters of the primitive function and the evaluation function of the optimal atom in the process of finding the optimal basis function. Therefore, the genetic algorithm can be used to optimize the MP process, greatly reducing the amount of calculation and saving the running time of the algorithm. Specific steps are as follows:

- The initial population is randomly generated according to the coding range of the upper and lower limits of the time-frequency atomic parameter, and it is used as a subspace of the centralized optimization parameter space. Set genetic algebra, residual termination threshold, population size and parameter coding length.
- Calculate the individual fitness value. Substitute the parameters into the Gabor atomic modulation analytical formula to obtain the corresponding time-frequency atom, project the signal to be detected onto the atom, and obtain the individual fitness value.
- Individual selection is performed through individual fitness evaluation parameters. Selecting the atom that meets the evaluation parameters as the "preferred atom" is equivalent to roughly finding a subspace that matches the signal function to be detected.
- Genetic operations such as cross-mutation are performed on individuals with "better atoms". Randomly select intersection points and mutation points in the form of binary coding.
- Substituting the parameter set obtained by the genetic operation into the Gabor atomic modulation analytical formula will obtain an optimal atom g and return it to the MP algorithm for a finer search with a smaller resolution.

## 3. Example simulation

This paper builds a simulation model on MATLAB/Simulink. In order to interconnection with AC system expediently and compatible with many existing loads. The voltage of this DC distribution network is set to 400V. Through setting faults or switching loads and other operations, simulate the power quality problems of the DC distribution network; import the simulation signals into the GA-MP algorithm to verify the feasibility and accuracy of the algorithm. The power system itself has its own complexity. The occurrence of certain disturbances often occurs, which leads to other disturbances. In addition, in the actual power grid, with a series of system operations, certain types of disturbances are not a single existence. The phenomenon of inter-aliasing is more common.

### *3.1. Detection of multi-frequency ripple mixed signal*

Figure 1 is the original mixed signal generated when an AC load is started, and Figure 2 is the extraction of the decomposed components using the algorithm of this paper.

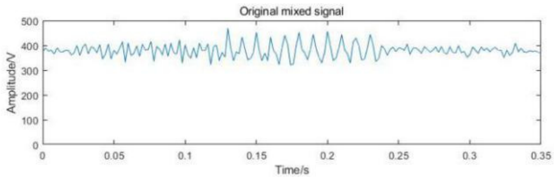
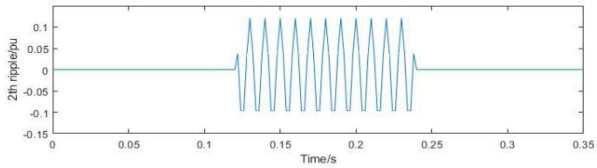
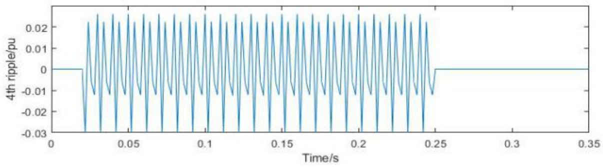


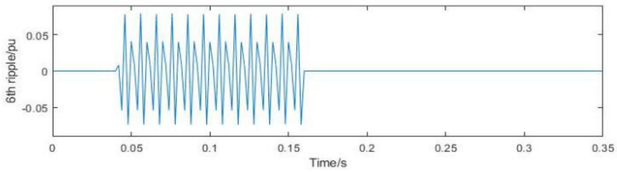

Figure 1. Multi-frequency ripple mixed signal.



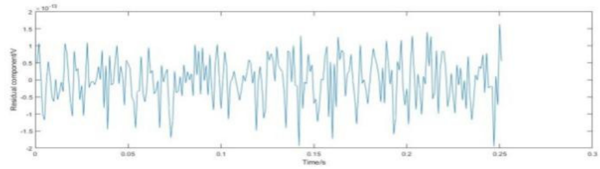

(a) The extracted second harmonic signal.



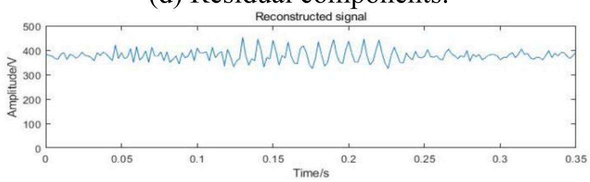

(b) The extracted 4th harmonic signal.




(c) The extracted 6th harmonic signal.



(d) Residual components.




(e) Reconstructed signal.

Figure 2. Decomposition and extraction results.

By analyzing the data and compared with the simulation setting, the error of each characteristic parameter is smaller, which is within the allowable range.

### *3.2. Detection of voltage sag and ripple mixed signal*

Figure 3 shows the voltage sag and ripple mixed signal generated by an actual DC distribution network due to increased load. Using this algorithm to extract the decomposed component waveforms is shown in Figure 4.

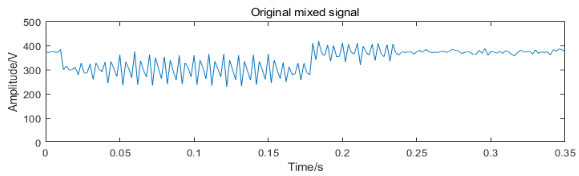
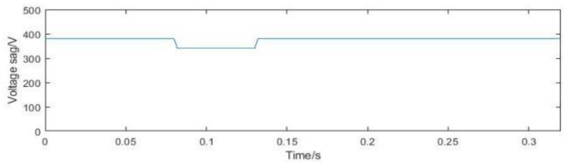
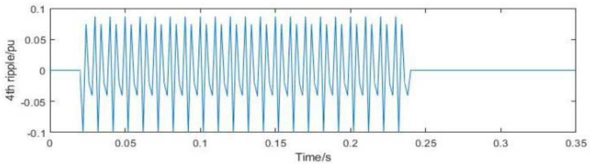


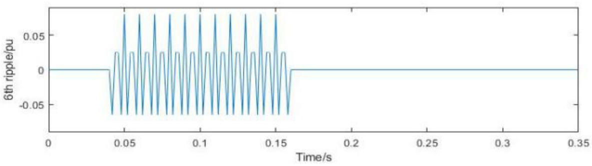

Figure 3. Voltage sag and ripple mixed signal.



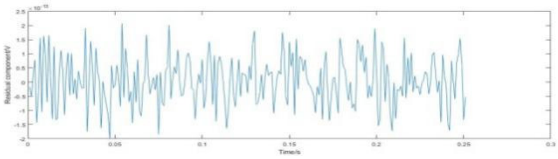

(a) Extracted sag signal.



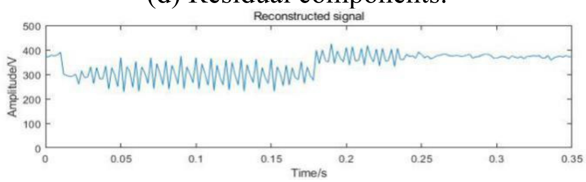

(b) The extracted 4th harmonic signal.




(c) The extracted 6th harmonic signal.



(d) Residual components.




(e) Reconstructed signal.

Figure 4. Decomposition and extraction results.

By analyzing the data that the error of each characteristic parameter is smaller than the simulation setting, that is within the allowable range.

## 4. Conclusion

The Matching Pursuit algorithm is an excellent algorithm, which can theoretically obtain a sparse representation of any signal, but it is indeed a greedy algorithm in implementation. Each step needs to solve the inner product operation between a large number of signals and atoms, so it will introduce an amazing amount of calculation. In this paper, according to the characteristics of DC distribution system disturbances, the MP algorithm is improved by intelligent algorithm—Genetic Algorithm, The result of GA rough optimization is used as the initial value of MP, and then optimization is performed within a certain range, and finally the matching atoms and characteristic parameters are obtained. This can avoid a considerable part of the operation of the inner product function. A numerical example verifies the applicability of the algorithm to complex disturbance signals. It realizes the decomposition and extraction of characteristic information from the DC bus signal, which proves the reliability and effectiveness of the algorithm in this paper. It provides a theoretical basis for the control of the power quality of the DC distribution network system.

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