Premium Power Park: the next step in Power Quality

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***Abstract*--This paper presents a summary of the work accomplished over the last year regarding the implementation and performance of the world's first Premium Power Park (PPP) located at an industrial park in central Ohio. Issues such as power quality monitoring, system configuration, system simulation and system performance are discussed in this paper. The PPP described in this paper is considered as a Distributed PPP in contrast to a Centralized PPP configuration. In particular, three major Power Quality Devices (DVR, ASVC and HSATS) will be used to meet the customer as well as the utility needs. Interaction between Power Quality Devices (PQD's) and control system requirements will also be addressed in this paper. Simulations of the system response to different power disturbances will be carried out in EMTP-ATP. Some field measurement results are presented as well.**

***Index Terms*-- Power Quality, FRIENDS, Power Park, SVC, DVR, STS, HSATS, Custom Power, EMTP, PPP.**

I. INTRODUCTION

Over the last few years there have been a continuing growth in the application of power electronics. This growth in the usage of microprocessor-based equipment and digital electronic devices is resulting in an increasing concern of commercial and industrial electrical power customers regarding power quality [1].

Electric utilities are looking to improve power quality to a new level to meet the sensitive customer needs, while keeping the balance with the low cost required by customers with basic power needs through the so called Premium Power Park (PPP).

In the original Premium Power Park concept, electric power customers having a wide range of power quality needs would receive their desired levels of power quality from a common site called "Quality Control Center" (QCC) [2],[3],[4]. The control center would have the following functions:

- Reconfiguration of the system according to system's state and load patterns by coordinating the response of the PQD's.
- Multi-menu service to allow customers to select the quality of electric power.
- Load leveling and energy conservation.
- Effective demand side management.

This type of approach can be easily implemented in new systems where the distribution system is designed in conjunction with the park's layout. However, for existing distribution systems, a new approach called Distributed Premium Power Park is considered. In this configuration the PQD's are installed at the customer's location based on their individual needs by retrofitting the industrial park.

In either configuration, the customer is able to select different levels of power quality through the latest state-of-the-art power quality devices that over last ten years have been used at medium distribution voltage levels [5].

Most of those devices are also available as commercial products. [6]. Individually, these products are designed to address specific aspects of power quality, solving problems such as sags and swells, outages, flickers, and harmonics. However, when different types of devices are used to solve multiple problems simultaneously and are operating in close electrical proximity, expected iterations may arise.

The Premium Power Park is the world's first Distributed PPP and has been developed in Ohio since 1999 by American Electric Power, and S&C as the system integrator in conjunction with EPRI. The project was divided into three phases:

1. Developing an application methodology. For more than two years the researchers monitored power and identified the range of power needed by the customers [7],[8].
2. Simulation and Implementation
3. Monitoring and performance achieved. Phase Three involves monitoring and evaluating the results of the newly-installed equipment.

This paper describes and summarizes each one of those phases, giving particular attention to the system modeling and performance.

II. POWER QUALITY MONITORING AND ANALYSIS

In order to identify the types and causes of the disturbances, and the power quality needs for each customer, and extensive power quality monitoring and analysis was done.

Fig.1 shows the Industrial Park layout as well as the location of the power quality meters.

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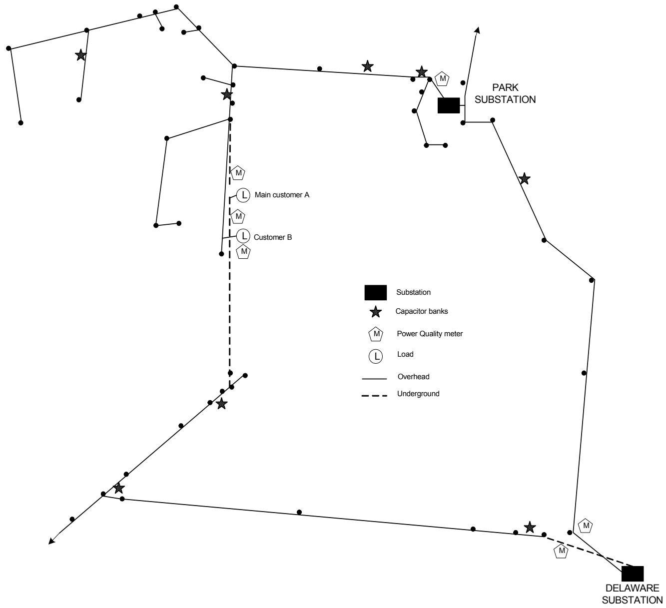


Fig. 1. Industrial park layout

After two years of field measurements, different types of reports were made. Tables 1, 2 and Fig. 2, 3 show how the data were collected and analyzed for each meter.

TABLE 1

LIST OF EVENTS CRITICAL ARE HIGHLIGHTED

Time	Event type	Magnitude	Comment
04/01/00 00:25:12.14	Waveshape Disturbance	-- -- -- -- --	Current disturbance. See fig. 2.
04/01/00 00:35:32.12	Waveshape Disturbance	-- -- -- -- --	DC offset. See fig. 1
04/01/00 00:40:46.31	Waveshape Disturbance	-- -- -- -- --	Current disturbance. See fig. 2.
04/01/00 01:03:33.59	Waveshape Disturbance	-- -- -- -- --	Switching off a load
04/01/00 01:03:34.49	Waveshape Disturbance	-- -- -- -- --	Current disturbance. See fig. 3.
04/01/00 01:03:35.26	Waveshape Disturbance	-- -- -- -- --	Current disturbance. See fig. 3.
04/01/00 01:03:35.56	Waveshape Disturbance	-- -- -- -- --	Current disturbance. See fig. 3.
04/01/00 01:03:35.80	RMS Swell Disturbance	8.4KV -- -- -- --	Small voltage swell. Vb=1.05p.u of nominal voltage.
04/01/00 01:03:35.85	Waveshape Disturbance	-- -- -- -- --	Current disturbance. See fig. 3.

TABLE 2

HARMONICS ANALYSIS

Time	Event type	Voltage distortion				Current distortion				Comment and trends
		THDa	THDb	THDc	#	THDa	THDb	THDc	#	
09/13/00 11:44:22.21	Snapshot Waveform	1.67			3		5.20		3-5-7	
09/13/00 12:44:22.21	Snapshot Waveform			1.66	5		4.50		3-5-7	
09/13/00 13:44:22.21	Snapshot Waveform	1.58			3			4.73	3-5-7	
09/13/00 14:44:22.21	Snapshot Waveform	1.48			3	3.37			3-5-7	
09/13/00 15:44:22.21	Snapshot Waveform	1.80			3			3.10	3-5-7	
09/13/00 16:44:22.21	Snapshot Waveform	1.67			3		4.24		3-5-7	
09/13/00 17:44:22.22	Snapshot Waveform	1.90			3-5			2.99	5-7	
09/13/00 18:44:22.22	Snapshot Waveform			1.83	3-5		4.82		3-5-7	
09/13/00 19:44:22.21	Snapshot Waveform			2.37	3-5			8.42	5	
09/13/00 20:44:22.21	Snapshot Waveform			3.24	3-5-13	6.95			5-13	

TABLE 3

SUMMARY TABLE OF VOLTAGE SAGS AND INTERRUPTIONS

Page	Date	Time	Fig. Type	Event	Retained Voltage	Duration (cycles , ms)	Phases	Comment
8	08/13/99	15:36:50.86 15:36:50.95	Wave Wave	Sag	Va=0.83 p.u. Vb=1 p.u. Vc=0.83 p.u.	+90ms	A,C	Back up system to customer B off
8	08/30/99	11:00:19.13	RMS Strip	Sag	Va=0.96 p.u. Vb=0.96 p.u. Vc=0.96 p.u.	?	A,B,C	Connection of Back up system to customer B
8	08/31/99	16:49:32.56	RMS Strip	Swell	?	?	A,B,C	Disconnection of Back up system to customer B
9	09/06/99	18:13:20.47	RMS Sag	Sag	Va=1 p.u. Vb=1 p.u. Vc=0.84 p.u.	82.2ms	C	Back up system to customer B off
10	09/06/99	20:19:23.10 20:19:23.12 20:19:23.57 20:19:23.89	Wave RMS Sag Wave Wave	Sag	Va=0.5 p.u. Vb=0.5 p.u. Vc=0.5 p.u.	1.37s	A,B,C	Back up system to customer B off

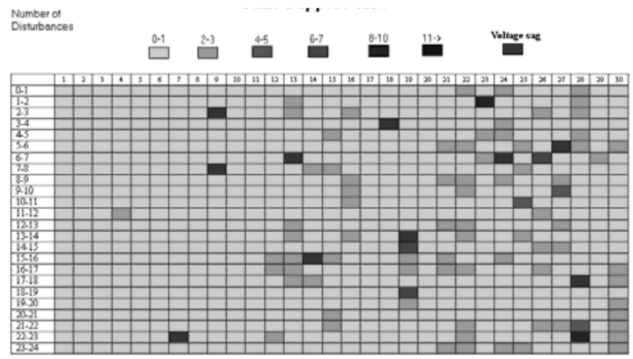
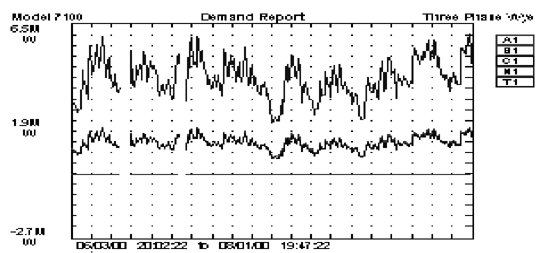
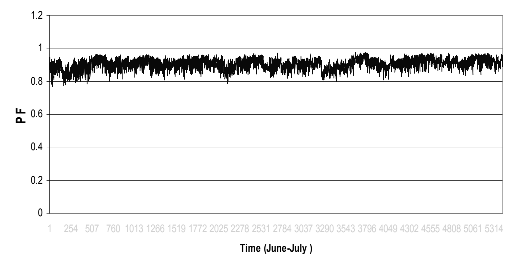


Fig. 2. Calendar of disturbances



a)



b)

Fig. 3. Demand report and power factor profile

These reports aided in the identification of the existing power quality at the park, the customer power needs as well as the loads' dynamical behavior. Fig. 4 shows the CBEMA curve for the most important customer in the park.

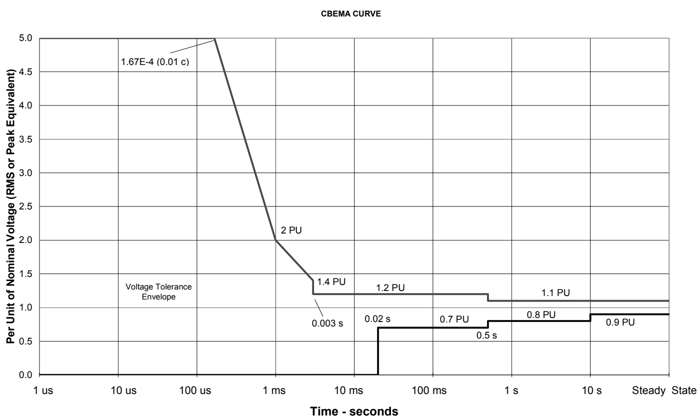


Fig. 4.- Main customer CBEMA curve

III. System Configuration and Modeling

Once the existing power quality and future required power quality were determined, an investigation regarding possible PQD's candidates needed to be done.

Some of the commercially available medium voltage PQ devices that could satisfy the requirements of the Premium Power Park are:

1. Distribution Static Compressor (DSTATCOM)
2. Dynamic Voltage Restorer (DVR)
3. Solid State Breaker (SSB)
4. Medium Voltage Sub-Cycle Transfer Switch (SSTS)
5. Transportable Battery Energy Storage (TBESS)
6. Static VAr Compensator (SVC)
7. Uninterruptible Power Supply (UPS)

However, after a technical and economical evaluation carried out by AEP and EPRI [7] only three of those devices were selected to be part of the fist Premium Power Park.

A. Power Quality Devices

The power quality mitigation-equipment used in the industrial park as well as the models used in the simulations are the subject of the next sections.

1) DVR

The S&C Medium Voltage Dynamic Voltage Restorer was selected among four other voltage support devices to be part of the PPP project. The Purewave DVR is a series connected device capable of injecting AC, three independent phase voltage of controllable magnitude and phase through an insertion transformer. The S&C DVR's main features are:

- Load Power Rating: 4MVA
- Voltage class: 15 kV
- Functions: Voltage sags and voltage swell corrections
- Response time: ¼ cycle
- Event duration: 10-30 cycles
- Energy storage: capacitors
- Sensitive control: per phase

The exact modeling of a DVR is fairly complicated. The simulation is simplified, yet proper DVR response to grid disturbances is maintained. The following table shows the main differences between the actual DVR and the one implemented in EMTP

TABLE 4
DVR MODEL COMPARION

	S&C DVR	EMTP DVR
Control System	PLL	PLL
	d-q components	d-q components
	α-β components	α-β components
	Control action saturation	--
	Digital Filters	--
	Load overcurrent trip	Load overcurrent trip
Hardware	PWM Passive filter	--
	DC Chopper	--
	Inverter	Ideal voltage source
	Series Transformer	Series Transformer
	Fast Electronic bypass	Fast Electronic bypass
	Mechanical bypass	Mechanical Bypass

Fig. 5 shows the DVR equivalent system implemented in EMTP/ATP draw.

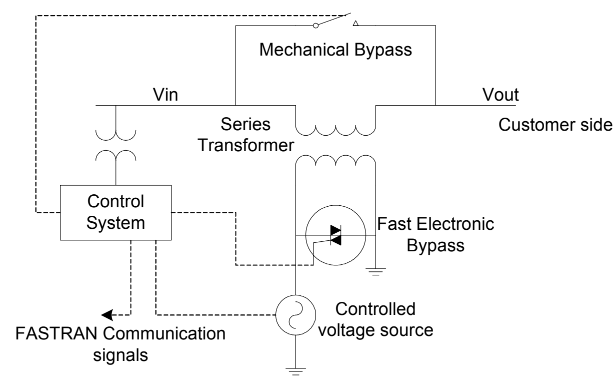


Figure 5. DVR equivalent system.

2) FASTRAN

The Joslyn FASTRAN25 High-Speed Mechanical Transfer Switch was selected among four other switching devices to be part of the PPP project. The FASTRAN is a high-voltage Transfer Switch that can provide nearly uninterruptible power to critical distribution-served customers who have two independent power sources. Fast-acting vacuum switches can rapidly transfer sensitive loads from a normal supply or preferred feeder, which experiences a disturbance, to an alternate or backup supply, such as another utility primary distribution feeder.

The FASTRAN main features are:

- Device Rating: 600A

- Symmetrical short Circuit current rating: 12.5kA
- Voltage class: 15 kV
- Problem addressed: Voltage sags and voltage swell.
- Response time: 2 cycles (25 msec)
- Sensitive control: SuperSwitch digital source Quality Sensing Strategy.
- Design life: 2500 operations
- Possibility of remote control.

The FASTRAN uses a state-of-the art patented control technology, able to distinguish in real time between swell, sags and open sources. However, the magnitude detector control algorithm implemented in EMTP was a sliding RMS (1).

$$V_{RMS}(t) = \sqrt{2 \cdot f \cdot \left(\int V(t)^2 \, dt - \int V\left(t - \tfrac{1}{2 \cdot f}\right)^2 dt \right)} \tag{1}$$

The vacuum transfer switch, one of the most challenging and crucial elements in the system modeling, was modeled as a time dependent resistor in parallel with an ideal switch (Fig. 5).

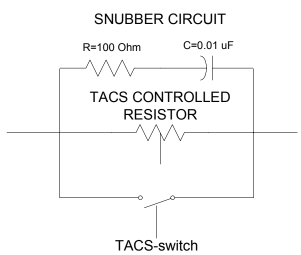


Fig. 6. Vacuum Switch topology

The Cassie's differential equation was chosen to model the electrical arc due to its simplicity and ability to describe an arc more clearly for high currents than other models [9]. Cassie's model is defined by the following equation:

$$\frac{dg}{dt} = \frac{1}{\tau_c} \cdot \left[\frac{i_{arc} \cdot u_{arc}}{u_c^2} - g \right] \tag{2}$$

where i_{arc} is the current through the breaker, u_{arc} is the voltage of the arc, g is the arc conductance, and τ_c, u_c are the arc parameters.

3) FASTRAN-DVR Communication Signals and Threshold Voltage Levels

In order to enhance the flexibility of the system with the resulting improvement in Power Quality, it was necessary to centralize some control functions.

The transfer thresholds for the FASTRAN are:

1. When the DVR is on, 62% retained voltage with a sensing time of 2ms
2. When the DVR is off, 80% retained voltage with a sensing time of 2 ms or 90% retained voltage with a sensing time of 4 ms (FASTRAN will go into automatic mode when DVR is off-line).
3. The FASTRAN will switch over if the DVR runs out of energy due to a deep sustained sag.

4) Intellivar

The Power Quality System Intellivar was selected among five other VAr control devices to be part of the PPP project. The Intellivar is an Advanced Solid State Static VAr Compensator (ASVC) that operates on a cycle-by-cycle basis, with advanced controls, which eliminate voltage transients and harmonic resonance problems.

The Intellivar main features are:

- Device Rating: 1500 kVAr/phase
- Voltage class: 15 kV
- Problem addressed: Flicker, Regulation and Harmonics.
- Response time: <2 cycles
- Sensing control: independent single phase units
- Capacitor steps: 100, 200, 400, and 800 kVAr
- Maximum resolution:1 Kvar
- TCR fills in the gaps between the 100 kVAr

The "switch=in" point of the capacitance of the IntellivAr occurs at the negative peak of the line voltage, and allows the capacitors to go on-line in a transient-free manner. The applied capacitive reactance per phase follows (3)

$$Applied\,KVAr = \left(\frac{P_{load}(kW)}{3.2} + Q_{load}(kVAr) \right) \cdot \left(\frac{7200}{V_{measured}} \right)^2 \tag{3}$$

From a circuit standpoint, the capacitive reactance is to be modeled as a series of LC circuit tuned at about 168 Hz. (e.g. if we apply 100 kVAr, model L=200 mH and C=4.5 uF; for 200 kVAr, L=100mH and C=9.0 uF, etc.). Fig. 7 shows the Intellivar equivalent circuit implemented in EMTP.

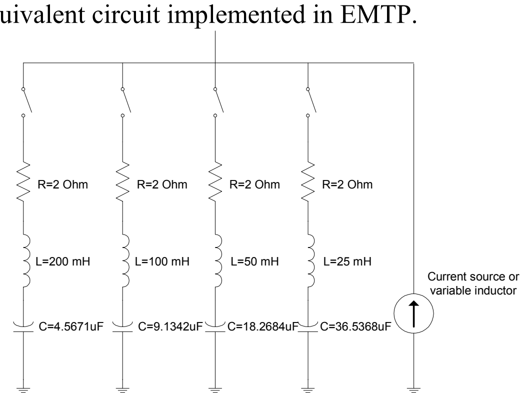


Figure 7.- Intellivar equivalent circuit per phase

While the TCR was modeled as a variable inductor (or variable current source), assuming that harmonic currents for TCR have no significant effect on the voltage or current of the Intellivar.

B. System Description

Two substations serve the industrial park. Fig. 11 represents the system equivalent that was modeled in the EMTP. AEP provided the data for source equivalents, transmission lines, cables, shunt capacitor, and loads in the system.

The main customer in the industrial park has a demand of at least 4500 kW on-peak and 3600 kW off-peak. The company's load profile is 50% of miscellaneous induction motors, while the rest are HVAC and lighting.

C. Load Modeling

During Phase One of the investigation, it was observed that the voltage at the customer site decays slowly based on the stored energy in the motors (Fig. 8).

A closed analysis of the data shows a low frequency component, the origin of which is unknown.

This type of low frequency component is very difficult to model, so in order to be able to compare field test measurements with simulation results, this low frequency voltage is removed from the voltage waveforms (Fig. 9).

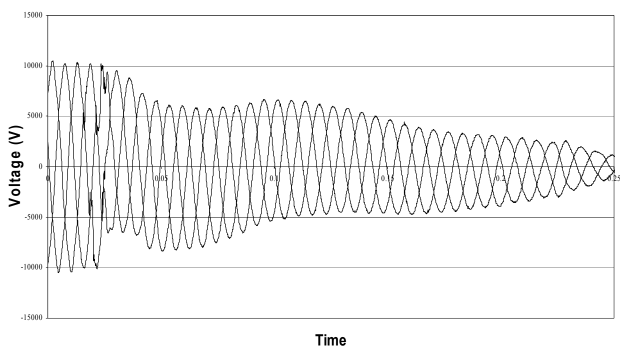


Fig. 8. Voltage at the main customer bus when line is opened. Filed measurements

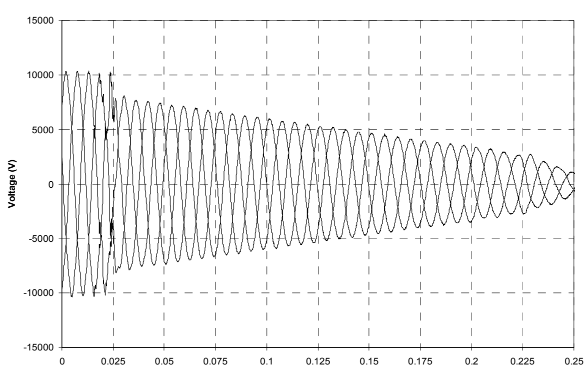


Fig. 9. Main customer voltage when line is opened without low frequency component. Field measurements

The load was modeled as an induction motor with a rated power of S=3.1 MVA in parallel with a passive load of S= 1MVA and PF=0.8 for voltage establishment.
The following data are the induction motor parameters.

- Shaft mass (moment of inertia) J1= 100000000 kg/m^2
- Shaft friction (viscous damping) = 100 Nm/rad/s
- Power Rating S= 3.1 MVA
- Voltage= 3kV

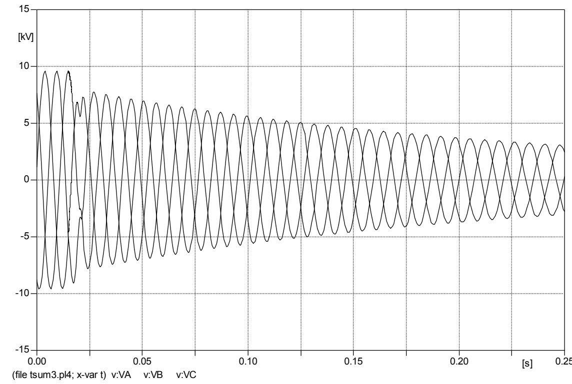


Fig. 10. Main customer voltage response when the line is open. Simulation results

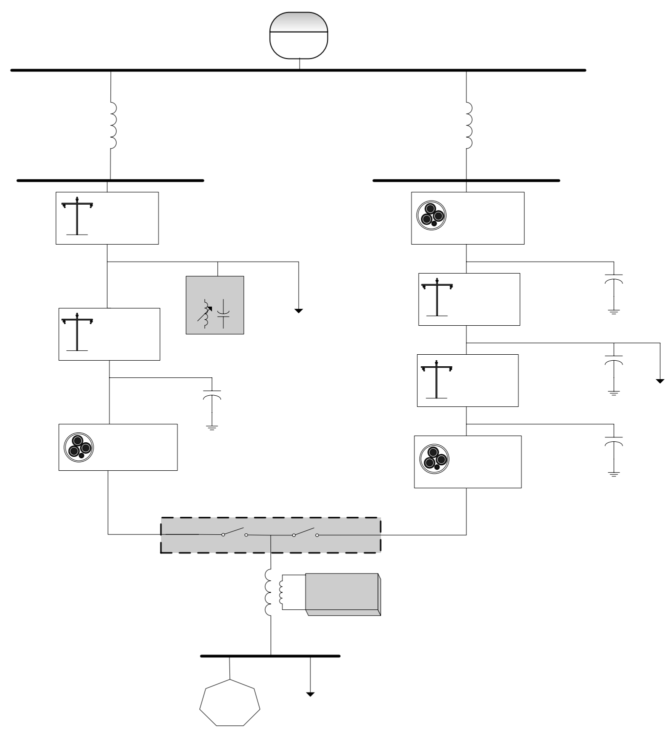


Fig. 11. Premium Power Park representation

IV. COMPARISON BETWEEN SIMULATION RESULTS AND FIELD MEASUREMENTS

Since the installation of the PPP equipment, there have been significant transient events that offer an excellent opportunity to compare the transient model predictions to actual field test data.

A. Event 1: Voltage sag

The following event (Fig. 12) took place on August 22nd, and shows a single phase voltage sag of 69% retained voltage, with a duration of 3 cycles.

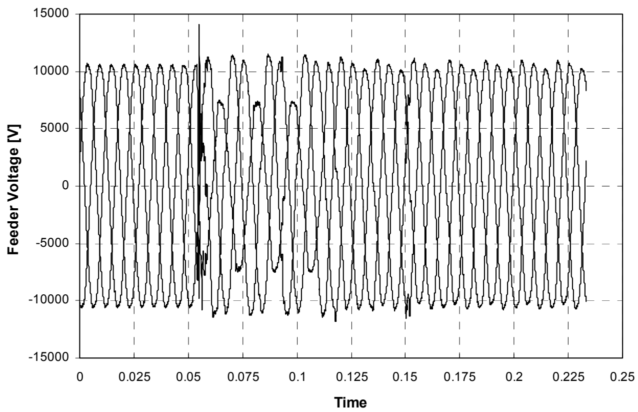


Fig. 12. Feeder voltage Field Measurements

Using TACS controlled voltage sources and a special function in MODEL called POINTLIST [10] we can enter field measurement data into the simulation.

Fig. 13 and Fig. 14 show the voltage injected by the DVR in order to overcome the voltage sag. Fig. 15 and Fig. 16 show that the customer voltage is maintained at about 100% during the sag.

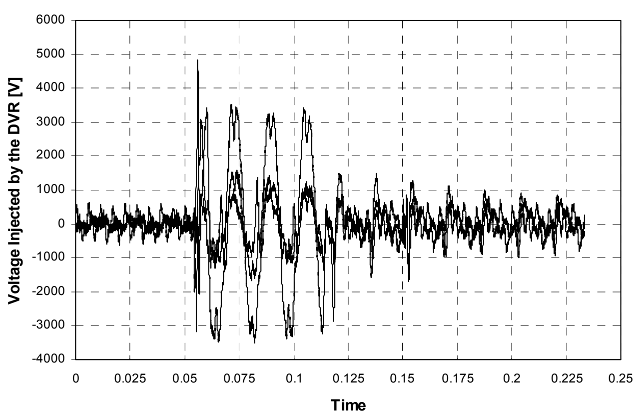


Fig. 13. Voltage injected by the DVR. Field measurements

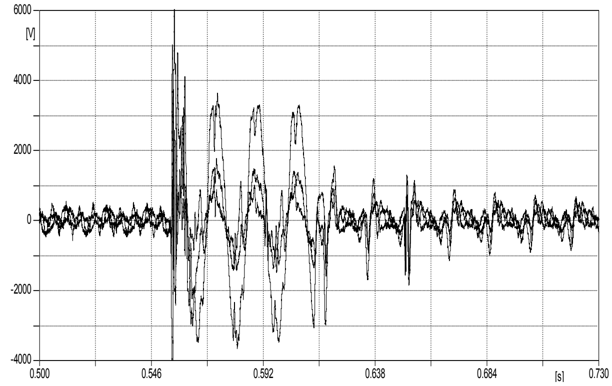


Fig. 14. Voltage injected by the DVR. Simulation results

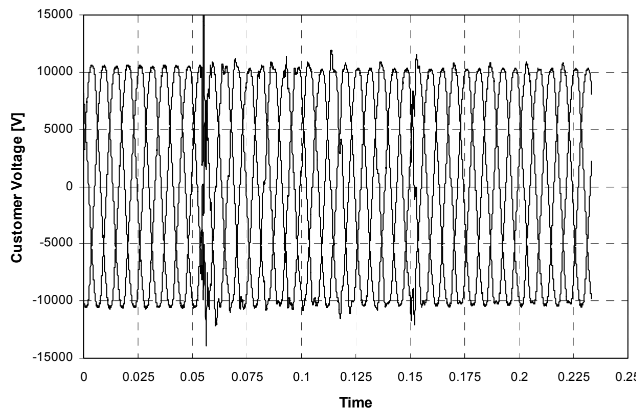


Fig. 15. Customer voltage. Field measurements

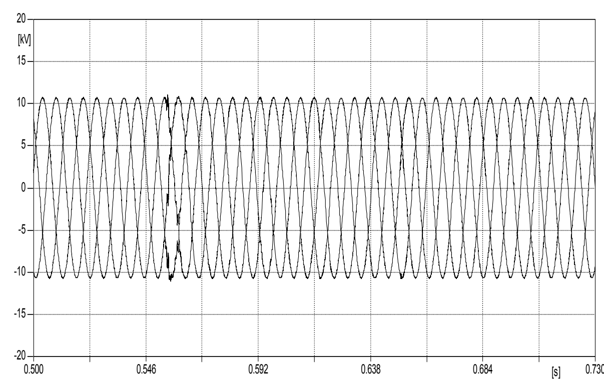


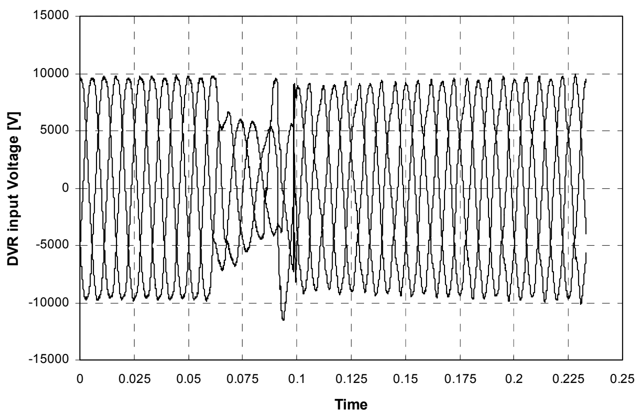
Fig. 16. Customer voltage. Simulation results

The main difference between field measurements and the simulation results is the high frequency voltage component that the DVR model is able to inject into the circuit. This difference is obvious at the beginning of the voltage sag, where high frequency transients are involved.

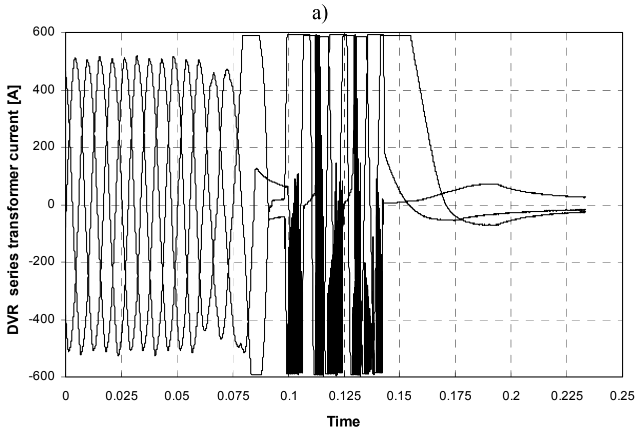
The reason for these discrepancies can be found in table 4.

B. Event 2: Switchover

The following event took place on June 21st, 2002, and shows a voltage sag deeper than 69% retained voltage. This voltage sag had a special importance since it caused not only the switchover between feeders, but it also caused the DVR to trip due to post transfer inrush current. Despite the DVR trip after the transfer, the voltage profile at the load still was good enough, such that the customer was not affected. Fig. 20 shows a) the DVR input voltage (a combination of the alternate and preferred feeder voltage), b) the DVR series transformer current, c) the voltage injected by the DVR in the field, and d) the customer voltage.



a)



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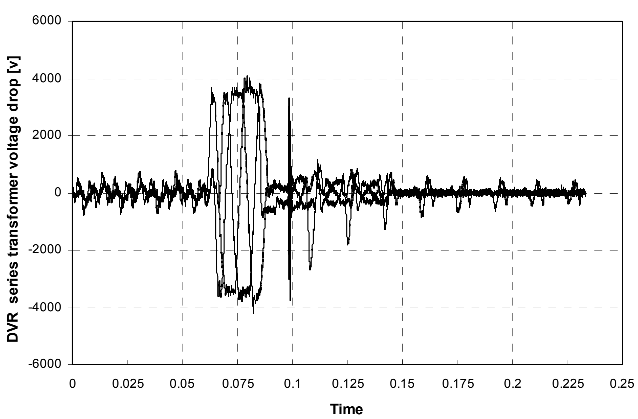
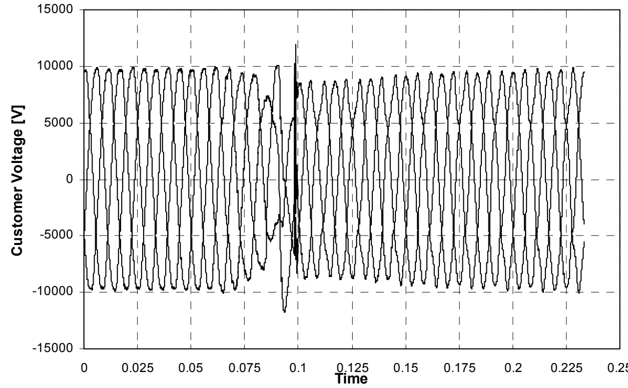


c)



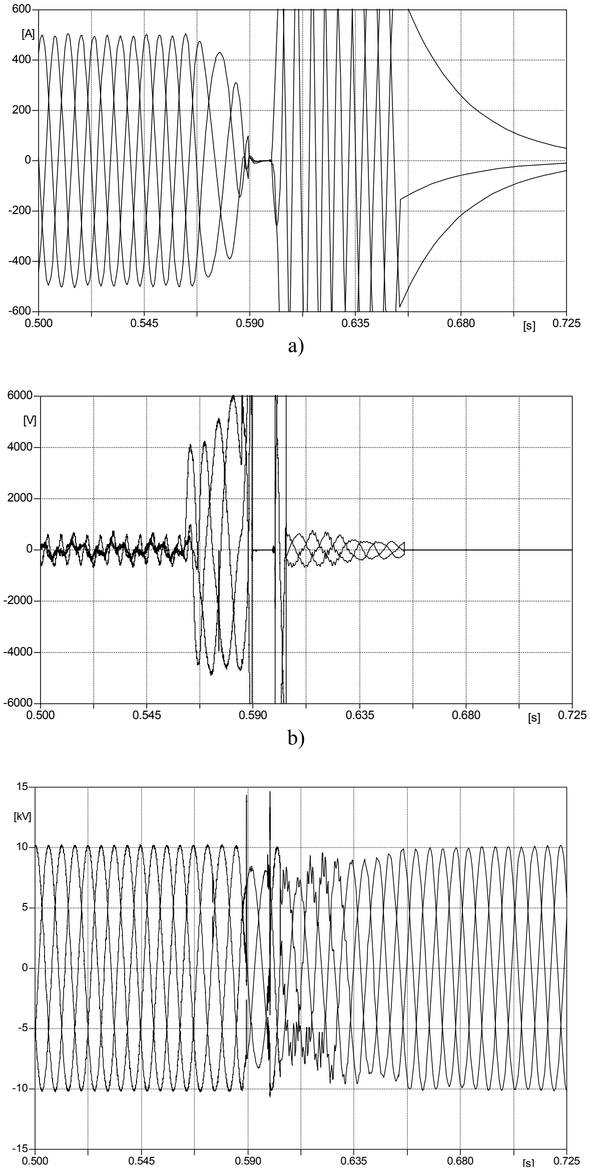
d)

Fig. 17. Switchover Field Measurement

As can be inferred from the previous figures, the inrush current after the transfer was much larger than expected. It may be due to some saturation effects plus additional pull-out torques of the motors. This is why the DVR tripped after the transfer had been completed. Despite the DVR's trip, the recovery voltage transient at the customer side, after the transfer, was not very significant. The voltage was therefore kept within acceptable levels.

In order to be able to compare the field measurements with the simulation results, some modifications were made in the load to match the actual power required by the load. Some adjustments in the timing of the Transfer Switch were made as well.

Fig. 21 a), b), c), and d) show the simulation results for the DVR series transformer current, the voltage injected by the DVR, and the customer voltage, corresponding to the field measurements represented by Fig. 20 b), c), and d) respectively. The simulated results compare well with the field waveforms. Thus, this modeling technique can be used to study the PPP equipment response to a variety of possible system events.



a)

b)

c)

Fig. 18.- Switchover event. Simulation results

V. CONCLUSIONS

This paper shows a summary of the recent studies and simulations of the first Premium Power Park .

This first Premium Power Park approach is based only on three main power quality devices, which are a Transfer Switch, a DVR, and an ASVC. These devices were modeled in EMTP-ATP draw to evaluate system performance to diverse power disturbances.

The following list summarizes the work accomplished so far about the PPP project.

- Power Quality Monitoring analysis.

The tabulation of results is very important to determine the park existing power quality, as well as the customer needs.

- System configuration.

The selection of the system topology can be considered as the most important and difficult task, because it involves the evaluation of all possible solutions for specific problems. No unique solution exits, however, there must be a balance between cost and customer needs.

- System modeling.

EMTP/ATP draw has been proven to be a very reliable and useful tool to study the system performance and response to different power disturbances.

- System performance.

The main goal of this PPP project is not just to provide the customers with different levels of power quality at a reasonable price, but the integration of different devices operating in close electrical proximity to each other. The following were the results of the system performance study:

1. There is no need for a supervisory system in this first approach of a PPP. However, a minimal set of communication signals between the DVR and the Transfer switch seem to be necessary to enhance the flexibility and improve the power quality of the system.
2. The ASVC can operate without any coordination between the other two Power Quality Devices.
3. Post transfer inrush currents can exceed load current thresholds, causing the DVR to trip offline. However, the DVR automatically returns to service after a short time. A number of options are being considered to avoid such trips due to the inrush current.

VI. REFERENCES

[1] EPRI “The Electricity Technology Roadmap Initiative. A Guide for Developing the Science and Technology of the Future” July 1999.

[2] Y.Mishima, H.Kita, J.Hasegawa "A Proposal of Interior Structure of Quality Control Center in the FRIENDS" *Proc. of The International Conference on Electrical Engineering (ICEE'98),* Vol.1., pp.346-349, Kyongju, Korea, July 1998

[3] T.Ise, K.Tsuji "Flexible, Reliable and Intelligent Electric Energy Delivery System : Configuration of Quality Control Center" *Proc. of The 61st American Power Conference*, Chicago, U.S.A., April 1999

[4] T.Ise, Y.Hayashi, K.Tsuji "Characteristics and location of the quality control center using three-phase four-wire AC system". *Power System Technology, 2000. Proceedings. PowerCon 2000. International Conference on*, Volume: 2 , 2000. Page(s): 661 -666 vol.2

[5] *Custom Power-State of the Art Cigre WG14.31, July 2000*

[6] Alvarez, C.; Alamar, J.; Domijan, A., Jr.; Montenegro, A.; Song, “An investigation toward new technologies and issues in power quality”, *Harmonics and Quality of Power, 2000. Proceedings. Ninth International Conference on*, Volume: 2 , 2000. Page(s): 444 -449 vol.2

[7] EPRI, “Premium Power Park (PPP): Phase 1 -- Application Methodology, ” Palo Alto, CA and American Electric Power, Gahanna, OH:2000000000000001000200.

[8] Domijan, A., Jr.; Song, Z.; Baptista, G.N.; Montenegro, A.; Wang, X.; Gurlaskie, G.T.; Mattern, K.E. *“ Power quality monitoring and analysis in a customized power industrial area using the FRIENDS concept ”. Harmonics and Quality of Power, 2000. Proceedings. Ninth International Conference on*, Volume: 2, 2000. Page(s): 379 -384 vol.2

[9] Bizjak, G.; Zunko, P.; Povh, D., “Circuit breaker model for digital simulation based on Mayr's and Cassie's differential arc equations”, *IEEE Transactions on Power Delivery*, Volume: 10 Issue: 3 , July 1995, Page(s): 1310 -131.5.

[10] Alternative Transient Program (ATP) Rule Book, Canadian/American EMTP User Group.

VII. BIOGRAPHIES

Alexander Domijan Jr. obtained his B.S.E.E. degree from the University of Miami, M.E. degree in electric power engineering from the Rensealaer Polytechnic Institute, Troy, N.Y. and Ph.D. degree in electrical engineering from the University of Texas at Arlington. He has been a consultant with many corporations. He is a member of the electrical engineering faculty at the University of Florida and is the director of Florida Power Affiliates and Power Quality Laboratory. His research areas are power quality and electricity metering, FACTS, Customer power and FRIENDS (Flexible, Reliable and Intelligent Electrical eNergy Delivery Systems).

Alejandro Montenegro obtained his BS degree in Electronic Engineering from the Polytechnic University of Valencia (UPV) in 1995 and his MSc in Industrial Engineering degree from the UPV in 2000. He has been a research assistant at the Dept. of Electrical Engineering of UPV and he is currently a research assistant and a PhD candidate at the University of Florida in the Department of Electrical and Computer Engineering. His field of interest is reliability and power quality of distribution networks using power electronics device.

Albert. J. F. Keri (SM) received his Ph.D. in EE from the Univ. of Missouri in 72 and MBA from the Ohio Univ. in 85. He joined AEP in 1972, and has been in Relay & Protection, R&D, and Planning sections. He has been involved with system stability analysis, FACTS, superconductivity, power quality, field tests, single-phase switching, loss reduction, overvoltage calculations, insulation coordination, failure analysis, fault current limiters, and consulting. Dr. Keri holds a P. E. license, is a member of HKN and Tau Beta Pi, and chairman of IEEE Gen. Sys. Subcommittee. He holds two U.S. Patents and has published over 40 IEEE & CIGRE papers

Ken Mattern joined the Power Electronics Laboratory of the Westinghouse Science and Technology Center in 1980 as an engineer specializing in the application of gate turn-off thyristors (GTOs). He was responsible for the development of the power inverter circuitry for a product line of ac motor drives and the application of power electronics to various alternate energy sources. In 1990 Mr. Mattern transferred to the ac drives product development group in Oldsmar, Florida. Recently, Mr. Mattern joined the FACTS and Power Quality Division of Siemens Power T&D as the Power Quality Business Manager, specializing in Medium Voltage Power Quality products. He currently is the Manager of Orlando Power Quality Operations of S&C Electric Company. He is responsible for the engineering and project activities associated with medium voltage Power Quality products.

Christopher B. Wyatt joined S&C (formerly Westinghouse) in 1990 as an Engineer working on all combustion turbine piping and air inlet systems. He was promoted to lead engineer in 1992. In 1995, Mr. Wyatt joined the FACTS and Power Quality Division of Siemens Westinghouse where he assumed the responsibilities of Project Manager for the Custom Power and FACTS product lines. Mr. Wyatt has managed both domestic and international projects ranging in value from $1M to $15M.

Charles.W. Edwards has more than 27 years of experience in the field of electrical engineering. This includes design and development of electronic controls for DSTATCOMs, DVRs, STATCOMs, static VAr generators, and ac motor drives. He is responsible for developing microprocessor- and DSP-based hardware, software, and the power circuitry for these systems. Mr. Edwards has worked on advanced, microprocessor-based control systems for use in sophisticated power electronic equipment for many years. He has made significant contributions to the field of power electronics and has played a vital role in maintaining first Westinghouse, then Siemens and now S&C as a world class leader in these technologies. Mr. Edwards holds 15 U.S. patents.