Paper accepted for presentation at 2009 IEEE Bucharest Power Tech Conference, June 28th - July 2nd, Bucharest, Romania

A Laboratory Setup of a Power System Scaled Model for Testing and Validation of EMS Applications

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***Abstract*— This paper describes a laboratory setup as the scaled model of a three substation power system. The scaled model has been developed at the Power System Control and Automation Laboratory of Georgia Institute of Technology. Elaborate physical models for the power system components along with high fidelity models for signal generation and interfacing to the laboratory setup are among its unique features. Accurately modeled transmission line modules have been built that truly model the natural asymmetries as well as mutual couplings between the phase/neutral/ground wires. In addition, a highly accurate dynamic model has been developed in software for the synchronous generator that allows for introducing various non-idealities to the power system such as voltage imbalances, voltage harmonics, and frequency/magnitude fluctuations. Multiple metering devices are connected to the scaled model that transmits the real-time measurement to a computer host, which functions as the Human Machine Interface (HMI). All the measurements are GPS-synchronized and are time tagged with an accuracy of 1 µs. Various Intelligent Electronic Devices (IEDs) are connected to the scaled model in order to perform different protection and control functions. The laboratory setup is a multi-vendor environment and is used as an highly accurate experimental platform for various EMS related applications such as performing distributed state estimation based on the SuperCalibrator concept, testing the performance of protective relays, testing the accuracy of Phasor Measurement Units (PMUs), implementing intelligent alarm processing algorithms, validating the interoperability of various IEDs in a multi-vendor environment, and testing the capabilities and functionalities of a IEC 61850 compatible communication network. In addition, the developed scaled model of the power system can be effectively used as a teaching tool for graduate/undergraduate studies in the field of power systems.**

***Index Terms*— Power system scaled model, state estimation, SuperCalibrator, Relay Testing, PMU Testing, IED interoperability, IEC 61850 standard.**

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Financial support by Concurrent Technologies Corporation (CTC), Power Systems Engineering Research Center (PSERC), the U.S. Department of Energy (DoE), Entergy, New York Power Authority (NYPA) and National Science Foundation (NSF) is greatly acknowledged. The authors also wish to thank Schweitzer Engineering Laboratories (SEL), Beckwith Electric, General Electric (GE), Areva, Arbiter Systems and Macrodyne for their generosity in donating equipment to the lab.

I. INTRODUCTION

POWER system related studies and experiments require an accurate model that truly reflects the nature of the system under study. Although various computer software exist that model power system components in details, many power system applications cannot solely rely on computer simulations and require laboratory experiments and validation before the actual testing in the field. Clearly, the accuracy and fidelity of the model used in the experiments directly impacts the reliability of the results obtained from the study. However, the main challenge lies in developing scaled models of components that are mathematically complicated, such as synchronous generators, or physically sizable, such as the transmission lines. Although these two components constitute the most important parts of any power system, they are often not given the deserved attention when building a laboratory setup.

The purpose of this paper is to present a laboratory setup as the scaled model of a power system that can accurately model its true dynamics. The network considered in this paper is a three substation power system that consists of transmission lines, transformers, a synchronous generator, and switches. The laboratory setup is essentially a scaled down model of the actual power system by a factor of 1000. Transmission lines are modeled and built in such a way that they represent the actual line with asymmetries and mutual couplings between the phases. In addition, the function generator developed to replace the synchronous generator is able to model various non-ideal conditions such as voltage imbalance, harmonic distortion and voltage magnitude and/or frequency fluctuations. Metering devices are located throughout the model in order to provide actual voltage/current measurements from different nodes and branches. All the measurements are GPS-synchronized with an accuracy of up to 1 µs. Various Intelligent Electronics Devices (IEDs) are also connected to the scaled model in order to obtain these time-tagged voltage and current readings, and perform their corresponding control/protection algorithms.

The system developed is a multi-vendor laboratory setup. Ultimately it is intended to serve as a test bed for validating various Energy Management System (EMS) related applications, such as distributed state estimation based on the

SuperCalibrator concept [1], protective relay and PMU testing, as well as validating interoperability between IEDs from different manufacturers.

The rest of this paper is organized as follows. In section II the main structure of the scaled model is discussed in details. Section III of the paper briefly discusses some of the typical applications of the scaled model. A case study is presented in section IV of the paper that focuses on the application of the developed scaled model in testing and validating the performance of protective relays. Finally, the summary and the concluding remarks appear in section V.

II. Laboratory Setup

The laboratory setup is developed at the Power Systems Control and Automation Laboratory at the Georgia Institute of Technology. It is built to reflect the true nature of a small size three substation power system, along with its metering equipment. Fig. 1 illustrates the schematic diagram of the three substation power system. It consists of a generation substation that through two transmission lines is connected to two remote substations, Yellow Jackets 1 and 2. The actual layout of the scaled model is shown in Fig. 2. All the measurements from across the scaled model are accessible by the substation computer, i.e., the Human Machine Interface (HMI) through a common Ethernet network.

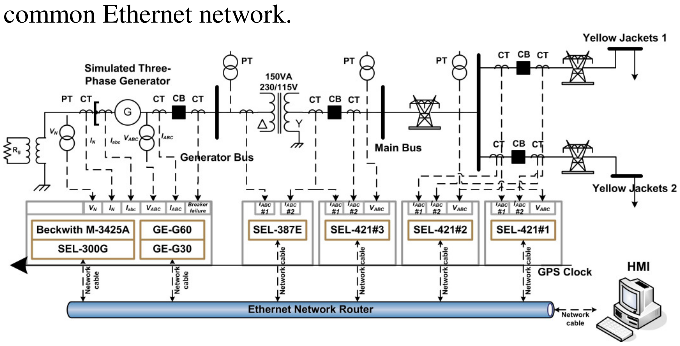

Fig. 1. One line diagram of the three substation power system scaled model.

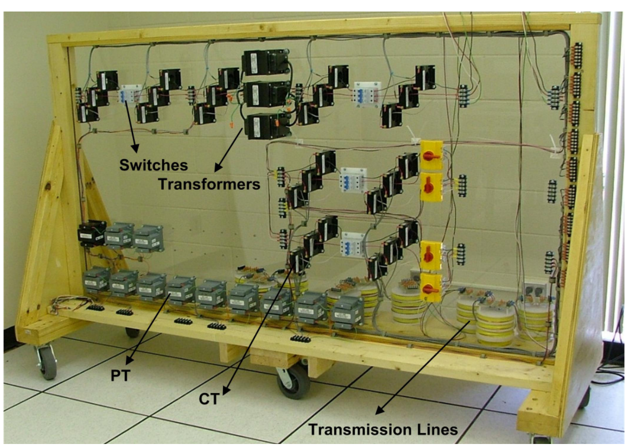

Fig. 2. Physical layout of the scaled model of the power system in Fig. 1.

A. Power Supply- Generator Model

The input voltage applied to the scaled model is generated by a computer-simulated synchronous generator. The generator model is a full time-domain, transient, two-axis synchronous generator model, which includes different rotor excitation systems and winding models. The model supports harmonics injection generated by the actual, non-sinusoidal winding layout. A generator control interface program sends real-time generated voltage signal to a D/A converter on demand. A PCI board converts the simulated voltages into analog signals. The converter is a National Instruments NI 6722 arbitrary waveform generator, with eight analog outputs and a voltage range of ±10 V in the output. The outputs from the board are fed to an amplifier. A 7-channel Sunfire TGA-7400 amplifier, 800 W per channel, generates voltages up to 56 V rms from the D/A converter signals. A transformer structure then further boosts the outputs of the amplifier to the required 115 V for the scaled model. The layout of the power source is shown in Fig. 3.

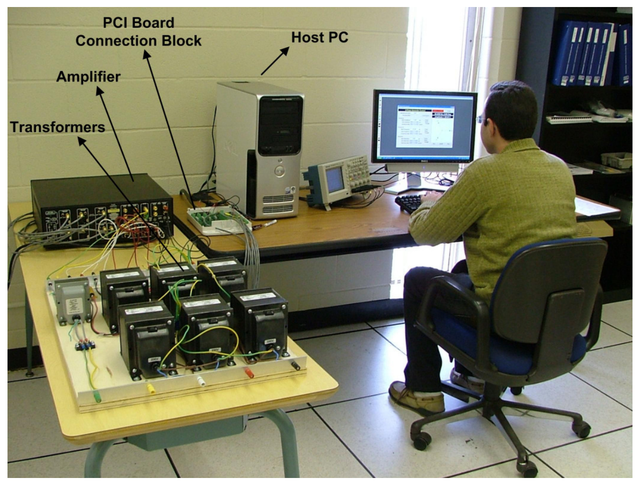

Fig. 3. Physical layout of the power supply.

The software developed for the voltage source enables the user to select the required voltage magnitudes and frequencies of the three phases. These values can be fixed or varied with time. This feature allows for the introduction of harmonics, voltage imbalances and various types of voltage or frequency fluctuations. Therefore, the designed source is able to model the generator outputs under all possible operating conditions. Fig. 4 demonstrates an example screenshot of the generator control menu.

B. Transmission Line Model

Lumped models of the 4-wire transmission lines are constructed that take the mutual couplings between the phases and the neutral as well as the power system asymmetries into account. The transmission lines are built using basic models based on the design of a 2-mile 3-phase transmission line with neutral conductor [2], [3]. Fig. 5 illustrates the circuit model of the high-fidelity transmission line model. The parameters of the transmission line are generated using the WinIGS software [4] and are modified for a 2-mile section. Clearly, the lengths of the transmission lines can be increased by installing more line modules in series. The portability of the line modules provides an additional degree of freedom to perform experiments with various line lengths with or without transposition.

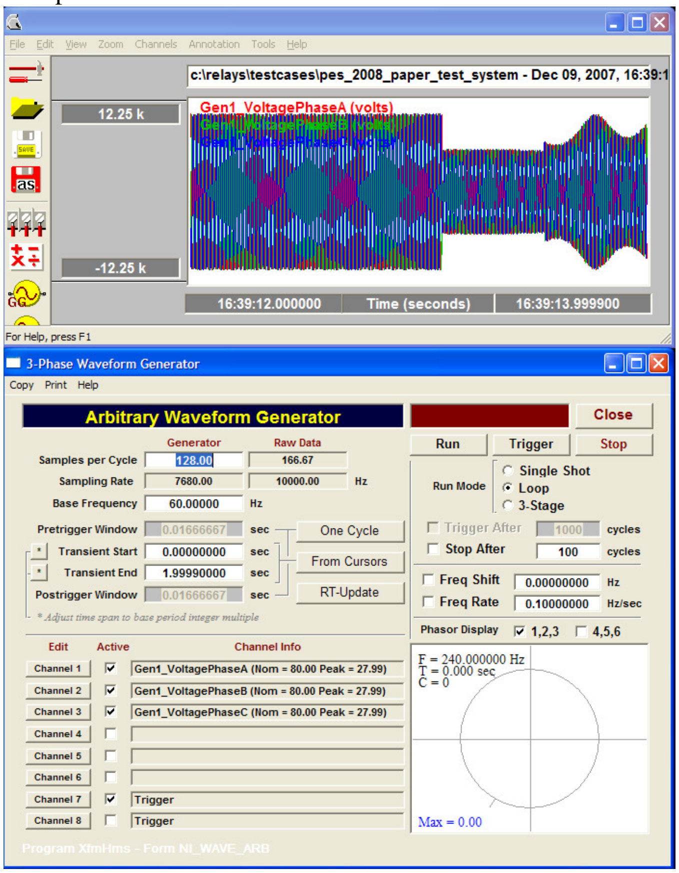

Fig. 4. Generator control menu.

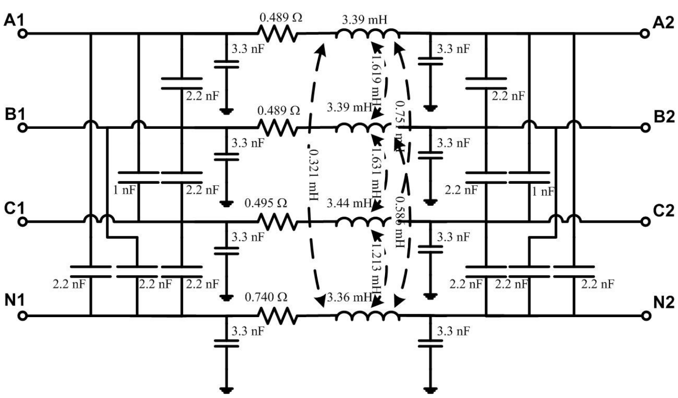

Fig. 5. 4-wire model of the transmission line. The parameters are adjusted for a 2-mile section of the line.

Solid copper wires of sizes AWG-12 and AWG-14 are used for the three phases and the neutral conductor respectively. The windings of the transmission line wrap around a dielectric core build from polypropylene. The dimensions of the core are derived in such a way that the line module has the same characteristics and electrical parameters as the high-fidelity model in shown Fig. 5. The capacitors are mounted on a printed circuit board (PCB) that is located on the dielectric core. Fig. 6 shows the final prototype of the transmission line. This module accurately models a 2-mile section of a 4-wire transmission line.

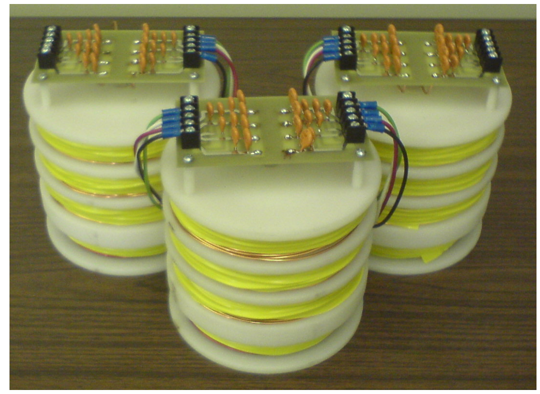

Fig. 6. Transmission line prototype for a 2-mile section.

C. Flow of Power

Two phase shifters are connected between the generation bus and the remote buses, Yellow Jackets 1 and 2 (Fig. 7). In this way, power can be circulated throughout the system with no need for any additional supplies at the remote buses. Also, by providing individual phase shifts for the three phases, the transformers allow for imposing voltage unbalance on the system. The phase shifter prototype is illustrated in Fig. 8.

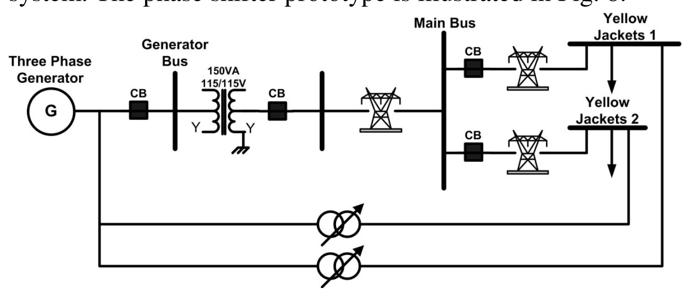

Fig. 7. Flow of power in the scaled model.

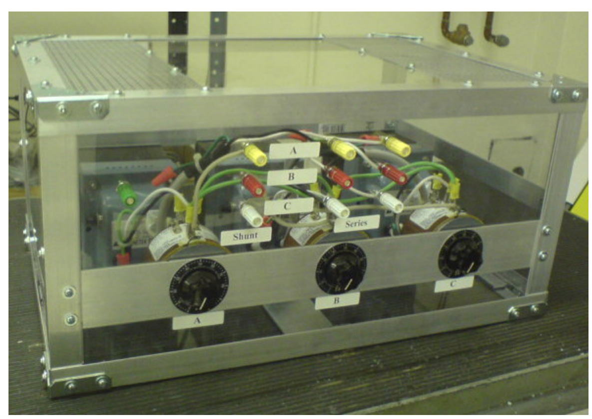

Fig. 8. Phase shifting transformer prototype.

D. Instrumentation and Metering

Various instrument transformers (PTs and CTs) are installed on the scaled model to provide actual measurements of the voltages and currents at different nodes/lines (see Fig. 1). All the measurements from across the scaled model are time tagged using GPS clock. These measurements are then transmitted to the relays and PMUs that communicate with the HMI. A partial list of the IEDs is provided in Table I.

TABLE I
RELAYS ID AND DESCRIPTION.

ID	Description
P142	Areva MiCOM P142 Feeder Management Relay
P442	Areva MiCOM P442 Numerical Distance Protection Relay
M-3425A	Beckwith M-3425A Generator Protection System
SEL-300G	Schweitzer SEL-300G Generator Protection Relay
SEL-AMS	Schweitzer SEL-AMS Adaptive Multichannel Source
SEL-387E	Schweitzer SEL-387E Current Differential and Voltage Relay
SEL-421	Schweitzer SEL-421 High-Speed Line Protection, Automation, and Control System
GE-G30	GE-G30 Generator Management Relay
GE-G60	GE-G60 Generator Management Relay
GE-N60	GE-N60 Network Stability and Synchrophasor Measurement System
1133A	Arbiter Power Sentinel Phasor Measurement Unit

An Ethernet network provides a common process bus for connecting all the IEDs. It is also connected to the host computer (HMI) to transmit the measurement data to different application modules hosted on the HMI (see Fig. 1).

E. Microsecond-Scale Data Acquisition

One key feature of the developed scaled model is the use of GPS-synchronized phase angle measurements. This is specifically crucial for performing state estimation based on the SuperCalibrator concept, where having at least one GPS-synchronized measurement is necessary. Verification of timing accuracy at the microsecond scale requires data acquisition with a sampling rate an order of magnitude higher than the microsecond rate. The sampling system used at NIST is capable of 500,000 samples per second [5]. The experimental setup takes precision to a further level by using the GaGe™ 1610 A/D oscilloscope capable of 10 million samples per second. This means errors of as low as 0.002° can be detected in the phase angles, which immensely benefits the state estimation accuracy.

F. Auxiliary Independent Voltage and Current Sources

The laboratory setup is also equipped with independent three-phase voltage and current sources. These sources generate reference signals for the initial configuration of IEDs. In addition, these auxiliary sources can replicate arbitrary voltage and current waveforms generated by the high-fidelity WinIGS simulator, which are used in order to perform relay and PMU testing experiments.

The independent voltage source delivers arbitrary voltages at low currents. It leverages the PC-controlled D/A converter and the existing Sunfire amplifier to generate nominal voltages of 115 V rms. Since this source is used to configure the IEDs, it provides oscilloscope and data acquisition ports. On these ports, the voltage is scaled down by a factor of 10 to avoid A/D converter saturation. The schematic diagram of the auxiliary voltage source is illustrated in Fig. 9, and its actual layout is shown in Fig. 10.

The independent current source with 5 A nominal current is being constructed using the same hardware platform. The goal is to complete a voltage generator with 4 channels and a current generator with two sets of 3 channels.

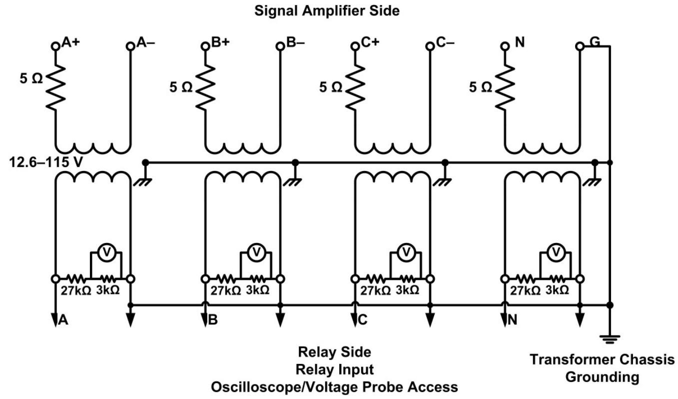

Fig. 9. Three-phase auxiliary voltage source for relay and PMU testing.

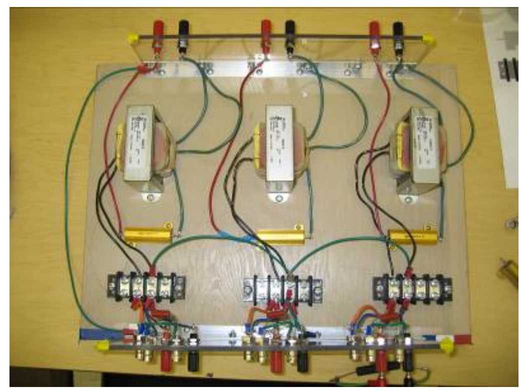

Fig. 10. Actual layout of the three-phase auxiliary voltage source of Fig. 9.

III. APPLICATIONS

The developed scaled model of the power system can be efficiently used for implementing many EMS and EMS related applications. Some of these applications are listed and briefly discussed in this section.

A. Distributed State Estimation based on the SuperCalibrator Concept

In energy management systems (EMS), state estimation provides operators with the most current estimated state of the system, which is uniquely defined as a set of voltage magnitudes and phase angles at different buses in the network. The output of the state estimator is a real-time model of the power system which is used for various applications in load forecasting, economic dispatch, optimal power flow, VAR control, security assessment, congestion management, etc.

Traditionally, state estimators are centralized and based on a single-phase equivalent model of the power system with non-simultaneous measurements. This approach leads to biased state estimators with asymmetry errors, unbalance errors and instrumentation errors. The centralized approach also places a burden on the communications requirements. As a result, centralized state estimators are not as reliable as required and historically they are available 95 % of the time, mostly when the system runs normally. The central state estimator is known to fail in critical situations when situation awareness is needed, for example during the early stages that led to the 2003 North American blackout [5].

Root causes of the unreliability of centralized state

estimators have been addressed in several publications:
(a) Biases from imbalances in the system,
(b) Biases from system asymmetries,
(c) Substantial errors from instrumentation channels,
(d) Non-simultaneity of SCADA data.

The centralized state estimator has a number of additional practical disadvantages:
(a) Processing all the data simultaneously at a central location generates a bottleneck resulting in longer execution times,
(b) When bad data exists, the detection and identification of the bad data becomes more complex and less sharp,
(c) Communication requirements are excessive since all SCADA data must be sent to a central location to be processed.

GPS-synchronized measurements allowof distributing the state estimation function. Meliopoulos *et al.* [1], [7] introduced the concept of the "SuperCalibrator"—a substation based state estimator based on detailed three-phase breaker-oriented models of the substation, with explicit representation of instrumentation channels (Fig. 10). The proposed approach performs state estimation locally at each substation and transmits local states to a central location (control center) where the overall system state is synthesized. This approach provides a more efficient and reliable state estimator, improved and sharper data detection and identification, and reduced data traffic between substations and the control center.

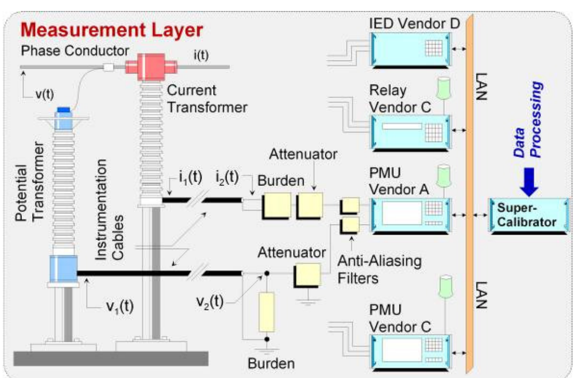

Fig. 10. State estimation based on the SuperCalibrator concept.

The SuperCalibrator concept was introduced to take advantage of GPS-synchronized equipment (PMUs). The concept is based on a statistical estimation process that fits the GPS-synchronized measurements and all other available data into a three-phase, breaker-oriented, instrumentation-inclusive model [8]. The basic idea is to provide a model based correction of the errors from all known sources of error. The main characteristics of the SuperCalibrator concept are as follows:

- It utilizes a detailed breaker-oriented model of the power system, which includes all the three phases, instrumentation channels and models of the data acquisition systems,
- The measurements obtained from devices such as PMUs, relays or SCADA are used in a statistical estimation method that fits the data to the detailed model,
- The bad data are identified using the confidence level of the estimated state of the system,
- It can be performed at the substation level leading to a distributed approach for state estimation. The final results are verified by a state estimation coordinator that functions as a central supervisor.

The laboratory setup provides an accurately modeled power system, with asymmetries and non-idealities associated with an actual power system, which allows for implementing the SuperCalibrator concept. GPS-synchronized measurements are provided from across the scaled model that will be used for implementing the state estimator (Fig. 11). Various pseudo-measurements are also calculated in order to increase the redundancy level of the state estimator. These are measurements in addition to the actual measurements of the system, which are often calculated based on mathematical and electrical equations governing the electric circuit. A set of defined pseudo-measurements for the scaled model, along with the detailed definitions of each one, are presented in [9].

Obviously, in order to perform the distributed state estimation based on the SuperCalibrator concept, all the instrumentation channels need to be modeled in detail in such a way that the complete electrical path from the actual metering device to the IED or the host computer (HMI) is fully considered in the calculations. Fig. 12 illustrates an example of an instrumentation channel modeled in SuperCalibrator.

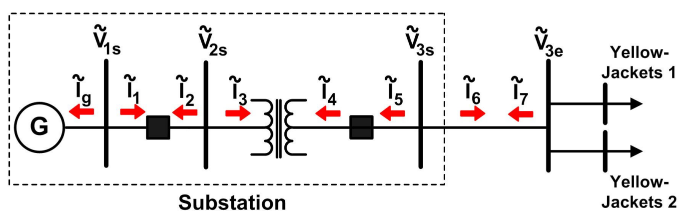

Fig. 11. One line diagram of the scaled model along with the set of available GPS-synchronized measurements.

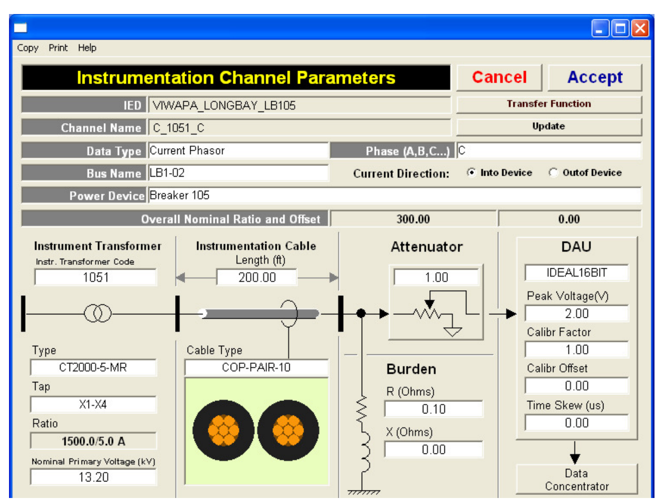

Fig. 12. An example of modeling an instrumentation channel in the SuperCalibrator state estimator.

B. Alarm Processing

The number of alarms generated by a disturbance depends on the size of the power system and the number of IEDs. Situational awareness in power systems calls for the ability of the system operators to process the incoming alarms and distinguish the root cause of the event. The ultimate objective of the alarm processor is to relate the set of alarms triggered to the originating event. This way, the operator has to deal with "one event" rather than "a set of alarms." In addition to root cause analysis of the event, efficient alarm processors may also suggest remedial actions to the operator.

Testing alarm processing algorithms is one application of the SuperCalibrator concept. Since all voltages and currents are measured through IEDs, a single event can trigger individual alarms in a large number of IEDs. The developed scaled model can be used for implementing an intelligent alarm processor through two different scenarios:

- Generating disturbances in the simulation model of the software model, for instance at the generator terminals, and applying the recorded data files to the protective relays in order to generate the set of alarms associated with each event.
- Applying simple test cases to the scaled model, such as tripping a single pole on a switch and recording and analyzing the alarms triggered by the various IEDs.

Once the set of alarms associated with a disturbance is created, it can be analyzed in the alarm processing module in order to classify the root cause of the event. Clearly, the performance of the alarm processing algorithm on the scaled model will match that of the actual power system with high precision since the scaled model closely and accurately models the actual power system.

C. Protective Relay Testing

Waiting for power system events to test protection schemes is risky, and collecting all transient data from individual instrumentation channels after an event for analysis is not always possible. Yet, protection schemes should be adjusted and tested against the most anticipated events in the field since an inappropriate response from the relays may have undesirable and expensive side effects.

To help studying and improving the response of a protection scheme to power system disturbances, a platform has been developed for transient response analysis. The uniqueness of the platform relies on high-fidelity simulation of power systems using quadratic integration and models that are based on physical parameters. The simulated waveforms at a specified location in the power system are generated using D/A converters, amplified to 115 V, and sent to protective relays set to monitor and control that location (Fig. 13). The generator model simulated in the WinIGS environment allows for accurate simulation of faults and other disturbances on the system. The resulting transient waveforms closely reflect situations seen by generator protection relays in the field.

The protection scheme can be validated or improved based on the response of the relays to the simulated events. The possible tests include but are not limited to:

- Time synchronization accuracy,
- Magnitude, phase and frequency errors,
- Transfer functions,
- Testing under heavy relay activity,
- Positive sequence and segregated phase waveform data,
- Magnitude, phase and frequency errors under large frequency excursions, ramps, and voltage step changes.

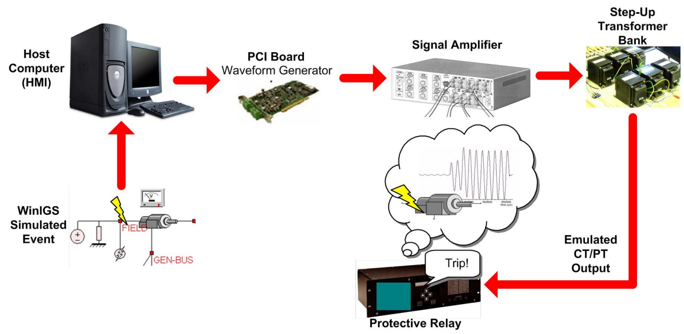

Fig. 13. Schematic diagram of the experimental setup for transient response analysis of protection schemes.

D. PMU Testing

The accuracy and interoperability of PMUs are subject to the IEEE C37.118, *IEEE Standard for Synchrophasors for Power Systems* [10]. In addition, the North American SynchroPhasor Initiative (formerly EIPP) has completed (a) a test guide to unify PMU testing [11], including proper time-stamp assignment and (b) a guide for assessing the accuracy of the overall synchrophasor measurements [8]. The proposed laboratory setup allows PMU testing while leveraging the equipment already used in transient analysis and state estimation. While the testing principle is similar to other laboratory setups [5], [12], the proposed experimental setup does not require equipment that generates waveforms with high-precision timing. Nevertheless, a high-precision data acquisition device is needed to time-stamp the waveforms beyond the desired accuracy level. The accuracy of the PMU is determined by comparing the retrieved waveforms "seen" by both the data acquisition device and the tested PMU, along with their own time information. The PMU test methodology is outlined in Fig. 14.

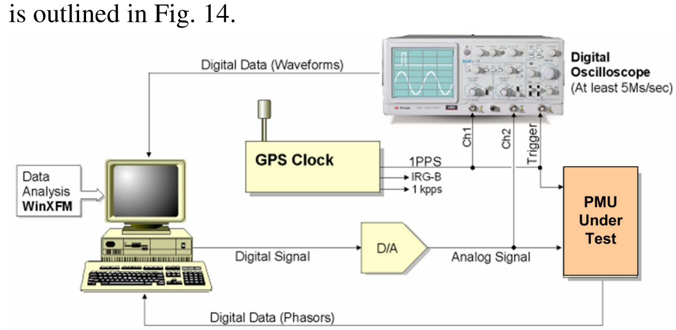

Fig. 14. Experimental setup for testing PMUs.

The goal is to obtain waveforms with a phase angle accuracy of 0.01° ideally. This corresponds to the PMU lagging the reference by 0.5 μs at 60 Hz. For voltage phasors, the 0.01° resolution combined with a 0.4 % magnitude error (instead of typical 0.4°/1.4 % instrumentation channel errors) dramatically improves the accuracy of state estimation to a 1 % total vector error. Overall, the accuracy of the PMU test relies on the resolution of data acquisition. We describe how the desired level of accuracy is achieved in Section IV.

E. Interoperability between Different IEDs

The laboratory setup is a multi-vendor environment, where different IEDs from different manufacturers are commissioned to provide protection and measurement functionalities for the power system. The ultimate objective of such an environment is to validate interoperability between these IEDs. Interoperability is defined according to the IEC 61850 standard for Communication Networks and Systems in Substations [13], and requires different relays from different manufacturers to:

- Be able to generate data signals in a format understandable by other IEDs,
- Receive and understand data generated by other IEDs,
- Be able to provide distributed protection functions incorporating multiple IEDs.

The laboratory setup provides an excellent environment for this purpose. The data derived from the IEDs is ultimately shared on an Ethernet network, where all the IEDs have access to. The final objective of the interoperability validation is to ensure that in a communication environment compatible with IEC 61850, all the IEDs will be able to use and share this data, and possibly provide joint protection functions.

F. IEC 61850 Based Communication Networks

In addition to providing a platform for validating interoperability between different IEDs, the scaled model can be used for testing various features of data communication in accordance with the IEC 61850 standard. The possible features to be tested include but are not limited to [13]:

- Sending and receiving non-critical data objects between different IEDs or an IED and the HMI using a client-server communication link according to IEC 61850-8-1.
- Sending and receiving critical and time-sensitive Generic Object Oriented Substation Event (GOOSE) messages between various IEDs in accordance to IEC 61850-8-1.
- Sending and receiving unicast sampled valued (SV) measurements between two IEDs or an IED and the HMI in accordance to IEC 61850-9-X.
- Sending and receiving multicast sampled valued (SV) measurements between one IED and several other IEDs in accordance to IEC 61850-9-X.

G. Power System Non-Idealities

One of the functionalities of the scaled model is to allow for modeling and analysis of the common non-idealities associated with typical power systems. This feature can be used for research purposes or as a teaching aid for students in the field of power systems. Some of these non-idealities that can be fully modeled using the laboratory setup have been discussed in the preceding sections; nevertheless they are listed below.

1) Mutual Coupling between Phases and Neutral/Ground Wire

Mutual coupling is neglected in most of the lumped models of the transmission lines built for laboratory purposes. However, the transmission line modules built in this laboratory setup take the mutual coupling between the phases and the neutral/ground wire into account.

2) Asymmetries

No matter how much effort is made into building power system components, no two components have the exact same characteristics. This causes a discrepancy in the electrical parameters of the individual phases of a three phase component. This feature has been incorporated in the design of the transmission line modules, where all the windings have been manually created.

3) Source Non-idealities

The power supply model allows for introduction of different types of voltage source non-idealities. These can be in the form of voltage imbalances, voltage harmonics or voltage/frequency fluctuations. Fig. 15 depicts the main generator menu for the arbitrary waveform generator, where the user can apply various non-idealities to the power system.

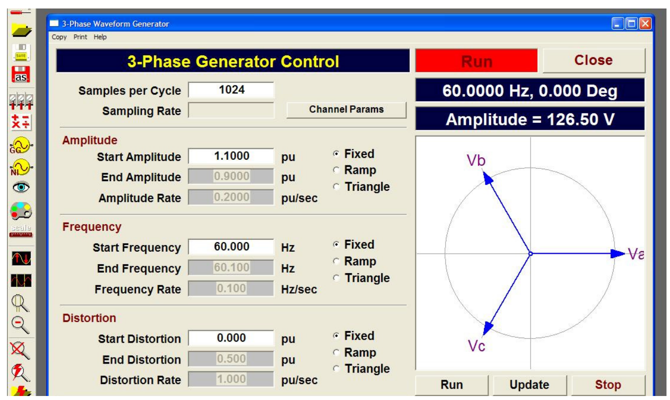

Fig. 15. Generator control menu.

4) Ground Potential Rise

The power supply allows for the introduction of Ground Potential Rise (GPR) by applying a user-defined voltage between the neutral and the grounding network of the scale model. This is achieved by the transformer structure that connects the PCI board to the scaled model (Fig. 3).

IV. Summary and Perspectives

Many EMS related protection and control applications require performing accurate experimental validations before actual field implementation. As the laboratory setup presented in this paper is further developed, the authors aim at demonstrating feasible implementations of the EMS applications discussed. The distributed state estimation foundation of these applications is complete and has been demonstrated on a live system. The next step is to complete demonstration experiments that confirm the accuracy of PMUs, perform testing of line and generator protection schemes under faults that mimic the conditions found in the field, and develop communications strategies between the different IEDs available at the substation level.

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V. BIOGRAPHIES

A. P. Sakis Meliopoulos (M ’76, SM ’83, F ’93) was born in Katerini, Greece, in 1949. He received the M.E. and E.E. diploma from the National Technical University of Athens, Greece, in 1972; the M.S.E.E. and Ph.D. degrees from the Georgia Institute of Technology in 1974 and 1976, respectively. In 1971, he worked for Western Electric in Atlanta, Georgia. In 1976, he joined the Faculty of Electrical Engineering, Georgia Institute of Technology, where he is presently a Georgia Power Distinguished Professor. He is active in teaching and research in the general areas of modeling, analysis, and control of power systems. He has made significant contributions to power system grounding, harmonics, and reliability assessment of power systems. He is the author of the books, Power Systems Grounding and Transients, Marcel Dekker, June 1988, Ligthning and Overvoltage Protection, Section 27, Standard Handbook for Electrical Engineers, McGraw Hill, 1993. He holds three patents and he has published over 220 technical papers. In 2005 he received the IEEE Richard Kaufman Award. Dr. Meliopoulos is the Chairman of the Georgia Tech Protective Relaying Conference, a Fellow of the IEEE and a member of Sigma Xi.

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Q. Binh Dam (S ’05, M ’09) is from Paris, France. He received the Ingénieur Diploma from the National Polytechnic Institute of Toulouse, France in 2003 and obtained the M.S. and Ph.D. degrees in electrical and computer engineering from the Georgia Institute of Technology in 2003 and 2009, respectively. His research is on circuit breaker reliability analysis and its applications to power systems operation and relaying. He has also interests in new tools and methodologies for testing protective relays. Binh was responsible for the operations and logistics of the Power Systems Control and Automation Laboratory at the Georgia Institute of Technology from 2007 to 2008.

Ramiz H. Alaileh (S ’99, M ’09) was born in Dubai, UAE in 1980. He received the B.Sc. in electrical engineering (magna cum laude) from the American University of Sharjah, UAE, in 2002 and the M.S. degree in electrical and computer engineering from the Georgia Institute of Technology, USA, in 2005. From 2003 to 2004, he worked with the Dubai Electricity and Water Authority (DEWA), UAE, as an energy management systems (EMS) engineer. He was a research assistant at the Power Systems Control and Automation Laboratory at the Georgia Institute of Technology from 2005 to 2007. Mr. Alaileh joined back DEWA in 2007 where he was assigned as the deputy manager for EMS & Studies at the transmission operations department until end of 2008. Since 2009, Mr. Alaileh has been the deputy manager for Energy Management Systems & Distribution Management Systems (EMS/DMS). He is a member of IEEE. His interests include control center design and technologies, energy management systems, distribution management systems, power system modeling and prototyping for advanced real-time applications, power system stability, and power system protection.

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