EFFECTIVENESS OF RURAL ELECTRIFICATION SCHEMES TO ENHANCE THE LIVING STANDARD OF RURAL COMMUNITIES

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in partial fulfillment of the requirements for the
Degree of Master of Science

by

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DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.

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I endorse the declaration by the candidate.

UOM Verified Signature

Prof. Ranjit Perera

ABSTRACT

Government of Sri Lanka spends large amounts of money to implement Rural Electrification (RE) schemes with the support of concessionary loans from various funding agencies such as Asian Development Bank, Japanese Bank of International Corporation and Kuwait Fund. The expectation of the government is to develop rural areas by providing electricity to those areas and enhance the living standards of rural people.

The aim of this study is to investigate the implemented RE schemes and to examine whether the desired targets have been achieved as planned in the initial stage and the reasons for failures if expected results have not been achieved, and to propose corrective actions to overcome those problems.

Nine RE schemes were selected from Kalutara, Monaragala and Badulla districts which are implemented in the period of year 1998 to year 2000 by CEB under Project – RE 3 funded by Asian Development Bank for investigation.

1. Social and Economical development achieved by these schemes
2. Technical problems related to these schemes and reliability of electricity supply.

The present situations of these schemes were investigated through a structured survey and compared the results with expectation of the planning stage. At the occasions of present results are deviated from the expected targets, corrective actions are proposed for implementation in existing RE schemes and also in future RE schemes.

The development in social and economic benefits in the villages due to rural electrification schemes can be summarized as, Achievement on economic benefits, poverty alleviation, household benefits, education level, community benefits and incentive to build houses are found to be satisfactory. Improvements on employment opportunities, small industries, commercial and agricultural activities and health services are found to be not satisfactory. Migration of villagers to urban areas was reduced and no harmful environmental effects are observed.

It is further revealed that reliability of electricity supply provided for rural villages are not satisfactory, Energy losses are considerably high, Load factor, Power factor and All-day efficiency of RE substations are at acceptable levels, Safety levels provided by the RE schemes are fairly low, The effectiveness of RE schemes were considerably reduced due to above technical reasons.

ABC (Ariel Bundle Conductor) conductors are recommended in place of bare aluminium conductors to minimize reliability and safety problems. Small size transformers are recommended to reduce overall losses and cost of implementation. Electronic energy meters are recommended to reduce revenue losses.

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Chapter 1

Introduction

1.1. Background

Government of Sri Lanka spends a large amount of money, amounting to several hundred million rupees every year to implement Rural Electrification (RE) schemes with concessionary loans from various funding agencies such as Asian Development Bank (ADB), Japanese Bank of International Corporation (JBIC), Kuwait Fund (KF)

The expectation of the government of Sri Lanka is to develop rural areas through these projects and to enhance the rural living standards. To implement these RE schemes, the government spends, taken from above funding agencies. Table 1.0 gives the funds spent to implement RE schemes in each year.

Period of Implementation	**Name of CEB Project**	**Funded by**	**Approximate Cost in Million USD**
1983 – 1987	RE 1	ADB	11.3
1992 – 1995	RE 2	ADB	74.3
1995 – 1996	RE 2 (Extension)	ADB	9.0
1996 – 2003	RE 3	ADB	55.0
2004 – 2006	RE 4	SIDA	23.5
2001 – 2003	RE 5	Kuwait	14.4
2003 – 2006	RE 6	ADB	52.0
2004 – 2006	RE 7	China	24.0

Table 1.0 – Cost of RE Projects funded by various funding agencies.

1.2 Present Electrification Level in Sri Lanka

The present overall electrification level of Sri Lanka is about 77% (mid 2006). However, there are several districts whose electrification levels lie far below the national average. Table 1.1 gives the Provincial and District wise electrification levels as they were in mid 2006.

Province	Electrification. Level	District	Electrification. Level
Central	79%	Kandy	76%
		Matale	80%
		Nuwaraeliya	83%
North Central	66%	Anuradhapura	67%
		Polonnaruwa	65%
North Western	74%	Kurunegala	72%
		Puttalum	78%
West-North	98%	Gampaha	98%
Eastern	58%	Ampara	62%
		Batticaloa	50%
		Trincomalee	53%
Northern	38%	Vavuniya	63%
		Kilinochchi	4%
		Jaffna	61%
		Mannar	37%
		Mulathive	1%
West-South	92%	Colombo	97%
		Kalutara	81%
Southern	88%	Galle	94%
		Matara	90%
		Hambantota	74%
Uva	58%	Badulla	67%
		Monaragala	50%
Sabaragamuwa	69%	Rathnapura	65%
		Kegalla	74%
Sri Lanka (Overall)		**77.1%**	

Table 1.1- Electrification levels in Sri Lanka as in mid 2006.

1.3 The Expected Outcomes from RE schemes

Rural electrification in Sri Lanka is generally carried out in villages with a certain level of development. Those villages enjoy the basic needs such as water, housing, transport, health, education, entrepreneurial support like extension services, credit facilities and markets.

The addition of electricity to the existing infrastructure of these villages becomes an effective catalyst in accelerating the growth in the villages and will improve the quality of life in the villages. It is expected to develop facilities described below by village electrification.

1.3.1 Economic benefits

Non electrified villages in Sri Lanka use Kerosene oil for domestic lighting. The first benefit to be seen immediately after the electrification is the savings in the use of imported fuel. The rural electrification gives an impetus to the industries and it opens up many opportunities for productivity growth, development of small scale industries and commercial activities. It is expected to promote small industries such as Rice Mills, Rubber Mills, Coconut Fiber Mills, Saw Mills, Carpentry & Metal Workshops, Stone Crushers, Sugar Cane Crushers, Brick Making Machines, Garment Industries, Food Industries and Farms.

Several of these industries may already exist in non–electrified villages using traditional techniques and power derived from Kerosene or Diesel. But with the availability of electricity these industries will eventually convert to electricity thus increasing their output and leading to substantial savings in fuel and maintenance costs.

In addition to the facilities made available to small scale industries, Medium and Large scale industries can also benefit from the availability of substation and the spur medium voltage lines. This gives a great contribution to the village in providing employment and opening opportunities to sell ancillary services to the main industries.

There are many more economic benefits which are of indirect nature. Households, commercial establishments and workshops are able to engage in more productive hours, creation of employment, increased home garden cultivation using domestic water pumps, backyard farms and small cottage industries are few of the engagements by which the electrification will contribute towards the economy of the village.

1.3.2 Social benefits

The social benefits of the electrification of the villages are tremendous. The electrification on its own and integration with other facilities brings in a package of improvements in the quality of village life. These improvements in turn contribute towards the economic upliftment of the village.

1.3.2.1 Household benefits

The immediate benefit to be seen on electrification is the domestic lighting. Almost all non-electrified households use kerosene for lighting. Many houses use bottle-lamps which are very inefficient and hazardous. Only a few houses use pressure type kerosene lamps. The introduction of the electric lamp makes the pattern of evening activities in the village home more comfortable and useful.

After some period of time, depending on the income of the household, other electric appliances get introduced to the household. The items generally used in electrified rural households are fans, TVs, refrigerators, domestic water pumps, smoothing irons, electric heaters kettles etc.

With the availability of electricity the life at home begins to improve in its quality. Extended hours will be available for whatever activity they wish to do. Villagers who spend long hours of work outside their homes will now be able to spend a few leisure hours at home reading news papers and watching television.

1.3.2.2 Improvement to education

Children will improve their educational standard due to the convenience and extended hours of study at home. In addition the school in the village will also be able to improve its activities.

1.3.2.3 Improvement in health services

The electricity will improve the quality of the service of rural hospitals or health centers in the village. As an example, the ability to have a refrigerator in the village health center to store vaccines will improve the child immunization programmes etc.

1.3.2.4 Community benefits

While electrified households enjoy many direct benefits due to the electrification the whole village too reaps some direct and indirect benefits. When villages are electrified, the distribution is generally limited to the main central area of village. This is due to the heavy cost of electrification and even within the electrified area only some houses obtain connections.

There are many ways by which every villager benefits from the electrification. They enjoy more activities at the community centers, and as the shops are kept open for longer hours with few street lamps at important places they are able to do shopping even during night time.

Repair shops, Carpentry shops etc. install new machines, welding plants and other equipment which would enable the villagers to get their needs within the village. Often the village worker is unable to attend in day time religious activities due to his need to be at the work place. With efficient lighting being available the temples, churches, kovils and mosques can arrange ceremonies in the evening hours of the day.

Job opportunities will also be created in the village due to improved and new commercial and industrial activities.

1.3.2.5 Incentive to build Houses

With the facility and opportunity being made available in the village due to electrification, the migration of the villagers to neighboring urbanized areas is reduced. The land prices will also be increased due to the demand.

1.3.3 Social Indicators

Generally, Sri Lanka enjoys the social indicators that are higher than those in other countries of similar economic status. In comparison, it has a high literacy rate, high life expectancy at birth, low child mortality and a reasonably unproblematic birth rate. These achievements are due to the efforts that have been made in providing vital basic needs in the villages. The inclusion of electricity to these basic needs will eventually contribute greatly in raising the social indicators.

1.3.4 Environmental Impacts

In order to erect medium voltage lines and low voltage lines, trees and other obstacles must be cleared to provide the path during construction and maintenance of electricity lines. The initial environmental inspection indicates that there is no significant environmental impact in the localities where the project is to be carried out. The studies on long term indirect environmental impact of RE projects [Ref 3] show that no adverse effects are recorded. The number of residents will increase, arresting the migration to urban areas but there will be no boomtown effect. Medium and large industries that may develop will pose environmental hazards but such industries will be adequately controlled by regulations in the country.

1.4 Motivation

Although the Sri Lankan government is spending large amounts of money every year to implement RE schemes through the Ceylon Electricity Board, most of RE schemes constructed by CEB are found not to be economically viable. Usually, any type of business will not be sustained unless it is profitable. Similarly, in case of RE schemes, if those schemes cannot be maintained by CEB in a profitable manner, it will always be a loss to the CEB and ultimately creates bad effects to both CEB and to the rural development.

As an Engineer in distribution sector of CEB, the author selected this topic to investigate the effectiveness of RE schemes to enhance the living standard of rural communities.

Chapter 2

Problem statement

2.1. Identification of the Problem

The expectation of the Sri Lankan government is to develop the country by upgrading rural villages. Therefore, the government is always seeking to develop infrastructure facilities of rural villages and thereby enhance the living standards of rural community and increase the productivity. To achieve this target the government is spending large amounts of money every year to provide electricity to the rural villages through the Ceylon Electricity Board.

The construction and maintenance of these schemes are handled by CEB. Generally, from CEB's point of view, RE schemes are not profitable. However, when the social factors are taken into consideration, they contribute to make significant changes in socio-economic development. Therefore, these schemes are essential to develop the living standards and to improve the productivity of rural communities. Therefore, it is required to find solutions to the problems,

I. How much do these schemes contribute to the rural development?
II. How well does CEB handle construction and maintenance of these schemes to ensure the best profitability?

2.2. Objectives of the Study

The aim of this project is to investigate the implemented RE schemes and examine whether the desired targets have been achieved as planned in the initial stage. If the desired targets have not been achieved this study will examine the reasons for failures and propose corrective actions to overcome those problems. During the investigation more attention is paid to the following,

I. Social and Economic improvements achieved through the schemes on
    - Education level
    - Employment level
    - Monthly Income
    - Household comfort

- Small industries and commercial establishments
- Conversion from uneconomical type of fuel into electrical energy
- Health facilities

II. Quality of electricity supply provided for these schemes
    - Voltage & power factor profile
    - Load curves & load factor
    - Energy losses
    - Reliability and safety

The details related to the present situation of a selected set of RE schemes were collected through a structured survey.
This study contains the following aspects as well,

III. To suggest corrective actions to be employed in future RE schemes in order to achieve desired targets.

For the success of this investigation, it was decided to select RE schemes from rural areas which are at least seven years old. All details used at the planning stage of these schemes were collected from relevant authorities.

2.3 Importance of the study

Since the cheapest and reliable form of energy is the electricity, it can be used to develop rural infrastructure facilities and thereby develop rural communities. Therefore, rural electrification schemes are essential to develop rural areas. However, if these schemes cannot be constructed and maintained in a profitable manner, it will create a series of problems to the supply authority as well as to the rural communities and ultimately creates harmful effects to the development of the country.

Therefore, it is essential to investigate the performance of these schemes and find out the reasons for failures, if these schemes are found to be un-profitable.

This research will help to find feasible solutions for the above problems and the results obtained through this study will help to construct and maintain future RE schemes in a profitable manner.

Chapter 3

Survey

3.1. Introduction

For the success of this investigation, it is required to select RE schemes from rural areas which are at least seven years old after implementation. All details used at the planning stage should be collected from the relevant authorities and details related to the present condition of these schemes are collected through a structured survey.

After collection of all related data, the originally expected targets should be compared with the present situation of the schemes. If a scheme failed to achieve the expected targets, suggestions to improve are to be made by analyzing the survey details.

The information collection comprises three parts as given below:

I. Collection of Technical, Social and Economic data used at the planning stage.
   - Collected from the initial investigation reports of the respective RE scheme.

II. Social and Economic data at present
   - Collected from all consumers through the survey (see Appendix I)

III. Technical data at present
   - Collected from field measurements and survey (see Appendix II)

3.2 Preparation of the questionnaire

In order to gather sufficient information regarding the impact of electrification, a detailed questionnaire was prepared by obtaining the information from investigation report prepared for the RE Project 3 of CEB, questionnaire prepared for Social and Economic investigation for RE schemes in 1997 by the Distribution Planning Branch, CEB and through the experience gathered by the author working as an Engineer in Distribution Maintenance Branch in CEB. The questionnaire was divided into two sections to gather information of Social & Economic impacts (Questionnaire for RE scheme survey – section 01) and details related to the technical problems of RE schemes (Questionnaire for RE scheme survey – section 02).

Section – 01 included fifty five questions / information grouped into ten sub sections under the headings general details of the scheme, details of the house, educational & financial details, details of electricity supply, details of electricity usage, quality of electricity supply, street lighting, health services, environmental effects and details of vehicles. (Appendix I)

Section – 02 included forty information grouped into seven sections under the headings general details of the scheme, development details of the scheme, technical details of medium voltage side and low voltage side, average load factor, average power factor, no-load loss of the transformer, and all-day efficiency of the transformer. (Appendix II)

3.3 Selection of Samples

In order to get more accurate results from this study, it was decided to select matured RE schemes, at least seven years or more after implementation from various parts of the Island. Nine RE schemes funded by Asian Development Bank and implemented from 1996 to 2003 under the Project RE3 were selected from Kalutara, Badulla and Monaragala districts.

The majority of rural people are farmers or labourers working on daily paid basis. They earn money from cultivating their lands or working as labourers in the same village or close to the village. It was noted that people in three districts have markedly different life styles.

As the majority of these people are farmers, they must have enough water resources to cultivate their lands. They obtain water for the cultivation by different means, such as rain water or from irrigation schemes. This factor will create significant changes in their life styles. The people who use rainwater can't cultivate their lands equally throughout the year. Therefore, they cannot earn money uniformly throughout the year and their lives are not much comfortable. But, the people who use irrigation water to cultivate there lands can earn more money better distributed over the year and hence their lives become more comfortable.

3.4 Description of the Samples

Table 3.0 gives the details of the selected samples for this investigation. All RE schemes selected are mature ones. (Project - RE 3, funded by ADB, 1996 - 2003). Geographical situation of the schemes are shown on the map in figure 3.0.

SI No.	District	Electorate	Name of the RE scheme and year of energized	No. of Consumers in the RE scheme	Total No. of Consumers in the sample
S1	Kalutara	Agalawatta	Kelinkanda Stage II 1998	092	575
			Batahenpitiya 2000	181	
			Kurupita 1999	187	
			Horagoda 1999	115	
S2	Badulla	Maiyanganaya	47th Mile post, Arawatta 2000	343	675
			Hobariyawa 1999	332	
S3	Monaragala	Monaragala	Punsisigama 1999	278	636
			Higurukaduwa 1998	217	
		Bibile	5th Mile post, Rideemaliyadda 2000	141	
Total No. of Consumers					**1886**

Table 3.0 – Details of the selected samples for the investigation.

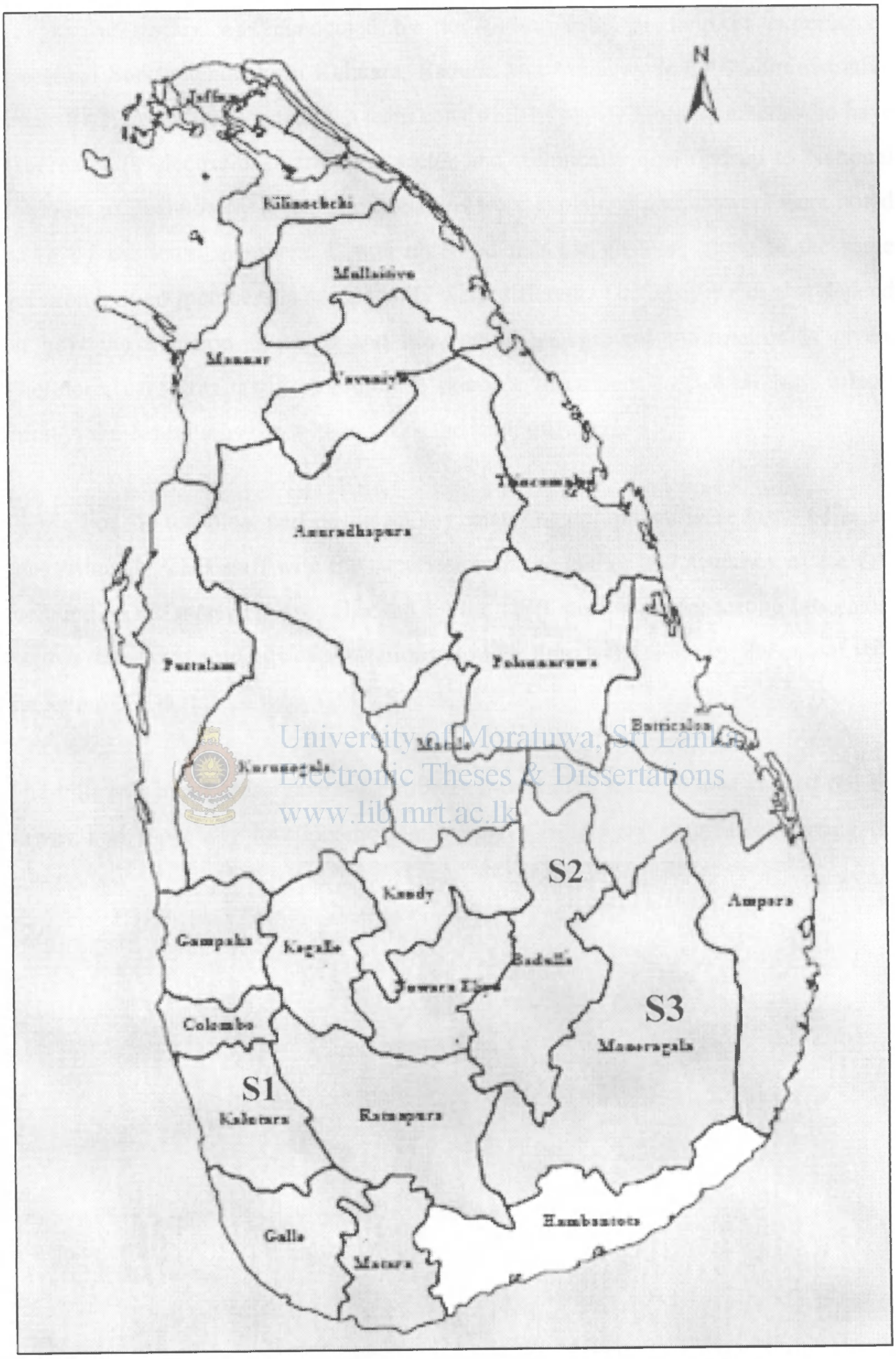


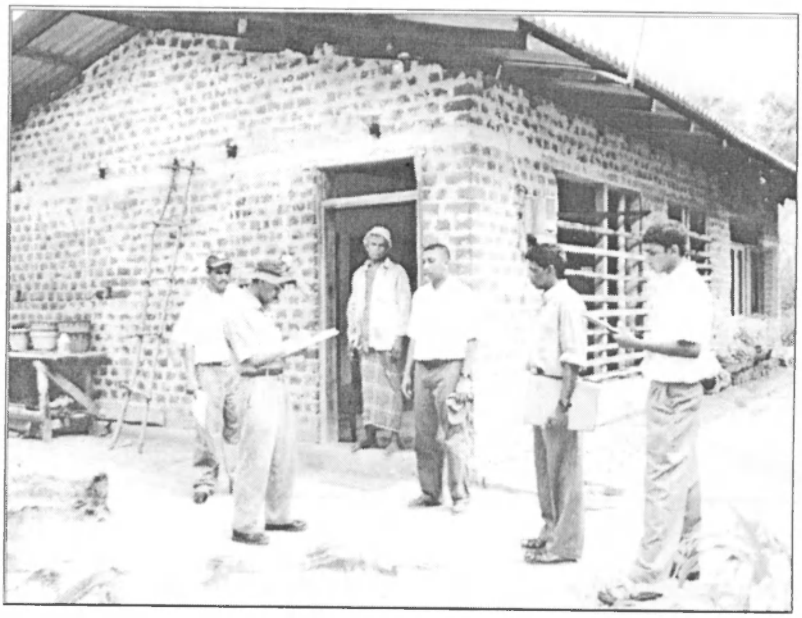
Figure 3.0 - Geographical situation of selected samples.

3.5 Conduct of the survey

The survey was conducted by the author with the help of experienced Electrical Superintendents in Kalutara, Badulla and Monaragala CEB administrative areas. Each house was visited by a team consisting of two or more members who have experience in electricity distribution sector and technically qualified up to National Diploma in Technology level. The questions were explained and answers were noted down by the team members. It was observed that the answers given to the same question by two members in same family were different. The answer can also depend on how the question is posed and how much background information is given. Therefore, care was taken to minimize possible discrepancies due to such effects through the continuous consultation with the team members.

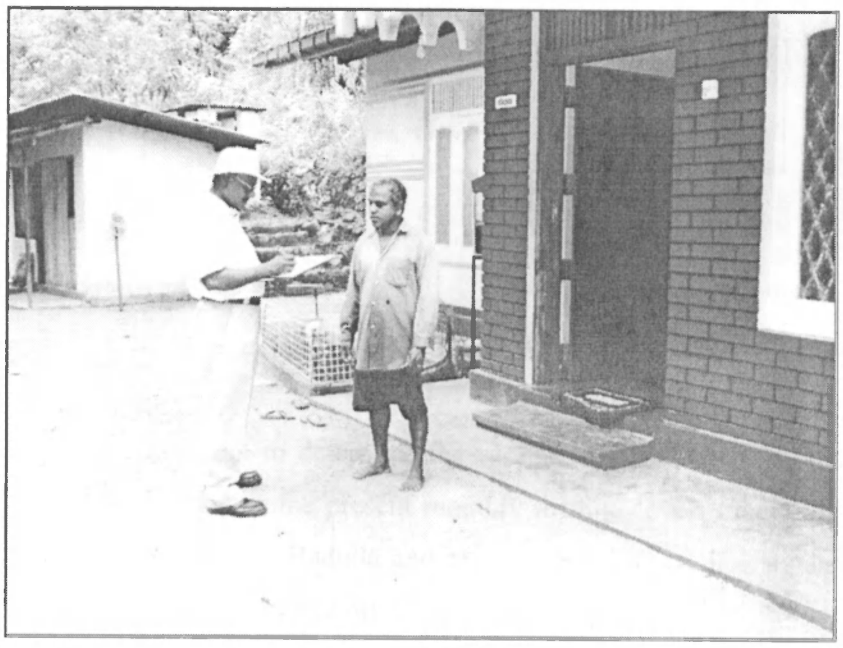
For the technical part of this survey, metering equipment were installed to the substations by CEB staff with the supervision of the author and accuracy of the data recorded in the meters were checked by the CEB staff of meter testing laboratory Region -04. Load readings of substations at night time were taken by the author with the help of CEB staff of relevant CEB area.

The villagers in all areas gave their fullest co-operation to the teams carried out the survey and especially low income families have been very open in answering the questions.



Collecting consumers' details by the survey team at Punsisigama, Monaragala.

Collecting consumers' details by the survey team at Horagoda, Baduraliya, Agalawatta.



Collecting consumers' details by the survey team at Kelinkanda, Agalawatta.

Chapter 4

Impacts of Rural Electrification

4.1 Economic benefits

After electrification of rural villages, imported fuel usage for domestic lighting has greatly been reduced and only very small quantities of Kerosene are still being used for emergency lighting purposes during electricity failures. Thus, the immediate economic benefit reaped by the villagers is the saving on imported fuel usage for domestic lighting.

Electricity alone is not enough to develop these villages and the quality of other infrastructure facilities like roads, transport, educational and medical facilities are also vital. Considerable economic development in rural villages has been achieved after provision of electricity in districts already having better infrastructure facilities.

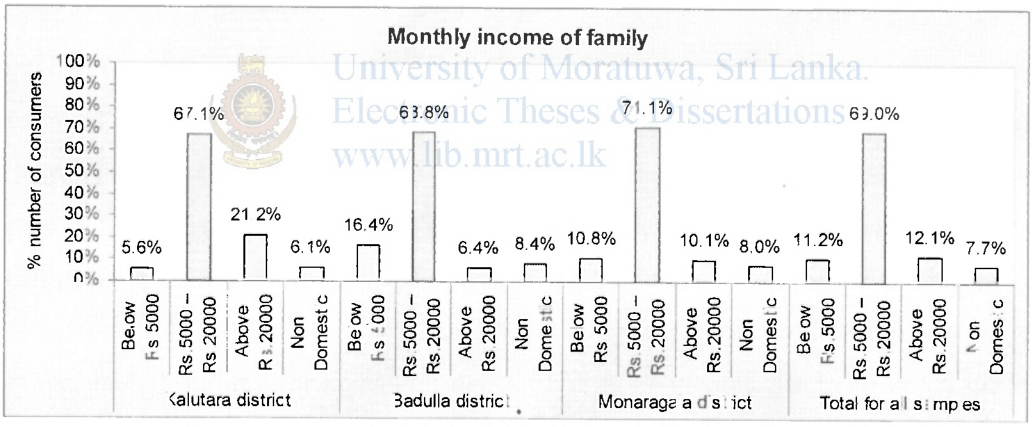


Figure 4.1- Monthly income levels of the families in electrified villages.

A good measurement to determine the economic development is the family income. The figure 4.1 shows the present monthly income levels of the families in electrified villages in Kalutara, Badulla and Monaragala districts investigated under this study. The income levels of families in these villages were divided into three categories for the convenience of analysis. Monthly Income level of the families is below Rs. 5,000.00 per month has been considered as low income level. Similarly, monthly income level of the families between Rs. 5,000.00 and Rs. 20,000.00 has been considered as moderate income level and income over Rs. 20,000.00 per month has been considered as good income level.

Here non-domestic consumers mean consumers like schools, community halls, government offices, hospitals, who has obviously no family income.

A significant increase in number of moderate income level families can be seen in each district after electrification. The figure of moderate income level in Kalutara district is 67.1%. This figure in Badulla and Monaragala districts are 68.8% and 71.1% respectively. The overall percentage of the moderate income level families is 69.0%. When comparing percentage of good income level families with the other districts, in Kalutara district its value is 21.2% and Badulla and Monaragala are 6.4% and 10.1% respectively. The reason for this change is the better availability of other infrastructure facilities like transport, market facilities and business opportunities in Kalutara district. The overall percentage of the moderate income level families is 12.1%.

When considering low income families, in Kalutara district it shows a lower value of 5.6% than in the other two districts. This value in Badulla and Monaragala districts are 16.4% and 10.8% respectively. One of the reasons for this situation is the poor educational background of the adults. Lack of education causes poverty. Children of poor families cannot obtain a good education unless good educational facilities freely available in the village, because, their parents are not in a position to spend enough money for education due to their poor income. It is observed during this study that a large number of children in poor families have very low educational levels (124 children of 232 families). Sometimes it was even lower than grade five standard and most of them are labourers.

When considering overall values, the above results indicate that the addition of electricity to the existing infrastructure will accelerate the development of rural villages. The ratio between (Low: Moderate: Good) income levels is (1.0: 6.2: 1.1). Therefore poverty has been alleviated significantly after electrification. The study revealed that the majority of good income level family members are well educated people employed as school teachers, police officers, officers in the military forces, businessmen etc. However, many people in this category are working far from their village.

4.1.1 Employment status of villagers

The majority of rural people are self employed as their education is insufficient obtain employment in the government or private sector. Those who own their own land engage as farmers.

Considerable percentages of rural people who do not have lands for cultivation are working as labourers within the same village or in the neighboring villages. Another section of rural people find employment in the private sector and they work in the close proximity to the village. A smaller group with good educational background of work in the government sector. The majority of them are working away from their own village.

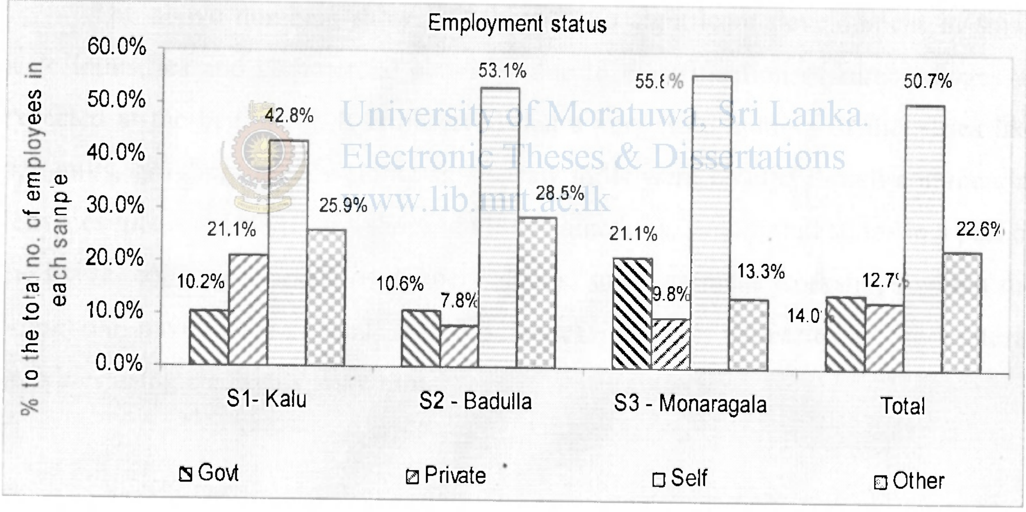


Figure 4.2 - Employment status of villagers.

Above figures confirm that the majority of rural people are self employed as farmers in all districts with a sample average of 50.7%. The second biggest group called 'Other' is working as labours on daily paid basis with a sample average of 22.6%. The third biggest group is the group of government servants with an overall value of 14.0%. Majority of these government servants are working in the government security forces. The remaining 12.7% work in private sector. Many of them work as labours, drivers, or security guards. Though a small increase in employment opportunities has been observed that cannot be directly attributed to electrification.

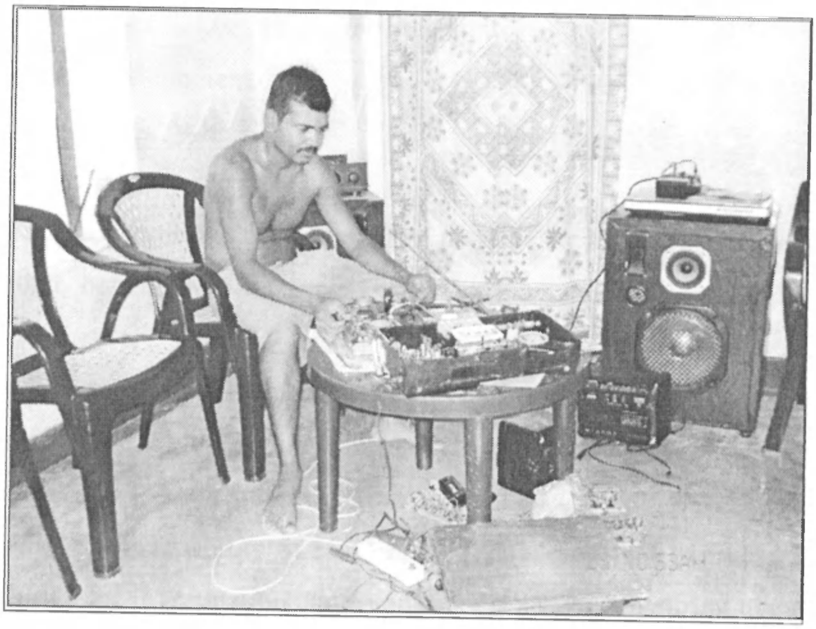
4.1.2 Development of industries and commercial activities

Table 4.1 gives the numbers of industries and commercial activities developed due to RE schemes. (Total number of RE consumers – 1886)

Sample	SI - Kalutara	S2 – Badulla	S3 - Monaragala	Total	% of the total consumers (1886)
Small industries	03	14	06	23	1.2%
Small commercial	18	35	43	96	5.1%

Table 4.1- Number of industries and commercial activities started after electrification.

The above numbers show that there is no significant development in small scale industries and commercial activities due to electrification of rural villages as expected at the beginning. It is observed that a very little number of industries like rice mills, grinding mills, welding shops, saw mills were created. Small commercial activities like retail shops, tea shops at village junctions, small retail shops in a part of the house, concrete workshops, barber saloons, small garment workshops within the household have been created in the schemes. Cottage industries or agricultural activities using electricity were rare.



A youth repairs electronic equipment at home as a self employment in Horagoda.

Sample No.	S1 - Kalutara	S2 – Badulla	S3 - Monaragala	Total	% to the total RE consumers
Small industries	06	08	10	24	1.3%
Small commercial	10	01	03	14	0.7%
Small agricultural	02	02	01	05	0.3%

Table 4.2 - Number of villagers who want to start industries, commercial activities and agricultural activities which require three phase electricity.

The percentage of small scale industries that were created during the last seven years is a mere 1.2%. But the people who have ability to start industries like rice mills, metal work shops, saw mills are awaiting three phase electricity supply to start their industries.

The table 4.2 shows that the percentage of this category is 1.3% which is even slightly higher than the industries created up to date from the beginning. Thus the non-availability of three phase electricity imposes limitations. Although three phase electricity lines are available in the vicinity, industrialist cannot obtain three phase electricity supply to start industries due to various technical problems. The distance to the transformer from the industrial premises is the main problem. Supply of three phase electricity to these premises was considerably restricted by the CEB rules and regulations. Frequent failures in electricity supply are also having a negative impact on the industrial development.

4.2 Social benefits

After electrification, large number of houses gained adequate lighting. This is the immediate benefit they received from electricity. Majority of rural people are farmers and they are working in their paddy fields or gardens until dusk. Rural women are also working in their paddy fields or gardens with their husbands but they tend to return home a little earlier to light night lamps and prepare meals. But, after electrification rural women were able to manage their evening works at their homes more easily due to availability of easy lighting extending their working times. It is observed during the investigation that some farmers work even during night time after electrification.

4.2.1 Household benefits

Generally, after electrification every house owner purchases electrical appliances according to their requirements. Time duration for this purchasing will depend on the income level of the family.

Figure 4.3 shows the usage of electric lamps. Figure shows that they widely use inefficient incandescent lamps. The usage of fluorescent lamps and compact fluorescent lamps for domestic lighting has been limited mainly due to their high initial cost.

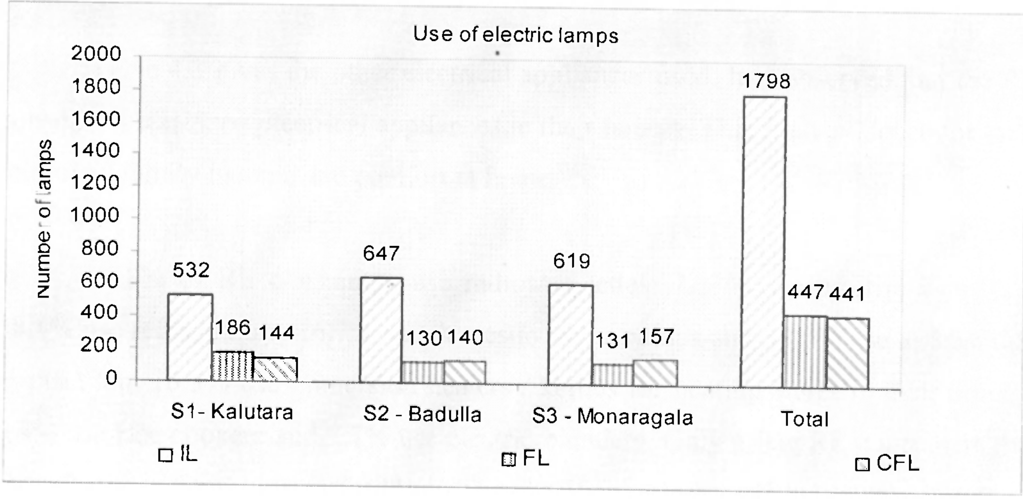


Figure 4.3 – Usage of electric lamps.

Televisions are very popular in rural homes as well. Usage and quality of television increased as a result of electrification and as a result the villagers are better informed. Mainly, they use this media for the family entertainment like watching tele-dramas and films. A small number of families use televisions for the educational purposes of their children. Televisions greatly help them to reduce isolation effect and enhance their satisfaction to continue to live in their villages.

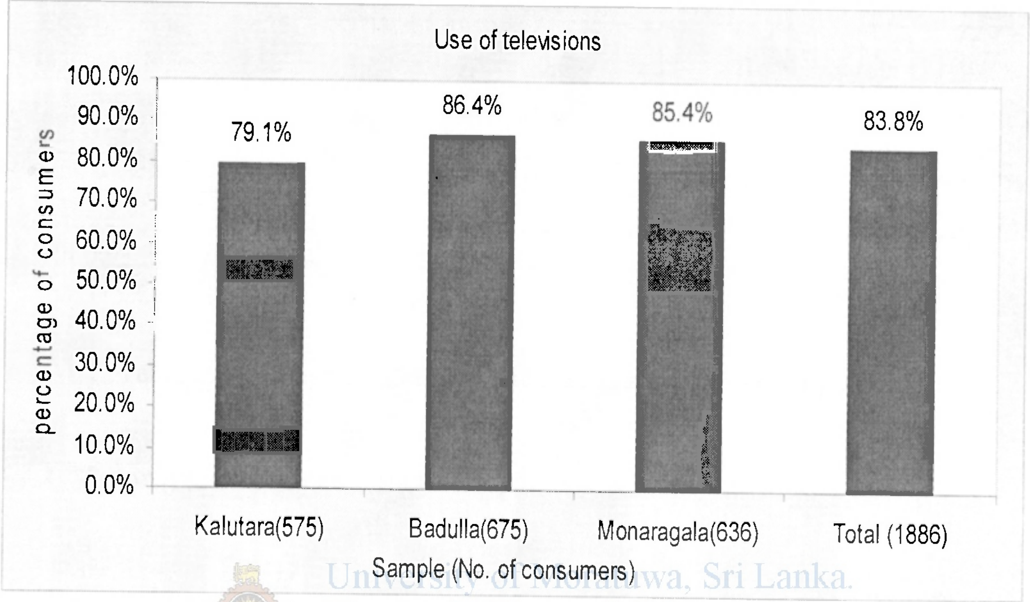


Figure 4.4 – Penetration of televisions in RE schemes.

Figure 4.4 shows the penetration of televisions in each sample. As an overall figure, 83.8% of families use televisions. The information in Figure 4.4 indicates that this media is almost equally popular among all of them.

Table 4.3 gives the other electrical appliances used. It is observed that the RE consumers use many electrical appliances in their houses. This is an evidence for their improved family income and comfort at home.

77.8% of RE consumers use radios/cassettes. 72.7% use electric irons and 18.1% use refrigerators. 16.7% use domestic water pumps and 33.0% use at least one electric fan. 16.5% use immersion heaters / kettles for heating water in their homes, 6.4% use rice cookers and 7.7% use electric blenders. Only a few RE consumers use electric ovens for baking and grilling. The use of computers is still at a very low level of 0.3%. However, it is clear that there is a considerable increment of household benefits created through electrification.

Use of other electrical appliances								
Sample No.	**S1**	%	**S2**	%	**S3**	%	**Total**	%
Consumers	**575**		**675**		**636**		**1886**	
Rice cookers	65	*11.3%*	25	*3.7%*	30	*4.7%*	120	***6.4%***
Heaters / Kettles	150	*26.1%*	71	*10.5%*	91	*14.3%*	312	***16.5%***
Refrigerators	162	*28.2%*	107	*15.9%*	73	*11.5%*	342	***18.1%***
Electric Irons	425	*73.9%*	491	*72.7%*	456	*71.7%*	1372	***72.7%***
Wash. machines	83	*14.4%*	4	*0.6%*	2	*0.3%*	89	***4.7%***
Electric fans	226	*39.3%*	245	*36.3%*	151	*23.7%*	622	***33.0%***
Radios/cassettes	416	*72.3%*	501	*74.2%*	550	*86.5%*	1467	***77.8%***
Dom. w/pumps	136	*23.7%*	114	*16.9%*	65	*10.2%*	315	***16.7%***
Blenders	94	*16.3%*	9	*1.3%*	43	*6.8%*	146	***7.7%***
Electric ovens	13	*2.3%*	2	*0.3%*	2	*0.3%*	17	***0.9%***
Computers	4	*0.7%*	0	*0.0%*	2	*0.3%*	6	***0.3%***

Table 4.3 – Usage of other electrical appliances by RE consumers.

4.2.2 Improvement of education

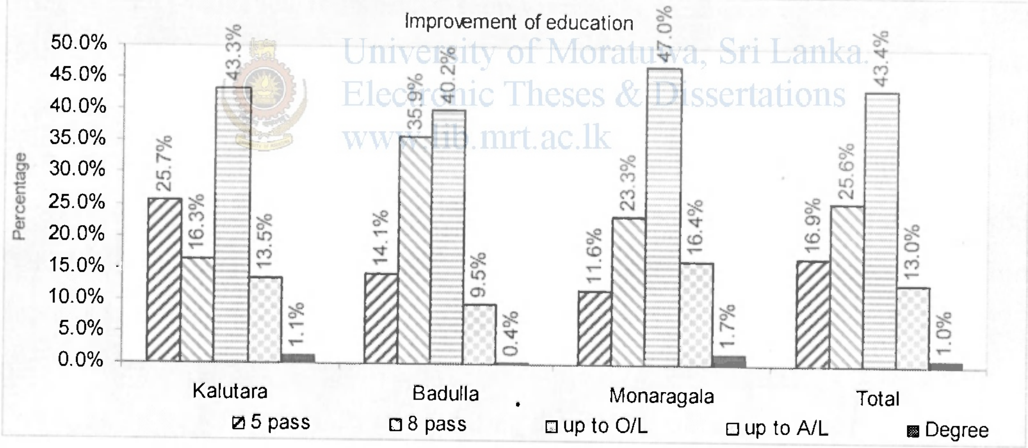


Figure 4.5 – Educational qualifications of rural villagers in electrified villages.

Figure 4.5 illustrates the education level in rural villagers. When considering total figures, only 1.0% of rural villagers were obtained education level up to degree level. 13.0%, 43.4% and 25.6% of young villagers were educated up to A/L, O/L, and grade eight respectively. All villagers in these categories had finished their school education few years after electrification. About 16.9% were obtained education up to grade five. But the majority of this category is elder persons in the villages. They had finished their school education before the electrification of these villages. Very little number of young persons in this category had finished their school education due to low income level of their families.

The above figures indicate that they have achieved considerable development in their education level after electrification. Although, provision of electricity creates positive impacts on education, lack of other educational facilities like, good schools and adequate numbers of teachers in rural schools have negative effects. Extremely low percentage (1.0%) was able to obtain higher education to the level of a university degree. However, it is clear from the above figures that the literacy level has increased significantly in rural villages as a result of electrification.

4.2.3 Development of health facilities and community benefits.

Health facilities: It is observed during the investigation, sanitary facilities of many households have improved. In Kurupita, Punsisigama and Higurukaduwa schemes villagers have launched mini water supply projects to obtain drinking water using electricity without any intervention of the government. About 95.6% houses have water seal type toilet facilities. Health centers or private medical dispensaries have not been created up to date within any other villages except in Higurukaduwa. In Higurukaduwa scheme a rural hospital have been opened by the government. Other than this dispensary no other improvements are observed in the villages apart from improved sanitary facilities.

Community benefits: It is observed during the investigation that the street lighting in these villages is very poor. Although, street lamps have been fixed at several locations, more than 85% of them are not in operating condition. The main reasons for this are the poor standard of street lamps and lack of proper maintenance. However, after electrification, working time of the villagers has extended significantly. People of some villages have agreed to shift their society meetings such as that of funeral society to night time. As the adequate lighting facilities are available, they were able to conduct the social activities even during night time. By doing this, their working time has extended and they are able to work longer in their paddy fields or gardens helping to increase the productivity.

Further, they were able to engage in religious activities in village temple during night time. This is very common to all rural villages. By arranging religious activities at night time, a new opportunity has been created for people who are otherwise unable to participate due to their commitments at the work places. A considerable improvement on community benefits have been created by the electrification.

4.2.4 Environmental effects

Though the trees are to be removed from time to time for the construction and maintenance of LT lines, no further environmental damages have been created locally in these villages up to date.

4.2.5 Incentive to build houses

Figure 4.6 gives the number of houses electrified up to date from the beginning of electrification. These figures indicate the considerable increment of number of houses in each village after electrification. The average time period is about seven years. This tendency has been occurred after electrification of these villages. The cost of living is significantly low in rural villages than the urban areas. Generally, their needs are very simple in nature and they can obtain those needs from their surrounding. As a result of electrification, these villages were become more comfortable and they have decided to stay further at the same villages. Therefore it is clear from the results of the investigation; migration of rural people to urban areas has been considerably reduced after electrification of these villages.

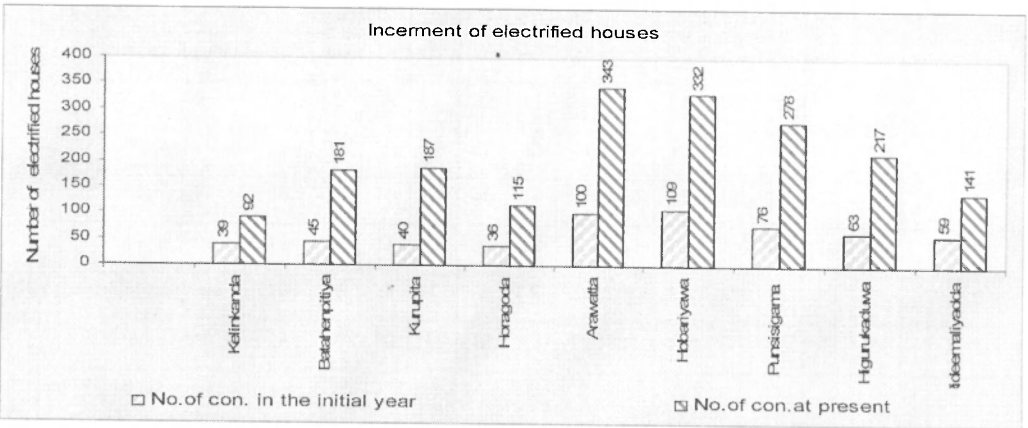


Figure 4.6 – Increment of electrified houses in RE schemes.

4.3 Quality of electricity supply provided for rural villages

Electricity supply provided to the rural villages cannot use efficiently due to various technical problems. As an example, consumers cannot use electricity to their day to day work efficiently if low voltage conditions occur frequently. The objective of the Ceylon Electricity Board is to provide continuous, adequate and reliable electricity supply to their consumers. In this section the technical matters of the rural electrification schemes are investigated and positive and negative effects created by these schemes to the development of rural villages are discussed.

4.3.1 Voltage variation along RE feeders

According to the regulations, stipulated value of the voltage variation should be within the limit ± 6%. At the commissioning of the schemes voltage variations might have been within the stipulated limits. But with the continued operation of the schemes, voltage drop has increased gradually and exceeded the lower limit. Table 4.4 gives the loading of LT feeders investigated in this study. All readings were taken within the period 7.30pm - 9.30pm to determine the worst case voltage drop of the feeders. The figures of the table 4.4 indicate that all feeders connected to each substation are in an unbalanced condition and some of them are severely unbalanced.

Loading of feeders of RE schemes																	
Sample	Scheme	Feeder 1				Feeder 2				Feeder 3				Feeder 4			
		R	Y	B	N	R	Y	B	N	R	Y	B	N	R	Y	B	N
S1	Kelinkanda	6	5	10	*	8	14	20	*	2	3	7	*	*	*	*	*
	Batahenpitiya	2	17	25	*	10	24	53	*	6	25	38	*	*	*	*	*
	Kurupita	28	46	24	*	25	40	21	*	*	*	*	*	*	*	*	*
	Horagoda	10	5	18	8	32	15	16	12	32	20	12	18	*	*	*	*
S2	Arawatta	21	11	1	18	52	43	44	12	10	7	5	6	21	32	13	21
	Hobariyawa	16	24	70	47	40	34	50	50	41	44	23	27	*	*	*	*
S3	Punsisigama	12	30	13	13	33	32	31	11	40	70	39	30	*	*	*	*
	Higurukaduwa	10	18	24	*	7	12	23	*	18	31	15	*	*	*	*	*
	Rideemaliyadda	32	20	30	11	12	43	11	31	16	9	10	7	*	*	*	*
N.B. unit of load current is Ampere.																	

Table 4.4 – Phase loads of the feeders of RE substations.

Practically, it is not possible to obtain an exact balance condition of LT feeders. But it is very essential to balance them approximately to reduce energy losses, breakdowns and other harmful effects to the consumer equipment. Due to severe unbalance conditions unwanted thermal stresses are created in contact points of LT switchgear leading to reductions in life time of the switchgear. Supply failures may also occur due to this reason. This situation can be seen in many RE schemes.

Voltage variation along the heavily loaded feeders of RE substations

Sample	Scheme	F No.	Length (km)	Voltage at Start (V)			Voltage at Middle (V)			Voltage at End (V)			Voltage drop (as a %)		
				R	Y	B	R	Y	B	R	Y	B	R	Y	B
S 1	Kelinkanda	2	1.591	224	224	224	220	218	215	214	212	210	4.5	5.4	6.3
	Batahenpitiya	2	1.74	**230**	230	230	237	225	206	**239**	224	203	**-3.9**	2.6	11.7
	Kurupita	1	1.577	220	221	220	219	209	203	218	203	202	0.9	8.1	8.2
	Horagoda	2	2.675	222	**223**	226	217	222	203	216	**230**	189	2.8	**-3.3**	16.4
S 2	Arawatta	1	1.865	223	224	226	222	218	223	202	223	220	9.4	0.4	2.7
	Hobariyawa	3	2.312	211	214	207	193	206	218	165	203	216	21.8	5.1	-4.3
S 3	Punsisigama	3	1.78	220	220	220	215	190	215	210	180	210	4.5	18.2	4.5
	Higurukaduwa	3	1.806	218	217	218	210	205	204	201	195	190	7.8	10.1	12.8
	Rideemaliyadd	2	2.303	220	**219**	**217**	205	223	219	197	**229**	**224**	10.5	**-4.6**	**-3.1**

Table 4.5 – Voltage variation along LT feeders.

Table 4.5 gives the results regarding the voltage variation along the LT feeders of RE schemes. In order to find out the minimum voltages which exist at present, voltage readings were recorded at the start, middle and end of the heavily loaded, longest feeder in each substation.

The above results show that in every RE scheme monitored, at least in one phase, voltage drop exceeds the stipulated 6% limit. This situation has occurred due to phase unbalances in the feeders. Although the feeder length of Kelinkanda, Batahenpitya, Kurupita, and Punsisigama schemes are less than 1.8 km, voltage drop have been exceeded the stipulated limit. This situation can be minimized by balancing the loads among the phases as much as possible. Arawatta and Higurukaduwa schemes are same and voltage drop can be minimized by balancing loads among the phases.

Length of the LT feeders of Horagoda, Hobariyawa and Rideemaliyadda schemes exceed the 1.8km limit prescribed according by CEB standard. Therefore it is necessary to reduce length of the feeder to overcome this problem. However, by balancing loads among the phases and properly maintaining the lines, voltage drop in these lines can be minimized to a satisfactory level until permanent solution is made.

It is observed that large numbers of bad jumper points exist at shackle points in LT lines. Many of these jumpers were made by small pieces of service wires (insulated twin core house service wire) and have not been properly clamped to the main line. A considerable drop in voltage is created by such jumpers as several jumpers are connected in series along the line. The cause for this is the bad workmanship of the maintenance teams.

It is observed that Batahenpitiya, Horagoda and Rideemaliyadda schemes, feeder end voltages of some phases are higher than the voltage at the substation end. In Batahenpitiya scheme, R-phase of the feeder No.2, feeder end voltage is higher by 3.9% than the voltage at the substation end. Similarly, Y – phase of the feeder No.2 of Horagoda scheme is higher by 3.3% and Y and B phases of the feeder No.2 of Rideemaliyadda scheme is higher by 4.6% & 3.1% respectively. Although, the voltage is expected to drop along the feeder from start to end, here the voltage increases along the line leading to a higher voltage at the far end.

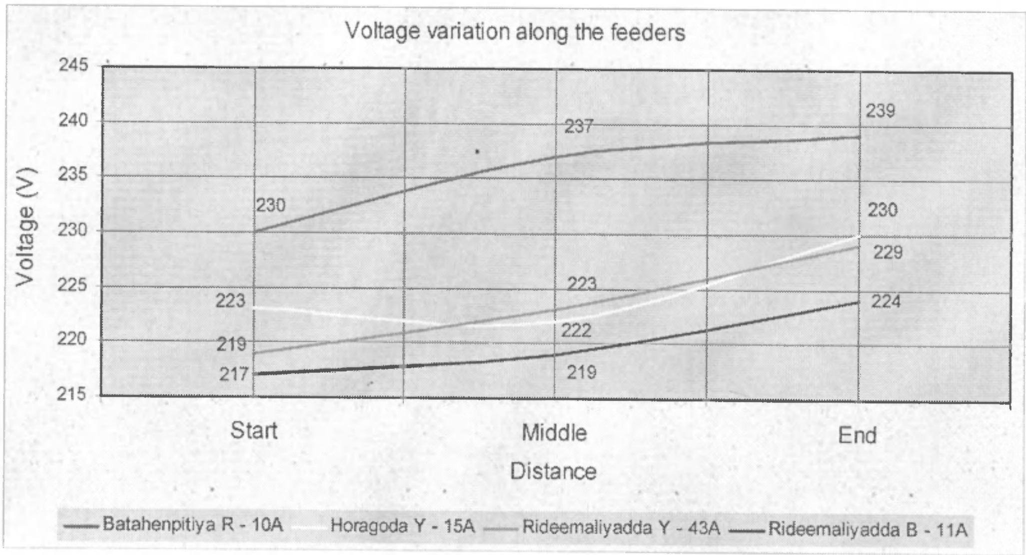


Figure 4.7 – Increment of voltage along the feeders of RE substations.

Figure 4.7 shows the voltage variation of the schemes where voltage increases were observed. The voltage variation along the feeders is continuous in Batahenpitiya and Rideemaliyadda schemes whereas a minimum in the middle is observed in the Horagoda scheme.

Following factors may cause to this change,

I. Increase of line resistance.
II. Unbalance of loads among the phases.
III. Generation of harmonic voltages in connected loads.

4.3.1.1 Effects of change of line resistance.

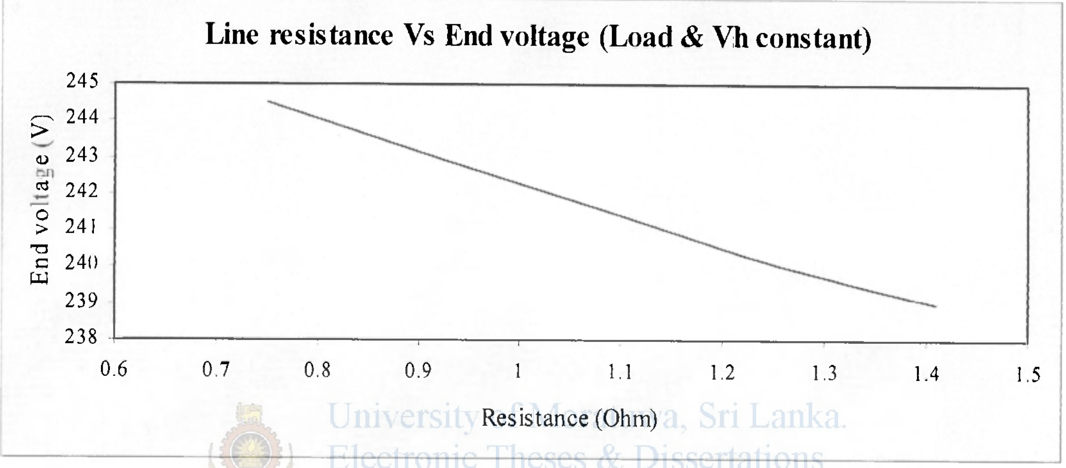
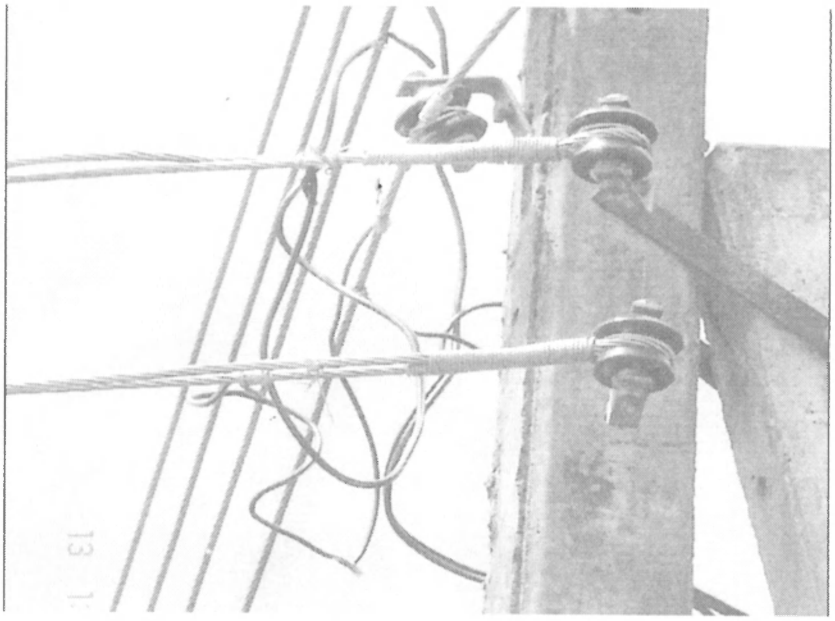


Figure 4.8 – Voltage variation at the end of LT line when increasing line resistance.



Bad jumpers increase the resistance of LT lines.

Under the condition of load and harmonics is constant, end voltage of a LT line will reduce with the increment of line resistance. Bad jumpers of these lines will increase line resistance and voltage drop.

4.3.1.2 Effects of change of load.

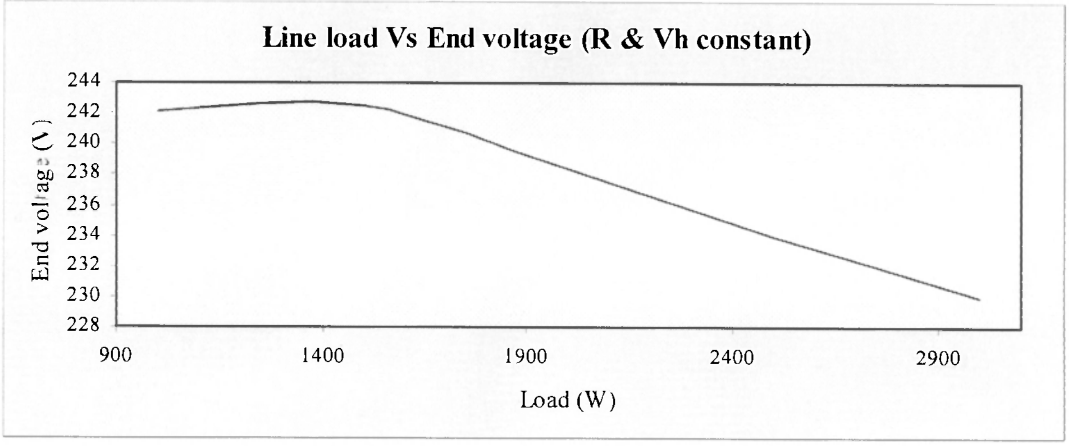


Figure 4.9 – Voltage variation at the end of LT line when increasing load.

Under the condition of line resistance and harmonics is constant, end voltage of a LT line will reduce with the increment of load current.

4.3.1.3 Effects of harmonics.

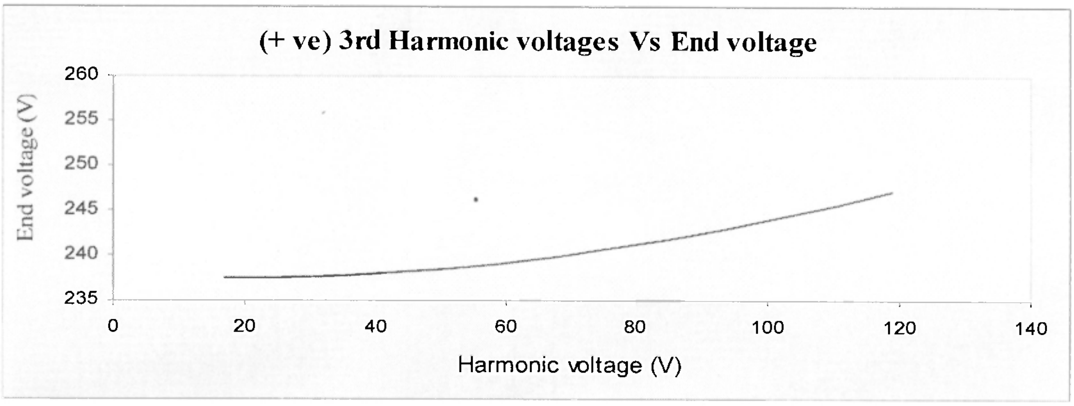


Figure 4.10 – Voltage variation at the end of LT line when increasing (+ve) harmonic voltages.

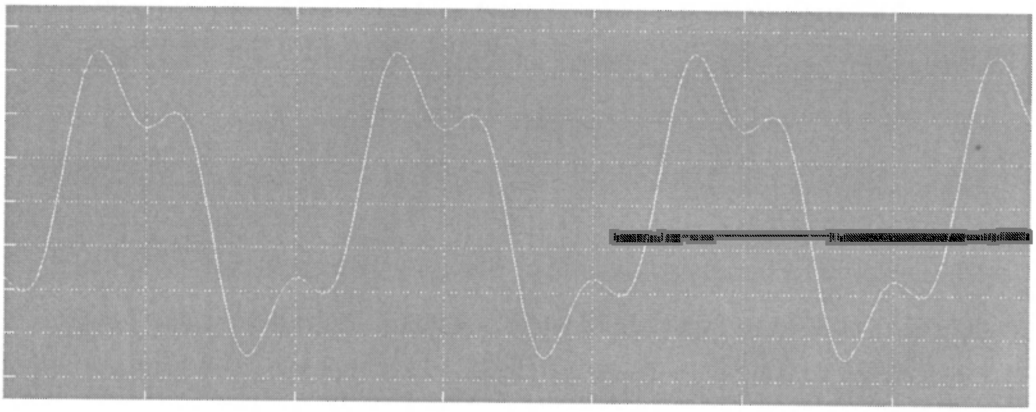


Figure 4.11 – Wave form of end voltage with (+ve) 3^{rd} harmonic voltages.

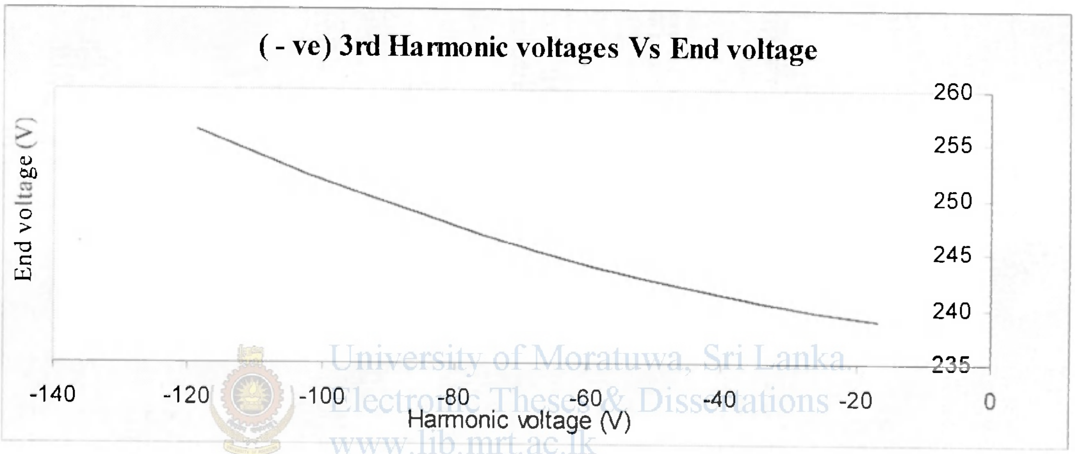


Figure 4.12 – Voltage variation at the end of LT line when increasing (-ve) harmonic voltages

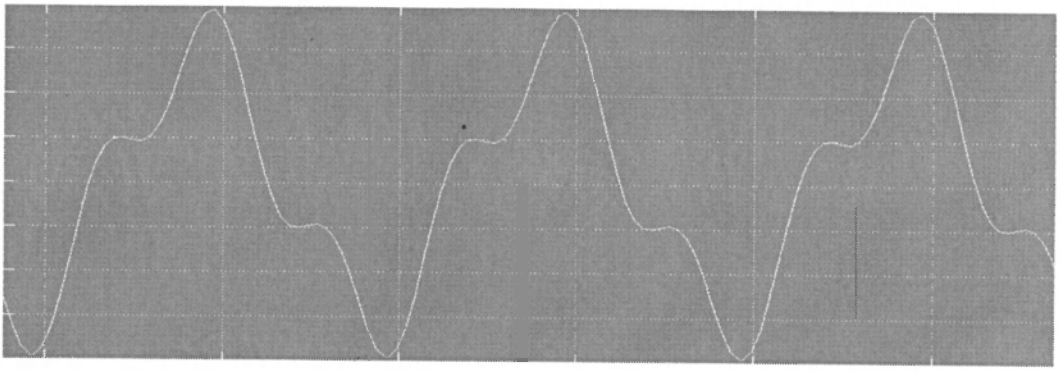


Figure 4.13 – Wave form of end voltage with (- ve) 3^{rd} harmonic voltages.

Under the condition of line resistance and load is constant, end voltage of LT line will increase with the increment of harmonic voltages. Figures 4.10 & 4.12 show the variation of end voltage in the presence of +ve 3^{rd} harmonic voltages and –ve 3^{rd}

harmonic voltages respectively. With the presence of any harmonic voltage can create this situation in LT lines. Wave forms of end voltage corresponding to the +ve 3rd harmonic voltages and –ve 3rd harmonic voltages are shown in Figure 4.11 & Figure 4.13 respectively.

Harmonics can be generated by the equipment connected to the power lines like welding plants, televisions, compact fluorescent lamps, capacitors. Harmonic voltages can also be generated in the substation transformer due to the change of magnetic properties of the transformer core. However, transformer generated harmonics influence the voltages on all three phases equally. As this is not the case in the schemes under consideration it is concluded that the harmonics are generated by the loads.

A basic model of three phase LT feeder built using MATLAB Sim Power System to investigate the voltage variations in RE schemes is shown in Figure 4.14. At the substation end, we use three star connected windings to represent the low voltage side of the transformer and this star point is directly earthed at the substation end. The line conductors are represented by series resistances as shown in the figure 4.14 since inductive and capacitive effects are negligibly small in low voltage lines.

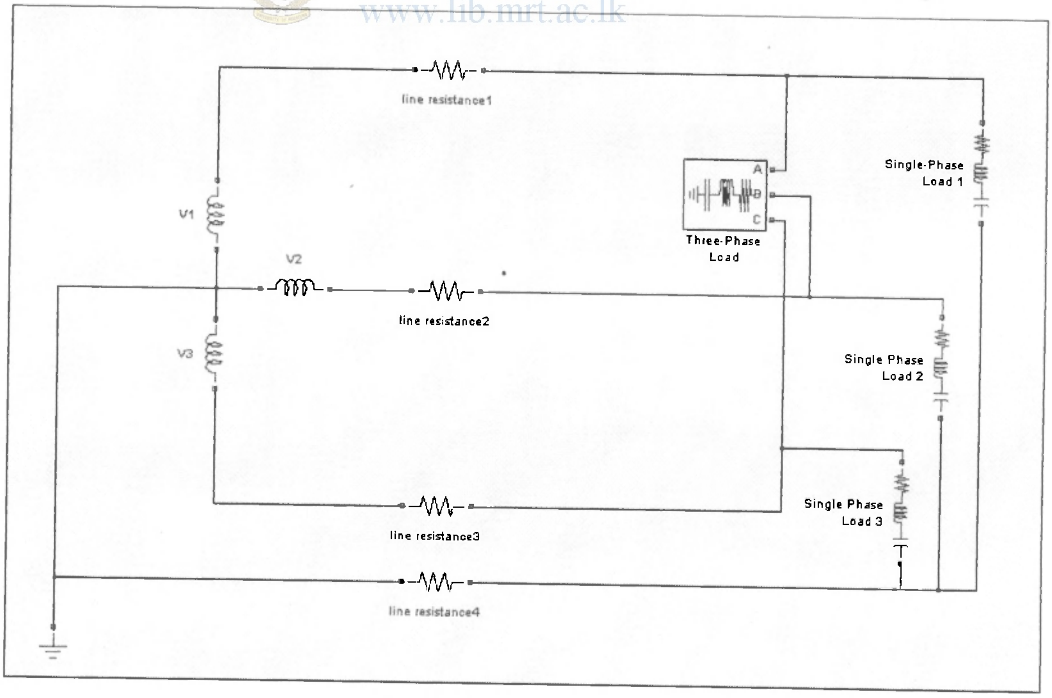


Figure 4.14 – Basic model of three phase LT feeder.

Although, the actual loads are connected in parallel, we can use the Thevenin's equivalent in series with the line resistance to represent all loads connected between phase and neutral conductors as shown in the figure 4.14.1. Finally, the star point of the individual loads should be connected to the ground through a series resistance to represent the neutral conductor of the feeder and complete the circuit.

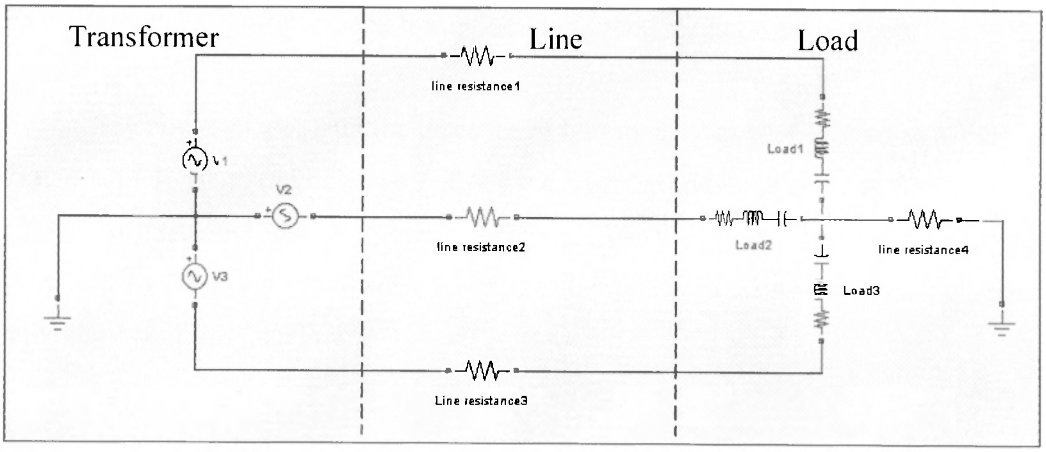


Figure 4.14.1 - Model of LT feeder with equivalent loads.

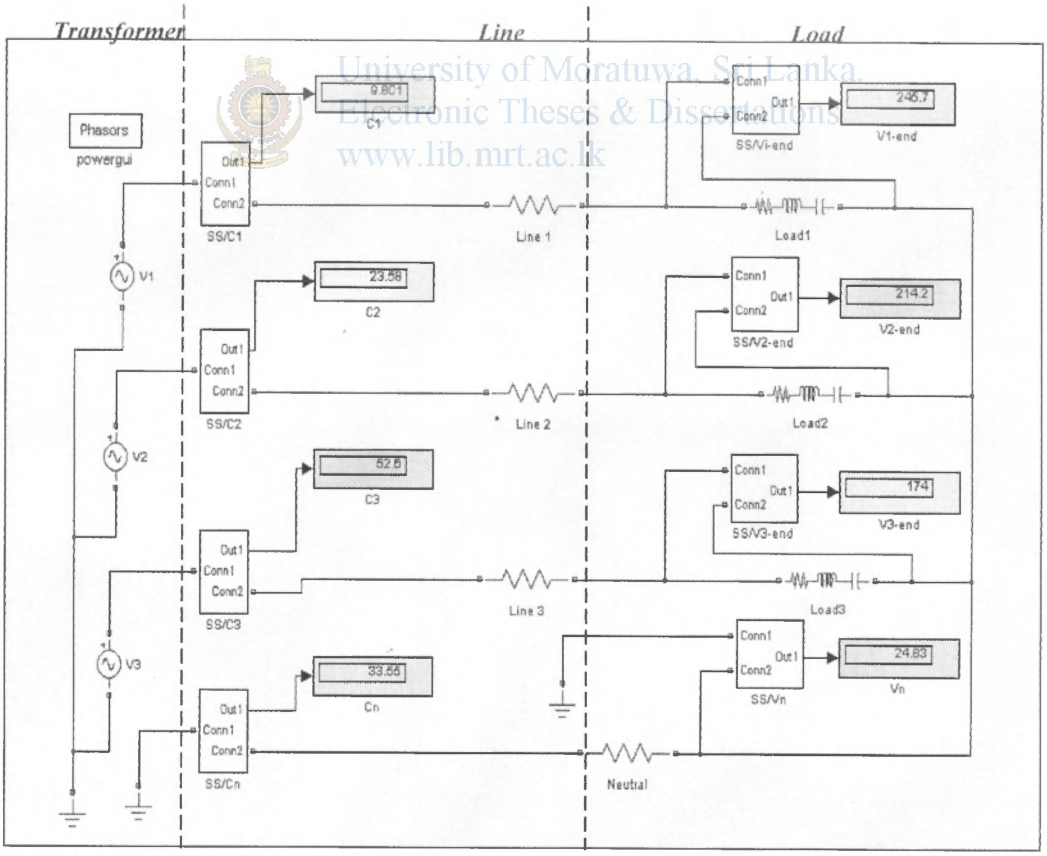


Figure 4.14.2 – MATLAB simulink model of three phase LT feeder (without harmonics).

MATLAB Simulink model of three phase LT feeder (without harmonics) is shown in Figure 4.14.2. In this model the transformer windings are replaced by three AC voltage sources and scopes are added to the model to measure the currents and voltages. Line voltages and phase currents of each phase can be obtained by setting AC voltage sources, line resistances and loads according to the line parameters. ***This model indicates the healthy line without harmonics.*** As an example, by analyzing Batahenpitiya feeder No.2 using this model, following results were obtained.

The above model with the presence of harmonics can be modified as shown in Figure 4.14.3. Here, only change is the three harmonic voltage sources added to the phases to represent the harmonics generated by the loads. Harmonic voltages generated by the loads which are connected to the lines can create significant changes on voltage profile of the line.

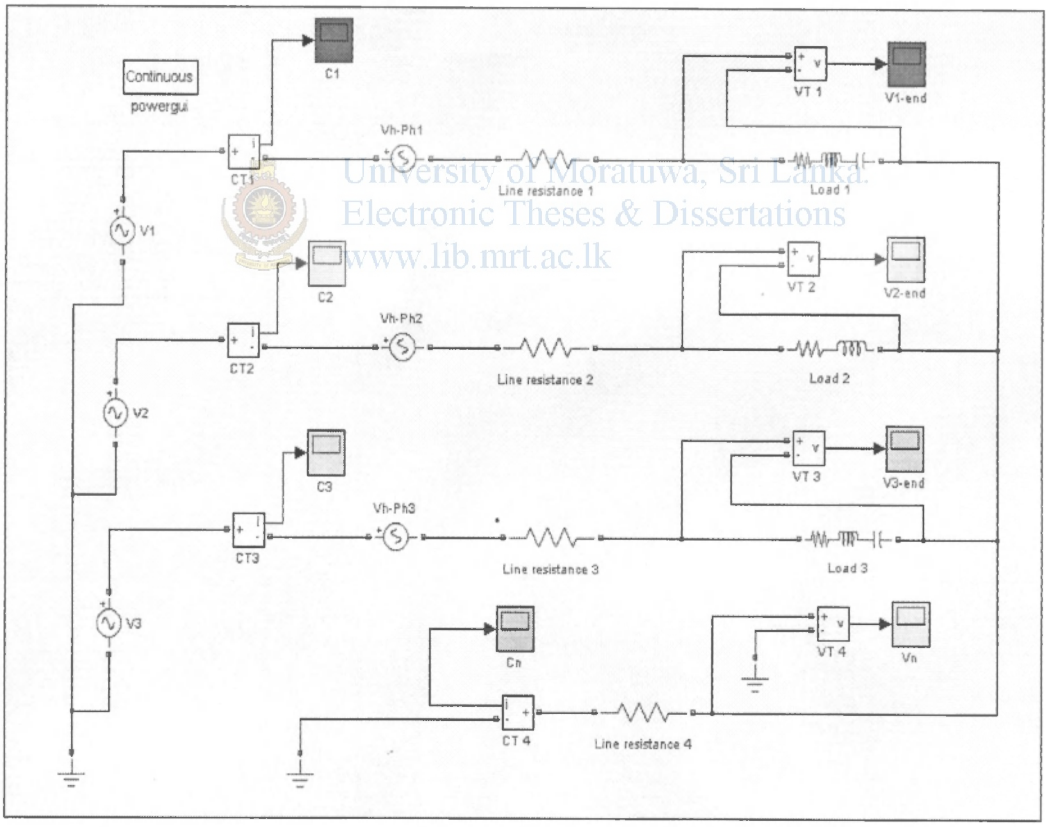


Figure 4.14.3 - MATLAB simulink model of three phase LT feeder (*with harmonics*)

The results obtained by analyzing Batahenpitiya feeder No. 2 using these models are shown in Table 4.6. Except harmonic voltages, all other values previously given to the models have not changed. Models were simulated by applying third & fifth harmonic voltages as shown in the table 4.6.

The simulated results with harmonics match with the measurements leading to the conclusion that the harmonics generated by the loads can create voltage rises in LT feeders. When increasing the magnitude of the harmonic voltage, distortions will occur in fundamental current and voltage wave forms and the quality of the electricity supply will be reduced. But, complains about harmonic problems in RE schemes have not been reported yet.

Simulation Results - Batahenpitiya (with harmonics)												
Set values	**V(pk) in volts**	**phase angle (deg)**	**Frequency (Hz)**	**Results obtained**								**Remarks**
				End voltage (V)				**Current (A)**				
				R	**Y**	**B**	**Vn**	**R**	**Y**	**B**	**N**	
V1	**325**	**0**	**50**	**239.0**	**224.0**	**203.0**		**9. 8**	**23. 6**	**52.6**		**Values measured at the field**
V2	**325**	**120**	**50**									
V3	**325**	**240**	**50**									
Vh-ph1	**-6**	**0**	**150**	**239.0**	**224.2**	**203.0**	**24.8**	**9. 6**	**25. 1**	**55.9**	**33.9**	**With presence of 3rd harmonics**
Vh-ph2	**-25**	**120**	**150**									
Vh-ph3	**-53.7**	**240**	**150**									
Difference				0.0	-0.2	0.0		0.2	-1.5	-3.3		
Vh-ph1	**-3**	**0**	**250**	**239.0**	**224.0**	**203.0**	**24.7**	**9. 8**	**23. 6**	**52.6**	**34.6**	**With presence of 5th harmonics**
Vh-ph2	**26**	**120**	**250**									
Vh-ph3	**50**	**240**	**250**									
Difference				0.0	0.0	0.0		0.0	0.0	0.0		
Simulation results - Batahenpitiya (without harmonics)												
V1	**325**	**0**	**50**	**245.7**	**214.2**	**174**	**24. 83**	**9. 814**	**23. 61**	**52.6**	**33.9**	**Without harmonics**
V2	**325**	**120**	**50**									
V3	**325**	**240**	**50**									
Deviation from measured value				6.7	-9.8	-29.0		0.0	0.0	0.0		
L1 = 1878W / pf 0.89, L2 = 5185W / pf. 0.89, L3 = 14230W / pf 0.89												
Line length = 1.66km, Resistance = 0.4486 Ohm / km												

Table 4.6 – Simulation and measured results of the feeder 2 of Batahenpitiya substation

4.3.2 Load development of RE schemes

Data collected from the investigation reports at planning stage of the RE schemes are shown in the Table 4.7. The maximum demand at the initial year, expected maximum demand after period of 10 years and the date of opening are given in the table.

Scheme name	**Date of Scheme opened**	**Max. demand (kVA)**	
		Year 1	**Year 10**
Kelinkanda stage II	31/03/2000	24.13	31.81
Batahenpitiya	05/04/2000	14.43	39.53
Kurupita	08/12/1999	14.73	26.07
Horagoda	05/04/1999	13.43	25.24
47th Mile post, Arawatta	06/04/2000	24.22	91.94
Hobariyawa	10/03/1999	26.95	104.04
Punsisigama	07/04/1999	38.25	55.04
Higurukaduwa	05/05/1998	28.94	48.53
5th Mile post, Rideemaliyadda	17/05/2000	18.03	55.75

Table 4.7 – Expected maximum demands of RE substations at the planning stage.

The deduced values of expected demand from table 4.7, measured values of present maximum demand, time duration and the difference between present and then expected demands of each scheme are given in the Table 4.8. It is observed that in all other schemes except that of Hobariyawa scheme, present maximum demand is higher than the expected value. Batahenpitiya, Kurupita, Horagoda, Punsisigama and Rideemaliyadda schemes have shown a rapid developed compared to others.

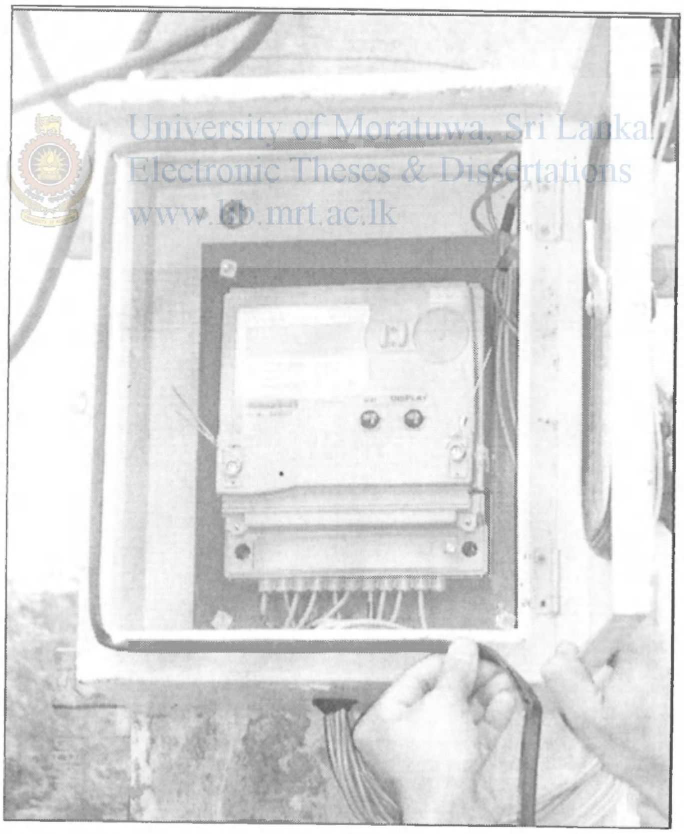
Scheme name	**Time duration (years)**	**Max. demand (kVA)**		**Difference (%)**
		Expected at the Planning stage	**at present**	
Kelinkanda stage II	07	29.51	**31.4**	+ 1.9 *(6.4%)*
Batahenpitiya	07	32.00	**48.0**	+ 16.0 (*50%)*
Kurupita	08	23.80	**49.6**	+ 25.8 (*108.4%)*
Horagoda	08	22.88	**43.2**	+ 20.3 (*88.7%)*
47th Mile post, Arawatta	07	71.62	76.5	+ 4.9 *(6.8%)*
Hobariyawa	08	88.62	84.0	- 4.6 *(-5.2%)*
Punsisigama	08	51.68	79.4	+ 27.7 (*53.6%)*
Higurukaduwa	09	46.57	**59.8**	+ 13.2 (*28.3%)*
5th Mile post, Rideemaliyadda	07	44.43	79.9	+ 35.5 (*79.9%)*

Table 4.8 – Initially expected and actual values of maximum demands of RE schemes.

The capacity of the transformers used in all the schemes is 100 kVA. However, it is observed that many of these transformers are operating at maximum load less than 60% of the nominal value.

4.3.2.1 Load pattern and demand curves of RE substations

In order to study the load patterns of these schemes data were collected by fixing PPMs (Programmable Polyphase Meters) to each substation. These meters were kept connected for about 14days to gather kVA, kVAh, kVArh, kWh readings recorded once in 15 minutes throughout. Readings recorded in each meter continuously for seven consecutive days were picked for analysis. For easy reference, demand curves of a selected substation in each district are shown in Figures 4.15, 4.16 and 4.17.



Fixing PPM (Programmable Poly phase Meter) to a substation

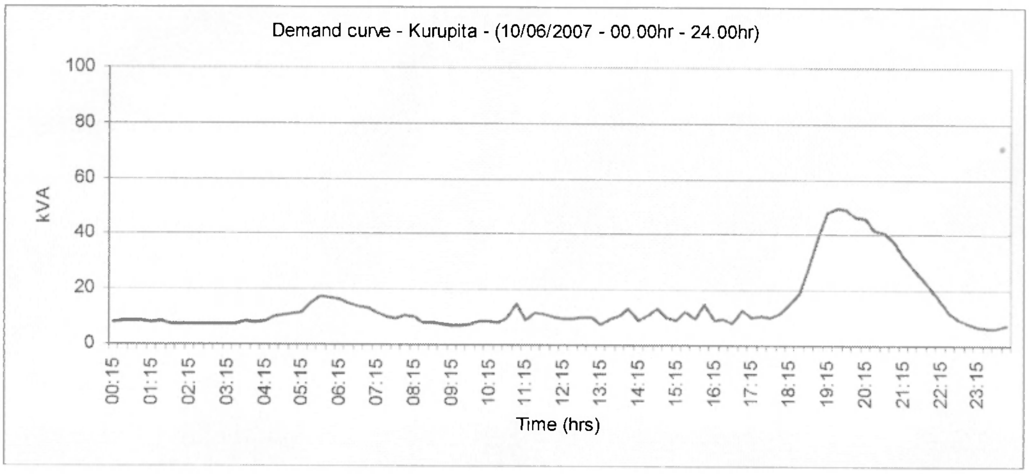


Figure 4.15 – Demand curve of Kurupita scheme (night peak 49.6 kVA at 18.30pm)).

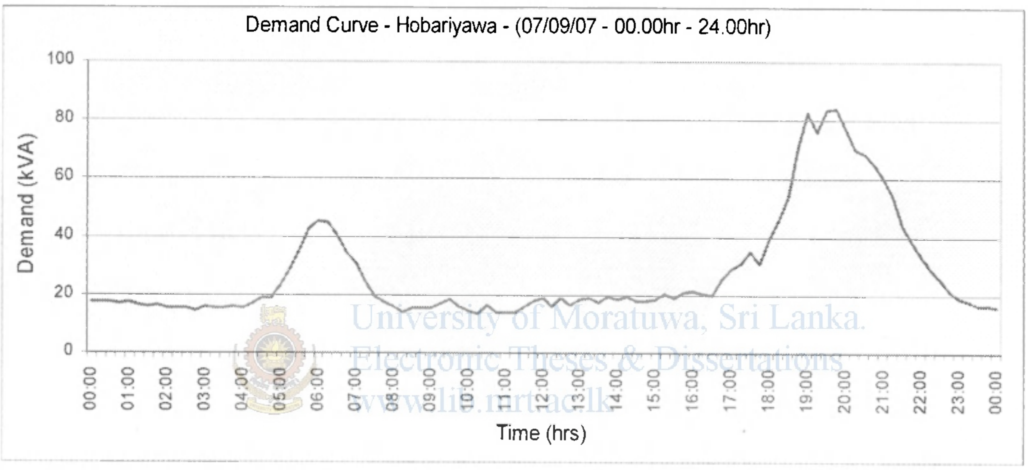


Figure 4.16 – Demand curve of Hobariyawa scheme (night peak 84 kVA at 19.45pm).

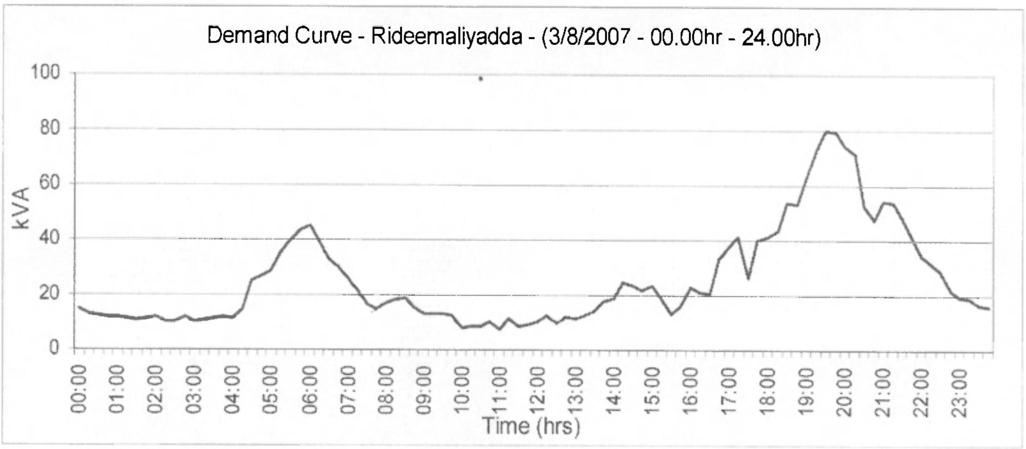


Figure 4.17 – Demand curve of Rideemaliyadda scheme (night peak 79.9 kVA at 19.30pm)

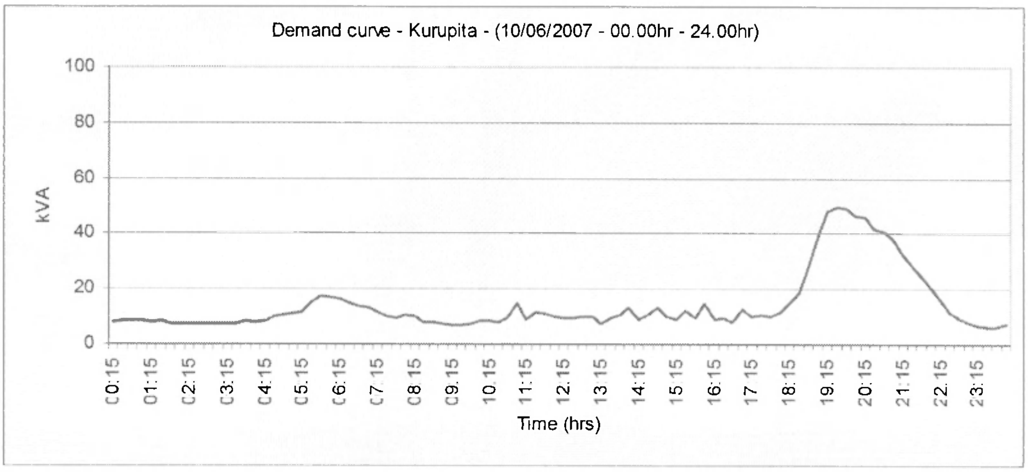


Figure 4.15 – Demand curve of Kurupita scheme (night peak 49.6 kVA at 18.30pm)).

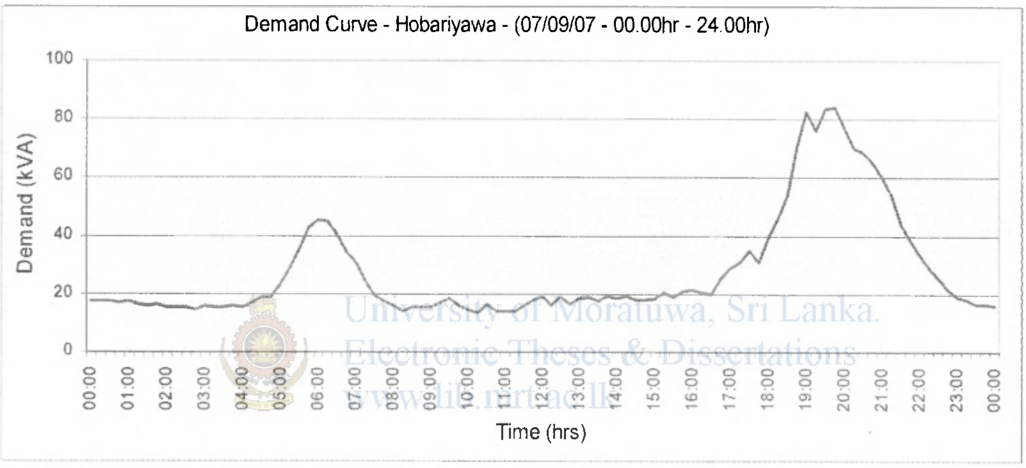


Figure 4.16 – Demand curve of Hobariyawa scheme (night peak 84 kVA at 19.45pm).

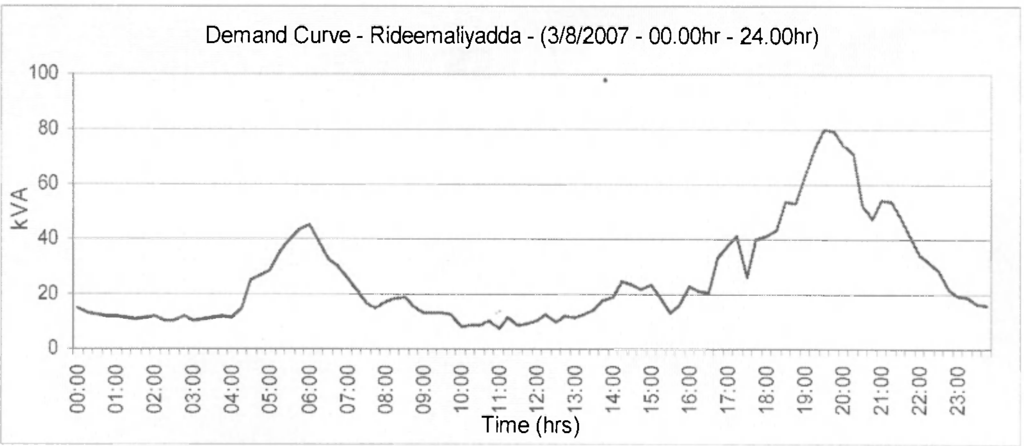


Figure 4.17 – Demand curve of Rideemaliyadda scheme (night peak 79.9 kVA at 19.30pm)

The above curves show that the RE substations are not loaded during the normal working hours of the day. Usually, the load level is less than 20 kVA in majority of the time during day time. This is an indicator for the level of industrial development in RE schemes.

Generally, RE substations are designed by considering the estimated maximum demand of the scheme. But it is seen form this study that the schemes have very low load factors. Therefore, use of bigger size transformers for many RE schemes is not technically necessary and is highly uneconomical because it leads to unnecessarily high initial cost, power losses and maintenance costs.

4.3.2.2 Load factor of RE substations

Scheme name	**Present Max. Demand (kVA)**	**Maximum Load Factor (daily)**	**Average Load Factor (weekly)**
Kelinkanda stage II	31.4	28.34 %	25.21 %
Batahenpitiya	48.0	34.35 %	30.86 %
Kurupita	49.6	31.81 %	30.46 %
Horagoda	43.2	52.39 %	45.24 %
47th Mile post, Arawatta	76.5	47.39 %	44.03 %
Hobariyawa	84.0	36.08 %	33.48 %
Punsisigama	79.4	40.68 %	37.15 %
Higurukaduwa	59.8	38.40 %	35.34 %
5th Mile post, Rideemaliyadda	79.9	40.71 %	36.57 %

Table 4.9 – Load factors of RE substations.

Load factor of each substation surveyed under this research is mentioned in the Table 4.9. Specimen calculation of load factor is shown below. The data required for the calculation has been obtained from the meters installed at each substation.

Specimen calculation of Load Factor: Batahenpitiya substation on 09^{th} May 2007.

Available data: Load in kW and power factor measured each 15 minutes throughout the day, and the maximum demand of the day in kVA.

No of units consumed / day = 346.45 kWh
Max. Demand = 45.8 kVA
Average power factor = 0.89

$$\text{Load Factor (daily)} \quad = \quad \frac{\text{No. of units consumed per day in kWh}}{(\text{Max. demand in kW x 24})} \text{ x } 100 \qquad (1)$$

Substituting above values to the formula,

$$\text{Load factor (daily)} = \frac{346.45}{45.8 \text{ x } 0.89 \text{ x } 24} \text{ x } 100 \quad = 32.16\ \%$$

Therefore the daily load Factor at Batahenpitiya substation on 09/05/2007 is 32.16 %.

The figures of table 4.13 show that the weekly average load factor of RE schemes is less than 50% and the maximum of the daily load factors is just above 50%. Although the maximum demand of Hobariyawa substation is 84 kVA, its maximum and average load factors have decreased to 36.08 % and 33.48 % respectively. Kelinkanda RE scheme shows the minimum load factor among the schemes investigated in this study. Its maximum and average load factors are 28.34 % and 25.21 % respectively. Therefore we can conclude that the load factor of RE schemes vary in the range of 25 % to 55 %.

4.3.3 Power factor of RE substations

The power factor of RE schemes investigated is given in the Table 4.10. It is observed that the minimum value of power factor is 0.79 and all the schemes have power factors close to 0.9.

Scheme name	Power factor (minimum)	Power factor (average)
Kelinkanda stage II	0.87 lagging	0.90 lagging
Batahenpitiya	0.82 lagging	0.89 lagging
Kurupita	0.88 lagging	0.89 lagging
Horagoda	0.79 lagging	0.82 lagging
47th Mile post, Arawatta	0.85 lagging	0.87 lagging
Hobariyawa	0.89 lagging	0.90 lagging
Punsisigama	0.85 lagging	0.87 lagging
Higurukaduwa	0.85 lagging	0.88 lagging
5th Mile post, Rideemaliyadda	0.85 lagging	0.87 lagging

Table 4.10 – Power factors of RE schemes.

4.4 Energy losses in RE schemes

Energy losses of RE schemes occur in two ways, the first one is the losses that occur due to technical reasons in LT lines, LT switch gear and in consumers' energy meters. The second one is the losses which are occurring due to illicit tapping of electricity lines by the people. All these losses occur beyond the transformer terminal. Generally, above losses in RE schemes are given attention to, but the losses in transformers also need attention. When calculating overall losses in distribution system these losses are accounted in medium voltage losses.

4.4.1 Energy losses in RE schemes (beyond LT terminals of the transformer)

Scheme name	Energy losses expected at the planning stage	Energy losses at present	Difference
Kelinkanda stage II	9.74 %	13.2 %	3.46 %
Batahenpitiya	4.78 %	11.0 %	6.22 %
Kurupita	5.37 %	24.8 %	19.43 %
Horagoda	6.83 %	14.4 %	7.57 %
47th Mile post, Arawatta	8.09 %	19.3 %	11.21 %
Hobariyawa	8.62 %	16.1 %	7.48 %
Punsisigama	9.48 %	18.2 %	8.72 %
Higurukaduwa	9.43 %	23.2 %	13.77 %
5th Mile post, Rideemaliyadda	7.77 %	17.3 %	9.53 %

Table 4.11 – Energy losses of RE substations.

Energy losses expected at the planning stage and the results obtained from the survey are shown in Table 4.11. Energy losses expected at the planning stage are taking from the initial investigation reports.

In order to guarantee the accuracy of the survey results, all consumers' meters were inspected to find defective meters. Only 5 to 12 meters were found to be defective. In order to take the readings the scheme was temporally switched off for a short period at the beginning and at the end of the 14 day interval. Using the total consumption recorded in the consumers' meters and substation meter the percentage energy loss is calculated. It should be noted that this value includes both technical and non technical losses.

Energy losses calculated at the planning stage comprise the technical losses only. It is observed that the measured values are significantly higher than the initially estimated values. The difference shown in column 3 of the table 4.16 can be attributed to non-technical losses assuming the original estimates to be correct. This assumption is justified by the fact that the present condition of LT lines of these schemes are in good condition.

Whether technical or non-technical the losses in the schemes are at a too high level. During the investigation period itself, some villagers informed about illicit tapping. Some villagers use electricity to kill wild boar in Kelinkanda, Horagoda, Higurukaduwa and Punsisigama schemes. In Kurupita, some villagers use tapped electricity to make illegal liquor ("Kasippu"). As bare conductor lines are used in the jungle areas of the villages, people are encouraged to do illicit tapping. Several deaths are reported in these villages due to unauthorized insecure use of electricity. Tempering of electricity meters by the consumers is another activity that contributes to theft of electricity. The investigation team detected such occurrences at several places and informed the relevant authorities for legal actions.

4.4.2 Energy losses and efficiency of the transformers in RE schemes

Although 100 kVA transformers are used in RE schemes, the study shows that many of them were not loaded beyond 50% of the total capacity. But in practice, efficiency level of the transformers is high when they are operating from 50% to 125% of full load. At the maximum efficiency level copper loss of the transformer is equal to its iron loss.

When considering efficiency matters of power transformers it is better to consider the all-day efficiency than the normal commercial efficiency. When loads are changing, commercial efficiency of a transformer changes and thus an exact value of efficiency cannot be assigned. Therefore, it is better to consider all-day efficiency because it gives an indication for the efficiency throughout the day.

Attention was paid during the investigation to find the All-day efficiency of the transformers. Specimen calculation of all-day efficiency is shown below:

Specimen calculation: all-day transformer efficiency

(1) **Copper Loss α (Current)^2**

Therefore, $W_{cu} = K_1\,(kVA)^2$ where, K_1 is a constant

Similarly $W_{cu\,(FL)} = K_1\,(kVA_{FL})^2$ .... **(a)**

$W_{cu\,(at\ load\ A)} = K_1\,(kVA_{at\ load\ A})^2$ .... **(b)**

Where,

$W_{cu\,(FL)}$	- Copper loss at full load in kW
kVA_{FL}	- kVA at full load
$W_{cu\,(at\ load\ A)}$	- Copper loss at any load A
$kVA_{at\ load\ A}$	- kVA at load A

Therefore (a) / (b),

$$\frac{W_{cu\,(FL)}}{W_{cu\,(at\ load\ A)}} = \frac{K_1\,(kVA_{FL})^2}{K_1\,(kVA_{at\ load\ A})^2}$$

Therefore,

$$\mathbf{W_{cu\,(at\ load\ A)} = W_{cu\,(FL)} \times \left(\frac{kVA_{at\ load\ A}}{kVA_{FL}}\right)^2} \text{ ....}\mathbf{(c)}$$

Units *Copper loss in kW*

(2) **Iron Loss of the transformer** is constant and it does not make a significant change with the transformer load.

Therefore,

Iron Loss = No load loss .... (d)

Using above formulas (c) and (d) we can calculate the copper loss and iron loss of the transformer during the period of 24 hrs.

$$\textbf{All day efficiency} = \frac{\textbf{Output during 24hrs}}{\textbf{(Output + Losses) during 24hrs}} \times 100$$

Sample Calculation - 09/05/2007, Batahenpitiya Transformer.

Available data: *Load (in kW) and Power factor in 15minutes intervals for 24hrs.*
T/f capacity = 100kVA, Voltage ratio = 33kV/400V,
Make – Lanka Transformers Ltd,
No load loss = 0.34kW, Full load copper loss = 2.125kW.

Time	kW	pf	Time	kW	pf	Time	kW	pf
0:00	7.6	0.88	9:15	7.6	0.82	18:30	25.4	0.98
0:15	7.4	0.88	9:30	7.2	0.79	18:45	33.8	0.97
0:30	7.2	0.86	9:45	7.2	0.79	19:00	42.2	0.98
0:45	6.7	0.88	10:00	7.4	0.86	19:15	44.1	0.98
1:00	6.9	0.85	10:15	7.6	0.84	19:30	45.1	0.98
1:15	6.4	0.89	10:30	7.6	0.82	19:45	44.1	0.98
1:30	6.7	0.85	10:45	7.6	0.79	20:00	43.6	0.98
1:45	6.9	0.87	11:00	6.9	0.8	20:15	43.2	0.98
2:00	7.2	0.89	11:15	7.9	0.79	20:30	41.7	0.98
2:15	7.6	0.88	11:30	5.2	0.72	20:45	38.8	0.98
2:30	6.7	0.88	11:45	7.2	0.82	21:00	37.9	0.98
2:45	6.9	0.87	12:00	7.4	0.84	21:15	33.6	0.99
3:00	8.1	0.89	12:15	8.6	0.83	21:30	30.7	0.98
3:15	7.4	0.86	12:30	8.1	0.84	21:45	27.6	0.97
3:30	7.6	0.9	12:45	8.1	0.84	22:00	23	0.98
3:45	7.4	0.84	13:00	8.8	0.88	22:15	19.6	0.96
4:00	7.4	0.88	13:15	8.6	0.86	22:30	16	0.94
4:15	9.3	0.89	13:30	7.9	0.85	22:45	13.6	0.94
4:30	11.2	0.93	13:45	6.9	0.82	23:00	11.5	0.93
4:45	12.7	0.95	14:00	8.6	0.86	23:15	9.8	0.91
5:00	17	0.97	14:15	8.4	0.88	23:30	7.9	0.9
5:15	18.7	0.97	14:30	7.2	0.86	23:45	7.6	0.86
5:30	21.3	0.97	14:45	6.2	0.84			
5:45	26.6	0.97	15:00	9.1	0.87			
6:00	31.9	0.98	15:15	7.9	0.82			
6:15	26.4	0.97	15:30	7.9	0.85			
6:30	22.5	0.97	15:45	12.2	0.88			
6:45	15.8	0.94	16:00	12	0.86			
7:00	13.6	0.92	16:15	8.4	0.84			
7:15	11	0.9	16:30	8.6	0.86			
7:30	10.3	0.9	16:45	8.1	0.89			
7:45	9.3	0.85	17:00	10.5	0.88			
8:00	8.6	0.83	17:15	13.2	0.92			
8:15	7.6	0.79	17:30	11	0.92			
8:30	9.6	0.87	17:45	12.2	0.91			
8:45	7.4	0.86	18:00	12.7	0.93			
9:00	6.9	0.78	18:15	17.2	0.95			

Transformer loading can be divided in to 5 intervals (time periods) as,

00.00hr – 05.00hr = 05hrs
05.00hr – 10.00hr = 05hrs
10.00hr – 17.00hr = 07hrs
17.00hr – 22.00hr = 05hrs
22.00hr – 24.00hr = 02hrs

From the above data,

Average load (00.00hr – 05.00hr) period =
(6.4x1+6.7x3+6.9x3+7.2x2+7.4x4+7.6x3+8.1x1+9.3x1+11.2x1+12.7x1+17x1) / 21
= 8.2 kW.

Average pf (00.00hr – 05.00hr) period =
(0.84x1+0.85x2+0.86x2+0.87x2+0.88x6+0.89x4+0.9x1+0.93x1+0.95x1+0.97x1)
= 0.89.

Average demand (00.00hr – 05.00hr) period = kW / pf = 8.2 / 0.89 = 9.2 kVA.

Therefore, using formula (c),
Average copper loss at (0.00hr – 05.00hr) period = 2.125 x (9.2 / 100) ^{2} = 0.018 kW.

Similarly we can calculate the average copper loss for the rest of the periods and the results are tabulated below:

Period (hrs)	Average Load (kW)	Average pf	Average Demand (kVA)	Average Copper Loss (kW)	Total Copper Loss (kWh)
00.00 - 05.00	8.2	0.89	9.2	0.018	0.018 x 5 = 0.09
05.00 – 10.00	14.7	0.94	15.6	0.052	0.052 x 5 = 0.26
10.00 – 17.00	8.5	0.87	9.8	0.020	0.020 x 7 = 0.14
17.00 – 22.00	31.6	1.01	31.3	0.208	0.208 x 5 = 1.04
22.00 – 24.00	13.6	0.93	14.6	0.016	0.016 x 2 = 0.032
				Total copper loss	1.562

Total Iron loss = 0.340 x 24 = **8.16 kWh**

Thus, the total losses of the t/f during 24 hrs. = Total Cu. Loss + Total Iron loss
= 1.562 + 8.16
= **9.722 kWh**

Total Output of the t/f during 24hrs = (8.2x5+14.7x5+8.5x7+31.6x5+13.6x2)

$$= \mathbf{359.2\ kWh}$$

$$\text{All day efficiency} = \frac{\text{Output during 24hrs}}{\text{(Output + Losses) during 24hrs}} \times 100$$

$$= \frac{359.2}{359.2 + 9.722} \times 100 = \mathbf{97.3\ \%}$$

Table 4.12 gives the all-day efficiencies of the transformers in each scheme. All-day efficiency are found not to be very bad. However this value can be further improved if the transformer is changed from 100 kVA to 50 kVA. It is noted that Arawatta, Hobariyawa, Punsisigama and Higurukaduwa schemes have too many consumers. Far end Voltage drops of some single phase lines in these schemes are very high. This has been repeatedly complained by the consumers and augmentation is urgently needed.

Scheme name	**Capacity of the existing t/f (kVA)**	**No of consumers in the substation**	**Present Max. Demand (kVA)**	**All-day efficiency (Average)**	**All-day efficiency (if changed to 50kVA) (Average)**
Kelinkanda stage II	100	92	31.4	96.3 %	98.2 %
Batahenpitiya	100	181	48.0	97.1 %	98.5 %
Kurupita	100	187	49.6	97.0 %	98.5 %
Horagoda	100	115	43.2	97.3 %	98.6 %
47th Mile post, Arawatta	100	343.	76.5	98.0 %	50kVA can be used after augmentation
Hobariyawa	100	332	84.0	97.9 %	50kVA can be used after augmentation
Punsisigama	100	278	79.4	94.2 %	50kVA can be used after augmentation
Higurukaduwa	100	217	59.8	95.2 %	97.5 %
5th Mile post, Rideemaliyadda	100	141	79.9	94.2 %	50kVA can be used after augmentation

Table 4.12 – All-day efficiency of RE substations.

4.5 Reliability and safety of electricity supply in RE schemes

Reliability of power supply is the ability to obtain power supply without outages. In rural electrification schemes number of outages for a particular time period (say one month) and the time taken to restore the supply is very high compared to urban areas. It is observed that many of villagers do not respond to supply failures in day time because they mainly need electricity supply at night time for their home needs.

The details of breakdowns from January to August in the year 2007, obtained from the breakdown records of the Agalawatta, Monaragala and Mahiyanganaya CEB consumer services centers are shown in Table 4.13.

Month & Year	**Consumer Services Center**					
	Agalawatta		**Maiyanganaya**		**Monaragala**	
	LT	***HT***	**LT**	***HT***	**LT**	***HT***
Jan-07	103	*24*	30	*12*	48	*12*
Feb-07	61	*38*	36	*14*	42	*7*
Mar-07	103	*33*	14	*5*	48	*18*
Apr-07	116	*40*	19	*8*	116	*36*
May-07	133	*33*	55	*20*	186	*54*
Jun-07	291	*60*	30	*13*	93	*48*
Jul-07	160	*53*	20	*8*	162	*47*
Aug-07	116	*55*	22	*10*	97	*28*
Average / month	**135**	***42***	**28**	***11***	**99**	***31***

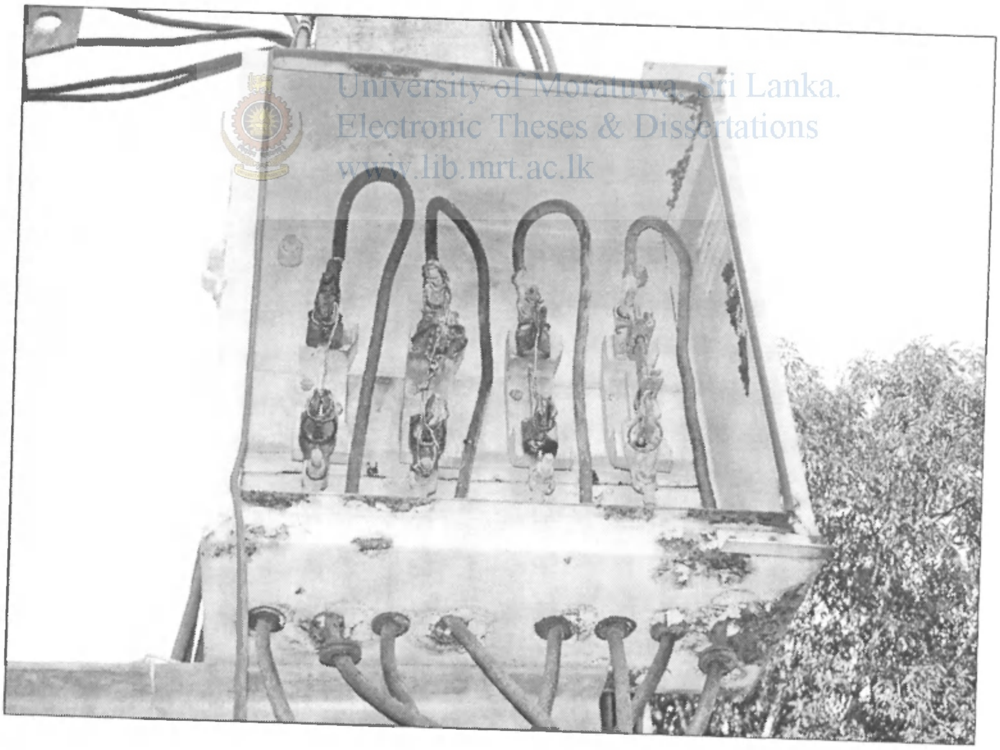
Table 4.13 – Number of breakdowns occurred from Jan 07 to Aug 07 in RE schemes of Agalawatta, Monaragala and Mahiyanganaya CEB consumer services centers.

Main reasons for above breakdowns are way leaves and bad weather conditions like heavy rain and wind. When considering numbers of breakdowns in each consumer services center, LT and HT breakdowns in Agalawatta CSC is very high and the average values are 135 and 28 respectively.

As the rain fall is high in this area, the rate of growing trees and creepers are high. Therefore, with the presence of rain and wind falling trees and branches cause many breakdowns. Bad switchgear and fuses also contribute to cause breakdowns at a lower percentage. Compared to Agalawatta, the monthly average number of breakdowns in Monaragala CSC area shows lesser values both for LT & HT breakdowns at 99 & 11 respectively.

Bad weather conditions like rain and wind in this area also contributed to cause breakdowns. In Mahiyanganaya CSC average numbers of LT and HT breakdowns are 28 & 11 respectively.

The average time taken to restore the supply is about one to ten hours, but in cases of major breakdowns like, lines broken due to big trees fallen on to the lines, restoring time can be as high as four days. Considerable numbers of short duration outages (about 5 to 30 minutes) are frequently occurring due to manual tripping of HT feeders for various maintenance works. However, above figures indicate that the reliability of electricity supply is very poor in RE schemes.



Bad switchgears and fuses also contribute to create breakdowns in RE schemes.

When considering safety matters, several deaths per year have been reported in RE schemes due to electrocution. Generally, these deaths are occurring due to contact with broken live conductors or with illegal live wire traps meant for wild boar. Low standard of street lighting also create dangerous situations in RE schemes. Low quality street lamp fittings, switches and wirings are used in every RE scheme for street lighting. In most places, street lamps are not working but live wire is exposed at the switching point. This situation imposes a high risk to the line maintenance people who work at night.

Dangerous voltages created at earth wires are frequently observed in these schemes. This situation occurs due to fallen trees or branches short circuiting earth and live wires.

Another fault which is occurring frequently in these schemes is the burning of consumers' electrical equipment by touching neutral and phase conductors together. Generally, two earth electrodes are used in RE substations. First earth electrode is used to ground lightning arresters, transformer body, and the metal parts of the substation structure. The Second one is used to ground neutral point of the transformer. The Earth resistance of many number of RE substations has a high value and due to this reason lightning surges can easily travel to the LV lines through the transformer and create damages to the consumers' equipment. Frequent burning of energy meters can be seen in these schemes as a result of high earth resistances of substations.

Chapter 5

Conclusion and Recommendation

5.1 Contribution of RE schemes towards the development

The objective of this investigation was to find the effectiveness of rural electrification schemes to enhance the living standard of rural communities. The results of the investigation show that significant development in economic benefits have been achieved in all villages after electrification. The poverty alleviation had been successful in all these villages. But this development was created not only due to the electrification but also due to the development of other infrastructure facilities in parallel.

Contribution of RE schemes:

5.1.1 to create employment opportunities

The employment opportunities in the villages were increased, but most of these employment opportunities have no direct relationship to electrification. Most of the employment opportunities were created by the development of other infrastructure facilities. Very small number of employment opportunities were created in all villages after electrification within the limits of the RE schemes. Considerable numbers of employment opportunities were created by the medium scale industries (Garments factories, Metal quarries etc) but these industries are fed from another bulk supply transformer independent of the RE scheme. Therefore, significant development in employment opportunities has not been achieved through RE schemes directly.

5.1.2 to promote small scale industries, commercial and agricultural activities

Contribution given by RE schemes to promote small scale industries, small commercial activities and agricultural activities is very low. Providing electricity supply for small scale industries (Three phase supplies, 30A & 60A) have been restricted by the CEB rules and regulations. This situation is negatively affected the industrial development in the villages. Considerable numbers of villagers who have ability to start small scale industries were abundant due to non availability of three phase power to start their industries.

5.1.3 to promote household benefits

Household benefits has significantly improved due to the RE schemes and comfort at home has increased. Availability of electricity were highly affected to work efficiently in their day to day activities. This has helped to reduce migration of villagers to the urban areas.

5.1.4 to the education of rural community

Successful development in education was created due to electrification of rural villages. Adequate lighting facilities at night time due to electrification of houses were help to create this situation. But this matter is directly related with the development of educational facilities in rural schools.

5.1.5 to promote health facilities

Except few household sanitary facilities, significant development of health services has not been created due to electrification of villages. However, good health practices like use of water seal toilets were improved in all villages. This situation was mainly created due to the government donations of toilet accessories to promote good health practices of villagers. Except, rural hospitals created by the government private medical centers were not created in these villages.

5.1.6 to promote community benefits

Considerable development of community benefits were created in these schemes due to electrification. Community centers were created in these villages and they conduct their meetings at night time without any interruption for their day works. Therefore, productivity of the rural people has been increased satisfactorily due to electrification of villages.

5.1.7 to promote housing

As the economic benefits increased, villagers were encouraged to build houses and take electricity supply. Government donations were significantly helped to encourage the people to build houses by themselves. House building works of the majority of houses were not completed fully. They are building their houses part by part according to the income of the family.

5.1.8 to environmental impacts

Though the trees have been cut to erect electricity lines and maintenance purposes of them, no harmful environmental effect has been reported due to RE schemes up to date.

The development in economic and social benefits in the villages <u>due to rural electrification schemes</u> can be summarized as follows.

Improvement of economic benefits	- Satisfactory *(Monthly Income of 81.1% families are above Rs. 5000.00)*
Improvement of poverty alleviation	- Satisfactory *(Monthly Income of 11.2% families are less than Rs. 5000.00)*
Improvement of employment opportunities	-Not satisfactory *(No significant development of employment opportunities in the villages due to electrification)*
Improvement of small industries, commercial and agricultural activities	- Not satisfactory *(Only 6.3% of small industries and commercial activities created due to electrification)*
Improvement of household benefits	- Satisfactory *(Comport at home has increased by 100 %)*
Migration of villagers to urban areas	- Reduced
Improvement of education level of villagers	- Satisfactory *(About 57.4 % of villagers are educated up to or above O/L)*
Improvement of health services	- Not satisfactory *(Except elimination of traditional oil lamps, no significant development in health facilities due to electrification)*
Improvement of community benefits	- Satisfactory
Incentive to build houses	- Satisfactory *(No of houses have been increased by 232.2 % than the beginning of scheme)*
Environmental impacts	- No harmful effect

5.2 Technical problems and reliability of electricity supply

The quality of electricity supply provided for rural villages is not satisfactory. Many numbers of feeders of RE substations are heavily unbalanced and voltage drop exceeds the stipulated value. Numbers of breakdowns in RE schemes are very high and the reliability of electricity supply is in very poor condition. Majority of breakdowns occur due to way leaves. Maintenance of lines and substations are not satisfactory. Maintenance cost of these schemes has been greatly responsible for this situation. As the maintenance cost is considerably high, supply authority is not in a position to carryout maintenance work of lines and substations properly and therefore breakdowns occur more frequently.

5.2.1 Energy losses in RE schemes

Energy losses of these schemes are considerably high. Illicit tapping and tempering of electricity meters at consumers' premises are contributing to increase the average losses. As bare conductors have been used for construction of these schemes illicit tapping is difficult to be eliminate.

Poor maintenance of consumers' energy meters increase revenue losses

5.2.2 Load factor, Power factor and all - day efficiency of RE substations

The maximum daily load factors of RE substations are less than 53% and over capacity transformers have been used at many schemes. This situation increases cost of implementation at the beginning of these schemes and the cost of maintenance in case of replacement of transformer. Due to defects of substation earthing lifetime of the transformers have considerably reduced. Average power factor and all-day efficiency are at acceptable levels.

5.2.3 Safety related matters of RE schemes

Safety level provided by the RE schemes is fairly low. Accidents occur due to falling live conductors on to the ground under bad weather conditions. Probability of damages to the consumer equipment in bad weather conditions is high.

The effectiveness of RE schemes has been considerably reduced due to above reasons. If this situation is not removed immediately effectiveness of RE schemes will be reduced further leading to non- achievement of desired results.

5.3 Recommendation

In order to overcome these problems and to increase the effectiveness of RE schemes some recommendations are given below:

5.3.1 Use of Arial Bundle Conductors (ABC) instead of Bare Aluminium Conductors

For LV lines in RE schemes, ABC conductors are recommended in place of bare Aluminium conductors. Use of ABC conductors provides following benefits:

(a). It will greatly reduce the number of LT breakdowns that occur due to way leaves. Reducing the number of breakdowns, maintenance costs reduced to a bearable limit and reliability of electricity supply increases considerably and improving the consumers' satisfaction about electricity supply.

(b). Illicit tapping of electricity lines will not be easy and can be avoided satisfactorily and reduce the revenue losses.

(c). The events of breaking poles and conductors due to fallen trees will be greatly reduced. This will avoid major breakdowns and reduce the cost of maintenance. It also helps to increase the safety of both personnel and equipment.

The main barriers to convert LV lines from bare conductors to ABC conductors are the cost of lines and lifetime of ABC conductors. Table 5.1 gives the cost difference between bare aluminium conductors and ABC conductors per kilometer. The cost is increased by 22.6% (Rs. 160,000.00) per kilometer, for ABC conductors. When comparing both bare aluminum conductors and ABC conductors, the cost difference is not much but the life time of bare conductors is greater than that of ABC conductors. However, the additional cost can be justified by the benefits achieved by using ABC.

The recommended maximum length of a feeder can be kept at constant level of 1.8 km for ABC conductors too. The recommended size of ABC conductors is ($3x70+50mm^2$) for 3 phase 4 wire LV lines.

New LV line construction cost per kilometer.

(A)	(B)		
Cost per km when use FLY conductor (7/3.40mm) 3ph,4wire (Rs)	Cost per km when use ABC conductor ($3x70+50mm^2$) 3ph,4wire (Rs)	Difference of Costs (A-B)	Remarks
708,000.00	868,000.00	160,000.00	Cost of line is increased by 22.6%

Table 5.1 – Costs of LV lines per kilometer. [Ref 9]

5.3.2 Use of 50 kVA transformers instead of 100 kVA transformers

Investigation results show that the maximum demands of many RE schemes are below 50kVA. The range of average load factors of all these schemes lies between 25% - 55%. [Although, some of these substations, the maximum demand have been increased up to 84 kVA for a short duration (about three hours per day) when considering voltage drop, line length and number of consumers of those substations augmentation is required].

If 50kVA transformers are used they can be loaded up to 125% (62.5 kVA) for a short duration (about three hours per day) without any harmful effect.

Therefore, considerable saving in cost of implementation and cost of maintenance can be achieved by using 50kVA transformers instead of 100 kVA transformers under the following recommendations.

I. Total distance of LV line from the substation to end of the line should not be increased from current value of 1.8 km.

II. Number of consumers per substation should not exceed 160.

Table 5.2 shows the power consumption of rural domestic consumers. The average power consumption of large, medium and small houses is 1.0 kW, 0.45 kW and 0.2 kW respectively.

Power consumption of rural domestic consumers						
Type of house	Avg. power consumption (kW)	% No. of houses	Total power (kW)	Avg. pf	Total demand (kVA)	Avg. current (A)
Large house	1.0	6%	10.2	0.88	11.6	5.2
Medium house	0.45	32%	23.0	0.88	26.1	2.3
Small house	0.22	62%	21.8	0.88	24.7	1.1
Total No. of houses per sub		160				
Allowable max. demand of sub (kVA)		62.5	Assessed demand (kVA)		62.5	

Table 5.2 – Power consumption of rural domestic consumers and assessment of maximum demand of RE substation.

By using 50 kVA transformers for the substations the total construction can be reduced further. Table 5.3 gives the amount of saving.[Ref 9]

Cost for 33kV/LT, 100kVA t/f	Rs. 558,560.00
Cost for 33kV/LT, 50kVA t/f	Rs. 400,000.00
Saving	Rs. 158560.00

Table 5.3 – Cost difference of 33kV / LV transformers used in RE schemes.

5.3.3 Use of Electronic energy meters instead of normal electro-mechanical energy meters

By using electronic energy meters instead of normal electro-mechanical energy meters losses created by tempering of energy meters can be reduced. Although electro-mechanical energy meters record the total electricity consumption, it does not record the past consumption in individual time periods (say one month period). As the domestic electricity tariff consists of block rates, the blocks with higher rates can be avoided by adding excess units consumed by the consumer to the following month with the help of meter readers.

As an example, suppose a consumer has used 100 units within a 30days period, according to the domestic tariff these 100 units will be distributed as, [Ref 10]

Block	Units	Rate (Rs)	Consumption	Amount(Rs)
1st Block	1 – 30	3.00	30	90.00
2nd Block	30 – 60	3.70	30	111.00
3rd Block	60 – 90	4.10	30	123.00
4th Block	90 – 180	10.60	10	106.00
	Total		100	430.00

Since, there is no permanent record in the electro-mechanical meters, consumer can avoid last 10 units in the 4th block and it can be added to the following month with the help of meter reader and his monthly electricity bill can be reduced by Rs. 106.00.

But, as the electronic meters record the past consumption with date and time, consumers cannot continue illegal practices. As there is no moving parts in electronic meters tempering is very difficult. Even the tempering affects will be recorded in the meter and such records can be used as evidence to take legal action against them.

Electronic meters can be used to take survey of consumer load parameters like kVA, kWh, Voltage, Current and number of power failures within a particular period of time. These details will help in planning and finding solutions to the problems related to the electricity supply.

Remote meter reading facilities can be added to the domestic programmable energy meters and can be used to take the meter readings form a remote place through a communication channel.

The main disadvantage of electronic meters is the cost of meters. The cost of normal electro-mechanical meter is about Rs. 1200.00, but the cost of programmable single phase electronic meter is nearly four times the cost of normal electro-mechanical meter. But with the development of software industry, these meters will be cheaper than the normal electro-mechanical meters in near future and will be more popular in electricity distribution sector.

5.3.4 Rehabilitation of existing RE schemes

As a temporary and immediate solution to reduce breakdowns, way leaves should be cleared to a satisfactory level in all LV and HV lines and loads of LV feeders should be balanced as far as possible.

A considerable saving of maintenance cost and reduction in energy losses can be obtained by replacing aluminium conductors of spur lines by ABC conductors of existing RE schemes. This should be done by studying individual RE schemes and identifying worst case problems. Initially, bare conductors of spur lines in bad condition and most liable to frequent breakdowns should be replaced by ABC conductors. This process to be continued step by step until breakdowns are reduced to a satisfactory level.

Substation maintenance programme should also be activated simultaneously with the above line rehabilitation programme and should carryout continuously.

A decision must be taken from the higher authority, not to extend spur lines of RE schemes by using bare aluminium conductors further in these schemes.

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[9] Ceylon Electricity Board - Distribution Planning Branch, “Standard construction costs – 2007”, Chairman Distribution Co-coordinating Committee CEB, January 2007,

[10] Democratic Socialist Republic of Sri Lanka, “Gazette Notification (Extraordinary) – No. 1429/39 – Friday January 27 2006”, Government of Sri Lanka, January 27 2006, pp 1A

Section (01). **Questionnaire for RE scheme Survey.** **Appendix (I)**

Scheme: ______ **Date of Survey :** ______

2.00 Details of the House

2.10	House No :	
2.20	Nature of the house :	Single house/Two storey building/Temporary house/ Line room/ still under construction.
2.30	Floor area :	Sq. ft.
2.40	Roof :	Tile / Asbestos / GI sheets / Other.
2.50	Walls :	Bricks / Cement block bricks / Clay / Timber plank / Other.
2.60	Floor :	Cement / Tile / Clay
2.70	No. of rooms :	
2.80	Ownership :	Own / Rent / Other
2.90	Water supply :	Own well / Common well / Common pipe / Irrigation cannel /Other.
2.10	Toilet facility	Water seal type / Other.
2.11	Current market value of land :	Rs. Per perch.
2.12	Did the land value increased after electrification :	Yes / No.

3.00 Educational and Financial details.

3.10 No. of members in the family:

3.20 Education level of the family members and employment status.

								Distance to the work place		
		5 pass	8 pass	O/L	A/L	Degree	Employment	Village	Town	Other
Father										
Mother										
Children	1									
	2									
	3									
	4									
	5									

3.30 Other sources of income:
(If any)

1							
2							
3							

3.40 Approximate monthly expenditure: Rs.

3.50 No. of school going children:

4.00 Details of Electricity supply.

4.10 Year & month of electricity supply taken : Tariff :

Domestic	
Commercial	
Industrial	

4.20 Nature of the service connection : single phase / three phase.

4.30 Length of the service wire : meters

4.40 Distance to the transformer : meters

4.50 No. of wired lamp points : Nos.

No. of wired 5A plug points : Nos.

No. of wired 15A points : Nos.

4.60 Average electricity consumption over last 12 months: Units/month

5.00 Details of Electricity usage.

5.10 Lighting purposes

Type of lamp	Wattage	Number	Usage (hrs / day)
Incandescent lamps			
Incandescent lamps			
Incandescent lamps			
Fluorescent lamps			
Compact Fluorescent lamps			
Compact Fluorescent lamps			

5.20 Other electrical appliances

Description	Wattage	Number	Usage (hrs / day)
Rice cooker			
Immersion heater			
Electric Kettle			
Refrigerator			
Electric Iron			
Washing Machine			
Electric Fans			
Television			
Radio			
Domestic water pump			

5.30 Other purposes.

Type of business	Description	No. of workers	Elec. Consumption / month	Monthly Income
Small industry				Rs.
Commercial				Rs.
Agriculture				Rs.

5.40 Do you use electricity for preparing meals in your home? Yes / No / Sometimes
If no, What is the main source of energy for cooking? Fire wood / LP Gas / Both

5.50 Do you wish to start small industry using electricity ? Yes / No
If yes, 1 What is the type of industry you wish to start ? ……………………………………………………………………
2 What are the barriers you come across in getting electricity connection ?

5.60 Do you wish to start small commercial activity using electricity ? Yes / No.
If yes, 1 What is the type of commercial activity you wish to start ? ……………………………………………………………
2 What are the barriers you come across in getting electricity connection ?

5.70 Do you wish to start small agricultural activity using electricity ? Yes / No.
If yes, 1 What is the type of agricultural activity you wish to start ? ……………………………………………………………
2 What are the barriers you come across in getting electricity connection ?

5.80 Do you think the life became more comfortable after getting electricity supply ? Yes / No
If yes, in which area,

Home lighting	
Cooking purposes	
Washing & Ironing cloths	
Water supply to the house	
Studying for children	
Use of television & radio	
Home security	
Sanitory & healthware	

6.00 Quality of Electricity supply.

6.10 Light condition of electric bulbs : Low / Moderate / High
6.20 Voltage fluctuations : Yes / No / Sometime
6.30 Any damage occured to your electrical appliances due to high voltage after getting electricity ? Yes / No.
If yes, how it occurred ?
6.40 How many electricity supply interruptions in last month ? Nos.
6.50 If there is a breakdown, how many hours CEB take to restore the supply after you inform them?

within one hour	
within one day	
after one day	

6.60 Can you manage your day to day works easily without electricity ? can / cannot / difficult

7.00 Street Lighting.

7.10 Street lighting : Available / Not available If available, how?

only at junctions	
along the road	

7.20 Benefits you gained from street lighting ?

Easy to travel at night time	
Improving security level of village	

8.00 Health services

8.10 Is health center or dispensary available in your village ? Yes / No.
8.20 Is it's service available even at night time for an emergency ? Yes / No.
8.30 Do you think health service is improved after electrification of village ? Yes / No.
8.40 Is any accident occurred due to electrification of the village? Yes / No.
If yes,

Place of accident	in your home	in your garden	in the scheme
Nature of accident	Electric shock / Death		
How many victims?			
How it occurred ?			
When it occurred ?			

9.00 Environmental effects.
9.10 Did you cut trees in your garden in order to obtain electricity ? Yes / No.
9.20 Did the CEB cut trees in your garden in order to install electricity lines ? Yes / No.
9.30 Do you think trees are necessary to be cut down in order to minimize breakdowns and safety of people from electrocution ? Yes / No.
9.40 Do you satisfy with the manner they did it ? Yes / No.
9.50 Is there any dispute between villagers due to electrification? Yes / No.
If yes, why ?

Section (02).

Appendix II

Questionnaire for RE scheme Survey.

1.00 General details of the Scheme

Date of research	

Name of the scheme:		Date energized:	
CEB area:		Consumer Service Centre:	
Province:		District:	
Electorate:		GSO Division:	
Divisional Secretariat:			

2.00 Development details of the scheme.

	At scheme open	At present	Time period (Years)
Population of the Village			
Total no. of houses			
No. of houses covered by CEB scheme			
Number of houses beyond 100m away from LT feeder			

3.00 Technical details.

Medium voltage side :

3.10 Capacity of the RE Substation : Medium Voltage :
3.20 Length of MV line to the tapping point of MV feeder :
3.30 Closest Grid Substation :
Installed capacity of the Grid Substation : MVA
Peak load of Grid Substation : MVA
3.40 Distance to the grid substation from RE scheme tapping point along the MV feeder :
3.50 Condition of MV lines from the grid substation to RE scheme :

Type of Line	Length (km)	Conductor size	DC or SC	Line condition
Tower line (back bone line)				
Tower line (MV feeder)				
Pole line 1				
Pole line 2				
Total length (km)				

3.60 Switch gears in series up to RE scheme from GSS and their condition.

Type of switch gear	No. of switchgears	Condition
OCB		
LBS		
ABS		
Auto Recloser		
DDLO		

Low voltage side :

3.70

Identification		F1	S1	S2	S3	F2	S1	S2	S3	F3	S1	S2	S3	F4	S1	S2	S3
Distance from TF.																	
Length of 3ph lines																	
Length of 2ph lines																	
Length of 1ph lines																	
Connected loads																	
No. of Houses	Large																
	Medium																
	Small																
No of Commercial	Medium																
	Small																
No of Industries	Medium																
	Small																
No of Religious premises																	
Condition of LT line																	
Condition of LT switchgears																	
Condition of way leaves																	

NB :
Small house below 750 Sq.ft.
Medium house between 750 Sq.ft. to 1500Sq.ft.
Large house over 1500 Sq.ft.
Line length in kilometers

Small industry below 10kVA
Medium Industry between 10kVA & 42 kVA.

Small commercial :
Shops, Boutiques, Farms etc adjoining the house and area less than 500 Sq.ft
Medium commercial :
Shops, Boutiques, Farms etc adjoining the house and area more than 500 Sq.ft.

3.80 Load measurements of the substation.

Load current (A)	F1	F2	F3
Phase R			
Phase Y			
Phase B			

Date & Time :	

Voltage of Longest & heavyly loded feeder (V)		F2 (Omatta side)		
		Start	Middle	End
	R			
	Y			
	B			

Peak kVA demand of the substation : kVA

Energy measurement of the substation.

	Period		KWh
	from	to	
Total energy input to the LT lines (as recorded in the substation meter)			
Total useful energy output. (as recorded in consumer's meters)			
Loss of energy			
Loss of energy (as a percentage)			

N.B. : It is required to confirm that no any defective meters at consumer's premises and all meters are working in order during the test period.

4.00 Average Load Factor : weekly

5.00 Average Power Factor : weekly

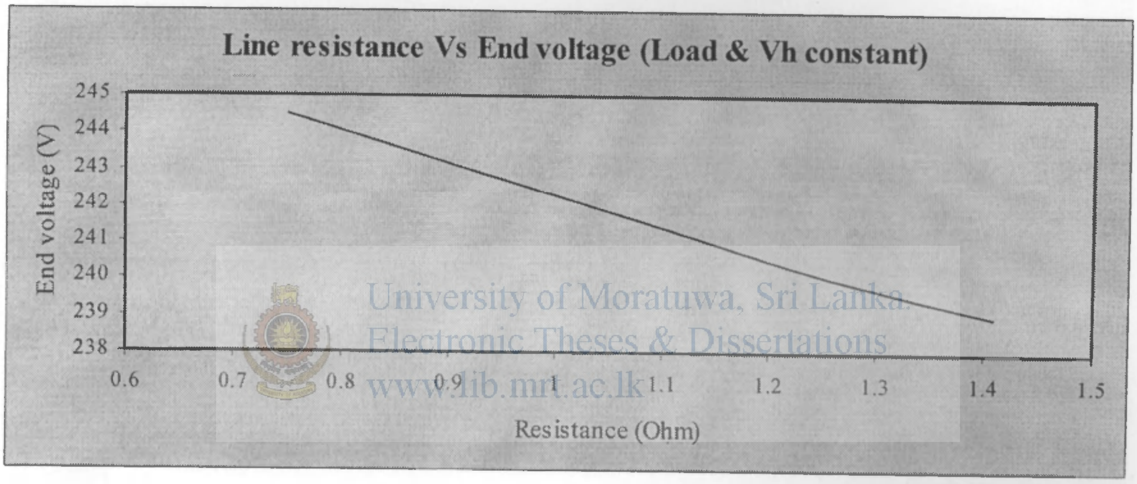
6.00 No Load Loss of the Transformer : W.

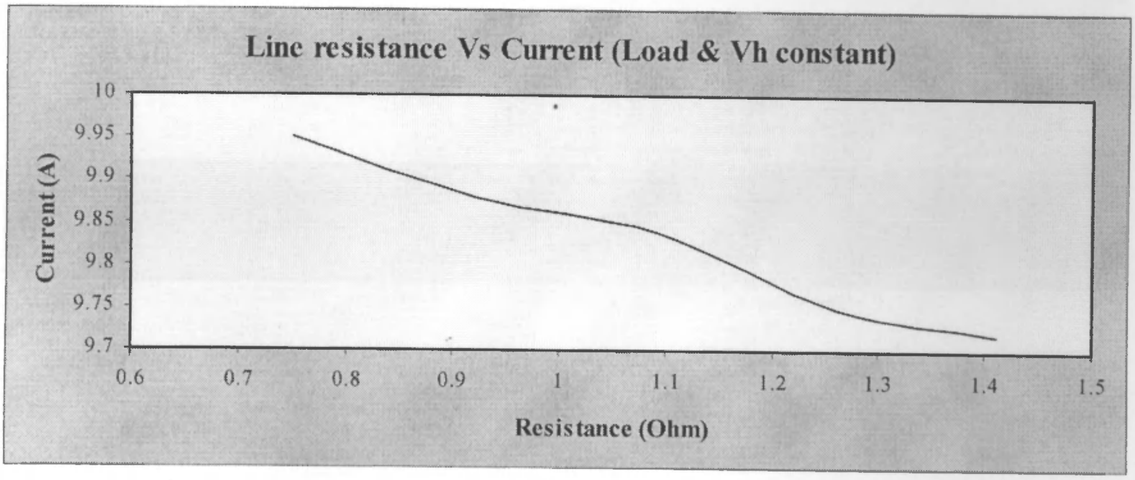
7.00 All day efficiency of the transformer:

Change of Line end voltage, current and fundamental wave form due to change of line resistance, load and the presence of harmonic voltages.

1. Changing the line resistance with keeping other variables is being constant.

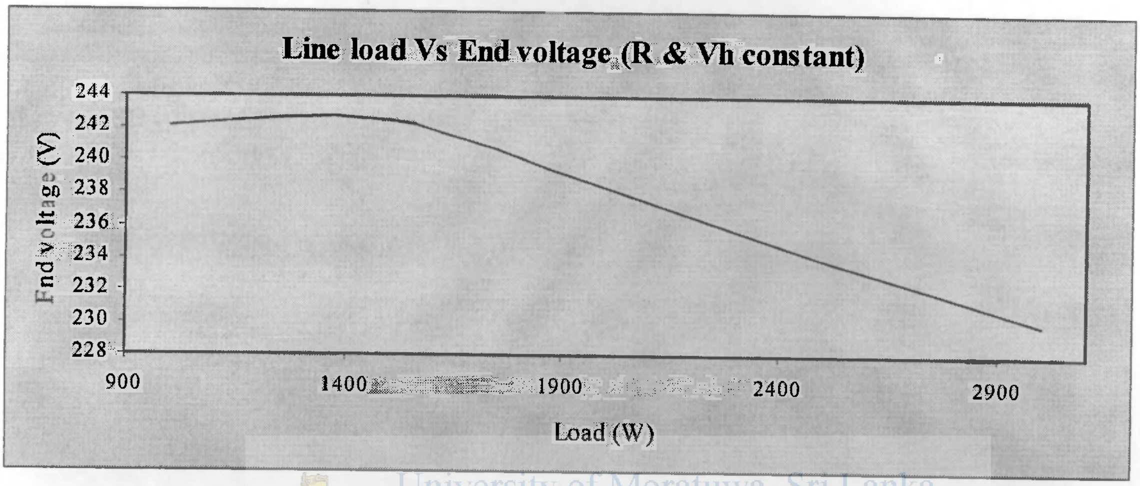
Changing Line Resistance - (Load & Vh constant)		
Vh = -18V,150Hz,0 deg. pf 0.89		
R (Ohm)	I (Amp)	Vend (V)
0.75	9.95	244.5
0.92	9.88	243
1.09	9.84	241.5
1.26	9.75	240
1.41	9.72	239

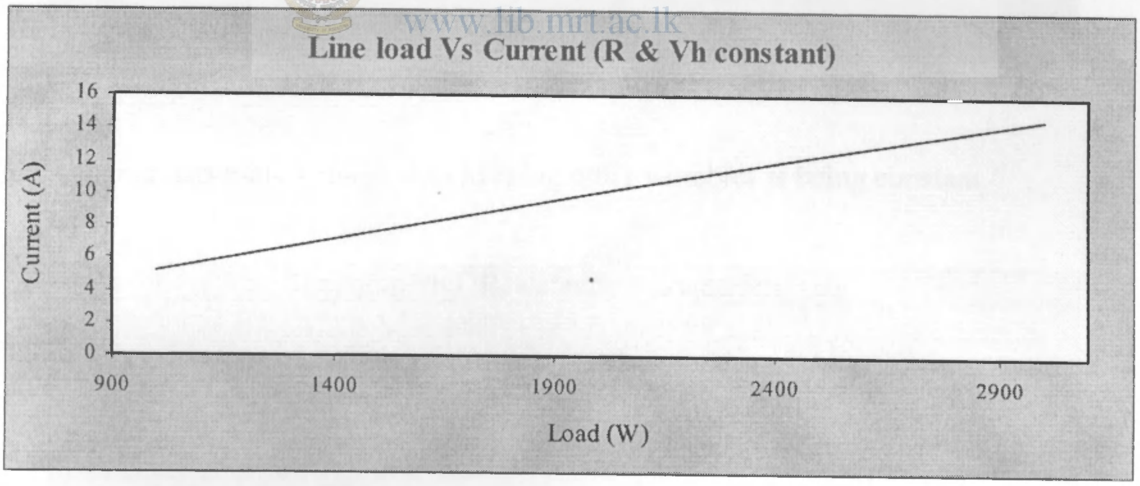




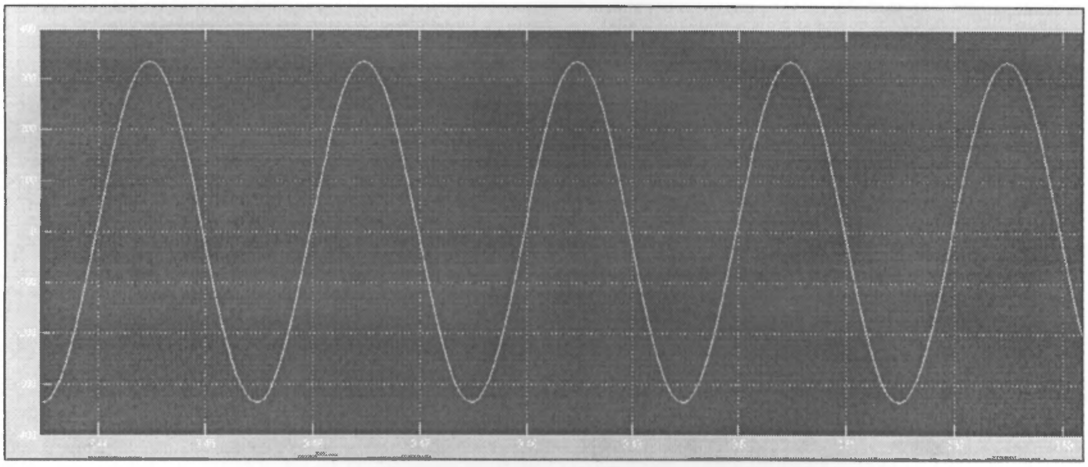
2. Changing the line load with keeping other variables is being constant.

Changing Load - (Resistance & Vh constant)		
R = 1.41Ohm,Vh = -18V,150Hz,0 deg, pf 0.89		
Load (W)	I (Amp)	**Vend (V)**
1000	5.22	242.2
1500	7.69	242.5
2000	10.07	238.4
2500	12.37	234
3000	14.59	230

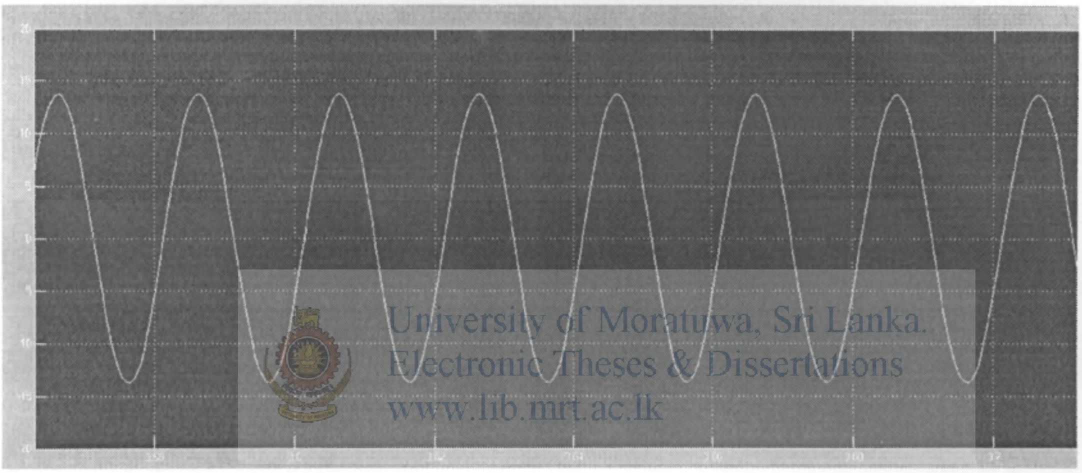




Wave form of end voltage (without harmonics)

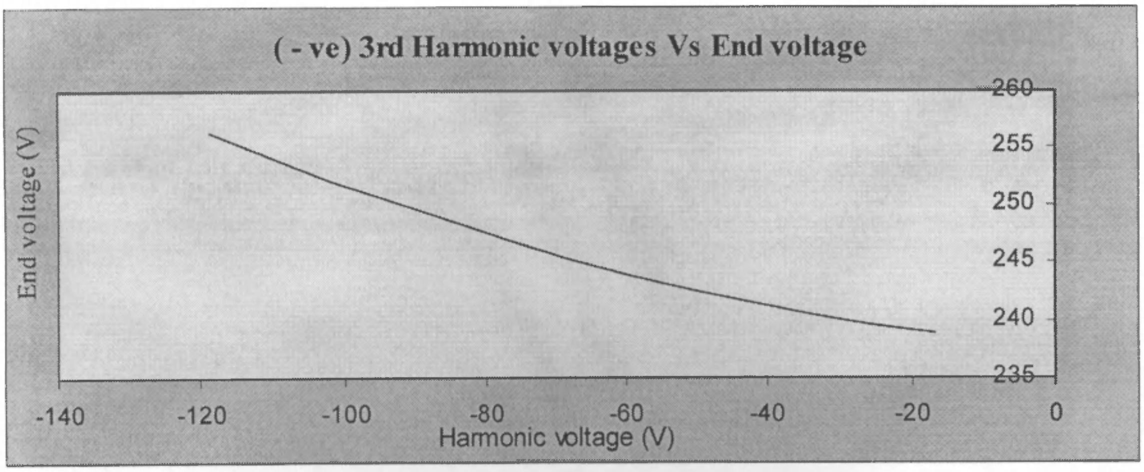


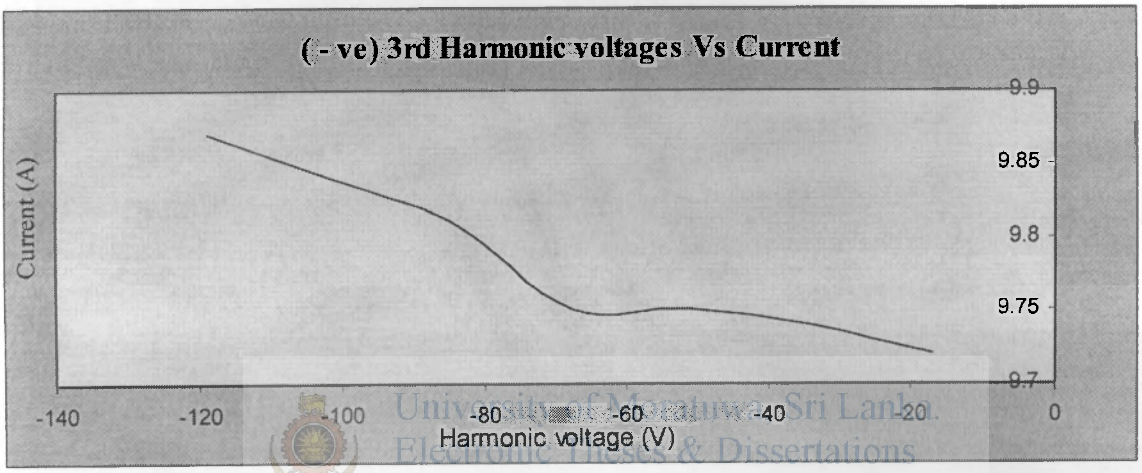
Wave form of phase current (without harmonics)



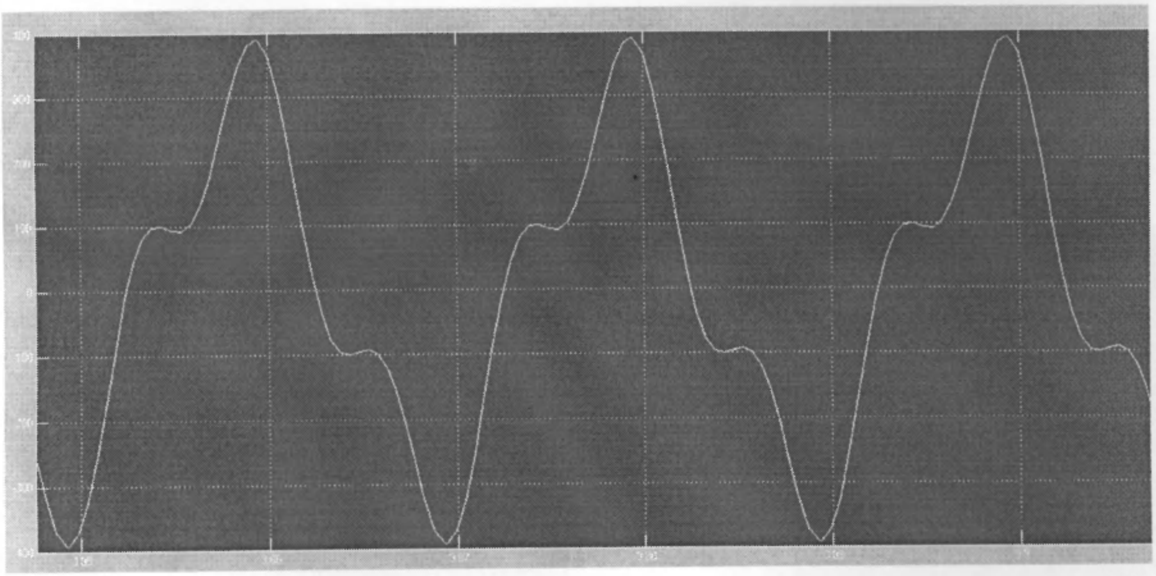
3. Changing harmonic voltage with keeping other variables is being constant.

Changing Vh - (Resistance & Load constant)					
R = 1.41Ohm, Load = 1925W pf 0.89					
Vh (150Hz,0)	I (Amp)	Vend (V)	Vh (150Hz,0)	I (Amp)	Vend (V)
-16.97	9.72	238.9	16.97	9.72	237.5
-33.94	9.74	240.4	33.94	9.71	237.7
-50.91	9.75	242.6	50.91	9.72	238.5
-67.88	9.75	245.2	67.88	9.73	239.8
-84.85	9.81	248.5	84.85	9.74	241.7
-101.82	9.84	252.1	101.82	9.76	244.2
-118.79	9.87	256.3	118.79	9.8	247.2

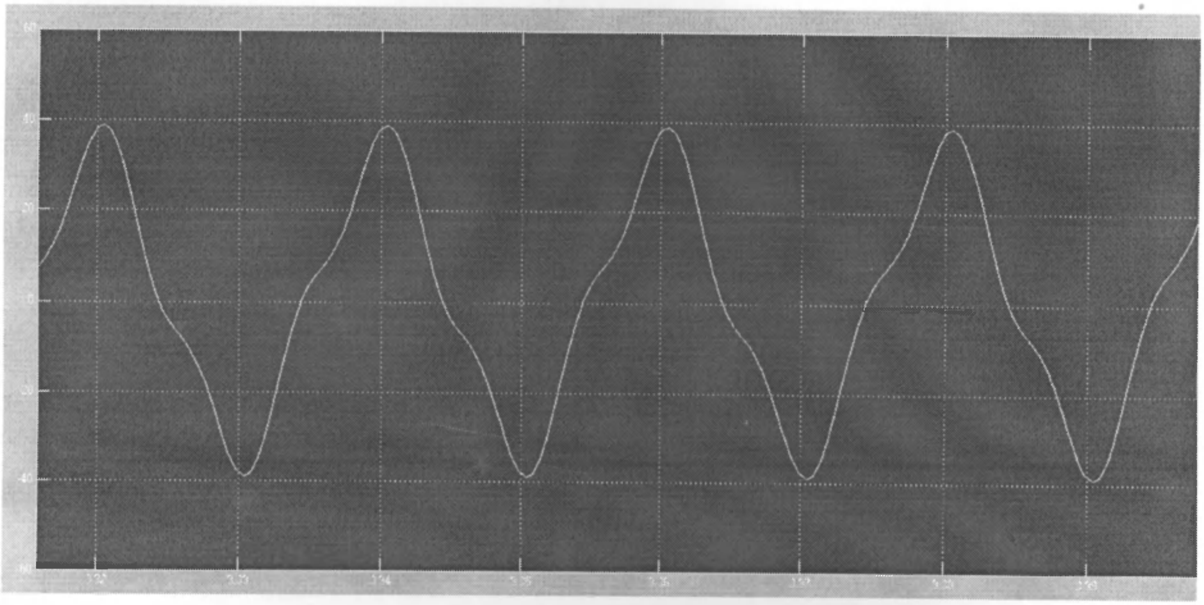


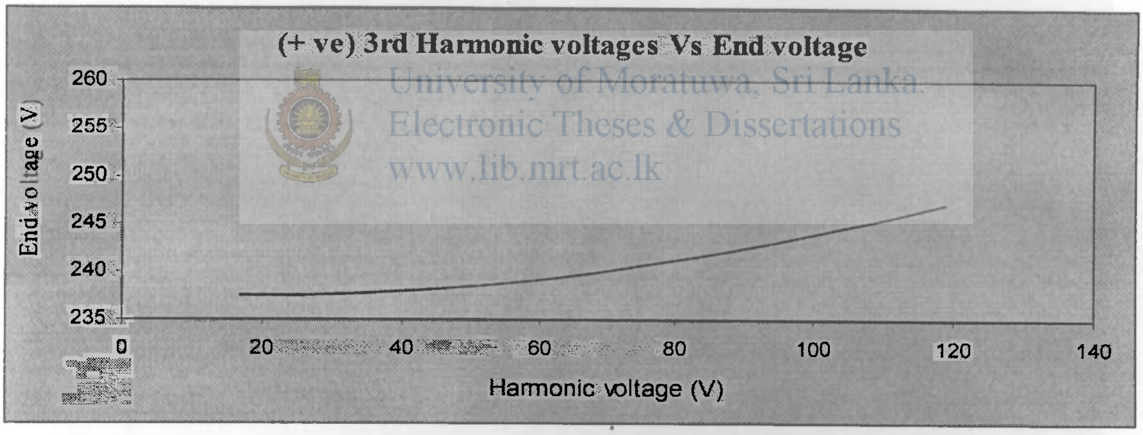


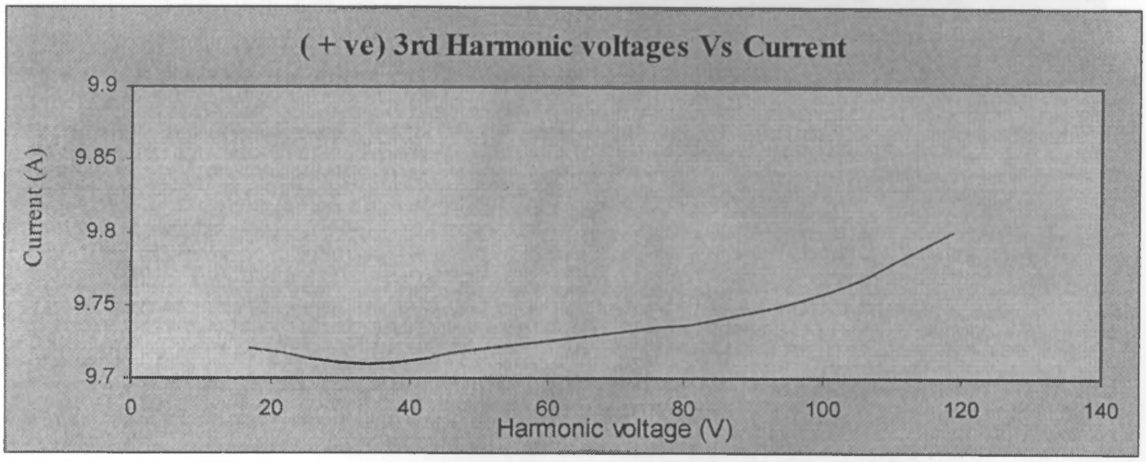
Wave form of end voltage with (–ve) 3rd harmonics.



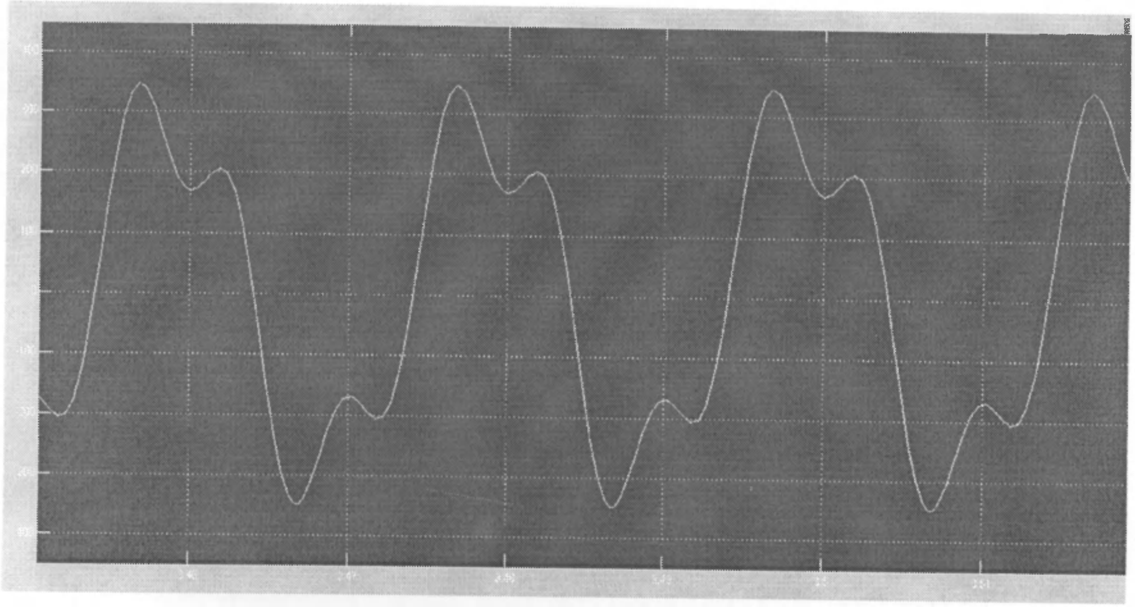
Wave form of line current with (–ve) 3rd harmonics.







Wave form of end voltage with (+ve) 3rd harmonics.



Wave form of line current with (+ve) 3rd harmonics.