ANALYSIS OF THE LINE VOLTAGE AND DISTRIBUTION LOSSES WITH LOAD DEMAND IN A RADIAL DISTRIBUTION SYSTEM - A CASE STUDY

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Introduction

Distribution system provides a final link between the high voltage transmission system and the end consumers. In Sri Lanka, distribution systems, because of their simplicity, are in radial configuration. The distribution network of the Ceylon Electricity Board (CEB) consists of about 24,000 km of 33kV/11kV lines, 95,000 km of low voltage lines (400V/230V) and 19,700 distribution substations. From observations made in 2004 after an island wide study, 60% of the LV schemes in Sri Lanka are having voltages below 90% of the stipulated voltage of 230V, about 55% of the LV schemes have unbalanced 3 phase feeders and the average voltage drop at the end of a LV distribution line is about 15%. This paper presents the variation of the line voltage and distribution losses with future load demand. A case study conducted in the Meewathura substation, Peradeniya was used to analyze the line voltage.

Objective

Power demand is increasing with time. Therefore, it is important to find the voltage at each point to maintain voltage within the acceptable range. Hence, a proper study should be done to avoid under-voltage problem. The main objective of this work is to analyse the line voltage and system loss with varying load demand and to find a suitable solution to improve the line voltage while reducing system loss.

Methodology

Different distribution substations were checked around Kandy area to analyse the distribution losses. The Meewathura substation in Peradeniya was selected based on reasons such as, the substation covers urban as well as rural areas, LV network consists of 3-phase consumers, easily accessible to the location for data collection and measurements and a known site to CEB for high losses and low voltage level. The site was visited several times and details such as pole by pole consumer data and details relevant to the substation (B136, 100kVA, 33000/415) were collected. The hourly phase current and voltages at the transformer end were obtained during a selected week day (Wednesday-12.05.2010). In order to analyze line voltage and distribution losses, the following two cases were considered.

- A typical constant load growth rate of 6% applied for years 2011, 2012 and 2013 and 5% applied for years 2014, 2015 in both feeder 1 and 2.(normal practice done by CEB)

- A point loads added at poles 8 and 11 in feeder 2 (51.8A) for a new housing scheme and extension of pole 19 (23.5A) due to a new road parallel to Mahaweli river

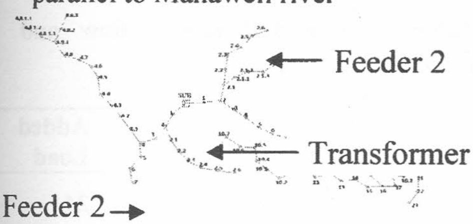

Fig. 1. Substation line diagram

Load Flow Analysis

Line diagram relevant to the substation was developed in Integrated Power System Analysis (IPSA) software package. Afterwards the load flow was run in IPSA to determine voltage at any location in the substation. In the load flow analysis, the per-unit impedance of the each section was calculated in the voltage and power bases of 400V, 100kVA respectively. The peak real and reactive power was calculated by using P=X/ (30x24xLF) and Q=XSinØ/ (30x24xLFxCosØ) respectively. Where, LF is Load Factor and X is average energy consumption of the consumer.

Loss Reduction Techniques

LV technical losses are mainly due to long length of LV lines from the distribution substations feeding the domestic and other retail consumers. Therefore, several loss reduction techniques such as phase balancing, substation relocation, feeder reconfiguration and capacitor placement were applied in the present system to find loss saving and voltage improvement from each loss reduction technique.

Results and Discussion

Line voltage

The voltage magnitudes of the feeder 1 and 2 were found from the load flow analysis to take correct action to avoid under-voltage. Fig.1 illustrates the voltage magnitude with demand.

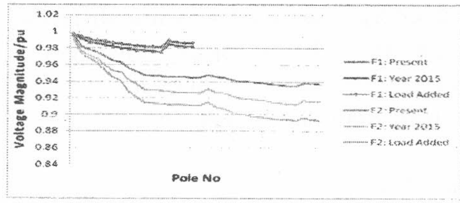

Fig. 1. Voltage magnitude with load demand for feeder 1 and 2

The voltage magnitude from added load is lower than voltage magnitude from load growth rate applied after few years in feeder 2. There is no change in the voltage in feeder 1 by added load. The voltage magnitude of the feeder 2 is not in the safe region after load was added. Therefore, a suitable technique should be applied to avoid under-voltage problem in feeder 2. The fig.2 illustrates the voltage improvement by each technique for feeder 2.

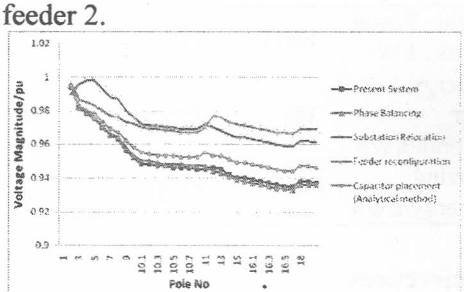

Fig. 2. Voltage improvement by lossreduction techniques for feeder 2

It is clear from the fig 1 and fig2 that the reduction in the voltage can be improved by the above techniques

Power loss

Table 1 shows the results of added load and load growth rate. The power loss of the present system was calculated in IPSA to compare the results of each technique. The Table 2 shows the summery of power losses and energy saving by using different techniques. It is clear that feeder reconfiguration gives high loss saving with substantial voltage improvement.

Conclusion

The adopted techniques are used to improve the voltage and to reduce the power loss. Expected voltage with load demand goes below the recommended voltage level. This paper shows that substantial voltage improvement with the maximum savings in power loss, solving the undervoltage problem could be obtained through the feeder reconfiguration technique. This can be used for the substations in the electricity distribution network with similar load characteristics.

Table 1. Expected power flow and power loss

		Present	2015	Added Load
Feeder 1	Power Flow/kVA	24	32	24
	Current per phase/A	34	46	34
	Power Loss %	1.6	2.2	1.6
Feeder 2	Power Flow/kVA	53	71	70.3
	Current per phase/A	77	103	101.9
	Power Loss %	4.4	5.9	5.8
Total power loss %		3.6	4.8	4.7

Table 2. Power saving by different techniques

	Present System	Phase Balancing	Substation Relocation	Feeder Reconfiguration	Capacitor Placement Analytical method	Capacitor Placement Heuristic Method
Real Power Loss / kW	1.611	1.348	1.051	0.999	1.449	1.473
Energy Loss per Month/kWh	341	285.5	222.5	211.5	306.7	311.8
Saving Energy/kWh		55.5	118.5	129.5	34.3	29.2

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