Pilot operation of Vdip system

Description

Operating period: 10/2020 – 12/2022

Author: David Topolanek

Contact: topolanek@vut.cz

Content

Description of pilot operation

The pilot operation of the Vdip system was implemented in a compensated 22 kV network with a capacitive current of 83A (overhead lines with a minimum share of cables).

The MV network is supplied from the primary substation 110/22 kV, belonging to distribution network operator EG.D. One MV feeder (Kubova Huť) was allocated for the installation of the Vdip system.

The monitored feeder consists of 326 nodes, 233 line sections, 96 switching elements, 61 distribution transformer stations MV/LV from which 16 were equipped with distributed measurement unit (DMU) on LV side. The total length of monitored feeder including branches is 82 km.

The monitored feeder of the network is shown in Fig. 1 (green) together with the DMU disposition (blue circles). In the standard operation state, the feeder is operated radially, where the loops of MV lines are disconnected in the places marked with a brown arrow (disconnector 820 and Bytovky). As part of the pilot operation, class A power quality meters with the possibility of signal analysis up to 9 kHz were used as DMUs. These DMUs record oscillograms of phase voltages when a fault occurred and on request transferred them to the Vdip system centre for data processing and evaluation. These DMUs represent negative sequence voltage monitors (NSVM), where a sampling frequency of 4 kHz was used for the fault recordings during the pilot project. In the primary substation, an RTU was installed on the monitored MV feeder, which substituted the function of the feeder protection, as it was not possible to directly download fault records from the feeder protection using the DSO infrastructure. For the purposes of the Vdip system, fault record of feeder protection is used as the negative sequence current monitor (NSCM).

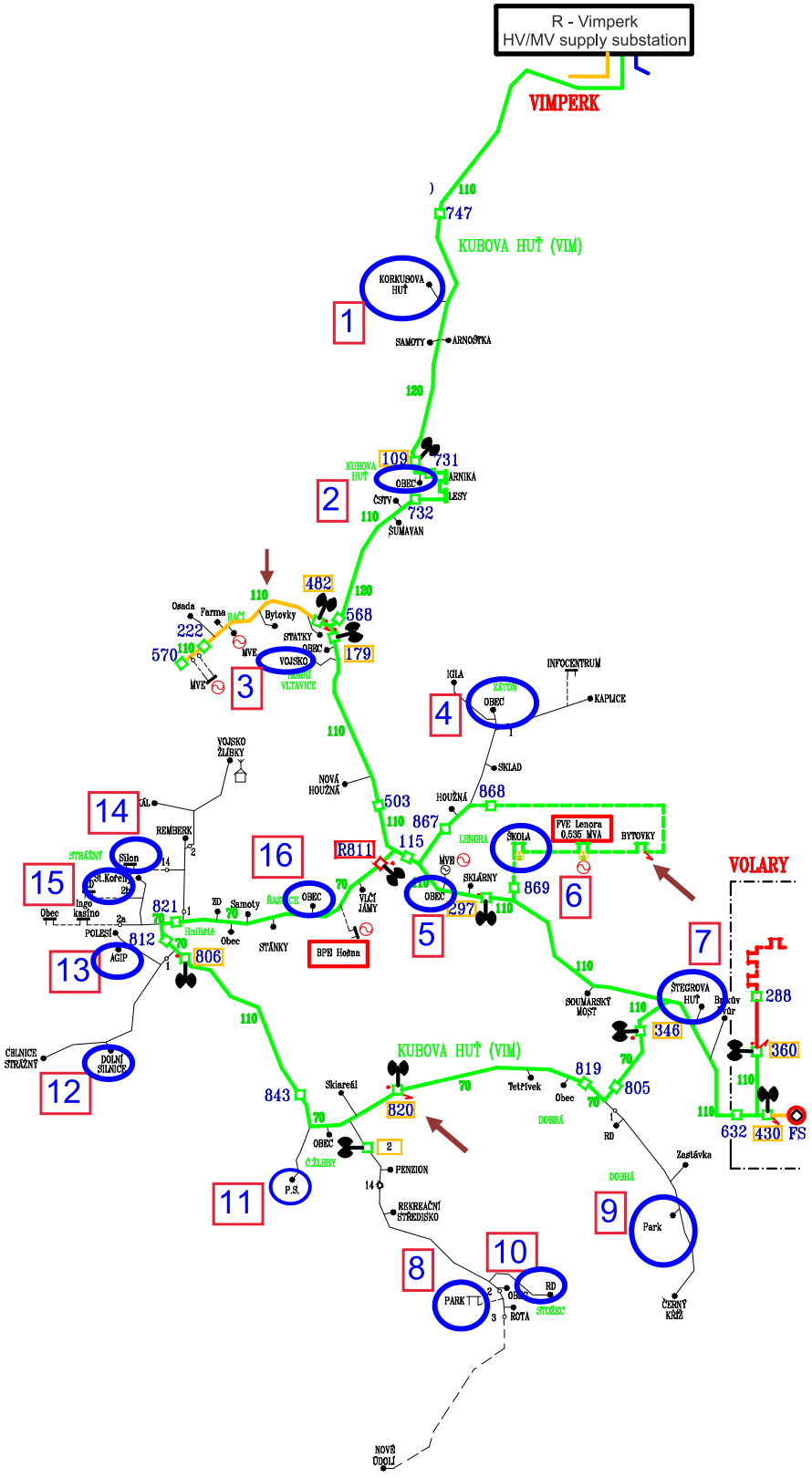

Fig. 1: Topology of MV feeder selected for pilot operation of system Vdip

Pilot operation evaluation

In order to test the developed prototype of the Vdip system, a pilot operation was launched in the presented network on 10/2020 and extended until the end of 2022. During this pilot, a total of 9 permanent faults occurred, which could be localized a total of 23 times, as in most cases the fault was reenergized several times. The list of all detected faults together with performed localizations is summarized in Table 1. For illustration, a detailed analysis of the Vdip localization process is demonstrated using only a few selected faults No. 2, 5, 9 and 13 (Tab. 1), available on web page [1].

Tab.1: List of faults localized by the Vdip system and found by DSO during pilot test

No.	Date	Fault Description		Real Fault Location	DMU records	Segments		Lokalization		Note
		Type	Characteristic			No.	Seg. Error (km)	Loc. Error (km)	Fault Distance (km)	
1	2020-10-27 22:28:21.387	SC	EF in L2 to SC L1-L2	Yes	17	2	**6**; 6	6	26,5	Successful localization
2	**2020-10-27 22:31:04.529**	**SC**	**EF in L2 to SC L1-L2**	Yes	17	2	**0,07**; 0,07	0,07	25,4	Successful localization
3	2021-02-04 3:53:46.359	EF	EF arcing L1	Yes	17	1	0	0	23,5	Successful localization
4	2021-02-04 3:54:11.509	EF	EF arcing L1	Yes	17	4	**0,6**; 1,6; 1,4; 1,7	0,6	23,5	Successful localization
5	**2021-02-04 3:56:38.119**	**EF**	**EF arcing L1**	Yes	17	3	**0,7**; 0; 0,3	0,7	24,7	Successful localization
6	2021-03-13 15:26:05.262	EF	EF arcing L3 (short therm)	2021-07-08	17	1	1,1	1,1	16,8	Supposed fault location
7	2021-06-29 17:42:04.228	SC	EF in L3 to SC L1-L2	Yes	17	2	**0,7**; 0,5	0,7	32,1	Successful localization
8	2021-06-29 17:43:56.448	SC	SC L1-L2	Yes	17	2	**0,7**; 0,5	0,7	32,1	Successful localization
9	**2021-06-29 17:45:36.818**	**SC**	**SC L1-L2**	Yes	17	2	**0,7**; >5	0,7	32,1	Successful localization
10	2021-07-08 15:48:14.571	SC	Cross Country EF L3-L1	Yes	17	3		Incorrect		Impossible cross EF localisation
11	2021-07-08 15:50:16.171	SC	Cross Country EF L3-L1	Yes	17	2		Incorrect		Impossible cross EF localisation
12	2021-07-08 15:52:55.141	SC	Cross Country EF L3-L1	Yes	17	2		Incorrect		Cross Country Fault
13	**2021-07-08 15:54:18.271**	**EF**	**EF in L3**	Yes	16	2	**0,1**; 0,1	0,1	18,1	Successful localization
14	2021-07-08 15:54:20.181	EF	EF L3 + auxiliary resistor	Yes	16	2	**0,1**; 0,1	0,1	18,1	Successful localization
15	2021-11-30 09:20:17.155	SC	L2-L3 + auto reclosing	Yes	5	4	**1,4**; 1,4; 1,4; 1,4	1,4	24,2	Limited DMUs
16	2021-11-30 09:20:18.855	SC	L2-L3 + auto reclosing	Yes	5	4	**1,4**; 1,4; 1,4; 1,4	1,4	24,2	Limited DMUs
17	2021-11-30 09:21:34.895	SC	L2-L3	Yes	4	2	**1,4**; 1,4	1,4	24,2	Limited DMUs
18	2021-11-30 09:24:11.545	SC	L2-L3	Yes	4	2	**1,4**; 1,4	1,4	24,2	Limited DMUs
19	2021-11-30 09:59:51.208	SC	SC L2-L3	Yes	2	2	**1,4**; 1,4	1,4	24,2	Insufficien No. of chenges
20	2022-01-19 12:26:26.473	EF	EF L1	Yes	7	0	x	x	x	No segment, disturbance/nois
21	2022-01-19 12:28:18.713	EF	EF L1	Yes	6	0	x	x	x	No segment
22	2022-02-16 09:29:58.589	SC	EF L1 to SC L1-L2	Yes	3	4	>5; >5; >5; >5	>5	24,2	Insufficien No. of chenges
23	2022-12-06 05:48:50.838	EF	Arcing EF in L3	Probable	5	2	**>5**; >5	>5	16,8	Two different EF in 3 hours

Summary evaluation of pilot operation results

Table 1 summarises the results of the localization based on fault records of all the discovered faults. The "Type" column describes the type of fault – short-circuit (SC) or earth fault (EF) – and is complemented by a brief description of the fault specifics. In Table 1, only faults found by the DSO are listed, with the exception of fault No. 6, which was not discovered, but the fault location estimated by the Vdip matches a fault which occurred 4 months later. The "DMU records" column defines the number of fault records received from the DMUs (NSVMs). The table shows that from fault No. 15 onwards, there was a significant drop in amount of received records having a major impact on the ability of the Vdip system to correctly locate the fault.

The "Segments" column shows the number of synchronization segments detected and relevant localization error (the electrical distance between the real location and the location estimated by Vdip system). The first value of Seg. Error corresponds to the segment that was selected as the result of the fault localization by the Vdip system. The “Localization'” column then indicates the electrical distance

of the real fault location from the location determined by the Vdip and the distance of the fault from the substation.

Based on the results of fault localization by the Vdip system, it can be stated that for most of the records it was possible to locate the fault with an error of up to 1.5 km. In the case of faults 15 to 23, it is necessary to take into account the effect of a rather large and long-lasting failure of communication between the central unit and the DMUs, which significantly reduced the Vdip localization performance (due to the lower availability of DMU location, the restoration of communication capability was postponed until 2023, when the HW upgrade will take place).

In the case of faults 10 to 12, the Vdip system was unable to successfully locate the fault as it was a cross country (double) earth fault. This type of fault cannot be localized by the Vdip algorithm at this time (for this reason faults 10 to 12 were not evaluated). Localization of this type of fault is only possible after disconnection of one single earth fault, as can be seen in faults 13 and 14, which could be further successfully localized.

References

[1] *Solutions for energetics | ELVAC a.s.* [online]. Available on: https://www.rtu.cz/microsite/vdip