D 4.5.11

Implementation of a DEMO system related to Smart Fault Management in LV network (normal/storm conditions)

Version 1.0

Created:	2013-2-27
By:	Joni Aalto, Empower IM Oy Jan Segerstam, Empower IM Oy

Table of Contents

1. Preface

This report is a part of the results from the third funding period of the Finnish national research project ”Smart Grids and Energy Markets”. The project has been funded by Tekes – the Finnish Funding Agency for Technology and Innovation. This document is based on the development work of Empower IM Oy and Kymenlaakson Sähkö Oy and the partner networks of both companies. The work has been carried out in cooperation with multiple specialists.

During the third funding period of SGEM, Task 4.5.2 B defined the most significant processes related to the smart fault management of low voltage networks in service based AMR infrastructure. The development work continued and a system map was built, based on the required systems, which would be needed to run the fault management processes. Also the required functionalities for the systems were identified. There were numerous issues, which required additional discussions and development to improve the designed system infrastructure. Finally, the developed processes and the functionalities were demonstrated, by implementing a demo system for this purpose. The goal was to verify the correct operation of the different functionalities and evaluate them, thus providing also information for the possible pilot planning, which could be later arranged in a real distribution network environment. This report introduces the demo system and the demonstrations which were carried through.

2. Demonstration planning

The functionalities which were designed during the third funding period of SGEM were planned to be demonstrated by building a demo system related to the smart fault management. This would provide valuable information about the possible flaws and deviations, which could not have been taken into consideration in the design phase. Also, there was a need to verify the smart functionalities which had been designed into the service provider's integration interface.

The demonstrations should be made in a test environment which corresponds to the real operational environment as much as possible. In this case, it would be challenging to create a physically matching test environment as the number of the meters is very big in the real distribution network and the real consumption places could not be used in these first demonstrations. Once the demo system would have been designed and implemented, it would provide a possibility to verify the different smart fault management functionalities before taking them into the piloting in the real network environment.

The implementation of the demo system would enable to verify that the different alarms would be possible to be delivered to the DSO's DMS system via the service provider's integration interface. In addition, it could be checked that the correct alarm types would be activated in the AMR meters once the corresponding fault type would be simulated to the metering devices and that this alarm would be delivered correctly to the DMS system, which would provide an indication about the corresponding fault type in the consumption place.

In a real operational environment there can be situations when a great number of alarms would be occurred for example due to a storm. Therefore, it would be important to also implement a stress test for the systems which are used to receive and deliver the alarms, to be able to confirm that even a large amount of alarms would not cause major system errors.

The SLA-levels were defined for the functionalities of smart fault management. A one goal in particular would be to verify that the designed functionalities can be operated inside the time limits which are defined by the SLA-levels. If the operations would not be operated within the SLA-limits in the demo system, it would be highly probable that the SLA-levels would not be possible to be followed also in the real network environment.

The implementation of the demo system was divided into three phases. First, the required field equipment would be determined and tested. In these test it would be verified that different simulated faults would produce a corresponding alarm, which can be delivered onwards in the system infrastructure. After this, all of the sub-systems of the overall system infrastructure would be tested. This would mean separate tests between the service provider and both of the field equipment providers, and finally tests with the DSO and the DMS system. Simulator applications were built for these tests. Couple of the simulators would act as field equipment, providing different generated alarms, while one of the simulators would act as a DMS system, receiving the alarms and providing response which corresponds to the description of the interface of the real DMS system. Finally, the actual demo system would be implemented, including the whole information delivery chain from the metering devices to the DMS system. A more detailed description of the demo system is introduced in the next chapter.

During conventional conditions, the faults in the low voltage networks do not usually emerge in large volumes. On the contrary, big storms can cause a big amount of faults in the low voltage network and this can happen over a short time span. Also, during this kind of situation there can be increased need to activate requests for customer site information, which also load the systems related to the smart fault management. Still, this kind of situation is challenging to be created in the demo environment and the demo system which was implemented for this development project reflects more the “normal” conditions. Although, by utilizing the simulator software which enables to generate a great number of alarms it is possible to obtain some preliminary information about the performance of the different systems under more extreme conditions.

3. Arrangement of the DEMO system

This chapter introduces the implemented demo system which was used to demonstrate the functionalities of smart fault management. The demo system is illustrated in the figure 1 on the below. During the tests, field equipment was located in two different places in the test laboratories of the field equipment providers. Service provider's test systems included the test environment's servers such as the test reading system servers and the test integration interface server. The DSO installed test DMS into its test server to receive the test alarms and to activate customer site status enquiries. Additionally, fictional consumption places were initialized into the different systems.

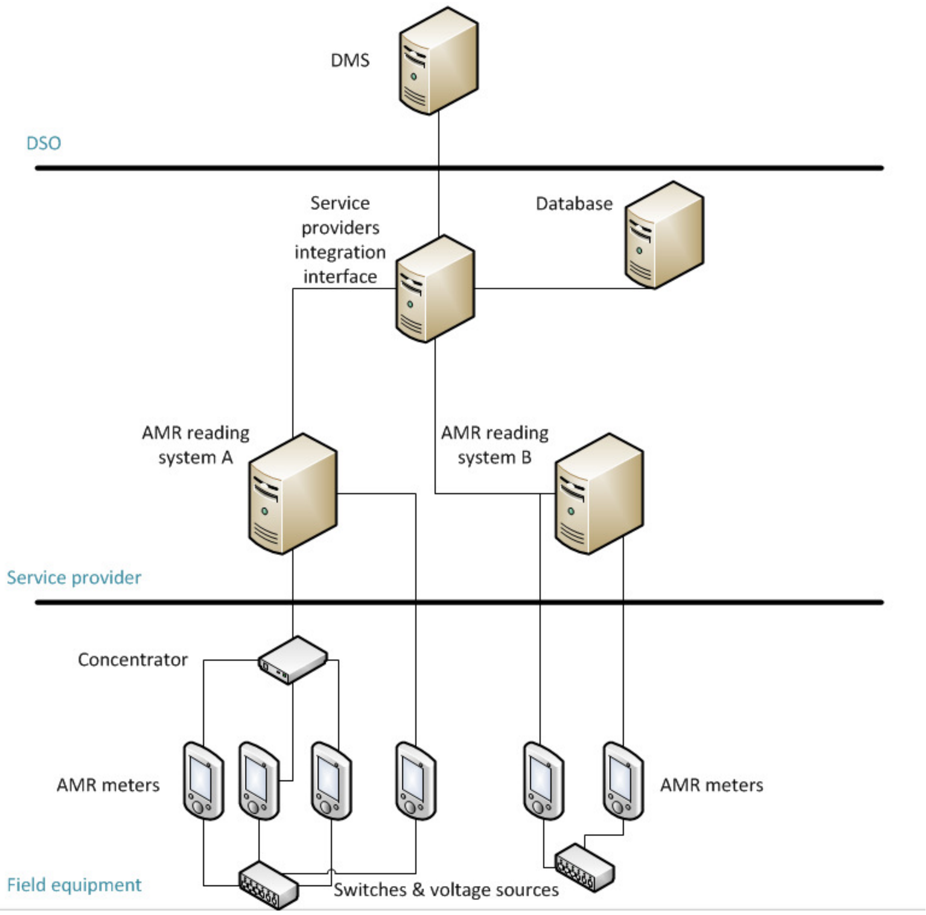

Figure 1. *The demo system related to the smart fault management of LV network*

The test participants communicated via the remote connections from the own offices, which made the test arrangements more fluent. A significant part of the overall demo system implementation process was to establish the required information exchange connections between the different systems. Next sub-chapters introduce the parts of the overall system infrastructure more in detail.

2.1 Field equipment

The basis for the selection of the field equipment for the demo system was that the real AMR metering device infrastructure and the different metering types included in it should be represented as diversely as possible. In addition, the test arrangements should enable to simulate a great majority of the different fault types which should activate an alarm. The arrangements were implemented by using switches and voltage sources. By using these, the different fault types were possible to be simulated to activate an alarm in the AMR meter. The following table 1 introduces the fault types which were possible to be demonstrated by the ARM meter providers A and B.

Simulated fault type	A	B
Zero fault	x	
Broken medium voltage wire	x	
Over voltage	x	x
Under voltage	x	x
Reversed phase order	x	
Blown fuse (missing phase)	x	x

Table 1. *Fault types which were possible to be simulated in the demo system with the laboratory arrangements*

Different meter types were selected into the demo system to demonstrate the real distribution network. Four meters were chosen from the first field equipment provider and two from the second one. The meter types included p2p-meters which communicate directly with the upper level system and meters which communicate through the concentrator. Also, 1- and 3-phase meters were both included. These pieces of equipment form the field equipment part of the overall demo system.

2.2 Service provider's systems

The required additional softwares were installed into the service provider's test systems. One of the AMR reading system servers needed to be equipped with additional software and for the second AMR infrastructure, a separate alarm server was installed. In the picture this alarm server is a part of the AMR reading system. Additionally, the softwares which handles the alarms and requests in the service providers integration interface were installed.

The simulators which generate alarms were possible to be run in the ARM reading system servers. This would enable to send a large amount of alarms to the service provider's integration interface. Integration interfaces database was utilized to store the required SLA and volume information about the operations.

2.3 DSO's systems

Test arrangements were quite straightforward from the DSO's point of view. It was needed to install the DMS system into the test environment and activate the required AMR interfaces. The demo system which was implemented didn't include the systems which communicate with the end customers. This could have been implemented, but it was not seen as a crucial part of the demo system and the scope of the demo system was selected to cover only the lower level systems.

4. Demo cases

The demo cases were designed to best utilize the available combinations of the different metering device types of the both field equipment providers. Basically, it was possible to activate alarms on single metering devices or on multiple devices simultaneously and similarly to activate requests for customer site status information to single consumption places or to multiple consumption places simultaneously. As previously mentioned, also the alarm simulators were possible to be used to generate greater number of alarms.

Testing was followed with a test record, which included for example all the different phases of the smart fault management functionalities with the expected outcomes of the phases. In addition to this, after a single test case, all possible time stamps were documented to evaluate the delays between the different systems. The table 2 provides a sum-up of the test cases which were carried out with the demo system.

Demo case	Number of test meters	Reading system
Delivery of a zero alarm	2	A
Delivery of a phase fault	2	A
Delivery of a broken MV-line alarm	2	A
Delivery of a changed phase order alarm	2	A
Delivery of an over voltage alarm	2	A
Delivery of an under voltage alarm	2	A
Deviation demo case 1	1	A
Delivery of a phase fault	3	B
Delivery of an over voltage alarm	4	B
Delivery of an under voltage alarm	4	B
Deviation demo case 1	1	B
Deviation demo case 2	1	B
Status request for meter type a	1	A
Status request for meter type b	1	A
Status request for multiple meters	2	A
Status request for meter type c	1	B
Status request for meter type d	1	B
Status request for meter type e	1	B
Status request for meter type f	1	B
Status request for multiple meters	4	B
Status request incl. both AMR reading systems	2/2	A/B
Deviation demo case 1	1	A
Deviation demo case 2	1	B
Deviation demo case 3	1	A
Stress demo case	220	B

Table 2. *Demo cases.*

Generally, the demo cases were carried through by using multiple meters simutalneously. Therefore, for example the alarms were activated on the multiple AMR meters at the same time. It can be expected that in the real system environment there will be some deviation in the information between the different systems and therefore it was decided to include some deviation demo cases into the testing. Deviation demo case 1 related to the alarm delivery means delivering an alarm from the consumption place which is not stored in the database of DMS. Deviation demo case related to the reading system B was a case when the alarm was activated on a meter whose meter number was not stored in the service provider's integration interface. Therefore the mapping of the meter number to the corresponding consumption place ID would not be possible.

The deviation demo cases 1 and 2 related to the request for customer site status information means requests for the consumption places whose information is not stored in the AMR reading system. Therefore, the request would arrive including the unknown consumption place ID as the identification. The demo case 3 was a case when the request was activated for a meter which was not equipped with the fault management software, as this could also be a real situation. Finally, a small stress demo case was also carried through. In this case a large amount of alarms was generated in the AMR reading system server and delivered to the service providers integration interface over a short time span.

Figures 2-5 illustrate the outcomes from the smart functionalities which were implemented into the service providers integration interface. The figure 2 illustrates the table which is generated based on the requests for the customer site status information. It indicates not only the volume of the consumption places in the requests, but also the time when the request arrived from the DSO and when the answer was delivered back to the DSO, including the required information which was red from the AMR meters.

Results | Messages

	ID	query_token	query_state	query_received	query_ended	query_item_count	query_wait_count
1	5	Token41757234405787	3	2013-01-18 07:55:23.0000000	2013-01-18 07:58:47.6788750	1	0
2	6	Token41761861213370	3	2013-01-18 08:03:06.0000000	2013-01-18 08:04:17.9039652	1	0
3	7	Token41763487182088	3	2013-01-18 08:05:48.0000000	2013-01-18 08:06:52.8288147	1	0
4	8	Token41765546440375	3	2013-01-18 08:09:14.0000000	2013-01-18 08:09:48.5978144	1	[illegible]

Figure 2. *Smart functionality related to the request for customer site status information*

The figure 3 illustrates corresponding functionality related to the alarm delivery. In this case, the information which is stored in the service providers integration interface includes the time stamps of the alarm event in the metering device and the time when the alarm was received into the integration interface. This forms a basis for the SLA calculation. In addition, the meter number and the consumption place ID as well as the indication of the source AMR reading system is listed. Values 1 and 2 refer to the AMR reading systems A and B.

The figure 4 illustrates the table which provides the connection between the meter number and the consumption place ID of the AMR meters of the AMR reading system B. The alarms from the reading system B did not include a consumption place ID, but only a meter number. The mapping of the metering number to the corresponding consumption place ID is done in the service provider’s integration interface by using the table which is illustrated in the figure 4.

	ID	alarm_timestamp	alarm_received	alarm_sent	alarm_measurementpoint	alarm_meter	alarm_source	alarm_statuscode
1	17	2013-01-17 07:18:29.0000000	2013-01-17 07:18:57.0000000	NULL	76150103	7350028676150103	2	0
2	18	2013-01-17 07:19:01.0000000	2013-01-17 07:19:23.0000000	NULL	75985805	7350028675985805	2	0
3	19	2013-01-17 07:30:30.0000000	2013-01-17 07:30:48.0000000	NULL	75985805	7350028675985805	2	0
4	20	2013-01-17 07:30:30.0000000	2013-01-17 07:30:49.0000000	NULL	76150103	7350028676150103	2	0
5	21	2013-01-17 07:33:00.0000000	2013-01-17 07:33:18.0000000	NULL	75985805	7350028675985805	2	0
6	22	2013-01-17 07:33:00.0000000	2013-01-17 07:33:28.0000000	NULL	76150103	7350028676150103	2	0
7	23	2013-01-17 07:40:59.0000000	2013-01-17 07:41:18.0000000	NULL	75985805	7350028675985805	2	0
8	24	2013-01-17 07:41:01.0000000	2013-01-17 07:41:21.0000000	NULL	76150103	7350028676150103	2	0
9	25	2013-01-17 07:43:29.0000000	2013-01-17 07:46:47.0000000	NULL	75985805	7350028675985805	2	0
10	26	2013-01-17 07:43:29.0000000	2013-01-17 07:48:14.0000000	NULL	76150103	7350028676150103	2	0
11	27	2013-01-17 07:46:00.0000000	2013-01-17 07:48:16.0000000	NULL	76150103	7350028676150103	2	0
12	28	2013-01-17 07:46:00.0000000	2013-01-17 07:48:16.0000000	NULL	75985805	7350028675985805	2	0
13	29	2013-01-17 07:48:31.0000000	2013-01-17 07:48:59.0000000	NULL	76150103	7350028676150103	2	0
14	30	2013-01-17 07:51:01.0000000	2013-01-17 07:51:48.0000000	NULL	76150103	7350028676150103	2	0
15	31	2013-01-17 07:48:31.0000000	2013-01-17 07:55:41.0000000	NULL	75985805	7350028675985805	2	0
16	32	2013-01-17 07:50:59.0000000	2013-01-17 07:55:41.0000000	NULL	75985805	7350028675985805	2	0
17	33	2013-01-17 07:55:00.0000000	2013-01-17 07:55:42.0000000	NULL	75985805	7350028675985805	2	0
18	34	2013-01-17 07:53:31.0000000	2013-01-17 07:55:42.0000000	NULL	75985805	7350028675985805	2	0
19	35	2013-01-17 07:53:29.0000000	2013-01-17 07:58:23.0000000	NULL	76150103	7350028676150103	2	0
20	36	2013-01-17 07:58:00.0000000	2013-01-17 07:58:23.0000000	NULL	75985805	7350028675985805	2	0
21	37	2013-01-17 07:58:00.0000000	2013-01-17 07:58:24.0000000	NULL	76150103	7350028676150103	2	0
22	38	2013-01-17 07:55:00.0000000	2013-01-17 07:58:24.0000000	NULL	76150103	7350028676150103	2	0
23	39	2013-01-17 08:02:00.0000000	2013-01-17 08:06:18.0000000	NULL	75985805	7350028675985805	2	0
24	40	2013-01-17 08:02:00.0000000	2013-01-17 08:06:18.0000000	NULL	76150103	7350028676150103	2	0
25	41	2013-01-17 08:16:01.0000000	2013-01-17 08:16:26.0000000	NULL	2927720001	7350028676150103	2	0
26	42	2013-01-17 08:16:02.0000000	2013-01-17 08:16:26.0000000	NULL	1817300001	7350028675985805	2	0

Figure 3. *Smart functionality related to the alarm delivery*

	ID	mpl_measurementpoint	mpl_meternumber	mpl_source	mpl_changed
1	30	76150103	UNKNOWN	2	2013-01-17 07:19:01.4830000
2	31	75985805	UNKNOWN	2	2013-01-17 07:19:24.2500000
3	32	2927720001	UNKNOWN	2	2013-01-17 08:16:33.0000000
4	33	1817300001	UNKNOWN	2	2013-01-17 08:16:33.5270000

Figure 4. *Database for the combination of a meter number and a consumption place ID*

Finally, the figure 5 illustrates the outcome of the SLA reporting application. In this case, the SLA report was printed based on the alarm deliveries. It provides information about the volume of the alarms and the share of alarms which were delivered within the determined SLA limits and which were not. The information is provided as overall rates and additionally as AMR reading system based information. In addition, similar report were possible to be printed based on the information related to the requests for the customer site status information.

Source	Total SLA notified alarm count	Alarms inside SLA limit	Alarms outside SLA limit	Alarms inside SLA limit (%)
All	240	61	179	25,4
AMR Reading system A	224	45	179	20,1
AMR Reading system B	16	16	0	100,0

Created on: 25.02.2013 16:12:40 1 / 1

Figure 5. *The SLA report of alarm delivery.*

To sum up, the planned demo cases were successfully carried through. Fault simulations caused a correct fault type to the AMR meter and it was first delivered to the service providers integration interface. The required pieces of information were stored in the integration interface and the required mapping related to the alarms from the reading system B was done before the delivery to the DSO's DMS. Finally, the corresponding alarm indications were available in the DSO's DMS system's user interface. Similarly, the request for customer site status information provided the planned information for the DSO. Also, in this case the required information was stored in the database of the service provider's integration interface. Additionally, the application which collected the data for the answer to the request by utilizing the interfaces of the reading system B operated as planned. In addition, the deviation demo cases could be handled in a controlled way and they did not cause any major inconveniences. Generally, in these cases the information would not just be delivered to the receiving system.

5. Piloting phase

Once the functionalities of the smart fault management have been tested with the described demo system, later it would be a time to put the functionalities to be piloted in the real network distribution network environment. Therefore also preliminary discussions considering the possible piloting were held. Based on the discussions the piloting should be started with a relatively small network area, but it should include diverse collection of different AMR meter types. Once everything would seem to be operating as planned the pilot area could be gradually expanded. In this phase the goal would still be on the system operability and for example the customers would not receive any sms-messages at this point regarding the possible faults in the low voltage network.

The nature of the smart fault management sets challenges for the piloting. For example the testing related to the AMR mass rollout projects is quite straightforward as the consumption data is delivered regularly on a daily basis. Therefore, also the testing can start immediately after the systems and AMR meters are installed in a certain pre-defined area. This is not the case with the smart fault management. The indications will be delivered only when there are faults in the low voltage network. Therefore, if there are no faults for example caused by a storm during the piloting period it will cause the piloting to be “useless”. Due to this, it could be practical if the piloting area would include AMR meters which are geographically widespread. Also, if possible, the piloting area could be selected based on the fault statistics which could indicate network areas which usually include more faults than average network areas.

6. Summary

During the third funding period of SGEM, Task 4.5.2 B identified and described the most significant processes related to smart fault management of low voltage networks. Additionally, the systems which would be required to run the processes in an integrated ICT infrastructure were defined and the required functionalities related to them were determined. Also, some ideas for further development were collected. Finally, at the end of the funding period, a demo system was implemented together with the partner network to demonstrate the functionalities which were developed previously during the funding period.

The work enabled to test the functionalities related to the smart fault management of low voltage networks and also to verify some of the different deviation situations which could be possible in the real operation environment. This information is useful to be able to design operation models to handle the deviation situations in a controlled way. The results from the demonstrations were positive as the designed functionalities operated as planned. The work acts as a basis for the continuation of the development work towards possible piloting of the smart fault management in the real distribution network environment. The work which was done during the funding period provides valuable information about the possibilities to utilize the functionalities of the second generation AMR meters in an integrated ICT environment to provide additional value for the DSO and for the end customers.