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IDENTIFIKACIJA FAZA I ISPADA U NN MREŽAMA ZASNOVANA NA DOGAĐAJIMA SA PODACIMA PAMETNIH BROJILA

EVENT-BASED IDENTIFICATION OF PHASES AND OUTAGES IN LV NETWORKS WITH SMART METER DATA

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KRATAK SADRŽAJ

Operatori distributivnih mreža se suočavaju sa raznim izazovima na NN mreži. Izazovi rezultiraju nepredvidivijim varijacijama opterećenja i napona. Da bi omogućili daljinski nadzor nad NN mrežom, operatori distributivnih mreža treba da omoguće digitalizaciju NN mreže uz primenu pametnih brojila. Pametna brojila su od vitalnog značaja za NN mrežu pošto se napon, struja, potrošnja, snaga za različite alarme i dodatne funkcije mogu koristiti za praćenje i kontrolu NN fidera i korisnika. Štaviše, pametna brojila se i dalje poboljšavaju. Danas su u stanju da pruže podatke skoro u realnom vremenu. Sa takvim podacima operatori distributivnih mreža mogu detektovati različite događaje na NN mreži kao što su ispadi, preopterećenja, fazna neravnoteža, itd. Štaviše, sa komunikacijom putem pametnog brojila u realnom vremenu, operatori distributivnih mreža mogu da predvide verovatnoću slučaja i kontinuitet procesa. Ovaj rad će dalje predstaviti identifikaciju faza i ispada u NN mrežama zasnovanu na događajima sa podacima pametnog brojila. Očekivani doprinosi rada su:

i) Povezivanje događaja sa podacima pametnog brojila, uz uključivanje, isključivanje kako bi se utvrdili jedinstveni događaji ispada za izveštavanje.
ii) Moguća fazna identifikacija jednofaznih korisnika, koristeći događaje o uključivanju, isključivanju ili faznim ispadima.
iii) Korišćenje informacija pametnog brojila iz alarma u realnom vremenu i pronalaženje komunikacione pouzdanosti u agregiranju NN ispada fidera.

Ključne reči: Ispadi, brojila, događaji, identifikacija faza, distribucija

ABSTRACT

DNO's are facing various challenges on the LV grid. Challenges result in more unpredictable variations of loads and voltage. To get remote monitoring over the LV grid DNOs need to enable digitalization of the LV network with implementation of smart meters. Smart meters are vital for the LV network since voltage, current, consumption, power to different alarms and additional functions can be used to monitor and control the LV feeders and users. Moreover, smart meters are still improving. Today they are capable to provide data near real-time. With such data DNO's can detect various events on the LV network like outages, overloads, phase imbalance, etc. Furthermore, with real-time smart meter communication, DNO's may ensure contingency and continuity of the processes.
This paper will further present an event-based identification of phases and outages in LV networks with smart meter data. The expected contributions of the paper are:

iv) Linking the events on smart meter data with power-up, power-down to determine unique outage events for reporting.
v) Possible phase identification of single-phase users using the power-up, power down information or phase outages events.
vi) Using smart meter information from real-time alarming and find communication reliability in aggregating LV feeder outages.

Key words: Outages, meters, events, phase-identification, distribution

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1. INTRODUCTION

Smart meters with all the available data and smart functions lead digitalization in DNOs. Smart meters can bring a lot of value to DNOs and to end users. Smart meters are used nowadays to monitor LV networks with detection voltage deviation, network line outages, faults, technical and non-technical losses, exc [1]. Smart meters are our probes in the distribution network, and using them enables us to get the estimation state of the distribution network vital variables such as voltages and power. Elektro Ljubljana d.d. collects data from smart meters in the metering center daily. From some smart meters that point-to-point communication via mobile network, data is collected near real-time. Derived meterings are collected, analyzed, and used for different purposes. The baseline is for calculation of power consumed and generated, others metrics is used for quality of power supply. For the monitoring LV network on some substations alarms and events are currently used. Events are historical data used to detect phase identification and control incidents on the LV network that already happened. Alarms are real-time information that enables localization of outages on the LV network in real-time. Alarms enable optimization of the processes in the future.
The purpose of this paper is to engage a process, that will enable the understanding of the parametrisation of the smart meters, to see how the events are triggered and detect if there are any possible offset in the timing at the smart meter side. Thus, the communication and the quality of delivery of the data can be checked and relate the SCADA triggered events with the events that occurred at smart meter side. The events can be planned and unplanned due to force-majeure. Smart meter data discovers the events since these events can be used for control and monitoring.
In this paper we present the linking the events on smart meter data with power-up, power-down to determine unique outage events for reporting. Our goal is to determine possible phase identification of single-phase users using the power-up, power down information or phase outages events. Finally, using smart meter information from real-time alarming and find communication reliability in aggregating LV feeder outages.

2. EVENT-BASED IDENTIFICATION OF OUTAGES

Smart meter event information is promising for DNOs providing data about different incidents on the LV networks. Events can provide information about voltage deviations and even about outages [2]. Events are historical data and usually are used for analysis of past incidents or to prevent outages or incidents in the future. At Elektro Ljubljana d.d., we use events also to control the reporting of outages and to detect phase identification on each smart meter.

2.1 Linking the events on smart meter data with power-up, power-down to determine unique outage events for reporting.

We are trying to connect an incident on a field with smart meters data. Incidents can be planned due to maintenance and repair works on the distribution network or unplanned due to force-majeure. Historical smart meter data enables us to analyze past incidents. From available smart meters data, we use events for power down, power up, and missing voltage by phase and voltage normal by phase. All events are collected with timestamps. For example, if on a substation we get a SCADA reported event about one phase failure, smart meter events can show us that there was actually a complete outage on the whole LV line from the substation. We detect and can control wrong SCADA reports from the field worker about the incident and with further analysis, we can even detect the phase connection of smart meters and single-phase users connection.

2.2 Possible phase identification of single-phase users using the power-up, power down information or phase outages events.

This paper explores the feasibility of identifying single-phase users by analyzing power-up, power-down information, and phase outage events. By examining patterns in power supply interruptions, such as consecutive power-down events or phase outages, we aim to differentiate the connection of single-phase users to one of the system phases. These events provide us valuable insights in efficiently managing and optimizing power distribution networks, thereby enhancing service reliability and addressing the unique needs of single-phase consumers.
To find the connected phase of a single-phase user we needed to test and understand the parametrisation of the smart meter. For example if an event of a phase outage is registered, the smart meter registry for the single phase users L1 is triggered with an event of a phase power down and restored, but no power down event, to be evident.

	Time	Event ID	Event description
1	09.04.2024 08:47:03	232	Power Down Phase L1
2	09.04.2024 08:49:14	235	Power Restored For L1
3	09.04.2024 08:49:14	88	Phase sequence reversal

Figure 1 - Power down for one phase

For a 3-phase smart meter, we can see in Figure 2, that if a phase is off, the value of voltage drops to 0.

Time	Status	3; 1-0:32.7.0*255; 2 [V	3; 1-0:52.7.0*255; 2 [V	3; 1-0:72.7.0*255; 2 [V
09.04.2024 08:46:40	Daylight Saving Time Active	240	240	239,9
09.04.2024 08:46:50	Daylight Saving Time Active	240,1	240,1	240,1
09.04.2024 08:47:00	Daylight Saving Time Active	240,2	240,2	240,2
09.04.2024 08:47:10	Daylight Saving Time Active	0	240,6	240,5
09.04.2024 08:47:20	Daylight Saving Time Active	0	240,7	240,6
09.04.2024 08:47:30	Daylight Saving Time Active	0	241	240,9
09.04.2024 08:47:40	Daylight Saving Time Active	0	240,9	240,8
09.04.2024 08:47:50	Daylight Saving Time Active	0	238	237,9
09.04.2024 08:48:00	Daylight Saving Time Active	0	238	238
09.04.2024 08:48:10	Daylight Saving Time Active	0	238,1	238,1
09.04.2024 08:48:20	Daylight Saving Time Active	0	238,1	238
09.04.2024 08:48:30	Daylight Saving Time Active	0	237,8	237,7
09.04.2024 08:48:40	Daylight Saving Time Active	0	237,6	237,6
09.04.2024 08:48:50	Daylight Saving Time Active	0	237,8	237,8
09.04.2024 08:49:00	Daylight Saving Time Active	0	237,4	237,4
09.04.2024 08:49:10	Daylight Saving Time Active	0	237,4	237,4
09.04.2024 08:49:20	Daylight Saving Time Active	237,2	237,1	237,1
09.04.2024 08:49:30	Daylight Saving Time Active	237,4	237,4	237,4
09.04.2024 08:49:40	Daylight Saving Time Active	237,3	237,3	237,3

Figure 2 - Phase voltage drops to zero for a single phase outage

When the phases are switched off one by one the final event of power down is created, meaning that all three phases needs to be off, so for a power down event is created and called forward to the notification centre. This enables us to make more efficient queries and search in the database for the needed events enabling us to determine the connection phase of single-phase users.

7	09.04.2024 09:12:11	232	Power Down Phase L1
8	09.04.2024 09:13:15	233	Power Down Phase L2
9	09.04.2024 09:14:26	234	Power Down Phase L3
10	09.04.2024 09:14:26	1	Power down
11	09.04.2024 09:14:48	2	Power up
12	09.04.2024 09:14:48	88	Phase sequence reversal
13	09.04.2024 09:14:49	235	Power Restored For L1
14	09.04.2024 09:14:49	236	Power Restored For L2
15	09.04.2024 09:14:49	237	Power Restored For L3

Figure 3 - Final power down-power up event

3. ALARMS-BASED IDENTIFICATION OF EVENTS

Alarms-based identification of events is possible where smart meters allow us to collect real-time information. In our case, we chose to test alarms on a substation (RAST LITIJSKA) with 15 measurement points. We can see a substation with 3 LV network lines in Figure 4. On each of the measurement points are installed smart meters with 4G modules that enable real-time information. The goal was to prove the detection of outages with alarms and phase identification.

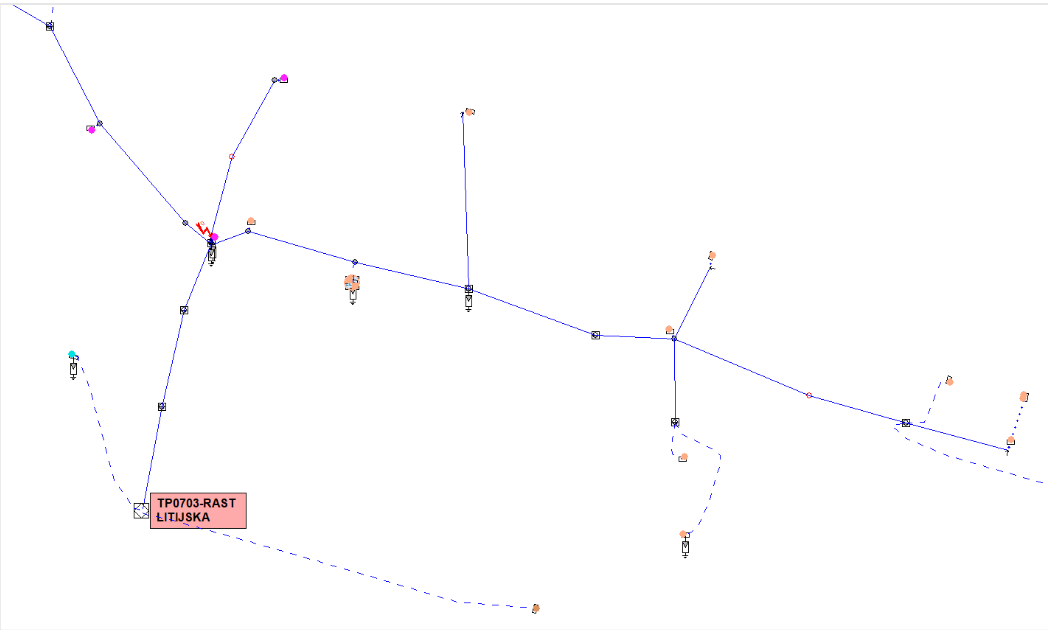

Figure 4 - LV substation RAST LITIJSKA

3.1 Using smart meter information from real-time alarming and find communication reliability in aggregating LV feeder outages

To detect alarms DNO needs to prepare HES and smart meters to establish a communication path for real-time information. In a case of Elektro Ljubljana as Head-End-System (HES) we are using SEP2W, where we set up »Push On Alarm« functionality (PoA) as well as »Push on PowerDown« functionality (PoPD) for AM550 meters.


Figure 5 - AM550 meter

Purpose of PoA is to send Alarms to HES as soon as they appeared in the alarm register. When HES receives certain alarm it triggers the job that reset descriptor and registers and read all the events from the meter and store them in the database (DB). Alarms will be triggered and sent to HES when one of the following events in Figure 3 occurs.

B1	Power resume	☑
B2	Voltage missing phase L1	☑
B3	Voltage missing phase L2	☑
B4	Voltage missing phase L3	☑
B5	Voltage normal phase L1	☑
B6	Voltage normal phase L2	☑
B7	Voltage normal phase L3	☑

Figure 6 - Selected events for triggering alarms

Within the alarms, the event »Total power failure« is not included, because it is sent as PoPD using last gasp functionality and it is still marked as Alarm. Since the meter is inaccessible at that moment of "Total power failure" we cannot trigger reading of the events, HES sends a notification to SCADA, and as soon as the meter connects to the network (APN) other alarms are sent and the job for reading all events is triggered.

NotificationPushAlarm		3. 04. 2024 09:16:37	3. 04. 2024 09:16:39		
PushNotifikacija	Succeeded	3. 04. 2024 09:16:37	3. 04. 2024 09:16:39	100% (1/1)	100% (1/1)
31985	Succeeded	3. 04. 2024 09:16:37	3. 04. 2024 09:16:39	100% (1/1)	100% (1/1)

Figure 7 - Sending Push Notification to SCADA

With such real-time information in SCADA monitoring of the LV network will be enabled with the help of the smart meters and HES. In Figure 8 we can see an example of alarms that were tested on a substation on one measurement point.

Alarms (14)

Alarms

Date	Name	Id	Data	Description
18.03.2024 09:02:16	PowerDown	1000	Push Power Down Data	Power down
19.03.2024 06:18:08	PowerUp	1001		Power up
19.03.2024 06:18:08	VoltageDownPhaseL1	1002		Missing voltage L1
19.03.2024 06:18:08	VoltageNormalPhaseL1	1008		Voltage L1 normal
19.03.2024 06:18:08	AlarmOn	1167		Alarm occurred

Figure 8 - Alarms on HES

Through the test on the substation, we have different test scenarios:

- Outage of one measurement point,
- Outage of one phase on one measurement point,
- Outage of the LV line from the substation,
- Outage of one phase on the LV line from the substation,
- Outage of two phases on the LV line from the substation,
- Outage of substation.

All tests were successful and in each test scenario, we got alarms in the SCADA system that fulfilled our goal. With such information, outages in the future will be detected when happen and enable our field workers to reduce the time of recovery on the LV network.

3.2 Communication path

In Figure 9 we can see the established communication path for smart meter alarms in the case of Elektro Ljubljana. It is expected that every day will be collected around 5000 alarms that will help SCADA monitor the LV network. To handle such amount of alarms system will need further automatization and integration with the system for work orders.

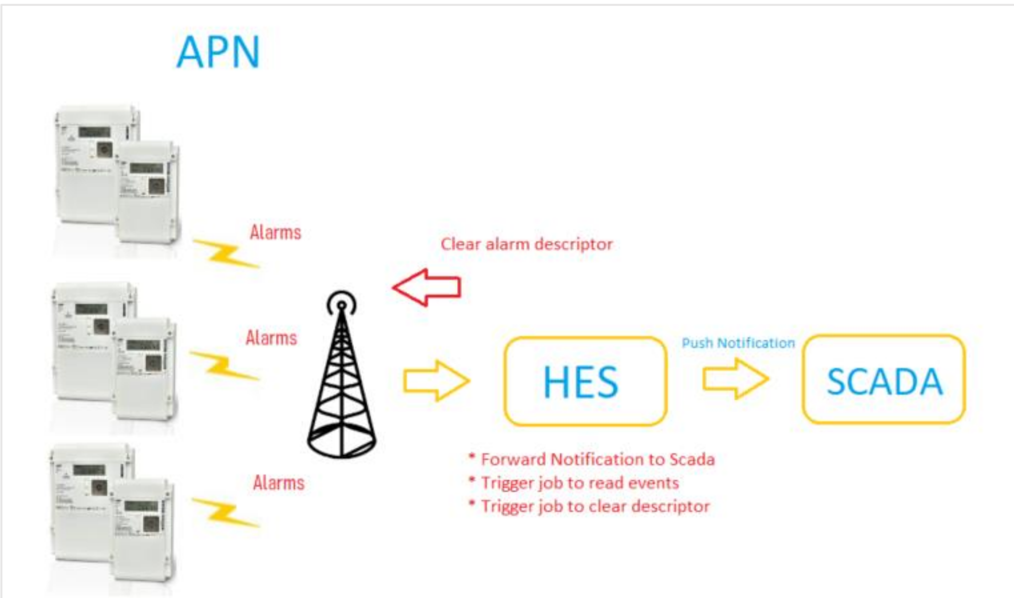

Figure 9 - Communication path

4. CONCLUSION

In the paper, we presented possibilities to determine outages and phase identification with smart meter historical data. Also, we presented an upgrade with the collection of real-time data. With real-time data, we get even more useful information that enables further automatization of the processes. Without automatization monitoring of real-time data like alarms will be impossible. In the future real-time data for outages will automatically create work orders and the information will be sent further to consumers. With such automatization, we will reduce unnecessary phone calls, optimize processes of outage detection, and most importantly increase power quality and consumer satisfaction.

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