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Distribution System Power Loss Segregation

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Abstract: Technical and non-technical losses occurring in distribution system of Pakistan have increased beyond acceptable limits of 5-7%. Hyderabad Electric Supply Company is suffering from distribution losses of around 25%, which are far above the accepted level. Segregation of power losses due to different reasons help in developing a priority based remedial programs that will enhance overall efficiency of the company and improve revenue generation. In this research work, one of the 11kV distribution feeder is analyzed for power loss segregation. Collected data shows 27% of total losses for the month of August 2018. Collected data is used for modelling and simulation of selected feeder using PSS SINCAL software. Simulation analysis of existing system gives 10.59% technical losses indicating 16.41% of theft. Effect of improper conductor size and jumpers, poor power factor and unbalanced loading are considered as major contributor to technical power losses. Maximum power loss reduction on feeder is possible with balancing of loads on L.T circuits of transformers. On the other hand power factor improvement through installation of capacitors on H.T side also reduce sufficient power losses on the feeder. Hence small efforts can improve system efficiency without much investment.

Keywords: Distribution system; Power losses; Poor power factor; Unbalanced loading; HESCO.

1. INTRODUCTION

Power sector of Pakistan is facing worst crises of its history. Demand supply gap is increasing rapidly. No serious efforts have been taken to increase generation capacity whereas power demand is increasing mainly due to increasing population and associated comfort level. It results in long duration load shedding (Sahito, *et. al.* 2014). Aged transmission and distribution result in high power losses and voltage drops, making it very difficult to supply quality power to consumers. Most of the consumers being supplied well below acceptable voltage limits (Sahito, *et. al.* 2015).

Old aged distribution and transmission network and improper operation results in high technical losses. Direct connection to low tension (L.T) lines and tempering with energy meters results in high amount of electricity theft mainly referred as non-technical losses (Aguero, 2012). Total losses of the distribution system increase to unacceptable level. Decreasing power losses is a quick method to reduce demand on generation. It improves efficiency of the system and thus will reduce overall cost of operation, which may result in reduced energy prices for consumers. Hyderabad Electric Supply Company (HESCO) is responsible for power distribution in lower part of the province of Sindh. The problem of energy losses is badly affecting performance of Pakistan's power sector in general and HESCO in particular (Umer, *et al.* 2013). No serious effort is being taken to reduce demand supply gap and thus reduce load shedding.

Power loss refers to difference of electricity units generated and billed. These losses can be due to inherent system resistance and termed as technical losses. Technical losses are further classified into fixed and variable losses. Fixed losses are independent of load and mainly occur in distribution transformers in the form of hysteresis and Eddy current losses. Variable or load dependent losses mainly occur in transformers and line conductors and cables (Favuzza, *et al.* 2018). Non-technical losses are due to illegal connection to service mains or by meter bypassing. Use of electricity without being billed are major contributor to overall power losses and is commonly known as electricity theft. Electricity theft can be controlled by proper vigilance. Technical measures to minimize chances of electricity theft include reducing L.T lines by replacing with H.T lines, replacing bare conductors on L.T circuits with insulated Aerial Bundled Cable (ABC) and replacing conventional meters with smart meters (Ghanghro *et. al.* 2016).

This paper focuses on segregation of power losses in technical and non-technical losses. Later technical losses are further classified according to different causes. Simulation analysis using Power System Simulator–Siemens Network Calculator (PSS SINCAL) is used to identify possible reduction in technical losses due to conductor reinforcement, proper jumpering and jointing, poor power factor and unbalanced loading on L.T network.

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Section 2 of the paper describes different causes of technical losses. System selected in this research work is described in section 3. Simulation based results are presented and discussed in detail in section 4. Finally paper is concluded in section 5.

2. POWER LOSSES

Power losses may be defined as the difference of energy supplied and energy billed. That can be classified into two categories; Technical and Non-technical losses. Technical losses are further classified into current dependent and independent losses. Technical losses are due to inherent electrical properties of system components (Sahito, *et al.* 2015). Current dependent losses depend upon resistance and current flowing through a circuit. Aged distribution system, under size conductors, improper maintenance, loose connections, improper joints and jumpers are some of the causes for high resistance of lines and transformers and thus contribute to technical power losses. Over loading, unbalanced loading, poor load power factor and improper reactive power compensation cause increase in current and thus contribute to power losses. Hence power losses will reduce by reduction of either current or resistance.

Poor power factor increases current drawn for a particular load. Increased load will result in increased power losses and increased voltage drop. Increased voltage drop further increases current and thus losses are increased. In order to reduce power losses caused by poor power factor, shunt capacitors are considered best choice (*Umer et. al.,* 2015). Shunt capacitors are primarily used for reactive power compensation in order to improve voltage profile of distribution feeder. Power loss reduction is an additional benefit. Hence installation of shunt capacitors on suitable locations will result in double benefits of improved voltage regulation and reduced power loses. In order to achieve maximum benefit, capacitors should be installed nearest to the load to meet its reactive power demand. It gives a general view that each load may be compensated individually but cost of individual compensation is impractical in most cases for utilities. Next step is to compensate on L.T side of the circuits as group compensation for small load groups. Cost of control circuitry in such cases is often high and therefore capacitors on L.T circuits are rarely used for reactive power compensation.

Unbalanced loading is commonly observed in three phase four wire system of secondary circuits of distribution transformers. Unbalanced loading is caused by single phase loads being supplied between one phase and neutral. Unbalanced loads results in different currents in different phases and thus power losses are different in all three phases. As power losses are function of square of the current thus total power losses are increased. As an example considering a system with 30A load shared equally as 10A per phase. If R is resistance of each phase then power losses will be $3(10^2)$ R= 300R. Now if there is an unbalanced condition such that three phases carry 5, 10 and 15A respectively then power losses will be $5^2R+10^2R+15^2R$ = 25R + 100R + 225R = 350R. Hence power losses are increased by unbalanced loading. In existing system 100% balanced loading is impossible to achieve all times as consumer load is varying with respect to time. But an effort can be taken to maintain a balance of loads on three phases by observing consumer loads at different time intervals and thus shifting of consumer connections from one phase to other to obtain a loading near to balanced condition.

3. RESEARCH METHODOLOGY

11kV Hayat feeder of HESCO is selected for this research work. (**Fig. 1**) shows node diagram of the selected Hayat feeder. Field surveys along with HESCO staff were carried to collect data including system parameters and load data.

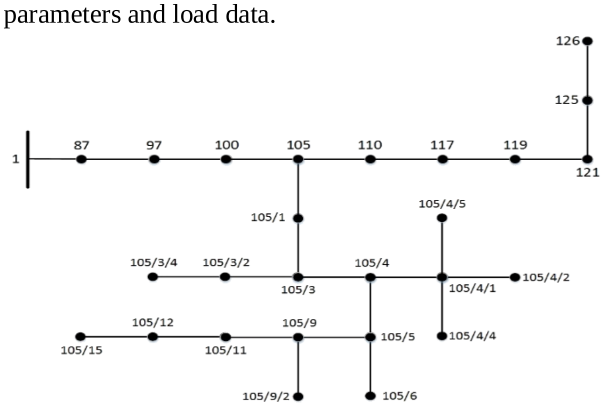

Fig. 1: Node diagram for Hayat feeder

System parameters collected for this research work include H.T network conductor type and length. Standard impedance data is used for conductor types. Transformer size and location is collected during survey. Water and Power Development Authority (WAPDA) standards for iron and copper losses are used during modelling of transformers. On L.T side, pole positions, line lengths and conductor types are the data inputs collected during field survey. H.T circuit is modelled first on PSS SINCAL. **(Fig. 2)** shows portion of H.T circuit for simulation. L.T circuits are modelled separately and linked with H.T circuits using connect key feature of PSS SINCAL. **(Fig. 3)** shows L.T circuit of transformer 2 for simulation.

After modelling of the complete existing feeder, simulation analysis is performed to observe technical losses of the existing system. Three different cases for modifications are selected to observe impacts of different causes of technical losses. Hence four cases are simulated as under

Case 1: Existing system

Case II: H.T network modified to reinforce under size conductors and eliminate impacts of improper joints by reducing the resistance.

Case III: installation of 4 capacitors each rated 450 kVAR and installed on H.T circuit to compensate for poor power factor

Case IV: Replacement of 90% of original unbalanced loads with balanced loads on L.T circuits.

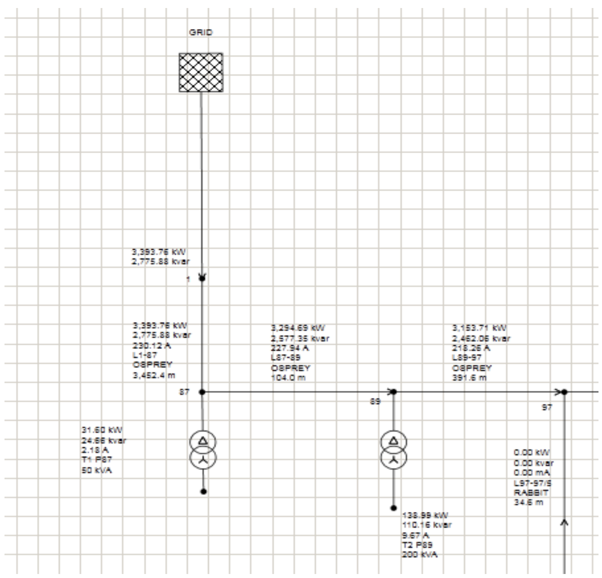

Fig. 2: PSS SINCAL simulation diagram for portion of H.T network of Hayat feeder

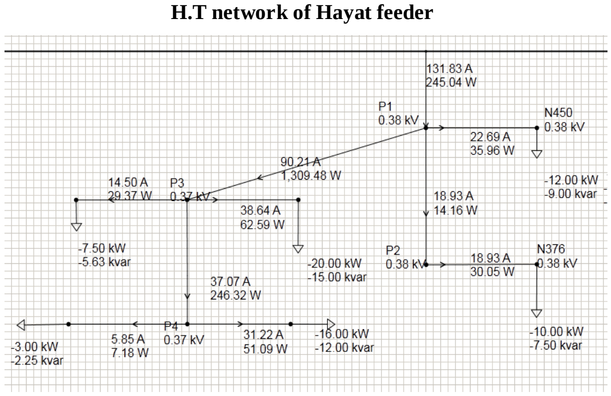

Fig. 3: PSS SINCAL simulation diagram for portion of L.T network of transformer 1 of Hayat feeder

4. RESULT AND DISCUSSION

Simulation of power losses of the existing network revels technical losses. Hence non-technical losses are calculated by deducting these technical losses from the total losses of the feeder found during survey. Feeder losses were observed as 27% and total technical losses are observed as 10.59% from simulation results. Hence non-technical losses are approximately 16.41%. It shows that non-technical losses are in excess of technical losses.

Simulation of four cases are compared for power losses in H.T and transformer circuits. Comparison of branch wise H.T networks are given in (**Table 1**). It is quite clear that maximum power losses are observed in case II, which is installation of capacitors on H.T network. This is because H.T capacitors minimize the reactive component of current and thus maximum power losses are reduced. Power losses are slightly reduced in case II for reinforcement of conductors and proper jointing. Reason for minimum reduction is due to small length of the H.T network of feeder.

Table 1. Comparison of H.T branch power losses

Node		Power Losses (kW)			
Start	**End**	**Case I**	**Case II**	**Case III**	**Case IV**
1	87	67.463	65.734	41.542	61.790
87	89	1.993	1.990	1.224	1.871
89	97	6.885	6.876	4.178	6.463
97	100	7.383	7.373	4.828	6.931
100	105	3.853	3.847	2.496	3.617
105	110	0.892	0.891	0.645	0.838
110	117	0.710	0.635	0.495	0.597
117	119	0.116	0.116	0.109	0.109
119	121	0.027	0.027	0.025	0.025
121	125	0.010	0.010	0.009	0.009
125	126	0.002	0.002	0.002	0.002
105	105/1	1.696	1.693	1.014	1.592
105/1	105/3	1.761	1.759	1.019	1.653
105/3	105/4	2.030	2.027	1.319	1.905
105/4	105/9	0.277	0.276	0.163	0.260
105/9	105/11	0.127	0.126	0.079	0.119
105/11	105/12	0.052	0.052	0.046	0.049
105/3	105/3/2	0.086	0.059	0.081	0.055
105/3/2	105/3/3	0.082	0.082	0.077	0.077
105/3/3	105/3/4	0.212	0.211	0.200	0.199
105/4	105/6	0.019	0.019	0.015	0.017
105/4	105/4/1	0.019	0.017	0.018	0.016
105/4/1	105/4/5	0.004	0.004	0.004	0.004
105/4/1	105/4/2	0.006	0.006	0.006	0.006
105/4/1	105/4/3	0.008	0.008	0.008	0.008
105/9	105/9/2	0.005	0.005	0.005	0.005
105/12	105/15	0.018	0.018	0.016	0.017
Total		95.735	93.864	59.622	88.232

(Table 2) contains comparison of power losses in transformers for four cases discussed earlier. Results show that maximum power losses are observed for case IV corresponding to unbalanced loading. Reason for maximum power loss reduction is due to the fact that unbalanced loading results in reduced currents on L.T side and through transformers.

Table 2. Comparison of transformer power losses

Transformer No.	Power Losses (kW)			
	Case I	Case I	Case I	Case I
1	1.37	1.37	1.34	1.04
2	4.22	4.22	4.09	3.19
3	2.32	2.32	2.28	1.78
4	2.71	2.71	2.62	2.05
5	2.36	2.35	2.30	1.79
6	0.78	0.78	0.76	0.59
7	0.97	0.97	0.94	0.73
8	6.73	6.73	6.42	5.01
9	10.91	10.90	10.15	7.92
10	5.80	5.80	5.50	4.29
11	6.15	6.14	5.81	4.53
12	4.68	4.68	4.50	3.51
13	0.95	0.95	0.97	0.75
14	1.71	1.71	1.66	1.30
15	2.28	2.28	2.21	1.72
16	5.70	5.69	5.28	4.12
17	1.15	1.15	1.14	0.89
18	3.38	3.38	3.26	2.54
19	2.46	2.46	2.40	1.87
20	0.78	0.78	0.76	0.60
21	5.91	5.90	5.55	4.33
22	9.21	9.18	7.57	5.91
23	2.79	2.79	2.67	2.08
24	1.80	1.80	1.75	1.36
25	0.97	0.97	0.98	0.77
26	9.99	9.97	8.82	6.88
27	5.10	5.10	4.70	3.67
28	4.03	4.03	3.89	3.03
29	1.59	1.59	1.58	1.23
30	4.03	4.03	3.89	3.03
31	3.12	3.11	2.99	2.33
Total	**115.97**	**115.85**	**108.77**	**84.84**

Comparison of total power losses for 4 cases are graphically shown in (**Fig. 4**). It is observed that maximum power loss reduction corresponds to Case II, which is installation of H.T capacitors. Unbalanced loading also results in almost same power losses.

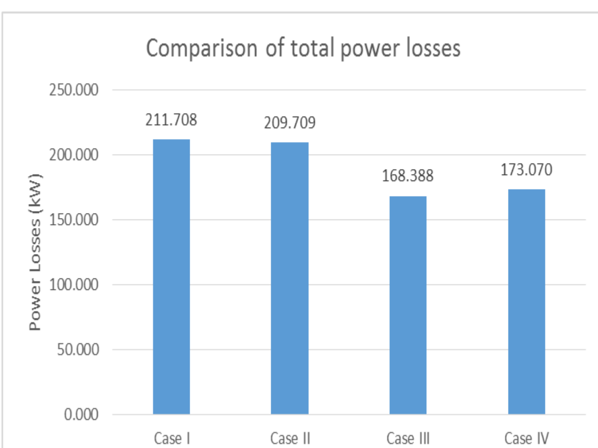

Fig. 4: Comparison of total power losses

5. CONCLUSION

In this paper, 11 kV Hayat feeder of HESCO is used to segregate power losses using simulation. Existing network simulation gives technical losses, which shows 10.59% of total losses are technical and rest 16.41% are non-technical losses. Simulation analysis is performed to segregate technical losses. Results show that poor power factor is major cause of technical losses, which can be overcome by installing shunt capacitors on H.T network. Unbalanced loading is another major contributor and power losses can be reduced using balancing of loads. These technical power losses can be reduced through small investment and proper vigilance. Additional work in this field is proposed for designing of an automatic system for load balancing and automatic monitoring of power losses including simulation software with real system components.

6. ACKNOWLEDGEMENTS

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