Wide-area system of registration and processing of power quality data in power grid with distributed generation

Part II. Localization and tracking of the sources of disturbances

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***Abstract*— This paper is a continuation of Part I [1] and presents the application of a comprehensive system of registration, archiving and data processing for the wide-area monitoring of power quality in a separated part of real power grid with distributed renewable generation. Real case studies related to tracking of disturbances' wandering and localization of sources of voltage disturbances are presented.**

Keywords-power quality, power distribution faults, power distribution reliability, power system restoration, power system transients, relational databases, distributed generation, location of disturbances, voltage dips

I. Introduction

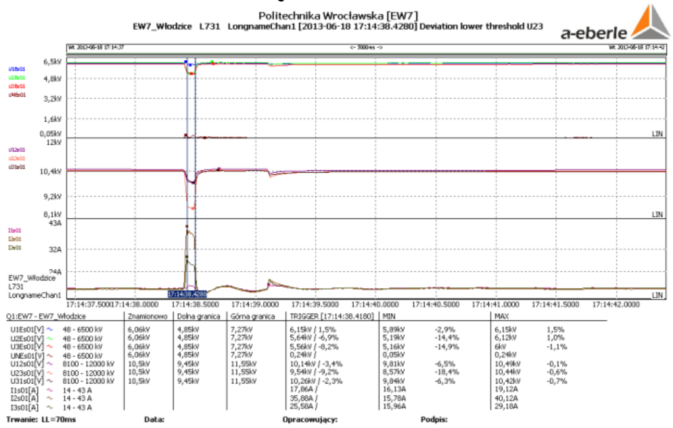
Presented project aims at building a distributed power quality monitoring system. Such a system is located at the nodes of the actual distribution network enables the study of phenomena occurring in the system containing distributed generation units [2]. The monitoring system is equipped with stationary time-synchronized power quality recorders with data transmission network. It allows to conduct effective research on phenomena occurring in modern distribution systems [3].

Using our previous experience [6-8] in the implementation of a distributed monitoring using mobile power quality analyzers with GPS synchronization we developed a stationary system to monitor network parameters. Fixed installation allows long-time diagnostic data recorded synchronously in selected locations of the distribution network that may indicate trends related to changes in network configuration, changes in the nature or size of the loads, and the impact of renewable energy sources.

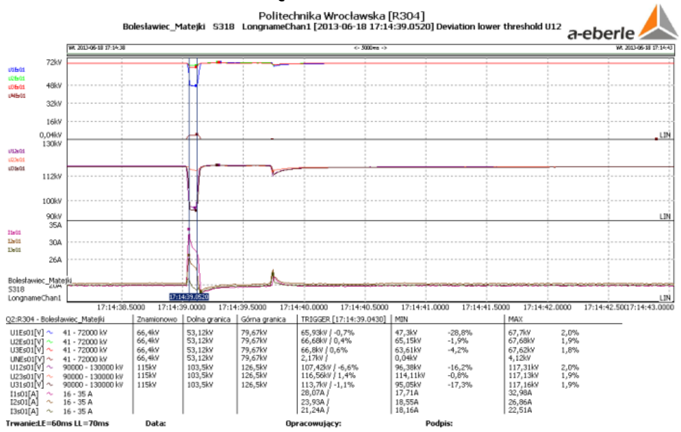
II. Synchronous recordings

The main advantage of synchronous monitoring systems is the possibility of so-called "Tracking of disturbance wandering". Figure 1 and Figure 2 show in detail synchronous registrations of disturbances' RMS values of the disturbance observed in different measuring points of the system. The time synchronization of disturbances' waveforms is possible , as well.

Q1 MV 10kV



Q2 HV 110 KV



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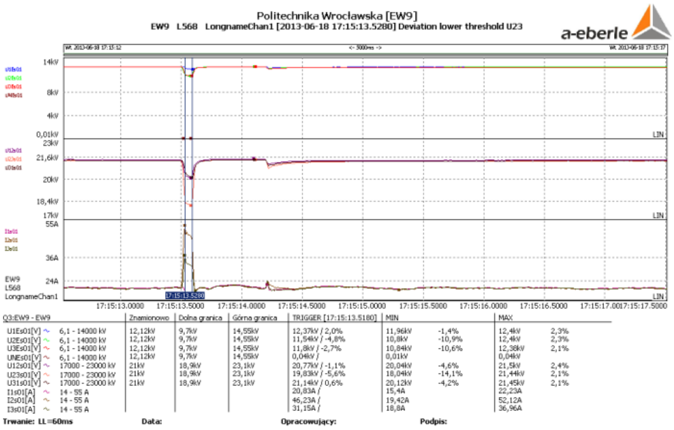
Q3 MV 20 kV



Q5 LV 0,4 kV

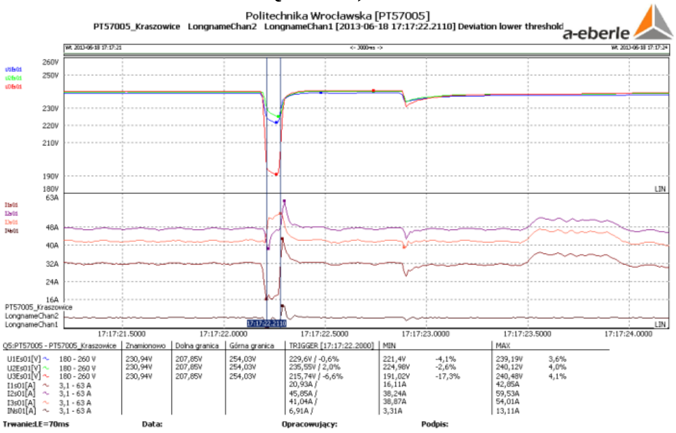


Figure 1. Registrations of RMS values by RecB of selected power quality disturbance seen synchronously in Q1, Q2, Q3 and Q5 measuring points at different voltage levels.

Using the review card of all disturbances in module PQVisu and selecting registrations associated with the disturbance it is possible to present simultaneously presentation of the wandering of disturbance in many measuring points of the system. Exemplary summary sheet using the time adjustment function is shown in Figure 2.

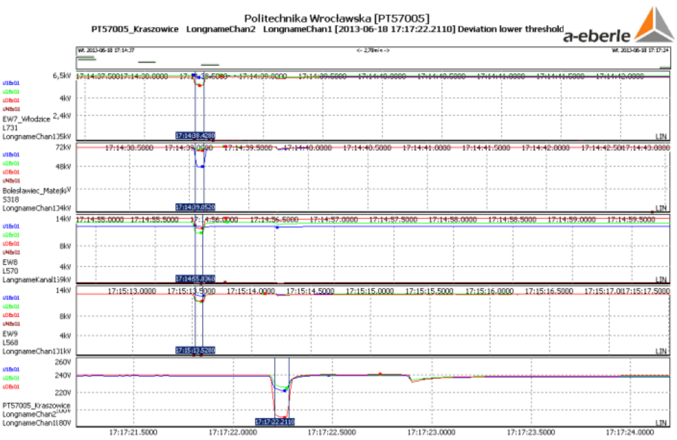


Figure 2. Synchronous registrations of a selected power quality disturbance seen at the measuring points of the system - a summary with time adjustment.

III. Localization of the sources of disturbances

On the basis of recorded signals in the monitoring system, we can investigate the properties of the selected algorithms for location of emission of power quality disturbance, like, voltage dip location and sources of harmonics. Such an analysis can support the elements of dynamic analysis, including detection and so-called "Tracking of disturbance wandering". In the literature one can find many proposed interference detection methods [4,5].

A. *Voltage dips*

In this paper, source localization of voltage dips is understood as determining whether the dip seen at the measuring point is caused by the activities in the supply mains or by the receiver. It is said that the cause of the voltage dip is above the measuring point, when the dip has its origin between the measuring point and the power source , and below the measuring point on the receiver side , ie , when the cause of the dip lies between the measuring point and consumer of energy .

Literature provides several methods for source localization of dips [9] :

- analysis of voltage and current waveforms ,
- trajectory analysis (I, U) during the dip ,
- analysis of power and energy during the disturbances ,
- analysis of the asymmetry factor and phase angle of the positive sequence ,
- analysis of the trajectory of change in the impedance .

In this paper we implemented the method to locate the source of the dip based on the analysis of voltage and current waveforms and the ensuing trajectory method (I, U) . The basis for inference about the location of the dip is the observation of voltages and currents during disturbances. The sharp increase in current during the voltage dip means that the source of the dip is below the measuring point ,i.e at the consumer side. This situation corresponds to the negative slope of the trajectory of the plane (I,U).

To determine the trend of the RMS value a classic one-period algorithm was implemented (20ms).

$$Vrms(k) = \sqrt{\frac{1}{N}\sum_{i=k}^{i=k+N-1} v^2(i)} \tag{1}$$

where *N*-number of samples per 1 period of the fundamental of the sampling frequency according to the recording system, *k* - the index of the position of the sliding window with a width of one period of the fundamental component, *i* - a vector of numbers of samples taken to determine the RMS value for a given position of the window.

To verify the location algorithm, the direction of the voltage dip detection algorithm was applied to two different cases:

B. Voltage dip caused by the switching on of the synchronous generator, viewed as inductive power receiver

Monitored small hydroelectric power (SHP) plant contains two independent asynchronous generators 200kW / 0,4 kV, driven by two Kaplan turbines. Connection to the power network is realized by a transformer 20/0, 4 kV. Distance from the substation to power station is about 4km. The recording device is installed in the main power output LV circuit of the plant.

Voltage dip is accompanied by a "surge" of current trajectory (I, U), the disturbance shows negative slope - implemented method indicates the location of the source of voltage dip on the side of the plant. Corresponding waveforms and trajectory are shown in Figures 3 and 4.

C. Voltage dip caused by a lightning stoke on the distribution network

This case study refers to a disturbance of voltage at the connection point registered in a small hydroelectric plant connected directly to the low voltage public network. The plant has an asynchronous generator with a capacity of 160kW working on voltage level 0.4kV, driven by a Pelton turbine. The system is equipped with an adjustable reactive power compensation. Nearest transformer station 20/0, 4 kV is located approximately 0.5 km from the plant. Station is located within a vast mountain medium voltage networks within 8km from the plant. Voltage dip (Figure 5) is accompanied by a "dip" in current trajectory (I, U) and it has a positive slope – (Figure 6)- implemented method indicates the location of the source voltage dip on the side of the supply network. The determined location is consistent with the operator logs.

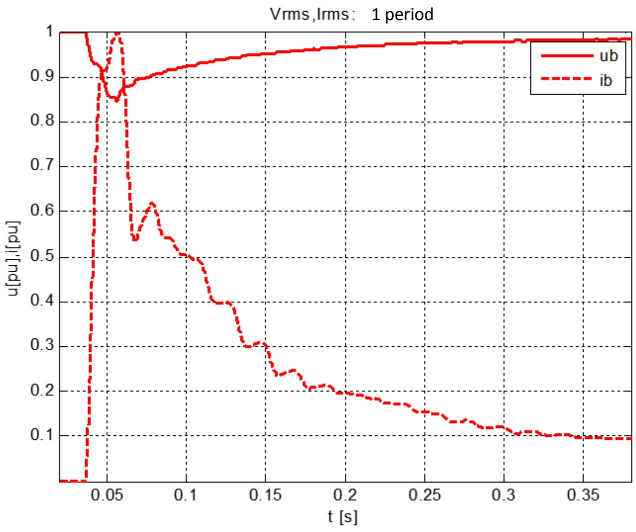


Figure 3. Changes of normalized 1-period RMS voltages and currents caused by the switching-on of the SHP asynchronous generator connected to the grid at the time of 0,05 s.

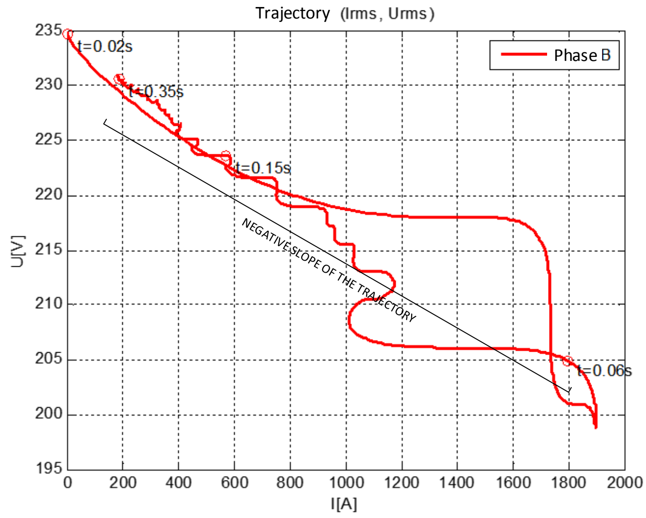


Figure 4. Trajectory (I, U) for the selected phase of the phase voltage dip caused by the switching-on of the SHP asynchronous generator connected to the grid.

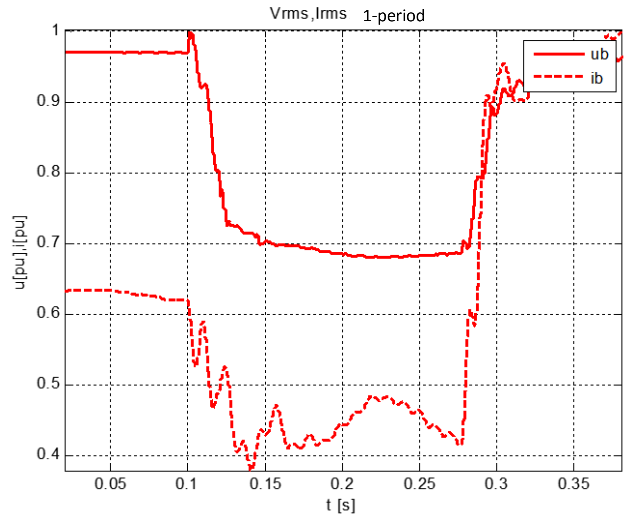


Figure 5. Waveform of 1-periodic normalized RMS voltage and current, at asynchronous generator in SHP connected directly to the low voltage power grid during voltage dip due to an incident from the network occurring at the time of 0,1 s.

IV. SUMMARY

Creation of a monitoring system of power quality installed on a selected part of the power grid containing distributed generation units allows to perform a series of original analyzes of the complex subject of cooperation of distributed generation with the grid .

In contrast to single-point measurements , a collection of synchronous measurement data archived in the database extends the analysis in the direction of simultaneous tracking of dynamic phenomena, area- reporting and statistics covering the monitored areas.

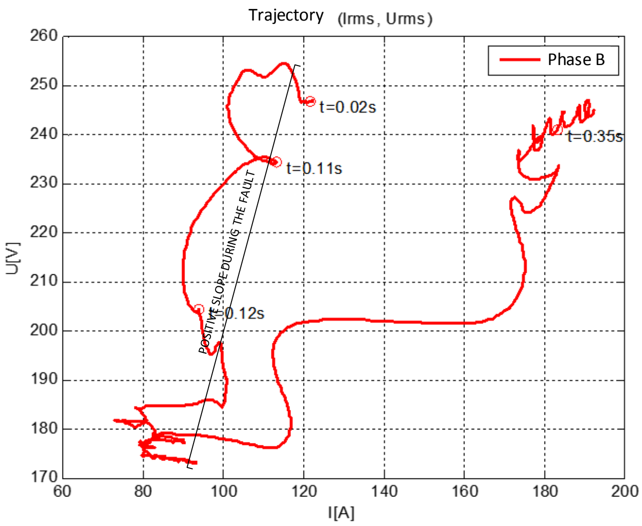


Figure 6. Trajectory (I, U) for the selected phase of the phase voltage dip caused by the lightning stroke.

In this part we showed the tracking of disturbances' wandering in the grid based on time-synchronized recordings of voltage waveforms recorded at different points of the system and we implemented and verified the method to locate the source of the dip based on the analysis of voltage and current waveforms and the trajectory method.

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