TRANSNATIONAL ACCESS
USER PROJECT FACT SHEET

USER PROJECT

Acronym	**TIPI-GRID**
Title	**T**ransient Stability of **I**nterference of **P**hotovoltaic **I**nverters Reactive Power control by the **GRID** voltage and Medium Voltage Transformer
ERIGrid Reference	**03.007-2017**
TA Call No.	**Call 3**

HOST RESEARCH INFRASTRUCTURE

Name	**AIT Austrian Institute of Technology – SmartEST Lab**		
Country	**Austria**		
Start date	**30.04.2018**	**Nº of Access days**	**14**
End date	**27.07.2018**	**Nº of Stay days**	**27**

USER GROUP

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Country (Leader)	**Switzerland**

1. USER PROJECT SUMMARY (objectives, set-up, methodology, approach, motivation)

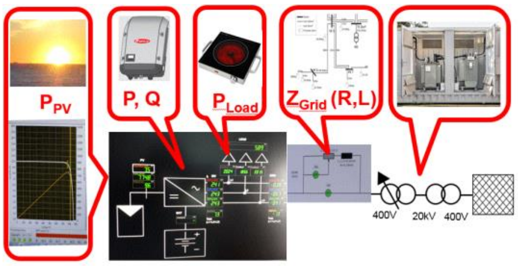

Fig. 1 Experimental Setup in the AITLab

Voltage control in the distribution grid (DG) is challenging at high photovoltaic (PV) power production due to the voltage drop across the electrical cables. PV inverters itself are able to deliver reactive power as function of line voltage Q(U) at the feeding point and thus help to reduce the deviation relative to the nominal voltage level. Due to the fact that dozens of distributed PV inverter Q(U) control loops are acting, the question of stability of the DG voltage level is essential. In addition, collateral actions effecting the DG stability like fast changing load levels and supplying transformers equipped with an On Load Tap Changer (OLTC) able to control with supply voltage from the higher voltage level of the grid. The overall benefit of this voltage control method using the PV inverter Q(U) function is the minimum costs to implement the Q(U) static characteristics by installing the inverter according to the DG regulations and the absence of any other IT infrastructure to be implemented by the DG operator.

Experimental tests of the stability of the PV inverters Q(U) control have been examined in the AIT SmartEST lab in Vienna. One example was the request of active power of the DUT during an excerpt of a typical cloudy day in the Zurich area in April, performed in the lab, by applying the alteration of the calculated current voltage characteristics of a crystalline silicon PV generator onto a DC amplifier according to the measured solar irradiance characteristics. The voltage changes in the grid were analysing according to the produced reactive power of the inverter on the selected grid impedance. In detail, several measurement series with following devices were performed according to the chosen parameter settings.

- The photovoltaic power characteristics applied at the DC input of the commercial 27 kW PV inverter was performed by a 15kW DC amplifier as a function of PV generator power
  - a) step function
  - b) based on real solar irradiance measurement daily weather profile 2 second interval
- The grid cables are emulated by a complex impedance equal to the long distance grid impedance which a typical PV plant is facing at the village boundary 550m away from the transformer
- Resistive loads turned off and on connected at the feeding station of the PV inverter
- A commercial substation transformer equipped with an OLTC able to change the line voltage in intervals of 1.5% of nominal AC voltage; the delay time constants of this controller
- PV inverter parameter settings:
  - a) static Q(U) characteristics with linear increase of Q at voltage V1 till max of Q at V2; the Q slope is adapted to a 100kW PV installation with a 550m distance to the substation in a the typical small village with a farmers house PV installation
  - b) the time constant of the Q(U) controller

The aim was to apply several combinations of above power flow in the grid, solar irradiance, load levels and substation voltage steps at different PV inverter static parameter settings to reach a point of instability.

Other outcomes during the experimental work in the laboratory improving the Q(U) operation in the distribution grid would be appreciated.

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

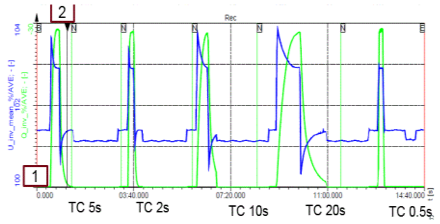

Fig. 2 Q reduce voltage rise at different TC

The main outcome of the work was that not all the lab experiments could obtain a system status outside the stability limits. An oscillation of the line voltage was observed for the uncommon practical case if the installer of a PV inverter mix up the sign of the static Q(U) characteristics. Thus the connected SUB station equipped with a OLTC will counteract the Q(U) voltage changes resulting an voltage oscillation with a time period of 20 sec depending on the delay time settings. However, the delay time constant of the transformer tap changer of above 10seconds is a very effective measure to remain in the stable voltage control regime of the inverters Q(U) of a smaller TC time constant. The recommendations to the grid operator is to inform and train the PV installers and make some sampling inspection. Additionally the parameters setting of the different PV inverters vendors should be harmonised or a simplified software solution should be implemented, for example based on SUNSPEC.

Detailed tests were conducted applying different TC values of the inverters Q(U) control. It was found that smaller TC values reduces dramatically the transient overvoltage during the deviation control, as illustrated in Fig. 2. In detail the analysis performed at a threshold of 102.8% of nominal voltage yield 45% of the time without Q(U) and 3.4% at TC of 20 seconds, only 0.3% at TC 5 seconds and never above at a TC of one second. The following practical recommendations to the optimized PV inverters Q(U) operation are found:

- PV inverter time constant of Q(U) should be below 5 sec to reduce the overvoltage of the transient line voltage emerging during the control process of increasing the reactive power even if the final voltage level is below the maximum allowed line voltage.
- In combination with a substation transformer controlling the line voltage within an interval of typically 1.5% by the use of the tap changer, the additional PV inverter Q(U) control, operating in that narrow voltage interval, will benefit in lower numbers of tap changer activities during a typical cloudy day with changing solar irradiance.
- Harmonising the procedure of static parameter settings of different vendors of PV inverters

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

Talks at dedicated international conferences:

- F. Baumgartner, F. Carigiet, C. Messner, C. Seitl, T. Strasser, R.Bründlinger;
  inv. talk at the Conference, Integration of Sustainable Energy, Nürnberg, Germany 18th July 2018, www.isenec.org
- C. Messner, F. Baumgartner, F. Carigiet, C. Seitl, T. Strasser, R.Bründlinger
  inv. talk at the 35th EUPVSEC European PV Solar Conference, Brussels, 26th Sept 2018, www.photovoltaic-conference.com
- F. Baumgartner, Laboratory-based services for smart Grids: Best practices from the ERIGrid project, side event of the IRED2018 conference in Vienna, 16th Oct 2018

Results are incorporated also into the running projects at ZHAW IEFE like

- Swiss Federal Office of Energy (SFOE) No SI/501370-01, CEVSOL cost effective solution.
- IEA ISGAN Annex 5 (SIRFN) SMART GRID INTERNATIONAL RESEARCH FACILITY NETWORK; under Swiss SFOE No. SI/501524-01