Distribution Loss of Electricity and Influence of Energy Flows: A Case Study of a Major Section in Kerala

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Distribution Loss of Electricity and Influence of Energy Flows: A Case Study of a Major Section in Kerala

P. R. Suresh, Shanavas Elachola*

1. Introduction

The importance of reducing T&D losses in the power system is well known. That this aspect receives topmost priority is evident from the report of the high level committee on Industry and Power (Govt. of Kerala, 1984), which states: "Additional investment in the transmission and distribution system to reduce power losses would have a high rate of return and is absolutely necessary and should be given high priority. Even if Kerala were to limit its transmission loss to 16 per cent which was achieved in 1950-51 it would improve power availability significantly".

Quantifying and Assessing the performance of a T&D system is rendered very difficult by lack of relevant data. Inefficient operation usually results from a combination of factors listed below.

(i) Failure to make optimal use of the intra-regional and inter-regional links to maximise the generation of power. This is due to inadequate linkage between the power system of the State and the poor regulation of voltage and frequency.

(ii) Poor quality of supply due to poor maintenance of distribution lines, transformer, and switchgear.

(iii) High T&D losses due to lack of supervision leading to leakages, thefts, faulty metering, and failure to maintain, and operate capacitors.

(iv) Poor load management and neglect of energy conservation measures.

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The Kerala power system losses

The T&D losses in the Kerala power system during 1996-‘97 was 20.5 per cent (Economic Review: 1998). This could be reduced considerably through systematic efforts. However, the attempts in this direction so far have remained sub-critical. The losses are calculated by the KSEB as:

$$L = \{ [(G-A) + (I-E)] - T \} / T \times 100$$

Where,

L = Loss
G = Annual generation
A = Auxiliary consumption
I = Import
E = Export
T = Total number of units sold including export sales, if any.

It is well known that inadequate metering, billing and collection, uneven revenue collection, and lack of enforcement are some of the major problems faced by the State Electricity Boards in India. It is, therefore, quite likely that the number of units sold (as per revenue records) is significantly at variance with the number of units actually consumed. Even the metered consumption might not reflect the real consumption values for a variety of reasons, like:

(i) Pilferage and theft
(ii) Faulty meters

(i.e., stopped meters, damaged/burned meters, slow-running-on-load meters, meters creeping in the backward direction and meters with defective cyclometer.)

The lower voltage levels at the consumer premises might also contribute to losses. It is important to segregate the T&D losses calculated by the KSEB into:

(i) Technical losses
(ii) Non-technical losses

The T&D losses may be separated into:

(i) Transmission loss
(ii) Distribution loss

Transmission loss itself comprises:

(i) Loss from generation voltage to the main transmission voltage.
(ii) Loss from main transmission voltage to sub-transmission voltage.
(iii) Loss from sub-transmission voltage to distribution voltage.

Further distribution loss may be separated into transformer loss and line loss. Splitting the overall loss into a variety of subgroups as above is important to formulate appropriate intervention measures. This study concentrates only on the distribution side. It would attempt to identify to a reasonable level of accuracy the extent of technical loss on the distribution side in a typical rural major section in Kerala.

Energy saved is equal to energy generated

It is a fairly well accepted concept that investment in cutting T&D losses is generally a far cheaper way of getting power to the consumer in a dependable and reliable way than investment in new generation capacity and should thus receive high priority in planning.

2. Project Area

Choosing a typical major section is a difficult task in the context of Kerala, which has 990 grama panchayats, 34 municipal towns, and 3 city corporations. Therefore, a strict rural-urban division does not hold any relevance in the case of Kerala as the whole State has been formed like an urban-rural continuum. Therefore, a typical major section would ideally be a suburban village, close to a medium-sized town.

The project area chosen for this study was the Kongad major section in Palakkad district because it is a rural area located adjacent to Palakkad, a medium-sized town. The Kongad major section feeds the following *panchayats*:

(i) Kadampazhipuram
(ii) Karimba
(iii) Keralassery
(iv) Kongad
(v) Mundur
(vi) Puduppariyaram

The electricity distribution system in Kerala has been divided into 14 distribution circles for operation and management. The circles are further classified into 40 divisions and these divisions are divided into approximately 300 major sections. The Kongad major section falls under the Palakkad distribution circle. It is fed from the Parali, Mannarkkad, and Ottappalam sub-stations via Kongad, Sreekrishnapuram, and Ottappalam 11 kV feeders. The distribution system consists of 77 transformers with a total transformation capacity of 7873 kVA. The particulars of the consumers in the major section are provided in the Table 2.1.

Table 2.1 Particulars of sample electricity customers

Category of consumers	Number of consumers	Estimated connected load (MW)	Estimated annual consumption in kilo units
Domestic	10515	12.93	4668.66
Commercial	1592	0.84	1002.96
Agricultural	1289	2.20	179.12
LT Industrial	250	3.15	2724.99
Total	13646	19.12	8575.73

Source: DEFUNDS study conducted by Integrated Rural Technology Centre, Palakkad 1996-'97.

3. Objectives and Method

The present study has the following major activities:

(i) To determine the distribution losses in a typical rural major electrical section, viz. Kongad Major Section of Palakkad Distribution Circle.

(ii) To estimate the magnitude of technical loss in the section.

(iii) To determine the impact of low voltage levels on the magnitude of loss.

(iv) To formulate strategies for loss-reduction with people's participation.

(v) To determine local strategies of loss reduction and voltage improvement.

Method

Project advisory committee

The methodology for this investigation was finalised in consultation with experts in this field. A one-day workshop was held at IRTC on 21 January 1997 in which the following experts participated.

- (i) Dr. K. Gomathy (Retired J.D. of Technical Education & Formerly Prof. of Electrical Engineering, College of Engineering, Thiruvananthapuram)
- (ii) Dr. K. A. Muraleedharan (formerly Professor of Electrical Engineering, C.E.T.)
- (iii) Sri. P. V. Krishnan (Retired Deputy Chief Engineer, KSEB)
- (iv) Dr. M. K. Radhakrishnan (Principal, Government College of Engineering, Kannur)
- (v) Dr. T. V. Babu Rajendran (Principal, N.S.S. College of Engineering, Palakkad)
- (vi) Dr. R. V. G. Menon (Director, IRTC, Mundur)
- (vii) Dr. T. N. Padmanabhan Nambiar (Prof., Government College of Engineering, Thrissur)
- (viii) Mrs. Geetha K. I. (Lecturer, N.S.S. College of Engineering, Palakkad)
- (ix) Mrs. Girijadevi (Lecturer, N.S.S. College of Engineering, Palakkad)
- (x) Sri. S. B. K. Menon, (Retired Chief Engineer, KSEB)

Method

At the beginning of this study, a convenient feeder was chosen. Three transformers identified under this feeder were considered representatives with respect to its connected load. Details of the feeder and transformer were collected from the local office of the Electricity Board.

In order to realise the objectives of the study it was necessary to measure the actual field loss. The power and energy output of the transformers can be easily measured by clamping a three-phase energy meter and three current meters to the secondary side of the selected transformer. The next step is to measure energy consumption by the consumers connected to this line, simultaneously. It is impracticable to take their energy meter readings all at the same time. We assumed that their consumption rate (load) remains more or less steady during the peak-time between 7 pm and 8 pm. With the help of a set of volunteers, we would make a note of the energy meter readings of all the consumers at some specified time, on a particular date. Exactly after one week, we would repeat the exercise at the same specified time. During this entire period, the instruments would remain connected to the transformer. The energy output of the transformer and the actual energy consumption were thus obtained. This would be repeated for four consecutive weeks to get a better estimate.

A method to measure the peak time loss was also suggested by the experts. This involved the assumption that the peak time consumption of each consumer is more or less the same, every day. Therefore, the real time consumption could be measured for each group of consumers for a specified period on a daily basis and compared with the steady peak time output of the transformer.

Procedure

Permission was obtained from the Chief Engineer, Research & Planning, KSEB to collect information and to conduct this study. As suggested by the advisory committee, we consulted the KSEB engineers of the major section to select the transformer. They listed 10 transformers, which would be representative of the patterns and parametres of our study. Out of these 10 transformers, we selected three transformers for detailed investigation to represent typical conditions of domestic, small industrial, and commercial loads. They are Poriyani 100 kVA, Mundur 250 kVA, and Keralassery 100 kVA. The technical details of the transformers were collected from the major section office.

Three-phase energy meters and three current transformers were calibrated and connected by proper clamping, in the transformer secondary. The faulty consumer meters were identified by allowing the consumers to put incandescent lamps and by checking the energy meter rotation simultaneously. Energy meter readings at both the consumer premises and the transformer secondary were taken at a particular time on a particular day. These readings were monitored at as close an interval as possible with the help of a group of volunteers, viz., a project batch from NSS College of Engineering, Palakkad, and IRTC staff. After this we got the faulty meters replaced with the help of the local office of the Electricity Board and repeated the procedure every week, for a month.

The power factor and peak load readings of the transformers at peak-load time interval, between 7 and 8 pm, were recorded. On the transformer side energy meter disc rotation, current in the different phases and in the neutral wire, and voltage in the phases were measured. The current and the voltage could be measured with calibrated clamp-on ammeters and voltmeter. Neutral current was also measured in order to find the phase imbalance. The voltage at tail end was measured to get voltage drop at peak time.

We also made an approximate estimate of the length of the LT line, by computing the number of spans and span length.The number of three-phase and single-phase connections and number of tappings taken were noted. The number of streetlights and their wattage were also noted with the help of KSEB officials.

The same procedure was repeated with two other transformers also. From this, the technical and non-technical losses were calculated. The overloading/malfunctioning of transformers was also found out.

The layout of the distribution network connected to a selected feeder was made and improper line conditions, touching, loose joints, jumpering without proper clamps, and sparking switches were noted. An attempt was made to identify possible problems of the layout in the distribution system and phase imbalances.

4. Load Details of Transformers

Transformer load

The load under a transformer depends upon its terrain, population and living standard, present and future development plans, cost of power, etc. Transformer may be over-loaded or under-loaded according to the type and number of consumers. It has maximum efficiency when its copper loss and core loss become equal. Copper loss depends on the current passing through its windings. In order to find out the load centre and the optimum position of a transformer in the load system, one must know the load distribution under the transformer.

General load characteristics

Nature of loads

Nature of loads is characterised by the demand factor, load factor, diversity factor, utilisation factor, and power factor. The following are the definitions of standard terms.

(i) Maximum Demand: It is usually expressed as the largest value of the demand of the transformer (or system) during a given period such as a month or year.

(ii) Demand Factor: The ratio of maximum demand to connected load (rated capacity) of a consumer is called the demand factor.

(iii) Utilisation Factor: The ratio of maximum demand of a system or part of a system to the rated capacity of system or part of the system is called utilisation factor.

(iv) Load Factor: This is the ratio of the average power to the maximum demand, i.e.;
Load Factor = [(Units consumed in a given period/Maximum demand) x (Hours in the period)].

(v) Power Factor: In a resistance circuit, the current is in phase with voltage but lags in inductive circuit and leads in capacitive circuit. The product of current and voltage does not give true power but gives apparent power known as volt-ampere. The ratio of true power to apparent power is defined as power factor or cosine of the angle of lag or lead (CosN = R/Z).

Types of load

In general, the types of load may be divided into the following categories.

Domestic: This category consists mainly of lights, fans, and domestic appliances, such as heaters, refrigerators, air-conditioners, mixers, ovens, heating ranges, and small motors for pumping. The various factors are: Demand Factor in the range of 70-100 per cent, Diversity Factor 1.2-1.3, and Load Factor 10-15 per cent.

Commercial: Lighting for shops and advertisement, fans, air conditioning, heating and other electrical appliances used in commercial establishments such as offices, shops, restaurants, and market places come under this category. The demand factor is usually 90-100per cent, diversity factor is 1.1-1.2 and load factor is 25-30per cent.

Industrial: These loads may be of the following typical power ranges:

Cottage industries	< 5kW
Small scale industries	5-25kW
Medium Scale industries	25-100kW
Large scale industries	100-500kW
Heavy industries	> 500kW

The last two types of loads need power more or less continuously and the demand remains uniform through out the day. For large-scale industrial loads, the demand factor may be taken as 70-80 per cent and the load factor 60-65 per cent and for heavy industries the demand factor may be taken as 85-90 per cent with a load factor of 70-80 per cent.

Municipal: This load is for street lighting and it remains practically constant throughout the night. In this case, the demand factor is 100 per cent and diversity factor must be reckoned as one. Streetlights require power only at night but there may be a small load demand for traffic signals throughout the day. The load factor for the streetlight is usually taken as 25-30 per cent. Water supply and drainage constitute another part of municipal power demand.

Agriculture: This type of load relates to supplying water for irrigation by means of suitable pumps driven by electric motors. The load factor is generally taken as 20-25 per cent, the diversity factor as 1-1.5 and the demand factor as 90-100 per cent.

Other loads: Apart from the above mentioned loads, there are other loads such as bulk supplies, special industries like paper and textile and traction and government loads which have their own peculiar characteristics.

System power factor

All electrical equipment except synchronous motors, resistance heaters and incandescent lamps consume power at lagging power factors. The approximate average lagging power factor of various devices is given below:

Fluorescent Lamps with electromagnetic choke	0.5
Fans	0.5-0.8
Induction motors	055-.85
Refrigerator	0.65
Radio	0.9
Electronic equipment	variable

Induction motors are widely used in industry and agriculture and constitute a major part of the load in a power system. The overall power factor of a system is likely to be below 0.7 (lagging) unless deliberate corrective measures are taken to improve it.

Rural load systems

In Kerala, rural loads mainly include home lighting, domestic appliances, street lighting, agricultural loads and loads for small-scale industries. The area catered by a single transformer is as wide as two or three sq.km and sometimes even more. Owing to this type of distribution network, the supply voltage at the tail end is less than half of the rated voltage of the distribution system. Quality electricity remains a dream for the rural people.

Load survey

Load details of the consumers in the selected area were collected through a survey using a questionnaire. Information was collected on different types of devices used, and the number of lamps operating continuously for 3 hours, 3-4 hours, 4-6 hours, and for more than 6 hours, in each household.

The survey was conducted during the second quarter of 1997 with the help of students from the NSS College of Engineering, Palakkad. The most important finding was that the major load of three transformers was for lighting and constituted about 22 per cent-33 per cent of the total connected load. About half of the 60W bulbs were being used for at least 4 hours a day.

Load details of these transformers are given in Table 4.1, and the details of the use pattern of incandescent lamps are given in Table 4.2.

Table 4.1 Load survey details of Poriyani and Keralassery transformers

Name of transformers	Poriyani 160 kVA	Keralassery 100 kVA
Total no. of consumers	181	218
Domestic	148	171
Commercial	22	25
Industrial	7	4
Agriculture	4	18
No. of 1-phase connections	170	207
No. of 3-phase connections	11	11
No. of faulty metres	49	64

Type of loads	Load in Watts	% Load	Load in Watts	% Load
Incandescent Lamp 40 W	5600	2.21	3040	1.18
Incandescent Lamp 60 W	47340	18.66	70260	27.31
Incandescent Lamp 100 W	4400	1.73	12200	4.74
Incandescent Lamp total	57340	22.61	85500	33.24
Florescent Tube light	5360	2.11	6840	2.66
Fan	12720	5.01	16800	6.53
Refrigerator	2600	1.03	2800	1.09
Mixer/grinder/juicer	43650	17.21	47700	18.54
Electric Iron Box	29400	11.59	39600	15.39
TV/VCR/Tape Recorder	6060	2.39	7370	2.86
Electric pump	42103	16.60	38762	15.07
Industrial load	51565	20.33	11252	4.37
Others	2860	1.13	630	0.24
Total load in Watts	253658	100.0	257254	100.0

Source: Data collected from field survey

Table 4.2 Deatalis concerning the use of incandescent bulbs

Incandescent bulbs	Poriyani 160kVA transformer		Keralassery 100 kVA transformer	
	60 W	100 W	60 W	100 W
Total wattage of connected lines	47340	4500	70260	12200
About 4 hours a day	38.84 %	24.44 %	29.89 %	17.21 %
Between 4 and 6 hours a day	3.91 %	6.67 %	6.49 %	9.84 %
More than 6 hours a day	2.39 %	0 %	1.11 %	4.92 %

Source: Data collected from field survey

5. Distribution Loss

The distribution system includes the 230V lines, connections, and supporting equipment, which carry electricity from the transformer to the consumer premises. The extent of the system depends upon the capacity and position of the transformer and the location of the consumers. Inevitably, losses occur in this part of the system due mainly to line resistance. These losses may be divided into technical and non-technical.

Technical loss

The major part of this loss is heat loss or I2R loss in the distribution conductors. Since this loss depends upon the value of current, it is the maximum during peak load. Other causes of the technical loss are low power factor, phase imbalance, improper joints, and extraneous factors like tree touching, etc. This loss is the difference between the transformer output and the sum of all individual consumption.

To find out the actual technical loss, we conducted simultaneous readings at each consumer's premises at a weekly interval for a month. For the Poriyani 160kVA transformer it was done in April '97, for Mundur 250kVA transformer in May '97 and for Keralassery 100kVA transformer in June '97. The number of consumers under the Mundur 250kVA transformer was rather high. Therefore, the transformer area was divided into two and simultaneous reading was done separately. For Keralassery 100kVA transformer, there are 208 consumers and they cover an area of about 3 sq. km.

Non-technical loss

This type of loss includes loss due to inadequate billing, faulty metering, overuse because of metres not working, and outright theft. Many of the domestic energy meters fail because of poor quality of the equipment. The problem of wilful damage by the consumers themselves is also said to be common, though we did not come across any such case in the study area. It is found from the survey and simultaneous readings that 30 per cent of domestic energy meters are faulty. The arrangements for repair / replacement are quite inadequate.

Faulty energy metres

Induction type energy meters are commonly used for measurement of energy in domestic and industrial AC circuits. They possess lower friction and higher torque-to-weight ratio. Some digital meters are also available in the local market.

Reliability of the induction energy meter is very low. From the survey it is noticed that one-third of energy meters are faulty and about 50 per cent of them has become faulty due to some mechanical defect making the readings in the energy meter getting stuck at digit '9'. This may be a manufacturing defect.

For estimating the actual technical loss, replacement of the faulty meters under these transformers was necessary. Hence, we approached the KSEB Executive Engineer with the list of faulty meters, which needed replacement. He instructed the concerned officials to replace these meters on a priority basis. All the faulty meters under Poriyani 160kVA were replaced during December 1997-January 1998.

During the second round of reading and analysis in February-March, another total of 22 meters also became faulty of which 5 metres were recently replaced. Some amongst these meters had been marked out in the earlier survey as having minor defects.

However, the impact of replacing the faulty meters could not be clearly measured, because during this interval some of the connections from this transformer area had been shifted to a nearby transformer.

Distribution loss

We entered all the simultaneous readings into the computer and they were analysed using the software Quattro Pro 6.0. For getting the actual consumption, both monthly and weekly average consumption were considered. In the case of faulty meters, we relied on their monthly bill to calculate their consumption. For getting the transformer readings, we used the energy meter (INDIA Make) with the three appropriate current transformers.

The total distribution losses calculated using the simultaneous readings are given in the Table 5.1.

Table 5.1 Distribution loss details of Poriyani 160 kVA transformer

Total number of consumers	181
Transformer reading (energy outflow from transformer)	18154.84
Total number of units allowed from the tariff rate	13910.50
Number of units actually consumed by the consumers from their metre reading	12038.00
Distribution loss	33.69%
After replacing the faulty meters	
Total number of consumers	167*
Transformer reading (energy outflow from transformer)	13,580.00
Total number of units allowed from the tariff rate	9445.00
Number of units actually consumed by the consumers from their meter reading	9708.62
The number of units consumed by the consumers whose meters were faulty (before their faulty meters were replaced), as obtained from their tariff rate	2290.00
Units consumed by the same consumers after replacing their faulty meters	2919.27
Distribution loss	29.00%

* Number of consumers were reduced, since some part of the transformer area was transferred to a new transformer nearby which was charged during the study period.
Source: Data collected from field survey

It is important to note that the number of units consumed actually by the consumers whose meters were faulty is actually 21.56 per cent higher than the number of units reserved for them. This gives an indication of the magnitude of commercial losses suffered by the KSEB because of faulty meters.

Distribution loss of Keralassery and Poriyani transformers is given below.

Table 5.2 Distribution loss of Keralassery and Poriyani transformers

Name of the transformer	**Poriyani 160kVA**	**Keralassery 100kVA**
Distribution loss before replacing faulty meters	33.69 %	36.66 %
Distribution loss after replacing faulty meters	28.51 %	-

Source: Data collected from field survey

6. Peak Load Line Losses

The peak load loss of a distribution system is the loss in power during the peak load time. Since the loss is dependent on the square of current and the current drawn by the consumers is high during the peak time, the loss must be comparatively high. To estimate the loss, the actual voltage, current, and energy consumed at the premises of each consumer at the peak load time have to be measured. It was difficult to conduct the peak load time measurements for Mundur 250kVA transformers since the number of consumers was very large. Hence, we decided to conduct the peak load time measurements only for Poriyani 160kVA and Keralassery 100kVA transformers.

Method

The method adopted for this work is given below:

(i) The peak load current and voltage of all consumers was measured using calibrated clamp-on Ammeters and voltmeters during the period 7 pm-8 pm. The peak load measurement was completed within a span of four days only because not all the consumers could be covered in one day with the available manpower.

(ii) By connecting a load analyser (KRYKARD load manager ALM-3) at the transformer secondary, information on the units transferred by the transformer during this period was obtained. The average kW at the peak time period was calculated. This was done on all the days, when the measurement on consumer premises was done and average of all these was taken for computation.

(iii) The peak load loss was found out by analysing the data.

Assumptions

The assumptions made for finding peak load loss are:
(i) The peak load time period is taken as 7pm - 8pm

(ii) The peak load current and voltage of the consumer and the transformer secondary remains more or less the same on all days.

(iii) The peak load power factor at consumer premises is unity (The power factor measured at the transformer end is nearly unity).

Peak load loss

It was found that at the peak time the load loss is 36 per cent for Poriyani 160kVA transformer and 46.2 per cent for Keralassery 100 kVA transformer. The LT line under Keralassery transformer being longer than that under Poriyani, the peak load loss at Keralassery is higher. The Peak load data obtained for the two transformers are given in Table 6.1.

Table 6.1 Peak load loss

Name of the transformer	Poriyani 160kVA	Keralassery 100kVA
Actual energy consumption by the consumers during peak hour	22.24 kWh	26.15 kWh
Energy delivered by the transformer	35.08 kWh	48.69 kWh
Peak load at the transformer end	43 kW	60 kW
Distribution loss during peak hour	12.84 kWh	22.53 kWh
Measured power factor at transformer end	Unity	Unity
Percentage distribution loss at peak time	36.6 %	46.3 %

Source: Data collected from field survey

Tail end voltage regulation

During the peak hour, the tail-end voltage of the distribution system was measured. Simultaneously, the voltage at transformer end was also noted and using this the tail-end regulation could thus be determined. It is given in Table 6.2.

Table 6.2 Peak load tail end regulation

Name of the transformer	Poriyani 160kVA	Keralassery 100kVA
Tail end voltage	110 V	100 V
Transformer end voltage	199 V	197 V
Peak load regulation in %	(199-110/100*100 = 44.72%	(197-100)/ 100 = 49.24&

7. Full Day Readings and Daily Graphs

To find out the performance of a transformer in the live system, it is important to note down the instantaneous values of phase and line variables and the peak time readings. Hence, with a “load analyser”, we measured the peak time readings such as line and phase voltages, line and phase currents, power factor, power in different phases and total power, peak time consumption, etc., in respect of the selected system. The specifications of the instrument used are given below:

Make: KRYKARD
Voltage: Max. 750 Vrms (Phase)
Current: 1000A (with current probe)
Frequency range: 20 to 600 Hz
Accuracy: 0.3%

The load analyser is adjusted in such a way that instantaneous values are obtained for intervals of 30 minutes. The values indicate phase imbalance at all these transformers. Moreover, with the clamp on power meter, we measured the phase voltages and the percentage imbalance was calculated from the general expression given below:

Percentage NPS (Negative Phase Sequence) $= \frac{71}{V_{av}} \left(V_{high} - (V_{middle}/4) - (V_{low} \times 3/4)\right)$

where,

V_{high} is the highest phase voltage among different phase voltages,

V_{middle} is the middle phase voltage among different phase voltages,

V_{low} is the lowest phase voltage among different phase voltages, and

V_{av} is the average of V_{high}, V_{high}, V_{high} and % NPS is found to be more than 2.5 per cent for each transformer which is above the IS Code limit (2 per cent).

Using this full-day data, the graphs for total power Vs time, phase power Vs time, Line and phase voltages Vs time, Line and phase current Vs time, power factor Vs time, frequency Vs time, kWh (units) Vs time, kVA and kVAr Vs time were plotted for all three transformers. From these curves it is clear that the power factor of a rural transformer is almost unity at peak time and at off peak hours it comes down up to 0.79 and the peak load is coming at 6.30-9.30 pm interval.

The different graphs plotted using full day readings and the readings for Poriyani 160 kVA transformer are shown in Appendix V. The full day readings of Keralassery 100 kVA and Mundur 250 kVA are given in Table 7.1

Table 7.1 One full day reading of Poriyani 160kVA transformer (08.03.1998, 7.00 am to 06.03.1998, 8.00 am)

Time	Volt	Amp	P.f.	kW	KVA	kVAr	Hz	kWh	kVArh	VA	kW	R-V	Y-V	B-V	R-A	Y-A	B-A	R-kW	Y-kW	B-kW
6.00	353	39.50	0.99	23.80	24.20	3.92	47.90	2.81	0.68	24.10	25.60	207.00	202.00	202.00	52.90	41.90	24.20	10.50	8.41	4.90
6.30	340	45.30	0.88	26.00	26.60	5.64	47.90	10.65	3.85	24.10	25.60	199.00	195.00	195.00	57.10	45.10	34.30	10.70	8.78	6.60
7.00	332	34.90	0.97	19.50	20.10	4.83	47.80	18.30	7.25	24.10	25.60	194.00	190.00	190.00	41.10	41.00	23.50	7.31	7.73	4.42
7.30	330	30.70	0.94	17.10	18.10	5.95	47.90	24.93	10.79	24.10	25.60	198.00	196.00	194.00	34.20	38.60	20.00	5.99	7.37	3.73
8.00	324	29.60	0.89	15.00	16.80	7.54	47.90	31.39	14.31	24.10	25.60	189.00	187.00	185.00	44.10	24.70	20.60	7.41	4.30	3.25
8.30	354	28.80	0.90	15.90	17.60	7.59	47.80	38.41	18.14	24.10	25.60	208.00	203.00	204.00	46.20	30.50	11.70	7.50	6.04	2.36
9.00	348	24.40	0.90	13.20	14.60	6.39	47.90	44.82	21.18	24.10	25.60	202.00	199.00	199.00	39.80	26.10	8.44	6.52	4.96	1.67
9.30	337	31.80	0.88	16.40	18.60	8.73	47.90	50.50	23.07	24.10	25.60	197.00	194.00	193.00	45.20	29.30	21.40	7.31	5.29	3.81
10.00	351	23.30	0.89	12.60	14.20	6.54	47.90	55.75	25.98	24.10	25.60	205.00	202.00	201.00	36.40	23.80	10.20	6.05	4.56	1.96
10.30	331	18.70	0.92	9.83	10.70	4.25	48.00	61.58	29.96	24.10	25.60	195.00	189.00	190.00	21.50	20.40	14.60	3.47	3.59	2.76
11.00	341	19.00	0.89	10.00	11.20	5.07	47.90	66.64	32.38	24.10	25.60	200.00	195.00	195.00	22.40	25.90	9.92	3.33	4.84	1.83
11.30	358	18.00	0.88	9.77	11.10	5.33	48.00	71.33	34.66	24.10	25.60	209.00	205.00	206.00	28.50	20.10	6.16	4.66	3.85	1.26
12.00	369	21.70	0.90	12.10	13.50	5.99	48.00	75.25	36.76	24.10	25.60	210.00	206.00	207.00	38.80	21.00	5.97	6.68	4.17	1.23
12.30	356	17.50	0.88	9.50	10.80	5.05	47.80	82.25	41.02	24.10	25.60	208.00	203.00	205.00	21.00	26.40	6.75	3.07	5.06	1.37
13.00	357	15.70	0.93	8.99	9.69	3.61	47.90	88.29	44.42	24.10	25.60	209.00	204.00	205.00	24.60	15.50	6.98	4.56	3.07	1.36
13.30	370	19.10	0.87	10.60	12.20	6.04	47.90	93.39	47.41	24.10	25.60	217.00	213.00	212.00	21.90	33.70	12.40	3.63	4.79	2.21
14.00	369	25.40	0.88	14.30	16.20	7.64	47.90	99.51	50.26	24.10	25.60	216.00	212.00	212.00	26.20	31.20	20.40	4.23	5.84	4.25
14.30	362	18.30	0.87	9.97	11.50	5.66	47.80	107.07	54.46	24.10	25.60	212.00	208.00	208.00	21.50	21.00	12.70	3.81	4.06	2.10
15.00	362	19.20	0.86	10.30	12.00	6.14	47.90	114.75	59.04	24.10	25.60	211.00	208.00	208.00	18.90	27.00	12.40	2.92	5.23	2.18
15.30	362	26.10	0.91	14.80	16.40	6.98	47.80	125.84	65.08	24.10	25.60	211.00	208.00	208.00	40.80	25.50	12.00	7.74	4.91	2.15
16.00	352	20.90	0.82	12.50	12.70	7.25	47.90	135.88	70.30	24.10	25.60	206.00	203.00	202.00	26.30	21.80	13.30	4.13	3.87	2.46
16.30	339	31.20	0.84	14.80	18.30	10.80	47.80	145.32	74.91	24.10	25.60	197.00	195.00	194.00	54.20	28.00	12.20	8.44	4.95	1.40
17.00	338	40.20	0.91	21.40	23.50	9.85	47.90	154.77	79.60	24.10	25.60	196.00	195.00	194.00	60.50	41.40	19.00	10.50	7.69	3.20
17.30	339	36.60	0.89	19.10	21.50	9.98	47.80	169.27	83.19	25.80	25.60	198.00	195.00	195.00	46.70	47.10	17.80	7.29	8.87	2.92
18.00	345	39.80	0.89	21.10	23.80	11.00	48.00	187.36	85.66	25.80	25.60	201.00	199.00	198.00	47.20	47.80	25.90	7.63	9.16	4.29
18.30	360	40.10	0.94	23.50	25.00	8.54	48.00	204.72	88.13	25.80	25.60	210.00	207.00	206.00	58.60	45.00	19.00	10.40	9.27	3.77
19.00	313	65.60	0.99	35.10	35.50	5.47	47.80	222.26	90.81	28.60	27.70	182.00	180.00	180.00	84.20	66.60	46.60	14.80	11.90	8.41
19.30	294	73.70	0.99	37.10	37.50	5.97	47.90	239.78	93.21	36.40	36.10	170.00	169.00	170.00	106.00	69.70	45.80	17.60	11.80	7.75
20.00	296	67.10	0.99	34.00	34.40	5.22	47.90	257.27	95.88	36.80	36.50	172.00	170.00	170.00	90.40	66.50	44.70	15.10	11.30	7.60
20.30	301	68.20	0.99	35.10	35.50	5.23	47.90	274.35	98.85	36.80	36.50	175.00	173.00	173.00	86.50	68.20	48.00	15.10	11.70	8.28
21.00	305	68.00	0.99	35.40	35.90	5.92	47.90	289.09	101.99	36.80	36.50	178.00	175.00	175.00	86.30	73.50	45.00	14.70	12.80	7.88
21.30	314	67.80	0.98	38.20	38.90	7.33	47.80	300.88	104.99	36.80	36.50	183.00	181.00	181.00	93.50	67.40	43.70	16.20	12.10	7.88
22.00	334	56.60	0.99	32.30	32.60	5.35	47.80	311.02	108.15	36.80	36.50	194.00	192.00	193.00	76.30	52.40	42.00	14.20	10.00	8.09
22.30	355	43.00	0.98	25.80	26.40	5.70	48.40	320.13	111.06	36.80	36.50	208.00	203.00	204.00	57.00	41.50	30.90	11.20	8.34	6.26
23.00	369	37.20	0.96	22.90	23.70	6.32	47.90	329.01	114.03	36.80	36.50	216.00	211.00	21'.00	49.70	36.70	25.50	9.93	7.60	5.34
23.30	376	27.90	0.96	17.40	18.10	5.24	47.80	338.03	116.88	36.80	36.50	219.00	216.00	216.00	36.00	30.00	18.70	6.96	6.41	3.99
24.00	365	30.60	0.96	18.40	19.30	5.73	47.90	346.45	119.50	36.80	36.50	215.00	209.00	208.00	43.30	30.10	18.60	8.44	6.21	3.79
0.30	376	29.40	0.95	18.10	19.10	6.20	47.90	354.69	122.02	36.80	36.50	221.00	216.00	215.00	38.80	30.60	18.40	7.78	6.48	3.86
1.00	369	30.00	0.95	18.30	19.20	5.78	47.80	363.31	124.48	36.80	36.50	215.00	211.00	212.00	45.40	29.10	16.40	8.79	6.07	3.42
1.30	369	26.00	0.95	15.80	16.60	5.07	47.80	371.53	127.09	36.80	36.50	216.00	211.00	212.00	33.60	29.40	15.70	6.41	6.10	3.28
2.00	373	29.20	0.95	17.90	18.80	5.95	47.80	379.69	129.69	36.80	36.50	218.00	214.00	214.00	44.30	29.00	14.60	8.73	6.05	3.08
2.30	377	26.30	0.96	16.50	17.20	4.67	47.90	387.32	131.88	36.80	36.50	220.00	216.00	216.00	38.60	26.90	14.00	4.79	5.73	3.00
3.00	378	24.00	0.96	15.00	15.70	4.68	47.80	395.12	134.34	36.80	36.50	221.00	217.00	217.00	31.90	26.20	14.70	6.28	5.60	3.15
3.30	374	29.20	0.96	18.10	18.90	5.56	47.80	403.09	136.70	36.80	36.50	219.00	215.00	214.00	41.00	33.00	14.20	8.07	6.97	3.01
4.00	376	25.90	0.97	16.30	16.90	4.43	47.80	411.99	138.77	36.80	36.50	220.00	216.00	215.00	38.60	26.50	13.10	7.84	5.64	2.82
4.30	376	23.30	0.96	14.50	15.10	4.30	47.80	422.34	140.86	36.80	36.50	220.00	215.00	215.00	30.20	26.10	13.90	6.02	5.55	3.93
5.00	372	24.40	0.97	15.10	15.60	3.94	47.80	435.15	142.61	36.80	36.50	217.00	213.00	213.00	35.30	23.40	14.10	7.13	4.94	2.99
5.30	366	31.50	0.98	19.20	19.90	5.45	47.80	445.73	145.45	36.80	36.50	213.00	210.00	210.00	43.20	32.20	20.90	8.21	6.71	4.23
6.00	353	39.50	0.99	23.80	24.20	3.92	47.90	454.21	148.33	36.80	36.50	207.00	202.00	202.00	52.90	41.90	24.20	10.50	8.41	4.90

Source: Data collected from field survey

Table 7.2 One full day reading of Keralassery 100kVA transformer (27.03.1998, 6.30 am to 28.03.1998, 3.00 am)

Time	Volt	Amp	P.f.	kW	kVA	kVAr	Hz	kWh	kVArh	R-V	Y-V	B-V	R-A	Y-A	B-A	R-kW	Y-kW	B-kW
06:30 AM	398	62.10	0.97	41.40	42.90	11.20	47.90	6.30	3.79	229	233	228	58.90	57.30	70.40	13.60	12.80	15.40
07:00 AM	403	51.00	0.95	34.00	35.60	10.80	47.90	19.68	11.40	231	236	231	53.40	43.20	57.00	12.00	9.52	12.40
07:30 AM	398	48.50	0.96	32.10	33.40	9.40	47.90	33.09	18.49	229	233	228	48.10	40.80	56.80	10.60	9.03	12.40
08:00 AM	399	41.40	0.94	26.90	28.60	9.79	47.90	46.78	25.97	230	232	229	32.80	49.90	41.60	8.00	11.00	8.78
08:30 AM	392	50.80	0.92	31.70	34.50	13.60	47.90	64.61	33.54	224	230	224	48.40	52.90	51.30	10.00	11.00	10.70
09:00 AM	424	35.10	0.88	22.50	25.80	12.50	48.30	89.33	38.56	244	248	242	34.70	29.30	41.50	7.55	6.33	8.66
09:30 AM	389	44.80	0.84	25.40	30.20	16.20	48.00	115.92	41.65	224	227	222	30.90	55.70	7.00	5.70	10.60	9.12
10:00 AM	390	58.20	0.86	33.90	39.40	20.00	48.20	142.76	44.55	224	228	223	43.40	76.40	54.70	8.45	14.60	10.90
10:30 AM	389	35.90	0.90	21.70	24.20	10.70	48.00	170.33	47.85	225	227	222	27.90	37.30	42.70	5.81	7.33	8.55
11:00 AM	373	49.60	0.85	27.20	32.00	16.90	48.20	198.13	51.60	215	216	214	33.60	65.60	49.90	6.13	11.50	9.55
11:30 AM	397	35.50	0.86	21.00	24.50	12.50	47.90	225.71	55.95	230	230	228	21.10	40.00	45.90	26.00	7.43	9.31
12:00 PM	397.	37.10	0.87	22.20	22.50	12.50	47.80	246.58	59.67	230	230	227	22.10	43.50	46.00	4.65	8.40	9.12
12:30 PM	403	33.90	0.83	19.70	23.70	13.20	47.90	264.34	63.62	233	235	230	24.00	38.30	40.10	4.95	6.72	8.00
01:00 PM	399	36.70	0.86	21.90	25.40	12.90	48.00	279.56	67.68	231	232	228	23.40	46.10	40.90	4.95	9.10	7.83
01:30 PM	408	33.60	0.88	20.70	23.70	11.50	47.90	292.08	71.41	234	238	234	27.30	36.40	37.10	5.44	7.86	7.43
02:00 PM	406	37.30	0.87	22.90	26.20	12.90	48.10	304.12	74.78	233	237	233	31.40	42.00	38.80	6.11	9.08	7.66
02:30 PM	398	34.30	0.89	21.00	23.70	11.00	47.90	315.69	78.13	229	234	227	31.70	34.40	37.00	6.20	7.33	7.45
03:00 PM	397	30.20	0.88	18.20	20.80,	9.93	47.90	327.08	81.56	229	232	227	24.50	28.30	38.00	4.88	5.89	7.45
03:30 PM	394	37.30	0.90	23.00	25.40	10.90	47.80	337.94	84.95	227	230	225	35.40	39.10	47.80	7.49	6.10	9.37
04:00 PM	387	47.40	0.86	27.50	31.80	16.00	47.90	348.68	88.25	224	226	221	35.60	54.00	53.30	7.16	9.75	10.60
04:30 PM	366	50.00	0.86	27.20	31.70	16.30	47.80	359.66	91.66	211	213	210	51.90	55.50	42.40	9.45	10.00	7.71
05:00 PM	360	59.20	0.90	33.10	36.90	16.30	48.00	370.49	94.93	207	210	206	54.60	74.90	48.10	10.10	14.40	8.65
05:30 PM	377	43.90	0.85	24.20	28.70	15.30	48.00	391.21	100.49	218	220	216	37.20	46.30	48.60	6.67	8.17	9.40
06:00 PM	381	49.00	0.86	27.90	32.30	16.30	48.30	406.87	106.07	220	221	219	52.20	54.50	40.50	10.40	10.10	7.36
06:30 PM	386	64.00	0.96	41.10	42.80	12.00	47.90	424.78	111.41	223	227	220	64.10	53.50	74.90	14.00	11.40	15.70
07:00 PM	334	97.20	0.99	55.80	58.30	7.64	47.90	440.15	116.83	192	197	189	104.00	87.80	101.00	19.80	17.10	18.90
07:30 PM	310	97.60	0.99	52.10	52.40	5.64	47.80	453.84	122.26	178	183	176	108.00	94.90	90.10	19.10	17.20	15.70
08:00 PM	319	98.30	0.99	54.00	54.30	5.94	47.90	466.20	128.84	184	188	180	102.00	97.80	95.30	18.70	18.30	17.00
08:30 PM	332	98.00	0.99	55.80	56.30	7.52	48.30	478.51	135.86	191	196	188	99.30	100.00	94.20	8.00	19.40	17.60
09:00 PM	371	97.70	0.99	62.00	62.80	9.63	47.90	491.70	144.03	214	218	211	97.10	96.50	99.70	20.50	20.80	20.80
09:30 PM	351	77.10	0.99	46.20	46.80	7.50	47.90	505.04	151.24	201	207	199	74.90	84.40	71.70	14.90	17.20	14.20
10:00 PM	373	59.80	0.98	37.90	38.60	7.60	47.90	515.67	157.20	215	218	213	51.70	73.30	54.00	10.90	15.70	11.30
10:30 PM	407	49.50	0.97	33.80	34.90	8.85	48.00	527.99	165.32	235	236	232	41.50	54.90	52.20	50.46	12.80	11.60
11:00 PM	409	39.30	0.97	26.90	27.80	7.11	47.90	539.52	172.53	235	241	234	33.60	44.30	40.00	7.52	10.50	8.94
11:30 PM	404	35.90	0.97	24.20	25.10	6.62	47.90	550.36	179.34	231	238	231	31.60	38.60	37.50	6.96	9.01	8.24
12:00 AM	410	33.40	0.97	23.00	23.70	5.65	47.90	561.14	185.91	236	240	234	27.50	36.90	36.10	6.36	8.72	7.96
12:30 AM	412	33.50	0.96	22.80	23.90	7.01	47.90	571.66	191.78	237	241	235	28.80	23.10	38.90	6.54	7.80	8.45
01:00 AM	417	32.90	0.96	22.70	23.80	7.01	47.90	582.92	197.67	240	244	238	29.70	34.00	35.10	6.71	8.02	7.97
01:30 AM	420	31.30	0.95	21.70	22.70	6.79	47.90	593.82	203.37	242	245	251	28.60	30.30	35.00	6.54	7.21	7.95
02:00 AM	422	31.20	0.95	21.70	22.80	7.02	47.90	604.09	209.35	243	247	242	28.80	30.00	34.90	6.55	7.26	7.89
02:30 AM	432	30.20	0.96	21.60	22.60	6.61	47.90	614.78	214.86	248	253	247	27.50	31.60	31.60	6.43	7.65	7.51
03:00 AM	434	32.00	0.96	23.00	24.00	7.03	47.90	627.77	222.13	249	254	249	26.10	35.80	34.10	6.18	8.75	8.07

Source: Data collected from field survey

8. Powerline Map Preparation and Its Digitisation

Powerline map is a scaled map of the distribution lines of an area plotted on a map with the consumer points marked. The single phase and three phase lines are marked separately, using separate colour for consumers of the three different phases. The domestic, commercial and industrial consumers are marked separately. Then, the 11 kV line is also plotted in the map so that guidelines can be prescribed for new transformer installations and transformer re-arrangements.

The preparation of powerline map involves massive labour and time. Until now, there are no such data available with KSEB regarding distribution system. It is difficult to get sufficient secondary data from KSEB to draw a power line map of a particular area.

Powerline map serves as a datum for effecting change and rendering the network power efficient. Distributed load centre calculations, low capacity transformer centre calculations, and recommendations for change into three-phase line from single-phase line are due on the basis of data provided by the powerline map.

Considering the above facts, a powerline map of these three transformers was prepared. By using the software jointly developed by Kerala Forest Research Institute (KFRI), Peechi and IRTC, Palakkad, the powerline map is digitised and the theoretical peak time loss and tail end voltage is calculated. The results are given in Table 9.1. The field results and calculated results are compared in Table 9.2.

It is clear that the I^2R loss calculated is very low in value compared to the measured total loss. This shows that the major component is the contact loss i.e., extraneous losses that include loss due to tree touchings.

The powerline map and voltage table got from the software POWER 3.2 for Poriyani 160kVA and Keralassery 100kVA is shown in Fig. 8.1 and Fig. 8.2.

Table 8.1 Distribution loss in kW using 'POWER'

Name of the transformer	Phase	R	Y	B	Total
Keralassery 100 KVA	Number of consumers	87	67	80	234
	Loss in kW	0.38	0.13	0.41	0.92
	Minimum voltage	206	216	206	206
	Phase currents	61	46	63	170
Poriyani 160kVA	Number of consumers	46	71	79	196
	Loss in kW	0.03	0.13	0.47	0.63
	Minimum voltage	218	216	209	209
	Phase currents	61	44	66	132

Source: Data collected from field survey

Table 8.2 Powerline map analysis comparison of two transformers

	Poriyani 160 kVA	Keralassery 100 kVA
Peak load regulation in % got by the readings from field	(199-110)/199* 100 = 44.72%	(197-100)/197*100 = 49.24%
Calculated regulation in % using the software POWER	(220-209)/220* 100 = 5%	(220-206)/220*100 = 6.36%
Peak load loss in % got from the readings from the field	36.6 %	46.3 %
Peak load loss in kW got from the readings from field	12.84 kW	22.53 kW
Peak load loss calculated by the software POWER	0.63 kW	0.92 kW

Source: Data collected from field survey

Figure 8.1 Poriyani 160 kVA: Powerline Map

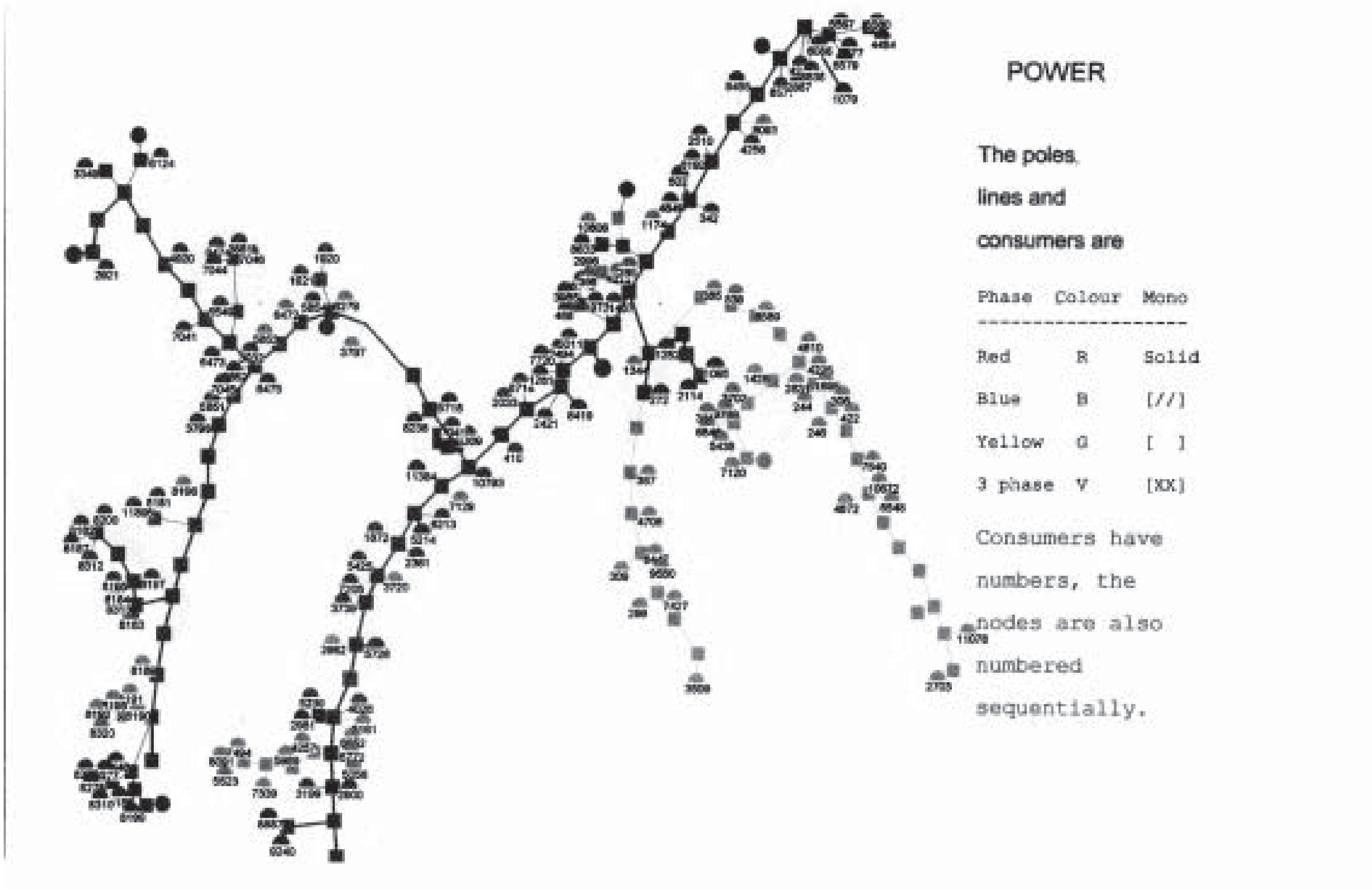
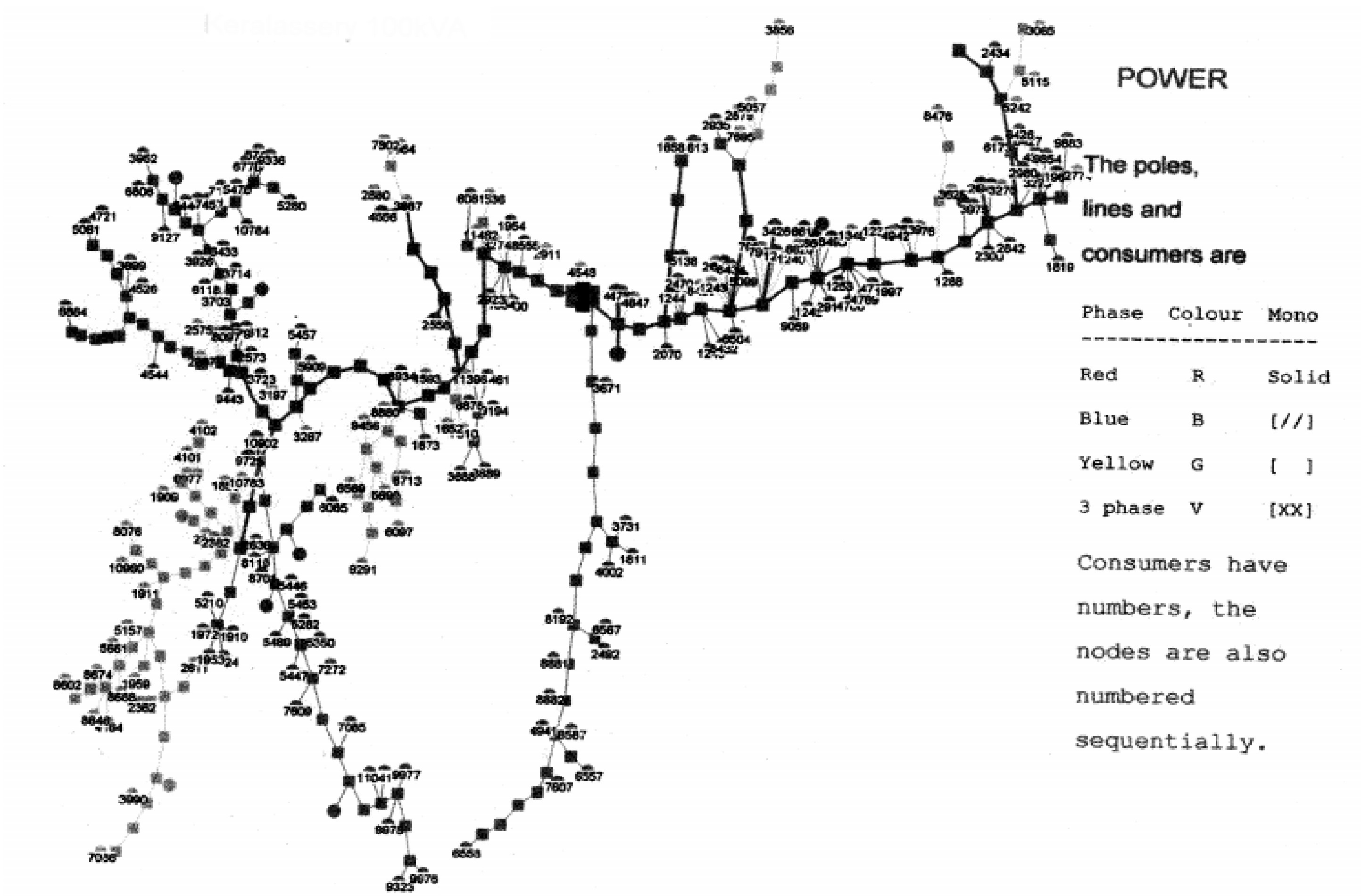


Figure 8.2 Keralassery 100 kVA: Powerline Map



II. Recommendations

9. Introduction

Distribution loss is quite high in rural areas, amounting to more than 30 per cent on the average, and approaching 40 per cent during peak hours. So urgent improvement measures are to be taken to reduce this loss. The main problem of the rural distribution system is its large number of low load consumers distributed over a large area. This is a consequence of the habitat patterns of the region where the distance between homesteads is comparatively large. Another problem is that the length of LT lines far outweighs the length of HT line. For optimum loss condition, the HT to LT ratio must be 1:1, but it is much lower in the Kerala power system. Still another factor is the lengthy single-phase lines that also contribute to the high I2R losses.

The following list will give the problems of the distribution system in Kerala, especially in the rural area:

(i) Technical losses:

- -I2R Losses or heat loss
- -High peak load current
- - Unoptimised location of transformers
- -Lengthy single-phase lines
- -Phase imbalance
- -Sparking at loose joints
- -Low power factor at off peak hours
- -Overloading of LT lines
- -High harmonics
- -Low quality of insulators and conductors
- -Low quality earthing at consumer premises

(ii) Non-technical loss

- -Faulty meters
- -Uneven revenue collection
- -Tree touching
- -Pilferage and theft
- -Inadequate metering and billing

The second part of this report discusses the remedial actions that could be undertaken by Electricity Board as well as local bodies like panchayats and municipalities. Without the participation of the local bodies, loss reduction will remain a difficult task.

The State Government and KSEB must aim to educate the local bodies and persuade them to do campaign work among the consumers. In addition, they may divert an amount from their funds for implementing some of the loss reduction techniques.

KSEB must take action to reduce the technical loss accepting it as its own work, and assure that the equipment used in the system is of high quality. It must replace the low quality equipment, which gives low power factor and high harmonics.

10. Optimisation of Distribution System

The optimum distribution system is the economical combination of primary line (HT), distribution transformer and secondary line (LT), which depends on the location, load density and diversity of the system, and capital cost. These factors vary from State to State. Lower the HT/LT line length ratio, the higher will be the voltage drop and more the line loss. To reduce this loss and improve voltage, HT/LT line length ratio should be optimised.

This calls for decentralisation wherein the high capacity transformers (viz. 160kVA, 250 kVA) are replaced by transformers of low capacity (25 kVA, 30 kVA), which would result in optional placement of transformers, thereby reducing distribution loss through optimisation of HT/LT line length ratio. The KSEB has been constantly adopting this strategy to reduce the distribution loss by installing low capacity transformers (63 kVA) in rural areas.

Nevertheless, these measures have not paid off substantially with the increase in HT/LT ratio. The loss at HT transformer end rises. De-augmentation as such, does not contribute to reduction in losses, unless low loss transformers viz. amorphous metal core transformers, which have only one-fourth the core loss of conventional transformers, are deployed. Proper reduction in terms of size of link conductors and optimal location of transformers should form part of the KSEB's strategy. Moreover, in the existing system it is seen that the LT conductors are extending up to kilometres of length with the transformer at one end. In this condition, the transformer position is to be shifted to the centre of the distributed load. This will improve regulation and at the same time reduce losses.

Electrical Load Centre (ELC) on the LT Side

The existing LT system and the transformer location could be drawn to scale on a map, which is called Powerline Map. The Electrical Load Centre (ELC) may be taken as an imaginary point having X-X and Y-Y axis. Taking these axes, the moments of these load points for the X-X axis can be calculated by multiplying the load by the distance along the X-X axis separately for positive and negative values of distances. Similarly, positive and negative moments of y-y axis are calculated. By balancing the positive and negative moments of X-X and Y-Y axis, the ELC can be calculated. Let there be **n** consumers with load L_1, L_2, Ln and the X co-ordinates from the transformer position X_1, X_2, Xn and Y_1, Y_2, …., Yn, the Y co-ordinates.

Then the moments are calculated as:

$$X_1L_1 + X_2L_2 + \ldots + XnLn = XL$$

$$\sum_{i=1}^{n} X_i L_i = XL$$

where, X = X co-ordinate of the ELC

$$\sum_{i=1}^{n} L_i = L$$

Similarly, Y co-ordinate can be found out from:

$$\sum_{i=1}^{n} Y_i L_i = YL$$

The ELC is obtained as (X, Y) and can be marked as near as practicable at site.

Balancing of phase loads

As a result of unequal loads on individual phases, negative and zero phase sequence components cause overheating of transformers, cables, conductors and motors thus increasing losses and resulting in the motors malfunctioning under unbalanced voltage conditions. Keeping the system negative phase sequence voltage within limits amounts to savings in capital (as otherwise equipment is derated) as well as energy losses.

IS: 325-1978 (clause3.2), BS 4999:31 and IEC 34-1 limit negative phase sequence (NPS) of 2% voltage.

11. Change of Single-Phase Lines to Three-Phase Lines

Our distribution system is the three phase four-wire system because it has specific advantages compared to all other systems. The main advantage is that the conductor required is the minimum for transferring the same power compared to all other systems. For the three-phase four-wire system, the conductor required is only 30 per cent of the single-phase two-wire system.

The problem of low voltage arises when single-phase lines are very long. It is found that single-phase lines with lengths ranging up to 1 km forms the single largest category of distribution links.

Immediate steps should be taken to change the single-phase lines to three-phase lines. The following calculation shows that single-phase lines are more energy-consuming than three-phase lines while delivering the same power. If a single-phase line is changed to a three-phase line, the savings in power is estimated to be 83.33 per cent.

Savings calculation when single-phase lines are converted to three-phase lines

Let there be X consumers in a single phase line drawing currents $I_1, I_2, I_3 \ldots, I_x$.

Then, line loss, $L1 = (\sum_{i=1}^{x} I_i)^2 (R_p + R_n)$

I_1 = Current drawn by ith consumer.
R_p = Resistance offered by phase line.
R_n = Resistance offered by neutral line.

If $R_p = R_n = R$, then $L_1 = (\sum_{i=1}^{n} I_1)^2 R$ .... (1)

If the same current is supplied by a three-phase four-wire system, each current Ii will be supplied by the three phases and if the three phase currents are balanced, the neutral current will be zero. Then,

Line loss, $L_2 = 3 \text{ x } ((\sum_{i=1}^{n} I_i)/3)^2 R$

ie., $L_2 = 1/3 (\sum_{i=1}^{n} I_i)^2 R$ .... (2)

Comparing (1) and (2)

$L_1/L_2 = 2/(1/3) = 6$

Therefore, the savings in loss if single-phase two-wire system is changed to three-phase four-wire system is 5/6th (83.33 per cent) of the present loss.

Single-phase system

$V_L = V_s - 2\,IR$
$L_1 = I^2 \times 2R = 2\,I^2R$

Three-phase system

$V_L = Vp - I/3\,R$
$L_2 = 3 \times I^2R/9 = I^2R/3$

Note: *On the distribution side the normally used conductor has less diameter than the phase conductor (Normally ACSR 7/3.1 for phase and 7/2.21 for neutral). The neutral resistance will be higher and hence single-phase loss increases further. If the 3-phase system is balanced, there will be no neutral current and hence, here no such problem arises.*

Economic feasibility study

For changing 1 km of single-phase line to three-phase lines the constructional and material expense as given by KSEB authorities is Rs. 67,000.

(As per cost data, 1998)	
Material cost for 3-phase 4 wire lines	= 59,857.76
Labour charge	= 11,000.00
Lorry charge	= 2,886.00
Total	= 73,743.76
Price of old conductors to be deducted	= 6,586.65
Net expense	**= Rs. 67,157.11**

After the conversion of single-phase to three-phase lines, there will be savings in the energy losses, which in turn would constitute a return. To get the complete investment within three years, daily return should be Rs. 61.19.

Taking an energy cost of Rs. 3 per unit, which is the tariff of a commercial consumer, the number of units to be saved from loss should be 20.39 units per day.

Then single phase line loss per day = 20.39 x 6/5 = 24.47 units

Then the peak load loss is calculated by using the empirical formula of loss load factor (LLF). Loss Load Factor, LLF = $0.8\,(LF)^2 + (0.2 \times LF)$

where LF = Load Factor = Ratio of average load to peak load.

The numerical value of the load factor (LF) for a rural area is normally 0.4-0.6

From the study on distribution losses, we have conducted full-day measurement of power of the secondary of three distribution transformers; the load factor is 0.47.

Therefore LLF $= 0.8 \times (0.47)^2 + 0.2 \times 0.47$
$= 0.2707$

Peak Load Loss in kW = Energy loss in a day/ (24 x LLF)
= 24.47/(24x0.2707) = 3.767 kW

If peak load current of 'I' is flowing through a distance of one km,
Peak Load Loss = $I^2 *1* 1.24$
where, 1.24 is resistance in ohm per km of the line

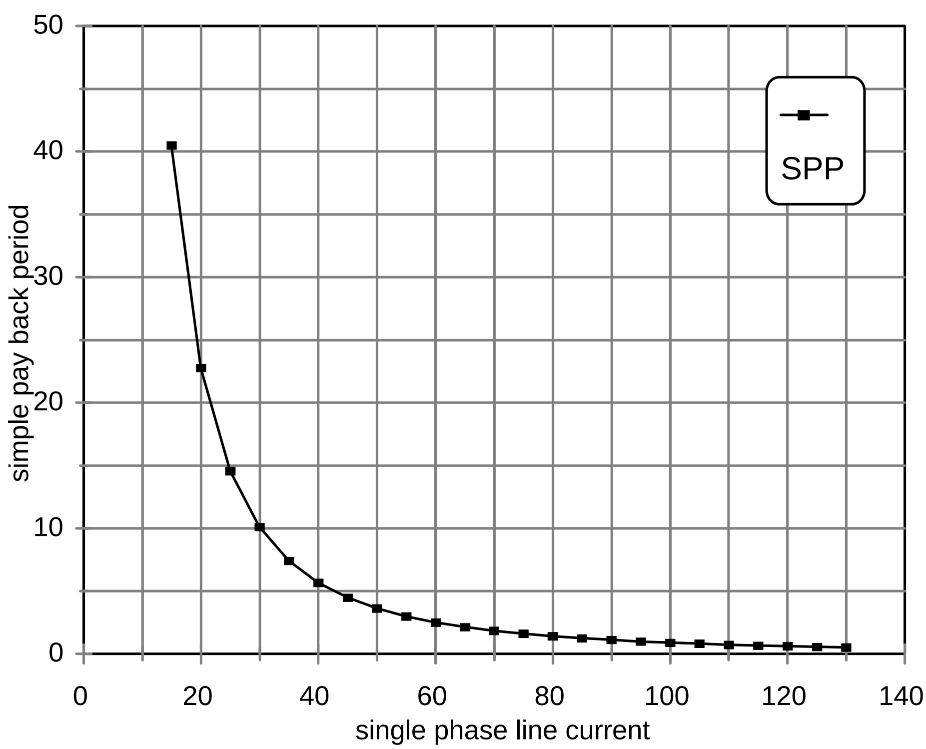
Now,

$I^2 * 1.24 = 3767$

I = 55.17 (55)

Any single phase line with current of 55 A will give a simple pay back period of three years. A graph plotted with single-phase line current versus simple pay back period is given in Fig. 11.1.

Figure 11.1 Simple pay back period Vs Single phase current curve



12. Role of Local Bodies in the Distribution Loss Reduction

The following are the main areas where a local body can play a useful role in achieving loss reduction. Local bodies such as grama panchayats can play a major role in energy conservation, by helping the KSEB to reduce distribution losses. Energy conservation is also achieved by reducing demand and energy consumption by effective use. Moreover, if they have the power line map of whole panchayat and they are aware of the problems in the distribution system in the panchayat, they can initiate remedial actions themselves.

The immediate steps for conservation at consumer end are:

(i) Consumer education: Consumers should be educated about the simple rules of energy saving with respect to efficient use of lighting, motors, and motor pump systems and the use of ISI-marked equipment, operating motor at its rated load, because motors are usually designed for optimum performance at their rated full load. If it is operated below the rated load, its efficiency drops gradually, in the initial stage and drips sharply at subsequent reduction in loads.

(ii) Demand reduction: The levelling off demand will decrease the maximum current flow, even though the demand for current flow may continue for a longer period. As the I^2R loss varies as the square of the current, the lower current will result in the reduction of the total energy requirement of the consumer and reduction of system losses. In the rural areas, the peak load is between 6 am and 9 pm. During these hours, there are only lighting loads, usually incandescent bulbs. Further, for peak demand reduction, these incandescent lamps are to be replaced by fluorescent tubes or Compact Fluorescent Lamps (CFLs). However, the major issue in this regard is the problem of low supply voltage. This problem could be overcome by using electronic choke. However, the quality of this energy-efficient equipment must be ensured. Otherwise there will arise the problems of low power factor, high ratio frequency interference and high harmonics. Local bodies could ensure quality with the help of research institutions, engineering colleges, etc., and provide subsidy for this equipment.

(iii) Field works: By using the powerline map they may suggest to the KSEB, how the system could be redesigned and offer assistance for designing by allotting funds, forming beneficiary groups, etc. Moreover, for the proper maintenance of streetlights, they may form beneficiary groups whose responsibility would be to protect them. A combined effort of KSEB and local bodies would be able to remove tree touching in the distribution lines, with people’s participation.

13. Faulty Meters

In Kerala, domestic tariff is one part tariff and is measured using energy meter readings at consumer end. The energy meter used is of the electro-mechanical type. These types of meters have low reliability; it is noticed from the study that about 30 per cent of meters are faulty. Faulty meters affect the revenue of the State Electricity Board adversely.

The remedial measure for this problem is to use reliable, high quality meters, and static meters.

During a discussion on this topic at the Institution of Engineers, Palakkad chapter, a resolution was passed, recommending that the consumers be given all rights to buy and repair energy meters by themselves. If an energy meter became faulty then the consumer must repair it as soon as possible with his own money, or pay for its replacement.

In addition, with the help of local body, training could be conducted for repairing energy meters and societies could be started for this purpose in selected *panchayats*.

Static meters

Nowadays some static meters are available in the market. The advantages of static meters are the following:

(i) High reproducibility of the measured results due to absence of moving components in the measuring circuits.

(ii) Very narrow error band over a large load range.

(iii) Less dependency of the measuring properties on network and environmental influences.

However, the expenditure to achieve these improvements is substantial and leads to correspondingly high costs for electronic instruments. Integrated circuits/microprocessors, if inducted, are expected to bring considerable cost reduction consequent on large-scale production. R&D institutions in this regard may undertake some developmental work.

14. Power Factor Improvements and Harmonics Reduction

Power factor

Low power factor will lead to increased current and hence increased losses and will affect the voltage. The study reveals that power factor at peak time is almost unity. However, during off peak hours mainly 11 a.m. to 3 p.m., the power factor decreases to around 0.8. This may be due to the following reasons.

i. Wide use of fans
ii. Wide industrial loads
iii. Wide use of agriculture and domestic pumping motors
iv. Less use of high power factor loads like lighting etc.

Now to improve power factor at off peak hours, the consumers must be aware of the effect of low power factor and must connect compensating capacitors with their equipment. KSEB and Local Bodies should monitor these installations.

Harmonics

With increasing use of non-linear devices, harmonic distortion of the voltage waveform is a problem, which is receiving considerable attention. Harmonic currents are generated with the use of devices such as rectifiers, inverters, cheap electronic ballasts, thyristor controlled variable speed drives, induction furnace, arc furnace and saturable reactors. IS: 325-1978 limits harmonics up to 5 % in LT supply voltage.

Effect of harmonics on the network

Harmonics in power distribution network can cause the following effects:

(i) Overloading of power factor correction capacitors due to tuning for particular frequency.
(ii) Resonance between capacitance and transformer reactance resulting in excessive voltage and currents.
(iii) Interference with telephone circuits and broadcasting due to zero sequence harmonics currents.
(iv) Malfunctioning of control equipment because of distorted waveform affecting firing position of thyristor circuits.
(v) Metering errors in rotating disc meters.
(vi) Overheating of rotating machinery due to increased iron losses due to eddy currents as loss of torque.
(vii) Overloading of delta connected windings of transformers because of either excessive third harmonics or excessive exciting currents through the winding.

Hence immediate action should be taken to reduce harmonics in the system such as insisting that the consumers use high quality equipment with harmonic filtering devices.

15. Conclusion

The distribution loss in a typical rural transformer was estimated to be of the order of 35 per cent.

The peak load loss is even higher and could be as high as 45 per cent.

The power factor during peak load is very near to unity and it comes down to about 0.8 during off-peak period.

The tail-end voltage regulation is of the order of 40 per cent during peak load period.

About 30 per cent of the energy meters is faulty.

The technical loss is the main component of the distribution loss. For a typical rural transformer, it could be as high as 85 per cent of the total loss.

Replacement of the faulty energy meters would further reduce the non-technical loss (ie., the energy consumption tendency is higher if the meter is faulty). The average energy consumption of a consumer with a faulty energy meter is 21 per cent more than their tariff level. This fact indicates a serious loss of revenue to the Board.

The technical loss component of the distribution loss can be reduced considerably by adopting system improvement measures such as
(i) replacement of high capacity transformers by more number of lower capacity transformers;
(ii) conversion of single-phase lines to three phase lines;
(iii) balancing of loads; and
(iv) demand management measures.

Local bodies such as *grama panchayats* can play a major role in the effective utilisation of electrical power. Hence, it is clear that it is extremely important to bring the attention of authorities to this hitherto neglected area of rural power distribution system. It is also clear that such measures are necessary for finding a least cost and time bound solution to the problem of energy shortage in Kerala.

16. Postscript

The results of this study were presented at a technical seminar organised by the Institution of Engineers (India), Palakkad Local Centre, on 23 April 1998. Fruitful discussions and meaningful recommendations ensued.

The findings were also presented at a National Seminar on Power Quality, organised by the Post-Graduate Engineers Association of KSEB, in Thiruvananthapuram on 20-21 August 1998. The paper was well received and it generated lively discussion.

A popular version of the findings was presented at a joint meeting of IRTC, *grama panchayat* functionaries and people's representatives, at Mundur on 5 October 1998. The meeting helped to generate considerable enthusiasm among the *grama panchayat* personnel regarding possible interventions in loss reduction activities. It was decided that IRTC would take the initiative to draw up project proposals, which the *grama panchayats*/Block *panchayats* may incorporate in their Annual Plan proposals.

References

Government of Kerala. 1997. *Economic Review*, State Planning Board, Thiruvananthapuram.

Integrated Rural Technology Centre. 1996. Internal document of IRTC study on 'Trends in energy consumption in Kerala', Palakkad.

Integrated Rural Technology Centre. 1996. Internal document of IRTC 'Kalliassery total energy programme', Palakkad.

A.S. Pabla. 1989. *Electric Power Distribution System*, Tata McGraw Hill.

Centre for Monitoring Indian Economy. 1990. 'Bulk Electric Power System and Distribution', 'Current Energy Scene in India'.

Ministry of Energy, Government of India, Report of the Committee on Power. 1980. Department of Power, New Delhi.

B.L. Theraja, A. K. Theraja, S.S. 1995. *A Textbook on Electrical Technology*, Chand & Co. Ltd., New Delhi

Grainger, Stevenson. 1994. *Power System Analysis*, McGraw Hill.

Appendix I
List of Transformers in the Major Section

Sl No.	Name of transformer	Capacity in kVA
1	Kairali	100
2	Poriyani Canal	63
3	Nochippully	63
4	Poriyani	160
5	Mundur	250
6	Manathakavu	63
7	Muzhikunnam	100
8	Oduvankadu	100
9	Challikkadu	63
10	Velikkad	160
11	Kanhikulam II	100
12	Vettithoda	100
13	Kanhikulam Central	100
14	Kanhikulam Check Post	100
15	Kalladikode Sara	100
16	Kalladikode Canal	250
17	Kalladikode Vakkad	63
18	Panakkode	100
19	Chathayankunnu	63
20	Konikkazhi	100
21	Thuppanad	100
22	Manickassery	63
23	Thiruvappara	63
24	Koottupatha	100
25	Thekkumpuram	100
26	Nampullipura	63
27	9th Mile	100
28	Kizhakkekara	100
29	Poothanur	100
30	Malampulam	63
31	Poomattukunnu	100
32	Labour School	63
33	Kannappullikavu	100
34	Ezhakkad	100
35	Chellikkal	100
36	Bunglowkunnu	100
37	Chathankulam	100
38	Kavuparambu	250
39	Poothankodu	63
40	Mucheery	63
41	Kongad	250
42	Ambalaparambu	100
43	Manjeerikavu	100
44	Kulassery	100
45	Parassery	100
46	Peringode	160
47	Mundacherypadi	100
48	Thirppalamunda	100
49	Vattamparambu	100
50	Palapatta	160
51	Ummanazhi	100
52	Charuparambu	100
53	Cheerikadavu	100
54	Illamadakunnu	100
55	Vadassery	100
56	Vellara	100
57	Chirakkad	63
58	Kandalassery	63
59	Keralassery High School	100
60	Keralassery	100
61	16th Mile (Azhiyannur)	100
62	Kanduvampadam	100
63	Water Supply	63
64	Pullandassery	100
65	Kadampazhipuram High School	160
66	Kannamkarissy	100
67	Sharu Kovil	63
68	Aravankode	63
69	Kadampazhipuram II	150
70	Thrikkoikkal	100
71	Kadampazhipuram I	100
72	Vettekkara	100
73	Alangad	100
74	Azhayannur	100
75	Chirakkalkavu	63
76	Panchappadam	63
77	Mavady	63

Appendix II

Load Details of Poriyani 160kVA Transformer

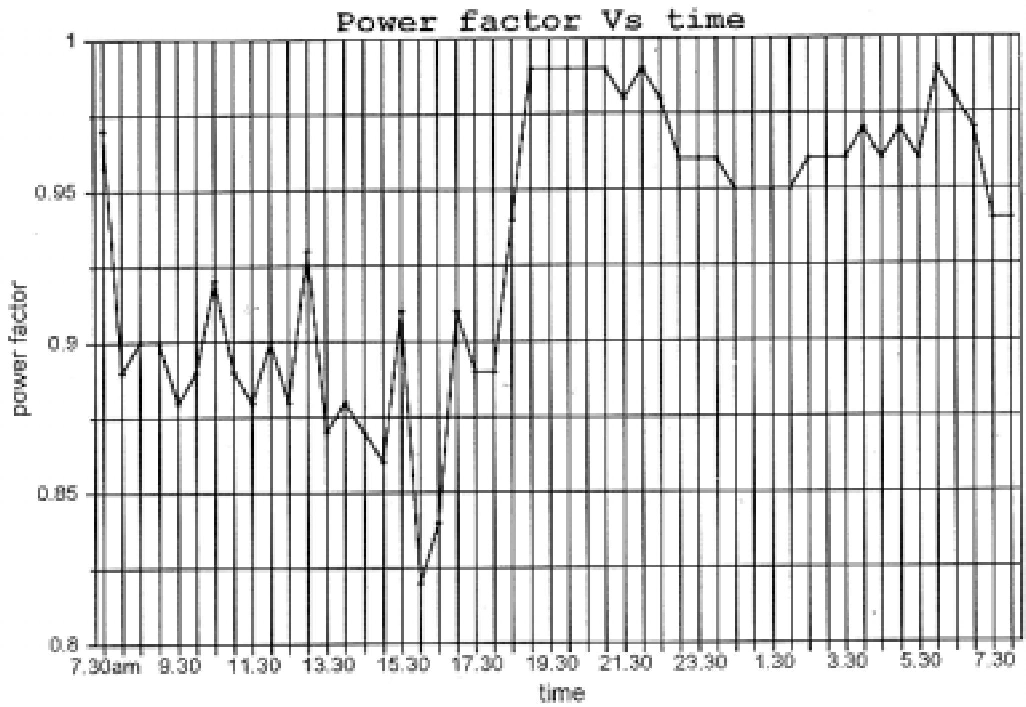
Total number of consumers	**181**	
Domestic	*148*	
Commercial	*22*	
Industrial	*7*	
Agriculture	*4*	
Number of faulty meters	49	
Total distribution loss	33%	
No. of three phase connections	11	
No. of single phase connections	170	
Type of loads	*Load in Watts*	*% Load*
Incandescent lamp 40W	*5600*	*2.21*
Incandescent lamp 60W	*47340*	*18.66*
Incandescent lamp 100W	*4400*	*1.73*
Incandescent lamp - Total	*57660*	*22.73*
Fluorescent Tube Light	*5400*	*2.13*
Fan	*12780*	*5.04*
Refrigerator	*2600*	*1.03*
Mixer/Grinder/Juicer	*43650*	*17.21*
Electric Iron Box	*29850*	*11.77*
TV/VCR/Tape Recorder	*6060*	*2.39*
Electric Pump	*42103*	*16.60*
Industrial Load	*51565*	*20.33*
Others	*2860*	*1.13*
Total Load in Watts	*254528*	*100.00*
Usage of Incandescent Lamps	*No.*	*Watts*
60W at least 4 hours a day	*308*	*18480*
60W at least 6 hours a day	*31*	*1860*
60W more than 6 hours a day	*19*	*1140*
100W at least 4 hours a day	*11*	*1100*
100W at least 6 hours a day	*3*	*300*
100W more than 6 hours a day	*0*	*0*
Low voltage bulbs	0	
Power saving capacitors for motors	7	
Electronic choke for tubes	4	
Step-up Transformers	1	

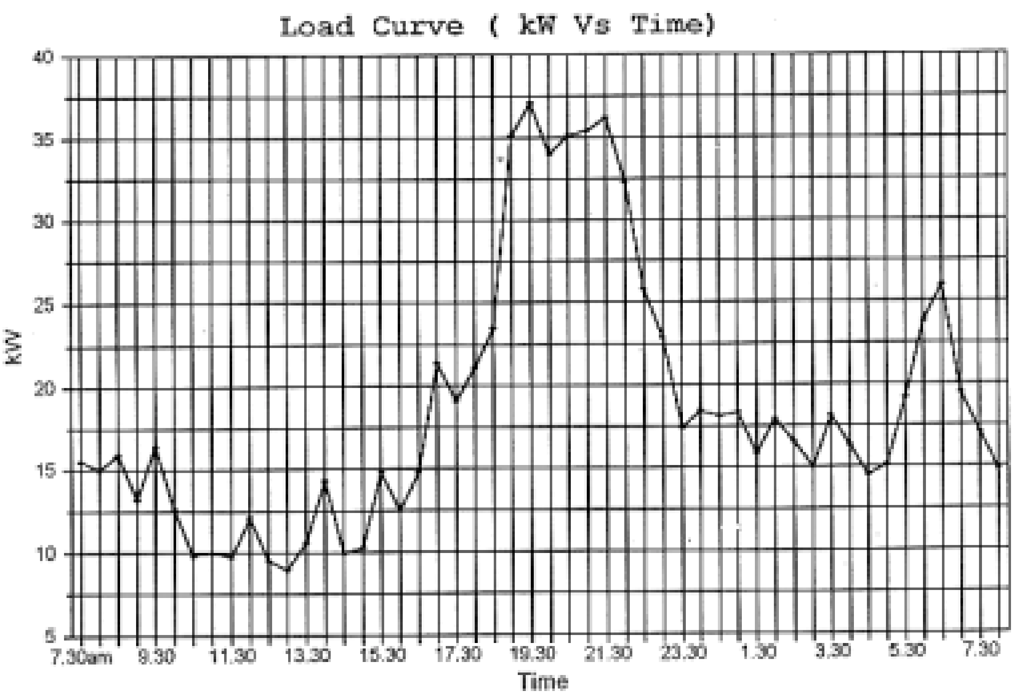
Appendix III

Load Details of Keralassery 100 kVA Transformer

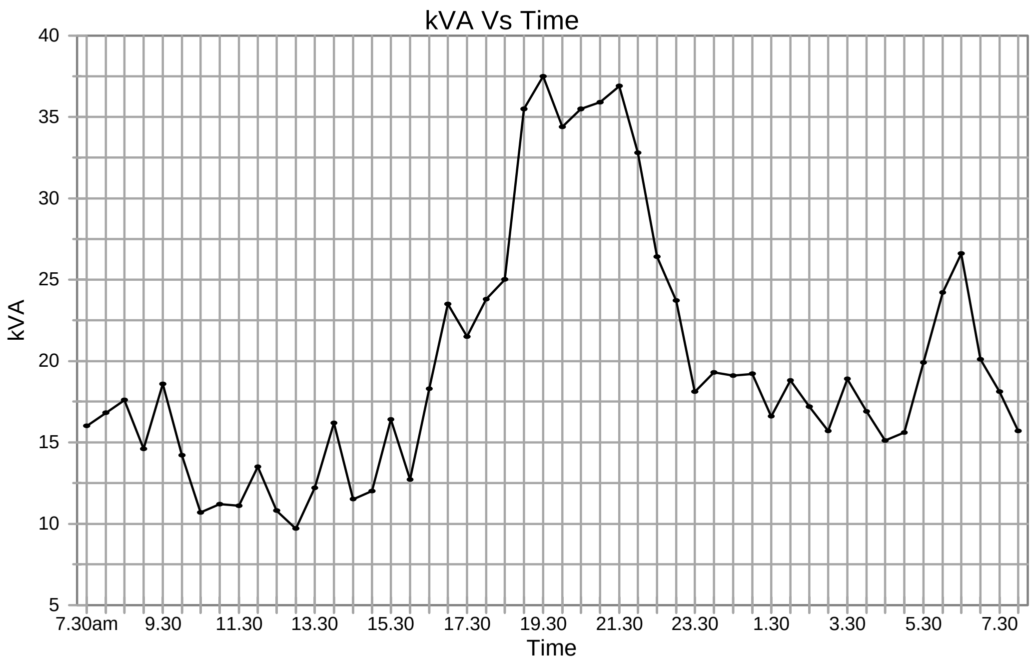
Total number of consumers	**218**	
Domestic	*171*	
Commercial	*25*	
Industrial	*4*	
Agriculture	*18*	
No. of single phase connections	207	
No. of three phase connections	11	
Number of faulty meters	64	
Type of loads	*Load in Watts*	*% Load*
Incandescent lamp 40W	*3040*	*1.18*
Incandescent lamp 60W	*70260*	*27.31*
Incandescent lamp 100W	*12200*	*4.74*
Incandescent lamp - Total	*85500*	*33.24*
Fluorescent Tube Light	*6840*	*2.66*
Fan	*16800*	*6.53*
Refrigerator	*2800*	*1.09*
Mixer/Grinder/Juicer	*47700*	*18.54*
Electric Iron Box	*39600*	*15.39*
TV/VCR/Tape Recorder	*7370*	*2.86*
Electric Pump	*38762*	*15.07*
Industrial Load	*11252*	*4.37*
Others	*630*	*0.24*
Total Load in Watts	*257254*	*100.00*
Usage of Incandescent Lamps	*No.*	*Watts*
60W at least 4 hours a day	*350*	*21000*
60W at least 6 hours a day	*76*	*4560*
60W more than 6 hours a day	*13*	*780*
100W at least 4 hours a day	*21*	*2100*
100W at least 6 hours a day	*12*	*1200*
100W more than 6 hours a day	*6*	*600*
Low voltage bulbs	1	
Power saving capacitors for motors	8	
Electronic choke for tubes	1	
Step-up Transformers	1	

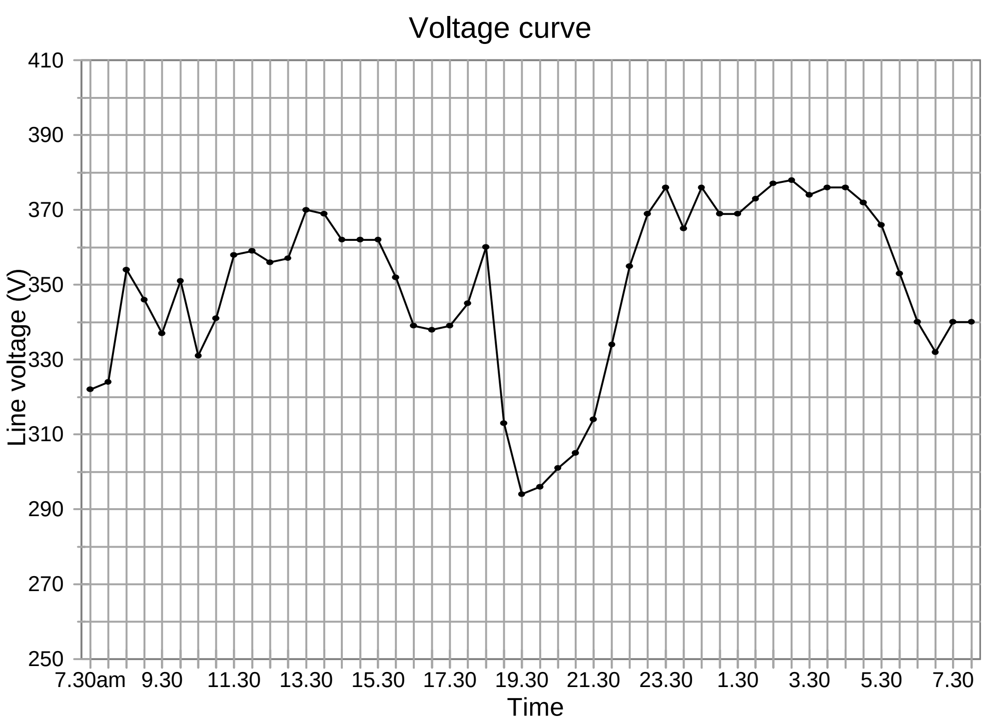
Appendix IV **Load and Power Factor Curve of Poriyani 160kVA Transformer**



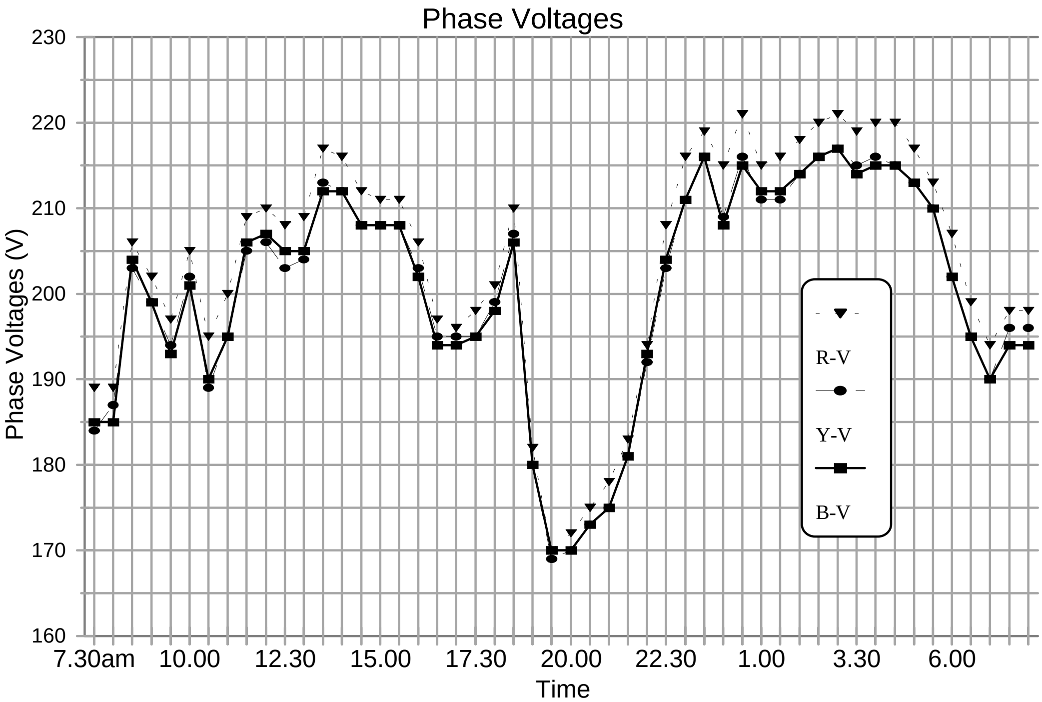


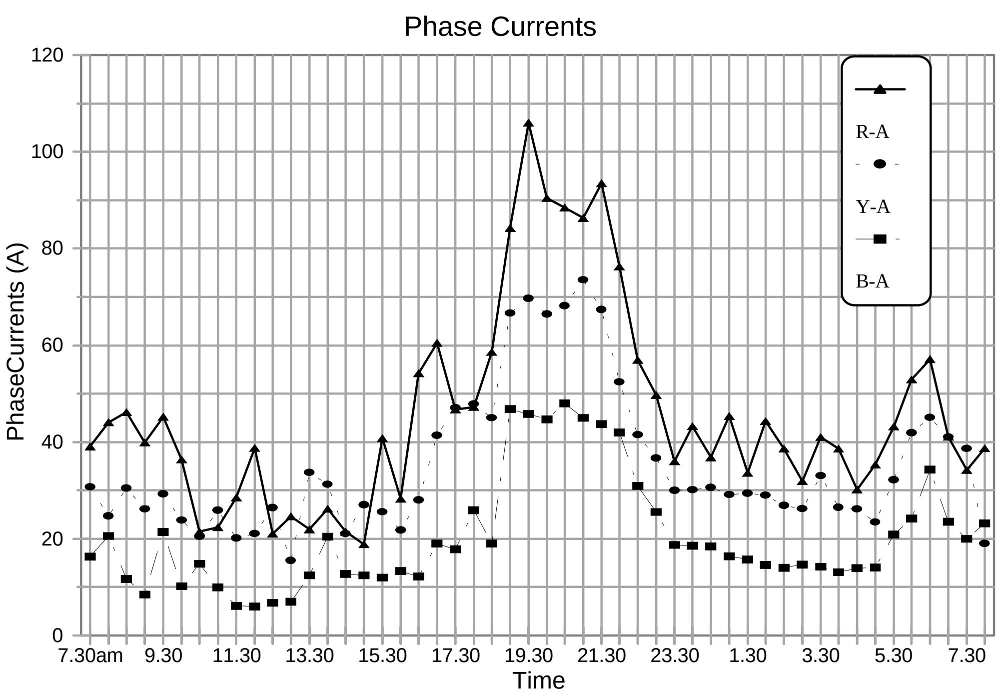
kVA and Phase Voltage Curve of Poriyani 160kVA Transformer



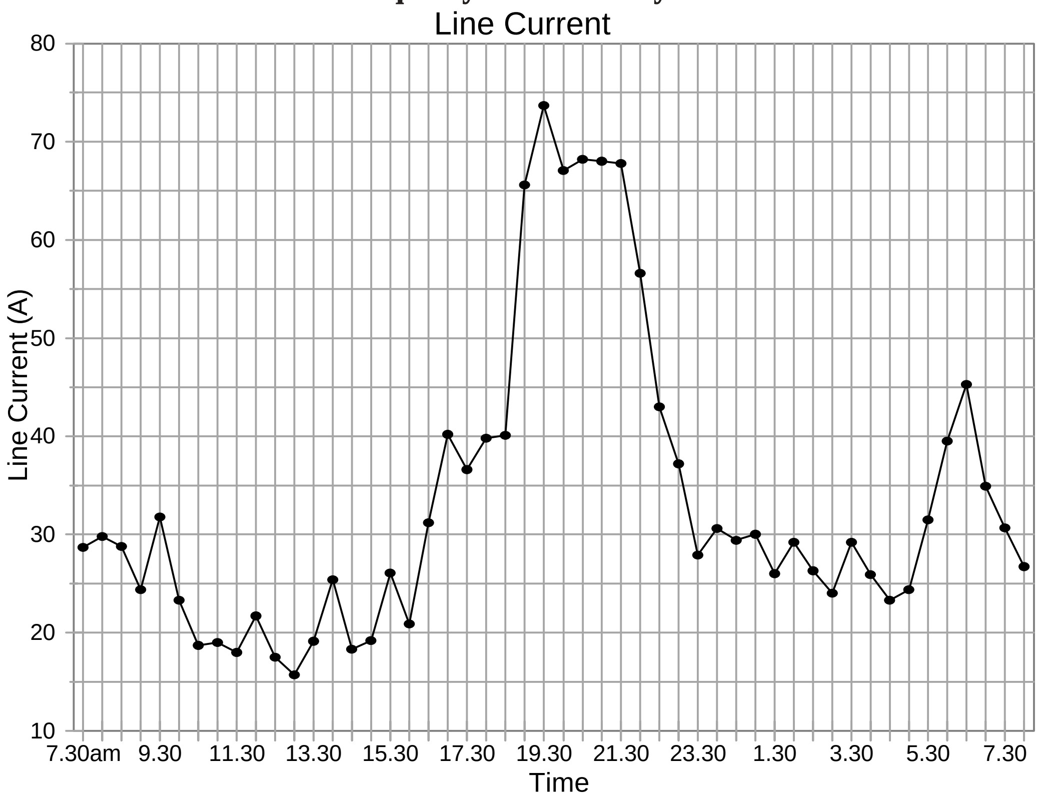


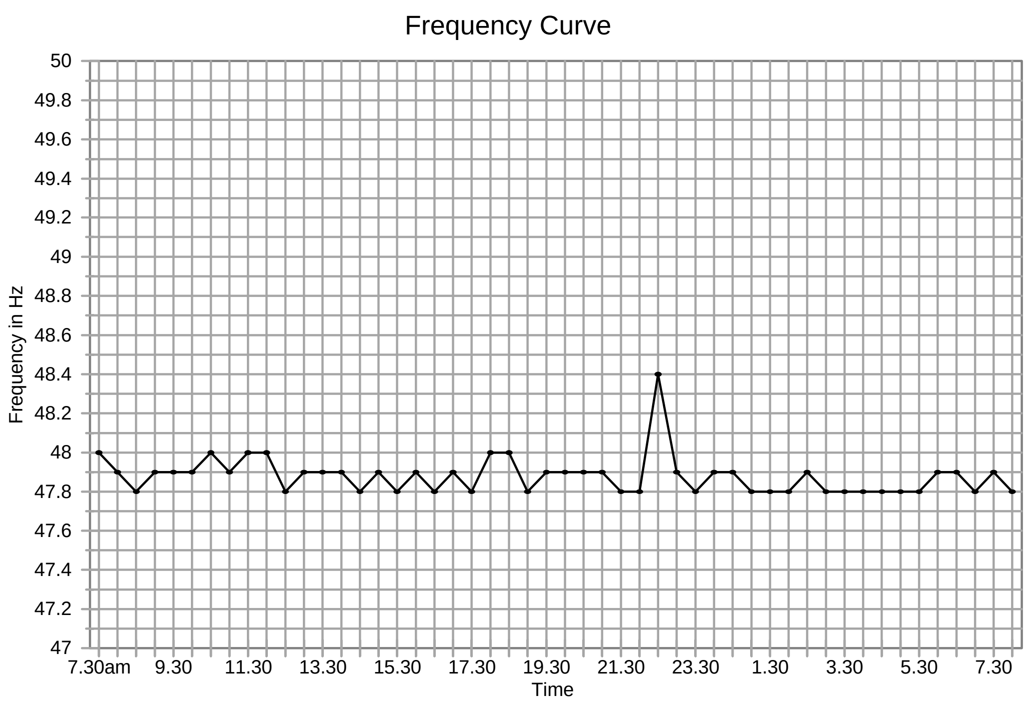
Phase Voltages and Phase Currents Curve of Poriyani 160kVA Transformer



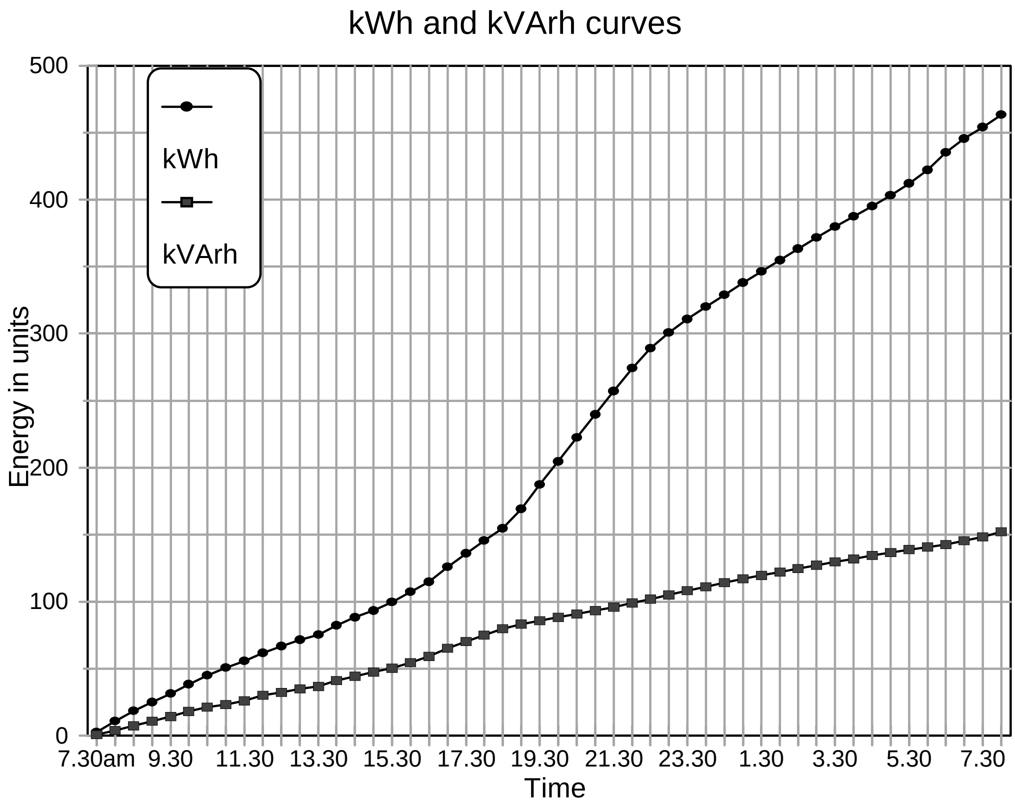


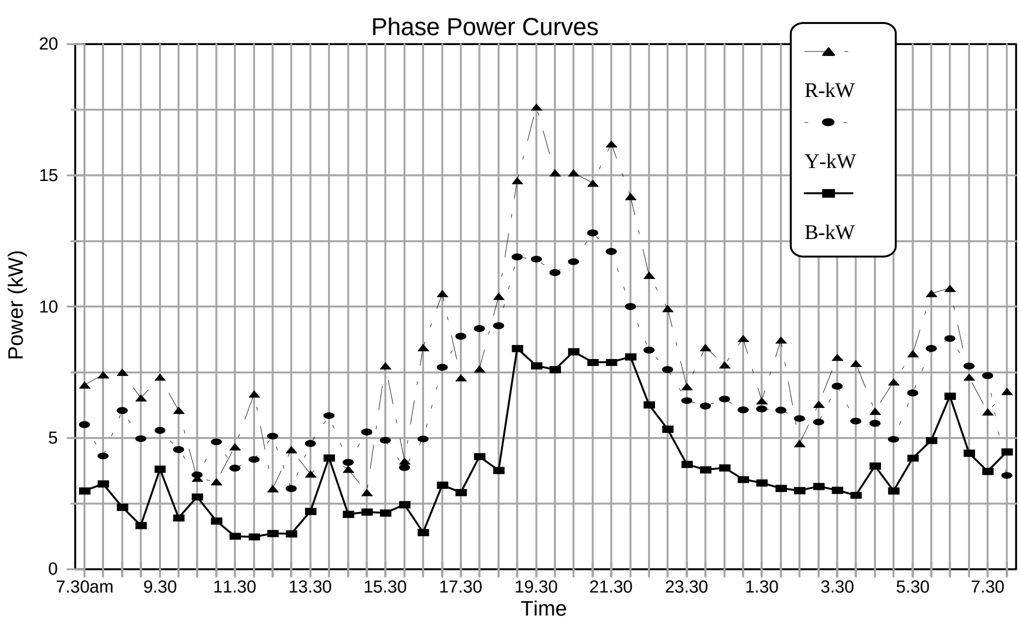
Line Current and Frequency Curve of Poriyani 160kVA Transformer



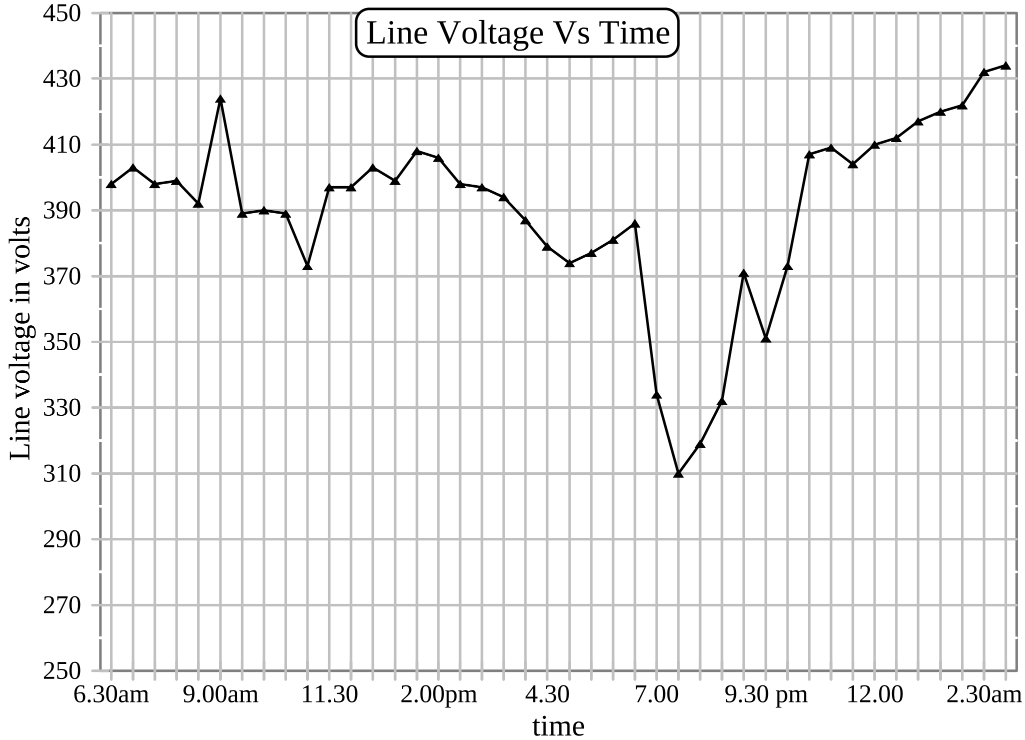


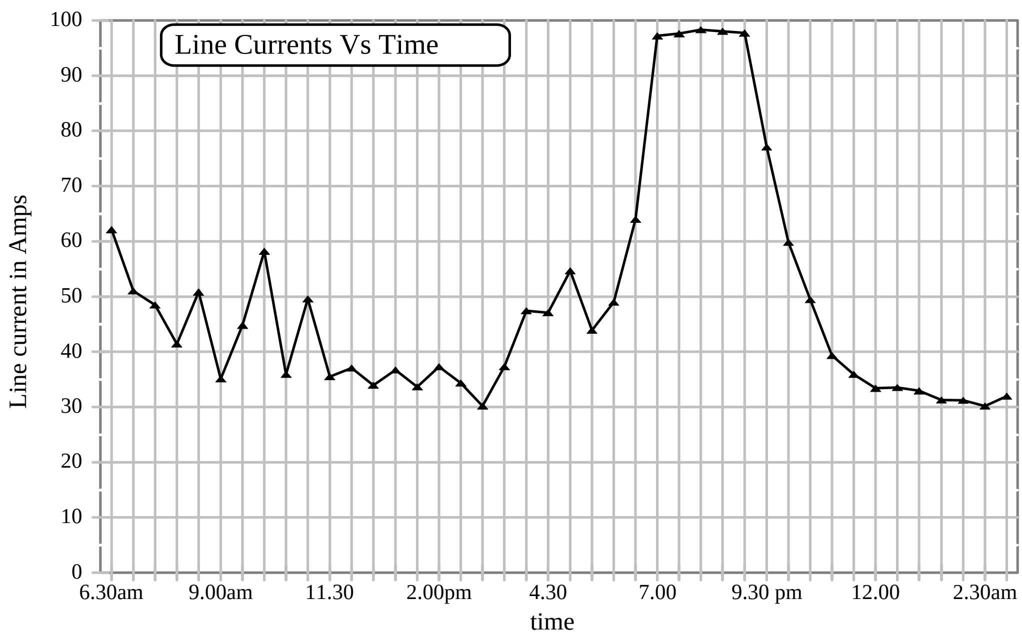
kWh, kVArh, and Phase Power Curves of Poriyani 160kVA Transformer



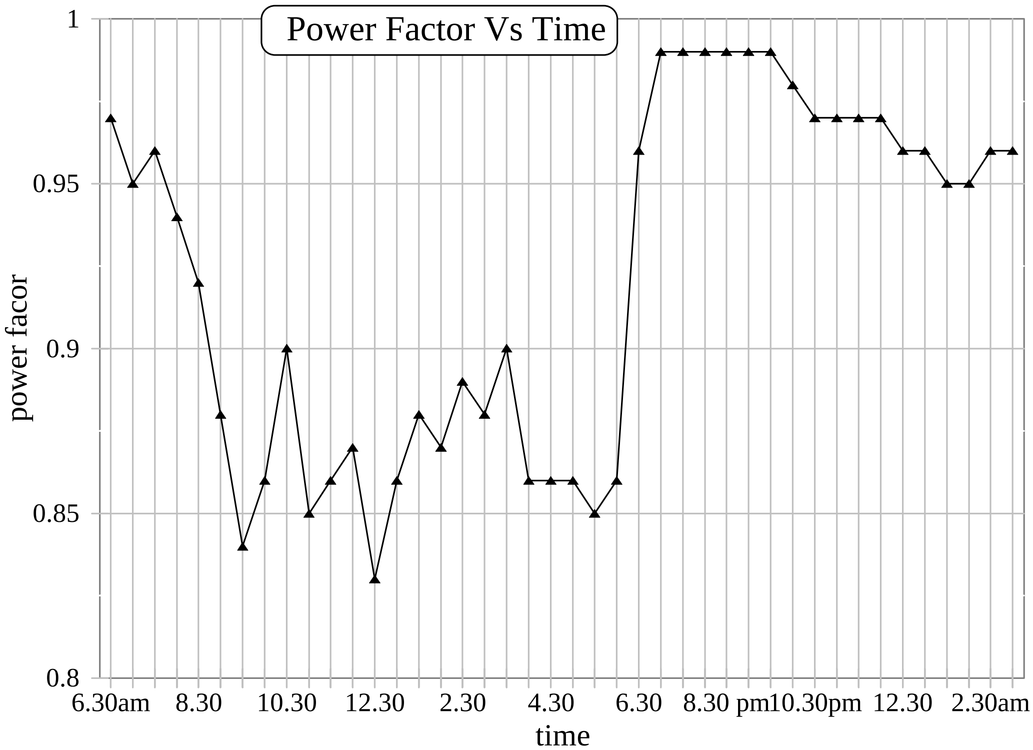


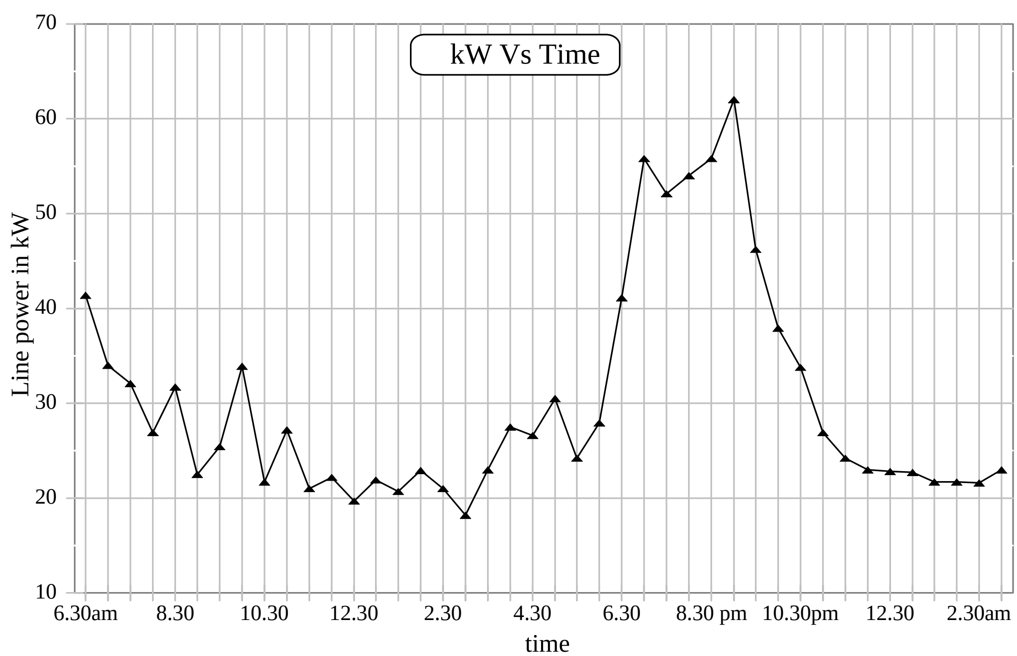
Line Voltage and Line Current Curve of Keralassery 100kVA Transformer



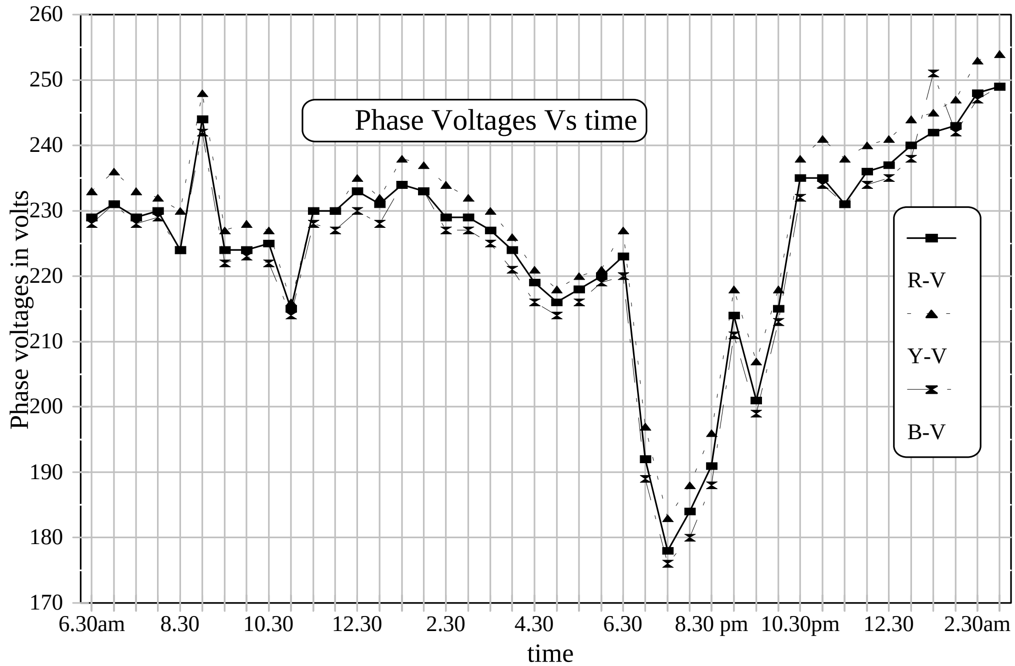


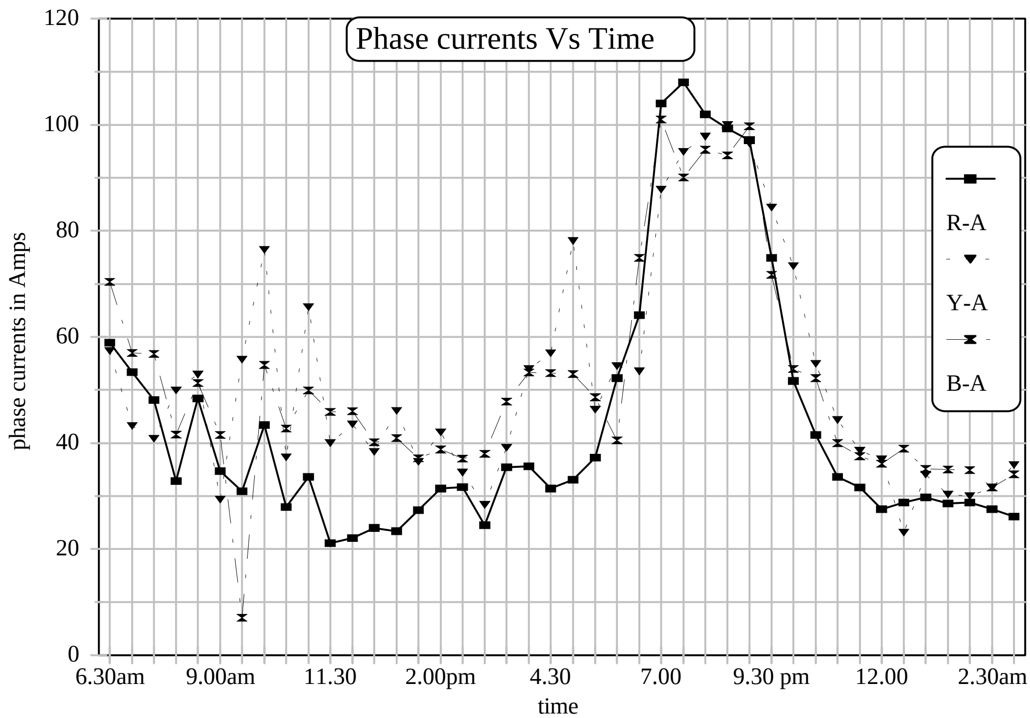
Power Factor and Load Curve of Keralassery 100kVA Transformer



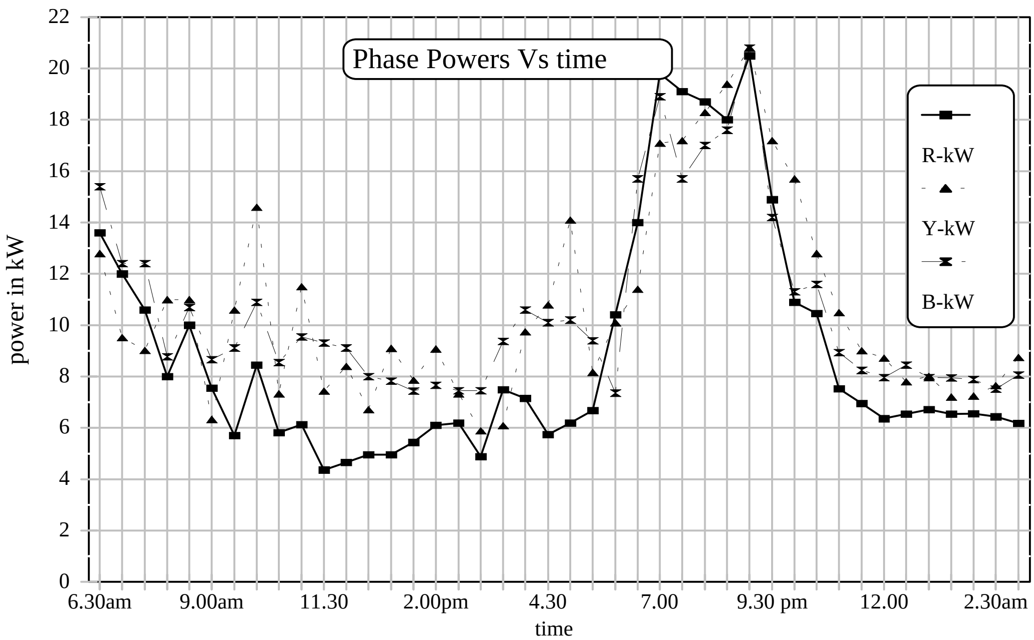


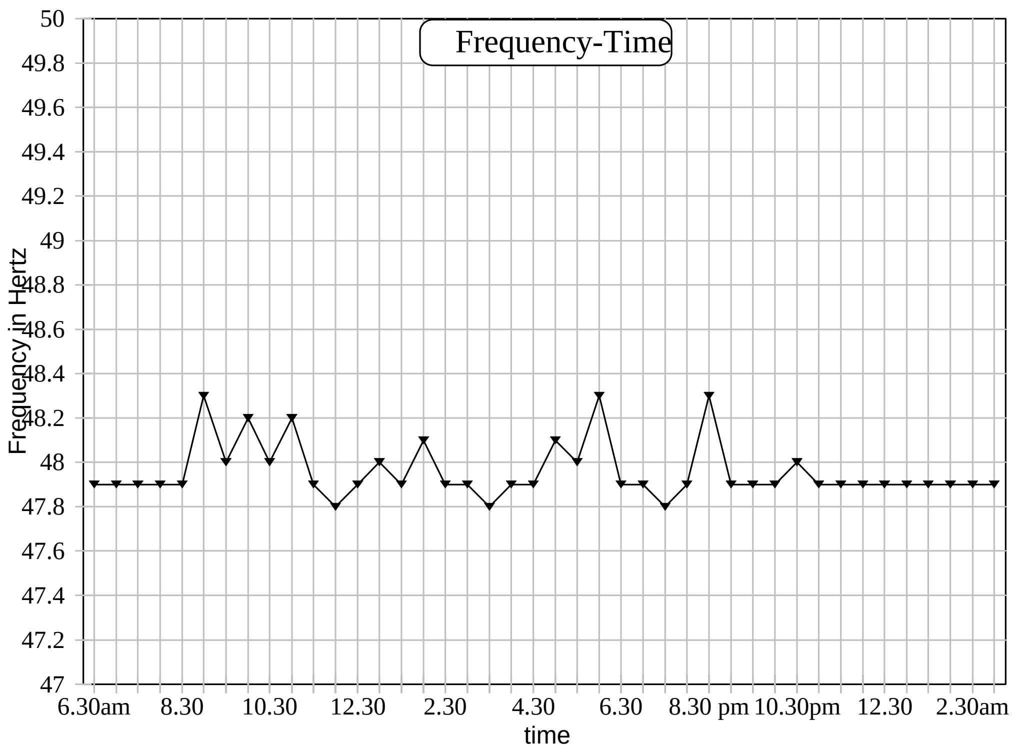
Phase Voltages and Phase Currents Curve of Keralassery 100kVA Transformer



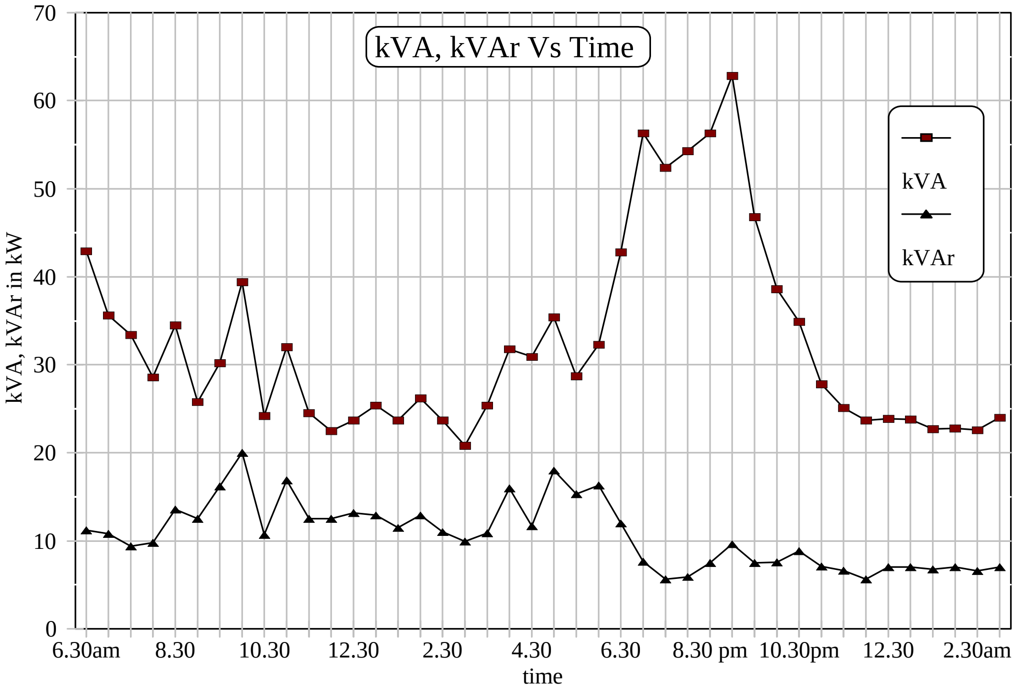


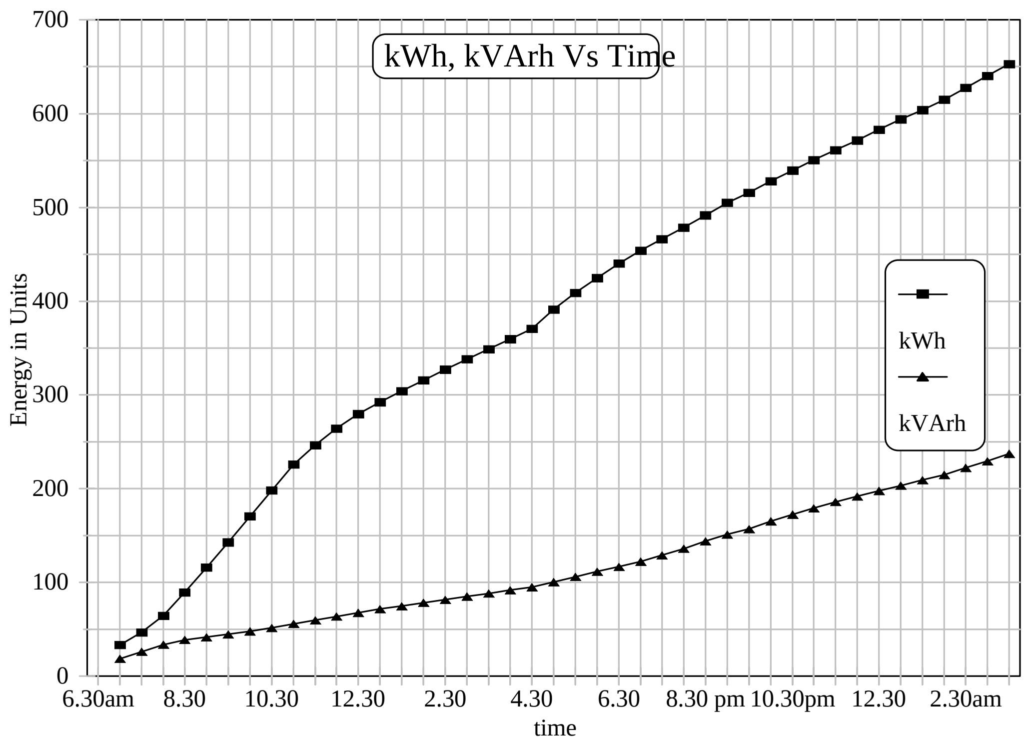
Phase Power and Frequency Curve of Keralassery 100kVA Transformer





kVA, kVAr, kWh, and kVArh Curve of Keralassery 100kVA Transformer





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