RURAL ELECTRIFICATION IN OYO STATE OF NIGERIA: ASSESSEMENT OF EXISTING 33kV FEEDER NETWORK CAPACITY

BY

AJEIIGBE, AKINADE JACOB

EEE/05/7510

APRIL 2010

LIBRARY • PSG. UNIV.

RURAL ELECTRIFICATION IN OYO STATE OF NIGERIA: ASSESSEMENT OF EXISTING 33kV FEEDER NETWORK CAPACITY

BY

AJEIGBE, AKINADE JACOB

(B.Eng., Electrical Engineering, MNSE, COREN Registered)

EEE/05/7510

A thesis in the Department of Electrical and Electronics Engineering submitted to the School of Postgraduate Studies, in partial fulfillment of the requirements for the award of Master Degree in Electrical and Electronics Engineering, Federal University of Technology Akure, Ondo State in Nigeria.

CERTIFICATION

(a) (By the student)

This work has not been presented elsewhere for the award of a degree, or any other purpose.

Candidate's Name: Ajeiigbe Akinade Jacob

Signature..

Date......13 – 05 – 2010......................................

(b) (By Supervisor(s):

I certify that this work has been carried out by Ajeiigbe, Akinade Jacob.In the Department of Electrical and Electronics Engineering of the Federal University of Technology, Akure.

Supervisor's Name: Engr. (Dr.) A.O.Melodi

Signature.................................Date......27-05-10..................

LIBRARY FED. UNIV. OF TECH. AKURE

ACKNOWLEDGEMENT

I register sincere thanks and deep sense of a great debt of gratitude to my Project Supervisor Dr.A.O.Melodi, Department of Electrical/Electronics Engineering, School of Engineering, Federal University of Technology, Akure, for his motivation, supporting and guidance, without which this project wouldn't have possible. I consider myself fortunate for having the opportunity to learn and work under his able supervision and guidance over the entire period of association with him. I have deep sense of administration for his innate goodness.

Also I hereby appreciate the following honorable persons: Dr. V.S.A. Adeloye (Departmental head), lecturers and other members of the Department for their services and support; Engineer H.Ngadda FNSE, and Engr.F.N.A.Olapade FNSE, Directors of Electrical Inspectorate Services Department, Federal Ministry of Power (Headquarters), Abuja, for their guidance, and support during the period of study; Engr.Oyeleye Mathew, Mrs. Omowumi Mustapha (Nee.Olomo), my course mates among others; Mr.Adeleke (PHCN:Ayede Control Center), Messer's Oyelade Adewale and Quadry Alaba (FMP),and the staff of Power Holding Companies of Nigeria Plc (PHCN) Ibadan Electricity Distribution Plc for giving me access to the relevant data.

Lastly, appreciate the Almighty God my ultimate provider in this work.

LIBRARY • FED. UNIV. OF TECH. AKURE

DEDICATION

This work is dedicated to my wife Abosede for her constant encouragement, and my children: Temiloluwa-Emmanuel, Wuraola-Faith, and Tinuola-Peace.

ABSTRACT

According to state reports only 45% of Nigerian populations have access to electricity and only 10% of rural dwellers have access electricity. 24% of the population and vast developmental potentials are in the rural areas of Sates such as Oyo, justifying the need of this study.

The aim of this study is to assess the transmission capacity of the existing rural primary feeder network (33 kV) and to determine ways of reinforcing the 33 kV network by thermal and voltage requirement for adequate distribution of electricity in view of prospective full scale electrification and power demand of the rural areas of Oyo State. The translations of results are expected to be useful for electrification planners.

This work is done by using data of maximum power demand allocations to fully electrified areas of the State to compute expected range of power demand per capita, and applying normal mode simulations and calculations by iterative approximation and direct methods (matrix) solutions of the equations of state.

The following conclusions were made from an analysis of the results:
The load densities per capita range from an expected 0.011 kW to 0.094 kW; expected potential load demand for the whole state is about 534 MW (this is huge compared to the total 103.7 MW supplied by the utility); at 33kV the capacities of these networks are inadequate due to overloading of lines (55%) and critical bus voltages (82%); the total injection substation capacity (225 MVA) is inadequate for meeting the potential demand of Oyo State, including electrification of the rural areas; and upgrading the voltage of the existing network will improve the distribution capacity significantly and solve overloading and voltage problems.

Consequently, the following recommendations were made: the 33 kV network should be reinforced by upgrading to 132 kV; the total substation capacity in Oyo State should be increased by installing more 132 kV substations to relieve the existing fully loaded ones. Otherwise, this will serve as a constraint to any full scale rural electrification development in Oyo State intending to feed from the national grid.

TABLE OF CONTENTS

1.8 Reasons and expected benefits of Rural Electrification in Oyo State 13

CHAPTER TWO LITERATURE REVIEW

LIST OF FIGURES

LIST OF TABLES

LIBRARY FED. UNIV. OF TECH. AKURE

CERTIFICATION

This is to certify that this thesis - "Rural Electrification in Oyo State of Nigeria: Assessment of Existing 33kv Feeder Network Capacity" was carried out by Ajeiigbe Akinade Jacob, matriculation. number EEE/05/7510 under my guidance and supervision, in partial fulfillment of the award of Master of Engineering in 'Power Systems Engineering' in the Electrical and Electronics Engineering Department of the Federal University of Technology, Akure, Ondo State. The work presented in this report has not been submitted for the award of any degree anywhere to the best of my knowledge. The whole thesis title and work therein are original.

Ajeiigbe Akinade Jacob. Signature……………..Date……………

Student

Engr. (Dr.) A.O.Melodi Signature……………..Date……………

Supervisor

ACKNOWLEDGEMENT

I register sincere thanks and deep sense of a great debt of gratitude to my Project Supervisor Dr.A.O.Melodi, Department of Electrical/Electronics Engineering, School of Engineering, Federal University of Technology, Akure, for his motivation, supporting and guidance, without which this project wouldn't have possible. I consider myself fortunate for having the opportunity to learn and work under his able supervision and guidance over the entire period of association with him. I have deep sense of administration for his innate goodness.

Also I hereby appreciate the following honorable persons: Dr. V.S.A. Adeloye (Departmental head), lecturers and other members of the Department for their services and support; Engineer H.Ngadda FNSE, and Engr.F.N.A.Olapade FNSE, Directors of Electrical Inspectorate Services Department, Federal Ministry of Power (Headquarters), Abuja, for their guidance, and support during the period of study; Engr.Oyeleye Mathew, Mrs. Omowumi Mustapha (Nee.Olomo), my course mates among others; Mr.Adeleke (PHCN:Ayede Control Center), Messer's Oyelade Adewale and Quadry Alaba (FMP),and the staff of Power Holding Companies of Nigeria Plc (PHCN) Ibadan Electricity Distribution Plc for giving me access to the relevant data.

Lastly, appreciate the Almighty God my ultimate provider in this work.

DEDICATION

This work is dedicated to my wife Abosede for her constant encouragement, and my children: Temiloluwa-Emmanuel, Wuraola-Faith, and Tinuola-Peace.

ABSTRACT

According to state reports only 45% of Nigerian populations have access to electricity and only 10% of rural dwellers have access electricity. 24% of the population and vast developmental potentials are in the rural areas of Sates such as Oyo, justifying the need of this study.

The aim of this study is to assess the transmission capacity of the existing rural primary feeder network (33 kV) and to determine ways of reinforcing the 33 kV network by thermal and voltage requirement for adequate distribution of electricity in view of prospective full scale electrification and power demand of the rural areas of Oyo State. The translations of results are expected to be useful for electrification planners.

This work is done by using data of maximum power demand allocations to fully electrified areas of the State to compute expected range of power demand per capita, and applying normal mode simulations and calculations by iterative approximation and direct methods (matrix) solutions of the equations of state.

The following conclusions were made from an analysis of the results:
The load densities per capita range from an expected 0.011 kW to 0.094 kW; expected potential load demand for the whole state is about 534 MW (this is huge compared to the total 103.7 MW supplied by the utility); at 33kV the capacities of these networks are inadequate due to overloading of lines (55%) and critical bus voltages (82%); the total injection substation capacity (225 MVA) is inadequate for meeting the potential demand of Oyo State, including electrification of the rural areas; and upgrading the voltage of the existing network will improve the distribution capacity significantly and solve overloading and voltage problems.

Consequently, the following recommendations were made: the 33 kV network should be reinforced by upgrading to 132 kV; the total substation capacity in Oyo State should be increased by installing more 132 kV substations to relieve the existing fully loaded ones. Otherwise, this will serve as a constraint to any full scale rural electrification development in Oyo State intending to feed from the national grid.

TABLE OF CONTENTS

1.8 Reasons and expected benefits of Rural Electrification in Oyo State 13

CHAPTER TWO LITERATURE REVIEW

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 Geopolitical Characteristics of Oyo State

Oyo State is an inland state in South Western Nigeria, with its capital at Ibadan. It is bounded in the north by Kwara State, in the east by Osun State, in the South by Ogun State and in the West by Ogun State and the Republic of Benin. The State covers an area of 2,560,959m². Historically, the population of the state was about 3,488,789 and 5,591,589 in 1991 and 2006 respectively (60.27% increase). More than half of the population, 69%, live in the rural areas. Fig.1.1 shows the map of Oyo State and its 33 Local Government areas.(Department of Macro-Statistics and Research, Ministry of Finance, Budget and Training. Oyo State, Ibadan,2006)

The population distribution for the Local Government Areas of Oyo State between 1991 and 2006 are present in the tables 1.1 and 1.2 respectively.

Oyo State Local Government Areas divided into three categories by level of development or urbanization, i.e. urban areas, semi-urban areas, and rural areas.

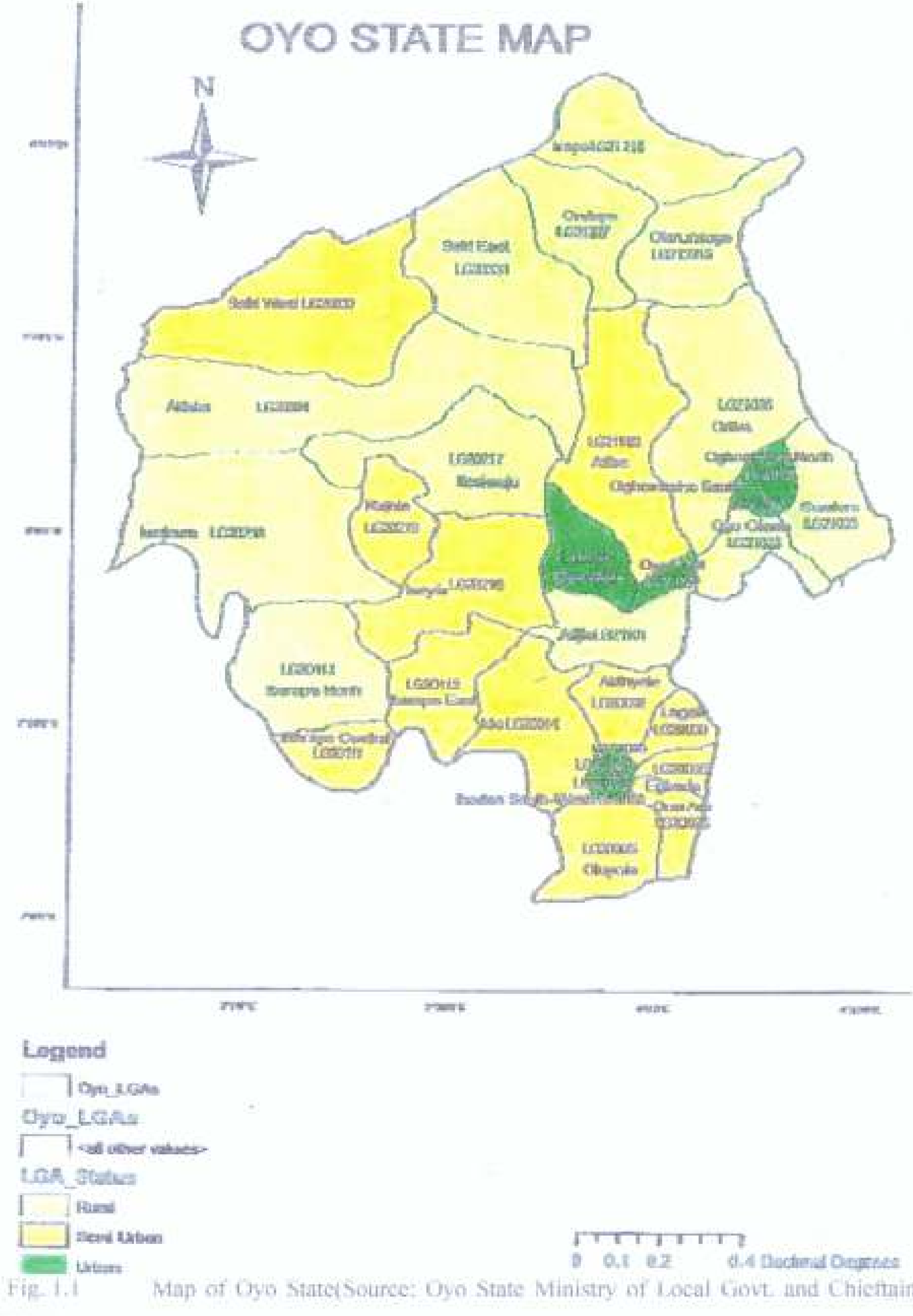

Fig. 1.1 Map of Oyo State(Source: Oyo State Ministry of Local Govt. and Chieftaincy Matters-Valuation Office)

Table 1.1: Population Distributions for the L.G.As of Oyo State in 1991 and 2006 Census Estimates

L.G.A	№ of households		Population		
1. Urban	1991	2006	1991	2006	Av. Annual increment
Ibadan North	68,464	69489	302,271	306,795	301.6
Ibadan N/East	65,335	78318	275,627	330,399	3651.47
Ibadan S/East	52,278	61596	225,800	266,046	2683.07
Ibadan S/West	64,333	65619	277,047	282,585	369.2
Ibadan N/West	36,667	37886	147,918	152,834	327.733
Oyo West	17,631	30333	79,187	136,236	3803.27
Oyo East	37,098	27834	165,068	123,846	-2748.1
Ogbomoso North	23,752	45256	104,295	198,720	6295
Ogbomoso South	15,157	23167	65,959	100,815	2323.73
Total	380715	439497	1,643,172	1,898,276	17,007
2. Semi-urban					
Saki West	23382.00	59397	109,437	278,002	11237.67
Atiba	3396.00	34628	16,643	169,702	10203.93
Kajola	24471.00	43914	112,006	200,997	5932.733
Iseyin	26984.00	58423	118,667	256,926	9217.267
Ibarapa East	14665.00	26311	65,897	118,226	3488.6
Ibarapa Cenral	13212.00	22984	59,197	102979	2918.8
Ido	12085.00	23290	53,582	103,261	3311.933
Egbeda	26085.00	56734	129,461	281,573	10140.8
Ona-Ara	26976.00	58109	123,048	265,059	9467.4
Oluyole	20268.00	44892	91,527	202,725	7413.2
Lagelu	14963.00	32131	68,901	147,957	5270.4
Akinyele	30257.00	45641	140,118	211,359	4749.4
Total	236744	506453	1,088,484	2,338,766	83,352
3. Rural					
Atisbo	11959	22624	58,565	110,792	3481.8
Iwajowa	11348	20774	56,254	102,980	3115.07
Ibarapa North	9555	22697	42,558	101,092	3902.27
Irepo	15051	28143	65,541	122,553	3800.8
Orelope	14522	22120	68,566	104,441	2391.67
Saki East	10041	21563	51,326	110,223	3926.47
Itesiwaju	10327	25418	52,269	128,652	5092.2
Orire	21457	31194	103,611	150,628	3134.47

Surulere	12503	27713	64,097	142,070	5198.2
Ogo Oluwa	7754	13967	36,188	65,184	1933.07
Afijio	18587	30122	82,792	134,173	3425.4
Olorunsogo	6961	14482	39,298	81,759	2830.73
Total	150065	280818	721,065	1,354,547	42,232
Sum Total	767524	1226767	3452720	5591589	142591

(Source: National Population Commission,2007)

Table 1.2: Oyo State Local Government Profiles

SN	LGA	HQRS	Geog. Area, km^2	Population (2006)	Pop. Density, per km^2	Economic. Activities of pop. and potential
	Urban					
1	Ibadan North	Bodija	132500	306,795	2.315	Small and large scale industries, trading and other commercial activities (predominant)
2	Ibadan N/East	Idi ape	51250	330,399	6.447	Banking and trading
3	Ibadan S/East	Mapo	58251	266,046	4.567	Transporters, tourist centre
4	Ibadan S/West	Oluyole	24455	282,585	2.117	Agro industries (farms), large scale food industries
5	Ibadan N/West	Onireke	59001	152,834	2.590	Banking and trading, processing and manufacturing industries
6	Oyo West	Ojongbodu	519377	136,236	0.262	Agricultural activities
7	Oyo East	Kosobo	176805	123,846	0.700	Farming predominant, trading and transportation, animal farming
8	Ogbomoso North	Sabo	207978	198,720	0.955	Farming predominant, trading and transportation
9	Ogbomoso South	Arowomole	145741	100,815	0.692	Farming predominant, trading and transportation
	Total		1,375,358	1,898,276	0.26-6.40	
	Semi urban					
1	Saki West	Saki	2022739	278,002	0.137	Farming predominant, trading and transportation
2	Atiba	Offa-Meta	1620825	169,702	0.105	Farming predominant, trading and transportation
3	Kajola	Okeho	646346	200,997	0.303	Farming predominant, trading and transportation
4	Iseyin	Iseyin	1341766	256,926	0.191	Agricultural activities,Aso-Oke makers
5	Ibarapa East	Eruwa	905316	118,226	0.131	Farming predominant, hunting and

						artistry work
6	Ibarapa Cenral	Igbo-Ora	480424	102979	0.214	Farming predominant, trading and transportation
7	Iddo	Iddo	1010954	103,261	0.102	Farming predominant, trading and transportation
8	Egbeda	Egbeda	185508	281,573	0.580	Farming predominant, Large-industries
9	Ona-Ara			265,059	0.622	Farming predominant, Large-industries
10	Oluyole	Idi-Ayunre	638384	202,725	0.032	Farming predominant, small and large industries
11	Lagelu	Iyana-Offa	310850	147,957	0.476	Farming predominant, engage in various economic activities
12	Akinyele	Moniya	464892	211,359	0.455	Farming predominant, palm oil production
	Total			2,338,766		
	Rural					
1	Atisbo	Tede	2837417	110,792	0.032-0.622	Farming predominant, palm oil production
2	Iwajowa	Iwerele	2397404	102,980	0.043	Farming predominant, palm oil production
3	Ibarapa North	Ayete	1137762	101,092	0.089	Farming predominant, palm oil production
4	Irepo	Kisi	972316	122,553	0.126	Farming predominant, trading and transporter
5	Orelope	Igboho	893082	104,441	0.117	Mineral resources, Farming predominant, cattle rearing
6	Saki East	Ago-amodu	14848843	110,223	0.074	Farming predominant, trading and transporter
7	Itesiwaju	Ottu	1246234	128,652	0.103	Agriculture and Livestock activities
8	Orire	Ikoyi	1908504	150,628	0.076	Farming predominant, cattle rearing
9	Surulere	Iresaadu	831912	142,070	0.171	Farming activities
10	Ogo Oluwa	Ajawa		65,184	0.157	Agriculture activities
11	Afijio	Jobele	685085	134,173	0.196	Farming predominant, State farm settlement-Ilora
12	Olorunsogo	Igbetti	4070216	81,759	0.02-0.19	Agriculture activities
	Total			1,354,547		
	Sum Total			5591589		

(Source: Department of Macro-Statistics and Research, Ministry of Finance, Budget and Training, Oyo State, Ibadan)

Analysis and Conclusion: From these profiles above, it seen that all these areas have high potential economic development prospects if adequately supplied with electricity.

1.2 Present Configuration and Level of electricity distribution network and development In Oyo State

In Oyo State, at present, the primary distribution is at 33 kV and secondary distribution – 11 kV. The load centres of the LGAs receive electricity at 33 kV, from where it is distributed to 11 kV load centres. There are three separate injection substations feeding the 33 kV distribution networks. They are: Ayede 132 kV/33 kV/11 kV; Iseyin 132 kV/33 kV/ 11kV; Ilorin 132 kV/33 kV/11 kV. These are radial networks.

LIBRARY • FED. UNIV. OF TECH. AKURE

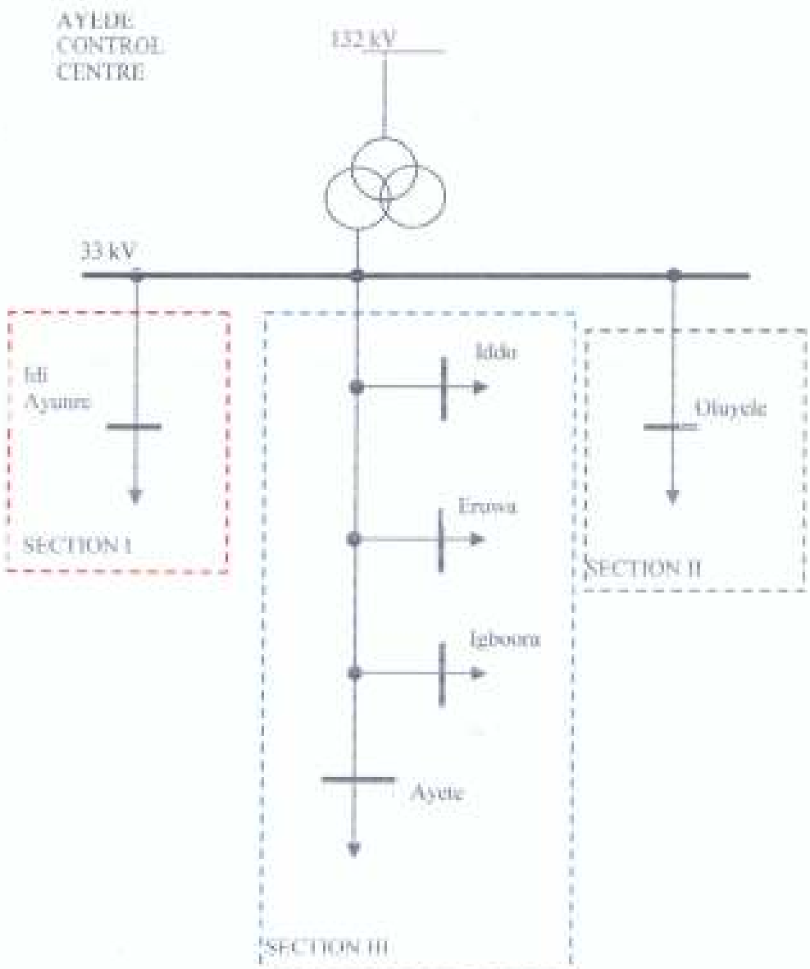

Fig.1.2 Single line circuit diagram of 33 kV distribution network fed from Ayede 132kV/33kV/11 kV

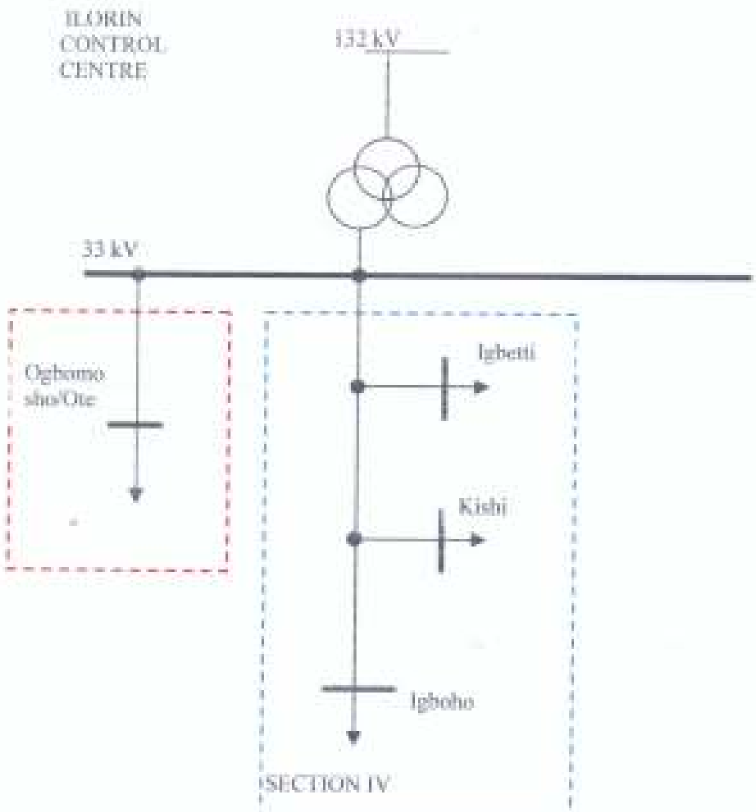

Fig. 1.3 Single line circuit diagram of 33 kV distribution network fed from Ilorin 132kV/33kV/11 kV

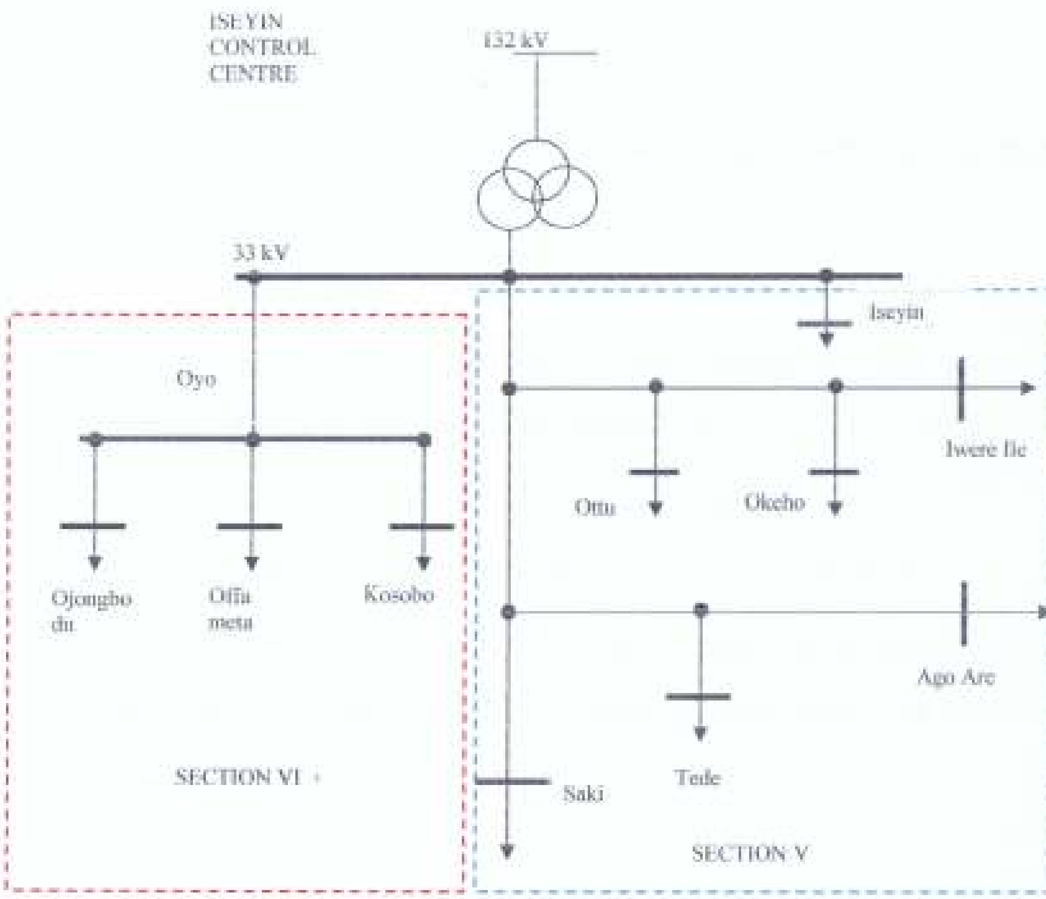

Fig.1.4

Single line circuit diagram of 33 kV distribution network fed from Iseyin 132kV/33 kV/11 kV

1.3 Historical problems of Rural Electricity supply in Oyo State

- The historical problems of Rural Electrification in Oyo State to date include the following:
- Large distances make grid extension unfeasible requiring huge funds.
- The capacity of power lines inefficiently used because of low population.
- Densities and demand levels are low.
- Low business activities and low incomes limit power consumption to an extant that economic operation of power plant is difficult.
- Low income limits money available for paying electricity fees.
- Poor feed roads and inadequate road network between the rural areas to transport electricity materials for constructing distribution network.
- Poor constructed network with substandard materials.
- Delays of funding payments to the contractors Land use interference.
- Incremental extension of the grid (rather than extension to optimize to minimized losses) causes lines to be string haphazardly, resulting in greater losses and often the terminal voltages are poor.
- Political interference.
- Vandalization, and pilfering/theft of construction line.
- Unfair regulations. The inaccessibility to services like electricity in rural areas is also aggravated with unfair regulations that discriminate against technologies that are especially suited to rural areas.
- Capital costs are relatively high and revenues are frequently poor transmission and distribution to rural areas.

LIBRARY • FED. UNIV. OF TECHN. MINNA

1.4 Aim and Objectives of project

The aim of this project is to identify the problems and prospects of rural electrification in Oyo State; to look ahead to opportunities for electricity supply to rural and remote areas, and to translate the results into recommendations that can be useful to decision makers. In line with this the objectives of this work are to:

- assess the transmission capacity of the rural primary feeder network (33 kV) in view prospective electrification of rural areas by thermal and voltage requirement;
- determine ways of reinforcing the 33 kV network for adequate distribution of electricity in view of prospective rural power demand.

1.5 Research Methodology and Scope of Work:

- Assesment of existing 33kV feeder network capacity in Oyo State rural areas was undertaken to facilitate of the study.The information needed for the research has been obtained from;
- Data collected on Oyo State and its 33kV network;components and mode parameters,values,power loads,population.
- Normal mode computations using direct methods of mode calculation.
- Comparative analysis of results with theoretical and practice standards.

The scope of this work comprises the assessment of transmission capacity of the existing 33kV Network(Rural Primary feeder Network). This includes:

- Computation of Relevant network parameters.
- Computation of expected maximum demand range.
- Computation and analysis of Normal mode operation parameters.
- Determination of power transfer capacity of network by thermal and voltage requirement.

Table 1.3: LGA Load densities based on Peak Load Supply and Population of Existing Rural Feeder-Network (33kv) of Oyo State

L.G.A	Hq	Population (p)	Feeder Substation	Name of feeder	LGA status	Peak Load mw	Load Density Kw/p
Section i							
Ibadan S/w	Oluyole	282,595	Ayede 330/132/33kv	Oluyole II	Urban	20	0.071
Section ii							
Oluyole	Idi-ayunre	202725	Ayede 330/132/33kv	Oluyole I	Semi-Urban	19	0.094
Section iii							
Iddo	Iddo	103261	Ayede 330/132/33kv	Lanlate & apata	Semi-Urban	11& 13.5 = 23.5	0.058
Ibarapa east	Eruwa	118,226			Semi Urban		
Ibarapa north	Ayete	101,092			Rural		
Ibarapa central	Igboora	102,979			Semi-Urban		
Section iv							
Olorun-sogo	Igbetti	81,759	Ilorin 132/33kv	Ilorin	Rural	14	0.045
Irepo	Kishi	122553			Rural		
Orelope	Igboho	104,441			Rural		
Section v							
Iseyin	Iseyin	256,926	Iseyin 132/33kv	Saki	Semi-urban	12.4	0.011
Kajola	Okeho	200997					
Atisbo	Tede	119792					
Itesiwaju	Otu	65616					
Iwajowa	Iwere-ile	102980					
Saki- east	Ago-amodu	110223					
Saki -west	Saki	278002					
Section vi							
Oyo-west	Ojon-gbodu	136,236	Iseyin 132/33kv	Iseyin	Urban	14.8	0.035
Atiba	Ofa-meta	169,702			Semi-urban		
Oyo-east	Kosobo	1123,846			Urban		

1.6 **Research justification**

The justification of this research is the necessity of the extension of the benefits of electricity applications for improved standard of living of the rural dwellers of Oyo State, and significance of development of the economic potentials of the rural areas.

1.7 Contribution to knowledge

The research work is expected to contribute to:

a) the planning and development of rural electrification in Oyo State; and

b) awareness of the typical condition of the existing primary distribution networks of Oyo State and Nigeria as a whole in view of full electrification prospects that includes rural communities.

1.8 Reasons and expected benefits of Rural Electrification in Oyo State

Bringing electricity to the people is, in itself, not a contribution to reducing poverty nor does it automatically lead to rural development. However, electricity will enhance rural development (human development) in the following areas:

1) Economic development,
2) Health. Reasons
3) Educational Reasons
4) Media and Information Access
5) Safety Reasons
6) Agriculture and Livestock
7) Political Reasons

An elaboration of these benefits are presented in Table 1.5

Table.1.5: Reasons and Expected Benefits of Rural Electrification in Oyo State

S/NO.	Reasons	Applicationsnm	Benefits
1.	Economic Reasons	Electrical Equipment for workshop and agricultural(including lighting and pumps) Establishment of small-scale industries. Establishment of new business and/ or expanding Current ones.	Increased income and employment Increased efficiency in small business
2.	Health Reason	Improvements to health facilities: cooking, lighting, and heating appliances.	Less dependence of cooking on kerosene.

		Improved health knowledge through increased access to television. Better nutrition from improved knowledge and storage facilities from refrigeration. Better nutrition and knowledge of health and family planning reduce ill health.	Culture of healty living. Health education via radio and television;and family planning. Retention of skilled staff.
3.	Educational Reasons	Improving the quality of schools and other the facilities.(electricity- dependent equipment) Time allocated at home for study. Increasing teacher quantity and quality. Improve women quality of life.	Increased study time at home and school. Reduced the eyestrain commonly associated with using candle &kerosene lamps. Reduce environmental harm. Retention of skilled staff.
4.	Safety Reasons	Community lighting (Public and outdoor lighting)	Improve Security (Theft) Protecting citizens from dangerous animals (e.g.) snail) River social life.
5.	Media and information Access:(radio, TV and in Term) fan/air conditioning Facilities)	Improved living condition Better social facilities with better equipment Extension of Rural Telephone	Greater comfort entertainment create more Awareness of current political world events Extents Access to rural telephone increases. Improving living condition.
6.	Agriculture and Livestock.	Vertical and horizontal extension of optical mechanization Transfer agricultural and health care directions (Through Broadcasting and television all over the state)	Enhance the rural inhabitants health condition Increase the animal health
7.	Political Reasons	Provision of social benefits e.g. improved health education, Social cohesion.	Promote political stability. reduce illiteracy Increase social amenities.

CHAPTER TWO

LITERATURE REVIEW

2.1 Concept of Rural Electrification

According to Jiahua (2004) the word rural is a regional concept, referring to country level and below Country Township (made of streets) and rural townships (mainly made of rural villages). Cities with large share of urban/non agricultural population is not included. Cities at country level with large population are counted as "rural". According to Encarta dictionary, a Rural Area means an area located outside of designated urban area or an area with a low population density.

In Nigerian policy (Ngadda,2005), and according to Power Sector Reform Act of Nigeria (2005), rural areas under the policy in Nigeria will be determined based on the following factors which is a relative concept but sufficiently flexible to allow for local interpretation:

1. Population size and density;
2. Remoteness and accessibility (to urban areas,given distance,terrain and existing transport infrastructure);
3. Availability of or proximity to basic infrastructure services;
4. Significance of agriculture to the local economy; and
5. Social-economy indicators,including income,education and health.

Zomer (2005 pgs 42-45) described Rural Electrification as referring to two categories of user groups: country townships and the rest of the country, mainly rural villages. Or the availability of electricity for use in rural communities, regardless of the form of generating. Or Rural Electrification comprises all activities aimed at enabling users situated outside major cities to have access to electricity.

2.1.1 Definition of Electrification.

Primary indicator is access to electricity, with detail measurement including quantity of supplied (frequency of cut-off, voltage, transmission losses); price of electricity. Under Nigeria policy,the un-electrified localities will be defined as areas that do not conform to the following definitions (Ngadda,2005):

2.1.2 Grid-connected. A locality or village shall be considered electrified if :

basic infrastructures such as distribution transformer and lines are provided in the inhabited areas;and electricity is provided to public places(e.g.schools,local government headquarters,worship centers,health centers,dispensaries,community centers etc)

2.1.3 Off-grid:

A locality or village shall be considered electrified if :Electricticity is provided to public (e.g.schools,local government headquarters,worship centers,health centers,dispensaries,community centers etc),for local networks,there should be a power source and distribution network in the community. In the case of low power battery-based and stand-alone (such as solar PV) systems,the minimum quality of service standards should be sufficient for,at a minimum,ligting one main room and powering a radio.

2.1.4 Feature of Rural Electricity Supply Areas. From the energy point of view, there are important differences between urban and industrialized areas and the rural areas. Urban and industrialized areas feature a substantial higher energy density and market opportunities for both heat and power relative to rural and remote areas. Linked with these differences are the methods and opportunities appropriate to satisfy the energy needs. The features of urban and industrialized areas make it economically more attractive to develop and operate connections to a local, regional or even a nation power system, efficiently deploy combined heat and power units, and to provide adequate services. These circumstances offer opportunities to prepare heat and power at reasonable price. Rural areas show other features. Scattered clusters of premises can for instance, characterize them. In most developing countries rural elect systems are characterized by dispersed consumers with often-limited consumption, a low load factor and relatively low quality of power supply. Dispersed consumer requires long supply line and/or diesel based or other generating units (Zomer (2005 pgs 42-43).

There are three major reasons suggested for a distinction between rural and urban power supply:

1. Rural electrification schemes generally cost more on a per connection basis because of dispersed loads, the rather low consumption and the poor load factor.
2. Rural electrification should be integrated or co-coordinated with other rural development programmed.
3. Urban and industrial power supply and rural power supply need different marketing and technical approaches.

The combined effects of the specific features of rural power system and their more problematic operation and maintenance, make the marginal costs of electricity supply to rural consumers high relative to that of consumers in urban areas (Nggada,2005).

2.2 Aims and Objective of rural electrification project

The main objectives of rural electrification programs are to:

(1) support agricultural, industrial and commercial development, including irrigation;

(2) reduce migration from rural to urban Areas;

(3) substitute for more costly and less convenient energy sources for cooking etc such as kerosene, charcoal etc;

(4) improve quality of life and timesavings through such means television, radio, and phone facilities;

(5) provide for lighting and use of domestic electrical appliances;

(6) enhance security, political stability and/or correction of regional disparities;

(7) improve the standard of living of the rural dwellers;

(8) alleviate urban/rural disparities

These objectives can theoretically be grouped into four categories: economic, social, political, and environmental objectives. In practice, however often two or more objectives occur simultaneously and are interrelated (Nggada,2005).

2.3 Types of Rural Electrification

There are two types of Rural Electrification in Nigeria.They are (Nggada,2005):

(1) Township Distribution Network,(TDN); and

(2) Inter- Township Connection;(ITC)

Moreover, there are three options for feeding Rural Primary Feeders. They are as follows(Rao S.):

(1) The main receiving substation feeders of the nearest city;

(2) from nearest distribution substation feeders; and

(3) from rural substation feeders.

The main receiving Station or Distribution substation steps down the voltage from 33kV to 11kV and feeds the rural primary feeders. Alternatively, 33kV lines may feed the rural substation, and step-down Transformers in the rural substations may feed the rural primary feeders at 11kV.The distribution system of rural areas may be of any one of the following types:

a) Simple radial distribution system.(single,double and triple radial)

b) Improved radial distribution system.

c) Interconnection distribution systems.

Radial System separate feeders radiate from a single substation and feed the distributiors at one end only.

The advantages of the radial system are:

i. Economy in large sub-transmission circuits.

ii. Several substations from each transmission circuit permits use of small multiple substations and short distribution feeders.

iii. The system takes maximum advantage of diversity factor between loads.

iv. The system permit transfer of load and thus allow maximum use of existing facilities.

v. Addition of load in small increments is possible and so the system offers considerable freedom in the location of additional capacity.

vi. Easy to protect,and low in cost.

2.4 Typical Network Elements of a Rural Electrical Networks

A typical Network of a Rural Electric networks comprises the following major elements (Bathia,S.L.2004):

(a) Conductor

(b) Supports

(c) Insulators

(d) Overvoltage Protective devices:(Lightning Arresters,D-Fuse;Earthing)

(e) Distribution transformers (main substation type; pole mounted type; ground mouted type)

An overhead line comprises mainly (i) conductor, (ii) supports, (iii) insulators and pole fittings. The function of overhead lines is to transmit electrical energy, and the important characteristics which the line conductors must have are:

(a) high electrical conductivity

(b) high tensile strength

(c) low density and

(d) low cost

The metals which posses the above properties are copper, aluminium and steel, which are used either alone or in combination.

2.4.1 Type of Conductors

The principal materials used as conductors in the construction of overhead lines are:

(i) Hard-drawn copper.

(ii) All-aluminium conductor (AAC)

(iii) Aluminium conductor, steel reinforced, (ACSR).

(iv) Cadmium copper.

(v) Steel

(vi) Aluminium alloy conductor

(i) Hard drawn copper:

The most common conductor used for transmission is hard-drawn copper, because it is twice as strong as soft drawn copper and it stretches to a much lesser extent than soft-drawn copper. The merits of this metal as a line conductor are:

i. It has a best conductivity in comparison to other metals. The conductivity of copper, however depends upon the percentage of impurities present in it, the more the impurities the lesser will be the conductivity. The conductivity of copper conductor also depends upon the method by which it has been drawn.

ii. It has higher current density, so for the given current rating lesser cross sectional area to wind loads.

iii. The metal is quite homogeneous

iv. It has low specific resistance

v. It has durable and has a higher scrap value

(ii) **All-Aluminium Stranded Conductor (AAC).**

AAC is used for urban and rural distribution where short spans are involved. Next to copper aluminium is the conductor used in order of preference as far as the conductivity is concerned. Its merits and demerits are

i. It is cheaper than copper

ii. It is lighter in weight

iii. It is second in conductivity (among the metals used for transmission). Commercial hard-drawn aluminium wire at standard temperature has approximately 60.6 percent conductivity in comparison to standard annealed copper wire.

iv. For same ohmic resistance, its diameter is about 1.27 times that of copper.

v. At higher voltages it causes less corona loss.

vi. Since the diameter of the conductor is more, so it is subject to greater wind pressure due to which greater is the swing of the conductor and greater in the sag.

vii. Since the conductors are liable to swing, so it requires larger cross arms.

viii. As the melting point of the conductor is low, so the short circuit etc. will damage it.

ix. Joining of aluminium is much more difficult than that of any other material.

x. For the same resistance and voltage drop, aluminium conductor has 1.6 times the cross-section of copper but due to low density, the weight is only 0.48 times, which is a big advantage in favour of aluminium.

(iii) **Aluminium Conductor Steel Reinforced.**

An aluminium conductor having a central core of galvanized steel wires is used for high voltage transmission purposes. This is done to increase the tensile strength of aluminium conductor. The galvanized steel core is covered by one or more strands of aluminium wires. The steel conductors used are galvanized in order to prevent rusting and electrolytic corrosion (since zinc is near to aluminium and there is no electro-chemical action between the two metals). The cross-section of the two metals are in the ratio 1: 6, but in case of high strength conductors their ratio is 1: 4. Thus the steel reinforced aluminium conductor has less sag and longer span than the copper conductor line since it has high tensile strength.

The aluminium steel conductor has a larger diameter than any other type of conductor of same resistance.

For all calculation purposes, it is assumed that the current is passing only in the alumini section.

(iv) **Cadmium Copper**. Addition of 1% cadmium to copper has the effect of Doubling its tensile strength and reducing its conductivity by 15%. Because of this, cadmium-copper is use as conductor in very long spans, and on tower lines for communication circuits and earthwire. ACSR conductors has replaced cadmium copper al for the reasons given in the preceding paragraph.

(v) Steel.

No doubt it has been got the greater tensile strength, but it is least used for transmission electrical energy as it has got high resistance. Bare steel conductors are not used since, deteriorates rapidly owing to rusting. Generally galvanized steel wires are used. It has t following properties.

1. It is lowest in conductivity
2. It has high internal reactance.
3. It is much subjected to eddy current and hysteresis loss.
4. In a damp atmosphere it is rusted.

2.4.2 Supports for Overhead Lines

The principal types of supports used for erecting overhead lines are:

(i) Wooden poles

(ii) Reinforced concrete (R.C.C) poles.

(iii) Steel tubular poles

(iv) Steel towers

The chief requirements for such supports are:

i. They must be mechanically strong with factor of safety of 2.5 to 3.

ii. They must have light in weight without the loss of strength.

iii. They must have least number of parts

iv. They must be cheap

v. They maintenance cost should be minimum

vi. They must be easily accessibly for point and erection of line conductors.

vii. They must have longer life.

viii. They must be of pleasing shape

The different types of poles, which can be used as, line supports

i. **Wooden Poles**. This use of such poles as line supports is limited to low voltages and are generally used for distribution purposes. Initially these poles are cheap and provide an insulating property. The poles preferably must be straight, strong with gradual taper and free from knots. The main disadvantage of such poles are that they are elastic and tend to rot, hence their life is short. The portion of the pole which is buried in the ground must be treated with a creosote oil or with any other preservative.

ii. **Reinforced Concrete Poles**. In the modern days, the reinforced concrete poles have almost replaced the wooden and are attractive to look at. Such poles are quite heavy, so transportation cost increases; but their maintenance cost is quite low and are mechanically very strong and hence have longer life.

iii. **Steel Tubular Poles**. The wooden poles may be substituted by by steel tubular poles. Since these poles are stronger than wood, so with the help of these poles increase the life of poles, they must be galvanized or painted regularly. For safety purposes, they must be earthed to increase the longitudinal strength of he pole, by steel rope guys.

iv. **Steel Towers**. The poles are used for distribution purposes, but the towers are useful for long transmission lines. It is not a hard and fast rule; even wooden poles may also sometimes be used for transmission purposes depending upon the need and circumstances. Generally very strong and have long life. It is said that if its design is given a proper care, the steel tower is good indefinitely. Due to robust construction, long spans can be used and are much useful for crossing fields valleys, railway lines, rivers (Bathia,S.L.2004).

2.4.3 Cross- Arms

i. Cross-Arms of painted hard wood (shisham) or creosoted soft wood (fir) are used on wood poles. The usual cross-section is 90 mm. X 120mm. They need replacement due to decay after five to seven years, depending upon the weather conditions. Wood is now both scarce and expensive.

ii. Steel cross-arms are stronger and last much longer, M.S. angle-iron size 60x60x6mm and 75x75x6mm and channel-iron sizes 75x40mm and 100x50mm are generally used for the purpose. smaller sections are used for communication circuits.

The shape and length of the cross-arm depends upon the desired configuration of conductors ((Bathia,S.L.2004).

Length of the Span. The transmission line for the purpose of economy is required to be constructed at the lowest possible cost and to achieve this span of the line must be optimum. This will reduce the number of poles and other fixtures thereby reducing the overall cost of the line. There is no definite mathematical expression which directly gives the length of the economical span. While deciding the length various factors as voltage, maximum tension on the poles during any part of the year, public safety and regulations imposed by government must be kept in mind. The usual spans are:-

(i) with wooden poles 40 – 50 meters

(ii) with steel tubular poles 50 – 80 meters

(iii) with R.C.C. poles 80 – 100 meters

(iv) with steel towers 100 – 300 meters

it should be remembered that

(i) the wires expand in the summer season and contract in the winter season, thereby decreasing and increasing the tension respectively.

(ii) In order to keep the insulation cost minimum the span is kept greater with the increasing voltages.

2.4.4 . Insulators (Bathia,S.L.2004).

These are made of glazed porcelain or tough glass and are used for supporting conductors.

The principal type of insulators are:

(i) Pin insulators. (ii) Shackle insulators.

(iii) Disc insulators. (iv) Strain insulators.

(v) Post insulators

The chief requirements for the insulators are:-

(i) They must be mathematically very strong

(ii) Their dielectric strength must be very high.

(iii) They must provide very high insulation resistance to the leakage currents.

(iv) They must be free from the internal impurities or flaws.

(v) They should not be porous

(vi) They should be impervious to the entrance of gases or liquids into the materials.

(vii) They should not be affected with change in temperature.

(viii) They must have high ratio of puncture strength of flash over voltage

LIBRARY • FED. UNIV. OF TECH., OWERRI

The main cause of failure of insulators is due to flash over or puncture. The flash over may occur between the line conductor and the earth i.e. the pin of the insulator, and due to production of extreme heat produced by the arc the insulator may puncture.

(i) **Pin insulators**. are manufactured for the voltages up to 33kV, and are cheaper than the other types.

Pin insulators. Of dimensions 100 x 65 mm and 105x 80mm are used for medium voltage work (Voltage below 1000V).Smaller insulators are used for telecommunication circuits.

(ii) **Shackle Insulator or Spool Insulators.** The shackle insulator or the spool insulator is mostly used for low voltage distribution lines. Such insulators can either be used in a horizontal position or in a vertical position. represent a shackle insulator. The conditions in the groove are fixed with the help of soft binding wires.

(iii) **Disc Insulators** . Disc insulators made of glazed porcelain or tough glass are used as insulators on high-voltage suspension lines. They can be assembled on form string-assemblies to suit any voltage .

The smaller disc insulator is used for voltages upto 11kV.

Disc insulators are provided with 'ball and socket' or 'tongue and clevis' type fittings. Either type is suitable for any application. A suspension clamp is used to support the conductor.

iv. **Strain Insulators.** When there is a dead end of the line, or there is corner or a sharp curve or the line crosses river etc. the line is to withstand great strain. For low voltage lines shackle insulators can be used, but for high voltage transmission lines, strain insulator consists of an assembly of suspension insulator

(v) **Post Insulators** are used for supporting bus bars in switchgear and in the manufacture of H.V. switches.

2.4.5 Overvoltage Protective devices (Bathia,S.L.2004).

The following devices are used to protect rural network equipment against possible damages causes by lightning surges due to direct strokes to the station or transmission lines:

a) Lightning Arresters,

b) D-fuse.

These devices are functioning as following:

a) **Lightning Arresters.**

A lightning arrester limits the voltage of the circuit by conducting current,just as a valve limits the pressure within a boiler by blowing off steam.It is capable of absorbing enough **transient** energy to prevent dangerous reflections and to cut off the flow of current at the first current zero after the discharge of the transient.

b) D-Fuse

High voltage explusion type "D" fuses are used extensively for the protection of feeders and transformers because of their low cost.The fuses are operated by a special operating rod from the ground below.A blown fuse can be readily spotted from a distance as the fuse-carrying barrels drop down whe the fuse blows.

2.4.6 Rural Distribution Transformers

The distribution transformers receive power from T-offs to the main radial primary feeders.The distribution transformers are located near the Group Loads or Unit Load(>10kW).

Distribution transformers are located far away from Main Distribution Substation usually 5 to 80 km away from the Main Distribution Substation feeding the primary distribution feeders.

Distribution transformers are necessary near service point near each remote village/consumer group or unit load.Norminal Voltage and Applications are shown in table 2.1.

Table.2.1 Reference values of Nominal Voltage Levels and Applications.

S/NO.	Nominal Voltage Levels	Type of Network	Type	Phase
1.	33kV	Distribution	HV	3-Phase,AC, at 50Hz Primary
2.	11kV	Distribution	HV	3-Phase,AC, at 50Hz
3.	415V,230V or 240V	Distribution Secondaries and Service to Custormers	LV	3-Phase,AC,Single Phase at 50Hz

Mounting of Distribution Transformers:

Oil Immersed Structure Mounted Distribution Transformers are used for Rural Distribution.The transformer is mounted on:

(a) Pole Mounted Transformer Substations.In rural areas where the load density is low and overhead are used,pole-mounted substations are natural choice.Single stout pole or H-pole and 4-pole structures with suitable platforms are employed for transformers of capacity below or upto 100kVA.All the equipment is of outdoor type and mounted on the supporting structure of ht distribution line.Triple Pole Mechanically Operated switch is used for switching "on" and "off" of ht transmission line.HT fuse unit is install for protection of ht side.To control lt side iron clad low tension switch of suitable capacity with fuses is installed.Lightning Arresters are installed over ht line to protect the transformer from the surges.Substation is earthed at two or more places.

(b) Foundation Mounted Substations.These substations are built entirely in the open and in such substations all equipment is assemble into one unit usually enclosed by a fence from the point of view of safety.Substations for primary and secondary transmission and for secondary distribution(above 100kVA) are foundation mounted outdoor type.

2.5 Equivalent Circuit Models of networks of economic voltage ≤ 33kV(Short Lines)

In a short transmission line the shunt conductance and shunt capacitance are neglected and so only the series resistance and inductance reactance are to be considered. If line length is less than 80km(50 miles), the line is known as a short line. The equivalent circuit is then just a resistance in series with an inductance

The resistance and inductive reactance are calculated by multiplying the per km(mile) values by the length of the line.

ABCD Model for a Short Line

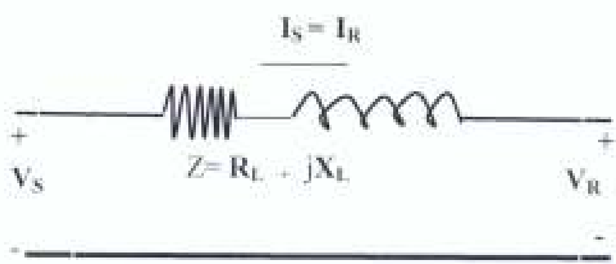

fig.2.1 Equivalent circuit of short line

U_S - Sending voltage U_R - Receiving voltage , $Z = R_L + jX_L$ (Impedance)

$I_S = input\ current; I_R = output\ current$

$V_S = A_S.$ $V_R + B.. I_R = V_R = I_R Z_{line}$

$I_S = S = C . V_R + . I_R = I_S$

For a Short line: $A = 1,$ $B = Z_{line}$ and

$C = 0 ,$ $D = 1$

2.6 Method of Successive Approximations

2.6.1 Local distribution networks

Analysis of Local distribution network is done by the first approximation:

1. determination of the largest voltage loss on the condition that voltage in all the nodes of the network equals the nominal;

2.6.2 Distric distribution networks

In radial distribution networks (with short lines or Unom <=33 kV), normal and steady network mode can be calculated in two stages:

1. first approximation-power distribution and losses in the network are determined;
2. second approximation-the determination of node voltages if the sending end voltage is given.

In conducting the second approximation,the successive determination of voltage losses in every section of the network is begun from the node where voltage is given.

The voltage U_1 at the beginning of a line section, having active resistance r and reactance x,during active power transfer,is determine,given powers and voltage P_2,Q_2,and U_2 at the end of the section by the following formula:

$$U_1 = \sqrt{\left(U_2 + \frac{P_2 r + Q_2 x}{U_2}\right)^2 + \left(\frac{P_2 x - Q_2 r}{U_2}\right)^2} \tag{2.1}$$

Or $$U_1 = \sqrt{(U_2 + \Delta U)^2 + (\delta U)^2}\,, \tag{2.2}$$

where ΔU and δU – direct and quadrature components of voltage drop in the given section.

Analogically,U_2 at the end of the section can be determined,given data at the beginning of the section by the following formula:

$$U_2 = \sqrt{\left(U_1 - \frac{P_1 r + Q_1 x}{U_1}\right)^2 + \left(\frac{P_1 x - Q_1 r}{U_1}\right)^2} \tag{2.3}$$

Losses in this section of line will be

$$\Delta P_l = \frac{P_2{}^2 + Q_2{}^2}{U_2{}^2} r \approx \frac{P_2{}^2 + Q_2{}^2}{U_2{}^2} r \tag{2.4}$$

$$\Delta Q = \frac{P_2{}^2 + Q_2{}^2}{U_2{}^2} x \approx \frac{P_2{}^2 + Q_2{}^2}{U_2{}^2} x \tag{2.5}$$

In approximate calculation of $power$ losses in the equations above the nominal voltage U_N is substituted for the actual voltages at the beginning and the end of line.

In Local distribution networks the voltages at the nodes are determined without considering the quadrature component.In such situation the voltage losses is calculated for the whole network and not by the sections:

$$\Delta U = \sqrt{3}\left(\sum_{j-1}^{n} i_{ja} R_j + \sum_{j-i}^{n} i_{jr}\ X_j\right) = \frac{1}{U_{norm}}\left(\sum_{j=1}^{n} p_j\ \ R_j + \sum_{j=1}^{n} q_j\ X_j\right). \tag{2.6}$$

Where i_{ja} , i_{jr},p_j ,q_j - active and reactive components of current and power load;R_j,X_j,- active resistance and reactance of line from the point to the point where j^{-th} power load is applied (connected).

In order to find the power flow in a double-end feed network with points A and B at the ends of the network,or in a loop network,calculation in the first stage is done without considering power losses.Power flow at the end sections are determine by:

$$\dot{S}_A = \frac{\sum_{m=1}^{n} \dot{S}_m \underline{Z}_{m\,B}}{\underline{Z}_{AB}} \tag{2.7}$$

$$\dot{S}_B = \frac{\sum_{m=1}^{n} \dot{S}_m \underline{Z}_{m\,A}}{\underline{Z}_{AB}} \tag{2.8}$$

Where $\dot{S}_m$ -load power;$\underline{Z}_{AB}$-total impedance of all the sections; $\underline{Z}_{mA}$, $\underline{Z}_{mB}$-impedances from the point where load is connected to the points A and B.

2.6.3 Voltage Regulation.Voltage regulation is a measure of line voltage drop and depends on the load power factor.Voltage regulation will be poorer at low lagging power factor loads. Percentage voltage drop in a feeder (or a line) with respect to receiving end voltage is

$$\%\,Voltage\ regulation = \frac{|U_S|-|U_R|}{|U_R|} \times 100 \qquad (2.9)$$

Where $U_S = Sending\ voltage, U_R = Receiving\ voltage = Nominal\ Voltage$

The following conclusions can be drawn from the above equation (2.9):

i. when the load p.f.is lagging or unity or such leading that $|U_s| > |U_R|$,then voltage regulation is positive i.e.receiving end voltage $|U_R|$ will be less than the sending end voltage $|U_S|$.

ii. For a given $|U_R|$ and I ,the voltage regulation of the line increases with the decreases in p.f.for lagging loads.

iii. When the load p.f. is leading to this extent that that $|U_R| > |U_S|$,then voltage regulation is negative i.e.the receiving end voltage $|U_R|$ is more than the sending end voltage $|U_S|$.

iv. For a given $|U_R|$ and I ,the voltage regulation of the line decreases with the decreases in p.f.for leading loads.(Metha V.K.and Metha R,2005 pg223).

2.7.1 Variable and Bus Type

Four variables are associated with each bus.They are:

1. Voltage magnitude $|U|$
2. Phase angle Θ
3. Real power P
4. Reactive power Q

The system buses are generally classified into three types and these are :

Slack Bus: It is reference bus, where the magnitude and phase angle of the voltage are specified.This bus makes up the difference between the scheduled loads and generated power that are caused by the losses in the network.

Load Bus: At these buses the active and reactive powers are specified.The magnitude and phase angle of the voltage are unknown.These buses are called P-Q buses.

Regulated Buses(Generator Buses): These buses are the generator buses.These are also known as voltage controlled buses.At these buses,the real power and voltage magnitude are specified.The phase angle of the voltages and the reactive power are to be determined.The limits on the value of the reactive power arealso specified.These buses are called P-V buses.

2.8 Case Examples of Rural Electrification Practice in other Countries

A brief on the characteristics of rural electrification networks in some foreign countries are presented below:

Australia

The network types and parameters are: high voltage - 11kV and 22kV with number of phases and neutral mode - 3-phase, and solidly earthed respectively; high voltage - 12.7kV and 19.1kV with single wire earth return; Distribution transformer winding configuration - Delta/Star; Low voltage systems - 415/240 V ,3-phase,4 wire solidly earthed neutral:240/480V,Single-phase 2/3 wire.

China

High voltage systems: 10kV,3-phase,4wire impedance earthed. Distribution transformer - Star/Star. Low voltage system - 380/220V ,3-phase, 4wire earthed neutral.

Fiji

High voltage system - 11 kV,3-phase,solidary earthed; distribution transformer - Delta/Star; Low voltage system - 415/240V, 4wire solidly earthed neutral

India

India is an agricultural country with over 95 percent population living in villages with electrical energy consumption around 35%. Prosperity of India is linked with improving standard of living of masses, providing electricity for lighting, irrigation pump sets, agro-based industries, communication facilities, education etc. and economic growth of rural India. Hence rural electrification has been give high priority in the five years plans. The rural loads must be also be created. *The per capital energy consumption of India* is lowest and around 298 kWh per year (2000) as against 10, 000 kWh per year in developed countries.

As per 9^{th} and 10^{th} five year plans of India, the average per capita energy consumption of rural sector and is to be raised to 350 kWh/year by 2003 AD and to 500 kWh/year by 2008 AD. The rural electrification plans were initiated with the first 5 year plan (1950). Rural Electrification corporation of India, a Govt. of India undertaking was set up during 1988. The village loads in India are growing. Rural electrification will need modernization and renovation during the 10^{th} five year plan (2004 – 2009) with reference to higher voltage and automation. Rural distribution requirements vary from state to state depending upon the nature of available and prospective loads in villages.

Rural Electrification planning in most of these countries is progressively on the increase (Ceelkski E.,Qunali A.,Aissa M.,Dunkerley J.).

CHAPTER THREE
METHODOLOGY

3.1 Preamble

The methods employed in carrying out the objectives in this report include the following:data collection on Oyo State and its 33KV network: components and mode parameters, values, power loads, population; Normal mode computations using numerical methods (iterative approximation methods); Comparative analysis of results with theoretical and practice standards.

3.2 Data Collection On Oyo State And Its 33 kV Distribution Network

For this work relevant data or information obtained include the geopolitical and economic activities of Oyo state; single line diagram and parameters of the distribution network; population of each Local Government Area; and maximum demand of each load center.

The geopolitical and economic activities of Oyo state are presented in chapter one. This information was obtained from the relevant ministries of the state government as indicated. The single line diagram of the state's distribution network and its quantities, and maximum power demand at each load center were obtained from the electricity utility, Power Holding Company of Nigeria (PHCN), and presented in fig.1.2-1.4 and tables1.4 for 2006. The quantities or network and mode parameters include the following: type and size or rating of line conductors; length of lines; and line voltages.

3.2 Normal mode computations

3.2.1 Calculation of using iterative approximation method

In this thesis, a radial configuration was considered and the normal mode parameters computed by using iterative approximation methods and validating the results afterwards using direct method (Matrix)

In order to do this, the equivalent circuit (impedance) diagram of the 33 kV network is drawn figs 3.4-3.6. The maximum power demand (P_{max}) for each load center is obtained by the following formula:

$$P_{\max(i)} = population(i) \times P_{\max 0},\qquad (3.1)$$ where $P_{max\,0}$ – expected maximum power demand per capita.

$$P_{\max 0} = \max\left\{\frac{P_{\max 1}}{population(1)}, \frac{P_{\max 2}}{population(2)}, ..., \frac{P_{\max N}}{population(N)}\right\},\qquad (3.2)$$ where N – node.Analogically, minimum power demand per capita can be calculated by the equation

$P_{\max N}$ is maximum power supplied to node N (see table 1.3 or section(i) with population(i)

$$P_{\min 0} = \min\{P_{\max 1}, P_{\max 2}, ..., P_{\max N}\},\qquad (3.3)$$

Where $P_{\min 0}$ -expected minimum power demand per capita

3.2.2 determination of line parameters

In iterative approximation ($\Delta P, \Delta Q$) the line active and reactive losses are calculated by the following equation (Wadhwa C.L.,2005):

$$\Delta P_{loss_{i-j}} = \frac{P_j^2 + Q_j^2}{U_j^2} R_{ij}\qquad (3.4)$$

$$\Delta Q_{loss_{i-j}} = \frac{P_j^2 + Q_j^2}{U_j^2} X_{ij}\qquad (3.5)$$

Active and reactive resistance of line:

$$R_{ij} = r_{o_{ij}} * l\qquad (3.5)$$

$$X_{ij} = x_{o_{ij}} * l\qquad (3.6)$$

Where i- index of sending end,

j-index of receiving end

In the first successive approximation $U_j = U_{nom}$

The voltage drops are calculated by the following formulae

$$\Delta U_{ij} = \frac{P_j R_{ij} + Q_j X_{ij}}{U_j} + j\frac{P_j R_{ij} - X_{ij}}{U_j} \tag{3.7}$$

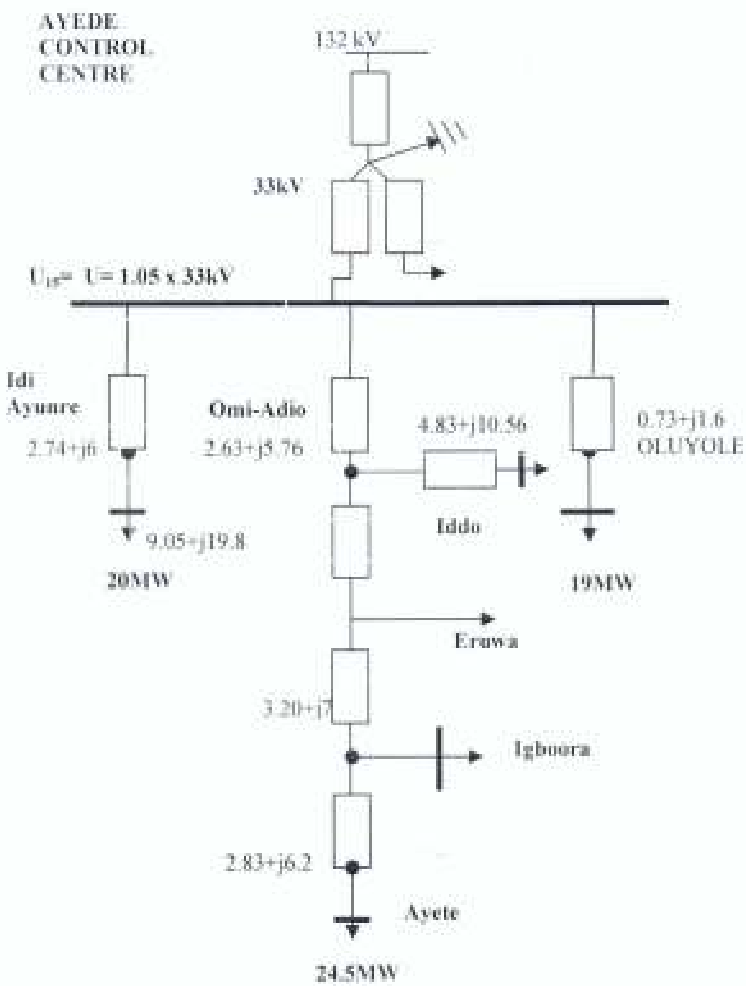

Fig.3.4 Equivalent Circuit Network Diagram (Ayede-Lanlate-Oluyole)

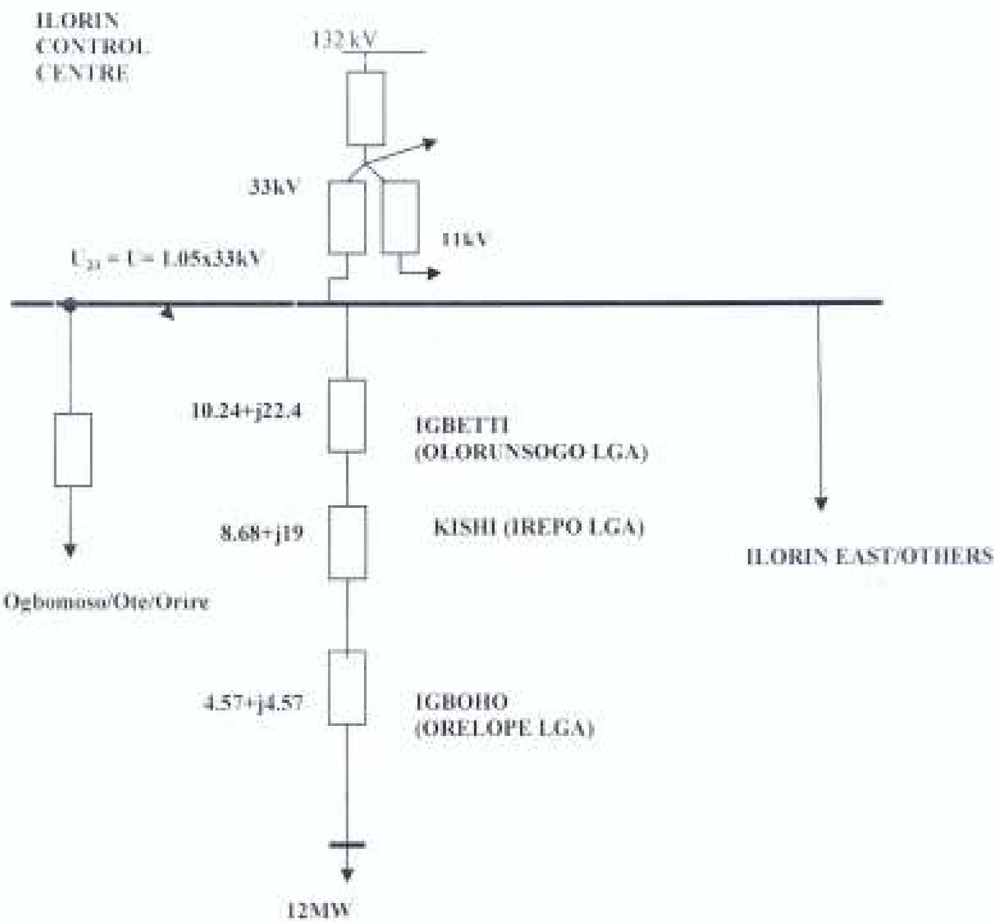

Fig.3.5 Equivalent Circuit Network Diagram (Ilorin-Igbetti-Kishi-Igboho)

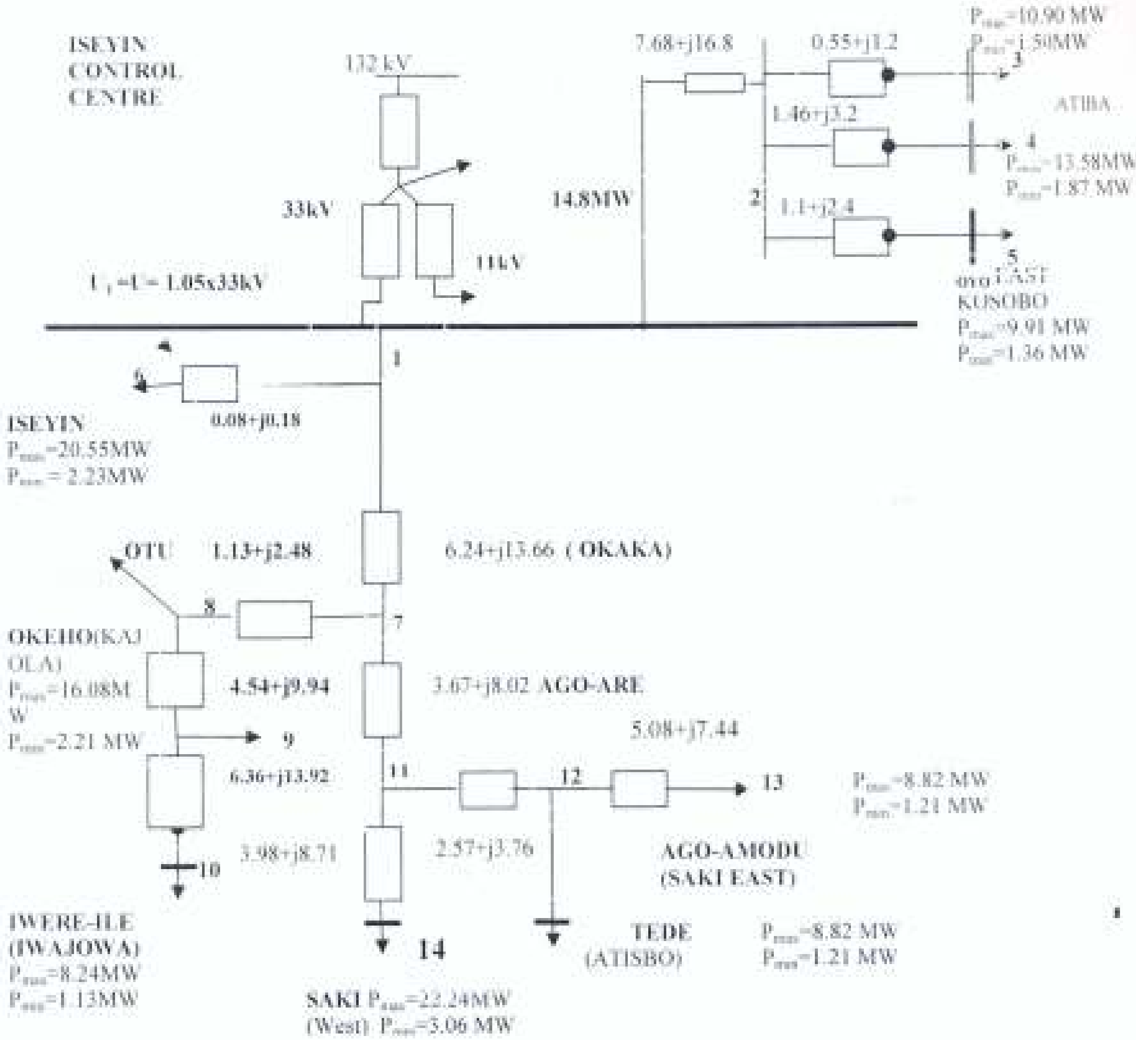

Fig.3.6 Equivalent Circuit Network Diagram (Iseyin-Oyo:Iseyin-Shaki)

3.3 Determination of Line Currents and Bus Voltages Using Direct Method (Matrix)

The operating mode is formulated as a system of linear algebraic equations based on current balance in matrix form. Consequently, equation of state is as follows (Gangadhar,2006; and Sadaat H,2002):

For n bus system,the node-voltage equation in matrix form is

$$\dot{J}_{bus} = Y_{bus}\dot{U}_{bus} \qquad (3.8)$$

Where J_{bus} is the vector of the injected bus currents (i.e.external current sources).

The current is positive when flowing towards the bus,and negative if flowing away from the bus.

U_{bus} is the vector of bus voltages measured from the reference node(i.e.node voltages).

Y_{bus} is known as the bus admittance matrix.

$$Y_{bus} = \begin{bmatrix} Y_{11} & \cdots\cdots\cdots & Y_{1n} \\ \cdots & \cdots\cdots\cdots & \cdots \\ \vdots & \vdots & \vdots \\ Y_{n1} & \cdots\cdots\cdots & Y_{nn} \end{bmatrix} \text{(nodal bus admittance matrix)} \qquad (3.9)$$

Note that the elements of matrices will include all shunt elements to ground.

$$Z_{bus} = Y_{bus}^{-1} \qquad (3.10)$$

$$J_{bus} = \begin{Bmatrix} J_1 \\ J_2 \\ \vdots \\ J_n \end{Bmatrix} \quad (bus\ current\ vector) \qquad (3.11)$$

$$U_{bus} = \begin{Bmatrix} U_1 \\ U_2 \\ \vdots \\ . \\ U_N \end{Bmatrix} \quad (bus\ voltage\ vector) \tag{3.12}$$

Note that the elements of matrices will include all shunt elements to ground.

The nodal current equation is a vector equation composed of n scalar equations.

In practice,the bus current is replaced by injected bus power S_n

$$S_n = P_n + jQ_n \tag{3.13}$$

It may sometimes be useful to write the bus current equation in the inverted form viz

$$U_{bus} = Z_{bus}\, I_{bus} \tag{3.14}$$

Where the nodal bus impedance matrix Z_{bus} is obtained from Y_{bus}

$$Z_{bus} = Y_{bus}^{-1} = \begin{bmatrix} Z_{11} \dots\dots\dots\dots\dots\dots Z_{1n} \\ \dots\dots\dots\dots\dots\dots\dots\dots \\ \dots\dots\dots\dots\dots\dots\dots\dots \\ \\ \dots\dots\dots\dots\dots\dots\dots\dots \\ \dots\dots\dots\dots\dots\dots\dots\dots \\ \dots\dots\dots\dots\dots\dots\dots\dots \\ Z_{n1} \dots\dots\dots\dots\dots\dots Z_{nn} \end{bmatrix} \tag{3.15}$$

Determination of line current

$$I = \dot{y_b} \times \dot{U_b}, \tag{3.16}$$

Branch potential difference

$$U_b = \dot{M}^T \times \dot{U_\Delta}, \tag{3.17}$$

where $M^T = Transpose\ of\ the\ bus\ incidence\ matrix$

$U_\Delta = Voltage\ drops\ in\ buses\ with\ respect\ to\ refrence\ bus\ or\ balancing\ node.$

U_b = Bus voltage

$$\dot{U}_{\Delta} = \dot{U}_{bat} - \dot{U}_{bus} \tag{3.18}$$

Estimation of most economical voltage of lines

The result of line currents with respect to existing distribution voltage demands selection of new distribution voltage. This is calculated using the formula (Pabia,.2003 and Gupta B.R,1998):

$$U = 5.5 * \sqrt{\frac{L}{1.6} + \frac{P}{100}} \tag{3.19}$$

where L – distance, km; P – active load, MW

CHAPTER FOUR

RESULTS AND ANALYSIS

LIBRARY FED. UNIV. OF TECH.

4.1 Level of Rural Electrification in Oyo State

Estimates of population rates (%) living in the rural ares of Oyo State based on classifications of LGAs (Table 1.1) and results of population census (2006 estimate) are presented in Table 4.1.

Table 4.1 Populations with access to electricity in Oyo State (2006 Estimate)

Level	Population,%	Population with Electricity,%
Urban	34	100
Semi-Urban	42	Not determined
Rural	24	Not determined

4.2 Estimation of Expected Maximum Demands in the Network

The expected P_{max} for each load node of the 33 kV network is calculated by (3.1) – (3.2

Using (3.2), $P_{max,0} = 0.094\ kW/p$. Analogically, $P_{min,0} = 0.011\ kW/p$.(see Table 1.3)

For example:

For $N = Jobele$, (Headquater of Afijio Local Government Area of Oyo State)

$$\begin{aligned} P_{max} &= 134,173 \times 0.094 \\ &= 12612\ kW \\ &= 12,612\ MW \end{aligned}$$

Analogically, P_{max} is calculated for other nodes and the results presented in table 4.2.

Table 4.2 **Expected Maximum Demand at the 33kV Load Centres**

Oyo State		Population (2006 est)			Land mass	P_{dmin}	P_{dmax}	P_{min}	P_{max}
L.G.A.	Hq	Females	Males	Total	Km^2	kW/þ	kW/þ	kW	kW
Afijio	Jobele	66603	67570	134,173	685085	0.011	0.094	1476	12612
Akinyele	Moniya	105726	105633	211359	464892	0.011	0.094	2325	19868
Egbeda	Egbeda	143275	138298	281573	485508	0.011	0.094	3097	26468
Ibadan n/e	Idi ape	166774	16362	330399	51260	0.011	0.094	3634	31058
Ibadan north	Bodija	153756	153039	306795	132500	0.011	0.094	3375	28839
Ibadan n/w	Onireke	77523	75311	152834	59001	0.011	0.094	1681	14366
Ibadan s/e	Mapo	130577	135469	266046	58251	0.011	0.094	2927	25008
Ibadan s/w	Oluyole	14070	139515	282585	133500	0.011	0.094	3108	26563
Ibarapa east	Eruwa	58182	60044	118226	905316	0.011	0.094	1300	11113
Iddo	Iddo	51750	51511	103261	1,010,956	0.011	0.094	1136	9707
Saki east	Ago-amodu	54219	56004	110223	1,484,843	0.011	0.094	1212	10361
Saki west	Saki	140771	137231	278002	2,022,739	0.011	0.094	3058	26132
Iseyin	Iseyin	126778	130148	256926	1,341,766	0.011	0.094	2826	24151
Kajola	Okeho	101544	99453	200997	646,346	0.011	0.094	2211	18894
Iwajowa	Iwere-ile	50675	52305	102980	2,397,404	0.011	0.094	1133	9680
Atisbo	Tede	54309	56483	110,792	2,837,417	0.011	0.094	1219	10414
Irepo	Kisi	60349	62204	122553	972,316	0.011	0.094	1348	11520
Olorunsogo	Igbetti	40373	41386	81759	4,070,216	0.011	0.094	899	7685
Orelope	Igboho	51291	53150	104441	893,082	0.011	0.094	1149	9817
Ogbomoso/ n.	Sabo	95401	103319	198720	207,978	0.011	0.094	2186	18680
Ogbomoso/s.	Arowomole	49566	51249	100815	146,741	0.011	0.094	1109	9477
Orire	Ikoyi	74293	76335	159628	1,908,504	0.011	0.094	1756	15005
Surulere	Iresadu	69776	72294	142070	831,912	0.011	0.094	1563	13356
Ogo-oluwa	Ajawa	32008	33176	65184	415,951	0.011	0.094	717	6127
Atiba	Ofa-meta	84366	85336	169702	1,620,825	0.011	0.094	1867	15952
Itesiwaju	Otu	63036	65616	128652	1,246,234	0.011	0.094	1415	12093
Oyo east	Kosobo	61334	62512	123846	176,825	0.011	0.094	1362	11642
Oyo west	Ojongbodu	67225	69011	136236	519,377	0.011	0.094	1499	12806
Ona-ara	Akanran	133588	131471	265059	425,944	0.011	0.094	2916	24916
Oluyole	Idi-ayunre	100505	102220	202,725	635,384	0.011	0.094	2230	19056
Lagelu	Iyana-ofa	73642	74315	147597	310,850	0.011	0.094	1624	13874
Ibarapa central	Igboora	50760	52219	102979	480,422	0.011	0.094	1133	9680
Ibarapa north	Ayete	49682	51410	101092	1,137,762	0.011	0.094	1112	9503.

4.3 Estimation Of Network Line Parameters

The network line parameters of the 33 kV distribution network of oyo State are presented in Table 4.3.

Table 4.3 **33 kV Line Parameters: active and reactive resistances**

Code	line	F,mm²	type	N	L, km	r_o, Ω/km	x_o, Ω/km	R, Ω	X, Ω
n15-16	Ayede-Ayre	150	ASCR	1	15	0.1828	0.4	2.74	6
n15-22	Ayede-OLuyole	150	ASCR	1	4	0.1828	0.4	0.73	1.6
n15-17	Ayede-Miadio	150	ASCR	1	14.4	0.1828	0.4	2.63	5.76
n17-18	Omiadio-Iddo	150	ASCR	1	26.4	0.1828	0.4	4.83	10.56
n17-19	Miadio-Eruwa	150	ASCR	1	49.5	0.1828	0.4	9.05	19.8
n19-20	Eruwa-Igbora	150	ASCR	1	17.5	0.1828	0.4	3.20	7
n20-21	Igboora-Ayete	150	ASCR	1	15.5	0.1828	0.4	2.83	6.2
n23-24	Ilorin-Igbetti	150	ASCR	1	56	0.1828	0.4	10.24	22.4
n24-25	Igbetti-Kishi	150	ASCR	1	47.5	0.1828	0.4	8.68	19
n25-26	Kishi-Igboho	150	ASCR	1	25	0.1828	0.4	4.57	10
n1-6	Iseyin	150	ASCR	1	0.45	0.1828	0.4	0.08	0.18
n1-7	Iseyin-Okaka	150	ASCR	1	34.15	0.1828	0.4	6.24	13.66
n7-8	Okaka-Ottu	150	ASCR	1	6.2	0.1828	0.4	1.13	2.48
n8-9	Ottu-Okeho	150	ASCR	1	24.85	0.1828	0.4	4.54	9.94
n9-10	Okeho-Iwere	150	ASCR	1	34.79	0.1828	0.4	6.36	13.916
n7-11	Okaka-Agoare	150	ASCR	1	20.05	0.1828	0.4	3.67	8.02
n11-12	Agoare-Tede	100	ASCR	1	9.4	0.2733	0.4	2.57	3.76
n12-13	Tede-Ago-amadu	100	ASCR	1	18.6	0.2733	0.4	5.08	7.44
n11-14	Agoare-SakiW	150	ASCR	1	21.78	0.1828	0.4	3.98	8.712
n1-2	Iseyin-OyoIJ/	150	ASCR	1	42	0.1828	0.4	7.68	16.8
n2-3	OyOIJ-IND	150	ASCR	1	3	0.1828	0.4	0.55	1.2
n2-4	OyOIJ-[illegible]	150	ASCR	1	8	0.1828	0.4	1.46	3.2
n2-5	OyOIJKSBO	150	ASCR	1	6	0.1828	0.4	1.10	2.4

4.4 Estimation of mode parameters

The loadflow parameters of the 33 kV networks were determined using eqns (3.4) to (3.18). Economic voltages for transferring power in each line was estimated using eqn (3.19). Based on these, mode simulation of network using 132 kV for distribution rather than 33 kV was done and its parameters calculated. The results for the two scenarios are presented in tables 4.3 to 4.10.

Table 4.4 Ayede 132kV/33 kV Transmission Substation: Distribution at 33 kV

From	To	L, km	I, A	Bus	U_{nom}, kV	U_{max}, kV	U_{min}, kV	Vbus, kV	V_{reg}, %	size, mm2	N	$I_{p\,max}$, A	LC	Remark		$V_{[illegible]}$, kV
														V_{bus}	LC	
Ayede	Idiayunre	15.0	437.39	1	33	36.3	31.35	31.3	-5.1	150	1	400	1.09	underVoltage	OL	61.45
Ayede	Oluyole	4.0	587.86	2	33	36.3	31.35	34.5	4.6	150	1	400	1.47	normal	OL	69.07
Ayede	Omi-adio	14.4	878.61	3	33	36.3	31.35	26.7	-19.2	150	1	400	2.20	underVoltage	OL	85.37
Omi-adio	Iddo	26.4	213.56	4	33	36.3	31.35	22.4	-32.2	150	1	400	0.53	underVoltage	normal	46.95
Omi-adio	Eruwa	49.5	665.06	5	33	36.3	31.35	1.6	-95.2	150	1	400	1.66	underVoltage	OL	79.04
Eruwa	Igboora	17.5	427.12	6	33	36.3	31.35	-4.1	-112.4	150	1	400	1.07	underVoltage	OL	61.17
Igboora	Ayete	15.5	213.56	7	33	36.3	31.35	-6.6	-120.2	150	1	400	0.53	underVoltage	normal	44.71

Table 4.5 Ayede Transmission Station 132kv/33 Kv: Distribution at 132 kV

From	To	L, km	I, A	Bus	U_{nom}, kV	U_{max}, kV	U_{min}, kV	Vbus, kV	V_{reg}, %	size, mm2	N	$I_{p\,max}$, A	LC	Remark		$V_{[illegible]}$, kV
														V_{bus}	LC	
Ayede	Idiayunre	15.0	109.35	1	132	138.6	125.4	144	9.1	150	1	400	0.27	OverVoltage	normal	
Ayede	Oluyole	4.0	146.96	2	132	138.6	125.4	144.8	9.7	150	1	400	0.37	OverVoltage	normal	
Ayede	Omi-adio	14.4	219.65	3	132	138.6	125.4	142.8	8.2	150	1	400	0.55	OverVoltage	normal	
Omi-adio	Iddo	26.4	53.39	4	132	138.6	125.4	141.7	7.4	150	1	400	0.13	OverVoltage	normal	
Omi-adio	Eruwa	49.5	166.26	5	132	138.6	125.4	136.5	3.4	150	1	400	0.42	normal	normal	
Eruwa	Igboora	17.5	106.78	6	132	138.6	125.4	135.1	2.3	150	1	400	0.27	normal	normal	
Igboora	Ayete	15.5	53.39	7	132	138.6	125.4	134.5	1.9	150	1	400	0.13	normal	normal	

Table 4.6 Iseyin 132kv/33 Kv Transmission Station: Distribution at 33 kV

From	To	L, km	I, A	Bus	U_{nom}, kV	U_{max}, kV	U_{min}, kV	Vbus, kV	V_{reg}, %	size, mm2	N	$I_{p\,max}$, A	LC	Remark		V_{min}, kV
														V_{bus}	LC	
Iseyin	Town	0.45	449.3	1	33	36.3	31.35	36.1	9.5	150	1	400	1.12	OV	OL	59.97
Iseyin	Okaku	34.15	1629.9	2	33	36.3	31.35	-6.1	-118.5	150	1	400	4.07	UV	OL	116.88
Okaka	Ottu	6.20	752.2	3	33	36.3	31.35	-26.2	-179.3	150	1	400	1.88	UV	OL	78.26
Ottu	Okeho	24.85	872.6	4	33	36.3	31.35	-34.3	-203.9	150	1	400	2.18	UV	OL	86.25
Okeho	Iwere-ile	34.79	757.3	5	33	36.3	31.35	-35.7	-208.2	150	1	400	1.89	UV	OL	81.89
Okaka	Ago-are	20.05	532.5	6	33	36.3	31.35	-22.6	-168.5	150	1	400	1.33	UV	OL	68.06
Ago-are	Tede	9.40	180.4	7	33	36.3	31.35	-28.9	187.7	100	1	308	0.59	UV	normal	40.23
Tede	Ago-amodu	18.60	486.6	8	33	36.3	31.35	-35.1	-206.4	100	1	308	1.58	UV	OL	65.10
Ago-are	Saki	21.78	386	9	33	36.3	31.35	-30.1	-191.2	150	1	400	0.97	UV	norm.	59.11
Iseyin	Oyojss	42.00	192.7	10	33	36.3	31.35	32.7	-0.8	150	1	400	0.48	UV	norm.	48.30
Oyojss	Oyo west	3.00	238.6	11	33	36.3	31.35	32.2	-2.4	150	1	400	0.60	normal	norm.	44.30
Oyojss	Atiba	8.00	297.1	12	33	36.3	31.35	30.9	-6.2	150	1	400	0.74	UV	norm.	50.24
Oyojss	Oyo east	6.00	216.4	13	33	36.3	31.35	31.8	-3.8	150	1	400	0.54	normal	norm.	42.91

Table 4.7 Iseyin Transmission Station 132kv/33 kV: Distribution At 132 kV

From	To	L_{ci} km	I, A	Bus	U_{nom} kV	U_{max} kV	U_{min} kV	Vbus, kV	V_{reg} %	size, mm2	N	$I_{p.max}$ A	LC	Remark		V_{nom}, kv
								V_{bus}						V_{bus}	LC	
Iseyin	Town	0.45	112.3	1	132	138.6	125.4	145.2	10	150	1	400	0.28	OV	normal	59.97
Iseyin	Okaka	34.15	407.5	2	132	138.6	125.4	135.6	2	150	1	400	1.02	normal	OL	116.89
Okaka	Ottu	6.20	188	3	132	138.6	125.4	129.6	-1.8	150	1	400	0.47	normal	normal	78.25
Ottu	Okeho	24.85	218.2	4	132	138.6	125.4	127.5	-3.4	150	1	400	0.55	normal	normal	86.26
Okeho	Iwere-ile	34.79	189.3	5	132	138.6	125.4	127.2	-3.6	150	1	400	0.47	normal	normal	81.88
Okaka	Ago-are	20.05	133.1	6	132	138.6	125.4	130.5	-1.2	150	1	400	0.33	normal	normal	68.05
Ago-are	Tede	9.40	45.1	7	132	138.6	125.4	128.9	-2.4	150	1	400	0.11	normal	normal	40.23
Tede	Ago-amodu	18.60	121.6	8	132	138.6	125.4	127.4	-3.5	150	1	400	0.30	normal	normal	65.08
Ago-are	Saki	21.78	96.5	9	132	138.6	125.4	128.6	-2.6	150	1	400	0.24	normal	normal	59.11
Iseyin	Oyojss	42.00	48.2	10	132	138.6	125.4	144.3	9.3	150	1	400	0.12	OV	normal	48.31
Oyojss	Oyo west	3.00	59.7	11	132	138.6	125.4	144.2	9.2	150	1	400	0.15	OV	normal	44.31
Oyojss	Atiba	8.00	74.3	12	132	138.6	125.4	143.9	9	150	1	400	0.19	OV	normal	50.25
Oyojss	Oyo east	6.00	54.1	13	132	138.6	125.4	144.1	9.1	150	1	400	0.14	OV	normal	42.91

Table 4.8 Ilorin Transmission Station 132kv/33 Kv: Distribution At 33 Kv

From	To	L, km	I, A	Bus	Unom, kv	Umax, kv	Umin, kv	Vbus,k	Volt.reg, %	size, mm^2	N	$I_{p.max}$, A	LC	Remark		V_{min}, kv
														V_{bus}	LC	
Ilorin	Igbetti	56.00	602.0	1	33	36.3	31.35	10.6	-67.8	150	1	400	1.51	UV	OL	76.59
Igbetti	Kisi	47.00	427.12	2	33	36.3	31.35	-4.8	-114.6	150	1	400	1.07	UV	OL	65.57
Kisi	Igboho	25.00	213.56	3	33	36.3	31.35	-8.9	-127	150	1	400	0.53	UV	Normal	46.67

Table 4.9 Ilorin transmission station 132kv/33 kV: distribution at 132 kV

From	To	L, km	I, A	Bus	U_{nom}, kV	U_{max}, kV	U_{min}, kV	V_{bus},k	ΔV,%	size, mm2	N	$I_{p.max}$, A	LC	Remark		V_{max}, kv
														V_{bus}	LC	
Ilorin	Igbetti	56.0	150.50166	1	132	138.6	125.4	138.8	5.1	150	1	400	0.38	Ov	Normal	
Igbetti	Kisi	47.0	106.77967	2	132	138.6	125.4	134.9	2.2	150	1	400	0.27	Normal	Normal	
Kisi	Igboho	25.0	53.389835	3	132	138.6	125.4	133.9	1.4	150	1	400	0.13	Normal	Normal	

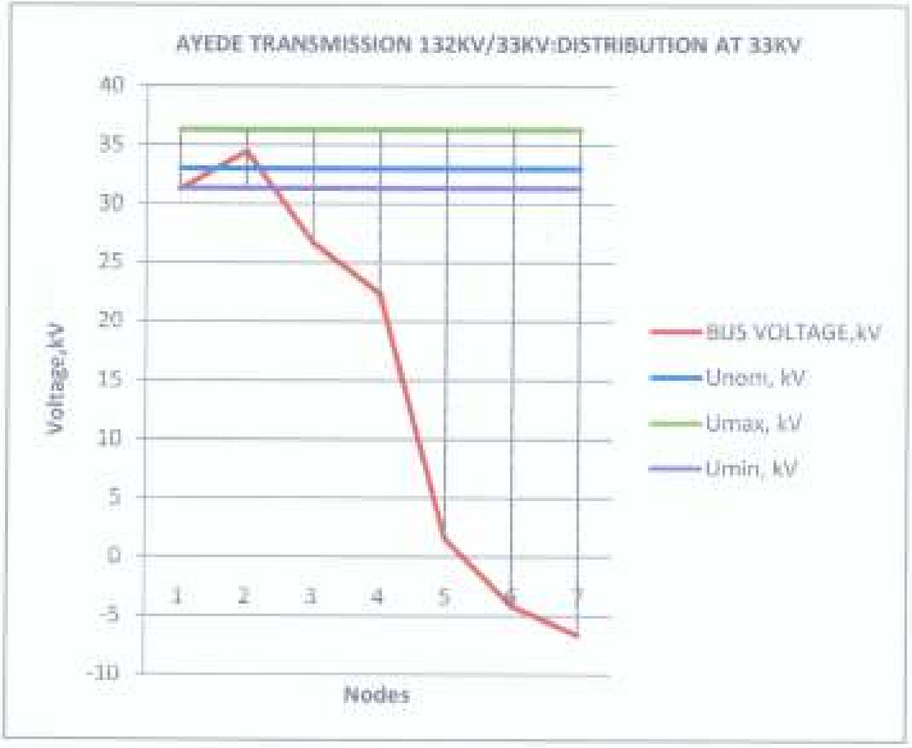

Fig.4.1 Graph of Bus Voltage of 33KV EDN feeding from Ayede33KV substation bus

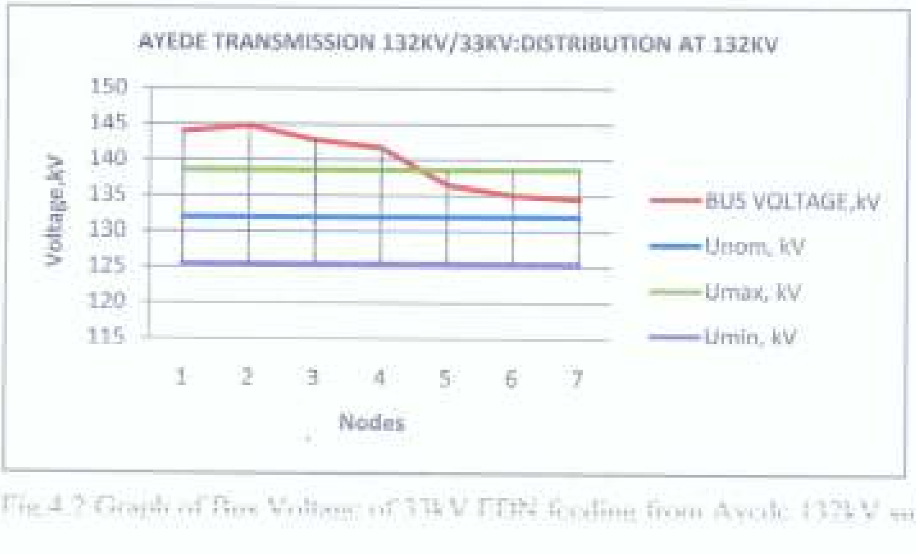

Fig.4.2 Graph of Bus Voltage of 33KV EDN feeding from Ayede 132KV substation bus

Fig 4.3 Graph of Bus Voltage of 33kV EDN feeding from Iseyin 33kV substation bus

Fig 4.4 Graph of Bus Voltage of 33kV EDN feeding from Iseyin132kV substation bus

Fig 4.5 Graph of Bus Voltage of 33kV FDN feeding from Ilorin 33kV substation bus

Fig 4.6 Graph of Bus Voltage of 33kV FDN feeding from Ilorin 132kV substation bus

Table 4.10 Summary of bus voltage and Line Load distribution conditions at 33kV

132/33kv	Number of buses			Number of line s	
	Normalvoltage	Undervoltage	Overvoltage	Normal loading	Overloading
Ayede	one	four	none	three	three
Iseyin	two	ten	one	Six	seven
Ilorin	one	three	none	one	two

Table 4.11 Summary of bus voltage and Line Load distribution conditions at 132 kV

132/33kv	Number of buses			Number of line s	
	Normalvoltage	Undervoltage	Overvoltage	Normal loading	Overloading
Ayede	Three	None	Four	Seven	none
Iseyin	Eight	None	Five	Twelve	none
Ilorin	two	none	one	three	None

Table 4.12 Total sum of Transformers Capacity at 132/33kV Substations

S/No.	Substation	Transformer Capacity 132/33kV	Total Capacity for 132/33kV	Expected Demand @ 33 kV	Expected Demand @ 132 kV
1.	Ayede	30MVA X 2Nos, 60MVA	120MVA	119.702 MVA	114.26 MVA
2.	Ilorin	60MVA	60MVA	78.132MVA	74.58 MVA
3.	Iseyin	45MVA	45MVA	190.129MVA	181.518MVA
Total		225 MVA	225 MVA	387.96MVA	370.36MVA

(Sources: N.C.C.Osogbo)

Analysis of results on existing and potential bus loads, and mode parameters of Oyo state reveals the following:

a) 24% of the population, 5591589 (2006 estimate), reside in the rural areas; the average annual growth rate is 42,232.

b) the load densities per capita range from an average minimum of 0.011 kW to a maximum of 0.094 kW. The maximum corresponds to the most energized local government (Oluyole), though semiurban;

c) Expected potential load demand for the whole of Oyo state is about 534 MW (2006 estimate). This is huge compared to 103.7 MW, being the sum total supplied by the electricity utility, PHCN.

d) In Oyo state 33 kV networks, only 4 load buses have permissible voltage levels, 17 load buses have undervoltages, 1 load bus has overvoltage. Only 10 out of 22 lines have permissible loading coeffiscients. Consequently, the capacities of these networks are inadequate and require reinforcements in view of prospective rural electrification.

e) The economic voltages of virtually all lines of the existing network are significantly above 33 kV. This implies that an upgrade of distribution voltage is necessary.

f) The total 132 kV/33 kV substation capacity is 225 MVA(Table.4.11), which is insuffiscient for the potential load demand of oyo state, i.e., including Rural Electrification.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 Conclusions:

In this study on the adequacy of the existing 33 kV network for prospective rural electrification in Oyo State, the following conclusions can be made:

i. 24% of the population, 5591589 (2006 estimate), reside in the rural areas; the average annual growth rate is 42,232.

ii. the load densities per capita range from an average minimum of 0.011 kW to a maximum of 0.094 kW. The maximum corresponds to the most energized local government (Oluyole), though semiurban;

iii. Expected potential load demand for the whole of Oyo state is about 534 MW (2006 estimate). This is huge compared to 103.7 MW, being the sum total supplied by the electricity utility, PHCN.

iv. In Oyo state 33 kV networks, only 4 load buses have permissible voltage levels, 17 load buses have undervoltages, 1 load bus has overvoltage. Only 10 out of 22 lines have permissible loading coeffiscients. Consequently, the capacities of these networks are inadequate and require reinforcements in view of prospective rural electrification.

v. Upgrading the voltage of the existing network will improve the distribution capacity of the existing network significantly and solve overloading and voltage problems.

vi. The total substation capacity is inadequate for meeting the potential demand of Oyo State, including electrification of the rural areas.

5.1 Recommendations:

Based on the conclusions made in this study, the following recommendations are made:

(1) The 33 kV network should be reinforced by upgrading to 132 kV;

(2) The total substation capacity in Oyo State should be increased by installing more 132 kV substations to relieve the existing fully loaded ones.

REFERENCES

Bhatia S.L., (2004). Handbook of Electrical Engineering, Sixth Edition. Khanna Pubhlisers New Delhi.pgs.428-503.

Ceeelski E., Qunali A., Aissa M., Dunkerley J.,(2005). Rural Electrification in Tunisia,(ESMPA).

Chakrabarti A., Soni M.L., Gupta P.V.Bhatnagar U.S., (2006). A Text Book on Power System Engineering, New Revised Edition, Dhanpat Rai & Co. (P) Ltd. Delhi.http://www.en.wikipedia.org/wiki/Oyo State.

Ministry of Finance, Budget and Training, Oyo State, Ibadan,(2007),Published by Department of Macro-Statistics and Research, Oyo State, Ibadan.Nigeria.

Gangadhar K.A.,(2006).Electric Power System,Published by Romesh Chandr Khanna for Khanna Publishers,2-B,Natth Market,Nai Sarak,Delhi-110006.pgs.204-217.

Gupta B.R. (1998),Power System Analysis and Design.S.Chand & Company Ltd.New Delhi. Pages209-228 & 503.

Jiahua P, (2004).China's Experiences with Rural Electrification, Electricity & Human Prospect Stanford University journal.

Khedkar M K.G M Dhole,V S Ingle,(2003),Optimal Load Transfer: Strategy for Loss Reduction of Distribution Network.IE(I) Journal-EL,Vol.84,December 2003.

Lakervi E. & Holmes E.J.(1989) Electricity Distribution Network Design, Reprinted by Peter Peregrinus Ltd, United Kingdom.

Metha V.K & Metha R.,(2005).Principle of Power Sysstem,Revised Edition 2005, S.Chand & Company Ltd.New Delhi.pgs.159-168&228-231.

Nagrath I.J and Kothari D.P.(2001).Power System Engineering, TataMcGraw-Hill Publishing Company Limited.New Delhi.pgs175-208.

National Population Commission: (2007) Federal Republic of Nigeria Official Gazette Lagos, Vol.94.

Nggada H. FNSE. (2005),Director,Electrical Inspectorate Services Dept.Federal Ministry of Power(former FMPS.& Fed.Min.of Energy Nigeria),The National Workshop on The Electricity Power Sector Reform (E.P.S.R) Act (2005).pgs.2-10.

Nggada H. FNSE. (2002),Director,Electrical Inspectorate Services Dept.Federal Ministry of Power(former FMPS.& Fed.Min.of Energy Nigeria),Review of Federal Rural Electrification.Published by ICEED PRESS,6 Sapele Street,Garki II,Abuja.pgs.93-109.

Pabia A.S.(2003),Electric Power Distribution,Fifth Edition,TataMcGraw-Hill Publishing Company Limited,New Delhi.pg.448.

Rao S. EHV-AC, HVDC (2004). Transmission & Distribution Engineering,. Third Edition, Hanna Publisher Delhi.pgs.1206-1230 & 1316-1330.

Sadaat H.,(2002),Power System Analysis,Eight Edition, TataMcGraw-Hill Publishing Company Limited,New Delhi.pgs.142-145.

Wadhwa C.L.:(2005) Electrical Power Systems, Fourth Edition, New Age International Publishers, New Delhi.pg.720-728.

Weedy B.M.Cory B.J.(1999).Electric Power Systems,Fourth Edition,John Wiley & Sons Ltd.Baffins Lane,Chichester,West Sussex PO19UD,England.pgs 228-246.

Zomers,A N.(2005): Rural Electrification, Ph.D.thesis, University of Twente.(http://www.tup.utwente.nl/uk/cataloque/technical/rural-electrification).pgs.42-48.

APPENDIX-I

Monthly Maximum Load Demand (Mw)

Feeder Substation	Jan.	Feb.	March	April	May	June
Iseyin/Saki	12.4	10.7	11	11.2	10.7	7.8
Iseyin/Oyo	13.6	10.7	13.6	12.6	12.6	9.7
Ayede/Oluyole ii	19	18	15	15	16	14
Ayede/Idi-Ayunre	0	14	0	14	13.5	0
Ayede/Lanlate	8.5	9	9	7	11	4
Ayede/Apata	6	11.5	13	12	11	10
Ilorin/Kisi-Igboho	14	14.9	15	14.5	14	14

Table A6.1: (Source: Ayede & Ilorin Control Centre)

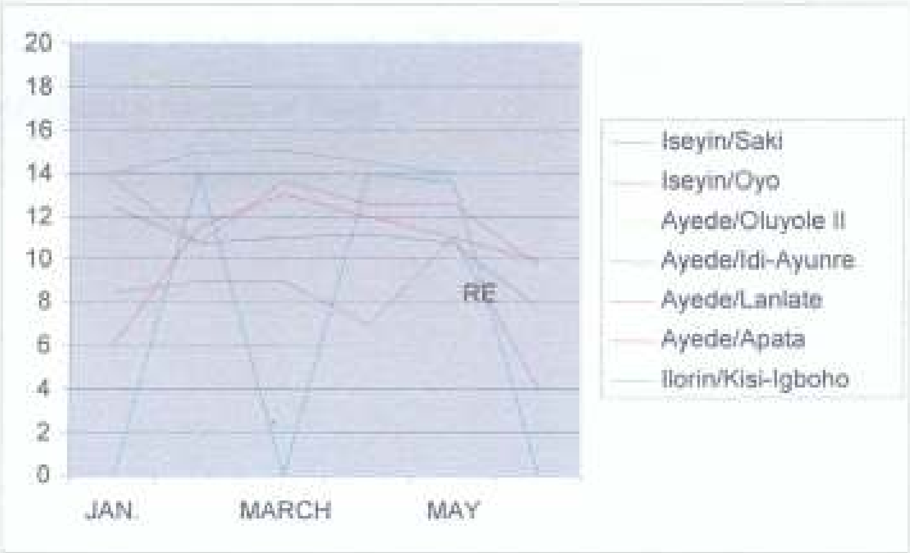

Fig.A6.1: Monthly Load Demand Curve (Jan.-June 2007)

(Source: Author)

APPENDIX-II

LIST OF ACRONYMS

HV = High voltage

OV = Overvoltage

UV = Under voltage

OL = Overload

UL = Under load

REN = Rural Electrification Network

MV = Medium voltage

LV = Low voltage

AAC=All- Aluminum Conductor

ACSR = Aluminum Conductor Steel Reinforcement

PHCN = Power Holding Company of Nigeria Plc

FMP = Federal Ministry of Power

EDN=Electricity Distribution Network