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FIRST PROGRESS REPORT PREPARED BY J. VILAR PEDROCHE, MARCH, 1986

PROJECT 4.210 SPONSORED BY A.I.D.

TITLE: "ELECTRICAL ENERGY SUPPLY TO RURAL COMMUNITIES DIRECTLY FROM TRANSMISSION LINES"

PERIOD COVERED: OCTOBER, 1985 TO MARCH, 1986

Activities performed during the mentioned period

I Contacts with CFE (Federal Commission of Electricity)

II New program of activities

III Steady State selection of capacitor banks

IV Conceptual design of protective scheme

V Transient behavior analysis

Each of these activities are described briefly in the following sections.

I. CONTACTS WITH CFE

Following the proposal acceptance and contract formalization, the Institute of Electrical Research (IIE) established contact with CFE (Federal Commission of Electricity) through Ing. Víctor Hermosillo V., General Manager of Distribution at CFE, to initiate the project. As a result, a site was proposed to the IIE for its electrification study.

This potential site to install the pilot capacitor divider is a small population called "Venta Vieja" located at the Municipio de Zumpango del Río, State of Guerrero near the road México-Acapulco, about 32 Km before arriving to Chilpancingo.

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The vicinity of Venta Vieja to the road makes it likely that its electrification may activate its economy. The expected load in the first year of electrification is of 10 KVA, with possibilities of having important growth in the first 3 to 5 years.

II. NEW PROGRAM OF ACTIVITIES

Considering the new policies of operation at the IIE, the activities plan was revised and remains as follows:

1. Characterization of the problem
2. Steady State selection of capacitor banks
3. Conceptual design of protective scheme
4. Transient behavior analysis
5. Capacitor banks design under transient state considerations
6. Capacitors acquisition
7. Inductor design
8. Inductor construction
9. Capacitors testing
10. Acquisition of protective equipment
11. Design and acquisition of racks
12. Laboratory testing of installation
13. Field tests
14. Final report elaboration

For the realization of this program, the following group has been assigned:

Víctor Carrillo
Fernando Martínez Ch.
Ramón de la Rosa
Julio Vilar as principal investigator

III. STEADY STATE SELECTION OF CAPACITOR BANKS

This activity had the objective of defining the criteria to select among conventional singlephase capacitors the appropriate types to form the capacitor banks C_1 and C_2 for a specific installation. That is a line to ground voltage and a nominal capacity to be powered.

The considerations to be taken into account are: The voltages V_{C1} and V_{C2} should not exceed nominal values under extreme steady state loading conditions. The voltage reduction should give a standard distribution voltage.

The method developed to select the singlephase capacitor elements to constitute banks C_1 and C_2 is an iterative process to find adequate values for powers P_{C1} and P_{C2} of both banks. With P_{C1} and P_{C2} intervals for Z_{C1} and Z_{C2} are defined, for which a trial and error selection of capacitor elements is performed.

Two alternative designs were developed to be analyzed under transient conditions:

High Impedance Design		Low Impedance Design	
C_1	4-50 KVAR units of 13.8 kV +2-50 KVAR units of 14.4 kV	C_1	5-100 KVAR units of 13.28 kV
C_2	2-100 KVAR units of 12.47 kV	C_2	2-100 KVAR units of 7.62 kV

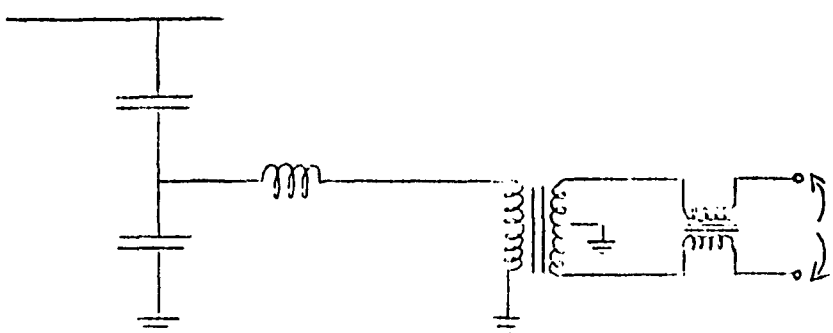
IV. CONCEPTUAL DESIGN OF PROTECTIVE SCHEME

The objective of this activity was to propose protective schemes in order to be analyzed under their transient behavior and evaluate their advantages and disadvantages.

The basic events considered are:

- Short circuit conditions at the distribution line.
- Transformer energization and inrush current associated.
- Switching operations of the transmission line.

Four schemes were studied and the one that gave better results consists in splitting the inductor in two parts. One part connected in the primary of the distribution transformer and the other in the secondary as shown in the following diagram.



V. TRANSIENT BEHAVIOR ANALYSIS

Using the Electromagnetic Transient Program E.M.T.P. (developed by H.W. Dommel), the designs of high and low impedance obtained from the steady state selection, were modelled under various situations. The protective schemes proposed were evaluated for short circuit conditions until one of them gave acceptable results.

This scheme was evaluated for both designs in the energization of distribution transformers. Finally, some conclusions about worst switching conditions were obtained.

PROJECT A.I.D. 4.210

FINANCIAL STATUS REPORT

Total Authorized Budget*:

Salaries	$ 42,300.00
Travel	2,200.00
Other	3,400.00
Equipment	29,200.00
Equipment transport	1,300.00
Consultants	2,000.00
TOTAL	$ 79,400.00

* In U.S. Dollars

First Semester Expenditures*

Salaries	$ 13,729.00
Travel	25.00
Other (computer services and documents)	331.00
Equipment	-
Equipment transport	-
Consultants	-
TOTAL	$ 14,085.00

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THIRD PROGRESS REPORT

Prepared by: J. Vilar Pedroche
April, 1987
Project N° 4.210
Sponsored by A.I.D.

TITLE: "Electrical Energy Supply to Rural Communities Directly from Transmission Lines"

Period Covered: October, 1986 to March, 1987.

Activities performed during this period

I. Inductors construction.
II. Capacitors testing.
III. Acquisition of protective equipment.
IV. Design and acquisition of racks.
V. Laboratory testing of installation (in progress).
VI. Final report elaboration (in progress).

These activities are briefly described below:

I. Inductors construction

Two air core inductors were constructed by the Equipment Division of the Institute of Electrical Research (IIE). The first one, a 4 H with nominal current of 3.5 Amp. which was constructed in five independent trench type sections. The second one, a 0.65 mH with nominal current of 200 Amp. Both units have been constructed and tested. Their measured inductances were respectively 3.9H and 0.63 mH.

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6

II. Capacitor Testing

According to the high impedance installation selected, three types of single phase capacitors were ordered with one reserve unit of each type. All eleven units were tested and their capacitance was found within the 15% tolerance specified. All other dielectrical characteristics showed that the units did not have an apparent defect.

III. Acquisition of protective equipment

The protective equipment that was acquired is listed below:

Equipment	N° of Units
115 kV Fuse disconnect & link	1
90 kV Zn oxide surge arrester	1
10 kV Zn oxide surge arrester	2
15 kV fuse disconnect & links	1
240 V disconnect	1

The only relevant aspect that should be mentioned is that of the Zn oxide surge arresters. After the order was placed with the Ohio Brass representative in México City, the plant changed its delivery time from 4 to 50 weeks. As a result the order had to be placed with Kleigo Supply with a resulting cost increase of around 50%.

IV. Design and acquisition of racks

The design and construction of the installation was made with the collaboration of "Comisión Federal de Electricidad" (CFE) at the laboratory of Salazar.

It did not include the 115 kV fuse disconnect nor the surge arresters since they had not been delivered at that time. However, the installation was protected by the high voltage switchgear of the substation. The presence of the switch gear allowed all the necessary operations for testing the installation.

V. Laboratory testing of installation

The set of tests to be performed to the pilot installation are listed below with some of the results that were obtained.

- Unloaded condition energization

  I_1 = 2.28 Amp. rms V_2 = 7.6 kV rms

- Short circuit on the 7.6 kV line

  I_L steady state under short circuit = 7.5 Amp.

  V_1 Steady state under short circuit = 11 kV

Some local maximum values of I_L and V_1 were detected in the first 5 cycles following the short circuit appearance and 5 cycles before the interruption by the 2 Amp. fuse.

The peak values for I_L lay between 17 and 19 Amp. peak. Regarding V_2 the peaks reached values between 25 and 31 kV. The fuse operates in an interval of 0.8 to 1.2 seconds.

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- Short circuit on the 127 volt side

This condition is more severe than the previous test specially because the fault impedance was negligible on the 127 V side. Another reason is that the tunning is almost complete on the 127 V side.

The short circuit was first liberated by the 2 Amp. fuse on the 7.6 kV side in a time of 0.4 seconds. The peak value for I_L was 29 Amp. peak and for V_2 it was 31 kV peak with a clear distortion of the wave form.

The 2 Amp. fuse was replaced by a 6 Amp. fuse and the test was repeated. The 200 Amp. fuse on the 127 volt side was unable to interrupt the current eventhough it melted. The circuit was deenergized by the 115 kV switch gear but the transformer was damaged. A perforation of isolation is suspected. Contacts with the manufacturer were established to repair the unit.

- Loading and switching surges

A load of 12.5 kVA was fed by the installation. The steady state low voltage recorded was 128 volts. When the load was disconnected the 2 Amp. fuse on the 7.6 kV side operated.

The fuse was replaced by a 3 Amp. fuse and the test was repeated. When disconnecting the load the voltage collapsed as a result of the transformer fault. The faul has been considered as a consequence of two factors. The first one is the previous problem of the transformer when performing the short circuit on the 127 volts side. The second cause could be due to the switching surges.

The test will have to be repeated with a fault -free transformer. If the switching of a smaller load interruption or load change is high enough to represent a risk to some part of the installation, a load interruption through pre-insertion resistors could be implemented.

An additional problem found with the pilot installation is that the first capacitor on the 115 kV line presented partial discharges in its high voltage bushing. The noise caused increased slowly until a complete discharge developed between the 115 kV line and the wooden pole of the installation. The actual tentative solution is to increase the distance to the wooden pole.

VI. Final report elaboration

The final report has been initiated. The general index is enclosed herewith. Chaper I is completed as well as points 2.1 through 2.2.

ACKNOWLEDGEMENT OF PARTICIPATION

Within the Transmission and Distribution Department, the collaborators are Víctor Carrillo R , Ramón de la Rosa A. and Fernando Martínez Ch.

The Equipment Division of the I.I.E. participated in the following activities:

10

- Inductors design and construction:
  Gregorio Hernández and Pedro Avelino

- Capacitors Testing:
  Andrés López

- Pilot Installation Testing
  Rubén Ochoa V. and Ramón de la Rosa A.

THIRD FINANCIAL STATUS REPORT (APRIL, 1987)

	PERSONNEL			EQUIPMENT			TRAVEL, EQUIPMENT TRANSP., CONSULTANTS, OTHERS		
	Unrequested Funds	Requested Available Funds	Expenditures	Unrequested Funds	Requested Available Funds	Expenditures	Unrequested Funds	Requested Available Funds	Expenditures
uthorized Budget	$ 48,142.75			$ 28,200.00			$ 8,900.00		
	$ 10,705.00	$37,437.34		$ 6,081.61	$22,118.39		$ 7,374.00	$ 1,525.51	
			$ 35,076.25			$20,833.79		$ 1,525.51	
		$ 2,361.09			$ 1,284.60				

THE CAPACITIVE VOLTAGE DIVIDER - AN ALTERNATIVE FOR RURAL ELECTRIFICATION

Chapter I Generalitites of Rural Electrification

1.1. The problem. 1

1.2. The voltage divider system. 3

1.2.1. Operating principle. 3

1.3. Pilot installation project. 6

1.4. Economical aspects. 8

Chapter II Installation Design

2.1. Steady State considerations.

2.2. Transient state considerations.

2.3. Protective scheme.

2.4. Components specifications.

2.4.1. Capacitors

2.4.2. Inductors

2.4.3. Protective equipment

2.4.4. Distribution transformers

2.5. Installation Layout

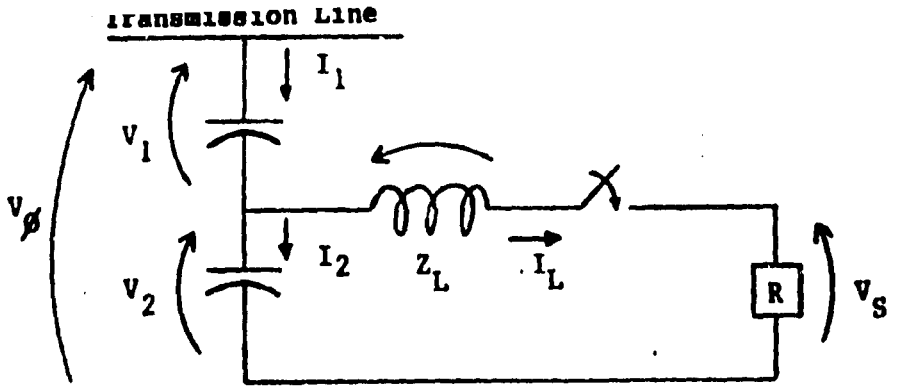
Chapter III Prototype laboratory tests and operating characteristics.

3.1. Components acceptance tests

3.2. Pilot installation tests

3.3. Operating characteristics

13



$$Z_L = \frac{Z_1 Z_2}{Z_1 + Z_2}$$