

## ***Program 1***

### **1-1 URD Overvoltage Protection**

Using full-scale impulse tests on buried URD cable, classical underground distribution system overvoltage protection theory was validated. Included were comparisons of SiC and ZnO arrester performance, comparisons of arrester placement, and mid-span voltage magnification due to taps.

**Deliverable:**

"Impulse Testing of Underground Direct-Buried Cable," Phase I Final Report, 11/15/88.

### **1-2 URD Overvoltages Considering Transformers and Grounding**

Using full-scale impulse tests, impulse overvoltages on URD systems were investigated considering: transformer characteristics and secondary currents due to a poorly grounded primary neutral. Also, a computer-based tutorial on underground distribution overvoltage protection was created.

**Deliverables:**

"Application Guidelines: Overvoltage Protection of Underground Cable Systems," Phases I and II, 2/17/89;

"Distribution Testing Tutorial and Spreadsheet Version 2.0," May 10, 1990;

"Secondary Surge and Jacketed Cable Investigation" Final Report, 5/14/90.

### **1-3 Fast and Slow-Front Surges**

Using full-scale impulse tests, cable system overvoltages due to fast and slow-front surges were investigated. Guidelines for mitigation of lead-length voltage effects were developed.

**Deliverable:**

"Fast and Slow Front Testing of Jacketed Cable" Final Report, 7/13/90.

## ***Program 2***

### **2-1 Field-Aged Cable Testing**

The objectives of this research performed on field-aged cable cross linked polyethylene cable samples, removed from service by DSTAR member utilities, were to:

1. Evaluate the linkage between impulse duty and insulation degradation in field-aged cross linked polyethylene primary distribution cable.
2. Determine if a recently developed partial discharge site detector can successfully assess cable insulation aging.

**Deliverable:**

"Testing of Field Aged Crosslinked Polyethylene Cable," Final Report, 8/4/92, Rev. 12/11/92.

## **2-2 Semi-Conductive Jacketed Cable Investigation**

The responses of semi-conductive jacketed cable to the following were investigated.

1. Impulses originating on the overhead system.
2. Lightning ground strokes near the cable trench.

### **Deliverable:**

"Semi-conductive Jacketed Cable Investigation" Final Report, 4/1/91.

## **2-3 Switching Surges in Underground Distribution Systems**

Field tests, augmented by simulation studies, were performed to:

1. Characterize voltage transients generated by routine cable and capacitor switching operations.
2. Compare the performance provided by different switching devices.
3. Generate guidelines for switching practice and arrester application which can minimize switching surge overvoltages applied to underground distribution systems.

### **Deliverable:**

"Switching Surges in Underground Distribution Systems," Final Report, 10/30/92.

## **2-4 Ferroresonance Guidelines for Modern Transformer Applications**

Based on extensive field tests, this research had the following objectives:

1. Characterize ferroresonant behavior when grounded-wye padmount transformers are switched.
2. Develop formulas for estimating ferroresonant overvoltage magnitude as a function of transformer and cable parameters.
3. Provide detailed guidelines specifying the maximum cable length which can be switched with a given transformer without exceeding a critical overvoltage magnitude.

### **Deliverable:**

"Ferroresonance Guidelines for Modern Transformer Applications" Final Report, Volumes 1 & 2, 7/24/92.

## ***Program 3***

### **3-1 Supplemental Cable Tests and Improved System Grounding**

The objectives of this investigation were twofold:

1. Complete the investigation of the impulse performance of insulated jacket, semi-conductive jacket, and bare concentric neutral cable. Included were tests of induced currents from ground strokes and, for the two jacketed cable types, neutral-ground voltages and the voltage required to puncture the jackets.
2. Evaluation of various grounding electrodes and comparison of impulse impedance to measured and calculated ground resistances.

**Deliverable:**

"Supplemental Cable Tests and Improved System Grounding" Final Report, 2/21/92 , revised 7/9/92.

### **3-2 Distribution Line Protection and Reliability**

Develop software allowing members to evaluate various overhead distribution line designs with respect to performance for direct and induced lightning strokes. (Project terminated in early stages due to overlap with an ongoing EPRI project with similar objectives.)

### **3-3 Mitigation of Distribution Feeder Harmonics by Passive Techniques**

Assess the effectiveness of passive techniques to mitigate harmonics from distributed sources on residential feeders. Passive mitigations evaluated included:

1. Optimal sizing and placement of distribution capacitors.
2. Tuned filters.
3. Grounded-wye delta transformers (to shunt zero-sequence harmonics).

**Deliverable:**

"Mitigation of Distribution Feeder Harmonics by Passive Techniques," final report 11/93.

### **3-4 Fault Energy Guidelines for Transformer Enclosures**

Establish critical fault energy withstand limits, above which padmounted transformers are expected to experience tank deformation and leaks, for:

1. Single-phase padmounted transformers.
2. Three-phase padmounted transformers.

**Deliverable:**

"Pad Mounted Transformer Tank Fault Withstand Capabilities", final report 4/98

## ***Program 4***

### **4-1a Ferroresonance Guidelines for Additional Padmount Transformer Types**

Create guidelines specifying the maximum cable length which can be switched for the following types of transformers without excessive overvoltage.

1. delta primary three-phase padmount transformer
2. grounded-wye primary three-phase transformers having amorphous metal cores
3. grounded-wye primary three-phase transformers having five-leg stacked cores.

**Deliverables:**

Ferroresonance Guidelines for Additional Padmount Transformer Types final report 5/94 and diskette containing Critical Cable Length Guidelines.

## **4-1b Survivability of MOV Arresters Subjected to Ferroresonance Overvoltages**

Determine the capability of metal-oxide surge arresters to survive exposure to ferroresonant overvoltage caused by the interaction of three-phase grounded-wye padmount transformers and URD cable capacitance. Create guidelines indicating the maximum cable length which can be switched with a transformer, in terms of the arrester type, arrester voltage rating, and system voltage class.

**Deliverable:**

Survivability of MOV Arresters Subjected to Ferroresonance Overvoltages" final report 11/94.

## **4-1c Ferroresonance Survivability of Under-Oil Arresters**

Extend the research performed in Phase 1B to perform a more in-depth evaluation of arrester survivability when exposed to amorphous-core three-phase transformer ferroresonance, and in particular to assess the performance of under-oil arresters in this condition. Create guidelines indicating the range of application parameters for which an under-oil arrester can be expected to survive extended exposure to amorphous transformer ferroresonance.

**Deliverable:**

Ferroresonance Survivability of Under-oil Arresters, final report 11/96.

## **4-2 Distribution Transformer Harmonic Derating Guidelines**

Measure the resistance of a diverse group of single and three phase distribution transformers from 60 Hz to 1500 Hz. Develop tables which indicate permissible harmonic loads for the following load combinations:

- 60 Hz and 6 pulse drives
- 60 Hz and 12 pulse drives
- 60 Hz and switch mode power supplies
- 60 Hz and compact fluorescent lighting

**Deliverable:**

Distribution Transformer Harmonic Derating, final report 12/94.

## **4-3 Secondary Surge Guidelines**

Develop Analytic Models to investigate lightning-induced surges on distribution secondaries. Determine which system parameters have the greatest effect on the first layer voltage in distribution transformers. Develop a spread sheet which calculates the overvoltage performance of 10 and 25 kVA transformers for rural and residential circuits over a range of pole ground resistances.

**Deliverables:**

Minimizing the Impact of Secondary Surges on Distribution Transformers, final report 2/96 and diskette containing Evaluation of Secondary Surges, 7/96.

## **Program 5**

### **5-1 Elbow Switching Capabilities for Unloaded Cable**

Identify the phenomenon or phenomena responsible for unexplained flashovers of elbow terminators, while switching unloaded or very lightly loaded distribution cables. Also, correlate these switching failures to system (e.g., cable length, circuit topology) and component (e.g., elbow and bushing insert) characteristics. Two stages of investigation are planned:

- Failure mechanisms will be identified in laboratory re-creations of typical field operations
- Insulation strength will be defined for varying positions and environmental conditions.

In addition, this effort will be continued in Program 6, where a switching performance test will be developed and recommended for incorporation into ANSI Standard 386.

**Deliverable:**

Investigations of Elbow and Insulated Cap Flashovers, joint final report for Projects 5-1 and 6-1, 9/97.

### **5-2 Floating Wye-Delta Overhead Bank Overvoltages**

Investigate and quantify overvoltages produced by floating-wye delta overhead transformer banks when switched or following fuse operation, and investigate the ability of arresters to withstand these overvoltages. Generate explicit recommendations on the application, overvoltage protection, and operating procedures for these banks.

**Deliverable:**

Wye-Delta Overhead Bank Overvoltages, final report 1/96.

### **5-3 Gapped MOV Arrester Characteristics**

Compare the protective performance of gapped and gapless distribution MOV arresters under the following non-standard conditions:

- wide range of rise times
- multiple impulses in succession
- bipolar impulses

Interpret the impact of any differences on equipment protection.

**Deliverable:**

Comparison of Gapped and Gapless MOV Arrester Characteristics final report 5/95.

### **5-4 Software Development for the Analysis of Cold Load Pickup**

Develop a tool which can be used by DSTAR engineers to aid in the determination of cold load pickup currents and selection of fuse ratings based on these currents. Standardized computational techniques will be incorporated in a spreadsheet form. Two modes of operation will be possible:

- Generic approximations, from simplified load responses and user-specified feeder characteristics
- Cumulative feeder response, when detailed loading data is available.

**Deliverables:**

Cold Load Pickup Spreadsheet (EXCEL and Lotus versions) 5/97; CLPUSS User's Manual 5/97.

## 5-5 Transformer Owing Cost Software

Develop a program to evaluate and optimize the lifetime cost of owning and operating distribution transformers. This tool will estimate the service life of specific distribution transformers under various overload duties, and will project the cost of owning and operating those transformers.

The approach will be general enough to accommodate individual utility practices, yet will apply standardized computational techniques. The program will be able to handle either default or user-specified thermal and economic parameters, and will include the option to correct for harmonic loading.

**Deliverables:**

DSTAR Transformer Owing Costs Software (D-TOCS) 4/97

Transformer Owing Cost Analysis Software - Application Guide 4/97

## 5-6 Service Entrance Protection Coordination

Investigate arrester application issues at secondary service entrances, specifically with regard to the overvoltage coordination between service entrance arresters and utility equipment. The results will:

1. Define whether service entrance protection may be applied without performing secondary surge mitigation.
2. Specify any steps needed to counteract an increase in utility equipment stress.
3. Indicate the application circumstances (e.g. grounding conditions, transformer type) where mitigation is necessary.

**Deliverable:**

Service Entrance Protection Coordination, final report, 11/96.

## *Program 6*

### 6-1 Elbow Switching Performance Tests

Develop a testing procedure to quantify acceptable performance when disconnecting "unloaded" separable connectors. Specifically, the proposed performance test was to address the propensity of energized (but unloaded) elbow connectors to occasionally flashover when being disconnected. Testing was conducted at vendor high-voltage labs, with test procedures and flashover performance observed by both DSTAR and vendor representatives. The objective was to demonstrate and quantify elbow flashover behavior with a test procedure that is acceptable to both vendors and users. The performance test procedure which was to be developed was to be ultimately proposed for adoption into ANSI standard 386. Despite extensive effort, however, this project was not successful in finding a realistic and practical means to accelerate flashovers to the degree necessary for meaningful evaluation of elbow performance.

**Deliverable:**

"Investigations of Elbow and Insulated Cap Flashovers", joint final report for Projects 5-1 and 6-1, 9/97.

## **6-2 Distribution Transformer Load Demand Algorithm**

Develop an algorithm by which peak summer distribution transformer kVA demand of existing loads can be predicted based on monthly kWh usage patterns, climatological data, and customer demographics. The expected application of this algorithm is identifying excessively overloaded transformers for replacement, and to determine if an existing transformer has available capacity to serve a new load.

### **Deliverable:**

"Distribution Transformer Demand Algorithm", final report, 2/98.

## **6-3 (This project number has been intentionally skipped)**

### **6-4a Distribution Transformer Owing Cost Software Enhancements, Phase A**

Enhance the D-TOCS (DSTAR Transformer Owing Cost Software) program to obtain enhanced user functionality. Included are new data management features, import and export of data, new analysis features, and a context-sensitive help function. Investigate application of D-TOCS for transformer inventory optimization and transformer purchase budget optimization.

### **Deliverable:**

DSTAR Transformer Owing Costs Software ,Version 3.0, Beta release 5/98  
Transformer Owing Cost Analysis Software - Application Guide Revisions (1/98)

### **6-4b Distribution Transformer Owing Cost Software Enhancements, Phase B**

Validate the thermal and loss of life algorithms of TOCS by comparing with other calculations. Enhance the D-TOCS (DSTAR Transformer Owing Cost Software) program to accelerate calculations and to implement a batch operating mode for analysis of multiple transformer designs. Develop software for automatic optimization of stocked transformer ratings, and optimized transformer procurement selection within budget constraints.

### **Deliverable:**

"Validation of DSTAR Transformer Owing Cost Software (TOCS) Thermal and Insulation Life Calculations", final report, 7/98.  
TOCS Optimizer - Excel spreadsheet application, 8/98

## **6-5 Unbalanced Transformer Bank Software**

Create a convenient Windows-based tool for calculating voltage imbalance and transformer loading when unbalanced transformer banks are used, or unbalanced loads are applied to a balanced bank.. Included are both inherently unbalanced bank connections (e.g., open-delta) and the application of transformers with dissimilar impedances in normally balanced banks (e.g., wye-wye).

Project commenced 5/97.

## **6-6 Cable Electrical Parameters Software**

Create a convenient Windows-based tool for calculating the electrical parameters of distribution cables as a function of the physical characteristics of the individual cables and the manner of cable installation (i.e., duct spacing, cable lay, etc.) Included are concentric, drain wire, tape shield, and longitudinally corrugated neutral cables, with and without separate neutral wires. Parameters include the cable impedances in both phase and symmetrical component form, charging current, losses, dielectric stress, etc.

**Deliverables:**

DSTAR Cable Electrical Parameters Software (CEPS), Version 2.1, Beta release 3/99  
"Cable Electrical Parameters Software (CEPS) Application Guide", draft final report and program application guide, 3/99

**6-7 Cable Ampacity Derating**

Investigate the thermal impact of external heat sources on cable for the following types of situations where longitudinal heat transfer along the cable or along the conduit may significantly affect ampacity: cable in parallel with another cable for a limited longitudinal extent, cables crossing other cables (perpendicularly or obliquely), or cable taps in and out of transformers and switchgear.

**Deliverable:**

"Ampacity of Underground Cables Near Limited-Distance External Heat Sources", final report, 7/98.  
Interference Temperature Calculation Spreadsheet, Excel spreadsheet application, final version, 6/98.

***Program 7*****7-1 Distribution Engineering Toolbox**

Develop a collection of Windows-based software tools to support routine distribution engineering operations. Included are applications for guy tension calculation, transformer loading analysis, cable pulling tensions, overhead line design (sag, blowout, loading), voltage drop and flicker analysis, and others. Stressed are user convenience and ease of customization to individual utility preferences.

**Deliverables:**

Guy Tension Calculator, Excel spreadsheet application, beta version, 2/99.

**7-2 Secondary Electrical Design Software**

Develop a graphic-oriented, user-friendly, Windows-based software to support the electrical design of single-phase secondary systems. Program allows user to "draw in" a radial circuit topology with multiple layers of connection nodes, and up to 25 loads. Program assists designer in transformer selection of the appropriate transformer rating. Service voltage regulation, transformer and secondary cable loading, voltage flicker, and service short-circuit currents are easily calculated

**7-3 Transformer Scrap/Repair Decision Software**

Develop a methodology and supporting software to generate decision criteria which can be used by a utility to make a rational, economic-based decision on whether to scrap or repair a transformer which has been removed from service.

## **7-4 Cable Electrical Parameters Software Enhancement**

Enhance the capabilities of the Cable Electrical Parameters Software (CEPS), developed previously in Project 6-6, to include secondary cables and paper-insulated, lead-covered primary cables.

## **7-5 (This project number has been intentionally skipped)**

## **7-6 Elbow Flashover Incident Reporting**

Develop and deploy a web-based database to gather reports of flashovers of separable connectors (elbows and insulated caps) from the utility industry. Emphasis will be on flashovers occurring during lightly-loaded or unloaded conditions. Data will be gathered describing the equipment, the switching operation, and system characteristics. The gathered data will be periodically analyzed and results presented.

## **7-7 Cable Temperature Effects of Limited-Distance Heat Sources**

Perform full-scale field testing to confirm the analytical predictions of cable temperature rise (and resulting need for cable derating) due to heat sources, such as other cables, crossing or in parallel to a cable for a short distance. Included are tests of temperature rise in the short tap sections at padmounted equipment where incoming and outgoing cables may be laid in the same trench for the distance between the equipment and the main cable trench. Previous analytical work shows the need for significant derating in this situation.

## **7-8 DSTAR Seminar**

Provide a tutorial seminar reviewing the significant findings of DSTAR research and development. A portion of this seminar will be open to all utilities, and a portion containing the most critical facts will be limited to participants from the funding utilities.

## ***Program 8***

## **8-1 (This project number has been intentionally skipped)**

## **8-2 Cable Parameters Software Enhancement**

As part of Program 8, the capabilities of CEPS will be greatly Expanded. The goal is to add the following features:

- Simple ampacity calculations
- Riser ampacity calculations, based on new information's obtained as part of DSTAR Program 7 research
- Asymmetric neutral currents and losses to allow more accurate evaluation of cable losses and ampacity
- Cable-by-cable neutral currents during faults to determine cable fault-current withstand limitations posed by cable neutrals
- Maximum cable pulling tension
- Maximum sidewall cable pressure

**Value to Participating Utilities:**

With Expanded capability of CEPS, member utilities will be able to engineer underground distribution systems with greater accuracy, and less engineering effort.

### **8-3 Capacitor Transient Currents**

This project will develop guidelines for avoiding nuisance operation of feeder capacitor bank fuses due to switching transient and lightning duty. The guidelines will consider factors such as:

- capacitor size
- capacitor bank neutral grounding (grounded wye or floating wye)
- rated system voltage
- relative location of other capacitor banks
- switchgear type and performance
- overvoltage protection practices
- feeder lightning exposure

This project will include field measurements to supplement simulations and engineering analysis, providing accurate and realistic results. Final results will be delivered in the form of concise guidelines, tables, and spreadsheets.

**Value to Participating Utilities:**

Guidelines provided by this research will allow member utilities to better coordinate fuses protecting feeder capacitor banks, and minimize nuisance fuse operations resulting in voltage imbalance affecting customer power quality and labor costs for locating and replacing blown fuses.

### **8-4 Primary Flicker And Impedance**

This modest-sized project will expand the present DSTAR Toolbox voltage flicker tool to calculate the impact of large motor starting or other flicker loads elsewhere on the feeder. The tool will allow the user to quickly and conveniently model the primary system. An impedance calculator will be built into the tool to allow the user to conveniently determine the impedance of a feeder section with a given configuration and conductor size. Voltage flicker results will be output for each specified point in the primary system model, as well as the secondary system to which the flicker-producing load is connected.

**Value to Participating Utilities:**

There is heightened interest in power quality provided to customers, and one significant aspect of power quality is limiting voltage flicker. Existing tools for distribution system analysis, such as load flow programs, are cumbersome to use for this type of analysis, and are often not available to the engineers needing to perform the flicker analysis. This tool fulfills this need, and offers convenience and ease-of-use which minimizes engineering effort required.

### **8-5 (This project number has been intentionally skipped)**

### **8-6 DSTAR T&D Show**

## **8-7 Overhead and Underground Total Owning Costs**

Utilities often need to evaluate and compare the system owning costs of overhead (OH) and underground (UG) distribution systems. While some utilities base their analysis solely on installation and equipment first cost comparison, it is recognized that there are O&M costs incurred during the lifetime of OH and UG distribution systems that need to be considered as well.

### **Deliverables:**

- A structured approach for the comparison of equal OH and UG distribution systems.
- A Windows based software implementing the OH vs. UG comparison algorithms.

## **8-8 Impact of Distributed Generation**

This project will develop "white paper" report which describes the various distributed generation technologies and summarizes their impact on distribution system design, operation, and protection. The evaluation will include the following topics:

- Characteristics of "distributed resources" technologies.
- Why and where DR are or might be applied.
- How they may affect distribution system performance
- Impact on system reliability
- Current interconnection standards activities
- How DR Impacts can be minimized
- Future concepts where DR can be used to help the distribution system.

## **8-9 (This project number has been intentionally skipped)**

## **8-10 Seasonal Loading Equivalentents**

The Transformer Owning Cost Software (TOCS), the Transformer Loading Analyzer (TLA) in the DSTAR Toolbox, and many other software packages for transformer thermal loading analysis base their representation of annual variations in load and ambient temperature on a four season method with typical load and temperature patterns within each season. Should the "seasons" be summer, winter, spring, and fall ?

This project will develop guidelines and algorithm for dividing the year into loading "seasons" which provide best use of loading program's capability.

### **Deliverables:**

- Develop a robust approach/algorithm for equivalencing actual load profile/climatic data into a four season load scenario that properly accounts for losses and transformer temperature duties.
- Implement the algorithm in Windows-based software. This implementation may be in the form of an Excel spreadsheet with graphic user interface enhancements or as an Access application.

## ***Program 9 (Current Program)***

### **9-1: DSTAR Distribution e-Handbook**

Distribution engineers and technicians frequently use one or more "paper" handbooks to find vital engineering information or refer to tables in these handbooks to obtain simple calculated values. The goal of the DSTAR Data e-Handbook is to create a dynamic electronic document that consists of information commonly used by the DSTAR membership. Covering a variety of distribution engineering topics, the DSTAR e-Handbook is intended to be an authoritative source of information. The material included in the e-Handbook has been obtained from existing distribution handbooks, manufacturer information, standards documents, results from DSTAR software programs, and surveys of the DSTAR membership.

### **9-2: Cable Pulling Assistant (CPA) Software Enhancements**

The Cable Pulling Assistant (CPA) software is used to quickly calculate cable pulling tensions and sidewall pressures for a given layout. It allows easy comparison of pulls in either direction. CPA also calculates probability of cable jamb, conduit fill, and conduit clearances. This software enhancement provides the user and administrator with additional flexibility in entering data and aligns the calculation algorithm with AEIC CG G5-90.

### **9-3: Guy Tension Analyzer (GTA) Software Enhancements 1**

GTA calculate tensions on guy wires and guy anchors for dead-end and angle distribution poles. This project updates GTA to calculate minimum pole class based upon the vertical loadings applied by user specified loading conditions and guying. Additionally, the pole loading and class are calculated for an unguyed pole situation.

### **9-4: Guy Tension Analyzer (GTA) Software Enhancements 2**

The Guy Tension Analyzer software tool is used to calculate tensions on guy wires and guy anchors for dead-end and angle distribution poles. The tool can handle three types of guy wire configurations: 1.) standard (guys connected directly to anchors from a line pole), 2.) span guy, and 3.) sidewalk guy. In the standard and span guy configurations, up to ten lines (ten lines in each direction for angle poles) can be accommodated, together with up to ten tap lines terminating at an arbitrary angle with respect to the main line (feature not supported with sidewalk configuration), as well as five guy wires and anchors. The tool provides complete flexibility to connect any guy to any anchor. This software enhancement focuses on updating the GTA calculation algorithm to include resultant guying.

### **9-5: Secondary Electrical Design Software (SEDS) Enhancement**

The Secondary Electrical Design Software (SEDS), developed during Program 7, has been successfully used by the DSTAR membership to perform electrical calculations, such as voltage drop and flicker, for multi-tiered, single-phase secondary systems. SEDS employs a drag and drop-style user interface that is very simple to use and affords users tremendous flexibility. There are some situations where unbalanced, three-phase loads are connected to the secondary system and need to be analyzed. This new project is intended to serve this need.