ANALYSIS OF UNBALANCED EFFECT IN LV DISTRIBUTION SYSTEMS

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Power transmission and distribution "Energy" losses in Sri Lanka is around 18% of the total power generation. This figure compared with that of developed countries which is in the region of 8 - 10% indicates that more emphasis should be made in developing techniques and systems in the area of loss reduction.

Unbalanced Distribution Systems

This article focuses on energy losses in low voltage electricity distribution systems caused due to unbalanced distribution of loads.

In a country like Sri Lanka where most domestic consumers are provided with single phase connection, a common problem encountered is, feeders with unbalanced currents. These unbalanced phase currents result in return current through the neutral conductors which dissipates valuable electrical energy into heat in process. This effect is further aggravated by the fact that the neutral conductors are smaller than phase conductors in some cases (Ex. Bundled Conductor Systems).

Load Balancing

Primary objectives in carrying out a load balancing exercise are :

* to reduce losses caused due to unbalanced currents
* to improve voltage regulation along the feeder

The following model and equation can be used for this purpose.

It may appear that balancing loads of LV feeders is a simple process as electricity consumption of single phase consumers are similar in pattern and magnitude. This may lead to a conclusion that load balancing could be achieved simply by connecting consumers to alternate phases along the feeder. In fact, this is the present approach adopted to carry out load balancing of LV feeders. However, unfortunately this 'rule of the thumb' cannot be applied accurately in most of the cases.

It should be noticed that balancing of currents at the beginning of the feeder may not be the best solution from loss reduction point of view. There are single phase and two phase spur lines/sections at various locations of the feeder which injects unbalanced currents at various locations regulating unbalanced neutral currents in mid spans.

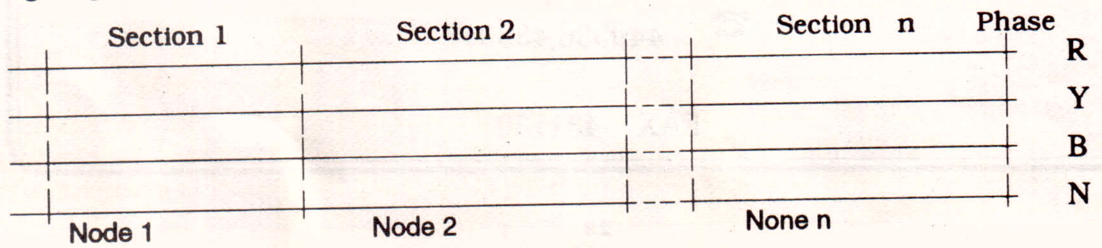
Therefore it is necessary that load balancing exercise should be supported by technical and economic calculations to minimize losses and to achieve optimal performance.

For this purpose it is necessary to develop a model to carry out technical and economic calculations.

LV Feeder Model

LV Feeder Model consists of a Substation, Sections and Nodes. Sections are LV lines of defined conductor type, length and No. of Phases. Nodes are points where a section starts or ends. Load through the section is assumed to be applied at the node.

Following diagram will illustrate this Model.



Data for Model

Following data is required :

i) Substation Terminal Voltage (at Peak Time)

ii) Substation Terminal Currents (at Peak Time)

iii) Average Power Factor

iv) System Load Factor

v) Section lengths

vi) Section Conductors

vii) Section Phasing

viii) No. of Consumer Units connected to each phase in a section

ix) Transformer capacity and percentage impedance

x) Capacity cost and energy cost of electricity

Assumptions

i) Loads through section are applied at the node

ii) Constant power factor is assumed for all loads

iii) Feeder currents are equally distributed among each consumer unit

iv) Period of analysis is one year

Analysis

$$IR = [I_R] \underline{/0} = [I_R]$$

$$IY = [I_Y] \underline{/120} = [I_Y](-1/2 + j\sqrt{3}/2)$$

$$IB = [I_B] \underline{/-120} = [I_B](-1/2 - j\sqrt{3}/2)$$

Current through Neutral Conductor :

$$IN = ([I_R] - [I_Y]/2 - [I_B]/2) + j([I_Y] - [I_B])\sqrt{3}/2$$

$$\text{Power Loss} = ([I_R] + [I_Y] + [I_B] + [I_N]) \times R \times L$$

$$\text{Energy Loss} = \text{Power Loss} \times \text{UTL}$$

Where Utilization time of losses (UTL) is the time taken to dissipate the same amount of energy (Annual Energy Loss) had the power loss level continued at the peak level (Peak Level of the Power Loss Vs Time Curve).

Sample studies carried out using this model has indicated that a loss reduction of 0.5 - 1.0% can be achieved by proper load balancing of LV distribution system. Results of a highly unbalanced LV feeder analysis is shown below :

	Unbalanced System	Balanced System
Terminal Phase Currents	146,277,240 A	211,288,224
Neutral Current	116A	15A
Source Power	140.9 kW	140.9 kW
Power Loss	29.4 kW(20.9%)	26.7% kW (19.0%)
Energy Loss	52.1 MWh/Yr	47.3 MWh/Yr (9.3%
Cost of Losses		
Capacity Cost	514,393 Rs/Yr	467,603 Rs/Yr
Energy Cost	89,027 Rs/Yr.	80,929 Rs/Yr.
Total Cost	603,420 Rs/Yr	548,532 Rs/Yr.
Conserved Energy		**4.8 MWh/Yr.**
Annual Saving		**54,888 Rs/Yr.**

Authors developed a computer programme to use this model for load balancing calculations incorporating computer graphics for convenient and quick analysis. This computer model is being introduced in CEB areas for load balancing.