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Preliminary Report on Task Order No. 20

Prepared By
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Mr N V Seshadri

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PRELIMINARY REPORT
ON
TASK ORDER No 20

PREPARED
FOR

THE UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT (USAID)

BY THE

IRG INTERNATIONAL RESOURCES GROUP
Management consultants in energy, environment & natural resources

NEW DELHI INDIA
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I INTRODUCTION

A BACKGROUND

The Haryana State Electricity Board (HSEB) was established in May 1967 under the Indian Electricity Act of 1948 It was established to generate and/or purchase, transmit and distribute electric energy to consumers of the State of Haryana Today, the HSEB serves about 3 4 million of electric service consumers The State of Haryana, located in the Northwest of India, has an area of 44,212 square kilometers and a population of 16 46 million The population density is 372 per square kilometer It has borders in the North with the State of Punjab, the East with the State of Uttar Pradesh and with the country's capital, New Delhi, and in the Southwest with Rajastha At present the HSEB continues to be responsible for the operation and maintenance of the generation, transmission and distribution systems that provide electric service to the 3 4 million consumers

It is the desire of the government of India and the State of Haryana to privatize the entire HSEB in a sequence of steps The initial step is to subdivide the HSEB into three to five companies namely, a generation company, a transmission company and two to three distribution companies referred to as GENCO, TRANSCO and DISCOS respectively Each of this power companies are to become self-sufficient entities with responsibility for their own operation and maintenance expenses while generating sufficient revenues to cover all expenses and generate an adequate rate of return for the private investors However, to meet these objectives it is necessary to improve the existing operational efficiency of the various systems that currently form the HSEB

B SCOPE OF WORK

In accordance with the USAID and IRg contractual agreement, IRG has provided to the Haryana State Electricity Board (HSEB) technical assistance services, which included the review of the operating efficiency of the existing distribution system The review has covered the existing structural organization, training programs, operation and maintenance procedures and the procedures to reduce system losses Recommendations have been developed, which, we believe, upon their implementation will improve the efficiency of operation of the power distribution system

IRg has also reviewed, in an effort to establish staff training priority requirements, the listing of equipment and material that is being procure under the US$ 60 million World Bank Loan APL-1 The material will be used to upgrade portions of the heavily overloaded distribution system facilities The World Bank has initially

provided US$ 60 million loan to the Central Government of India as part of the Emergency Assistance Program, World Bank Loan APL-1

In addition, IRg conducted a series of Workshops to the HSEB Chairman, Board Members and staff from various Circles, Divisions and Sub-Divisions These Workshops were also presented to Power Finance Corporation LTD (a government of India undertaking) and to some participating State Electricity Boards The Workshops presented the problems affecting the distribution systems and the solutions to improve the operational efficiency of these power distribution systems

C SUMMARY

1 To meet the scope of work objectives IRG conducted a series of interviews with key staff of the HSEB and visited many of their transmission and distribution system facilities in an effort to identify the problem areas affecting the utility

2 Upon the completion of the series of interviews and visits to the HSEB facilities and evaluation of the results, IRg presented its findings on a Workshop format to the HSEB Participants on this Workshop were Mr Rajit Issar, HSEB Chairman, the Board Members, Chief Engineer Zone I and various Superintendent Engineers Circles from Zone 1 as well as staff from the transformer repair shops The Workshop meeting was held at the facilities of the HSEB in Panchkula on June 4, 1998

3 The Workshop was well received by the HSEB and it generated a series of action items for immediate implementation Among these action items, upon the conclusion of IRg's Workshop of June 4 and after a meeting with the Board Members, the Chairman Mr Rajit Issar, assigned a task to IRg

4 IRg was to perform an evaluation of the causes of large power and distribution transformer failures that are severely affecting the financial capability and the distribution system reliability of supply of HSEB

5 Based on the Chairman's request, IRG went back to the field to visit specifically the 220 kV, 133 kV, and 66 kV substations IRG prepared a schedule of visits to cover as many of the key transmission and sub-transmission substations

6 Upon the completion of the visits to the substations and interviews with the Seniors Substation Engineers, Junior Engineer and other key substation staff, IRg prepared and organized a second Workshop primarily on the causes of transformer failures Representatives from the

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World Bank and the HSEB attended the Workshop As in the previous one, the Workshop was a success The Workshop meeting was held at the facilities of the HSEB in Panchkula on June 18, 1998

7 At the July 18, 1998 Workshop, the World Bank raised many questions regarding the distribution system preventive maintenance, actions that HSEB would be taken to correct the problems identified and where or how the World Bank could help Haryana resolve the problems identified during the performance of the IRg work

8 A substation preventive maintenance manual has been developed The manual has been written in a clear and concise language for all staff levels to understand The manual complements an existing HSEB manual

9 It is expected that a database will be developed and that the preventive maintenance program will be computerized The manual procedures must be implemented to obtain maximum technical and economic benefits

10 At each of the Workshops recommendations have been made for the implementation of an on-the-job-training program that will improve not only the equipment installation workmanship but the performance of preventive maintenance activities

11 Based on the previous workshops, one additional workshop was prepared and organized for presentation to the Power Finance Corporation Ltd (PFC) The Workshop meeting was held at the facilities of the PFC in New Delhi on July 22, 1998

12 At the request of the HSEB, another Workshop was organized for presentation to the HSEB staff from the southern regions of the State of Haryana Primarily the staff of Zone II, including the Chief Engineer or Zone II, Superintendent M and P Circle, Superintendent Engineers Operation Circles and Executive Engineers As in the previous workshops, participants were very receptive and eager to implement recommendations made This Workshop was held at the Taj Palace Hotel in New Delhi on July 23, 1998

13 Requests have been made for two additional workshops to cover staff from Zone III and II

II HSEB DISTRIBUTION SYSTEM

A LOAD AND ENERGY PRODUCTION-1996-97

Table I illustrates the number of consumers, energy sales and percent distribution of sales for the fiscal year 1996-1997

TABLE I
CONSUMER CLASSES NUMBERS AND ENERGY SALES

CONSUMER TYPE	CONSUMERS (NUMBERS)	MAXIMUM DEMAND (MW)	ENERGY SALES (GWH)	SALES (%)
Residential	2,510,670		1637	18 72
Commercial	321,288		258	2 95
Industrial	77,422		2,017	23 07
Irrigation And Agricultural	366,540		3,904	44 64
Others	9,317		929	10 62
Totals	**3,285,237**	**1,973**	**8,745**	**100 00**

Table II illustrates the generating installed capacity and capacity and energy generated during fiscal year 1996-1997

TABLE II
GENERATING INSTALLED CAPACITY AND CAPACITY AND ENERGY GENERATED DURING FISCAL YEAR 1996-1997

GENERATION TYPE	INSTALLED CAPACITY(1) (MW)	CAPACITY (MW)	ENERGY (GWH)	LOAD FACTOR (%)
Hydroelectric	1063 6	884	3,342	43
Thermal	1283 6	878	3,675	48
Purchases			6,112	
Auxiliaries			(391)	
Totals	**2347 2**	**1762**	**12,738**	

B ENERGY LOSSES 1996-1997

The total power system energy losses, including generation, transmission and distribution based on Tables I and II are **12,738-8,745 GWh or 3,993 GWh or 31 4 percent** of total energy produced It is estimated that the generation and transmission system losses are about 11 percent and therefore the distribution

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system losses are about 21 5 percent The 21 5 percent is assumed to include the technical and non technical losses TABLE III shows the historical transmission and distribution systems losses for key years of the 1986-1998 period

TABLE III
COMBINED NON-AND TECHNICAL
SYSTEM ENERGY LOSSES IN PERCENT

YEAR	HARYANA	INDIA
1986-87	20 62	20 57
1993-94	24 53	21 41
1994-95	28 20	23 00
1995-96	31 47	23 00
1996-97	31 59	23 00
1997-98	32 50	23 50

C TRANSMISSION AND DISTRIBUTION SYSTEM

The Table III illustrates the system voltages and quantity of substations, transformers and lines that make up the transmission and distribution systems There are approximately 54,150 circuit-km of high-tension (HT) feeders, 99,524 distribution transformers in service and 103,215 circuit-km of low-tension (LT) lines

TABLE III
SYSTEM VOLTAGE LEVELS AND
QUANTITY OF SUBSTATIONS AND LINES

SYSTEM VOLTAGES (KV)	SUBSTATIONS	LINES (CKT- KMS)
400	3	N/A
220	24	860
132	74	2,018
66	68	1,688
33	252	4,275
HT	99,524	54,150
LT		103,215
Totals	**99,942**	**166,206**

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D EMPLOYEES

The HSEB total number of employees is 46,597 distributed as shown in Table IV

TABLE IV
CLASSIFICATIONS
AND NUMBER OF EMPLOYEES

EMPLOYEE CLASSIFICATION	NUMBER
Graduate Engineers	1,371
Accountants and Other Officers	175
Technical Staff	30,800
Non-Technical Staff	14,251
Total	**46,597**

E TRAINING CENTERS

There are seven training centers located throughout the service territory of the HSEB Each training center can accommodate about 30 trainees at the time

F HSEB ORGANIZATION

The Haryana State Electricity Board structural organization is as shown on Slide 47 of Attachment I The smallest organizational working unit is the Subdivision Office (SDO) under the responsibility of a subdivision officer (SDO) The SDO scope of responsibilities include preparation of technical and cost estimates for new consumer connections, issuance of connection and disconnection orders, meter reading of energy consumption, consumer billing and collection of revenues, correcting system break downs and resolution of consumers billing complains Also, he is responsible for the operation and maintenance of the transmission substations and lines as well as for the distribution system

Slide 47 shows that the next hierarchical levels within the organization are the Division and the Circles The Division is under the responsibility of an Executive Engineer Each Division supervises four to five SDOs It is the Divisions responsibility to review periodic reports, prepare annual budgets and monitor SDO's performance Each Circle is responsible for four to five Divisions The Circle is under the responsibility of a Superintendent Engineer

The Circle Superintendents report to the Chief Engineers Zone There are three Zones and 19 Circles The Circles include Operation, Metering and Protection and Construction Circles

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TABLE V lists the Operation Circles by name

TABLE V

SERIAL No	OPERATION CIRCLE
1	Ambala
2	Yamuna-Nagar
3	Kurukshetra
4	Karnal
5	Sonepat
6	Faridabad
7	Gurgaon
8	Narnaul
9	Rohtak
10	Hisar
11	Sirsa
12	Biwhani
13	Jind

III DISTRIBUTION SYSTEM PROBLEM AREAS

At present the Haryana State Electricity Board operates and maintains all transmission and distribution substations The operating voltages and the number of substations, as stated in Table III, are 24 - 400/220 kV, 74 - 132 kV, 68 - 66 kV and 252 - 33 kV for a combined total of 418 substations This will change when HSEB gets subdivided into a Generation Company (GENCO), Transmission Company (TRANSCO) and a Distribution Companies (DISCOs) The present plan is that the DISCOs will be responsible for the operation and maintenance of the 33 kV and lower voltage substations and systems The problem areas identified herein are derived from an evaluation of the existing conditions at substations, feeders and distribution transformers

Attachment I, Part I, and Attachment II, Part II, include a series of slides that were used during the workshop presentations given to the Haryana State Electricity Board Chairman and Members as well as to key staff of the HSEB

A PART I-DEFICIENCIES

1 Generation Resources

The total generation resources of HSEB are illustrated in Slide No 6 Including purchases the generating resources amount to about 2,700 MW of capacity and 13,000 GWh of energy These are the basis to calculate the HSEB energy losses

2 Energy Sales

Slide 7 shows the total energy sales by consumer classes Total sales for the fiscal year 1996-1997 period are 8760 GWh The largest load class in terms of GWh is the industrial consumer class followed by the residential class with 23 and 18 72 percent sales respectively

3 System Losses

Based on the data shown on slides 6 and 7 the total system losses amount to 31 percent of the energy resources (Slide 8) These losses are assumed to include technical losses resulting from the characteristics of the electric power transmission and distribution systems and losses derived from illegal connections, billing and reading errors as well as defective meters The energy losses are 3,993 GWh and the estimated auxiliary power losses at the generating power plants is 64 MW

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Slide 9 shows the technical and economic effect of these losses A power plant or an equivalent purchase of 760 MW is needed to supply the losses on annual basis If these loses are reduced by 15 percent from 31 percent, there will be an equivalent reduction in the production of capacity and energy of 380 MW or a reduction of purchases of 380 MW

Assuming an investment requirement of US $ 1,000/kW in generation capacity, reducing power losses by about half will defer the installation of 380 MW power plant to supply future load demand as well as an investment of US $ 380,000,000

4 Consumers By Class

Slide 10 illustrates that as of February 1998 there were 3,381,486 consumers The residential class is the largest contributor with 77 percent of the total number of consumers followed by the agricultural sector The industrial consumer class is only about 2 % percent of the total

5 Employees

HSEB has about 46,000 employees, which includes about 40,000 distribution system employees A review of the total number of consumers versus the number of distribution system employees shows that the ratio of consumers to employees is 84 5 as shown on Slide 11 This ratio shows an overstaffing problem that is affecting the distribution system's efficiency

Slide 12 indicates that the number of available engineers compared to the entire population of employees is very low A detailed evaluation is needed to determine the need to modify the present ratio of professional to non-professional staff

6 Price Per kWh Per Consumer Class

Slide 13 summarizes the tariff structure before the recent increase approved by the Board It is observed that the 79,000 industrial consumers are subsidizing the 2 6 million residential consumers A cost of service study is needed to determine the actual cost of providing electric service to each consumer class This will have to be the basis for establishing the future electricity rates

7 Distribution Transformers

Slide 14 shows that there are about 100,000 transformers installed at the present time The available records show that there is an annual distribution transformers failure rate of 31 percent This failure rate is rather high with a significant financial impact upon the HSEB Slide 15 shows that HSEB has been repairing transformers for some time There are ten transformer repair shops that are operational Each of these shops is operating at maximum capacity As a result HSEB has been forced to subcontract the repair of transformers to outsiders

In spite of having more than double the repair capacity by subcontracting out transformer repairs, there are 16,000 distribution transformers waiting to be repaired

Also, the HSEB has relaxed the repair criteria to allow an increase in the no-load and load losses An increase of twenty percent in the losses is acceptable to the HSEB as shown on Slide 16 Slide 17 and 18 illustrate the economic impact upon the HSEB of such a large increase in no-load losses of transformers that are sent back to the field Over a two-year period these incremental losses will cost HSEB about 148,000,000 Rupees This amount does not include the cost of the load losses for which there is a similar allowance of 20 % increase on the repair criteria

Based on available information, HSEB repaired in 96-97 about 11,713 distribution transformers and the private contractors repaired over the same period 16,092 distribution transformers The situation is alarming and appears to be out of control

8 Training Needs

Slides 19 through 26 are self explanatory of other problems affecting the HSEB, including areas for which training will be required It is necessary that adequate training be provided for the optimum use of the material that is being procured under the AP-L1 World Bank loan

B PART II

Based on the recent failure of five power distribution transformers, Chairman HSEB request IRg to conduct an investigation to the determine the causes of these failures In addition, he requested that a preventive maintenance document be prepared for use by the HSEB maintenance staff

1 Substations Visited

The schematic diagram shown on Figure 1 illustrates the northern part of the Haryana service territory A number of high voltage substations were visited including Pinjore, Babyal, Manda Pur, Hissar, Karnal, Shahabad, Narwana and others shown in the map of Figure 1

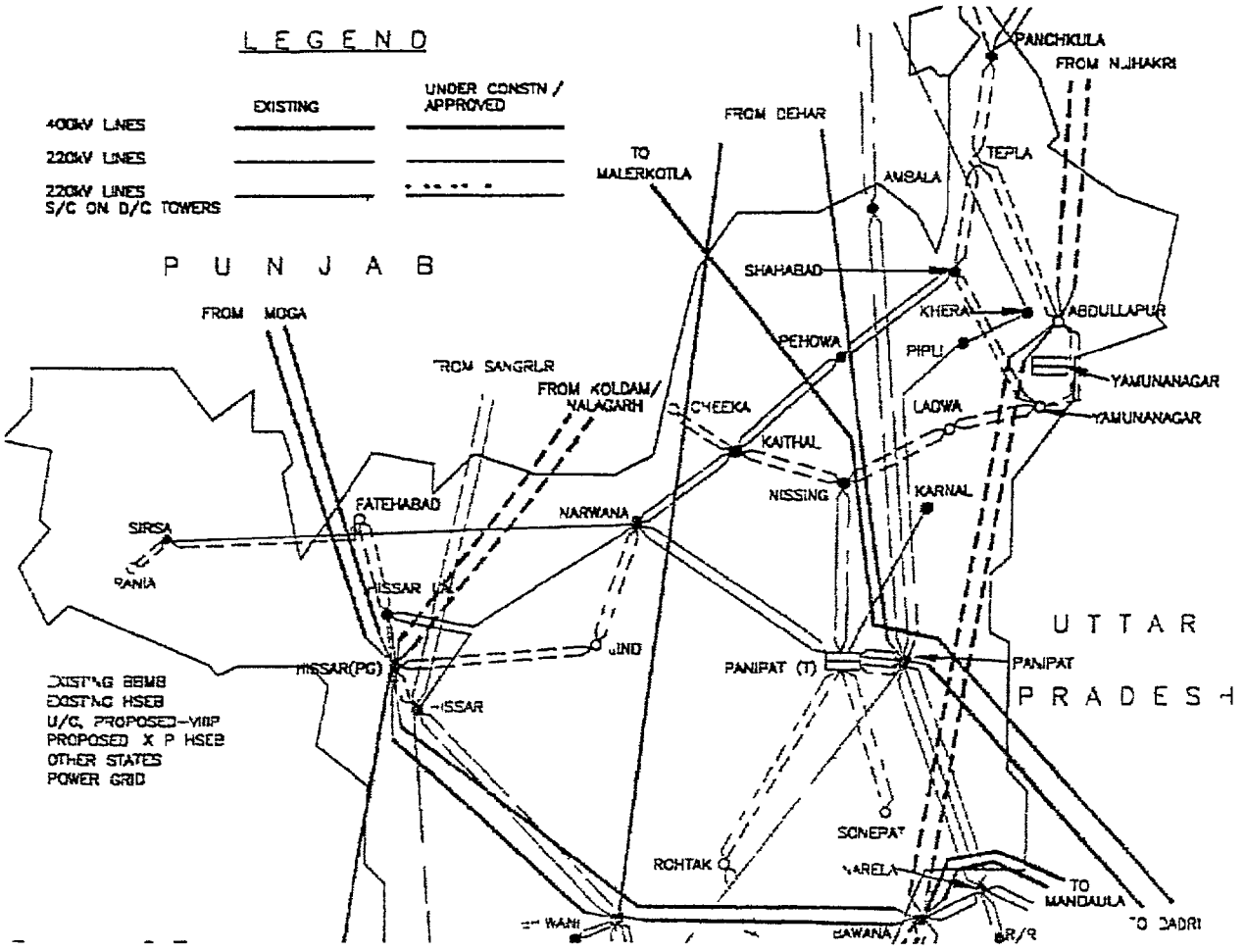

FIGURE 1- MAP OF HARYANA STATE ELECTRICITY BOARD

2 Lightning and Switching Surges-Protection System

Slides 7-10 illustrate that the operational performance of the lightning arresters There were intended to show the importance and benefits of having them operational at all times In a similar manner a description of the system protection is given

3 Lightning Arresters

The lightning arresters are installed to provide protection to HSEB's most valuable equipment, the power transformers Substations were found without these devices installed These are sufficient causes for the failure of the various transformers in addition to the defective protection systems

4 Breakers And Protection System

A breaker at one of the substation was found out of service due to internal damage The breaker was providing protection to a large bank of capacitors at the substation There are many of the substations that require proper maintenance of the breakers as well as the protection system The remaining Slides illustrate the actual conditions at some of the substations visited

C PARTS I AND II-CORRECTIVE ACTIONS

1 System Technical Losses

a Substations

At the substations the system losses occur at the main power transformer, core, load and auxiliary losses Also, the use of non-standard connections (twisted or wrap around splicing), non-utilization of bimetallic, compression and/or parallel groove connectors, as well as continuous use of non-essential equipment, all of these are sources of system losses

b Distribution System Technical Losses

Technical losses are losses derived from the electrical characteristics of the substations and distribution system The distribution system losses occur at the distribution substation transformers and auxiliary equipment, high tension and low tension feeders, distribution transformers and revenue metering system

c High tension Feeders

On the high tension feeders, the major source of power losses is unbalanced loading of the individual feeder phases, under sized conductors, low power factor and excessive feeder lengths between the substation and the power delivery points

d Distribution Transformers

The system losses on distribution transformers are the result of the transformer design and the materials used to build the transformer as well as a function of the transformer load current These losses are referred to as "core losses and load losses Core losses are constant as long as the transformer remains energized The 'load losses" increase in proportion to the square of the load current as the load increases

e Voltage Regulators

Voltage regulators when available are installed at key locations on the high-tension feeders and/or at substations to maintain voltage at specified limits If the voltage regulation level is not properly set, the additional regulator impedance resulting from operating the regulator in the extreme upper-tap ranges increases power losses Voltage regulators also have core and load losses

2 Approach To Reduce Power Losses

The approach to reduce the technical losses and the substation power and distribution transformers failures is to provide on the-job-training and classroom training to key staff of the HSEB The steps leading to the meeting project objectives are as follows

a Organize Teams

Organize teams formed by IRG consultants and HSEB substation and operation and maintenance, and engineering staff The selected staff must be experienced and familiar with their system configuration and overall performance

The teams will work under the technical guidance of a System Planning, System Protection and Substation and Line Construction specialists

Each team will work separately on each of the tasks with each corresponding specialist providing the technical guidance as needed

b Equipment installation

The data loggers, voltage monitors will be installed at key locations during the performance of the work for a period not to exceed three days These data will be used as input to the computer program to simulate existing distribution system conditions

c One-Line Diagram Development

Develop a geographical One-Line Diagram (S) for selected distribution substations that are currently highly overloaded Feeders emanating out of selected substations will be represented in the computer program by their electrical parameters Assisted by the staff from the selected Division, the one line diagram will be developed showing the geographical configuration of the system under study, indicating distances, location of distribution transformers along the feeders and the electrical characteristics in terms of line impedances

d Current and Voltage Measurements

Prior to the undertaking of any major changes in system configuration, measurements will be taking of current and voltages at selected points in the system The objective of this activity is to collect data before any changes are made to the configuration of the system and then to collect equivalent data after the system modifications are made This will permit the calculation of the economic benefits derived from the modifications made to high-tension system and substation

e Short Range Planning Studies

Based on the geographical system configuration shown on the one-line diagram and the electrical system characteristics, short-range planning studies will be made Voltages, power flows, power losses and location of capacitors will be determined Larger ones will replace distribution transformers as the need justifies it, feeders bifurcated, and loads transferred in an effort to reduce system losses by optimization of the system configuration

f System Modification Implementation

Assisted by the O&M staff of HSEB and utilizing the HALO ammeters, a load-centered effort on the low-tension side of the distribution system will be made

g System Protection

Starting at the 220 kV substations, evaluations will be made of the existing system that protects the power transformers Relays will be examine for consistency with their intended function and coordination between transformer and feeder breakers/fuses will be made to minimize substation outages by selective tripping of the various devises including fuses

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h. Lightning Arresters

The substation lightning arresters type, size and proper physical location will also be evaluated to ensure adequate protection from lightning and surges.

i Scanning Equipment

At the substations scanning will be made of the equipment and busses and bus connections to identify hot spots

Distribution transformers of the selected substation will be scanned to identify overloaded transformers and those operating at high temperatures The HSEB staff under the supervision of IRG staff will replace distribution transformers

3 Distribution Transformers Installation

The present practice of not having practically no protection on distribution transformers is the major contributor to the large number of transformer failures Distribution transformers do not have fuse cutouts, fuses and/or lightning arresters Figure 2 illustrates a typical distribution transformer installation with adequate protection to prevent damage during lightning, surges, and over currents flowing through the transformers caused by overloading conditions

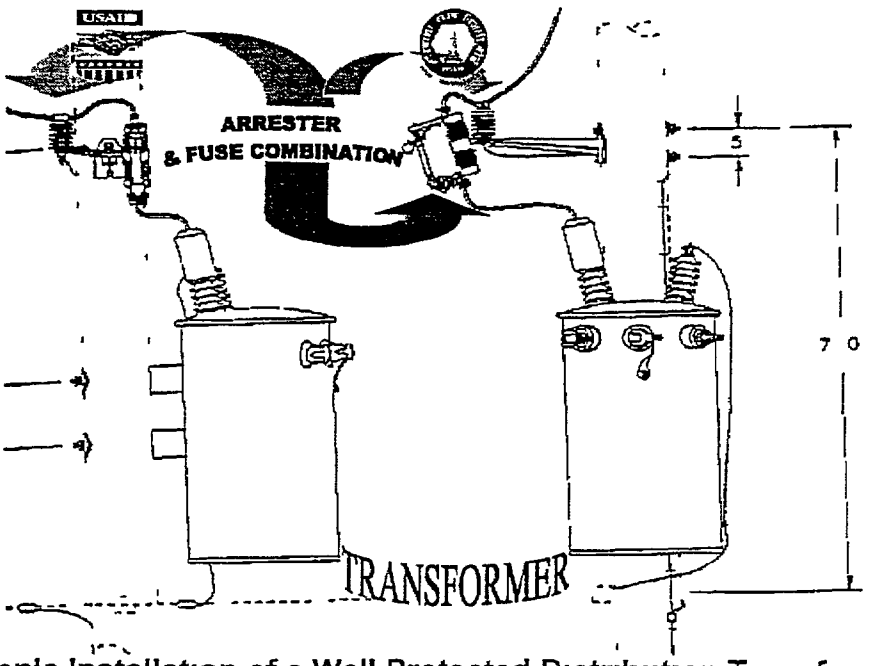


Figure 2 -Sample Installation of a Well Protected Distribution Transformer

4 Power Transformers

As in the case of the distribution transformers, the power transformers failures can be attributed to the lack of adequate protection such as lightning arresters, defective auxiliary equipment, batteries and battery charges, protective relays and breakers and lack of spare parts to provide the preventive maintenance

5 Capacitors

Capacitors as stated in various Slides of Attachment II are one of the most valuable pieces of equipment of a power system They release system capacity, improve voltage regulation and reduce power losses The capacitors as shown on the Slides were found at almost every substation disconnected from the system An inventory of these capacitors is necessary to determine what is available for use at the appropriate locations on the 11 kV distribution system

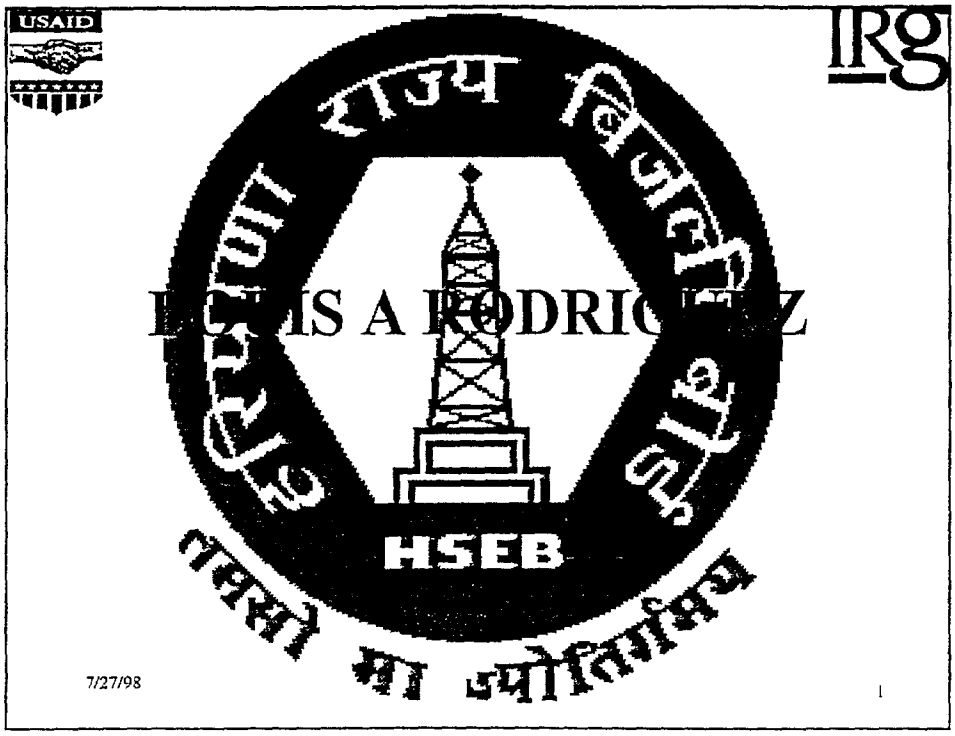
Training is necessary on the technical and economic benefits of the capacitors as well as on the optimum location on the power system

ATTACHMENT I

SLIDES PART I

WORKSHOPS OF JUNE 4, JULY 22 AND 23 1998

WORKSHOP-HARYANA STATE ELECTRICITY BOARD-ZONE I
WORKSHOP-POWER FINANCE CORPORATION LTD
WORKSHOP-HARYANA STATE ELECTRICITY BOARD-ZONE II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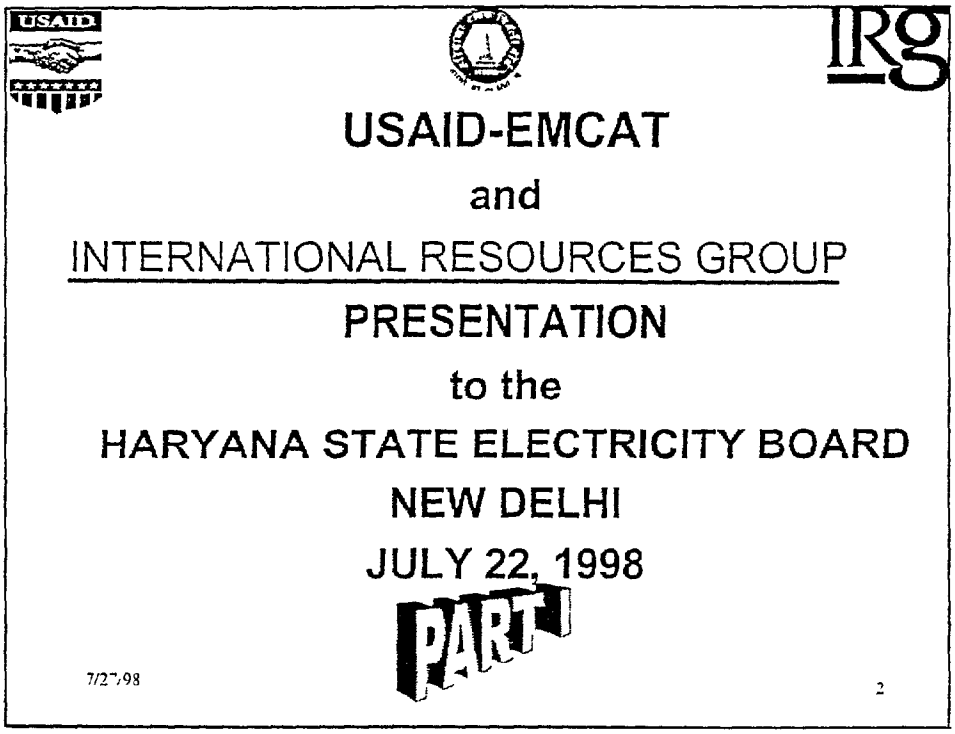
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to the
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NEW DELHI
JULY 22, 1998
PART I
7/27/98
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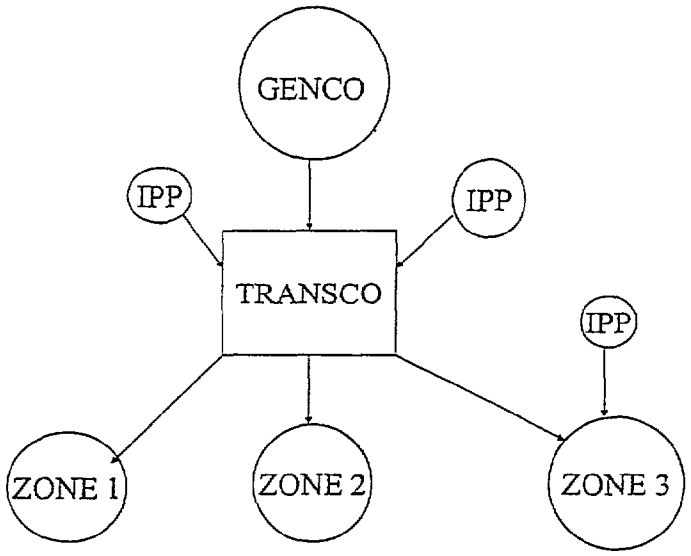
22

BACKGROUND

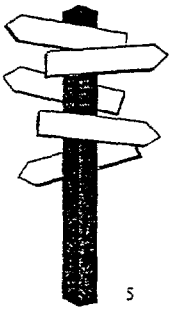
- THE STATE ELECTRICITY BOARD WILL BE SUBDIVIDED INTO DISTRIBUTION ZONES
- EACH ZONE WILL BE MANAGED BY AN INDEPENDENT COMPANY
- INITIALLY THESE ZONES WILL BE OWNED BY STATE GOVERNMENT
- SUBSEQUENTLY THE ZONES WILL BE PRIVATIZED



SCOPE OF WORK

In a level of effort, the Scope of Work is to examine

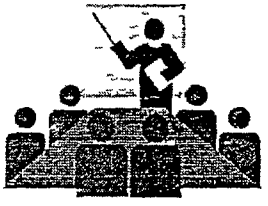
- The operating efficiency of the existing Distribution Zones This includes a review of the existing
  - Structural organization,
  - Training programs
  - Operation and maintenance procedures
  - Procedures to reduce system losses



SCOPE OF WORK (Cont.)

All activities leading to the formation of self sufficient Zones which are

- Financially viable
- Managerially capable
- Professionally sound
- Staffed to provide reliable service to all consumers
- To generate their own revenues to cover all expenses while providing adequate RR to PIs



GENERATION RESOURCES

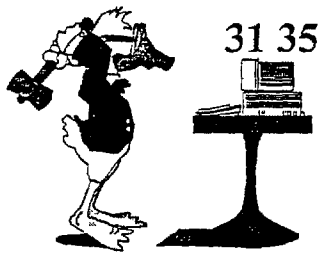
GEN TYPE	MW	GWh	PLF(%)
• HYDEL	884 0	3,342	43
• THERMAL	877 5	3,675	48
• PURCHASES	1,000 0	6,112	70
• AUXILIARIES	(64 0)	(391)	
TOTALS	2,697 5	12,738	

ENERGY SALES

CLASSIFICATION	GWh	DIST (%)
• RESIDENTIAL	1,637	18 72
• COMMERCIAL	258	2 95
• INDUSTRIAL	2,017	23 06
• AGRICULTURE	3,904	44 64
• OTHER	929	10 63
TOTAL	8,745	100 00

SYSTEM LOSSES

- ENERGY SUPPLIED 12,738 GWh
- ENERGY SALES -8 745 GWh
- ENERGY LOSSES 3,993 GWh
- **PERCENT** **31 35%**



EQUIVALENT SYSTEM LOSS IN MW

- ENERGY LOSSES ARE 3,993 GWh
- ASSUME A LF OF 60%
- EQUIVALENT POWER LOSSES IS 760 MW
- ASSUME ENERGY LOSSES CAN BE REDUCED TO 15% FROM 31%
- WHICH IS **EQUIVALENT TO 380 MW REDUCTION IN PURCHASED POWER**

CONSUMERS BY CLASS (FEBRUARY 1998)

CLASS	NUMBER	% DIST
• **RESIDENTIAL**	**2,598,372**	**76.85**
• COMMERCIAL	330,128	9 76
• INDUSTRIAL	78,805	2 33
• **TUBEWELLS**	**365,395**	**10.80**
• OTHER	8,736	0 26
TOTAL	**3,381,486**	**100.00**

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EMPLOYEES

ESTIMATED BREAKDOWN

- DISTRIBUTION 40,000
- G & T 6,000
- TOTAL 46,000

CONSUMERS PER DIST EMPLOYEE

3,381,486/40,000 =

84.5 CONSUMERS PER EMPLOYEE

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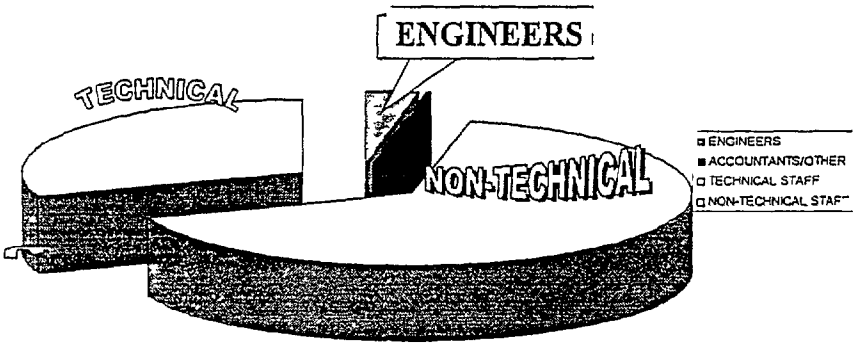
EMPLOYEES BY CATEGORY



PRICE PER kWh PER CONSUMER CLASS

CLASS	CLASS	Rs/kWh
• Residential	2598372	2 18
• Commercial		3 36
• Industrial	78,805	3 52
• **Agriculture**		**0 69**
• Bulk		3 09
• Railway		3 78
• Street Light		8 91
• Board Supply		12 00

SUBSIDY

COST OF SERVICE

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DISTRIBUTION TRANSFORMERS

- IN SERVICE BY 4-97 97,280
- IN SERVICE BY 2-98 99,558
- INCREMENT 2,278
- DAMAGED DURING FEB -98 1,904
- REPAIRED DURING MAR-98 957
- REPAIRED OUTSIDE MAR-98 1,773
- CUMULATIVE DAMAGED 31,345

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USAID

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DISTRIBUTION TRANSFORMERS

- **AVAILABLE REPAIR SHOPS 10**
- **AWAITING REPAIR 16,236**
- 96-97 REPAIRED BY SEB 11,713
- 96-97 REPAIRED BY PRIVATE 16,092 ⟸

TOTAL REPAIRED 27,805

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DISTRIBUTION TRANSFORMERS

NO LOAD LOSSES LIMITS-**before 1981**

SIZE (kVA)	Orig Watts	Limit Watts	CHANGE (kWh)
• 25	195	234	342
• 63	350	420	613
• 100	450	540	788

DISTRIBUTION TRANSFORMERS

- REPAIRED IN 96-97 **27,805**
- ASSUMED 38% 25 kVA 10,566
- ASSUMED 31% 63 kVA 8,620
- ASSUMED 31% 100 kVA 8,620
- BASED ON (342 kWh/T x 10 566T x Rs 3 0/kWh) = Rs 10,840,716

10,840,716+15,852,180+20,377,680

= Rs. 47,070,576 or US $ 1.18 million/year

DISTRIBUTION TRANSFORMERS

REPAIRED 96-97 OF 27,805 Rs. 47,070,576

REPAIRED 97-98 OF 31,345 Rs. 53,063,377

2ND YEAR OPERATION Rs. 147,204,529

Exclusive of actual repair, transportation costs, removal/installation labors costs and material charges. Also, core losses cost estimate does not include full load losses incremental costs.

DISTRIBUTION TRANSFORMERS

- INCOMING INSPECTION PROCEDURES DO NOT VERIFY TRANSFORMER LOSSES
- EVALUATION OF BIDS IS BASED ON "LOWEST INITIAL INVESTMENT COST" RATHER THAN ON ECONOMIC EVALUATIONS
- HIGHER EFFICIENCY TRANSFORMERS USING AMORPHOUS MATERIAL ARE NOT SPECIFIED ON TRANSFORMERS

WB -UPGRADING METER TESTING LABORATORIES (T)

- Commission one modern test laboratory utilizing modern meter testing equipment which also allows for testing of electronic meters
- Computerized the existing 14 meter testing, repair and calibration laboratories

WB - OTHER PROCUREMENT (T)

- ABOUT 180,000 METERS
- 5,000 - 36 kVAr SWITCHABLE CAPACITORS
- 20 PC COMPUTERS TO BE LOCATED AT SDO WITH REVENUES > 1 CRORE
- COMPUTERIZE BILLING AND COLLECTION SYSTEM FOR GENERAL CONNECTIONS (NETWORK 20PCS)

WB - OTHER PROCUREMENT (T)

- COMPUTERIZED COMPLAINTS RECORDING SYSTEM
- 17 MOBILE RADIO COMMUNICATION SYSTEM BASE STATIONS PLUS TEN MOBILES
- 45 BASE PLUS 4 MOBILE RADIOS
- 100 PAGERS FOR SUPERVISORY STAFF

TRAINING

WB - 33 kV SUBSTATIONS UPGRADING (T)

- PROCUREMENT OF 48 - 6 3 MVA TRANSFORMERS TO UPGRADE 24 OVERLOADED SUBSTATIONS
- TRANSFORMER SUBSTATION TOTAL CAPACITY WILL BE INCREASED FROM 170 2 MVA TO 302 2 OR 132 2 MVA ADDED TO THE SYSTEM

ECONOMIC EVALUATIONS

PLANNING

WB -10,000 SAFETY KITS (T)

A KIT INCLUDES

- Insulated Pliers
- Insulated Screw Drives, Wrenches
- Rain Coats
- Safety Belts
- Rubber Hand Gloves
- Test Pens and Torches, etc

HARD HATS & RUBBER SHOES

TRAINING

WB - DISTRIBUTION TRANSFORMERS

TRANSF SIZE	QTY	UC	Rs (LACS)
100 kVA	5,000	45,000	2,250
200 kVA	500	80,000	400
L Arresters	5,500	1,060	58
G O Switches	5,500	3,900	216
Grounding Sets	5 500	1 000	55
TOTAL COST			**2,979**

PROTECTION

IN US $ 7.5 MILLION

FUSES ?

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WB -TRANSPORTATION FLEET (T)

• Pick -Up/Vans	100
• Supervisors Inspection Vehicles	50
• Heavy Duty Trucks	45
• Meter Vans	45
• Cable Jointer Vans	13
• Mobile Cranes	13
• **TOTAL**	**266**

- **COST (Rs. 10 Crores) US $2.5 million**

MOTOR POOL

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IMPROVE SYSTEM OPERATION EFFICIENCY AND

REDUCE SYSTEM POWER LOSSES

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SOURCES OF TECHNICAL ENERGY LOSSES

- REVENUE METERING
- SUBSTATIONS Transf/Conn
- HIGH TENSION feeders
- DISTRIBUTION TRANSFORMERS
- LOW TENSION Conductors
- SERVICE DROP Conductors

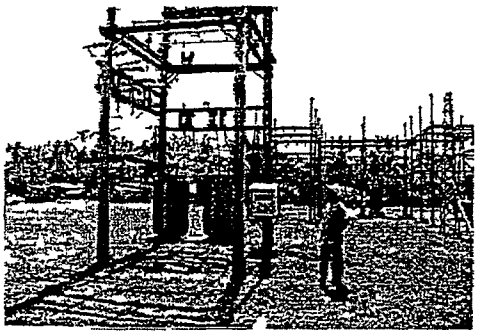
APPROACH-PRODUCTIVE OJT

OBTAIN AND USE ADEQUATE TOOLS:

- THERMO VISION SCANNER
- LOAD LOGGERS
- HALO AMMETERS
- LINE VOLTAGE MONITORS
- CAPACITOR BANK TO MEASURE PF
- DISTRIBUTION SYSTEM PLANNING SOFTWARE
- ORGANIZE TEAMS

SUBSTATION

INSPECT AND SCAN FOR HOT SPOTS



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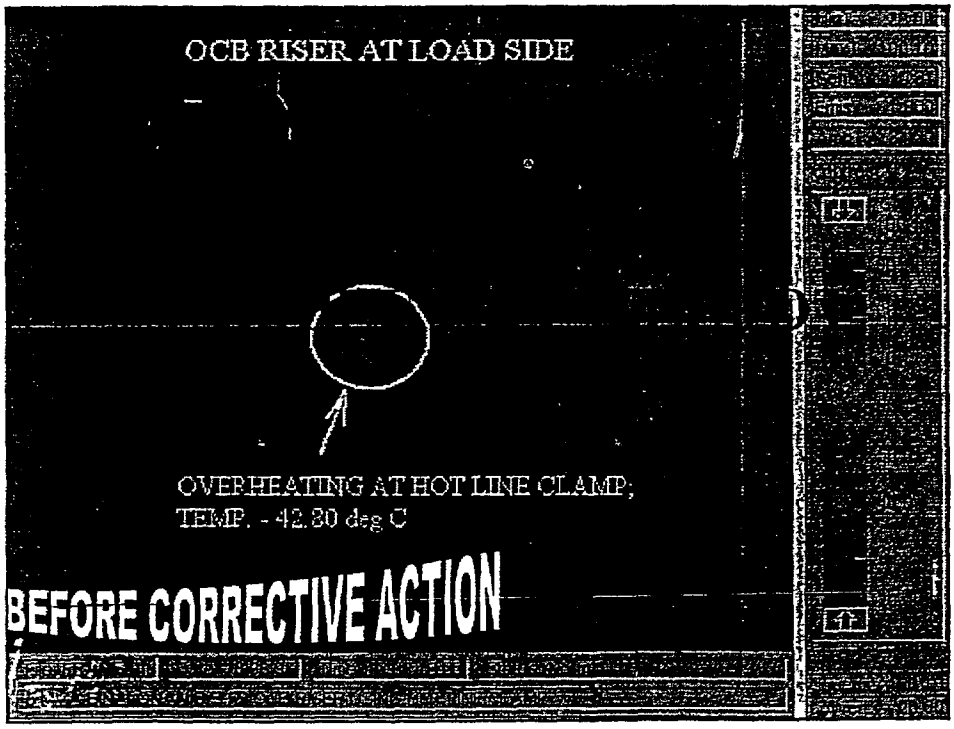

SUBSTATION

AT THE TIME OF SUBSTATION LOAD PEAK

- SCAN ALL CONNECTIONS AND EQUIPMENT
- IDENTIFY MODIFICATIONS
- PREPARE LIST OF MATERIAL

SUBSTATION

IMPLEMENT MODIFICATIONS

SUBSTATION

INSPECT COMPLETED WORK

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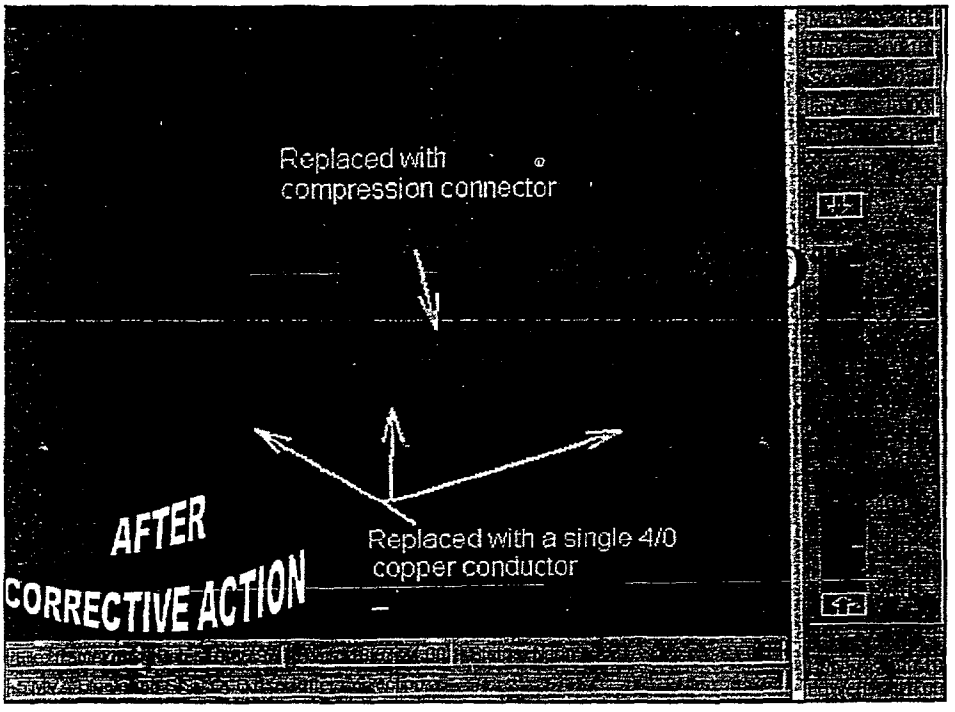
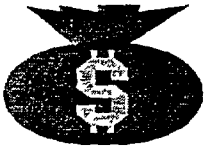


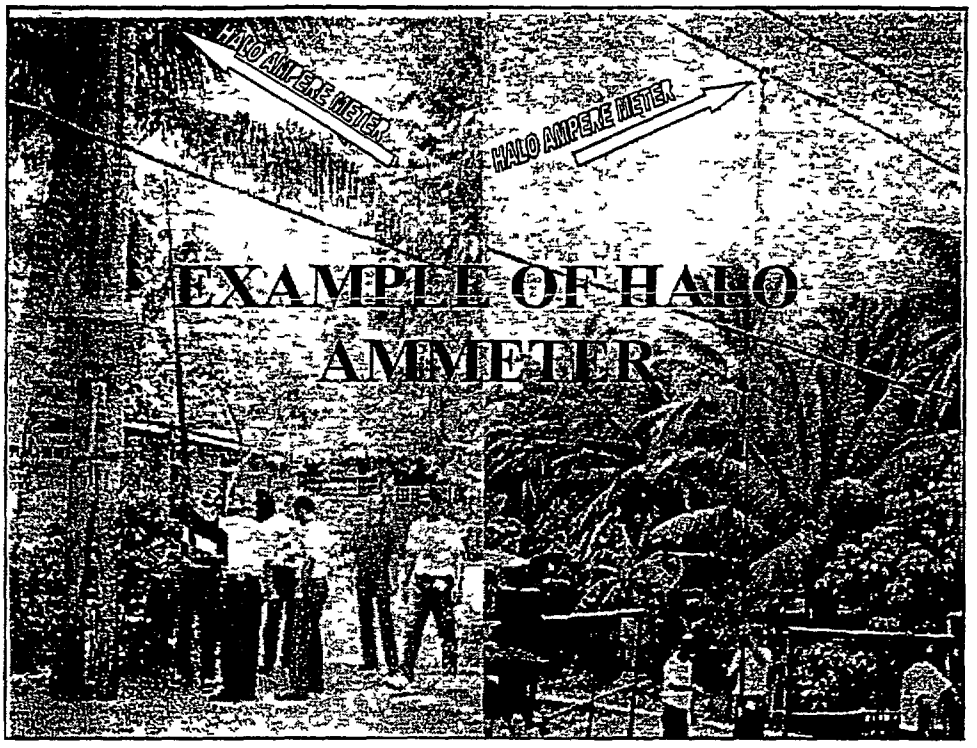
SUBSTATION

- VERIFY THAT HOT SPOTS HAVE BEEN REMOVED
- MEASURE RESISTANCE ACROSS THE CONNECTIONS TO DETERMINE IMPROVEMENTS
- CALCULATE ECONOMIC BENEFITS



OPERATIONS & MAINTENANCE

- HIGH TENSION SYSTEM COLLECT DATA
- INSTALL LOAD LOGGERS & LVMs
- DEVELOP SINGLE LINE DIAGRAM SHOWING
  - CONDUCTOR SIZES AND LENGTHS
  - TRANSFORMERS LOCATION & KVA
  - CAPACITORS IN kVAr



O & M

- COLLECT LOAD LOGGERS & LVMs DATA
- REPRESENT HT SYSTEM IN PLANNING SOFTWARE (S&S) PROGRAM
- VERIFY DATA
- CALCULATE POWER FLOWS, VOLTAGES AND POWER LOSSES B/O EXISTING SYSTEM
- DEVELOP ALTERNATIVE IMPROVEMENTS

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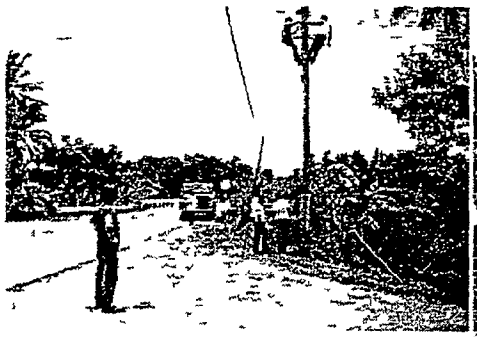
O&M

IMPLEMENT ACTIONS AS DERIVED FROM THE S & S STUDIES



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ACTIONS

- LOAD CENTERED DIST TRANSFORMERS
- INSTALL CAPACITORS
- RELOCATE EXISTING CAPACITORS
- ADD TRANSFORMERS
- BIFURCATE FEEDERS
- RECONDUCTOR
- REHABILATE FEEDERS

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O&M

BENEFIT EVALUATION

- DETERMINE
- ENERGY SAVINGS IN kWh
- DEMAND SAVINGS IN kW
- INVESTMENTS REQUIREMENTS
- PAYBACK PERIODS
- PREPARE ACTION PLAN MATRIX

COMMERCIAL IMPROVEMENTS

- Rehabilitate and rewire metering system
- Computerize manual procedures to save manpower
- Enforce collection and disconnection policies
- Expand energy surveillance teams to reduce pilferage

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PILFERAGE & DEFECTIVE METERS RANDOM SAMPLE

- CONSUMERS CHECKED = 655,615
- RESULTS:

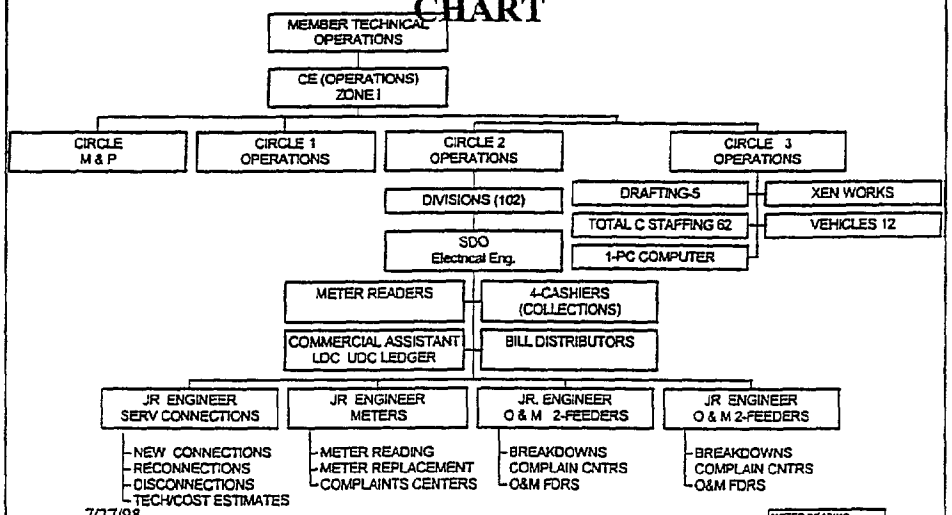
ILLEGAL CONNECTIONS=	14,566
PERCENT	2.22
DEFECTIVE METERS =	84,993
PERCENT	12.96

COMBINED IMPACT 15.2 %

REVENUE RECOVERED

- PROJECTED REVENUE LOSS IN MILLIONS OF RUPEES = 1,456.
- ACTUAL REVENUE RECOVERY IN MILLIONS OF RUPEES = 30.6

SIMPLIFIED EXISTING ORGANIZATION CHART



PROPOSED ACTION PLAN

1 Set Up A "Working Group" To Work On Reorganizing A Circle/Division

2 Identify Need, If Any, For Additional Consultants

3 Purchase Data Collection Equipment And Distribution Planning Software

4 Develop And Implement A Computerized Transformer And Meter Tracking System

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PROPOSED ACTION PLAN

6 Develop And Implement QC System For New And Repaired Transformers Emphasis on Losses and Workmanship

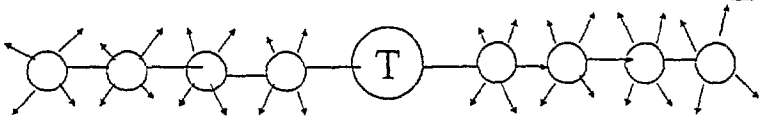
7 Review Bid Evaluations Procedures Lowest Initial Investment Cost May Not Be the Economic Choice for SEB

8 Investigate The Purchase Of Transformer That Use Amorphous Material But That HAVE AT LEAST 60 % LOWER LOSSES

PROPOSED ACTION PLAN

9 Consisting With Proposed Reorganization begin Hiring Some Engineers, Transfer And Retrain Others

10 Initiate Upgrading of LT System by Load Centering The Distribution Transformers



FINAL OBJECTIVE

- INCREASE SEB EFFICIENCY
- PREVENT ADDITIONAL TRF FAILURES
- REDUCE SYSTEM LOSSES
- REDUCE ENERGY PURCHASES
- RELEASE SYSTEM CAPACITY
- INCREASE REVENUES

THIS CONCLUDES PART I OF IRG'S PRESENTATION

ATTACHMENT II

SLIDES PART II

WORKSHOPS
OF
JUNE 18, JULY 22 AND 23 1998

WORKSHOP-HARYANA STATE ELECTRICITY BOARD
WORKSHOP-POWER FINANCE CORPORATION LTD
WORKSHOP-HARYANA STATE ELECTRICITY BOARD-ZONE II

USAID

IRG

हरियाणा राज्य बिजली बोर्ड

HSEB

तमसो मा ज्योतिर्गमय

Louis A Rodrig

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1

USAID

IRG

INTERNATIONAL RESOURCES GROUP

PRESENTATION

TO THE

HARYANA STATE ELECTRICITY BOARD

NEW DELHI

JULY 22, 1998

PART II

7 27/98

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BACKGROUND

- FIVE LARGE POWER TRANSFORMERS HAVE FAILED DURING THE LAST FEW MONTHS
- 1- AT THE Babyal S/S
- 2-AT THE "Hissar" S/S
- 1-AT THE "Panipat" S/S
- 1-AT AT THE "Rotakh"S/S

Scope Of Work

IRG WAS REQUESTED TO

- ASSIST IN IDENTIFYING THE PROBABLE CAUSES OF THE RECENT FAILURES OF LARGE POWER TRANSFORMERS
- MODIFY/ UPGRADE THE EXISTING SUBSTATIONS PREVENTIVE MAINTENANCE MANUAL

SURGES OR TRANSIENTS

- *LARGE OVERVOLTAGES* THAT DEVELOPED SUDDENLY ON ELECTRIC TRANSMISSION AND DISTRIBUTION SYSTEM ARE REFERRED TO AS "SURGES OR TRANSIENTS"
- THESE ARE CAUSED BY LIGHTNING STROKES OR BY CIRCUIT SWITCHING OPERATIONS

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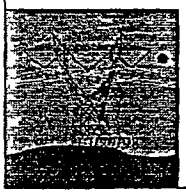
SYSTEM PROTECTION OPERATION

- IF THE POTENTIAL EXCEEDS THE INSULATION LEVEL OF THE EQUIPMENT,
- FLASHOVER WILL RESULT CAUSING A POWER ARC WHICH WILL INITIATE THE OPERATION OF PROTECTIVE RELAYS AND
- REMOVAL OF THE EQUIPMENT/LINE FROM SERVICE



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PARTIAL LISTING OF SUBSTATIONS VISITED

- BHORE
- MADAN PUR
- PINJORE
- HTM HISSAR
- SHAHABAD
- KARNAL
- BABYAL
- HISSAR 220 Kv
- KAITHAL
- PEHOWA

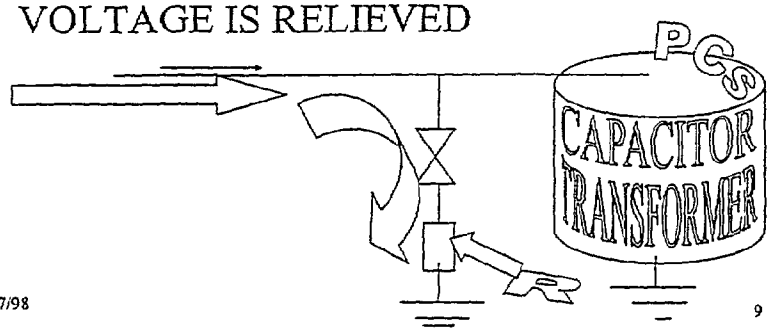
SURGE ARRESTERS

SURGE ARRESTERS PERFORM A TWO FOLD FUNCTION

1 PROVIDE A POINT IN THE CIRCUIT AT WHICH THE OVERVOLTAGE IMPULSE CAN PASS TO EARTH WITHOUT DAMAGE TO LINE INSULATORS, ***TRANSFORMER INSULATION***, MOTORS, ***PCS***, AND OTHER EQUIPMENT

SURGE ARRESTERS

2 PREVENTS ANY SUBSEQUENT FLOW OF POWER CURRENT TO GROUND BY PLACING A HIGH RESISTANCE IN THE CIRCUIT AFTER EXCESS VOLTAGE IS RELIEVED



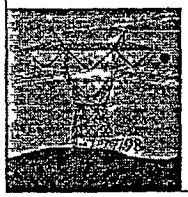
SURGE ARRESTERS

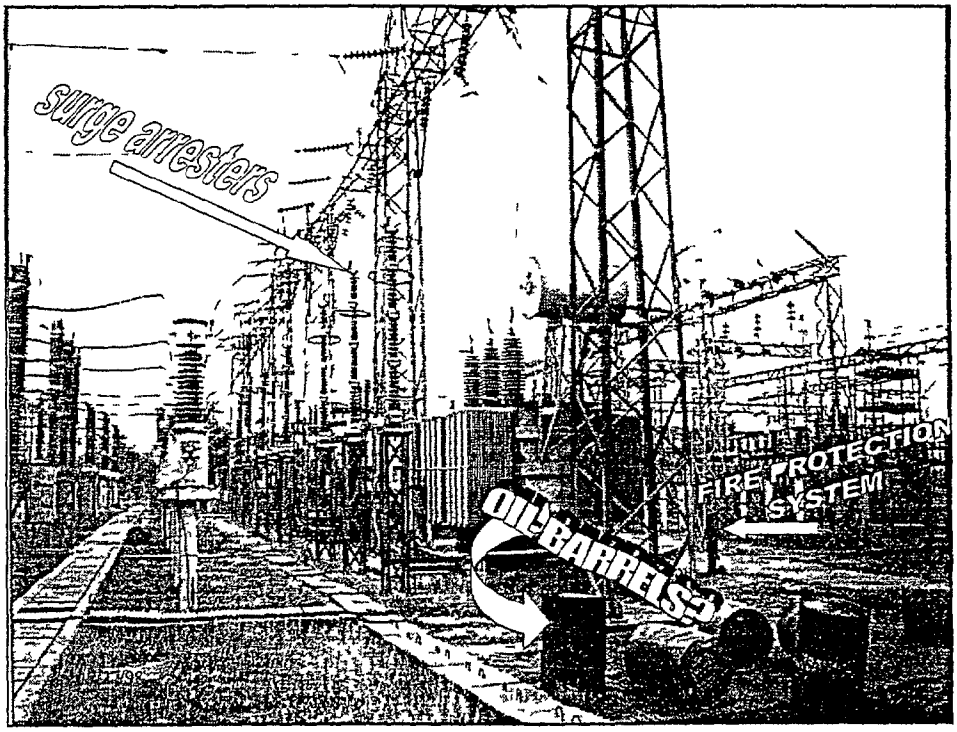
- LIGHTNING OR SURGE ARRESTERS ARE INSTALLED IN A SUBSTATION NEAR THE TERMINATION OF OVERHEAD CIRCUITS AND CLOSE TO
- THE MOST VALUABLE PIECES OF EQUIPMENT, SUCH AS
- POWER TRANSFORMERS

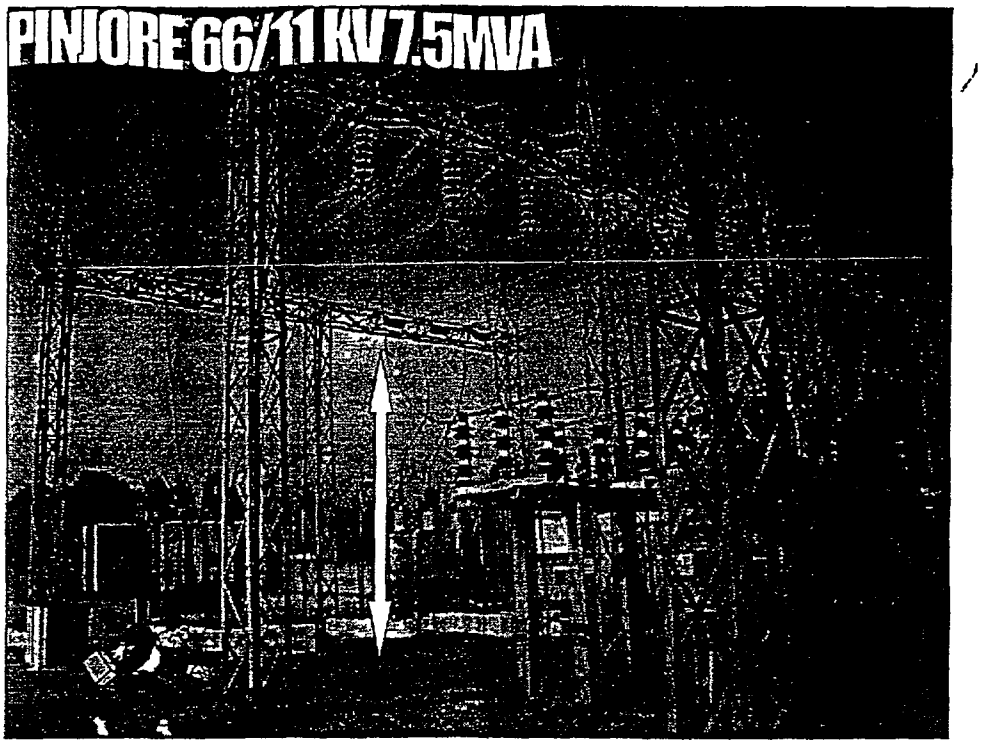
SYSTEM PROTECTION OPERATION

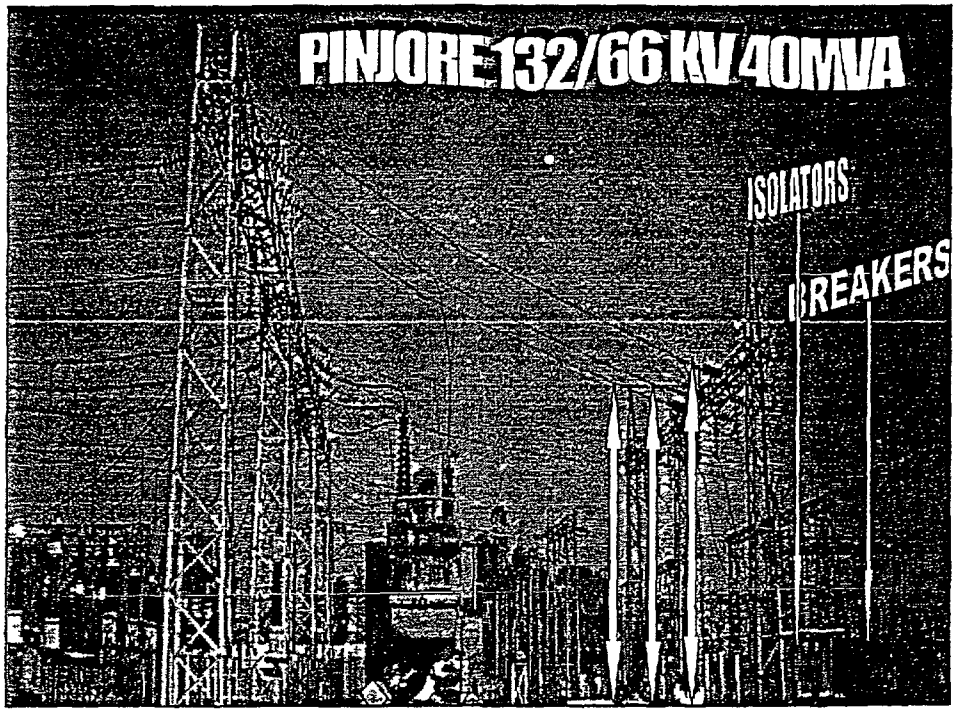
- IF THE POTENTIAL EXCEEDS THE INSULATION LEVEL OF THE EQUIPMENT,
- FLASHOVER WILL RESULT CAUSING A POWER ARC WHICH WILL INITIATE THE OPERATION OF PROTECTIVE RELAYS AND

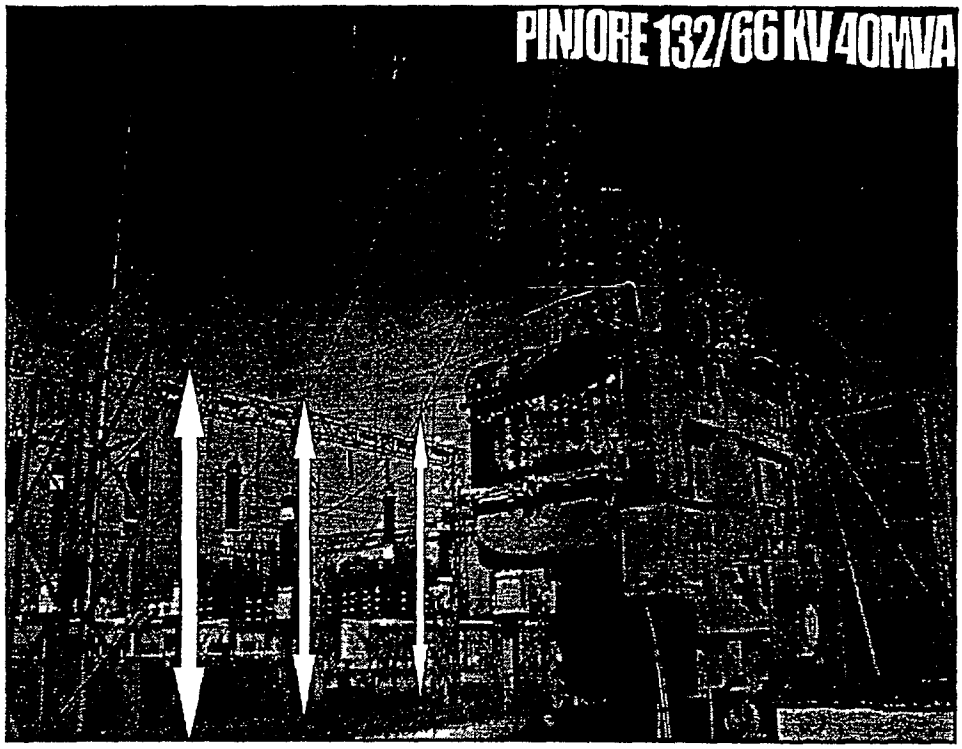
REMOVAL OF THE EQUIPMENT/LINE FROM SERVICE






PINJORE 66/11 KV 7.5MVA


PINJORE 132/66 KV 40MVA
ISOLATORS
BREAKERS

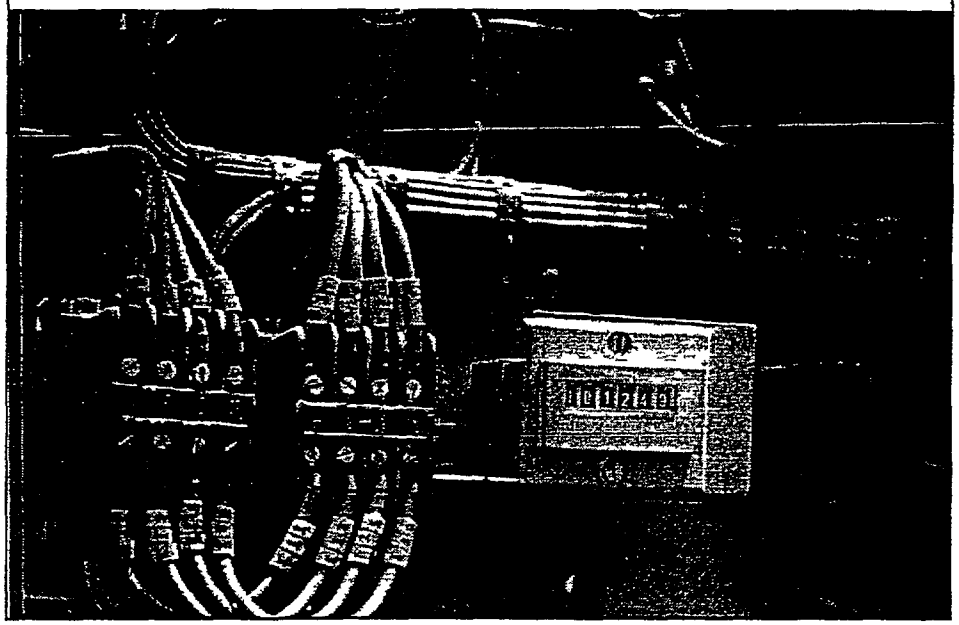


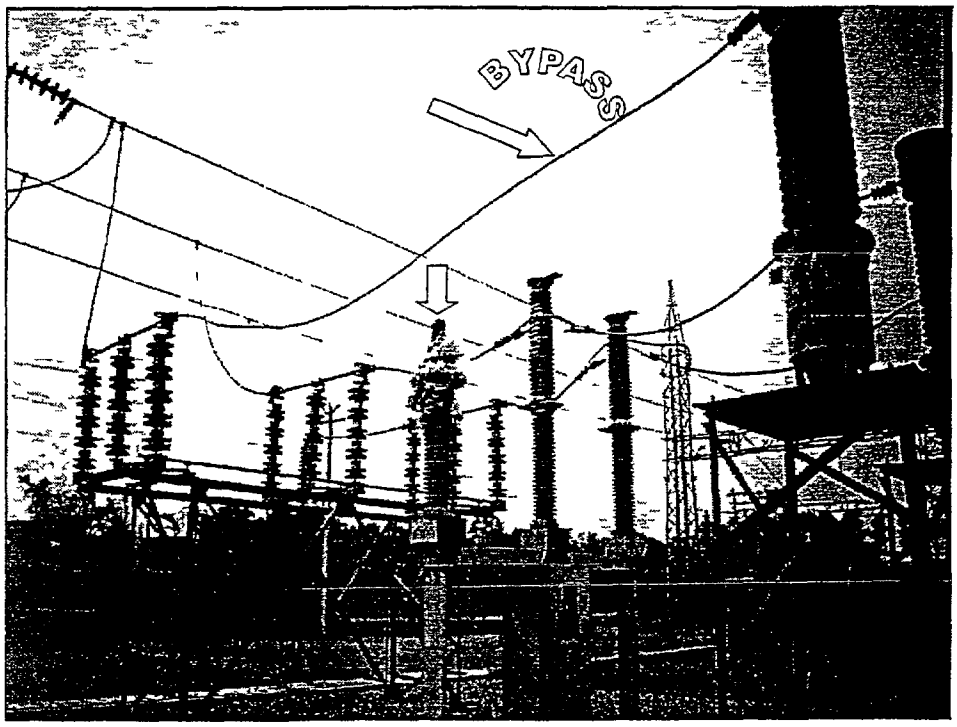
CIRCUIT BREAKER

- IT HAS A MECHANISM THAT MECHANICALLY, HYDRAULICALLY OR PNEUMATICALLY OPERATES A SET OF CONTACTS
- INSULATING OIL, AIR, COMPRESSED AIR, VACUUM, OR SF6 GAS IS USED AS AN ARC - INTERRUPTING MEDIUM

STANDARDIZATION

BRAKER AND SURGE ARRESTERS COUNTERS MUST BE READ AND ANALYZED AS NEEDED





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PEHOWA S/S
BREAKER DAMAGED
AND CAPACITORS O/S
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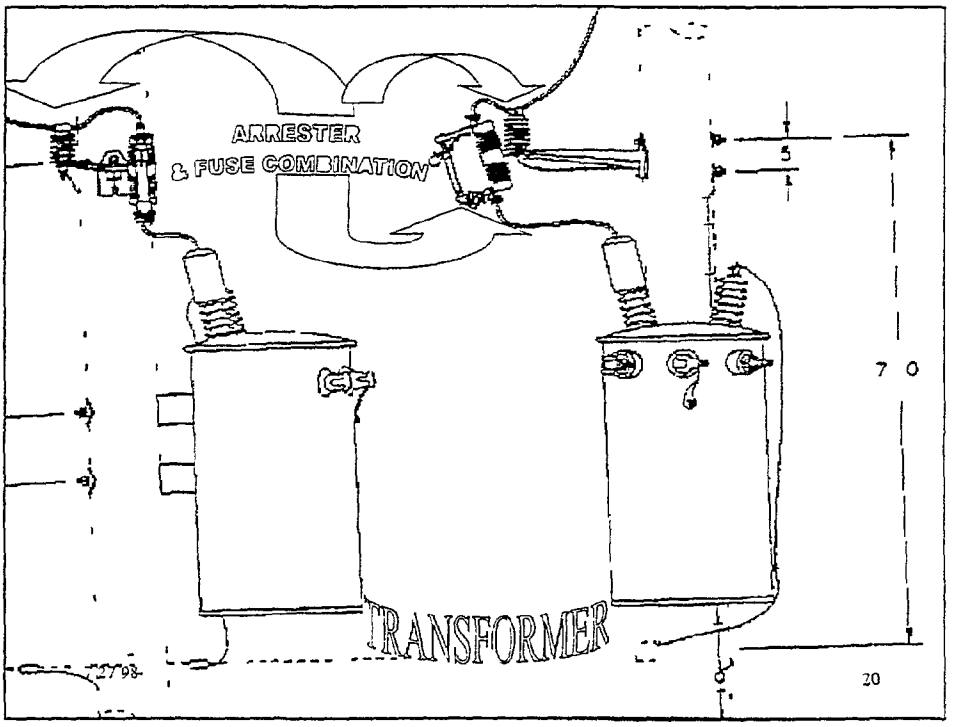
ARRESTER
& FUSE COMBINATION
5
7 0
TRANSFORMER
7/98
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USAID
THIN WIRE
Thick Wire
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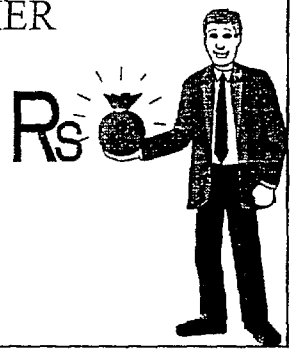
CANNIBALIZING PRACTICE

- OUT OF THREE FAILED TRANSFORMERS TWO ARE USED TO REPAIR ONE
- ANNUAL FINANCIAL IMPACT TO SEB ASSUMING A PER TRANSFORMER AVERAGE COST OF Rs 30,000
- IS 20,000 DTs X Rs 30,000/DT =
- **Rs. 600M**
- OR **US $ 14.3 MILLION (Rs 42/$)**



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BATTERIES

- **CONTROL BATTERIES SUPPLY ENERGY TO OPERATE PROTECTION EQUIPMENT SUCH AS *BREAKERS* AND OTHER EQUIPMENT**
- **DC CONTROL SYSTEMS USE A STORAGE BATTERY AS A SOURCE TO OPERATE EQUIPMENT DURING SYSTEM DISTURBANCES AND OUTAGES** ⟸

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CONTROL PANNELS

- CONTROL PANELS INSTALLED ON A CONTROL HOUSE PROVIDE MOUNTING FOR METERS, RELAYS, SWITCHES, INDICATING LIGHTS, AND OTHER CONTROL DEVICES
- THERE ARE SOME AMPERE METERS WHICH ARE DAMAGED
- ONE CAN NOT TELL WHAT THE LOADINGS ARE ON FEEDERS

NEEDED SPARE PARTS

- SPARE TRANSFORMER OF SUITABLE SIZES
- CIRCUIT BREAKERS, AT LEAST ONE PER CB TYPE
- SUBSTATION LIGHTNING ARRESTERS
- BATTERIES
- AIR COMPRESSORS
- CAPACITORS
- DISTRIBUTION LIGHTNING ARRESTERS
- FUSE AND FUSE CUTOUTS

NEEDED SPARE PARTS (Cont.)

- CLOSING/TRIPPING COILS
- CONTACTS
- WASHERS OF VARIOUS SIZES
- SAFETY VALVES FOR COMPRESSORS
- DRAIN VALVE FOR COMPRESSORS
- RESISTANCES
- RELAYS OF ALL TYPES

PETTY CASH FUND

"NARWANA" 220/132 kV

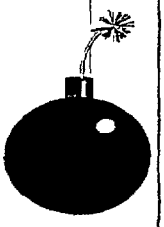
- **EQUIPMENT WITH INSULATING OIL MUST BE CHECKED FOR MOISTURE OR CONTAMINATION OF THE OIL.**
- THE PERIODIC TESTING OF THE 220/132 kV, 50 MVA TRANSFORMER (T3) OIL AT "N" INDICATES THE NEED FOR OIL REPLACEMENT

NARWANA 220/132 kV

- ON THE 220/132 kV, 100 MVA (T2) GASES CONTINUE TO ACCUMULATE SINCE ITS COMMISSIONING DATE
- ONE AIR COMPRESSOR IS NEEDED TO MAINTAIN AIR PRESSURE ON OCBS
- CAPITAL MAINTENANCE IS URGENTLY NEEDED

NARWANA 132/33 kV

- ON THE 33 KV SIDE 24 CAPACITORS CELLS HAVE BEEN DAMAGED OUT OF 84 CELLS
- CAPITAL MAINTENANCE IS OVERDUE ON THE TWO TRANSFORMERS
- THIS IS CONFIRMED BY REVIEWING THE IR VALUES OF 10-15 MOHMS



NARWANA 132/33 kV S/S

- OIL TESTING RESULTS SHOW THE NEED FOR TRANSFORMER OIL REPLACEMENT
- 28 BATTERY CELLS OUT OF 110 ARE DAMAGED
- REMAINING MAY GO AT ANY TIME

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HISSAR S/S

- AN ADDITIONAL 132/66 KV, 50 MVA TRANSFORMER HAS BEEN REQUESTED TO REDUCE LOADINGS ON THE OTHER TRANSFORMERS

1322/66 KV PINJORE SUBSTATION

TRANSFORMERS WITHOUT ANY LIGHTNING ARRESTERS

- 132/66 kV, 40 MVA 2-SETS MISSING
- 66/11 kV, 7 5 MVA 1-SET MISSING

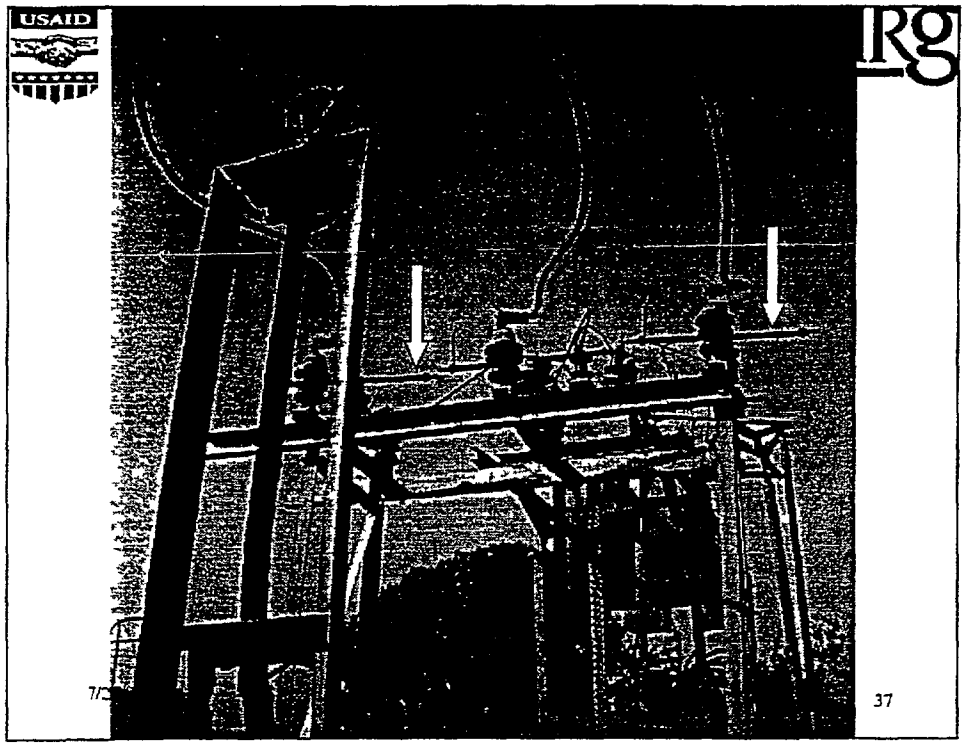
AUX EQUIPMENT

- COOLING FANS
- COOLING PUMPS
- COMPRESSORS
- BATTERIES

CAPACITORS

CAPACITORS PROPERLY LOCATED ON THE POWER SYSTEM PROVIDE SIGNIFICANT ECONOMIC AND TECHNICAL BENEFITS TO SEB

- THEY RELEASED
  - GENERATION CAPACITY
  - TRANSMISSION CAPACITY
  - DISTRIBUTION CAPACITY
- REDUCE ENERGY LOSSES
- REDUCE VOLTAGE DROPS AND THEREFORE IMPROVE VOLTAGE REGULATION
- INCREASE REVENUES
- DEFER CAPITAL INVESTMENTS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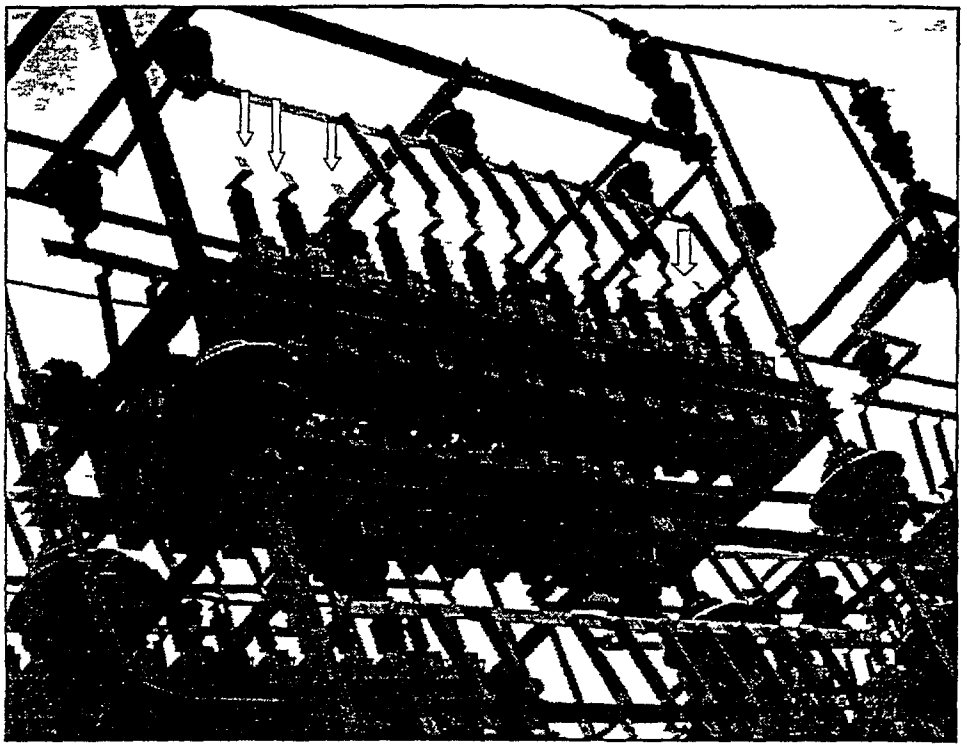
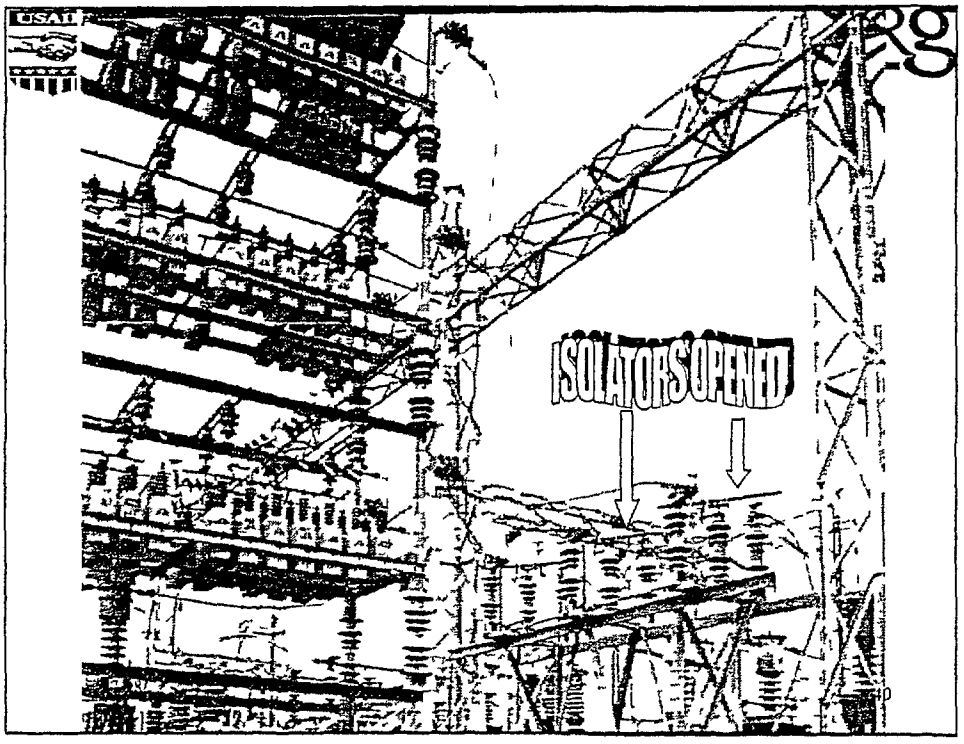
ISOLATORS ARE OPENED!

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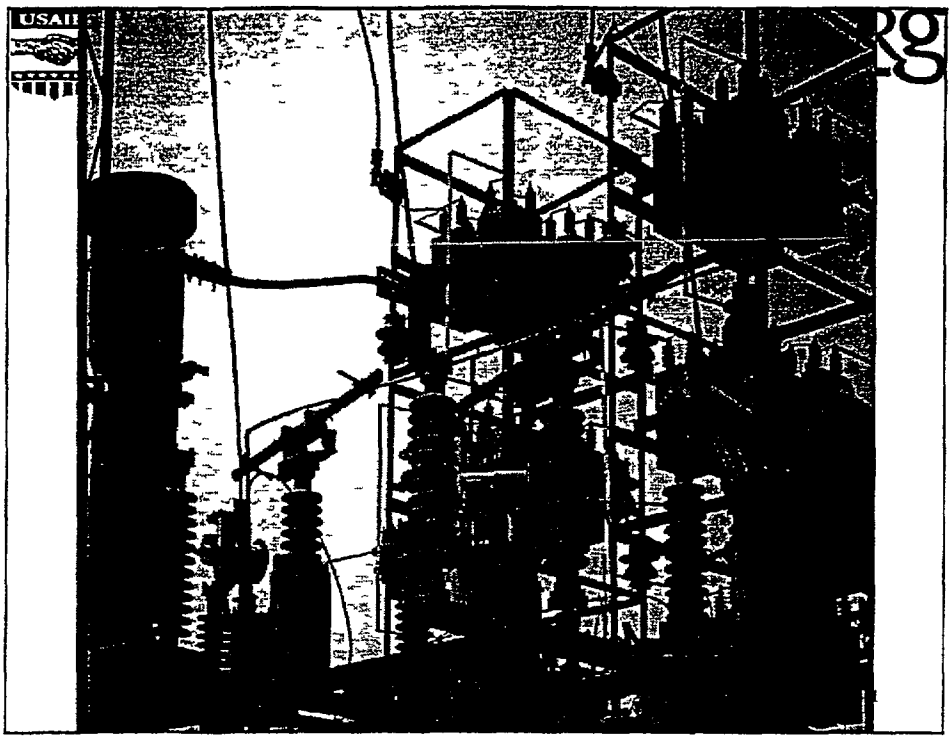
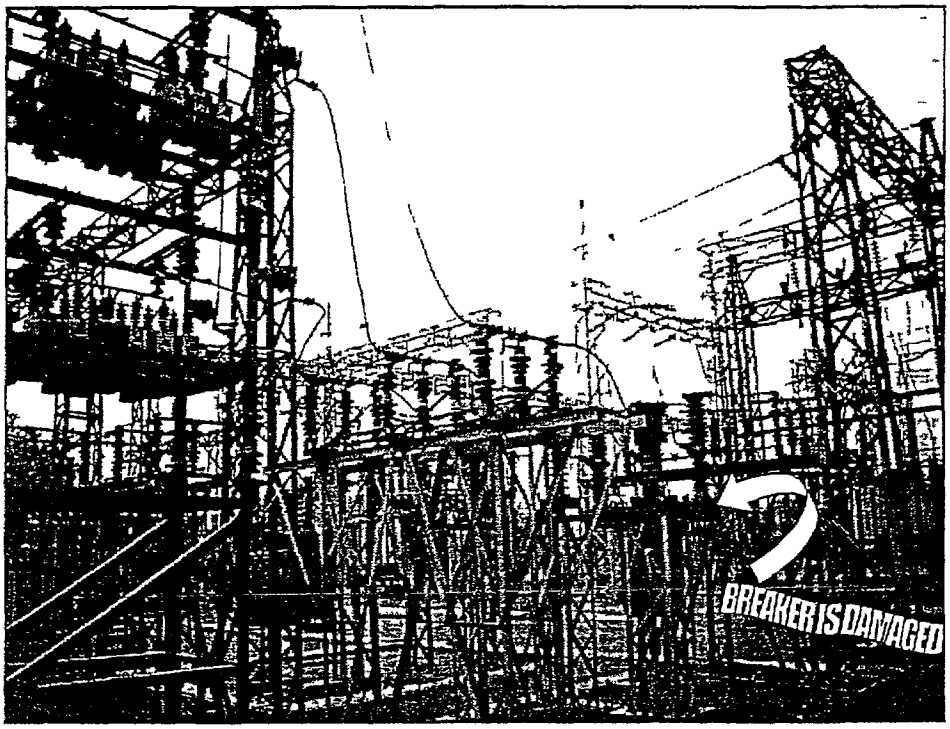
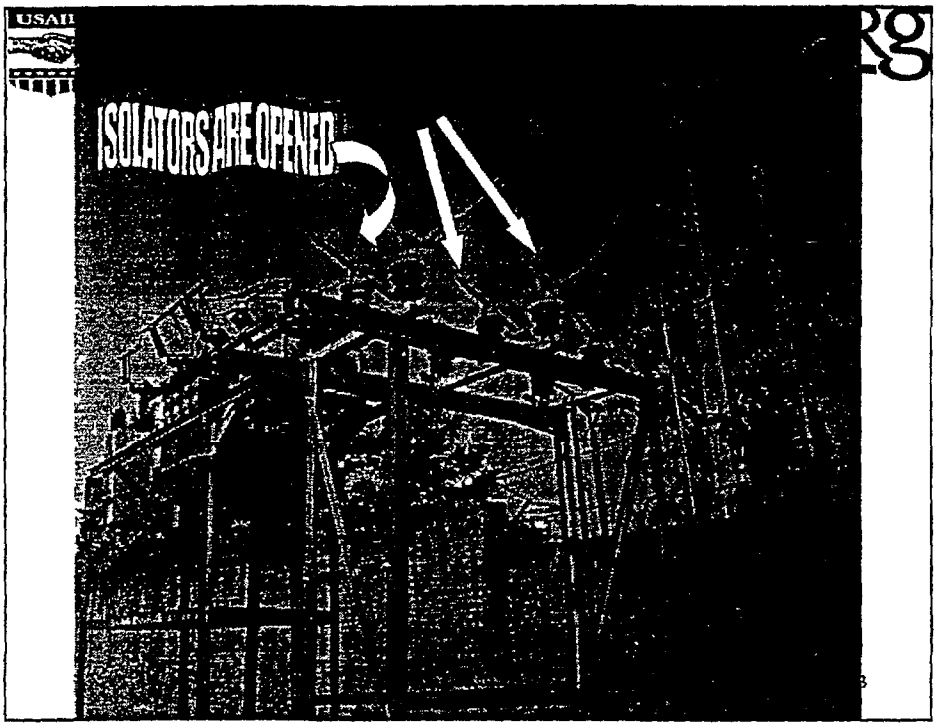
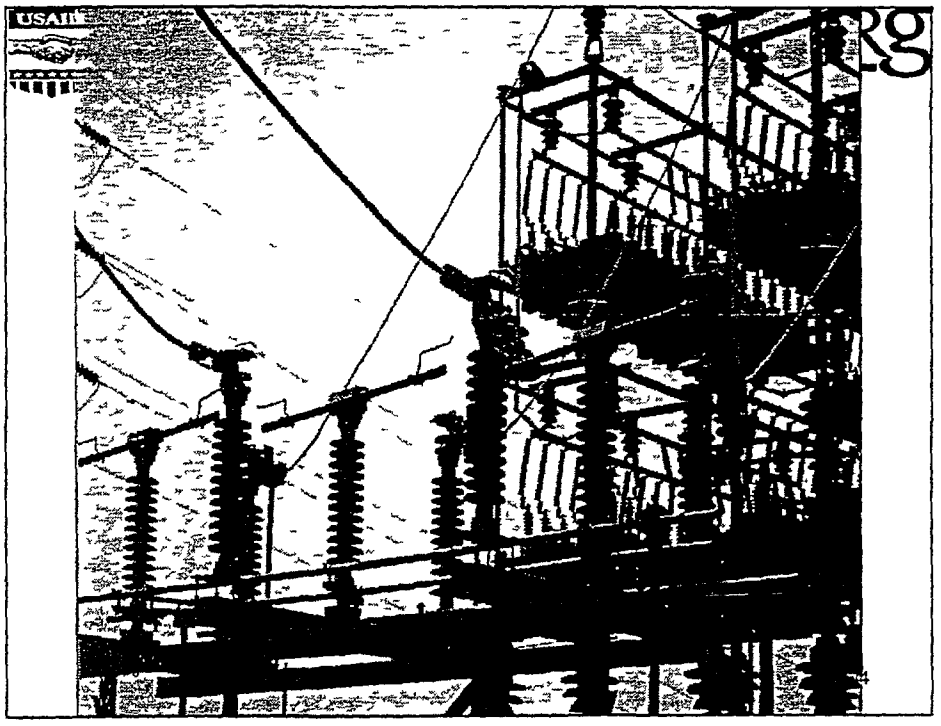
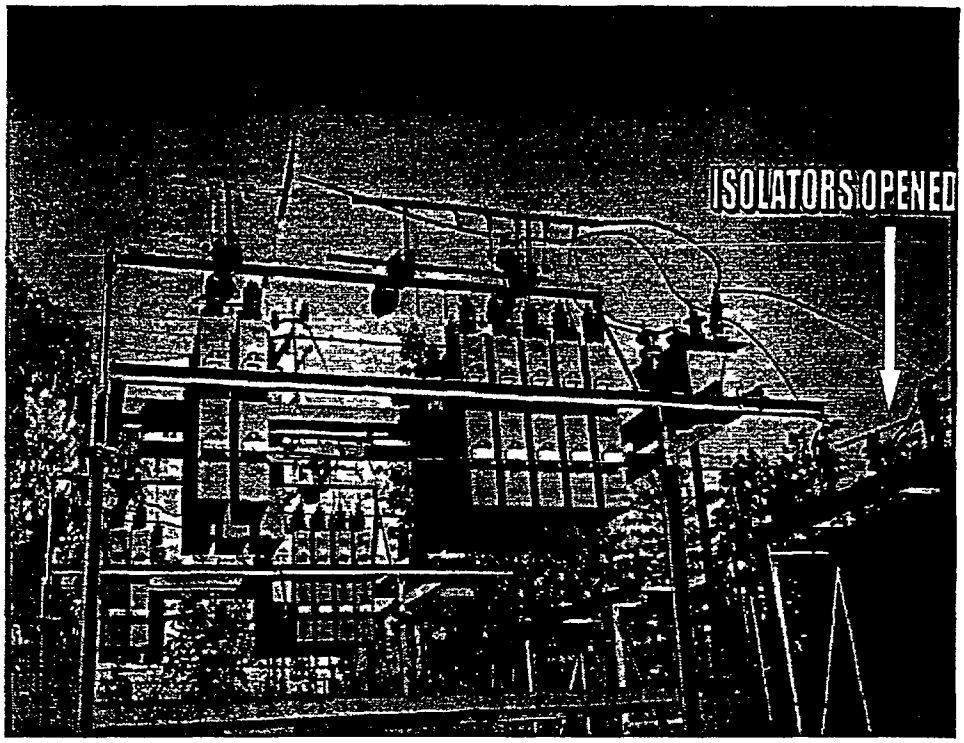
ISOLATORS OPENED

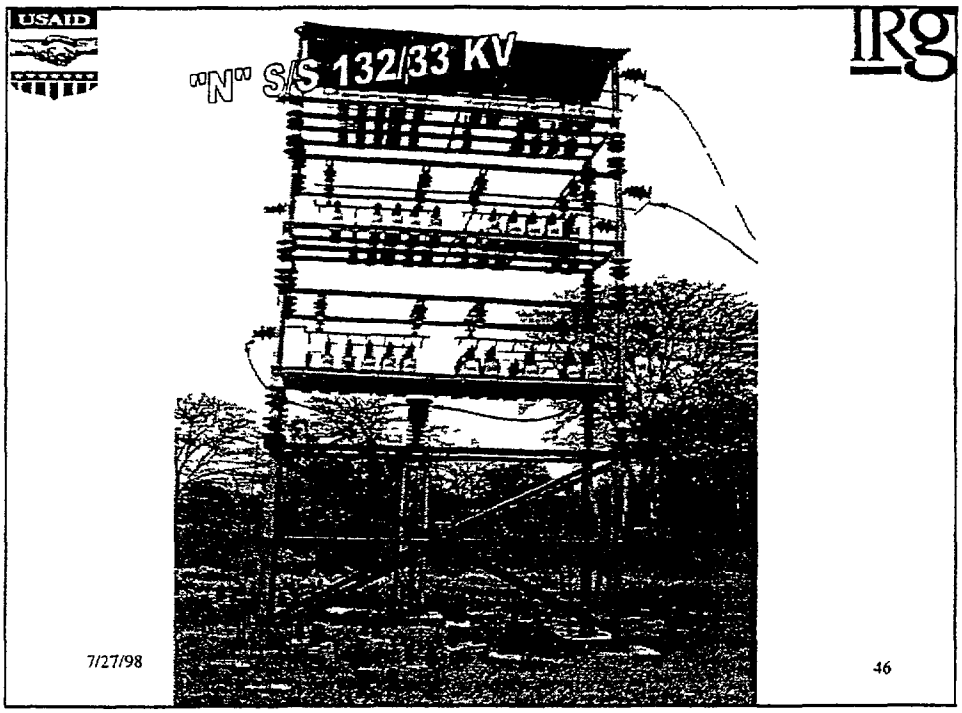



BREAKER IS DAMAGED


ISOLATORS ARE OPENED







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Is it SAFE?
HARD HAT
EYE PROTECTION
RUBBER GLOVES AND SHOES
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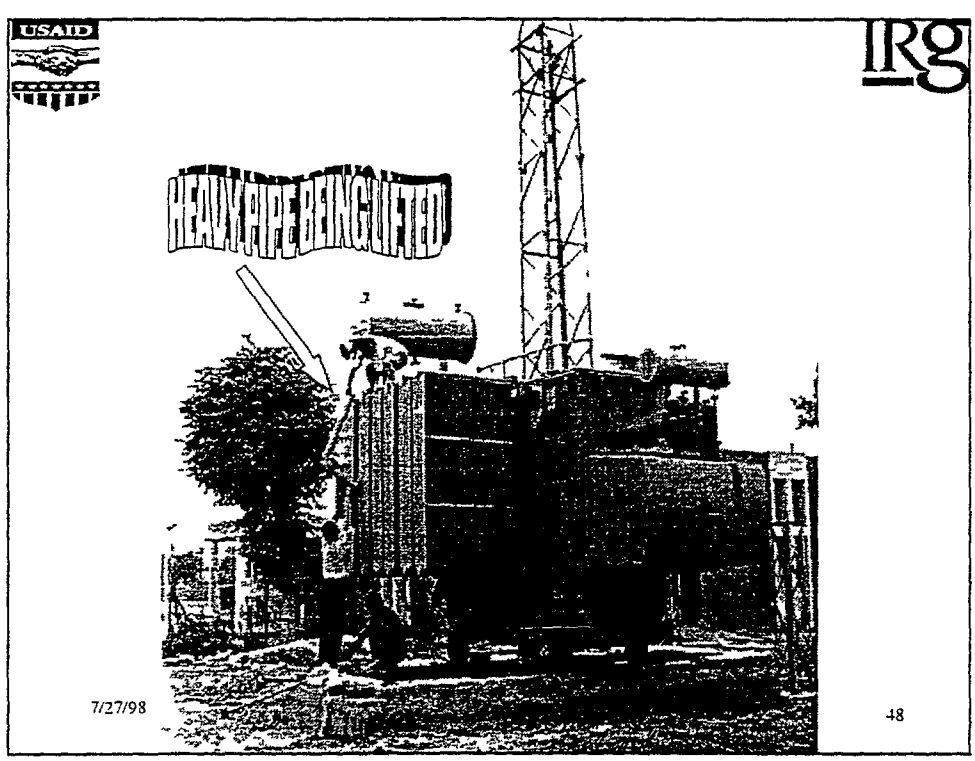
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HEAVY PIPE BEING LIFTED
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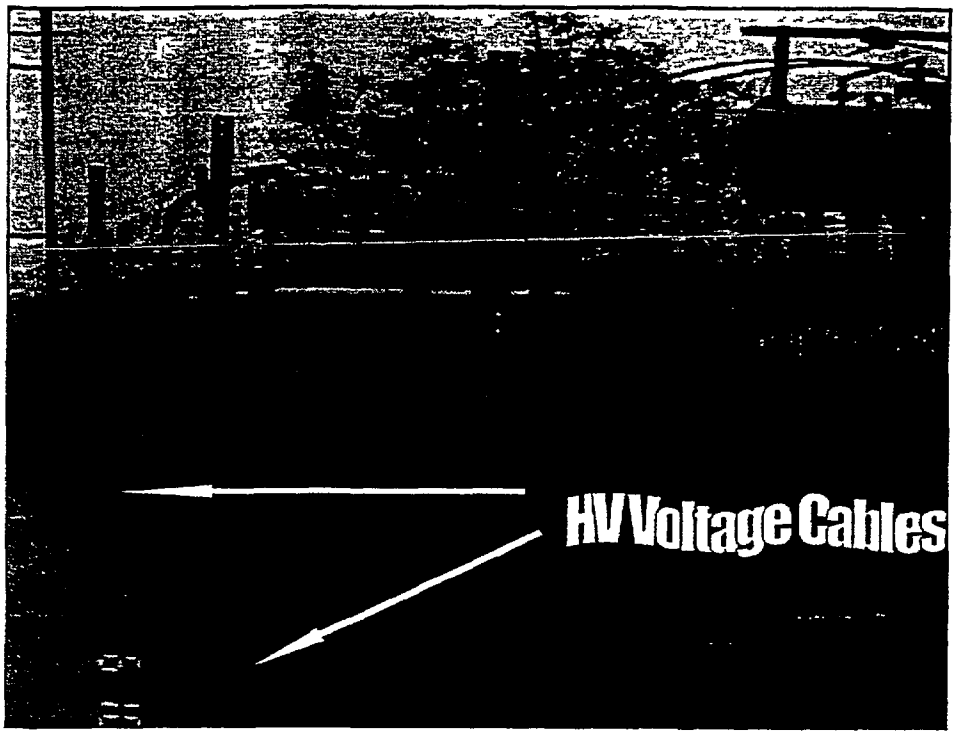
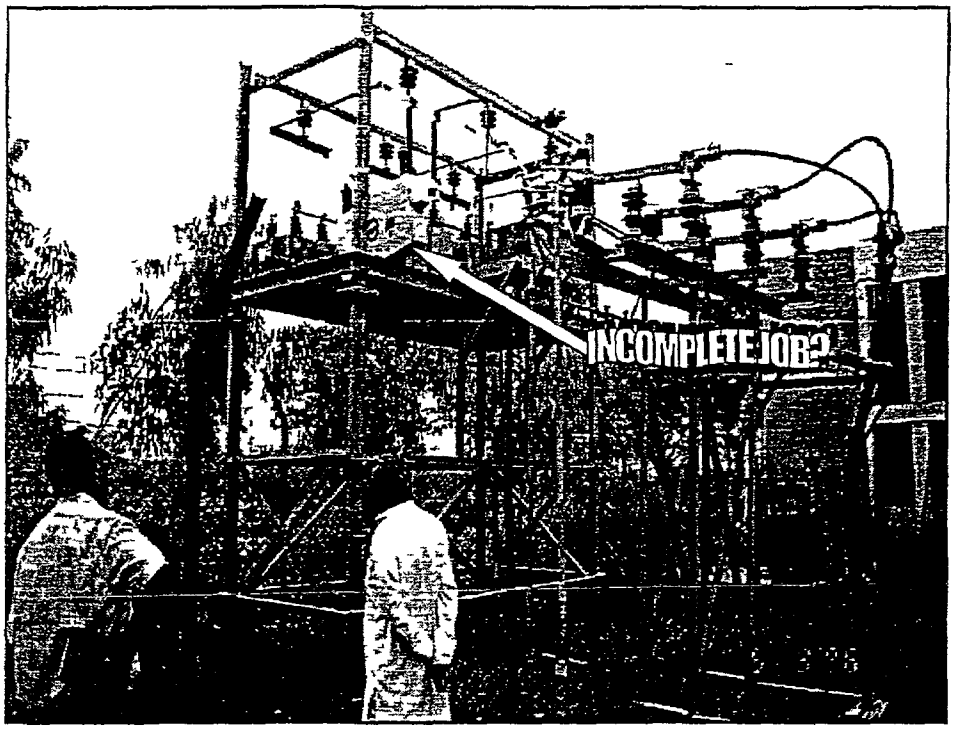
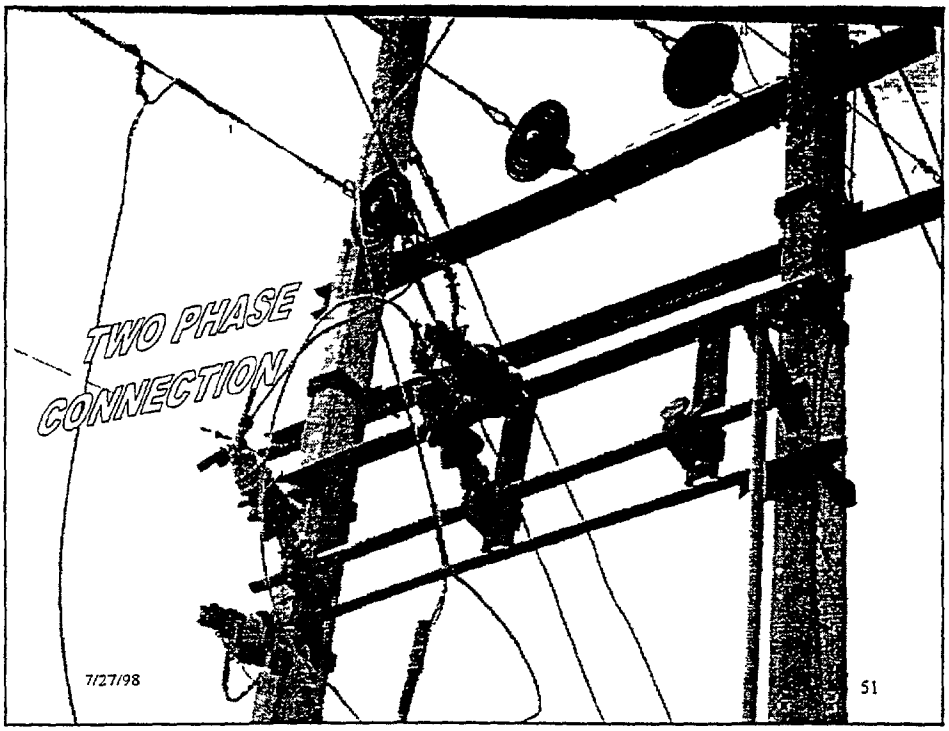

HV Voltage Cables


INCOMPLETE JOB?



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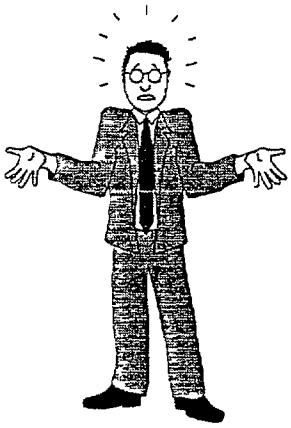

WHAT CAN WE DO ABOUT IT?

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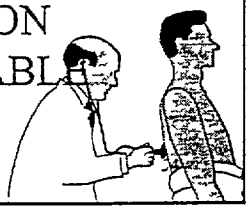
ESTABLISH PRIORITIES

- THERE ARE **THREE LARGE POWER TRANSFORMERS** WHICH
- **COULD BE NEXT ON LINE FOR FAILURE**
- TWO NEED LIGHTNING ARRESTERS AND ONE A BREAKER AT THE EARLIEST
- PERFORM OTHER MAINTENANCE AS REQUIRED, SPECIFICALLY CHECK OIL, I AND BREAKERS

ESTABLISH PRIORITIES (Cont.)

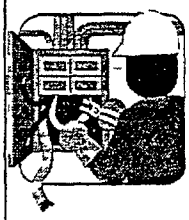
- PROCURE BATTERIES, RELAYS, CLOSING/TRIPPING COILS, AIR COMPRESSORS AND OTHER MINOR PROTECTION EQUIPMENT
- M&P CIRCLE TO REVIEW ON AN ITEM BY ITEM BASIS TRANSFORMER PROTECTION SYSTEM TO ENSURE RELIABL OPERATION



ESTABLISH PRIORITIES (Cont..)

- REVIEW REQUESTS FOR SPARES OR CAPITAL PM MADE BY SENIOR SUBSTATION ENGINEERS OR BY THOSE RESPONSIBLE FOR EACH SUBSTATION
- YOU MAY FIND SOME MEMORANDUMS FOR WHICH A REPLY HAS BEEN IGNORED DUE TO
- LACK OF FUNDS, NEGLIGENCE, OR OTHER REASONS

QUALITY CONTROL CELL



- ESTABLISH OUT OF THE M & P CIRCLE A TRANSFORMER PM TEA TO
- INSPECT SUBSTATIONS ON A PERIODIC BASIS, BASED ON A PM PRIORITY LIST
- MODIFY PM PRIORITIES AS NEEDED
- IDENTIFY AND IMPLEMENT URGENT PM WORKS

QUALITY CONTROL CELL

- THEY SHOULD BE MADE RESPONSIBLE FOR ENSURING THAT ASSIGNED PM STAFF PERFORM PM DUTIES
- THAT URGENT REQUESTS FOR PARTS ARE SATISFIED AT THE EARLIEST AND
- FOR THEIR OWN PM WORK

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ARE THERE ANY AVAILABLE CAPACITORS?

- THERE ARE MANY CAPACITORS AT MOST OF THE SUBSTATIONS
- IF IN FACT THERE IS NO NEED FOR THEM AT THESE SUBSTATIONS THEN
- ESTABLISH AND IMPLEMENT A PROGRAM TO TRANSFER THEM WHERE THE NEED EXISTS

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MOVE THE CAPACITORS

- PERFORM DISTRIBUTION SYSTEM PLANNING ANALYSIS AND LET US MOVE THEM WHERE THEY REALLY BELONG
- AT THE 11 KV OVERLOADED AND HIGH LOSS FEEDERS
- TRAIN STAFF IN THE ECONOMIC BENEFITS OF HAVING THE CAPACITORS IN SERVICE AND IN
- WHAT POWER FACTOR IS ALL ABOUT

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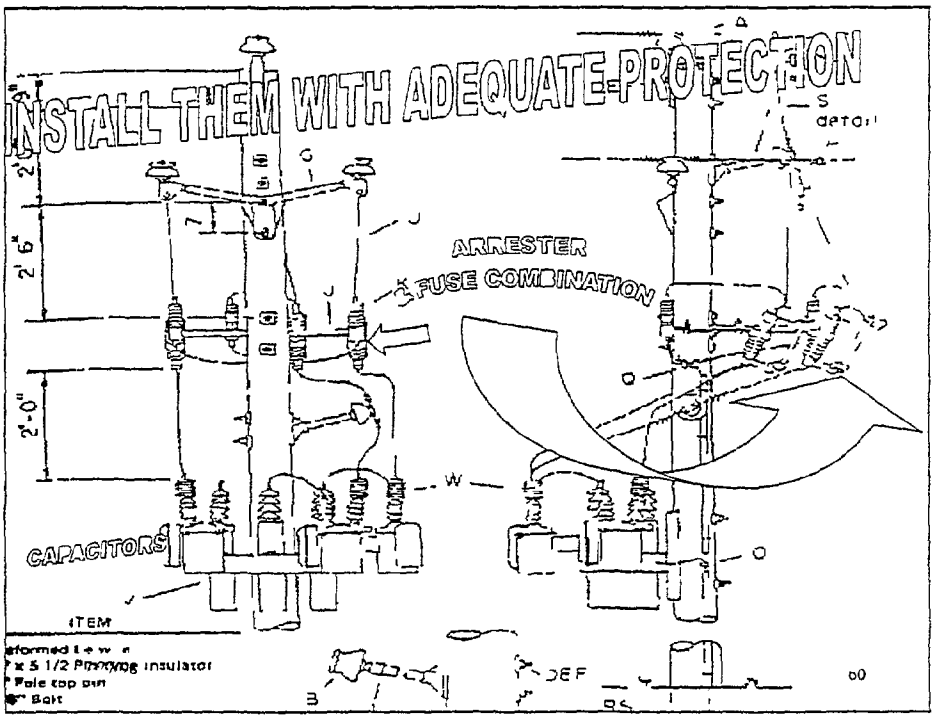

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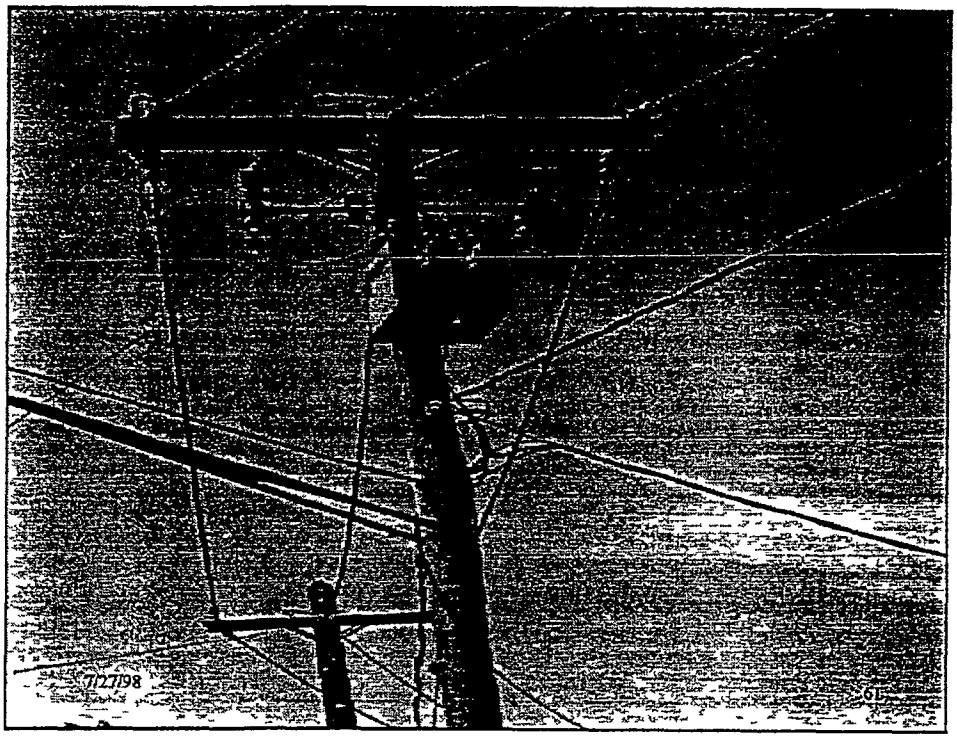

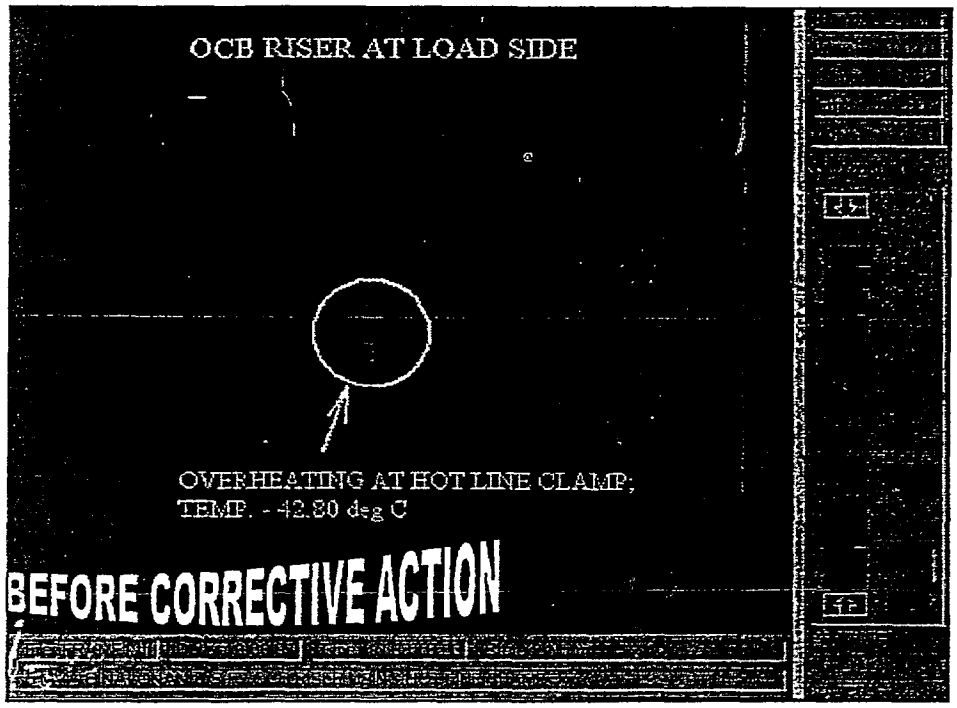

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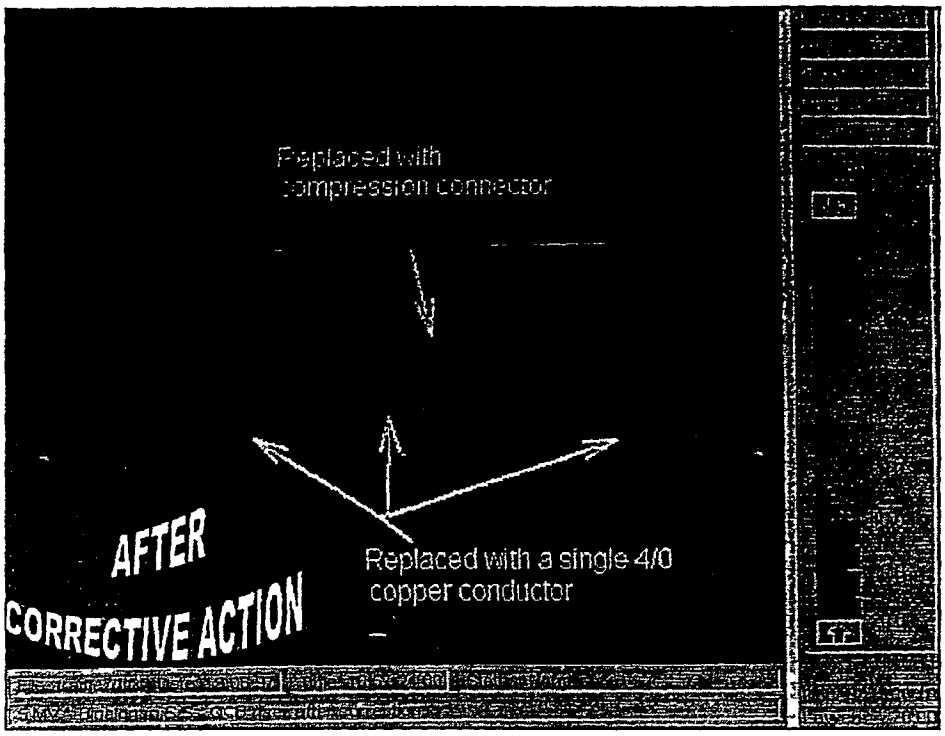

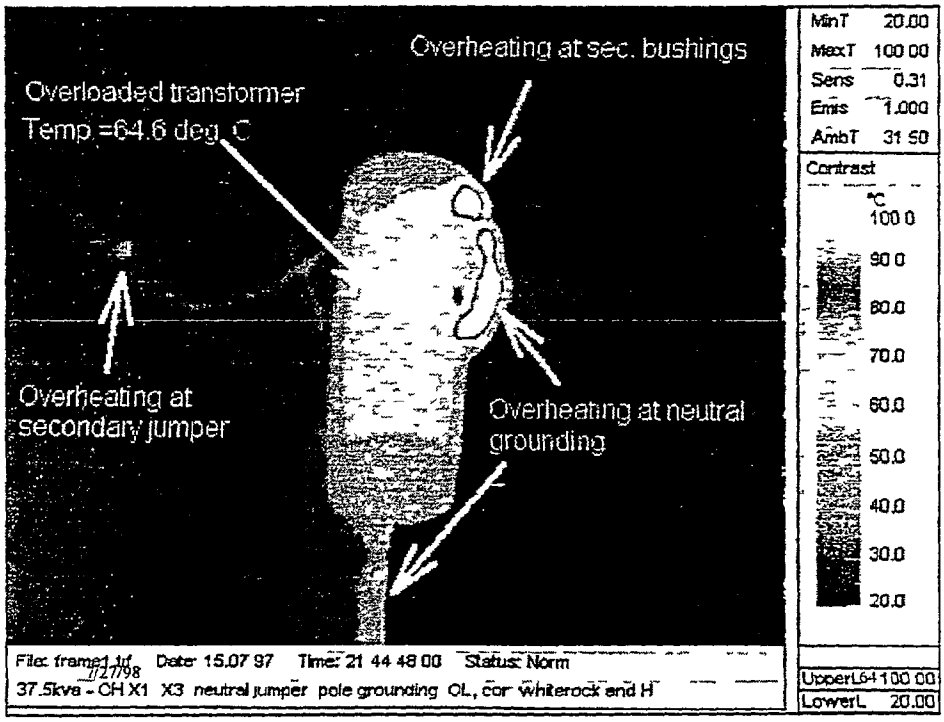

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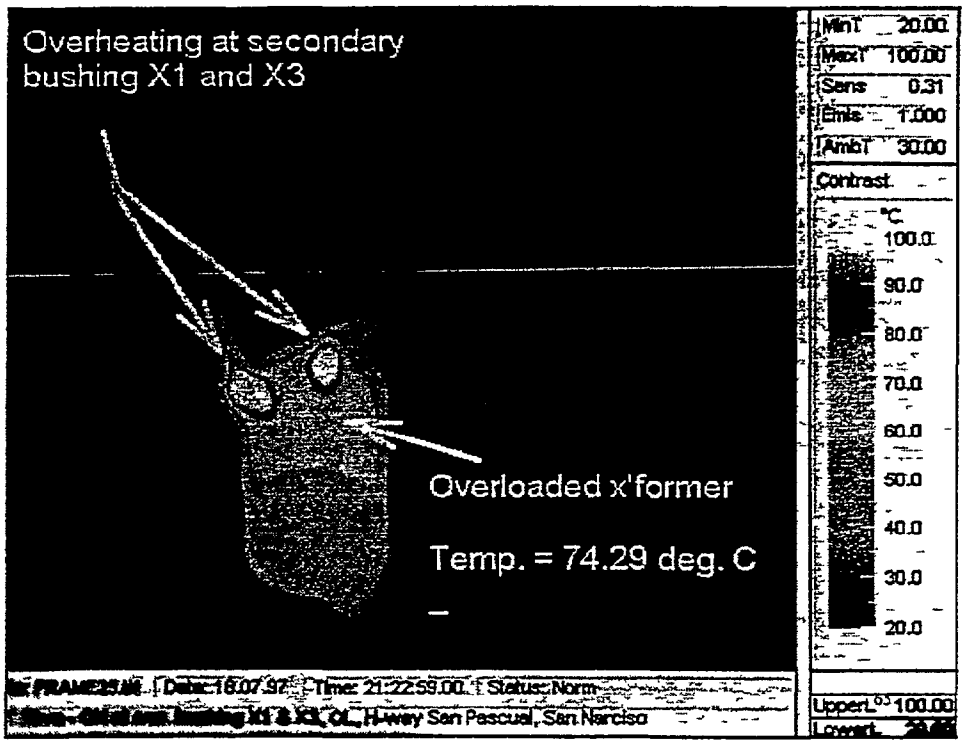

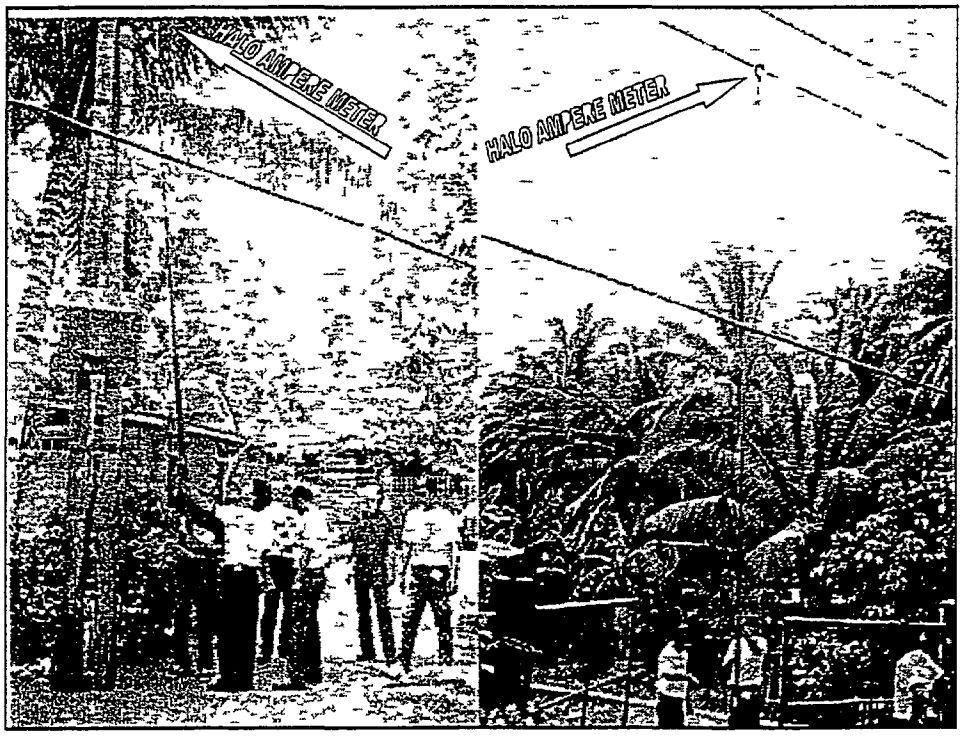

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OTHER ACTION ITEMS

- PREVIOUS RECOMMENDATIONS REMAIN THE SAME RE TOOLS NEEDED AND OJT
- OJT WHICH COMBINED WITH OBTAINING AND USING TOOLS SUCH AS:
- THERMO VISION SCANNER
- LOAD LOGGERS

OTHER ACTION ITEMS (Cont.)

- HALO AMMETERS
- LINE VOLTAGE MONITORS
- PF METERS
- DISTRIBUTION SYSTEM PLANNING SOFTWARE
- ORGANIZE TEAMS UTILIZING EXPERIENCED STAFF

PREVENTIVE MAINTENANCE MANUAL

- SEB HAS ALREADY A PREVENTIVE MAINTENANCE MANUAL
- THE MANUAL IS COMPLETE BUT APPARENTLY IS NOT OR IS PARTIALLY USED BY THE STAFF
- THERE WAS ONLY ONE INSTANCE WHERE THE PM STEPS WERE LISTED ON A WALL OF THE CONTROL ROOM

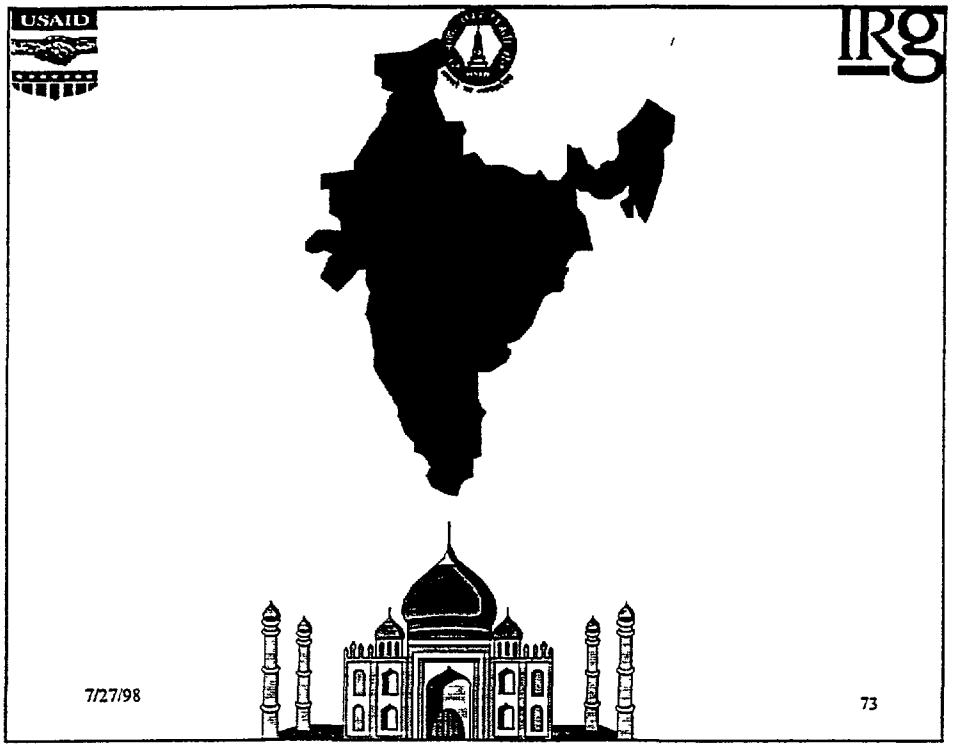
PREVENTIVE MAINTENANCE MANUAL

- IRG IS FINALIZING A COMPLEMENTARY PM PROCEDURES MANUAL
- IT IS BASED ON SOME OF THE ACTIONS THAT HAVE BEEN DESCRIBED ON TODAY'S PRESENTATION AND THOSE WE DISCUSSED DURING PART I OF THIS PRESENTATION

- WE HAVE INDENTIFIED PROBLEMS
- AND SOLUTIONS WHICH WE BELIEVE UPON THEIR IMPLEMENTATION WILL IMPROVE THE OPERATION EFFICIENCY OF THE DISTRIBUTION SYSTEMS
- WHILE INCREASING REVENUES AND CUSTOMER SATISFACTION

SUMMARY

- IT IS URGENT THAT THE ACTION ITEMS RECOMMENDED BE IMPLEMENTED AT THE EARLIEST



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WISHES

TO

THANK YOU

FOR

ALLOWING US TO SHARE WITH YOU

THE RESULTS

OF OUR

INVESTIGATIONS

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