2016 1st International Electrical Engineering Congress (IEEC 2016)
May. 13-14, 2016 in IEP Centre, Karachi, Pakistan

A Practical Way to Reduce Technical Losses in Distribution System

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Abstract: **This paper is aimed to present techniques to reduce technical losses in Power Distribution System and a practical approach to achieve it in systems which are plagued with unplanned consumer expansions causing LT losses to increase in an exponential manner and where the HT/LT ratio is low. The following paper describes the criteria of feeder selection for the purposes of calculation of technical losses in a particular feeder which is then re-configured with the sole intent of optimizing technical losses, through a number of techniques using CYMDIST software as a tool for simulation. The techniques considered for reducing losses are reconfiguration of complete network, using smaller KVA units on load center, load balancing and switching optimization. From the practical implementation found technical loss reduction of 36% in terms of KW with considerable improvement in Voltage profiles and HT/LT faults.**

Keywords: Distribution System, Feeder Selection Criteria, Network Re-configuration, Technical Loss Reduction, Cymdist, Power distribution, Power distribution planning, Power system planning, Power system simulation, Load flow analysis, Losses.

I. INTRODUCTION

Distribution system of K-Electric in Karachi, consists of 1475 feeders covering the city of Karachi along with Hub, Uthal, Vinder and Bela of neighboring Balochistan province. Karachi is the capital of Sindh province as well as the largest and most populous metropolitan city of Pakistan and main seaport and financial center of the country. The city of Karachi has population of around 25 million people covering a total area of around 3,500 square kilometers resulting in a population density of around 7000 people per square kilometer.

K-Electric is the only vertically-integrated power utility in Pakistan serves its licensed area through 5 power plants having installed capacity of 2341 MW, along with a further provision of 1021 MW from various Independent Power Producers, WAPDA and KANUPP. K-Electric transmission system comprises a total of 1249 km of 220 KV, 132 KV and 66 KV lines with 62 grid stations and 128 power transformers. The Company's current transmission losses are less than 1.03%. The Power distribution and customer service is efficiently managed through distribution of the area into four regions, which are divided into a total of 28 distribution centers. The distribution system consists of 1475 feeders with 8071 km of 11kV lines and 12,044km of low voltage lines. The no. of consumers of K-Electric is around 2.5 million. The annual T&D losses of K-Electric were 35.9% in FY09 which have gone down to 23.7% in FY15. The major portion of these losses is attributable to distribution loss consisting of both Technical and Non-technical Losses. The power supply is controlled through a segmented load-shedding program based on reward and reprimand policy and 58% of feeders are free of any load-shedding.

II. BACKGROUND

K-Electric has come a long way in bringing down its losses, however, the major portion of this reduction was due to decrease of non-technical losses through installation of Automatic meter reading (AMR) meters and check meters at feeders and PMT (Pole-Mounted Transformers) respectively, installation of Aerial Bundled Conductors, Segregation of high loss areas from low loss areas through PMT segregation and segmented load-shedding policy.

However, realizing that technical loss plays an important part in the overall loss figures, a Technical Loss Reduction initiative was taken. K-Electric distribution system consists of 11kV feeders emanating from grid stations and usually hitting initial sub-station of the area containing 11/0.415kV transformers of capacity from 750 to 1600kVA. From this initial sub-station, the HT lines (11 kV) are extended via underground XLPE cables (300sqmm) or overhead ACSR conductors (Dog, Rabbit and Gopher) to other local sub-stations or PMT's. It is from the PMT's that the low voltage is extended through overhead / underground lines to individual consumers. (The distribution network also contains old overhead bare stranded copper conductors of sizes 3/0, 2SWG, 4SWG, 6SWG and 8SWG).

The usual configuration of distribution transformers in K-Electric is Pole Mounted Transformers (from 25kVA to 500kVA) and Sub-Station Transformers (750kVA to 1600kVA).

K-Electric has already had AMR meters installed at all of its feeders, hence energy sent out are exactly determined. However, due to cost constraints it is not possible to install AMRs at all individual consumers.

III. TECHNICAL LOSS REDUCTION

Technical Loss reduction has been proposed through feeder reconfiguration techniques by Ramesh et al [1] using Cymdist software and Baran and Wu [2] through development of power flow methods using custom software built in FORTRAN. Furthermore, technical loss evaluation is explained by Grainger and Kendrew

[3] using hierarchical loss calculation methods.

However, the problem with the evaluation methods is the use of extensive historical loading information or in case of reconfiguration solutions, the use of feeder combinations without any knowledge of internal loss configuration of each feeder. Queiroz [5] has also given a method of estimation of technical loss in LV distribution system with low level information.

The explained method in this paper uses a minimum historical data, of maximum one year, along with independent feeder loss evaluation. This is particularly helpful in distribution systems which are plagued with unplanned consumer expansions causing LT losses to increase in an exponential manner and where the HT/LT ratio is low. The method mostly uses the distribution transformer management techniques mentioned by Ghosh [4].

After completion of all feeders in a neighborhood, the resulting scenario can then further be enhanced using feeder re-configuration method or SOM module in Cymdist.

K-Electric has around 1475 feeders in its distribution system with varying lengths, loss categories (Very High Loss, High Loss, Medium Loss and Low Loss) and area demographics (slums, urban planned, urban un-planned, suburbs etc). The initial problem faced was to develop a selection criterion that would result in selection of feeders having a high potential of technical loss reduction.

A. **Feeder Selection Criteria**

At the start of the project, the selection criteria used consisted of many variables however, it was quickly realized that too many variables were creating a difficulty in feeder selection. After much trial and error, the following selection criteria were implemented.

a) Have a feeder peak load of more than 200A (maximum capacity of 300A)
b) 30% or more of the system PMT's are loaded beyond 80%
c) Have a relatively large amount of Sent Outs (preferably 10m units annually)
d) Single feeder on switch with separate AMR (so that actual sent outs are exactly known)

The above has resulted in selection of feeders having an initial loss configuration from 200kW to 350kW. After successful TLR on individual feeders, a cluster of 15 – 20 feeders were taken up and same techniques were applied on whole cluster including an important factor of feeders load balancing.

B. **Physical Survey**

Once the feeders were selected, a physical survey of the feeder is undertaken. The scope of survey work includes the following main parameters.

a) Area mapping of HT and LT network
b) Marking of all PMT's, poles and brackets
c) Length of each span
d) Each conductor details per span
e) No. and Type of services on each span (single phase residential, three phase residential, three phase commercial, three phase industrial etc)

In the meantime, the following data is also obtained from the Network and billing department.

a) Peak loadings of all PMT's along with individual circuits
b) Feeder monthly peak loadings for the last 12 months
c) Loss category of feeder
d) Units sent out and billed data of feeder and each PMT

C. **Software Simulation**

The above data from physical survey is used to map the existing network, to be used as a basis for proposal formation. The software used for simulation purposes is Cymdist from CYME International. Feeder is completed mapped on Cymdist along with exact mapping of each conductor on each span. The loadings on each span in extrapolated from the PMT and circuit loadings based on no. and type of services obtained from the survey.

Load flow is run on Cymdist to obtain feeder load along with loss figures given the peak PMT loadings. The obtained feeder load is compared with the peak and average feeder load, to obtain the multiplying factors. Load Flow is run in Cymdist using the average multiplying factor, obtained above, on input loadings to obtain loss figures at average feeder load. This loss becomes the existing loss of the feeder at average load. Load flow is again run by using the peak multiplying factor to simulate the feeder at peak loads. Overload cables, conductors and PMT's along with sections facing under-voltages are noted. The aim of the project was reduction in technical loss which ultimately reduce faults, improve power quality, system reliability and customer satisfaction.

Network re-configuration is then done using an iterative technique to obtain the best possible result w.r.t. to resolving overloads and under-voltages. Following loss reduction techniques are currently being used:

a) Re-conductoring overloaded lines with bigger conductors
b) Splitting higher KVA PMTs to smaller KVAs
c) Relocation of transformers to load centers
d) Guarding against loss in transformers through oversized transformers operating at low loadings, unbalanced loads on secondary side, oil leakage etc
e) Feeder load balancing

This best possible proposal is then simulated on average multiplying factor, to obtain the average loss figures of the proposed re-configuring.

The loss reduction is the difference between average loss figures of the proposed network re-configuration and existing average loss figures.

The area mapping based on proposed network re-configuration is then done and submitted to the Execution team. The execution team surveys the area and assesses the possibility of the network re-configuration including new PMT additions, re-location of existing PMT's, laying new HT & LT lines, re-conductoring based on ground realities, since the area is inhabited and open space is scarce.

Any changes / revisions pointed out by the execution team are then incorporated in the network re-configuration to obtain a final pre-execution, simulated loss reduction.

D. Execution

The bill of material is then prepared by the execution team to ascertain the cost of network re-configuration. The benefits through expected loss reduction are then compared to the cost of network re-configuration to obtain the payback period and IRR of the scheme. Necessary financial approvals are obtained and the execution is started.

Any further changes to proposal based on immediate ground realities during execution are noted. Major changes are not done without re-simulation in Cymdist to ascertain the effect on proposed loss reduction.

Automated Meters with GSM option is installed on the LT side of all PMT's of the feeder during execution while the same is already installed on the feeder on the grid side.

The proposed network is revised on Cymdist after completion of execution, based on changes during execution, to obtain the As-Is of the newly re-configured feeder.

E. Post-Execution Loss Reduction Performance

After completion of execution, the total of the AMR sent outs of all PMT are compared against the feeder sent out, to determine the HT and Transformation losses over a month.

The PMT and circuit loadings are obtained after execution along with monthly sent out and billed data of individual consumers. The loadings are then input as new loads in the As-Is simulation and load flow is run on Cymdist to obtain the LT loss figures. The total loss reduction (HT and Transformation losses from AMR, and LT losses from post execution loadings are also compared to the actual loss figures from monthly sent out less billed data to determine the variance. However, a little variance is expected due to difference in billing quality.

F. Voltage Improvement

The PMT and circuit loadings obtained after execution completion are also used to simulate the expected voltage profile at tail-end. The results of simulation are found to be near the actual voltages recorded manually at consumer's end. The voltage profiles of before and after execution are compared to determine percentage improvement in voltage profile.

G. Faults Reduction

Faults after execution are compared with faults before execution to compare the percentage reduction in faults

IV. Actual Figures of Model Colony Feeder

Model Colony Feeder was completed using the above methodology. Model Colony Feeder has total length of around 16km (both HT and LT) and consists of 13 PMT's and 1 substation.

The network re-configuration resulted in the addition of 13 new PMT's and removal of two PMT's making the final quantity of PMT's as 25.

The figures given in Table-1 are based on November 2014 values.

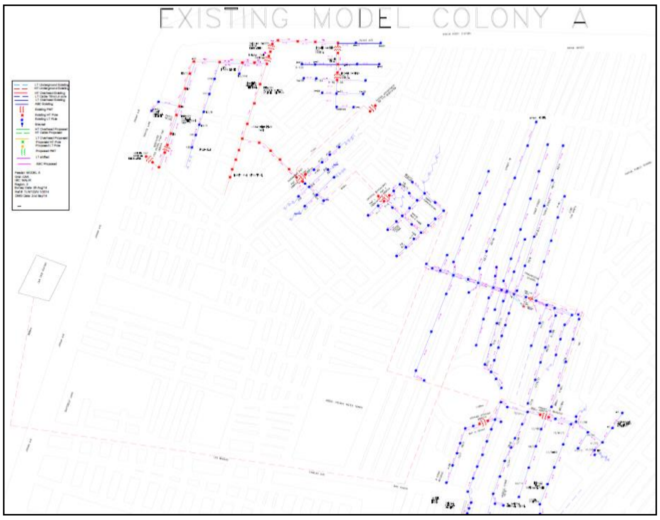

Fig-1 Existing Feeder Mapping

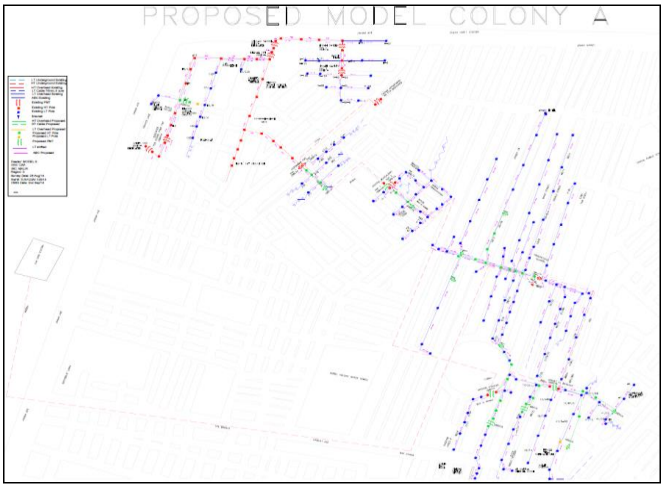

Fig-2 Proposed Feeder Mapping

Note: For clear resolution of the images, please check following link:

https://drive.google.com/open?id=0BwXEbulSGmeaSzNINlg5VWxPTTg

A. Simulated Performance Management

Table-I Performance Management

		Before Optimization	After Optimization
A	**Technical Loss Reduction (kW)**		
	Technical Loss on HT	57.09	56.90
	Technical Loss on LT	171.39	72.80
	Transformation Losses	49.60	48.47
	Total Loss	**278.08**	**178.17**
	Reduction in Technical Loss (kW)	**99.91**	
		36%	
B	**Units Lost**	**2,131,483**	**1,365,673**
	Reduction in Units Lost	**765,810.15**	
C	**HT / LT Ratio**		
	Total HT Length	6,762.00	8,000.00
	Total LT Length	9,412.60	9,459.60
	HT / LT Ratio	**0.72**	**0.85**
D	**Lines having Loading / Voltage Issues**		
	Overload	64	13
	Low Voltage	512	26
	Total	**576**	**39**
	Improvement	**93%**	

B. Actual Performance Management

Table-II Actual Performance Management

		Before Execution	After Execution
A	**Technical Loss Reduction (kW)**		
	Technical Loss on HT	57.09	31.97
	Technical Loss on LT	171.39	47.58
	Transformation Losses	49.60	27.78
	Total Loss	**278.08**	**107.33**
	Reduction in Technical Loss (kW)	**170.75**	
		61%	
B	**Units Lost**	**2,131,483**	**822,720**
	Reduction in Units Lost	**1,308,764**	
C	**HT / LT Ratio**		
	Total HT Length	6,762.00	8,000.00
	Total LT Length	9,412.60	9,578.80
	HT / LT Ratio	**0.72**	**0.84**
D	**Lines having Loading / Voltage Issues**		
	Overload	64	2
	Low Voltage	512	15
	Total	**576**	**17**
	Improvement	**97%**	

C. Results

The technical loss reduction on Model Colony feeder was 37% in terms of KW. The HT faults on the feeder dropped by 33% as compared to the same period last year while the LT faults dropped by 59%.

The same methodology was implemented on 18 individual feeders and 14 feeders in a cluster. Post Execution analysis of these 32 feeders' revealed technical loss reduction of 37% in terms of KW, 28% reduction in HT faults and 71% reduction in LT faults.

Note: For detailed line losses, please check following link:
https://drive.google.com/open?id=0BwXEbulSGmeaSzNINlg5VWxPTTg

D. Financials

The actual cost of network re-configuration was PKR 8.9m with an expected benefit of PKR 12.5m per annum, resulting in a payback of 8.5 months. The calculated IRR for the scheme was 130% with a useful life of 10 years and discount rate of 10%.

However, the actual cost on 32 feeders was PKR 216mn with a payback of 15.9 months.

VI. CONCLUSION

The actual results achieved are in line with the expected benefits obtained through Cymdist simulation. The loss reduction will further be augmented through network re-configuration and capacitor placement, at a later stage.

The working described above can be used for reduction of technical loss reduction of individual feeders especially in utilities where the feeders are in dilapidated condition and are plagued with unplanned expansion in both loads and equipment, with minimal historical data.

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