TRANSNATIONAL ACCESS
USER PROJECT FACT SHEET

USER PROJECT	
Acronym	HARSH
Title	Harmonic stability under sympathetic transformer inrush
ERIGrid Reference	02.007-2017
TA Call No.	2nd Call 2017

HOST RESEARCH INFRASTRUCTURE			
Name	DNVGL Netherlands BV - FPGLab		
Country	The Netherlands		
Start date	03.04.2018	**Nº of Access days**	5
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USER GROUP	
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Organization	
Country	

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

This project was commissioned to examine the harmonic stability of voltage source converters (VSCs) during sympathetic transformer inrush condition. The real-field inrush experiment of 250kVA transformer was carried out to capture the transient behavior of transformer in the time domain. Then the harmonic state-space modeling technique was further employed to modeling non-linear effect inrushed transformer in the frequency domain, which permits the relatively rapid evaluation of harmonic stability for a large number of system operating conditions. The effectiveness of the proposed modeling methodology and harmonic stability assessment is then verified by hybrid virtual and physical hardware test, which combined hardware in the loop (HIL) and real power converter groups.

The research draws attention to harmonic instability in the form of resonances or abnormal harmonics that aroused by the dynamic interaction between the VSCs and its isolation transformer. Further investigations reveal that the energization of one transformer may lead to the saturation of the other transformers within short electrical distance. In this case, the equivalent impedance of the transformer seen by the VSC is highly nonlinear, and the dynamic interactions between the VSC and nonlinear transformer impedance tend to bring in the sustained or even amplified harmonics. Moreover, designing the VSC control system to be immune from the adverse consequences of harmonic instability during the sympathetic transformer inrush requires examination of a large number of cases, which can be difficult when using only time-simulation tools.

The impedance-based method provides a powerful yet intuitive way to address the harmonic instability problem between the power electronics converters and passive components in the grid, which has been already heavily used in power electronics communities. This research project extends the impedance-based method to include the non-linear effect of transformer inrush core saturation. The harmonic-state space impedance models are developed both for the inrushed transformer and the VSC, and thereby the theoretical harmonic stability assessment can be performed in the frequency domain. Meanwhile, the detailed nonlinear models of transformers and VSC are established in the Opal-RT, and then high-bandwidth power converters are controlled by Opal-RT to mimic the dynamic interactions between the transformers and VSC in the real world.

Fig.1 Power hardware in the loop system

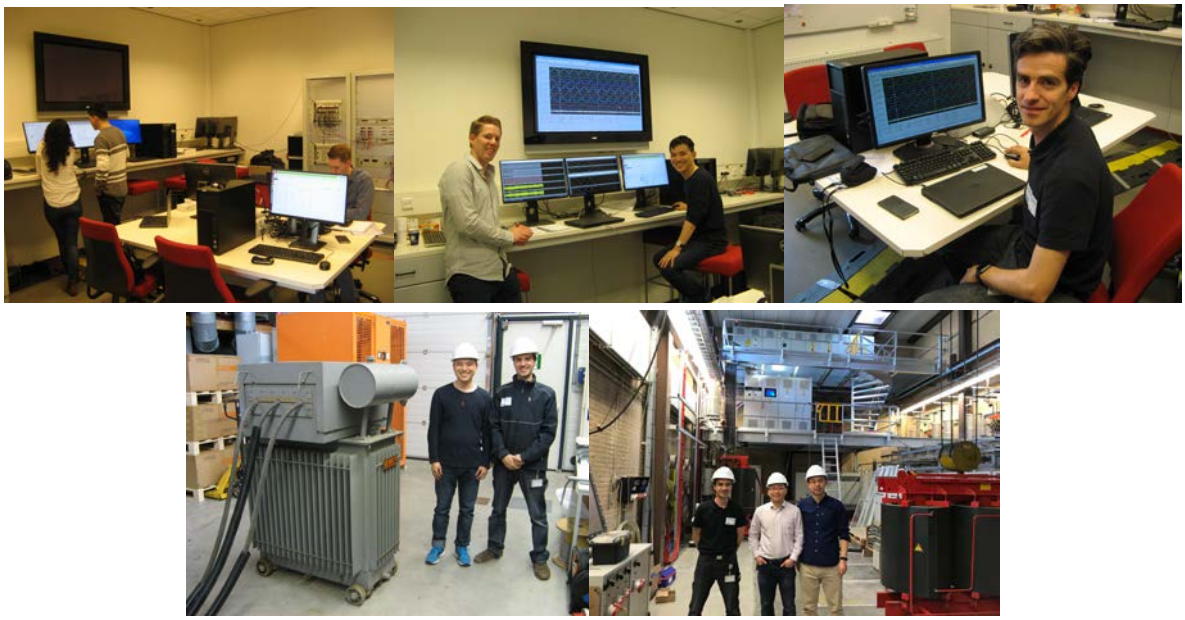

Fig.2 Photos of testing field

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

According to the theoretical analysis and realistic experimental test using the field-measured data, the report concludes that the harmonic instability can occur during the sympathetic transformer inrush condition, and harmonic-state-space impedance models allow rapid evaluation of harmonic stability hazards for a large combinations of control parameters, circuit parameters, and different operating conditions, which paves the way for the future system-level harmonic stability analysis.

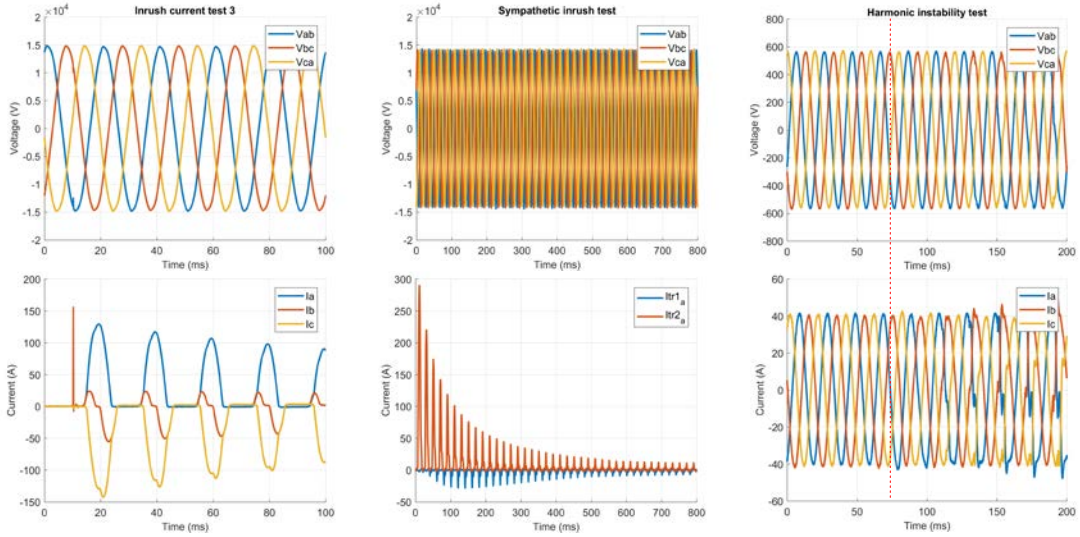

Fig.3 Chosen test results

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

"Harmonic state-space model of converter transformer during the inrush condition for the harmonic instability assessment in the offshore wind farm" Conference paper to IEEE International Power Electronics and Application Conference and Exposition (PEAC) 2018