European Research Infrastructure supporting Smart Grid Systems Technology Development, Validation and Roll Out

TRANSNATIONAL ACCESS
USER PROJECT FACT SHEET

USER PROJECT	
Acronym	REPRMs
Title	**Reliability Enhancement in PV Rich Microgrids with Plug-in-Hybrid Electric Vehicles and Data Centres**
ERIGrid Reference	**01.006- 2016**
TA Call No.	01

HOST RESEARCH INFRASTRUCTURE			
Name	**National Smart Grid Laboratory (NSGL), SINTEF Energy Research - Trondheim, Norway**		
Country	**Norway**		
Start date	**28-May-2017**	**Nº of Access days**	**6 days**
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1. USER PROJECT SUMMARY (objectives, set-up, methodology, approach, motivation)

Motivation:

Europian Union Energy Policy and the Indian National Electricity Policy of 2005 have emphasized the need of strengthening the regional power grids, power transmission and distribution networks, and the need to develop an emergency response system for power safety and reliability, and the necessity to reinforce the priority policies for generation of electrical energy from renewable sources.

There are concentrated efforts in research, development, and demonstration (RD&D) currently in progress in Europe, the United States, Japan, Canada and in India on microgrids which are capable of providing quality power with imporoved reliability when compared with state-of-art power distribution systems.

In this connection, there is a need to study and understand the reliability of the existing power distribution systems, thereby, identification of potentional threats which can affect the operation of the existing power grid systems.

Objectives:

This project proposes to achieve the following objectives.

1. To study the reliability of existing microgrid systems with photovoltaic (PV) generators, plug-in-hybrid vehicles (PHEVs) and data centres (DCs)
2. To enhance the reliability of microgrid through optimal integration of distributed generators (DGs)
3. To develop a methodology to emphasize the contribution of PHEVs and DCs in improving the reliability of microgrids with high PV penetration.

Methodology& Approach:

This project execution involves the following steps:

a) Modelling, integration of DGs thereby realization of microgrid

b) Develop/define reliability metrics/indices

c) Reliability assessment in microgrid

d) Finding optimal dispatch of DGs, PHEVs and DCS with the help of BA while minimizing the loss, and cost with improved reliability

e) Experimental validation of dispatch schedule and their actual applicability in the system considered

Optimal placement and sizing of the DGs with improved reliability are taken from the Bat optimization algorithm. From the results of optimization algorithm, the PV generator is decided to connect at bus number 9. Since the developed microgrid system is a virtual power system and is running in real time in Opal-RT system, all the three phase terminals of bus number 9 have been brought out for physical access. However, the terminals brought out from Opal-RT system are virtual terminals representing the original terminals. These terminals which are brought out for access are operating at low voltage (20V maximum) and cannot handle currents more than few milli amperes.

On contrary, the DGs which are expected to connect to the virtual power system running in Opal-RT are real converters which are running at actual system voltage of 208V and are expected to deliver powers in the range of KW and KVAr. Hence, a grid emulator is employed to interface the actual DGs with the virtual bus from the Opal-RT.

Due to the limitation in number of DGs that can interfaced with the grid emulator (6 output terminals), which is in-turn used to interface with the microgrid in Opal-RT system, the maximum number of DGs that can be interfaced are limited to two. Hence, in the later part of the experiment, two DGs are interfaced at bus number 9 and at bus number 5. The converter DG at bus number 9 is considered as PV generator while the DG interfaced at Bus number 5 is considered as PHEV/DC.

Set-up:

An experimental set-up has been made to validate the proposed solution which resulted in optimal schedules as calculated from Bat optimization algorithm, for the improvement of reliability in the considered European MV distribution system.

The considered distribution system which is operating as microgrid in this study is modelled in Matlab-Simulink environment. The same system is synthesized in Opal-RT system shown in Figure.1.

A grid emulator which is used to interface the real converter based DGs to the virtual microgrid system running in Opal-RT is shown in Fig.2

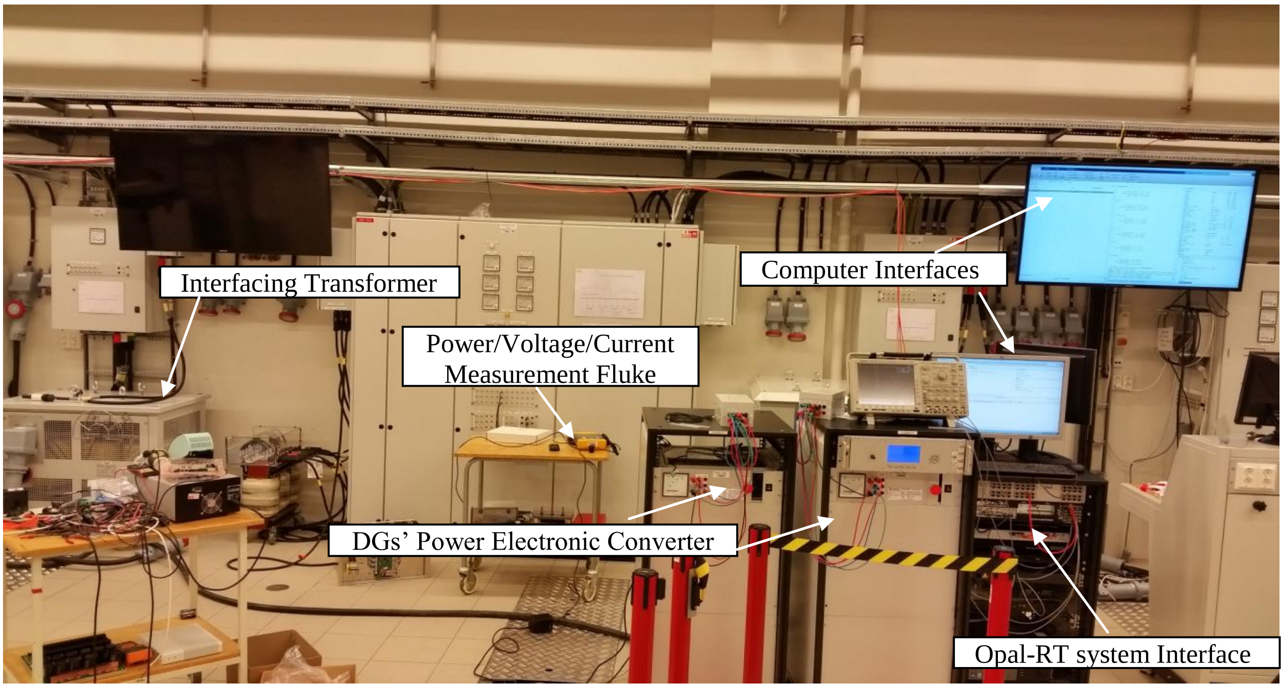


Fig.1 . Experimental Set-up Part-1


Fig. 2 Experimental Set-up Part-2 (Grid Emulator)

2. MAIN ACHIEVEMENTS (results, conclusions, lessons learned)

Results:

The PV DG is connected at bus number 9, whereas PHEV/DC is connected at bus number 5, the concluded optimal locations for respective DGs. According the optimal scheduling DGs are controlled to deliver, 10KW at 0.9 pf lead by PV DG and the PHEV/DC is controlled to deliver 6KW at 0.9pf lead.

In experiment-1, only one DG is connected and the power generation within the DG is only 10kW, where as in experiment-2, the generation within the sources is 10KW+6KW. Due to the increased generation within the microgrid, the power, hence the current drawn from slack has decreased which results in reduction of drops, therefore the increase of bus voltage from 192.4v to 194.2V as shown in Figs. 3 and 4.

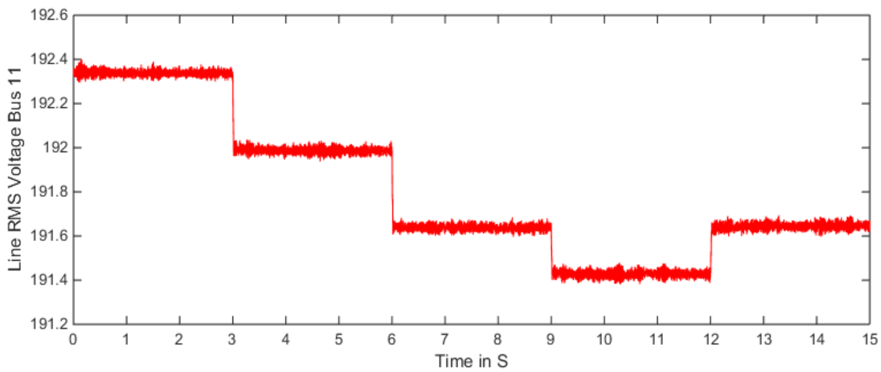


Fig. 3 RMS Line Voltage at bus number 11

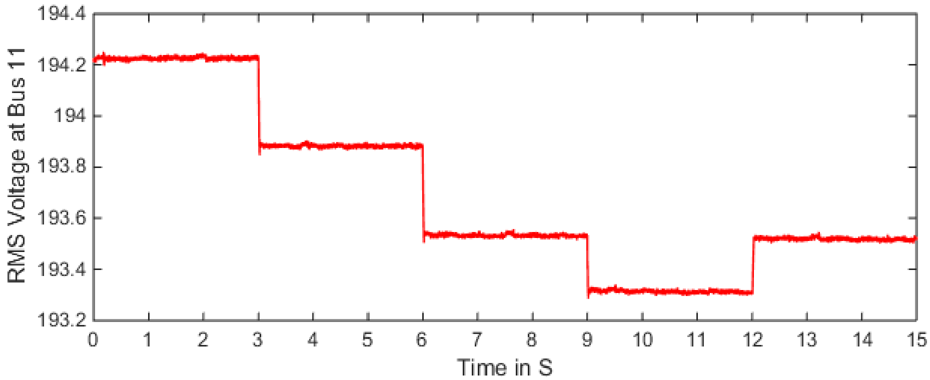


Fig. 4 RMS Line Voltage at bus number 11 with two DGs

It can be inferred that, in experiment-1, since only DG is there in the microgrid, the microgrid is drawing more current, (198A peak) from slack bus. However, in experiment-2, since two DGs are there within the microgrid, the current drawn from the microgrid has decreased from 198A peak to 191.5A peak which is clearly depicted in Figs. 5 and 6.

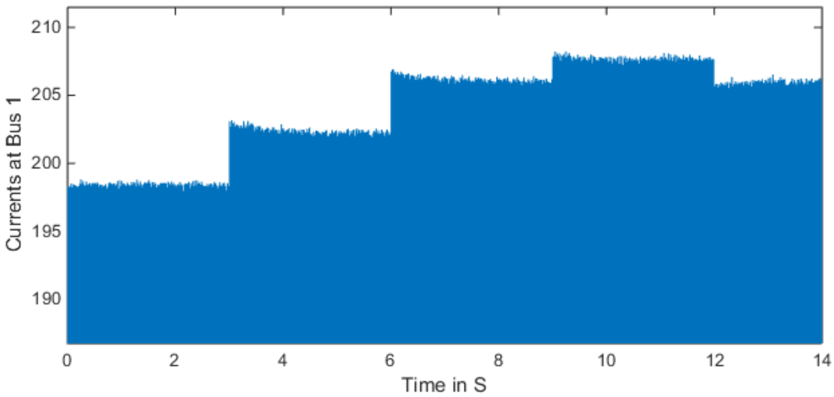


Fig. 5 Zoomed-in instantaneous phase currents at bus number 1, Slack bus

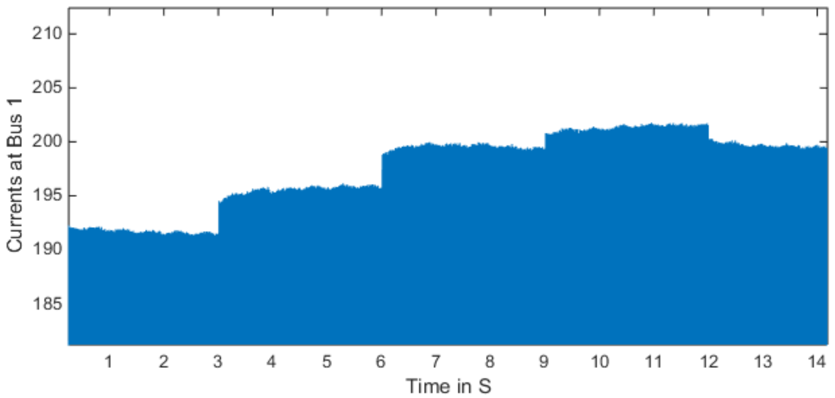
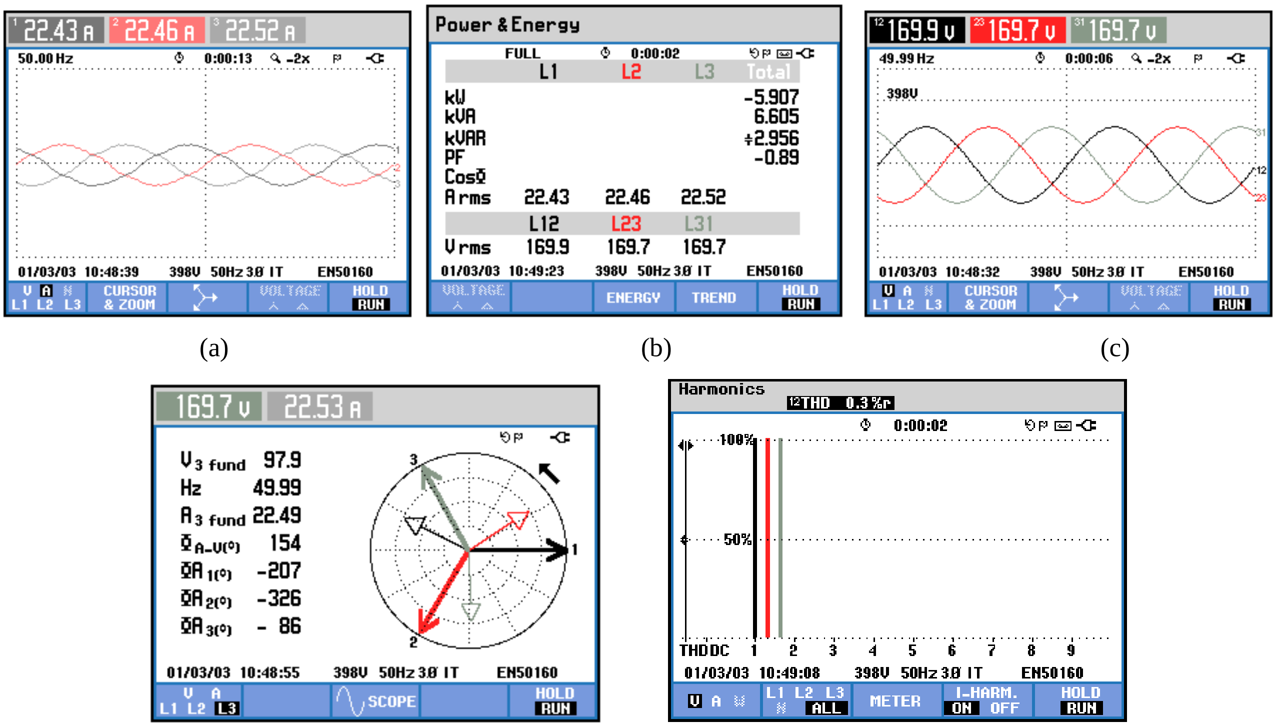


Fig.6 Zoomed-in instantaneous phase currents at bus number 1, Slack bus, with two DGs interface within the microgrid

The actual currents, voltages at bus number 5 and the power fed by PHEV/DC at bus number 5 is shown in Fig. 7.



(a) (b) (c)

(d) (e)

Fig. 7 Different electrical quantities at PHEV/DC bus (at bus number 5) (a). Instantaneous currents (b) Real and Reactive power feeding by PHEV/DC DG at bus number 5 (c) Instantaneous voltages (d) Phasor diagram of voltages and currents (e). THD in the current fed by PHEV/DC

Conclusions:

In the emerging trend of increasing renewable penetration, reliability plays a critical role for successful realization and operation of microgrids. In this connection, this project considered a European Medium Voltage distribution system with two different DGs, PV and PHEV/DC for the improvement of reliability. With an objective of improving the reliability of the considered microgrid system, an optimal DG schedules have been found using metaheuristic optimization algorithm known as bat algorithm. System loss, cost and voltage deviations have been minimized while finding the optimal DG schedules for improving the reliability.

For the considered CIGRE distribution system, if no DG is added to the system, the ERI can be calculated as ERI=1-(44.39*0.015/44.39)= 0.985.

Total system load is 44.39kW, 0.015 is FOR for Conventional Generation (grid).

With Addition of 1DG with 10kW: ERI=1-((34.39*0.015)+(10*0.002)/44.39)=0.9879

With addition of 2DGs: ERI=1-((24.39*0.015)+(10*0.002)+(6*0.003)/44.39)=0.991

The optimal schedules calculated are validated for their practical feasibility through experimentation using the Power-hardware-in-loop with the help of Opal-RT system integrated with real power electronic converter based DGs and grid emulator based interface.

After successful experimentation, the calculated schedules can be practically feasible and successful integration of DGs with scheduled power flows can be achieved to improve the reliability.

3. PLANNED DISSEMINATION OF RESULTS (journals, conferences, others)

Planned to publish in Prestigious International/National Journals and Transactions like, IEEE Transactions, IET Proceedings, Elesevier/Science Direct Journals.