

## **The list of projects on VISOR related topics, carried out by the University of Manchester**

**The lead investigator is Prof. Vladimir Terzija.** Vladimir is the convenor of the Cigre SC B5 Working Group on “Wide Area Protection and Control Technologies (EGB5.14). He is also a member of a number of other Cigre WGs, as well as IEEE Task Forces and Working Groups.

### **2007- IFI 0713, “Wide area monitoring, protection and control in future Great Britain power system,” The University of Manchester**

The University of Manchester will evaluate existing WAMPAC solutions from applications, system architecture and technology point of view. It is anticipated that there will be an element of this knowledge transfer to the utility companies during the development of WAMPAC algorithms for improved network monitoring and control. Information captured from the deployment of the PMU within the collaborative parties operational networks will be shared.

<b>Expected Benefits of Project</b>	<ul style="list-style-type: none"><li>• As a safety net for the management in future uncertainties in system stability particularly on the England-Scotland interface. This is achieved by better understanding of the current capability and stability of the GB and Irish transmission networks, considering constraints, intermittent generation and changing generation and demand patterns.</li><li>• Knowledge of the current network conditions will allow future development of smart protection, control and automation applications and will ensure the network is ready and able to accommodate new generation in line with SmartGrid and Intelligrid initiatives.</li><li>• The successful application of Wide Area Monitoring is seen to be a major factor in managing the risks and opportunities and to facilitate the connection of renewable and intermittent generation.</li><li>• A better understanding of system conditions and margins will enable better use of available network capacity and constraints and ensure that plant operates safely within its capability and design limits</li><li>• This project has the potential to create a cost effective method of predicting and identifying a very high impact, low probability event and contributes to better informed asset management.</li><li>• The project will support the system reinforcement programme, ensure better use of existing assets and provide an alternative to Operational Tripping and Remedial Action schemes, which are required to manage thermal and stability constraints.</li><li>• Typically the Financial Benefits will be achieved through avoided investment in infrastructure reinforcement and replacement as part of the current Capital programme.</li></ul>
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### **Project Outcomes:**

- 1) Review of the state of the art of Synchronized Measurement Technology (SMT) applications and the worldwide experience of the operation of WAMPAC systems.

- 2) Construction of an architecture prototype for the future GB WAMPAC system, based on the international experience with WAMPAC and the likely characteristics of the future GB power system.
- 3) Introduction of a methodology for designing a roadmap to implement WAMPAC in the future GB power system.
- 4) Proposal of the UK's strategies (short term and long term) to guide the development of the future GB WAMPAC system.
- 5) Development of a novel nonlinear numerical algorithm, Newton Type Algorithm (NTA), for identifying dominant inter-area oscillation mode.
- 6) Modelling of Power electronic devices, HVDC, TCSC and SVC.
- 7) Proposal of a detailed procedure for the design of a wide area inter-area oscillation damping control system using power electronic devices, i.e. HVDC, TCSC and SVC.
- 8) Establishment of a testing platform in the DigSILENT software package for demonstrating and evaluating the operation of the GB Wide Area Monitoring and Control System (WAMCS).

#### **Selected publications:**

1. D.Cai, P.Regulski, M.Osborne, V.Terzija, "Wide Area Inter-area Oscillation Monitoring Using Fast Nonlinear Estimation Algorithm", IEEE Trans. on Smart Grid, VOL. ??, NO. ?, Month Year, pp. ?-?, DOI: 10.1109/TSG.2013.2257890. Day of publication 29 April 2013
2. V.Terzija, D.Cai, V.Stanojevic, G.Strbac, "Frequency and Power Components Estimation from Instantaneous Power Signal", IEEE Transaction on Instrumentation and Measurement, Volume: 60, Issue: 11, pp 3640-3649, 2010, DOI: 10.1109/TIM.2011.2138190.
3. V.Terzija, G.Valverde, D.Cai, P.Regulski, V.Madani, J.Fitch, S.Skok, M.Begovic, A.Phadke, "Wide Area Monitoring, Protection and Control of Future Electric Power Networks", Proceedings of IEEE, Volume: 99, Issue: 1, pp 80-93, 2011, DOI: 10.1109/JPROC.2010.2060450.
4. Alexandru Nechifor, Pawel Regulski, Deyu Cai, Vladimir Terzija, "Development of a flexible laboratory testing platform for assessing steady-state and transient performance of WAMS", AMPS 2011 Conference, Aachen, September 28-30.
5. Vladimir Terzija, Deyu Cai, Alfredo Vaccaro, John Fitch, "Architecture of wide area monitoring systems and their communication requirements", Paris Cigre Session 2010
6. V.Terzija, G.Valverde, D.Cai, P.Regulski, P.Crossley, J.Fitch, C.McTaggart, R.Adams, "Wide Area Monitoring, Protection and Control Practices in the United Kingdom", Cigre Study Committee B5 Colloquium, Jeju Island, Korea, October 19-24, 2009

7. V.Terzija, D.Cai, and J.Fitch, "Monitoring of inter-area oscillations in power systems with renewable energy resources using Prony method", 20th International Conference and Exhibition on Electricity Distribution (CIRED 2009), IET Conf. Pub., Volume 2009, Issue CP550, p.746
8. Vladimir Terzija, Deyu Cai and John Fitch, "Protection Scheme for Blackout Prevention in Distribution Networks with Mixed Energy Resources", Proc. of 1st International Conference on Sustainable Power Generation and Supply (SUPERGEN), Nanjing, Apr 6-7, 2009

#### **List of finished research projects (2006 – now); The University of Manchester**

1. Project: **"The location and analysis of arcing faults on overhead transmission lines using synchronized measurement technology"**; funding body: The University of Manchester; 3.5 year PhD project (**Dr Gary Preston**); project start 2007

The project has demonstrated the application of Synchronized Measurement Technology for advanced protection and fault location of overhead transmission lines. It has opened new avenues for a design of new algorithms for calculation of network impedance. Several IEEE journal papers published. E.g.

1. Z.Radojević, V.Terzija, G.Preston, S. Padmanabhan, D.Novosel, "Smart Overhead Lines Autoreclosure Algorithm based on Detailed Fault Analysis", *IEEE Trans. on Smart Grid*, **accepted on 31/3/2013**.
2. V.Terzija, G.Preston, M.Popov, N.Terzija, "New Static 'AirArc' EMTP Model of Long Arc in Free Air", *IEEE Trans. on Power Delivery*, VOL. 26, Issue 99, pp 1344-1353, 2011, DOI 10.1109/TPWRD.2010.2086082
3. G. Preston, Z. Radojević, C.H. Kim, V. Terzija. 'New Settings-free Fault Location Algorithm Based on Synchronized Sampling', IET Generation, Transmission and Distribution, Volume: 5, Issue: 3, pp 376-383, 2011, DOI: 10.1049/iet-gtd.2010.0053.

2. Project: **"Wide area monitoring, protection and control in future Great Britain power system"**; funding body: NG, SP, SSE; 3.5 year PhD project (**Dr Deyu Cai**); project start 2008

See above.

3. Project: **"Uncertainty and state estimation of power systems"**; funding body: EPSRC; 3.5 year PhD project (**Dr Gustavo Valverde**); project start 2008

In the project a novel Hybrid State Estimator has been developed. New probabilistic power flow and probabilistic state estimator are created. Published papers:

1. G.Valverde, A.T.Saric, V.Terzija, "Stochastic Monitoring of Distribution Networks Including Correlated Input Variables", *IEEE Trans. on Power Systems*, VOL. 28, NO. 1, FEBRUARY 2013, pp. 246-255, DOI: 10.1109/TPWRS.2012.2201178, 2012

2. G.Valverde, A.T.Saric, V.Terzija, "Probabilistic Load Flow with non-Gaussian Correlated Random Variables using Gaussian Mixture Models", *IET Generation, Transmission & Distribution*, Volume: 6, Issue: 7, pp 701 – 709, 2012, DOI: 10.1049/iet-gtd.2011.0545.
3. Valverde, G.; Kyriakides, E.; Heydt, G. T.; Terzija, V.; "Nonlinear Estimation of Synchronous Machine Parameters Using Operating Data," *IEEE Transactions on Energy Conversion*, vol.26, no.3, pp.831-839, Sept. 2011, DOI: 10.1109/TEC.2011.2141136.
4. G.Valverde, V.Terzija, "Unscented Kalman Filter for Power System Dynamic State Estimation", *IET Generation, Transmission & Distribution*, Volume: 5, Issue: 1, pp 29 – 37, 2011, DOI: 10.1049/iet-gtd.2010.0210.
5. Valverde, G.; Chakrabarti, S.; Kyriakides, E.; Terzija, V.; , "A Constrained Formulation for Hybrid State Estimation," *Power Systems, IEEE Transactions on* , vol.26, no.3, pp.1102-1109, Aug. 2011, DOI: 10.1109/TPWRS.2010.2079960.
6. Gustavo Valverde, Elias Kyriakides, Vladimir Terzija, „A NON-LINEAR APPROACH FOR ON-LINE PARAMETER ESTIMATION OF SYNCHRONOUS MACHINES“, *Proceedings of PSCC Conference, Stocholm, August 2011*

4. Project: **“Estimation of parameters of dynamic load models for voltage stability studies”**;  
funding body: EPSRC, FlexNet; 3.5 year PhD project (**Dr Pawel Regulski**); project start 2008

In this project a new FlexNet WAMS system, a full scale practical demonstration of a real-time operating WAMS has been developed. Furthermore, new methods for estimation of unknown load model parameters were developed. Publications:

1. H.Novanda, P.Regulski, V.Stanojević, and V.Terzija, "Assessment of Frequency and Harmonic Distortions during Wind Farm Rejection Test", *IEEE Trans. on Sustainable Energy*, Volume: PP, Issue: 99, DOI: ???, 201?, (accepted for publication on 18/01/2013)
2. Regulski, P.; Terzija, V.; , "Estimation of Frequency and Fundamental Power Components Using an Unscented Kalman Filter," *Instrumentation and Measurement, IEEE Transactions on* , vol.61, no.4, pp.952-962, April 2012, DOI: 10.1109/TIM.2011.2179342
3. F. Gonzalez-Longatt, P. Regulski, H. Novanda, V. Terzija, "Impact of Shaft Stiffness on Inertial Response of Fixed Speed Wind Turbines", *Automation of Electric Power Systems*, No. 8 Vol. 36, April 2012, DOI: 10.3969/j.issn.1000-1026.2012.08.001
4. P. Regulski, F. Gonzalez-Longatt, V. Terzija, "Estimation of composite load model parameters using improved particle swarm optimization", *Present Problems of Power System Control, Scientific Papers of the Institute of Electrical Power Engineering of the Wroclaw University of Technology*, no. 2, 2012

5. Project: **“Online prediction of the post-disturbance frequency behaviour of a power system”**;  
funding body: EPSRC and National Grid, PNRA; 3.5 year PhD project (**Dr Peter Wall**); project start 2009

This project opened new avenues for development of the next generation Dynamic Security Assessment Tools, in particular those related to system frequency response. New methods for determination of system inertia are proposed. Publications:

1. L.Ding, F.Gonzalez-Longatt, P.Wall, and V.Terzija, "Two-Step Spectral Clustering Controlled Islanding Algorithm", *IEEE Trans. on Power Systems*, VOL. 28, NO. 1, FEBRUARY 2013, pp. 75-84, DOI: 10.1109/TPWRS.2012.2197640, 2012
2. Wall, Peter; Gonzalez-Longatt, Francisco; Terzija, Vladimir; , "Estimation of generator inertia available during a disturbance," *Power and Energy Society General Meeting, 2012 IEEE* , vol., no., pp.1-8, 22-26 July 2012, DOI: 10.1109/PESGM.2012.6344755
3. Peter Wall, Francisco González-Longatt, Vladimir Terzija, "Demonstration of an Inertia Constant Estimation Method Through Simulation", *UPEC Conference, Cardiff, 2010*

**List of currently running projects and those approved and planned to be started in near future**

6. Running Project: “Graph theory approach for intentional controlled islanding and power system restoration”; funding body: **EPSRC and National Grid**; 3.5 year PhD project (Jairo TQ); project start 2010
7. Running Project: “Transient stability and operational limits of mixed ac-dc power systems”; funding body: **EPSRC**, Top & Tail; 3.5 year PhD project (Melios H); project start 2011
8. Running Project: “Intentional Controlled Islanding and Restoration of Power Systems”; funding body: **UMIP, Alstom-Grid and National Grid**; 1 year Proof Of Principle project (3 PDRAs); project start 2013

This project should generate two new patents (islanding and restoration) and through links to Alstom-Grid make new products. New solutions will be tested using hardware-in-loop testing facilities.

9. Approved Project: “ACCEPT Project”; funding body: **EPSRC**; 3 year project (1 PDRA); project start January 2014
10. Approved Project: “CLIP Project”; funding body: **NG, SP, SSE, Alstom-Grid**; 3.5 year project (PDRAs and PhD students); project start October 2013