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Proceedings of the IEA Implementing Agreement on Photovoltaic Power Systems

Annex IV Workshop

Sponsored by the
National Renewable Energy Laboratory
for the U.S. Department of Energy

September 21-22, 1995
National Renewable Energy Laboratory
Golden, Colorado

January 1996

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1617 Coles Blvd
Golden, Colorado 80601

January 1996

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I. Workshop Summary

Introduction and Purpose

The International Energy Agency (IEA) Implementing Agreement on Photovoltaic Power Systems (PVPS), established in 1993, is a collaborative effort of sponsoring countries to reduce costs of technology applications, increase awareness of potential value, and foster market deployment of PV. Task IV, the Modelling of Distributed Photovoltaic Power Generation in Support of the Electric Grid, is one of six project work areas established under the Implementing Agreement. The work under Task IV has been assigned to Annex IV.

Although Task IV was framed in 1993, no progress had been made in implementation as of mid-1995. The Annex IV Workshop, described herein, was a focused effort by the participants to redefine the issuer in light of today's knowledge, and to gain interest among potential collaborators and participants.

At the request of the Office of Utility Technologies at the U.S. Department of Energy (DOE), the National Renewable Energy Laboratory (NREL) developed and hosted a two-day workshop on September 21 and 22, 1995. The invited workshop participants were a blend of laboratory, utility, consultant, and government personnel who are knowledgeable and interested in the subject of modeling grid-support PV.

The purpose of the workshop was to determine the current status of methods for evaluating the benefits of and planning for grid-connected PV systems and to establish a plan for further action according to the needs and priorities of participants.

Attendees
Peter Ahm, PA Energy Ltd., Denmark
Eva Elena Bruno, ENEL, Italy
Adrian Cole, ETSU, United Kingdom
Lynn Coles, NREL
Christy Herig, NREL
Joe Iannucci, Distributed Utility Associates
Alberto Iliceto, ENEL, Italy
Angelo Invernizzi, ENEL, Italy
Per Kristensen, VOH, Denmark
Richard Perez, State University of New York at Albany
Mike Pulscak, DOE
Dan Shugar, New World Power Co.

Roger Taylor, NREL
Roberto Vigotti, ENEL, Italy
Howard Wenger, Pacific Energy Group
Doug Whyte, Southern California Edison

History and Background

In the late 1980s and early 1990s, researchers at Pacific Gas & Electric Company in California began investigating PV generating systems to support the AC power grid. The resulting study and 500-KW demonstration plant installation at Kerman Substation clearly illustrated distributed PV values that were higher than traditional utility capacity and energy values. These positive results show that PV can provide valuable grid support and potential early markets for PV. To investigate whether such grid-support installations might have more widespread applicability, researchers in the United States and other countries have examined other sites using the Kerman methodological model and other evaluation techniques.

The proposed Task IV under the Implementing Agreement seeks to improve the methods for planning and evaluating the benefits of PV in grid-support applications through collaborative international research and development.

Summary of Discussions

The Workshop consisted of three sessions: (1) a series of presentations by U.S. participants reviewing the status of grid-support activities in the United States and discussing key tasks and research projects, (2) a series of presentations by Italian (ENEL) participants discussing key tasks and research projects, and (3) a joint work session to define evaluation needs for PV grid-support applications under the auspices of Annex IV.

The U.S. session consisted of presentations by Lynn Coles, NREL; Howard Wenger, Pacific Energy Group; Richard Perez, State University of New York at Albany; and Doug Whyte, Southern California Edison. Coles reported on the status of distributed activities in the United States, and Howard Wenger reported on the Quickscreen Model and the Kerman Validation Report. Perez discussed his PV load-matching analyses, and Whyte reported on Southern California Edison's PV programs.

The Italian session included discussions by Roberto Vigotti, Angelo Invernizzi, and Alberto Iliceto, all of ENEL, the major Italian utility. Vigotti described the IEA and the role of Annex IV under the PV Implementing Agreement. Invernizzi discussed the optimized location of PV in Sicily, and Iliceto discussed the status of inverters and inverter standards. Invernizzi also presented a strawman list of activities under Annex IV. Copies of presentation materials are included in the next section of this proceedings.

Summary of Results

The final group session provided two work products and the basis for a third work product included in the proceedings. Work Product 1 is a condensed list of needs for PV grid-support planning and evaluation. The list, which represents the consensus of the attendees, was the result of considerable discussion and debate.

There was general consensus in the work session that there was strong need for a user-friendly workbook of grid-connected PV. Such a workbook would assist both beginners and more experienced individuals in evaluating PV in grid-support applications. The result of these discussions is Work Product 2, which outlines the contents needed for this workbook.

Work Product 3, a proposed scope of activity for Annex IV, was developed by NREL after the workshop based on Work Products 1 and 2 and the discussion during the workshop.

Next Actions

Although all countries in the participating IEA PVPS were invited to attend the Annex IV Workshop, only four countries were represented—Denmark, Italy, the United Kingdom, and the United States. The proceedings developed from the workshop, are, therefore, limited to the views, opinions, and conclusions of these participants.

The proceedings will be presented at the next Executive Committee (ExCo) meeting in Kobe, Japan, November 6–9, 1995. The presentation will be made by Michael Pulscak, U.S. ExCo member. Draft proceedings of the Annex IV Workshop will be made available for review and comment to all ExCo members, who may then express their interest in participating in the Annex. Final proceedings of the workshop will be available in December 1995 and will be forwarded to any countries expressing a further interest in the Annex. All correspondence regarding these proceedings activities may be directed to Lynn Coles of NREL, who will incorporate suggested changes into the proposed Annex IV Scope of Work. He will also record those countries expressing an interest in participating in the Annex, and notify the other participants. Please contact Lynn at (telephone) 303-275-4699 or (fax) 303-275-4611.

A final presentation on the status of Annex IV will be made at the ExCo meeting in spring 1996. Recommendations will be made as to the future direction of the Annex based on subsequent discussions and the vote of the ExCo.

Presentation Materials

Lynn Coles, NREL

Review of Status of U.S. Distributed Methods

Synopsis

- Distributed Resources/Distributed Utility Concept
- Institutional and Economic Drivers
- History of Distributed Utility and Distributed PV Evaluation in the U.S.
- Current Trends

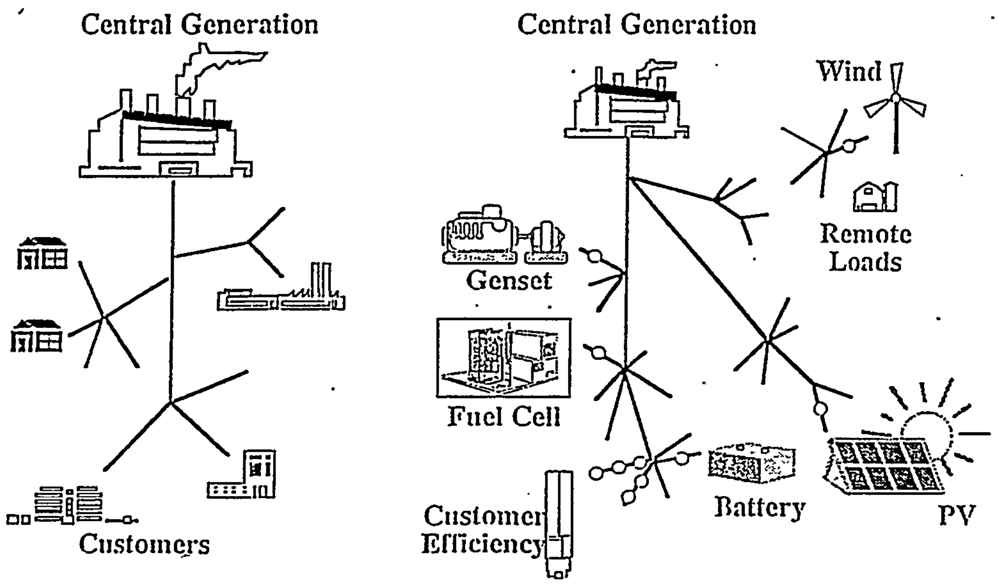
Status of Distributed Evaluation in the U.S.
IEA Annex IV Workshop
September 21-22, 1995

NREL

2

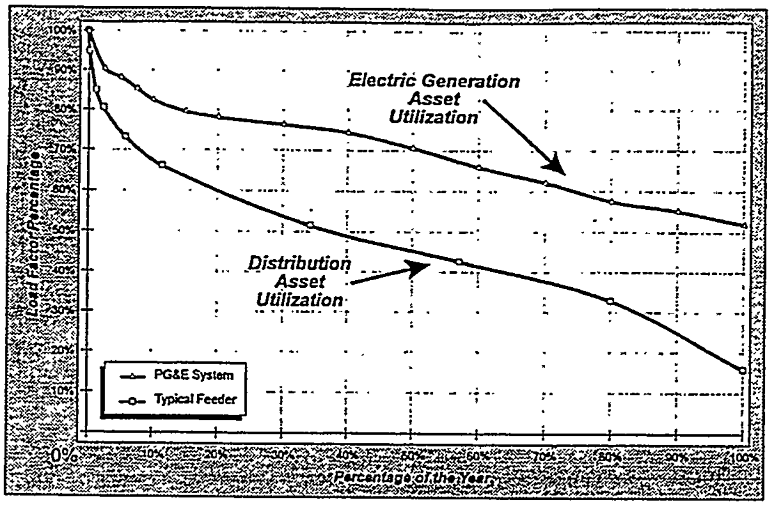
Distributed Resources/Distributed Utility Concept

Today's Central Utility	Tomorrow's Distributed Utility?

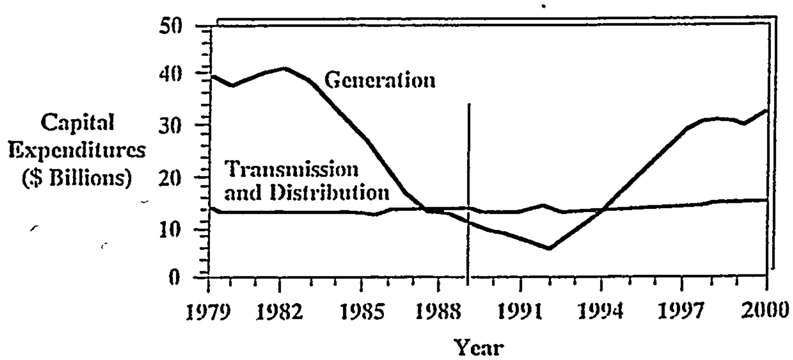


How Benefits Occur

Figure ES-2. Comparison of Load Duration Curves for a typical PG&E Distribution Feeder to the Entire PG&E Generation System for a Full Year.



National Generation and T&D Expenditures



Reference: Annual Industry Forecast Electrical World, 203 (10) October, 1989

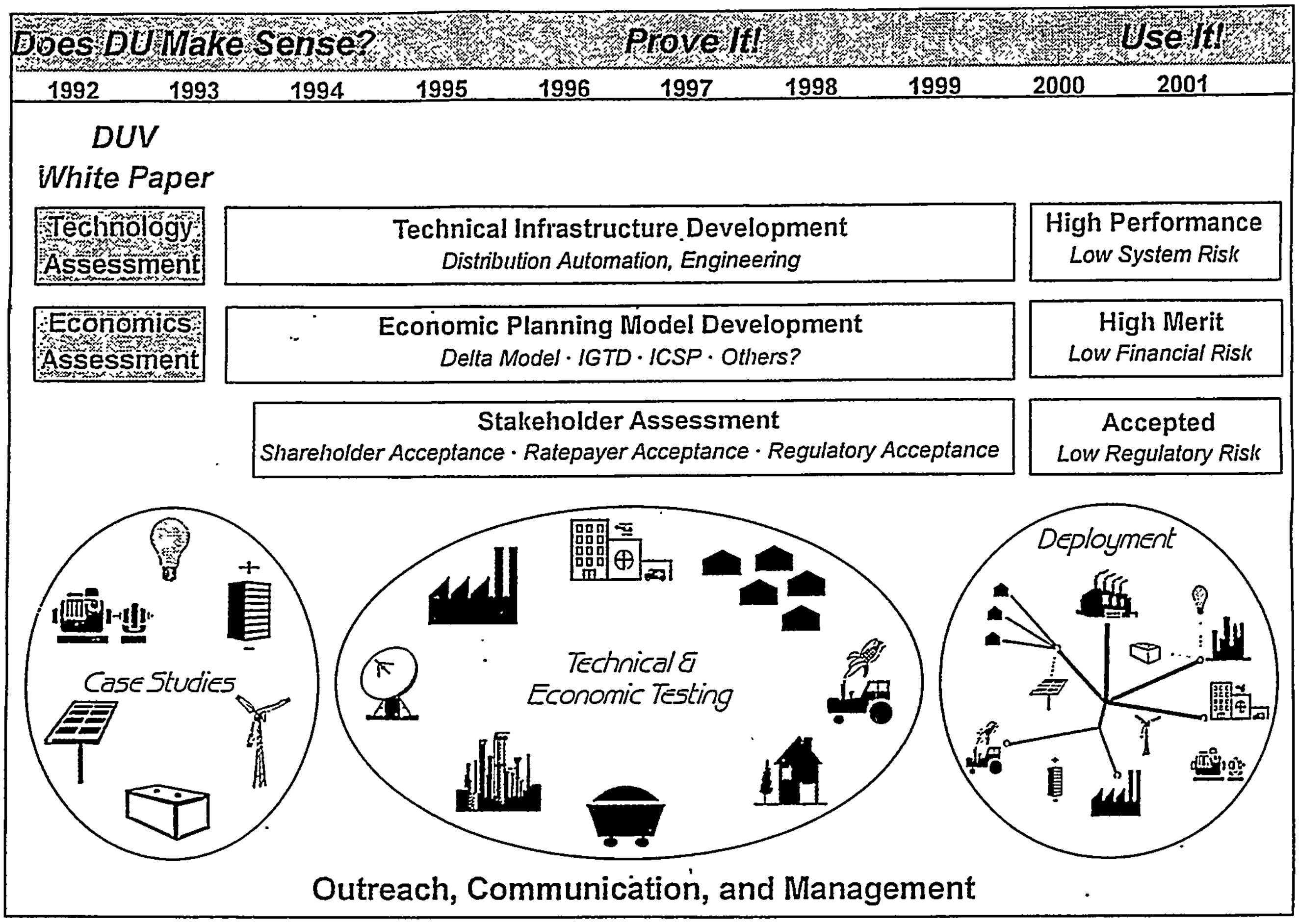
Institutional and Economic Drivers

- Threat of Competition
- Restructuring
- Difficulty in siting major energy facilities
- Progress of modular technologies

History of Distributed Evaluation in the U.S.

- Early Work - dispersed generation
- Kerman Substation PV Analysis - Shugar et al
- Distributed Utility Valuation Project (DUV) 1992-95
  - Joint NREL, PG&E, EPRI, PNL
  - Monograph, Annual Workshops, Cost and Performance, Stability Impacts, Penetration Analysis, Integrated G,T,D model

DISTRIBUTED UTILITY ROADMAP

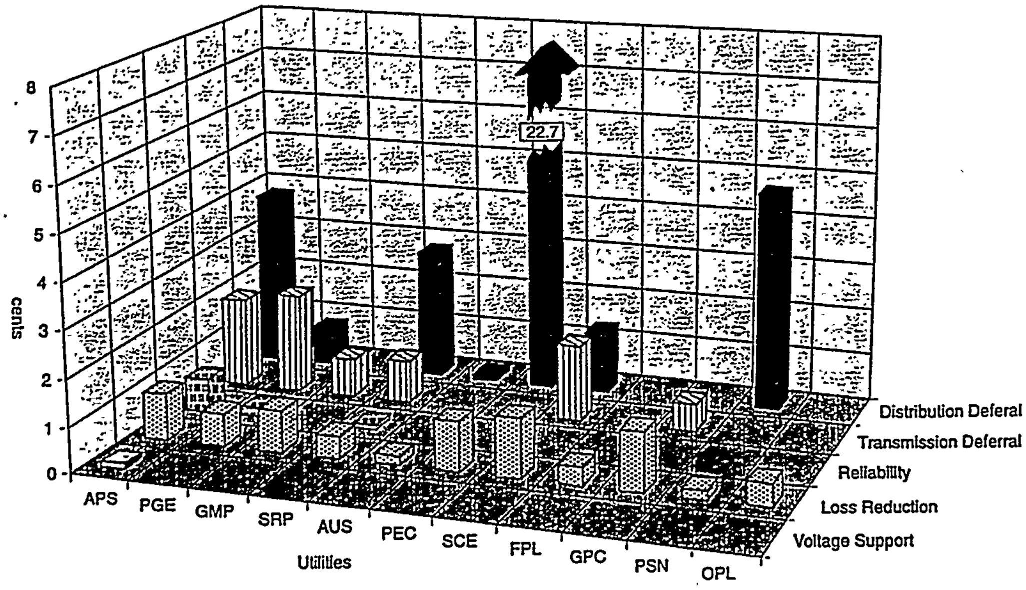


- EPRI Distributed Resources Activities - Continuing
- Sandia sponsored Kerman Methodology Studies
- Kerman Validation Study
- Other PV Distributed Valuation Studies and PV Demand-side Management Studies
- Other Distributed PV Applications

  -Sacramento Municipal Utility District
  -Southern California Edison - Hilltop circuit

Summary of PV "Distributed" Benefits

Per kWh of PV Output
1996 Levelized cents/kWh



Notes: PGE: Pacific Gas and Electric Company; AUS: City of Austin, TX; FPL: Florida Power & Light Company; OPL: Orcas Power and Light Company; APS: Arizona Public Service; SCE: Southern California Edison; GPC: Georgia Power Company; PEC: Plains Electric Corp.; SRP: Salt River Project; GMP: Green Mountain Power Corporation Co.; PSN: Public Service of New Mexico

Status of Distributed Evaluation in the U.S.
IEA Annex IV Workshop
September 21-22, 1995

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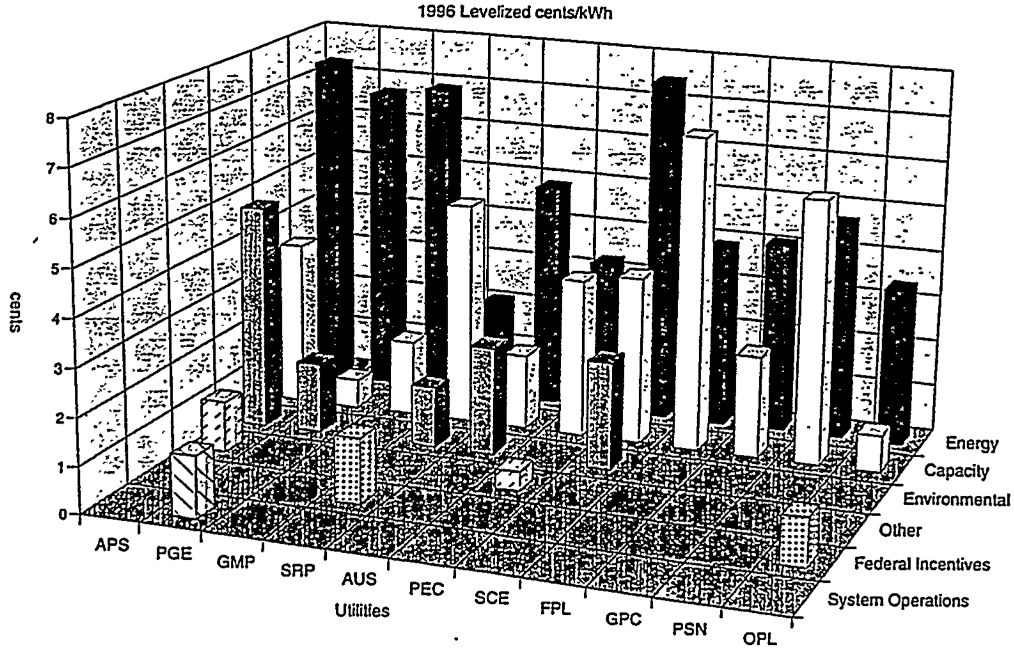
Summary of PV "System" Benefits

Per kWh of PV Output
1996 Levelized cents/kWh



Notes: PGE: Pacific Gas and Electric Company; AUS: City of Austin, TX; FPL: Florida Power & Light Company; OPL: Orcas Power and Light Company; APS: Arizona Public Service; SCE: Southern California Edison; GPC: Georgia Power Company; PEC: Plains Electric Corp.; SRP: Salt River Project; GMP: Green Mountain Power Corporation Co.; PSN: Public Service of New Mexico

Status of Distributed Evaluation in the U.S.
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September 21-22, 1995

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Progress as Measured by Utility Industry Participation: 1992 vs. Early 1995

- 1992: Only A Few Utilities Analyzing DU
- 1995: 108 Distributed Utility Projects/Studies:
  - -60 Utilities
  - -94 DU Evaluations
  - -27 Actual Hardware
- Technologies (in addition to T & D):
  - -Gen-Sets (38)
  - -DSM (34)
  - -Fuel Cells (17)
  - -Cogeneration (6)
  - -Batteries (36)
  - -Photovoltaics (31)
  - -Thermal Storage (3)
  - -Combustion Turbines (2)

Current Trends

- Major transmission and distribution projects become targets of opportunity distributed applications

  - Tennessee Valley Authority -- Nashville Expansion

- Purchase of customer-owned capacity

  - For system peaking -- Southern Company, Northern States Power, Boston Edison

  - For distribution deferment ?

- Interruptible rate implementation for distribution deferment

  - Pennsylvania Power and Light -- Defers $3.3 Million project for 4 years

- Load Management Control for Distribution Benefit

  - Air-conditioning load control -- Baltimore Gas and Electric

- New Participants involved:
  - Technology advocacy Groups - PV4U,
  - State energy organizations
  - Others

- New Valuation Techniques Developed and Exercised
  - Local IRP Methodology: Ontario Hydro
  - Area Investment Model (AIM): EPRI, PECO, E3, PS New Mexico
  - PV Screen: Pacific Energy Group
  - Decision Analysis Approach: Green Mountain Power
  - Area- and Time-Specific Marginal Costs: EPRI
  - Integrated Distribution Planning Model: PG&E

- Institutional Issues Affecting Distributed Resources
  - Ongoing study by NREL, and four utilities
  - Legal and regulatory issues
  - Natural monopoly character
  - Anti-competitive issues
  - Ownership and control of DR sources
  - Regulatory treatment

Conclusions

- Increasing U.S. interest in distributed valuation
- Early work on PV was instrumental in driving early valuation methods and "proof" of benefits
- PV valuation against central station not sufficient, needs comparison with other distributed options
- Multiple modeling options are available
- Competition and restructuring key concerns

Howard Wenger, Pacific Energy Group

Emerging Modeling Techniques for Distributed PV Grid-Support Systems

Distributed PV Grid-Support Systems:

Emerging Modeling Techniques

Howard Wenger
Pacific Energy Group

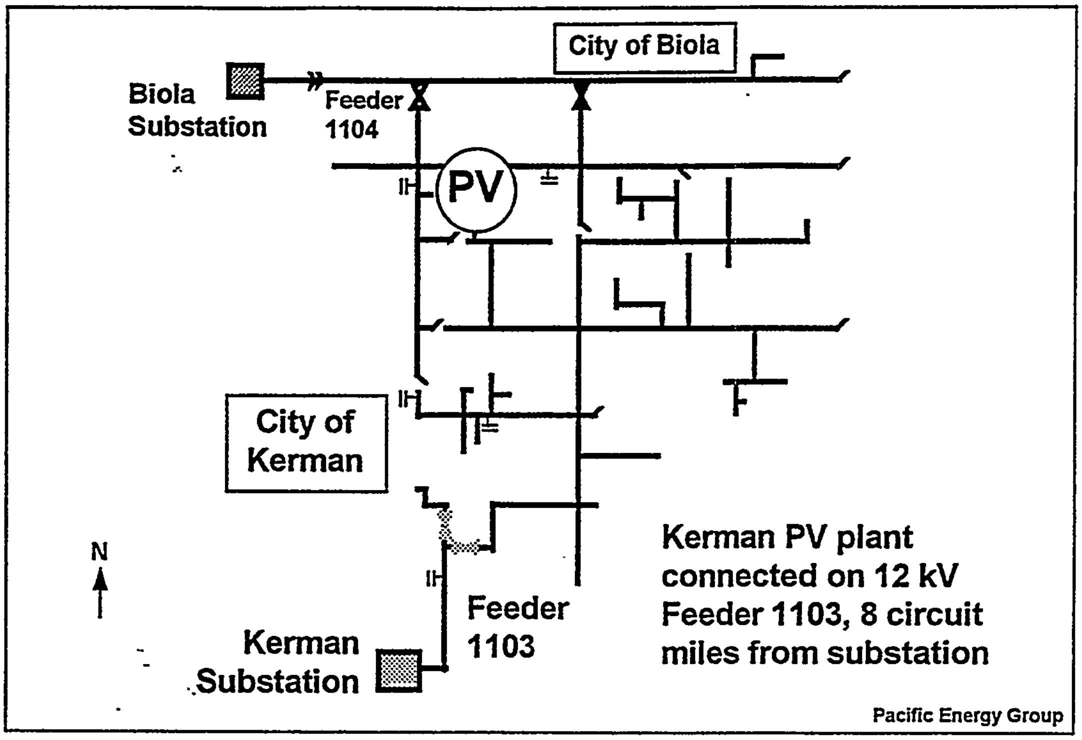
Presentation Highlights

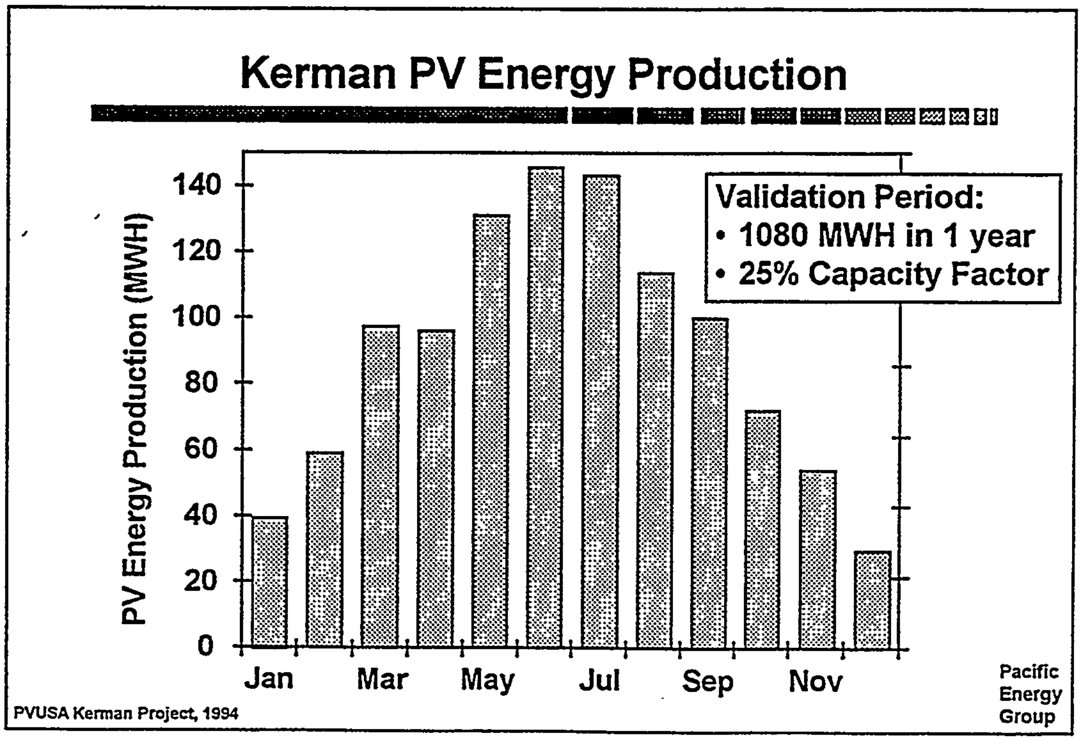
International Energy Agency, Annex IV Workshop
NREL, Golden, Colorado USA
September 21-22, 1995

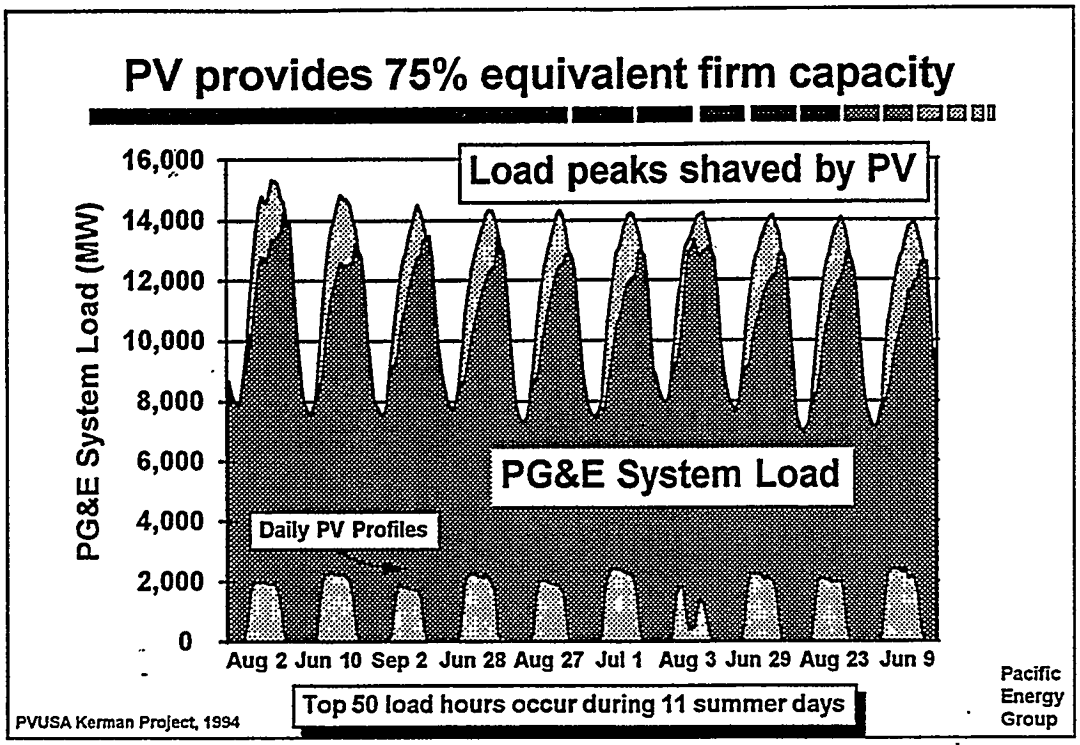
Presentation Topics

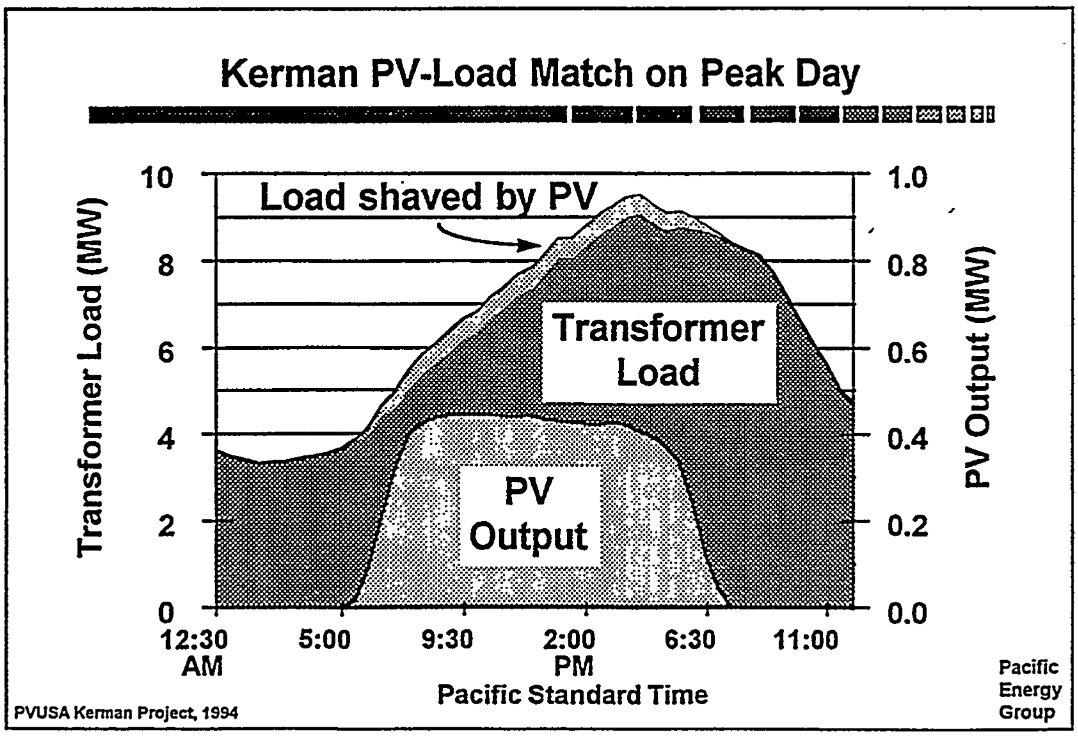
- Overview of PG&E Kerman Case Study
- Construction of 500 kWac PV plant at Kerman
- Validation results
- How to find the best project sites
- Overview of QuickScreen, a tool to help define the market

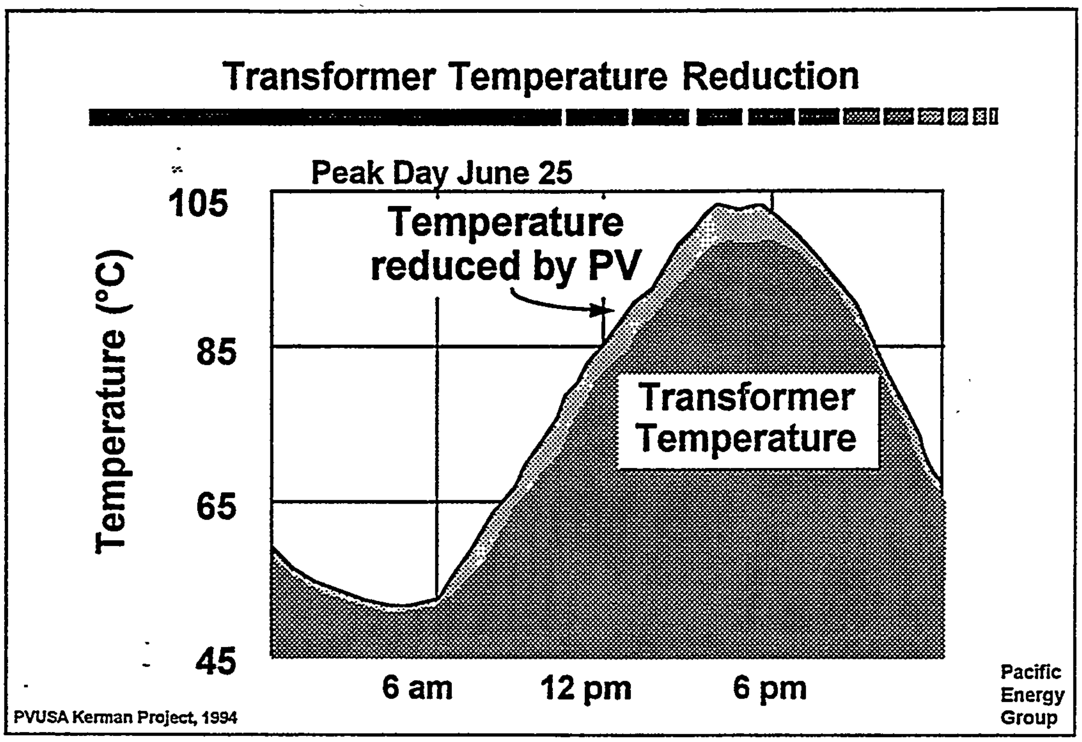
Pacific Energy Group

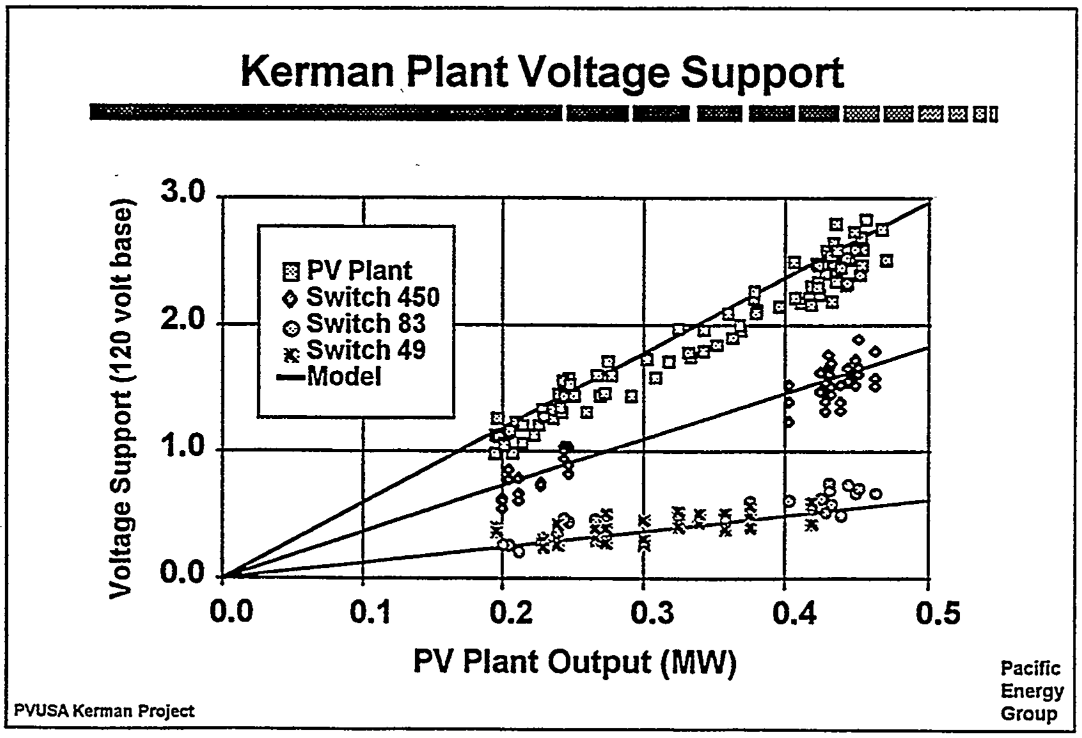

City of Biola
Biola Substation
Feeder 1104
PV
City of Kerman
N
Kerman Substation
Feeder 1103
Kerman PV plant connected on 12 kV Feeder 1103, 8 circuit miles from substation
Pacific Energy Group


Kerman PV Energy Production
Validation Period:
• 1080 MWH in 1 year
• 25% Capacity Factor
PV Energy Production (MWH)
0
20
40
60
80
100
120
140
Jan
Mar
May
Jul
Sep
Nov
PVUSA Kerman Project, 1994
Pacific Energy Group

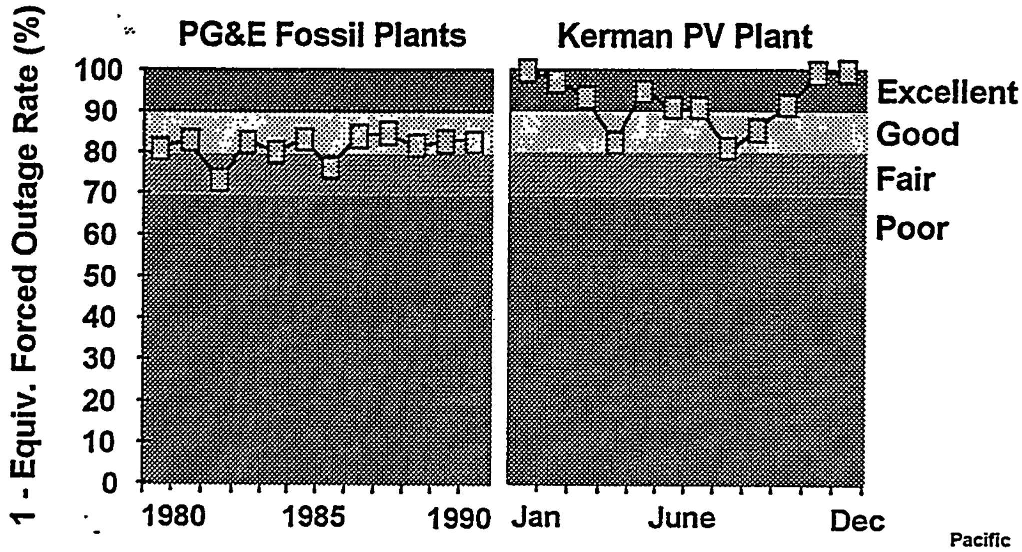

PV provides 75% equivalent firm capacity
Load peaks shaved by PV
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
PG&E System Load (MW)
PG&E System Load
Daily PV Profiles
Aug 2 Jun 10 Sep 2 Jun 28 Aug 27 Jul 1 Aug 3 Jun 29 Aug 23 Jun 9
Top 50 load hours occur during 11 summer days
PVUSA Kerman Project, 1994
Pacific Energy Group


Kerman PV-Load Match on Peak Day
Load shaved by PV
Transformer Load
PV Output
10
8
6
4
2
0
Transformer Load (MW)
1.0
0.8
0.6
0.4
0.2
0.0
PV Output (MW)
12:30 AM
5:00
9:30
2:00 PM
6:30
11:00
Pacific Standard Time
PVUSA Kerman Project, 1994
Pacific Energy Group


Transformer Temperature Reduction
Peak Day June 25
Temperature reduced by PV
Transformer Temperature
Temperature (°C)
105
85
65
45
6 am
12 pm
6 pm
PVUSA Kerman Project, 1994
Pacific Energy Group


Kerman Plant Voltage Support
PV Plant
Switch 450
Switch 83
Switch 49
Model
Voltage Support (120 volt base)
3.0
2.0
1.0
0.0
0.0
0.1
0.2
0.3
0.4
0.5
PV Plant Output (MW)
PVUSA Kerman Project
Pacific Energy Group

PG&E fossil and grid-support plant availability



Sources: Resource, PG&E, 1992 and Kerman PVUSA Project, June 1993-1994

Pacific Energy Group

The Kerman Plant proves distributed benefits are real

The Kerman PV Plant:

- Cools the substation transformer by more than 4 °C and increases capacity by 410 kW on peak day
- Increases feeder capacity
- Provides ~3 volts of voltage support (on a 120 V base)
- Increases transmission system capacity by 450 kW
- Increases generation system capacity by 385 kW
- Achieves about a 25% capacity factor (over 1080 MWh/year) highly correlated with PG&E loads
- Reduces line losses by 58,500 kWh/year (5 percent)
- Reduces pollution by 155 tons of CO_2 and a half ton of NO_X each year

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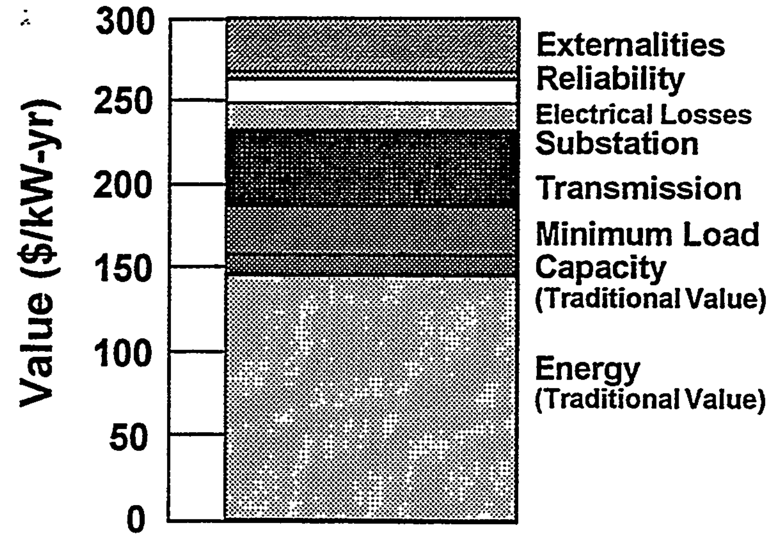
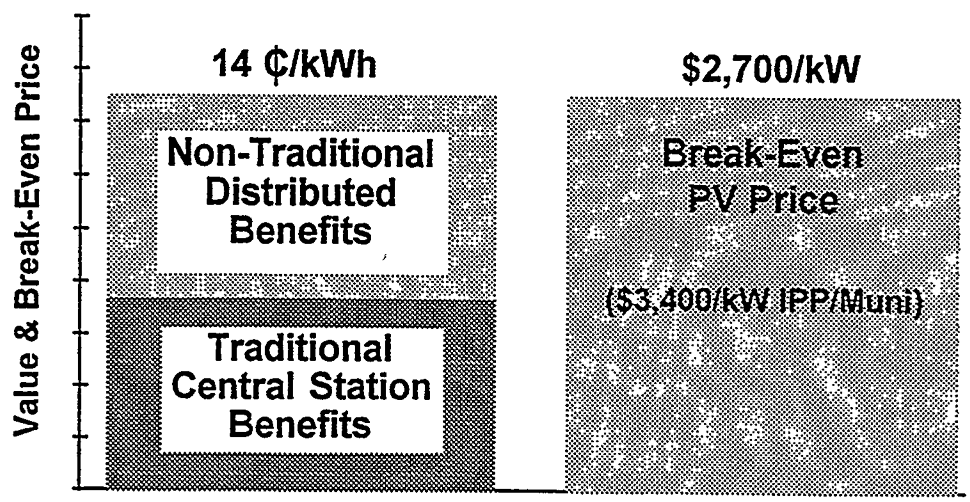
Value of Kerman PV Plant



PVUSA Kerman Project

Pacific Energy Group

Value and Break-Even Price



PVUSA Kerman Project

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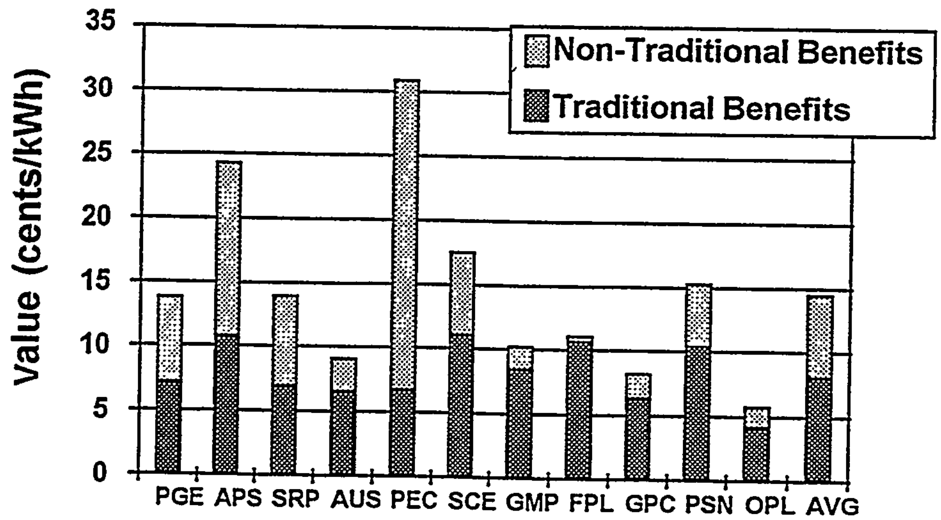
Many utilities have conducted distributed PV studies

- Arizona Public Service
- City of Austin
- Plains Electric Cooperative
- Salt River Project
- Empire Electric
- Southern California Edison
- Green Mountain Power
- Florida Power & Light
- Georgia Power Company
- Public Service Company of New Mexico
- Orcas Power and Light
- Niagara Mohawk
- Pacific Gas & Electric

> ***Distributed PV is the #1 utility application with over 4,000 MW of near-term market potential***
>
> ***- Utility PV Group***

Pacific Energy Group

Utility PV Case Study Results



Source: Analysis of PV Benefit Case Studies, Results and Methods Used, NREL, Draft, May, 1995

Pacific Energy Group

Performing Case Study Evaluations

A painful exercise involving many utility departments

- Time Consuming
- Costly
- Data Intensive
- Requires many experts
- Thick reports
- Single site only

- Distribution Planning
- Transmission Planning
- R&D
- Generation Planning
- Economics & Financial
- Rates
- Marketing
- Environmental Dept.
- Operations

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Introducing QuickScreen

- A cost-effectiveness evaluation tool
- Requires no modeling and no data collection
- Requires very limited utility information
- Good for project screening and quantifying the distributed PV market

Pacific Energy Group

QuickScreen Background

- Developed by Pacific Energy Group with sponsorship from U.S. DOE (Sandia, NREL)

- Based on work developed over last 7 years
  - PVUSA Kerman Project, Sandia Utility Case Studies, PG&E, Stanford University, University of Colorado, Pacific Energy Group

Pacific Energy Group

The First Step

Finding the best sites...

Pacific Energy Group

Six guidelines to find the best sites

❶ Capital expenditures planned for T&D upgrades

❷ Load growth is low enough ($5,000/kW)

❸ Isolated radial lines, underground lines, small subs

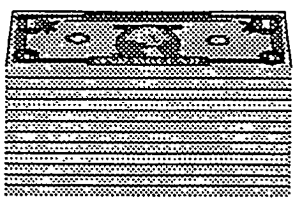
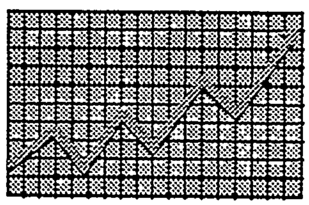
❹ No lower cost alternatives

❺ Summer peaking loads between 8:00 am - 4:00 pm

❻ Location-specific issues considered

Pacific Energy Group

Load growth guideline

 —  $\geq$ **$5,000/kW**

$1,000,000
T&D upgrade

Load growth should
be no more than 200 kW/yr

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The Next Step

Use QuickScreen to determine break-even PV price...

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QuickScreen Inputs

- T&D investment cost
- T&D load growth rate
- Marginal energy and externality costs
- Utility discount rate, inflation rate, and cost of ownership factors
- Project location
- Time of peak loads

Pacific Energy Group

QuickScreen Worksheet

	User Inputs		Figure A	Table B	Figure B or C	Column 6
	(1)	(2)	(3)	(4)	(5)	Cost Savings ($/kW)
Capacity Cost-Savings	Investment Cost	Load Growth (kW/yr)	Economic Factor (real)	Present Value Conv.	Load Match Factor	(1)x(4)x(5) / (2)x(3)
Distribution	*1,400,000* ($)	*200*	*13*	*1.67*	*0.80*	*719*
Sub-trans.	— ($)	—	—	—	—	—
Bulk-trans.	*462* ($/kW)			*1.00*	*0.80*	*370*
Generation	*560* ($/kW)			*1.52*	*0.80*	*681*
Variable Cost-Savings	Marginal Cost	Electric Loss Adjustment	Economic Factor (real)	Hours in year	Capacity Factor	(1)x(2)x(3)x(4)x(5)
Energy	*0.024* ($/kWh)	*1.14*	*20*	*8,760*	*0.30*	*1,438*
Externalities	*0.022* ($/kWh)	*1.14*	*13*	*8,760*	*0.30*	*857*

Arizona Public Service Example

Total Cost Savings (add column 6)	*4,065*
—PV plant present value conv.	*1.30*
= **Break-Even PV Price**	*$3,125/kW*

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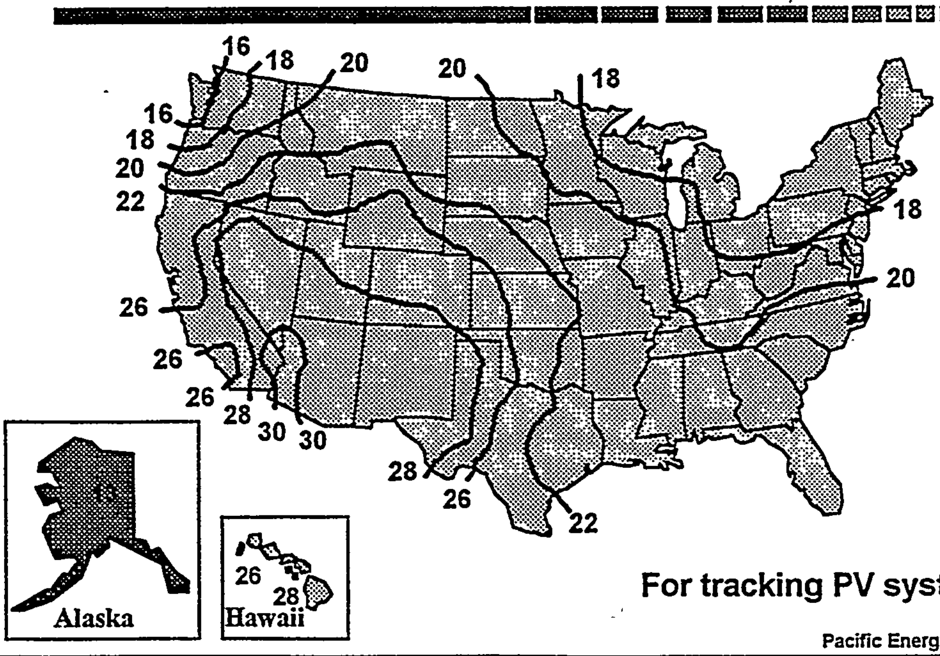
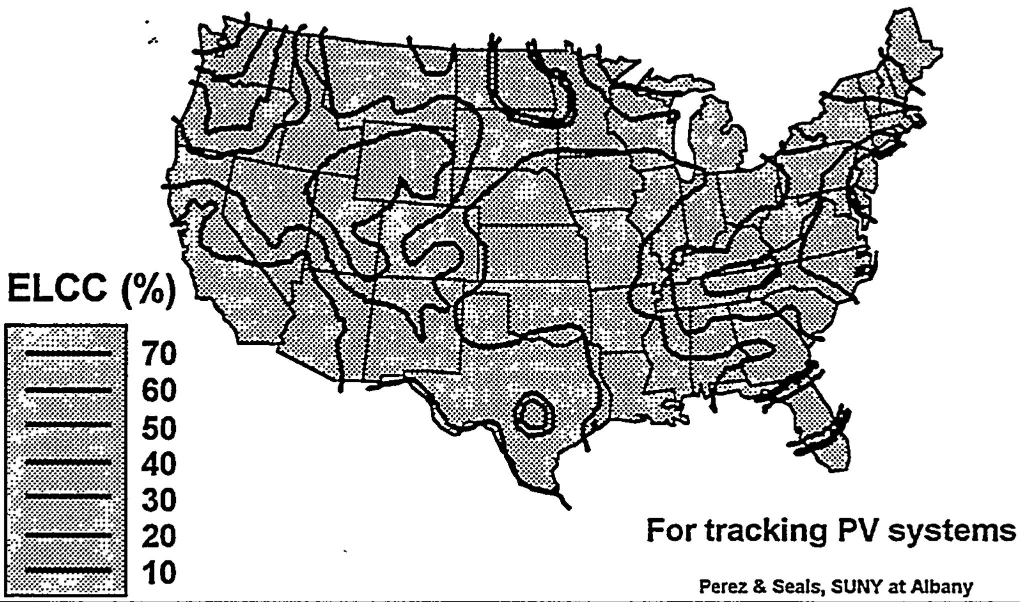
PV Capacity Factor (%)



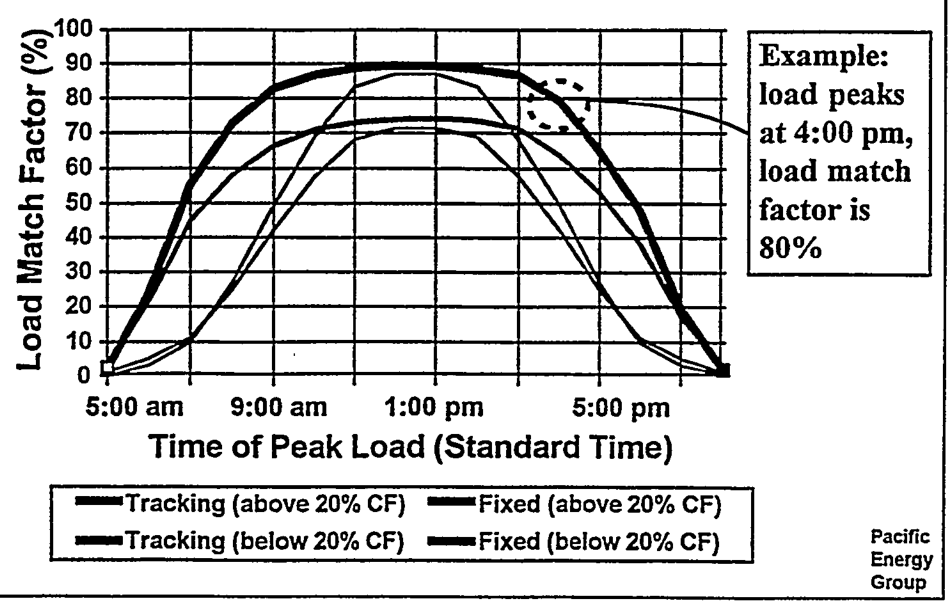
For tracking PV systems

Pacific Energy Group

Utility System Load Match, ELCC (%)



Load Match Factor for Summer Peak Load



QuickScreen vs. three utility activities

- **Sandia Distributed PV Case Studies**
  - Arizona Public Service (APS)
  - City of Austin Electric Department (COA)
  - Plains Electric G&T (Plains)
  - Salt River Project (SRP)
- **Kerman Distributed PV Plant Operation**
- **Targeted DSM in PG&E's Delta District**

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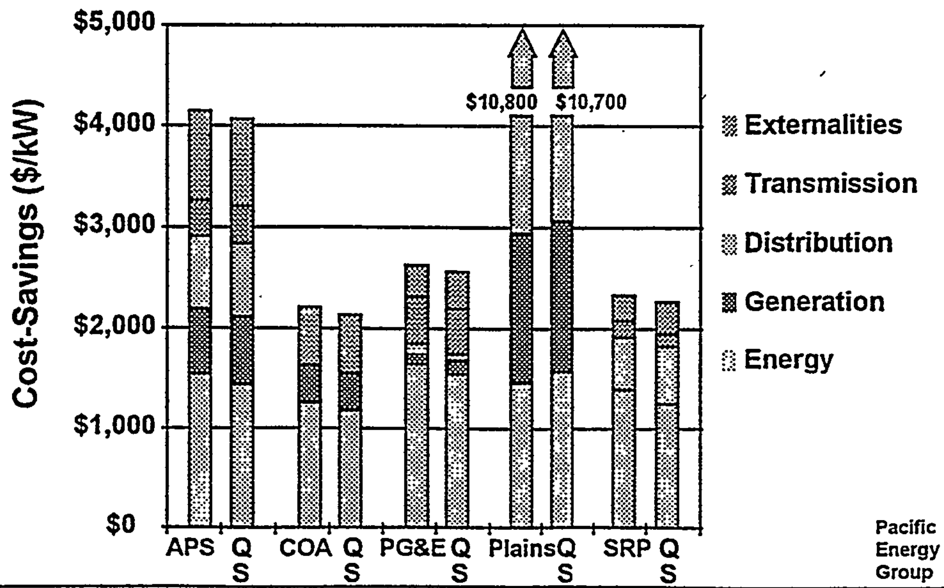
QuickScreen model validation: Utility PV Case Studies



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Next Steps

- Convert QuickScreen to software
- Incorporate uncertainty analysis

Pacific Energy Group

Summary

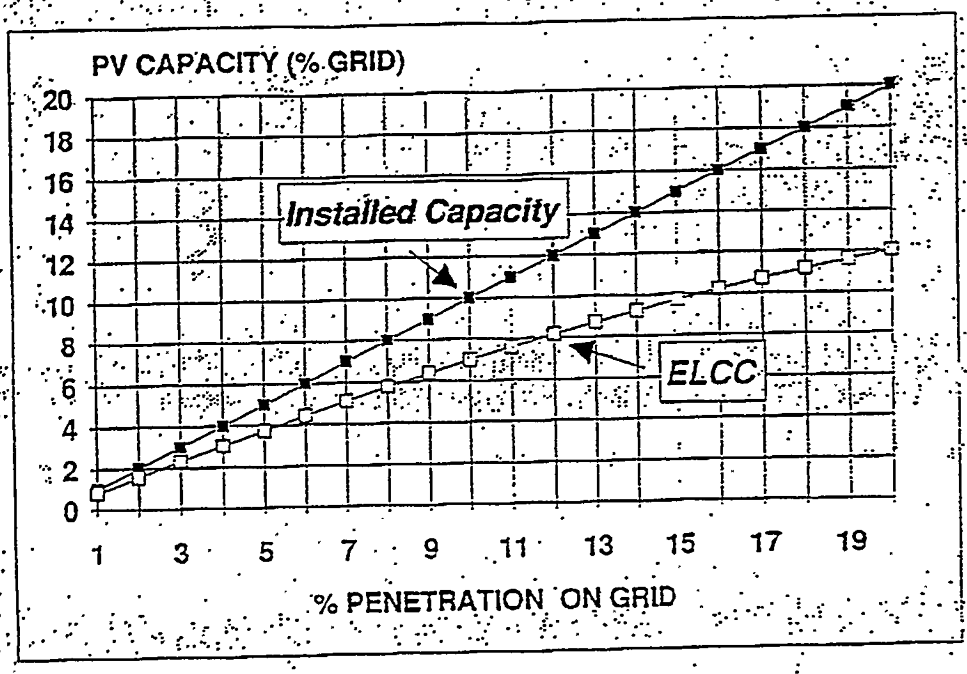
- PV grid-support is real
- Cost-effective PV grid-support sites exist
- QuickScreen, accurate to within 10%, can help you find them
- Copy of the QuickScreen Guide?

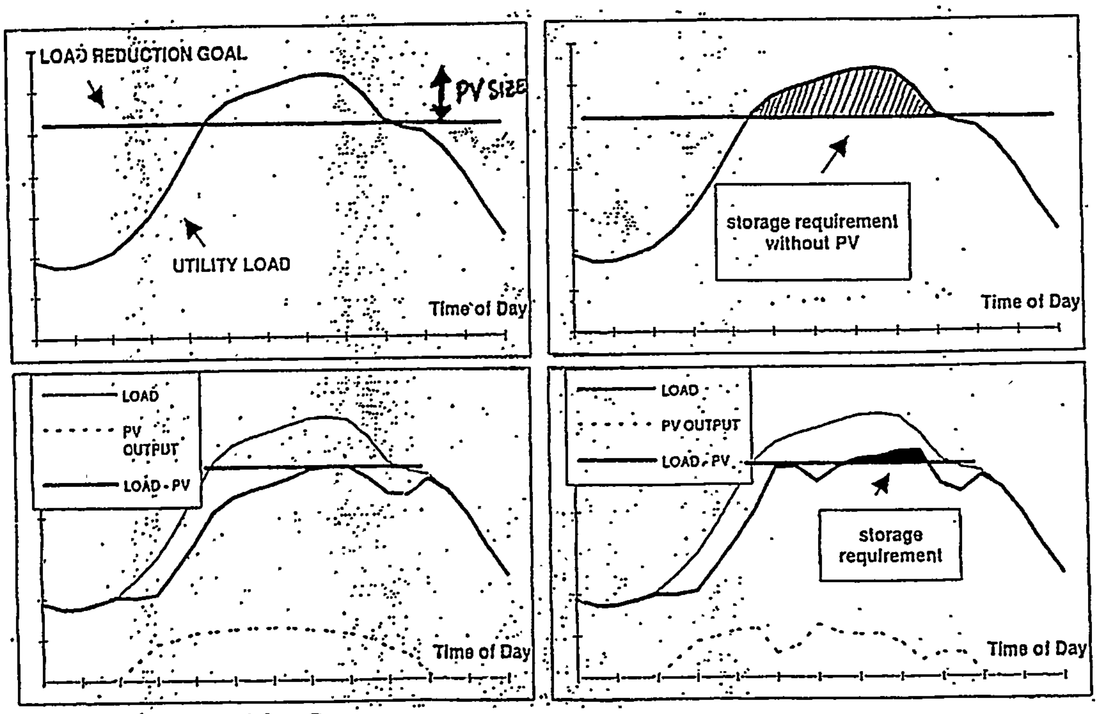
Pacific Energy Group

Richard Perez, SUNY at Albany

Utility Effective Load-Carrying Capability

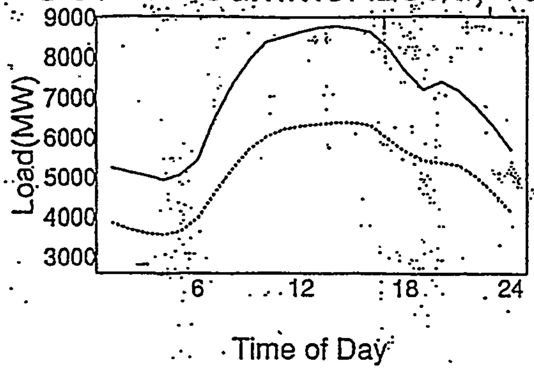
Increase in Utility's Effective Capacity @ Constant LOLP



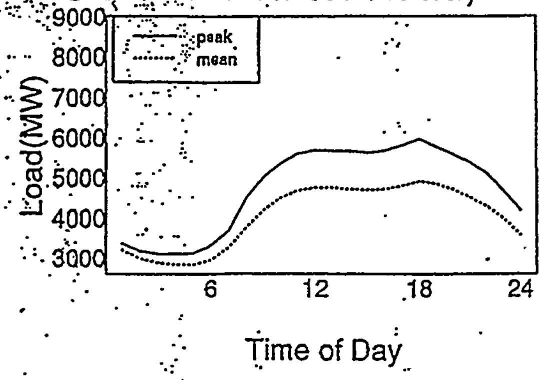


Minimum Buffer Energy Storage (MIBES)
as a measure of load matching

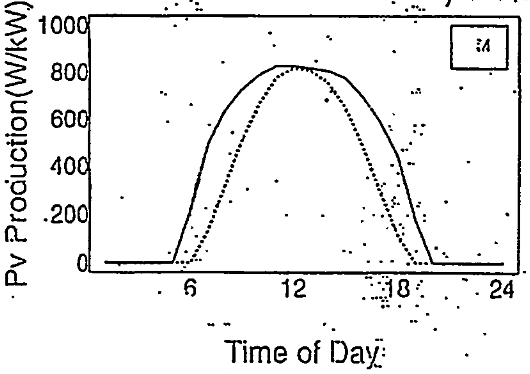
CONED Summer Load; 1988



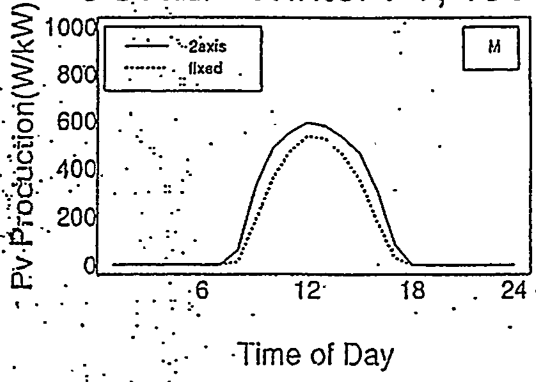
CONED Winter Load; 1988



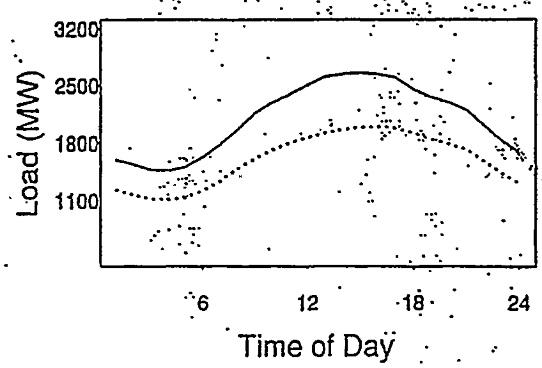
CONED Summer Pv; 1988



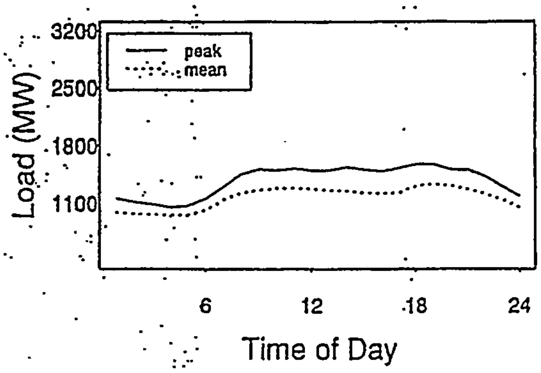
CONED Winter Pv; 1988



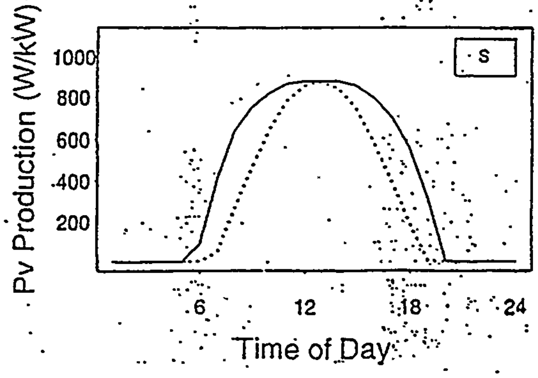
KCPL Summer Load; 1988



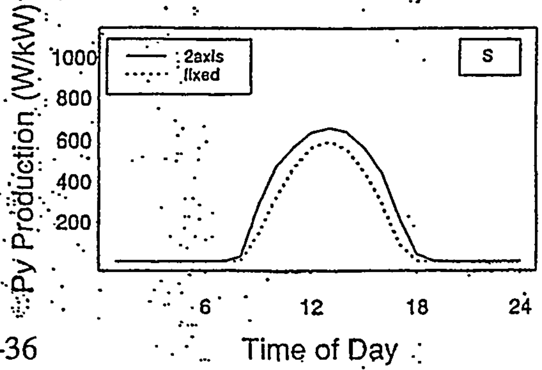
KCPL Winter Load; 1988



KCPL Summer Pv; 1988

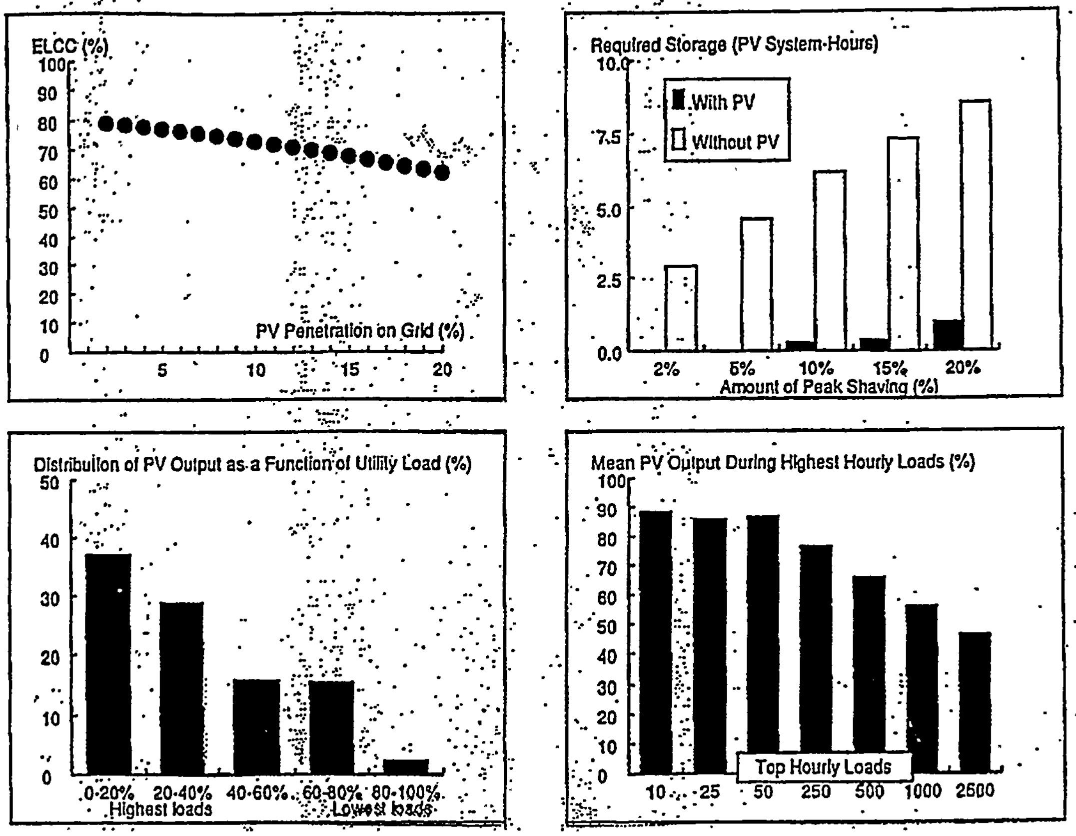


KCPL Winter Pv; 1988



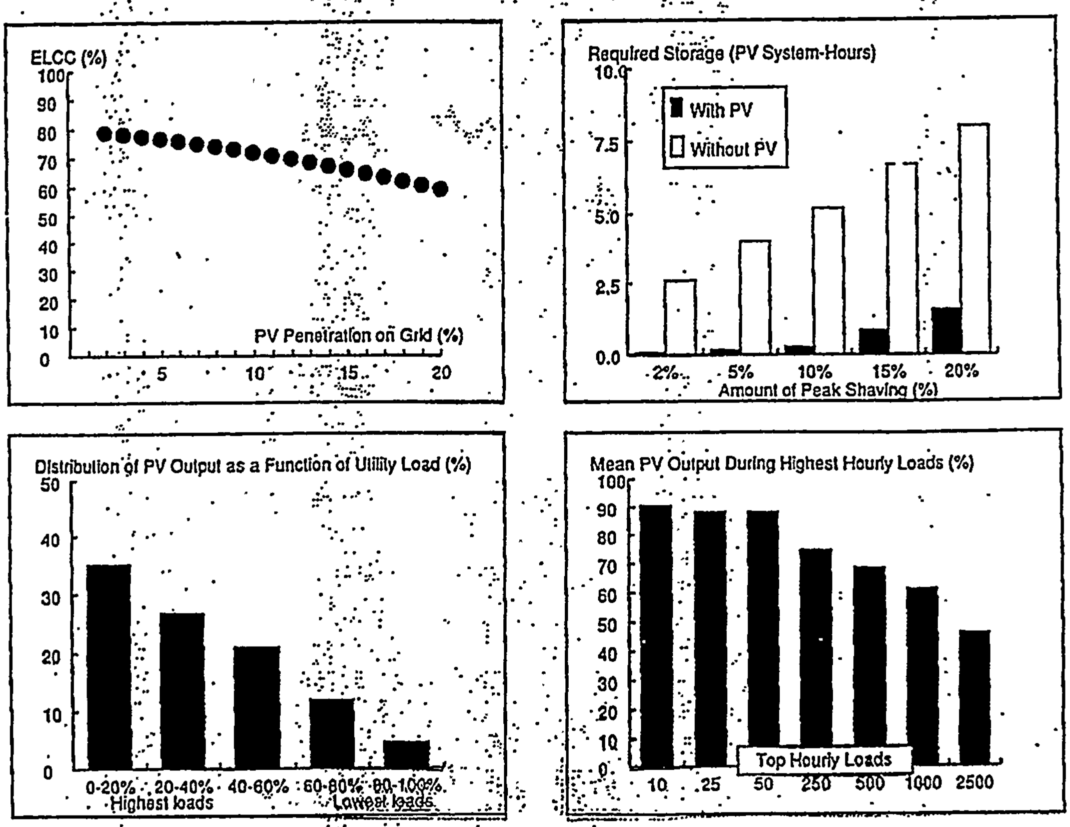
Load Matching Summary

CONED 2axis 88 M

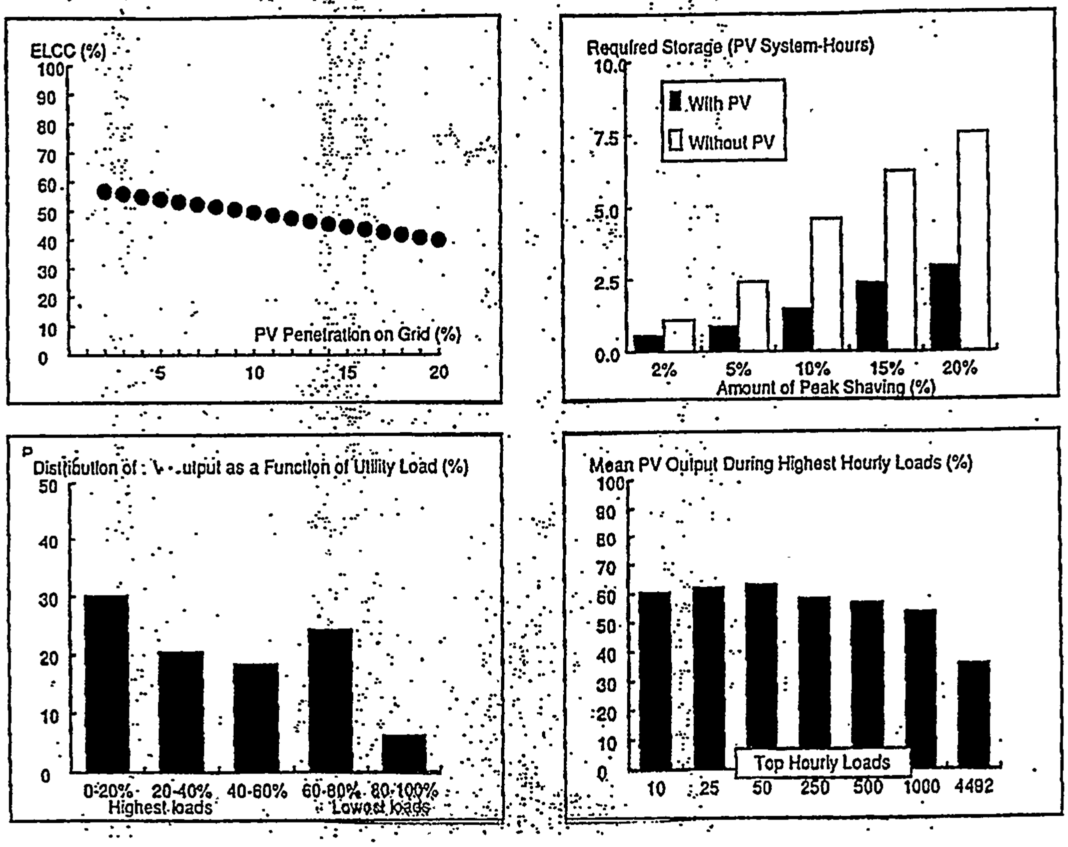


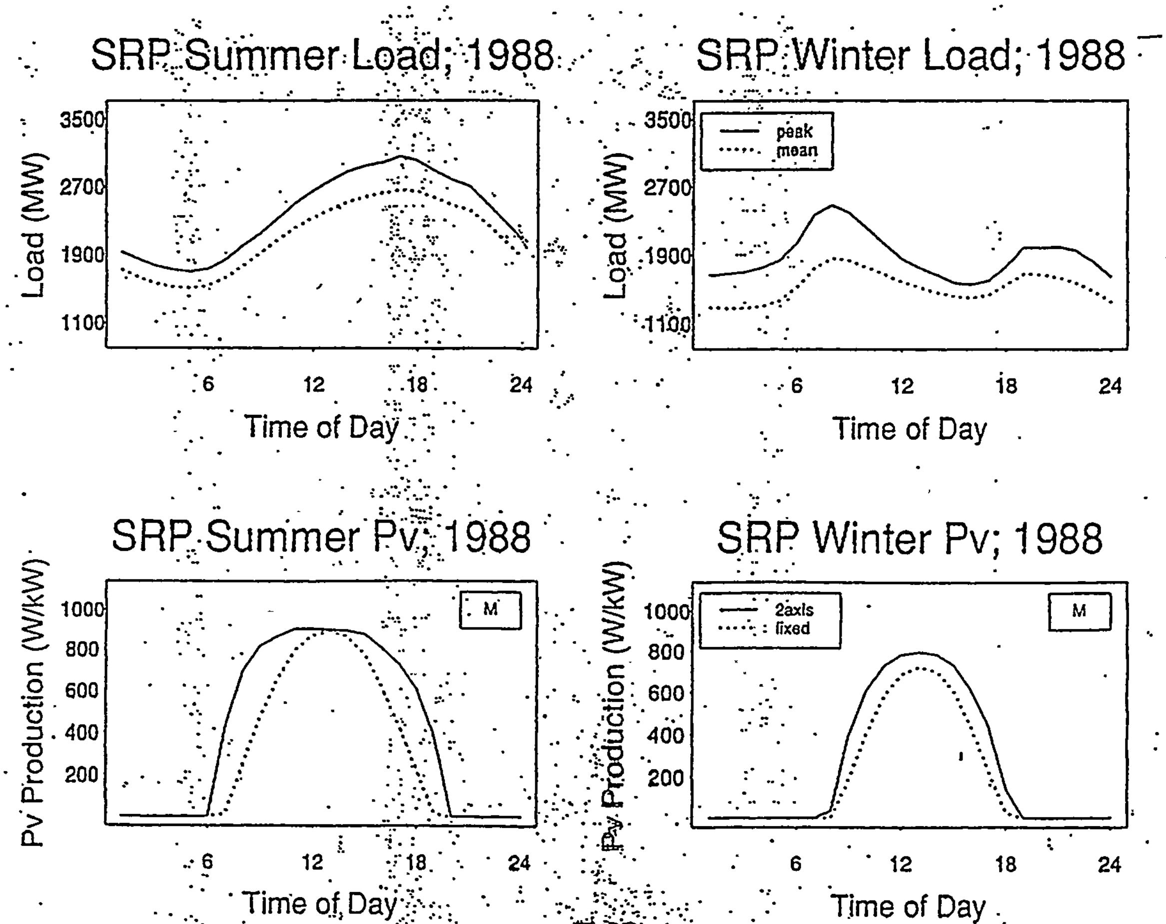
Load Matching Summary

KCPL 2axis 88

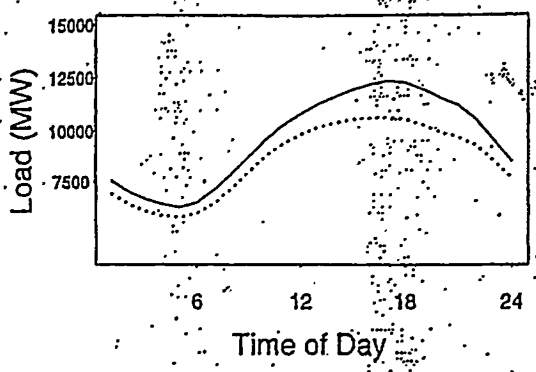


Load Matching Summary **SRP 2axis 88**

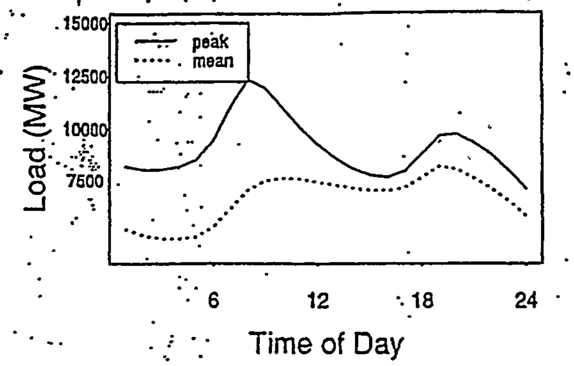




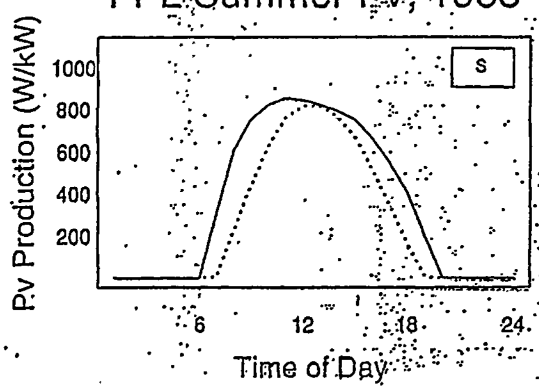
FPL Summer Load; 1988



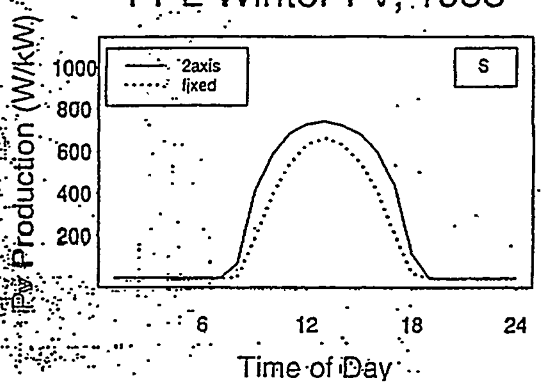
FPL Winter Load; 1988



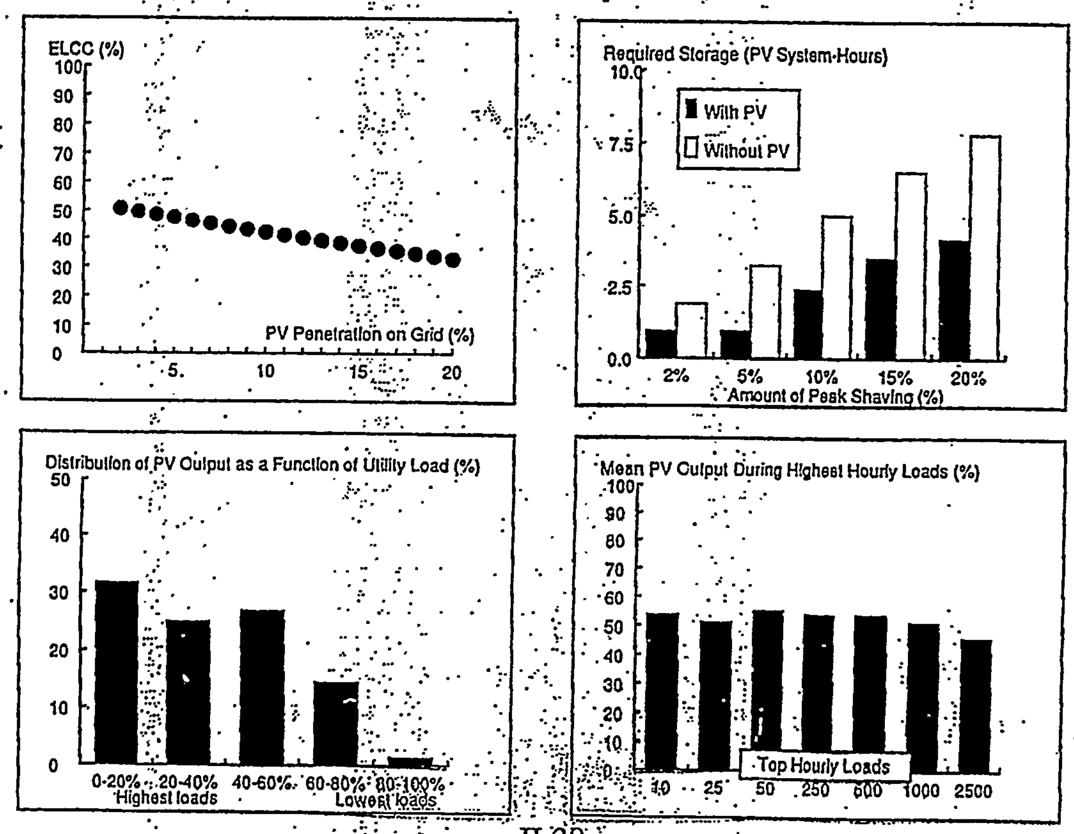
FPL Summer Pv; 1988

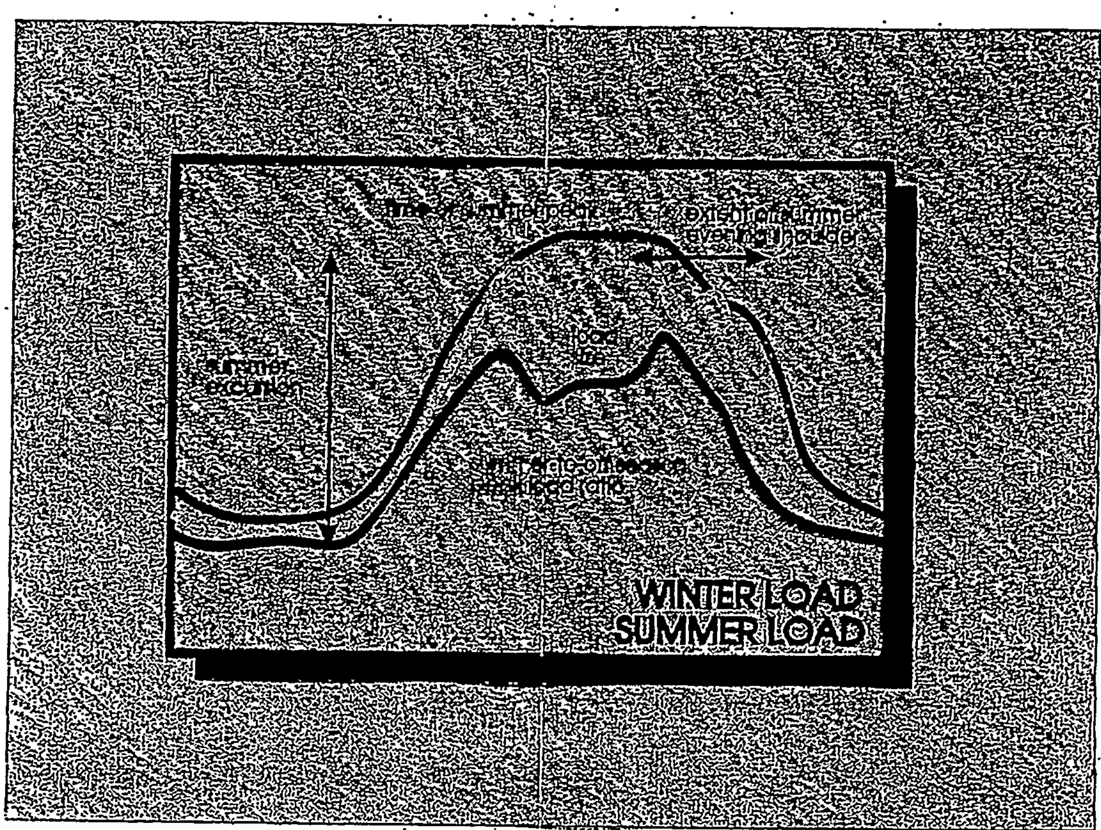


FPL Winter Pv; 1988

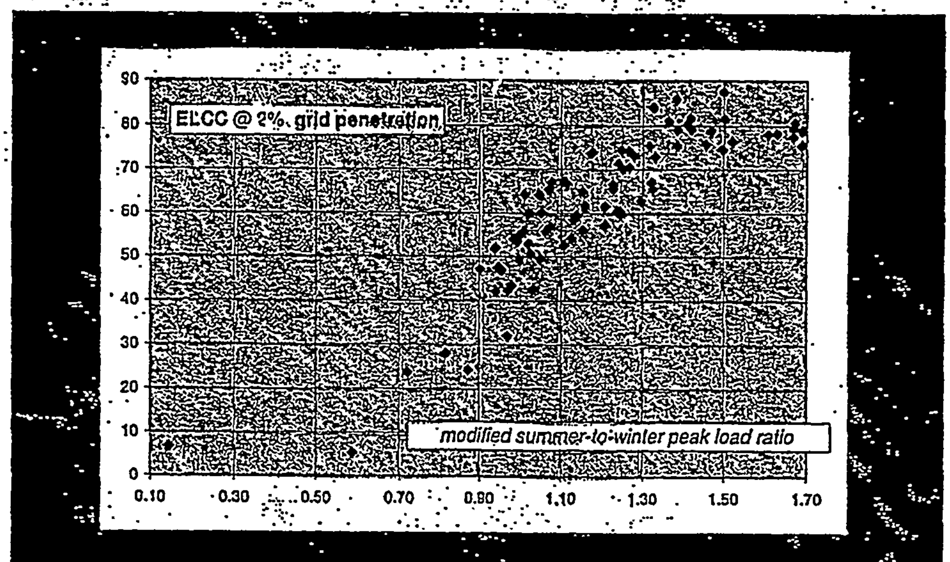


Load Matching Summary **FPL 2axis 88**



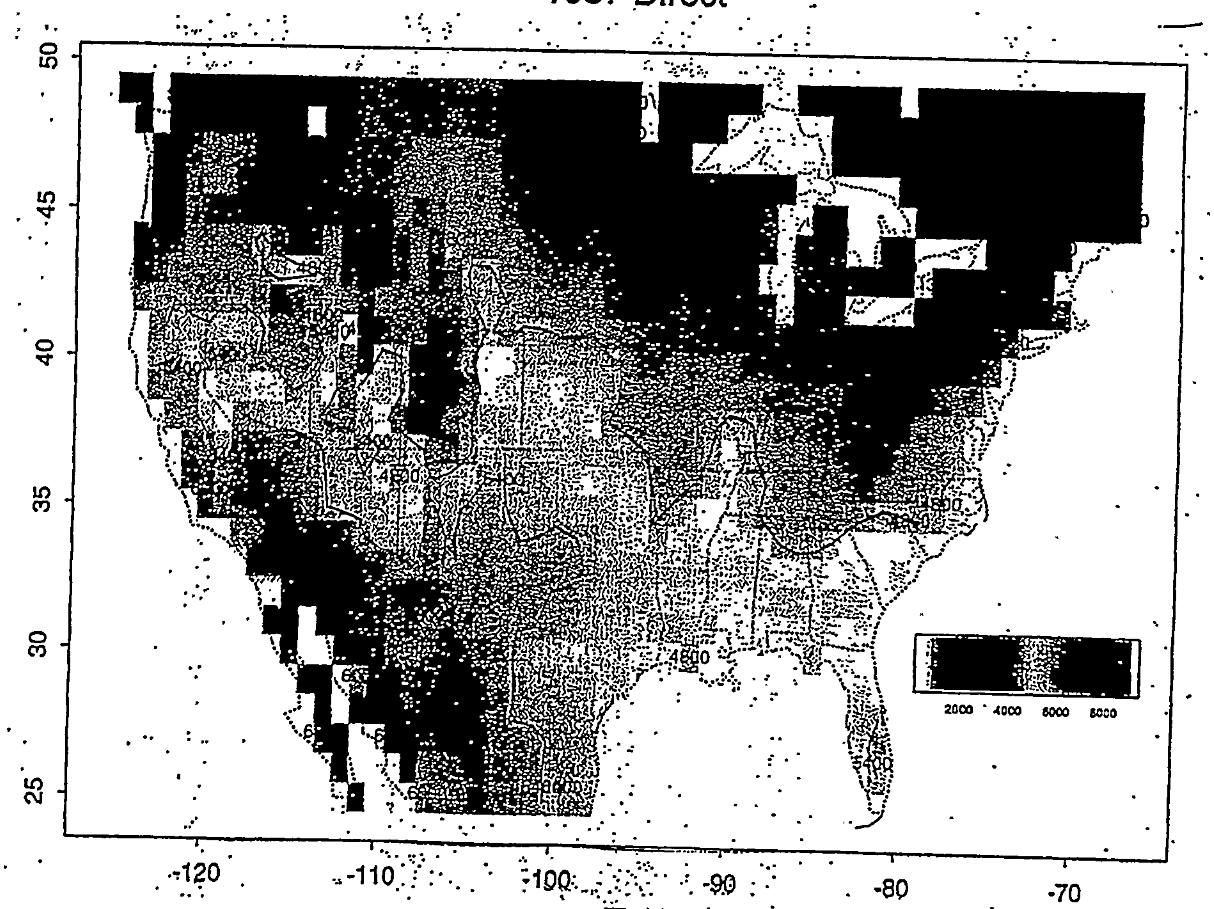


Key load shape parameters included
in the modified summer-to-winter peak load ratio



PV effective capacity is strongly correlated with load shape parameters

1987 Direct



Doug Whyte, Southern California Edison

Dispersed Energy Applications

Dispersed Energy Applications

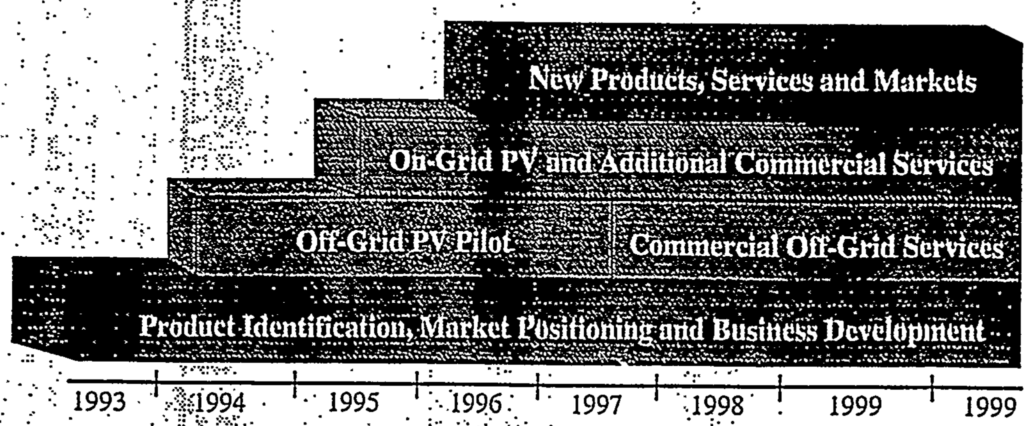
For Use In Remote And Dispersed Applications To New And Existing Customers

Southern California Edison   May, 1995   Dispersed Energy Applications

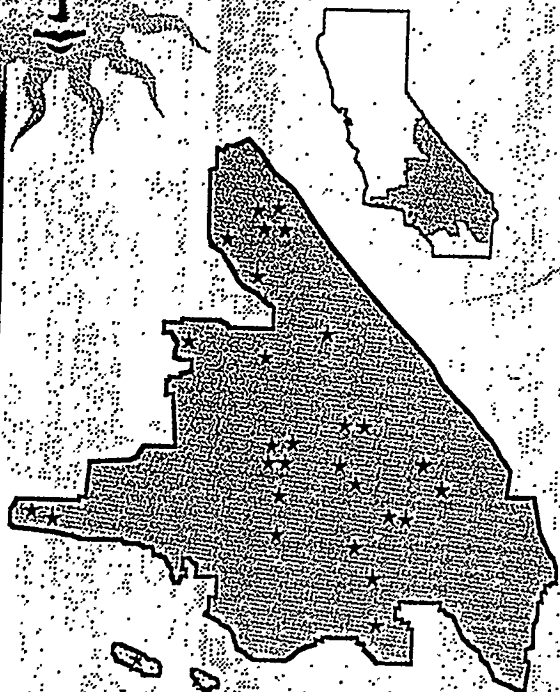
Commercial PV Programs

- Public Utilities Code #2775.5
- California PV4U Collaborative
- Programs initiated by "Advice Letter"
- 3 year Off-Grid PV Pilot Program initiated May, 1994
- On-Grid PV Pilot Program - Advice Letter Filed with CPUC in July, 1995

DEA Commercialization Strategy



PV Off-Grid Pilot Program



Market

6,000 Potential Residential Customers

Market Survey Response

80% Want Edison PV Service

70% Want Edison Financing

60% Want Edison O&M Services

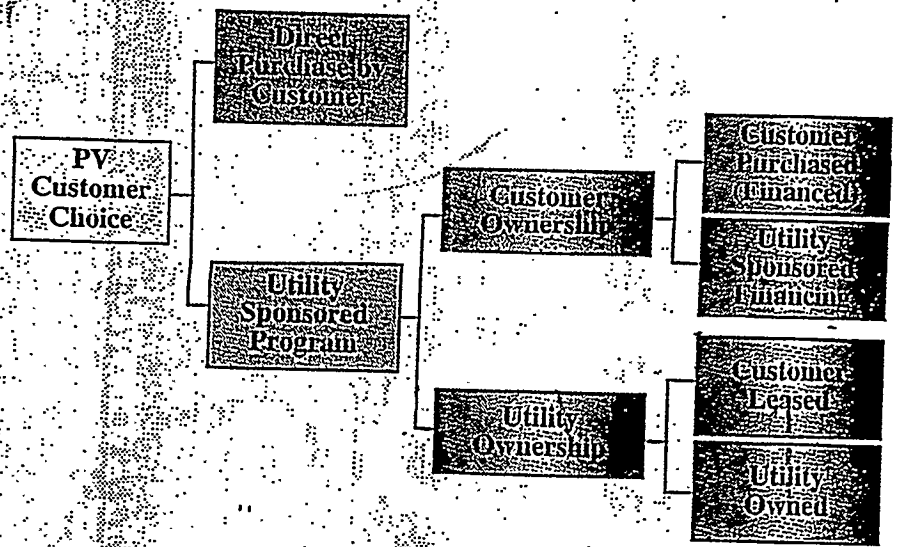
Status

	#	kW
• Customers Expressing Interest:	270	-
• Total Applicants:	37	-
Active Applicants:	29	258
$500 Deposits:	7	-
Bid Process:	6	27
Projects Under Construction:	1	1

Edison's PV Off-Grid Program

- Edison finances and manages the installation and maintenance of photovoltaic systems
- Procurement, construction and maintenance is performed by the PV industry
- Each project is competitively bid
- Edison offers financing using traditional utility/ customer financing terms
- Customers can purchase the PV system at any time

On-Grid Customer Options



Grid-Support R & D Project

- Underground 4 kv Circuits
- Monterey Hills Elementary School
  - 115 kW (Hilltop Circuit)
- Three Other 4 kv Circuits
- "Precursor Project"

On-Grid Status

- R & D Project
- UPVG 1995 Team-Up Funds
- On-Grid Commercial Program
  - "Buy down" price with UPVG Funds
  - Customer Designated Contractors
  - Edison or other Financing
- EPRI Screening Study
- SMUD / Edison Value Study

Angelo Invernizzi, ENEL

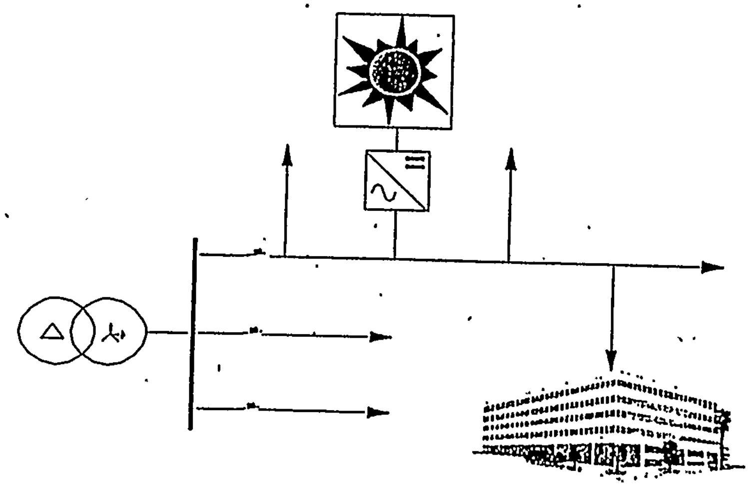
Optimized Location of Grid-Support Distributed PV Generation

EURE Joule 2

Strengthening Cooperation among Leading Utilities on Development and Integration of Renewable Energies

Area 3

Utilities Integration of Photo-Voltaic (PV) Generation under the Distributed Utility Concept



UTILITIES INTEGRATION OF PV GENERATION UNDER THE DISTRIBUTED UTILITY CONCEPT (DUC)

New technologies (in the area of renewable energy conversion, power electronic, storage) are rapidly developping.

Special characteristics, as:

- small size units, modular
- easy siting near loads
- easy integration into the environment
- easy matching load requirement

promote their use for distributed generating plant

ENEL S.p.A.
Direzione Studi e Ricerche
Centro Ricerca Elettrica

IEA TASK IV
Workshop at NREL

UTILITIES INTEGRATION OF PV GENERATION UNDER THE DISTRIBUTED UTILITY CONCEPT (DUC)

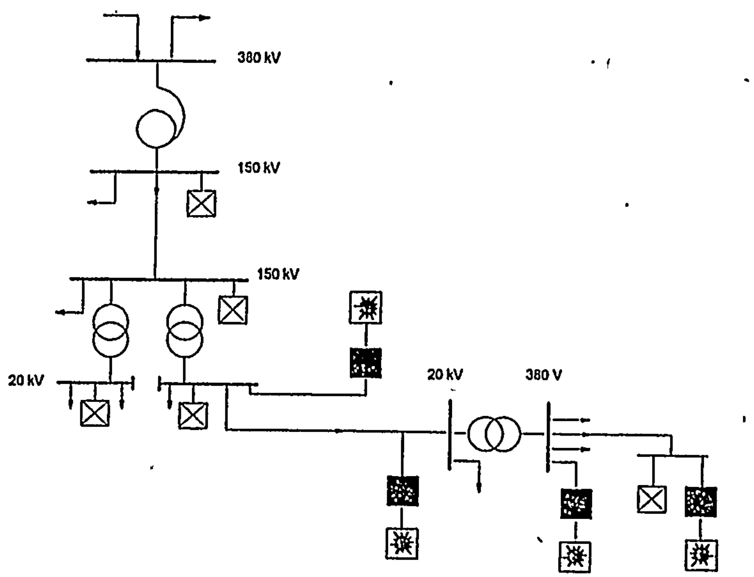
- Special features of PV allow to investigate a wide range of problems, some of them quite new.
- PV integration is significant as preliminary feasibility study of DUC
- Main study issues:
  - Optimal location of grid support distributed PV generation
  - Main technical aspect of PV integration in the distribution network

Denver 21+22/9/95

OPTIMAL LOCATION OF GRID SUPPORT DISTRIBUTED PV GENERATION

STUDY OBJECTIVE

TO ASSESS A GENERAL METHODOLOGY ABLE TO SINGLE OUT SPECIAL SITUATIONS (NICHES) WHERE NETWORK AND LOAD CHARACTERISTICS MAXIMIZE BENEFITS PROVIDED BY DISTRIBUTED PV GENERATION



OPTIMAL LOCATION OF GRID SUPPORT DISTRIBUTED PV GENERATION

STUDY METHODOLOGY

- CLASSIFICATION OF NETWORK AND LOAD CHARACTERISTICS
- SELECTION OF NETWORK SECTIONS
- ECONOMIC APPRAISAL OF DISTRIBUTED BENEFITS
- CLASSIFICATION OF SITES ON THE BASIS OF BENEFITS

OPTIMAL LOCATION OF GRID SUPPORT DISTRIBUTED PV GENERATION

STUDY METHODOLOGY CRITERIA FOR CLASSIFICATION AND SELECTION OF DISTRIBUTION NETWORK SECTIONS

- COST EFFECTIVNESS OF SERVICE:
  To single out substation and lines whose load is close (or over) to the rating and with high losses

- QUALITY OF SERVICE: To single out
  - Distribution feeders with poor voltage profile and inadequate reactive power compensation
  - Load supply points with high number (per year) of rapid voltage variations (voltage oscillation, voltage sags, short voltage interruptions)

- CONTINUITY OF SERVICE:
  To single out distribution feeders with high forced outage rates or weak feeders not able to guarantee complete re-supply of close feeder where a failure occured.

- ELECTRICITY CONSUMPTION PATTERNS
  To identify areas with summer and daily high load levels

OPTIMAL LOCATION OF GRID SUPPORT DISTRIBUTED PV GENERATION

ECONOMIC APPRAISAL OF BENEFITS

- SYSTEM BENEFITS
  - Reduction of energy production (fuel) consumption
  - Deferral and/or reduction of additional generating capacity
  - Reduction of transmission and HV distribution costs
  - Reduction of gas emissions of fossil fuel generation

- DISTRIBUTED BENEFITS
  - Deferral and/or reduction of distribution network reinforcement
  - Reduction of joule losses
  - Improvement in service quality
  - Improvement in service continuity

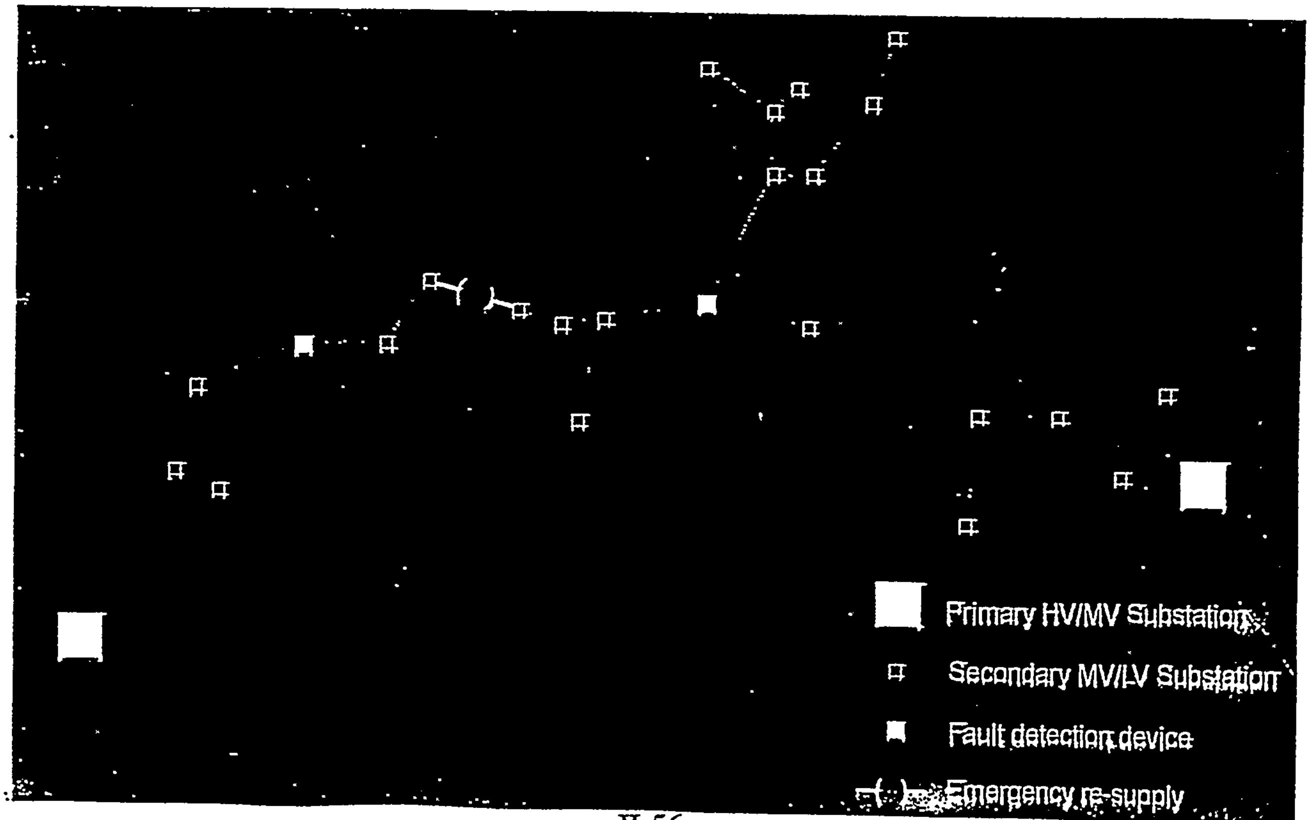
OPTIMAL LOCATION OF GRID SUPPORT DISTRIBUTED PV GENERATION

ECONOMIC APPRAISAL OF BENEFITS

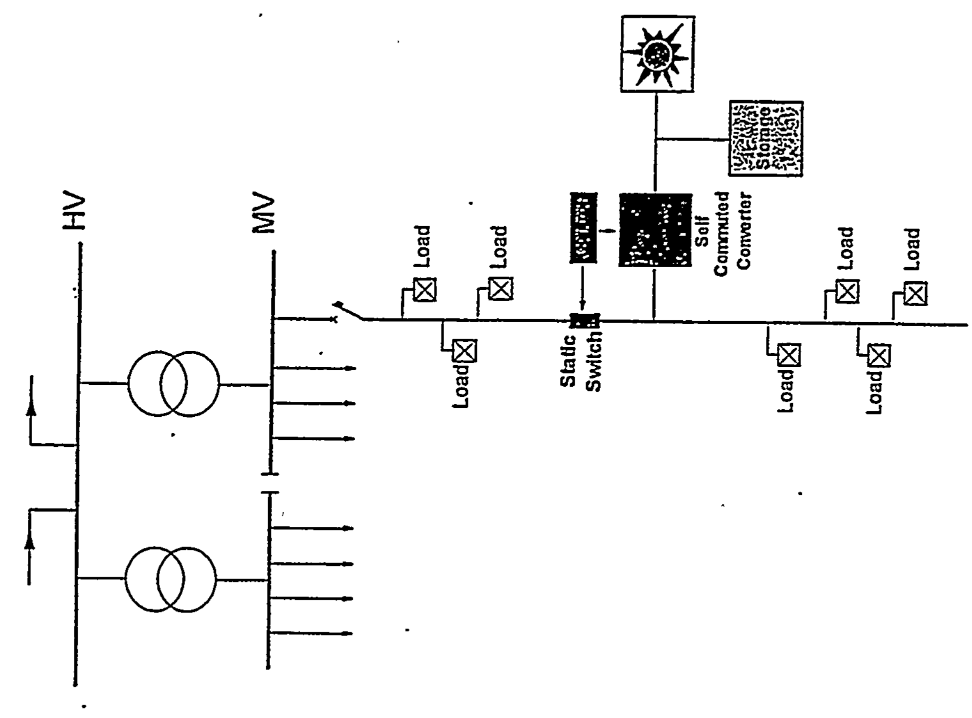
TO ACHIEVE BENEFIT PROVIDED BY "SERVICE QUALITY IMPROVEMENT" SHALL BE NECESSARY:

- to adopt a PV integration scheme as the one shown in the figure
- to modify rules and criteria at present used to operate public distribution networks
- to develop an adequate control system to allow the islanding operation of a part of the MV distribution feeder

MV DISTRIBUTION SCHEME



OPTIMAL LOCATION OF GRID SUPPORT DISTRIBUTED PV GENERATION



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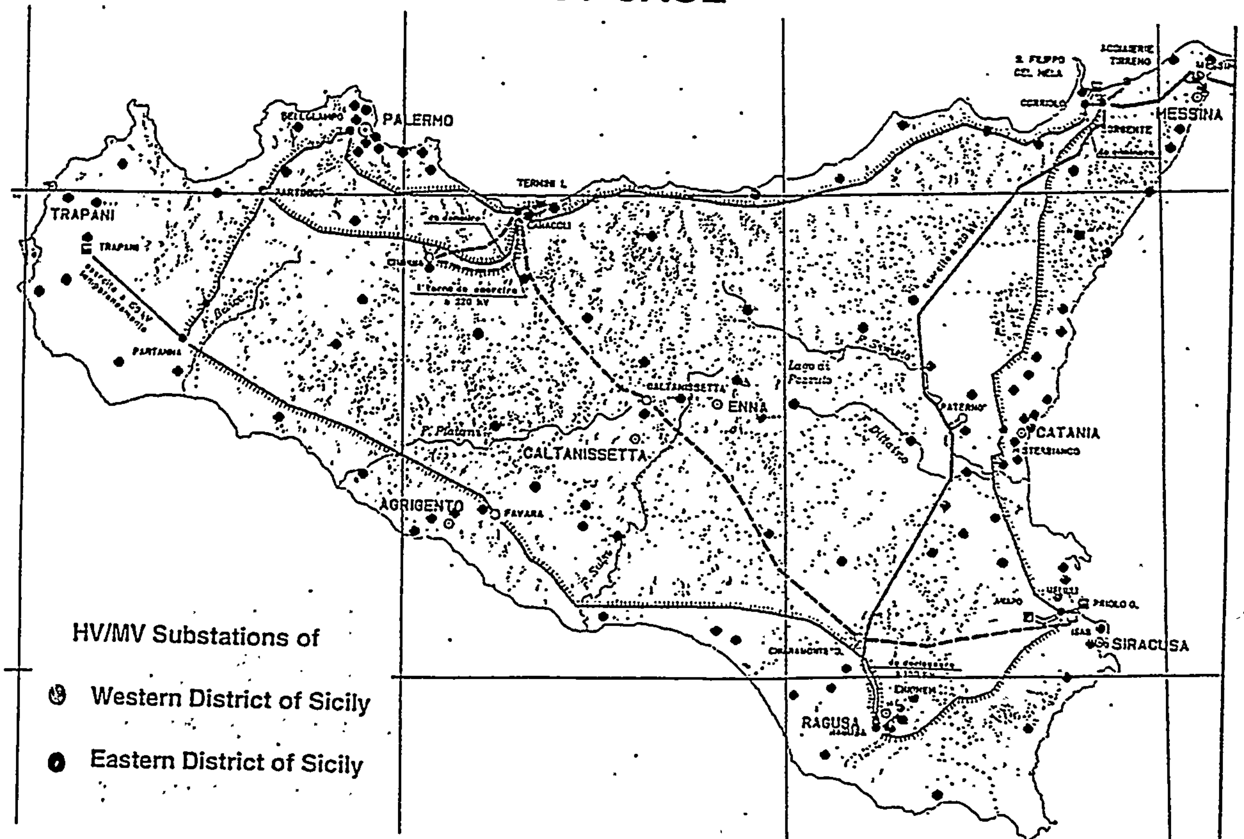
TEST CASE



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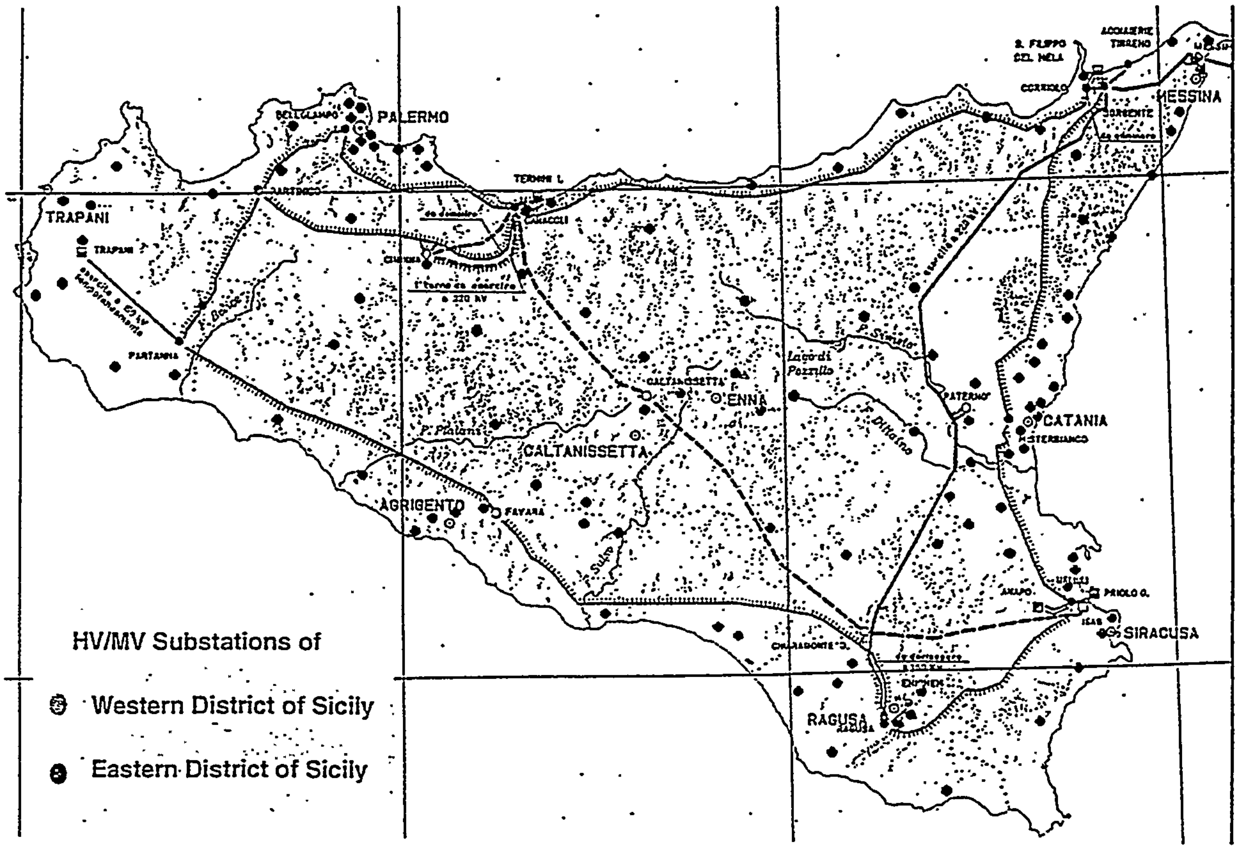
TEST CASE



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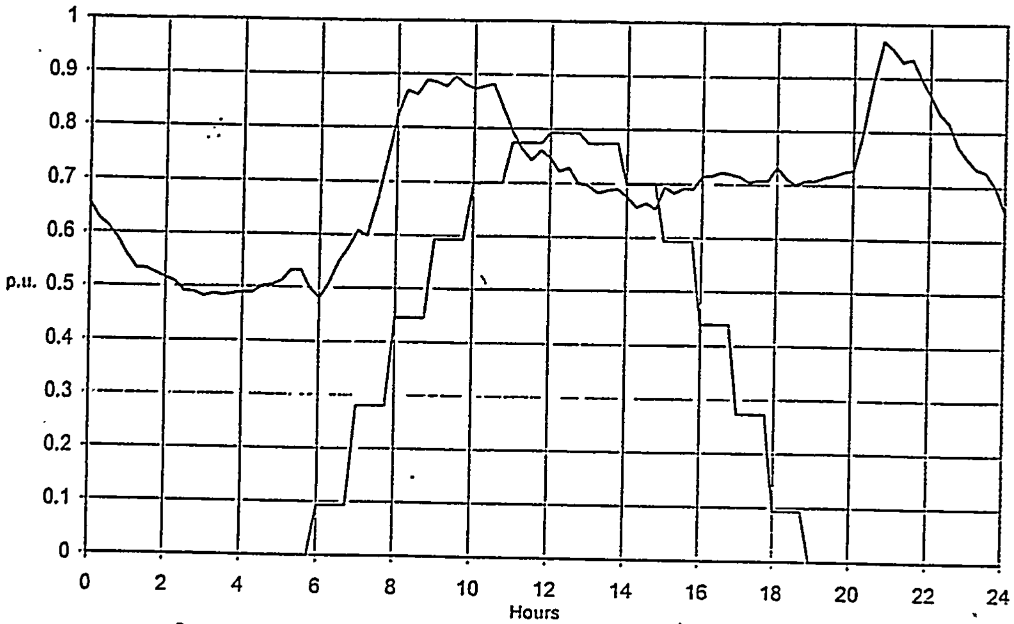
OPTIMAL LOCATION OF GRID SUPPORT DISTRIBUTED PV GENERATION

TEST CASE : DATA

Area :	Western Sicily District
Area surface :	12470 sq km
Area max load :	962 MW
Area load density:	77 kW/sq km
Primary subs. :	48
Mean influence area:	260 sq.km
N. of MV feeders :	578
Mean length :	15 km

OPTIMAL LOCATION OF GRID SUPPORT DISTRIBUTED PV GENERATION

Typical Daily Load Diagram Versus Solar Radiation



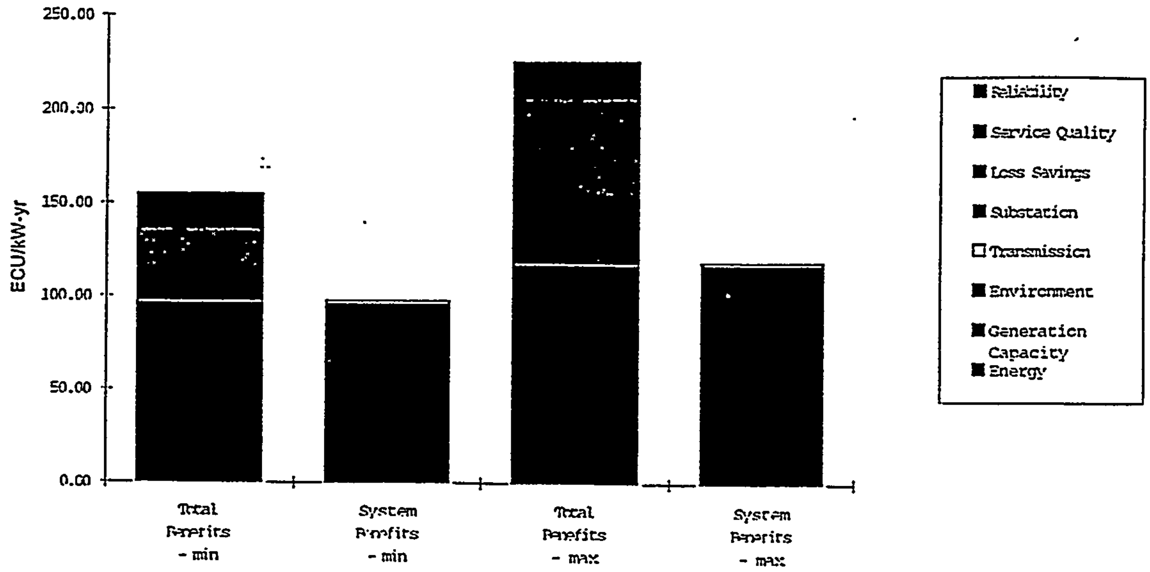
OPTIMAL LOCATION OF GRID SUPPORT DISTRIBUTED PV GENERATION

TEST CASE - RESULTS

INDIVIDUATED MV FEEDERS WITH:

- overall length in the order to 100-150 km
- joule losses > 3% up to 8-9%
- voltage drops > 5% up to 9-11%
- forced interruptions of the order and more than 500
- 40-80 MV feeder tripping for maximum current
- 500-1000 voltage dips

OPTIMAL LOCATION OF GRID SUPPORT DISTRIBUTED PV GENERATION
TEST CASE - PV Generation Benefits

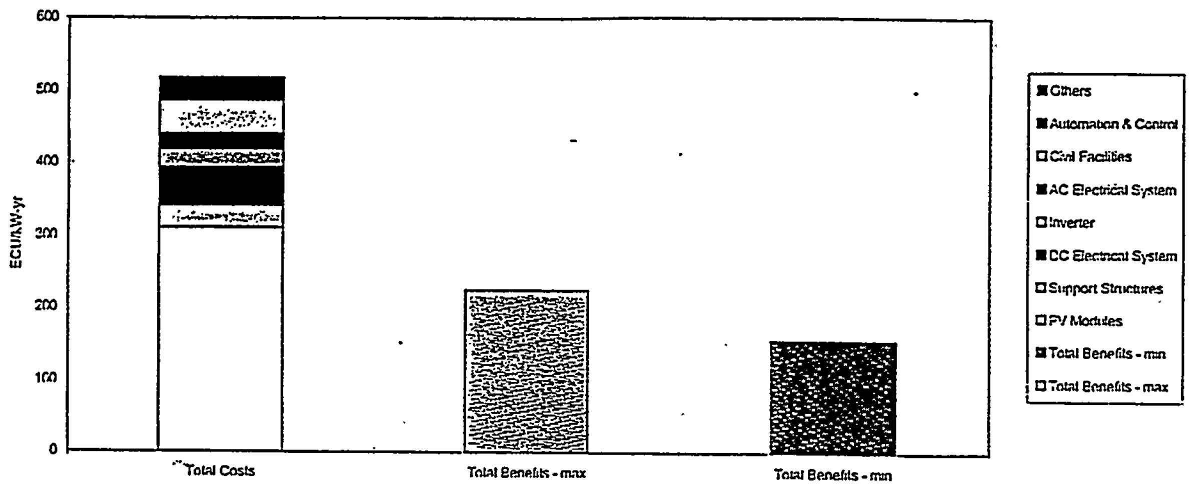


OPTIMAL LOCATION OF GRID SUPPORT DISTRIBUTED PV GENERATION

TEST CASE - RESULTS

- IN THE MOST FAVOURABLE CONDITIONS THE DISTRIBUTED BENEFITS PROVIDED BY PV GENERATORS INTEGRATED INTO MV DISTRIBUTION NETWORK ARE OF THE SAME ORDER OF SYSTEM BENEFITS
- IN TOTAL THE OVERALL (SYSTEM + DISTRIBUTED) BENEFITS ACHIEVE ABOUT THE 50% OF PV GENERATION COSTS

OPTIMAL LOCATION OF GRID SUPPORT DISTRIBUTED PV GENERATION
TEST CASE - PV Generation Costs and Benefits



FURTHER POSSIBLE ACTIONS
TO IMPROVE PV ECONOMICS

- To investigate all possible PV utilizations, in order to develop a wider PV market
- To develop standardization in PV application
- To experiment the use of grid interface devices (dc/ac inverter) already developped and used for other applications (power quality improvement, electric vehicle, grid integration of other distributed generating facilities, etc.)
- To study and experiment other functions (in addition to fuel saving) provided by PV
- To study and experiment PV applications with other (DSM) actions

Alberto Iliceto, ENEL

Technical Aspects of Integrating PV into the Distribution Network

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Laboratory and field tests

GENERAL ASPECTS

The widespread use of distributed generation systems using renewable primary energy (photovoltaic, eolian) raises a certain number of technical problems, like:

- harmonic currents,
- reactive power absorption,
- necessity to disconnect the distributed generation plants from the public network in the event of malfunctioning or fault that may occur on the network or in the generation plant order to avoid consequences regarding the safety of the personnel and the operation of both the public network and the PV systems (the present operation criteria does not allow the islanding functioning of a part of the public network).
- effects on the efficacy of the automatic protections installed in the network (contribution to fault current and effects on the automatic O-C-O-C sequence)

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Laboratory and field tests

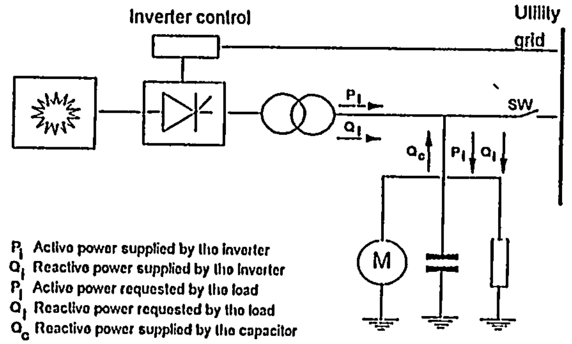
PURPOSE OF TESTING

- To investigate the islanding, laboratory and field tests on grid connected PV generation systems have been performed with the aim of
  - identifying the generation and load conditions for which islanding is possible;
  - characterizing islanding as regards the voltage, the current and the frequency.
- Reclosing effects on the convertion equipments have also been investigated.

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Laboratory and field tests

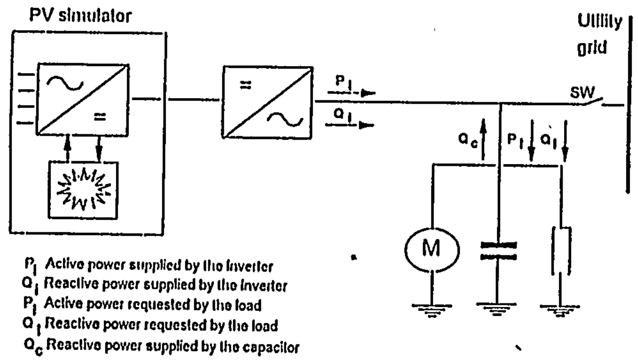
TEST CONDITIONS

Field tests



Adrano test plant

Laboratory tests



Laboratory test circuit

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Laboratory and field tests

FIELD TESTS

Results of islanding tests on the inverter at ENEL's PV test field at ADRANO

Type of load	Resistance	Capacitor	Motor	Resistance+ Capacitor+ Motor
$P_{inverter}$ (kW)	2	2.2	1.9	1.4
$Q_{inverter}$ (kVAR)	-3.5	-3.8	-4.4	-1.9
P_{load} (kW)	2		2	2.2
Q_{load} (kVAR)			8.5	9.1
$Q_{capacitor}$ (kVAR)		3.8		8.4
Islanding	NO	YES	300÷400 ms.	600 ms.
Voltage variation	-	2÷3 p.u.	1.4 p.u.	1.4 p.u.
Frequency variation	-	60 Hz	49 Hz	49 Hz

$P_{inverter}$: Active power supplied by the inverter
$Q_{inverter}$: Reactive power supplied by the inverter
P_{load}: Active power requested by the load
Q_{load}: Reactive power requested by the load
$Q_{capacitor}$: Reactive power supplied by the capacitor

ICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Laboratory and field tests

LABORATORY TESTS

s were carried out on the following inverters:

- Siemens line-commutated, 5 kW
- Sun-Power self-commutated, 5 kW
- Invertomatic self-commutated, 20 kW
- Omnion self-commutated, 20 kW

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS THE DISTRIBUTION NETWORK
Laboratory and field tests

LABORATORY TESTS

- Results of islanding tests on line-commutated inverter SIEMENS

D.C. side internal protections	over current under/over voltage			
A.C. side internal protections	fuses under/over voltage			
Type of load	Resistance	Capacitor	Motor+ Capacitor	Resista · Moto Capa (see fi
$P_{inverter}$ (kW)	3	3	3	3
$Q_{inverter}$ (kVAR)	-1	-1	-1	-1
P_{load} (kW)	3		3	3
Q_{load} (kVAR)				1.(
$Q_{capacitor}$ (kVAR)		2.6	2.6	2.(
Islanding	YES	NO	YES	YE:
Voltage	0.9 p.u.	2 p.u.	1.5 p.u.	1 p.
Frequency	~60 Hz	-	~60 Hz	~60
Reclosure effects				
Inverter peak overcurrent relative to I_n	-	-	-	>> 4
Grid peak overcurrent	-	-	-	>> 5(

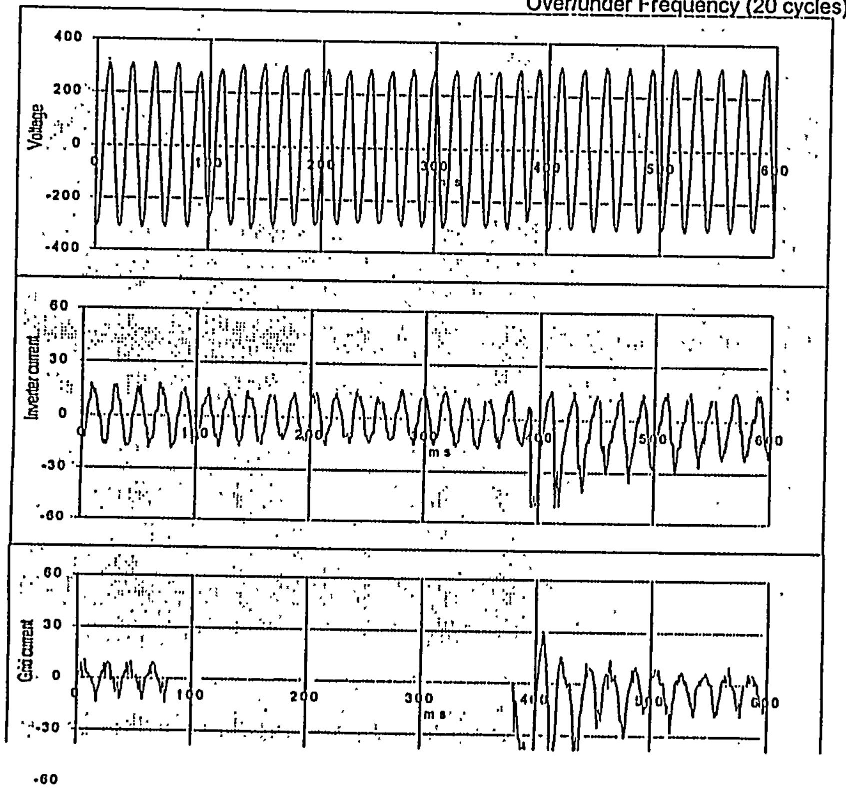
$P_{inverter}$: Active power supplied by the inverter
$Q_{inverter}$: Reactive power supplied by the inverter
P_{load}: Active power requested by the load
Q_{load}: Reactive power requested by the load
$Q_{capacitor}$: Reactive power supplied by the capacitor

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Laboratory and field tests

LABORATORY TESTS

Self commutated Inverter OMNION
Type of load: Resistance + Motor + Capacitor

A.C. side internal protection
Overcurrent
Over/under Voltage (1sec.)
Over/under Frequency (20 cycles)



TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Laboratory and field tests

CONCLUSIONS

- Though **line-commutated inverters** are designed in order not to sustain islanding, tests demonstrated islanding with particular generation and load conditions. Moreover, in some cases, the voltage values observed result to be dangerous for the appliances insulation.

- The **self-commutated inverters** may, in principle, support islanding, but Italian standards, like those of other countries, do not allow this possibility. The tests confirmed that for self-commutated inverters generation and load conditions exist for which islanding is possible.

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Laboratory and field tests

FUTURE WORKS

- Development and validation of an EMTP model of grid connected PV systems with line or self commutated inverters.
- Execution of field (Adrano site) tests on PV grid connected systems with line or self commutated inverters (tests on inverters equipped with new islanding protection devices, i.e. P.F. control).
- Utilization of the EMTP model to perform an exhaustive analysis of PV grid connected systems under different network conditions.

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Rules and Standards

MAIN ASPECTS

- CHARACTERISTICS OF THE ELECTRIC ENERGY SUPPLIED
  - voltage fluctuations
  - harmonics
  - power factor
  - EMC
- ELECTRIC SYSTEM LAYOUT
- PROTECTIONS
  - co-ordination with the utility's protective devices
  - settings
- SAFETY
- ISLANDING

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Rules and Standards

THE ITALIAN CASE

CEI 11-20 ITALIAN STANDARD REGULATES THE CONNECTION OF DISTRIBUTED SYSTEMS TO THE LV AND MV GRID AS REGARDS:

- CHARACTERISTICS OF THE ELECTRIC ENERGY SUPPLIED
  - harmonic pollution
  - reactive energy exchange
- ELECTRIC SYSTEM LAYOUT
- PROTECTIONS
  - co-ordination with the utility's protective devices
  - settings
  - reclosing
  - islanding

Note:

PRESENT RULES CONCERN SYSTEMS EQUIPPED WITH ROTATING GENERATORS, BUT AN EXTENSIVE REVISION HAS BEEN ALMOST COMPLETED TO TAKE INTO ACCOUNT SYSTEMS EQUIPPED WITH STATIC CONVERTERS.

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Rules and Standards

INTEGRATION CRITERIA

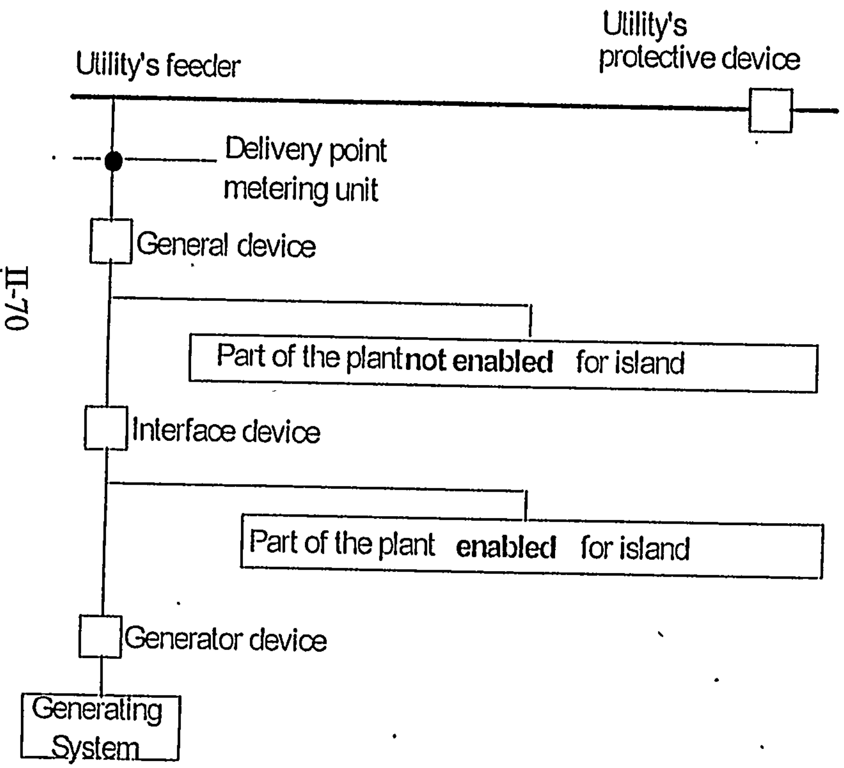
- CONNECTION TO THE LV NETWORK IS ONLY ALLOWED FOR SYSTEMS NOT ABLE TO SUSTAIN VOLTAGE IN THE ABSENCE OF NETWORK SUPPLY

Systems ABLE to sustain voltage	Systems NOT ABLE to sustain voltage
synchronous generators	asynchronous generators
self-excited asynchronous generators	line-commutated static converters
self-commutated static converters	*self-commutated static converters provided they always absorb a fixed quantity of reactive power (PF = 0.95 ÷ 1)*

- THE SINGLE AND OVERALL POWER OF THE DISTRIBUTED GENERATING SYSTEMS SHOULD BE COMPATIBLE WITH THE FEATURES OF THE NETWORK
  - 3 kW is the limit to connect single-phase systems to the LV network
  - 50 kW is the limit to connect three-phase systems to the LV network
  - 3 MW is the limit to connect three-phase systems to the MV network (8 MW in special cases)

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Rules and Standards

INTEGRATION SCHEMES



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Direzione Studi e Ricerche
Centro Ricerca Elettrica

IEA - Task IV
Workshop at NREL

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Rules and Standards

PROTECTION CO-ORDINATION

Co-ordination Sequences

Event	Utility grid device	General device	Interface device	Generator device
Fault or malfunctioning of the utility grid	YES 1st level	NO	YES 2nd level	YES 3rd level
Fault or malfunctioning of the distributed generation plant	YES 3rd level	YES 1st level	YES 2nd level	YES 3rd level
Fault in generating system	NO	YES 3rd level	YES 2nd level	YES 1st level
1st, 2nd and 3rd levels: priority order of relays operation				

- THE GENERAL DEVICE ELIMINATES INTERNAL FAULTS IN THE GENERATING SYSTEM BEFORE THE OPERATION OF NETWORK PROTECTIONS
- THE INTERFACE DEVICE ASSURES THE SEPARATION OF THE GENERATING SYSTEM FROM THE NETWORK IN CASE OF FAULTS OR MALFUNCTIONING ON THE DISTRIBUTION NETWORK OR WHEN THE NETWORK BREAKER IS OPENED INTENTIONALLY
- THE GENERATOR DEVICE ELIMINATES INTERNAL FAULTS IN THE GENERATING SYSTEM

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Rules and Standards

INTERFACE PROTECTIVE RELAYS AND RELEVANT SETTINGS

Utility voltage level	Type of generating systems	Protective relays	Settings
Low Voltage	All	over voltage under voltage over frequency under frequency	1.2 V_n instant. 0.8 V_n delayed 51 Hz instant. 49 Hz instant.
Medium Voltage	Able to substain voltage in the absence of distribution network	over voltage under voltage over frequency under frequency zero sequence voltage overcurrent	1.2 V_n instant. 0.7 V_n delayed 50.3 Hz instant. 49.7 Hz instant. delayed delayed
	Unable to substain voltage in the absence of distribution network	over voltage under voltage over frequency under frequency	1.2 V_n instant. 0.8 V_n delayed 50.3 Hz instant. 49.7 Hz instant.

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Rules and Standards

LIMITS FOR HARMONIC EMISSIONS

- LIMITS FOR HARMONIC CURRENT EMISSIONS FOR EQUIPMENTS WITH CURRENT ≤ 16 A ACCORDING TO IEC 1000-3-2

Harmonic order n	Maximum permissible harmonic current A
Odd harmonics	
3	2.30
5	1.14
7	0.77
9	0.40
11	0.33
13	0.21
$15 \le n \le 39$	0.15 x 15/n
Even harmonics	
2	1.08
4	0.43
6	0.30
$8 \le n \le 40$	0.23 x 8/n

- LIMITS FOR HARMONIC CURRENT EMISSIONS FOR EQUIPMENTS WITH CURRENT > 16 A (ACCORDING TO FUTURE IEC 1000-3-4)

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Rules and Standards

LIMITS OF INDIVIDUAL HARMONIC VOLTAGES AT THE SUPPLY TERMINALS FOR LV AND MV

- VOLTAGE CHARACTERISTICS OF ELECTRICITY SUPPLIED BY PUBLIC DISTRIBUTION SYSTEMS (CENELEC EN 50160)

Odd harmonics non-multiple of 3		Odd harmonics multiple of 3		Even harmonics	
Harmonic order n	Harmonic voltage %	Harmonic order n	Harmonic voltage %	Harmonic order n	Harmonic voltage %
5	6	3	5	2	2
7	5	9	1.5	4	1
11	3.5	15	0.5	6...24	0.5
13	3	21	0.5		
17	2				
19	1.5				
23	1.5				
25	1.5				

The THD of the supply voltage (including all harmonics up to the order 40) shall be ≤ 8%

TECHNICAL ASPECTS OF INTEGRATING PV SYSTEMS INTO THE DISTRIBUTION NETWORK
Rules and Standards

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Meeting Agenda

NREL

Annex IV Workshop
Modeling of Distributed PV Power Generation in Support of the Electric Grid
Agenda

Thursday, September 21, 1995

1:00-1:15 p.m.	Welcome, introductions, and review of meeting objectives and approach - Mike Pulscak, DOE
	US panel session:
1:15-2:00 p.m.	Review of status of US distributed methods - Lynn Coles, NREL
2:00-2:45 p.m.	Emerging methods/modeling techniques - Howard Wenger, Pacific Energy Group
2:45-3:15 p.m.	Break
3:15-4:00 p.m.	U.S. utility perspective, Doug Whyte, SCE
4:00-5:00	Questions for Panel and others
7:00 p.m.	Group Dinner - Location map to be provided

Friday, September 22, 1995

	Overseas panel session:
8:30-9:00 a.m.	Methodology and modeling for the optimal location of distributed generation from renewables - Angelo Invernizzi, ENEL
9:00-9:30 a.m.	Application study to the location of PV in a MW distribution network, covering a regional area, TBD
9:30-9:45 a.m.	Break
9:45-11:00	Investigation of technical aspects of integrating PV generating sets into distribution network -General aspects - Angelo Invernizzi -Laboratory and field tests on generating sets with ac/dc converters - Alberto Iliceto -Simulation tools - Angelo Invernizzi -Rules and standards - Alberto Iliceto Questions for panel presenters

11:00-12:00 noon.	Working session 1 (all participants): Needs assessment - Are there further needs for distributed PV evaluation and modeling that are not being met? What are these needs and what are their relative priorities? - Facilitator: Christy Herig
12:00-1:00 p.m.	Lunch (brought into conference room) Complete session 1
1:00-2:30 p.m.	Working session 2 (all participants): Development of alternatives - What are potential ways to meet these needs? What are the pros and cons of these alternative approaches? What are the advantages of conducting this through Annex IV? - Facilitator: Mike Pulscak

Results of the Working Sessions

General

In the workshop group session on Friday afternoon, Work Products 1 and 2 were developed to assist in facilitating progress on Annex IV. The products were derived through joint discussion and consensus to reflect the general views of the group. The initial discussion of needs resulted in Work Product 1. After reviewing the results, the group decided to reflect these needs into a content list for "workbook or guidebook" on grid-connected PV shown as Work Product 2. Work Product 3 was developed by NREL after the workshop, but is based on Work Product 2 and other workshop discussions. Work Product 3 is the proposed Scope of Activity for Annex IV.

Work Product 1:

LIST OF ANNEX IV NEEDS

International Energy and Capacity
Conversions
Localized Effective Load-Carrying Capability (ELCC)
Optimum Siting Conditions on Grid Relating to Capturing Benefits
Unique Attributes of PV Relating to Benefits
Financials/Customer Preference/Utility Decision Criteria
Investigate and Experiment System Efficiency & Verify Benefits
Hardware Tests
Functional Specifications for Distributed Resource PV Applications
Distribution Planning Models with Incorporating Grid Support PV
- Scaling Factors
- Minimum Sizing Criteria
- Siting and Sizing

Policy and Institutional Issues

Work Product 2:

CONTENTS FOR ANNEX IV WORKBOOK ON GRID-CONNECTED PV

Work Product 3:

PROPOSED ANNEX IV SCOPE OF ACTIVITY

1. Objective

The objective of this task is to refine definitions and advance evaluation methodologies that capture the full technical and economic benefits of PV grid-support applications and to advance planning techniques for these systems to maximize the benefits to the electric grid. Both functional and operational technical attributes of the PV technology will be linked to the electric grid system attributes to ensure optimum siting and sizing of PV systems. Benefits to be considered include load match, relief of overloads, reduced losses, voltage support, enhanced reliability, and others. Additionally, nontechnical benefits and possible barriers related to policy, institutional, and procurement issues will be addressed.

PV grid-support research, development and demonstration (RD&D) work has been accomplished in many countries. It is the overall objective of this task to plan, coordinate and disseminate this international grid-support work to ensure maximum market deployment of PV solar energy.

2. Means

Work in pursuit of this objective will be performed by PV power system experts and generation, transmission, and distribution planners in participants' countries. Participants will carry out the following subtasks:

(a) <u>Subtask IV/1</u> Develop definitions and methodologies to enable a complete technical benefit evaluation of PV grid-support applications.

Participants will improve methods of developing and applying technical issues of PV grid connection, as follows:

(1) Define and quantify the different types of attributes related to PV connection to the power system grid
(2) Develop energy and capacity charts to simplify evaluation of capacity and energy values
(3) Improve techniques to evaluate localized effective load-carrying capacity (ELCC) to allow capture of PV capacity benefits
(4) Refine ELCC definitions, criteria and calculation methods to allow more widespread acceptance of use
(5) Evaluate benefits of multiple small units vs large systems

(6) Define optimum siting attributes and methods to maximize benefits
(7) Develop grid connection and PV hardware standards to encourage acceptance of distributed PV installations
(8) Develop new and improved grid-integration schemes
(9) Develop an overview of possible applications and functional specifications
(10) Define operating and maintenance requirements
(11) Perform sample case studies and field tests

(b) Subtask IV/2 Develop definitions and methodologies to enable maximum economic benefit evaluation of PV grid-support applications, as follows:

(1) Develop energy and capacity conversion factors and other standard methodologies, converting capital costs to levelized energy costs

(2) Define the financial structure of the privatized utility industry and develop methods to evaluate customer preference and energy company or utility decision criteria

(c) Subtask IV/3 Develop and validate evaluation methodologies for all technical and economic benefits, as follows:

(1) Develop new models or accessory modules for existing utility planning models that include the full slate of distributed technical attributes and economic benefits

(2) Perform case studies of grid-connected PV to validate models or module accessories

(d) Subtask IV/4 Define and identify potential resolution of nontechnical barriers for PV grid-support applications such as policy and institutional issues, as follows:

(1) Analyze general policy and institutional issues that can lead to nontechnical barriers to the adoption of distributed PV

(2) Develop a set of strategies that have broad application in overcoming nontechnical barriers

(e) Subtask IV/5 Develop procurement guidance that meets existing criteria for utilities and energy companies, as follows:

(1) Analyze current procurement practices

(2) Develop a suggested procurement procedure to facilitate acquisition of grid-connected PV

(f) Subtask IV/6 Consolidate and integrate the material developed above in Subtasks IV/1 through IV/5 into a user-friendly workbook addressing the issues of distributed PV applications.

3. Results

The products of work performed in this annex will be designed for use by PV power system experts and utility and energy company planners and decision makers and will be developed from work accomplished in Subtasks IV/1 through IV/6, as follows:

(a) Definitions, data and methodologies for evaluation of technical and economic benefits for use in planning and implementing PV grid support applications pursuant to Subtask IV as described in subparagraphs 2(a), 2(b), and 2(c) above

(b) Identification and suggested resolutions to policy and institutional issues that present nontechnical barriers to PV grid-support applications pursuant to Subtask IV as described in subparagraph 2(d) above

(c) Procurement guidelines for PV grid-support applications pursuant to Subtask IV as described in subparagraph 2(e) above

(d) A consolidated and integrated framework that can address a wide variety of user needs pursuant to Subtask IV as described in subparagraph 2(f) above. This will be presented in a "guidebook" or "workbook" configuration.

4. Time Schedule

This annex shall remain in force for three years. It may be extended by agreement of two or more participants, acting in the executive committee, taking into account any recommendations of the Agency's Committee on Energy Research and Technology concerning the term of this Annex, and shall thereafter apply only to those participants.

5. Specific Responsibilities of the Operating Agent

In addition to carrying out the specific responsibilities enumerated in Article 5 of the Agreement, the Operating Agent shall coordinate, review, revise, and distribute to participants the documents and reports specified in section 3, Results, above.

6. Funding

(a) *Publications.* The cost of funding analytical reports pursuant to the Subtasks of this Annex shall be met by the operating agent.

(b) *Individual Financial Obligations.* Each participant shall bear all the costs it incurs in carrying out its obligations under this Annex, including reporting and travel expenses

(c) *Task-Sharing Requirements.* The total level of effort to perform the work described in this Annex is estimated to be four person-years per year. The expected contribution of each participant to task sharing under this Annex is therefore 0.5 to 1.0 person-years of effort during each year that the Annex remains in force.

7. Operating Agent

[To be determined]

8. Participants

[To be determined]

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13. ABSTRACT *(Maximum 200 words)*
Proceedings of a workshop about the current status of methods for evaluating the benefits of and planning for grid-connected photovoltaic systems. The workshop was part of Task IV, the Modelling of Distributed Photovoltaic Power Generation in Support of the Electric Grid, one of six projects established under the International Energy Agency Implementing Agreement on Photovoltaic Power Systems. This agreement is the collaborative effort of sponsoring countries to reduce costs of technology applications, increase awareness of potential value, and foster market deployment of PV. The workshop consisted of three sessions: (1) status of grid-support activities in the United States and discussion of key tasks and research projects, (2) key tasks and research projects presented by Italian participants, and (3) defining evaluation needs for PV grid-support applications under the auspices of Annex IV. In addition to the presentation materials, results of the working session on needs evaluation are also summarized.

14. SUBJECT TERMS
photovoltaic power systems; distributed utility; utility planning models; PV grid support; international

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