Rural Electrification with Loss Minimization Through different Strategies for Sustainable Infrastructure Development

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Abstract—The problem of electricity supply with minimum possible losses is the challenge to countries like India where 72% of human resources inhabited in 600 villages. Electricity on one hand is identified as key component of socio economic development, at the same time it is also identified as a commodity to be traded and large scale restructuring of power system is being taken up with vertical unbundling. Rural electrification is an important component of Integrated Rural Development. Rural electricity distribution is costly due to dispersed distribution of loads in spread over areas. The problem needs to be addressed from several view points as social, economic, and technological advancements. This paper emphasizes on development of new techniques for minimal power loss in electricity distribution system .The proposed high voltage distribution system being cost effective on one hand is equally applicable to urban areas as well.

Index Terms— *High voltage, line losses, feeder,*

I Introduction

Expansion of electrification and electricity services are vital to both the economic and social development of India. The current state of electricity services in most of the states of India is worse than ever. Some of the signs of this crisis are severe shortcomings in

a) Access to electricity for rural and urban poor,

b) Generation capacity that cannot meet peak demand and
c) Reliability of supply, in terms of predictability of outages and quality of power supply. According to National statistics, shortages in energy demand and peak power demand have been around 8% and 12% on average between 2009 and 2010. Inspite of various attempts to achieve 100% rural electrification, India has achieved 44% electrification to rural households only. Rural networks are characterized by long low tension (LT) network fed from an 11/0.4 kV transformer. Even for supplying to widely dispersed load blocks of agricultural pumps, similar LT network arrangement was adopted resulting in an unsatisfactory situation arising from various factors like:-
(1)Pilferage from accessible low voltage lines causing revenue losses.
(2) High technical losses due to high LT current on the network
(3) High peak power loss of network due to unauthorized load
(4) Unsatisfactory voltage profile at consumer installations.
(5) Low reliability of supply consequent upon overloading of LT lines

Electricity Act 2003 mentions rural electrification in a law. Section 6 of the act mandates the hitherto implied Universal Service Obligation by stating that the government shall endeavor to supply electricity to all areas including villages and hamlets. Section 5 further mandates the formulation of national policy on RE focusing specially on management of local distribution networks through local institutions. The broad goals of RE as set out in the draft REP (Rural Electrification Policy), referred to as **AARQA** goals, are as follows:

Accessibility – electricity to all households by 2012
Availability – adequate supply to meet demand by 2012
Reliability- ensure 24 hour supply by 2012
Quality- 100% quality supply by 2012 Affordability- pricing based on consumer ability to pay

These factors paves the way for formulation of new High Voltage Distribution System which is technically superior to conventional LV distribution system with regard to quality of power supply.

II Loss Contributors

The main factors that contribute to high technical losses inappropriate conductor size, lack of reactive power control, low voltage pockets etc.The major components can be listed as follows-

1. Lengthy Distribution lines

In practice, 11 KV and 415 volts lines, in rural areas are extended over long distances to feed loads scattered over large areas. Thus the primary and secondary distribution lines in rural areas; by and large radials laid, usually extend over long distances. This results in high line resistance and therefore high I^2R losses in the line.

2. Inadequate Size of Conductors

As stated above, rural loads are usually scattered and generally fed by radial feeders. The conductor size of these feeders should be adequate. The size of the conductors should be selected on the basis of KVA X KM capacity of standard conductor for a required voltage regulation.

3. Distribution Transformers not located at Load center on the Secondary Distribution System

Often DTs are not located centrally with respect to consumers. Consequently, the far off consumers obtain an extremely low voltage even though a reasonably good voltage levels were maintained at the transformer secondaries. This again leads to higher line losses in order to reduce the voltage drop in the line to the farthest consumers, the distribution transformer should be located at the load center to keep voltage drop within permissible limits.

4. Overrated Distribution Transformers and hence their Under-Utilization

Studies on 11 KV feeders have revealed that often the rating of DTs is much higher than the maximum KVA demand on the feeder. Over rated transformers draw unnecessary high iron losses. In addition to these iron losses in over rated transformers the capital costs is also high. From the above it is clear that the rating of DT should be judiciously selected to keep the losses with in permissible limits.For an existing distribution system the appropriate capacity of distribution transformer may be taken as very nearly equal to the maximum KVA demand at good pf (say 0.85).

5. Low Voltage (less than declared voltage) Appearing at Transformers and Consumers Terminals

Whenever the voltage applied to induction motor varied from rated voltage, its performance is affected. Within permissible voltage of +/- 6% of the affect practice, the supply voltage varies by more than 10% in many distribution systems. A reduced voltage in case of induction motor results in higher currents drawn for the same output. For a voltage drop of 10%, the full load current drawn by the induction motors increase by about 10% to 15% the starting torque decreases by nearly 19% and the line losses in the distributor increases by about 20%.

.Power losses can be divided into two categories, real power loss and reactive power loss. The resistance of lines causes the real power loss, while reactive power loss is produced due to the reactive elements. Normally, the real power loss draws more attention for the utilities, as it reduces the efficiency of transmitting energy to customers. Nevertheless, reactive power loss is obviously not less important. This is due to the fact that

reactive power flow in the system needs to be maintained at a certain amount for sufficient voltage level. Consequently, reactive power makes it possible to transfer real power through transmission and distribution lines to customers. The total real and reactive power losses in a distribution system can be calculated using equation 1 and 2.

$$(1)\ P_{LOSS} = \sum_{i=1}^{n_{br}} \left| I^2{}_i \right| R_i$$

$$(2)\ Q_{LOSS} = \sum_{i=1}^{n_{br}} \left| I^2{}_i \right| x_i$$

Where n_{br} is total number of branches in the system, │Ii│is the magnitude of current flow in branch I, r_i and x_i are the Resistance and reactance of branch i, respectively. Different types of loads connected to distribution feeders also affect the level of power losses.

III HVDS System

The existing rural distribution system in India consists of largely 3 phase 11 KV main distribution feeders with 3 phase spur lines and 11/0.4 KV three phase distribution transformers. The distribution system on low voltage side is done by 3 phase 4 wire, 3 phase 5 wire, single phase 3 wire, and single phase 2 wire LT lines. This system involves nearly 2:1 ratio of LV and HV line lengths. Large LT network results in high occurrence of LT faults leading to frequent interruptions in supply and high incidence of distribution transformer failures due to LT fault currents. This system is unsuitable to cater certain areas like desert, tribal and forests, where the load density is very low and the development of load in these areas is slow. Heavy capital investment on 3 phase 11 KV lines with higher rating 3 phase transformers is not economically justified. To improve the quality of supply, one of the recommendations is the implementation of "Single phase HT distribution system with small capacity single phase transformers. Under this system HT line is extended up to or as near the load as possible and to erect small capacity distribution transformers. Due to use of smaller rating transformers, either 3 phase or single phase length of LT lines is considerably reduced and power is distributed mainly through HV (11 KV) lines. Distribution system employs a suitable mix of 11 KV 3 phase and single phase or 3 phase configuration for giving supply either to small rating lines. With the main line being 3 phase, the spur line comprises of either single phase or three phase configuration for giving supply to small rating single phase or three phase distribution transformers.

Types of HV Distribution System

a) Single phase and 1 Neutral (continuous neutral from Sub-station)
b) 2 Phase 2 wire (Rigidly earthed neutral system)
c) 3 Phase small rating transformers with 3 phase HV system

In case of (a), Single Phase + Neutral, the Primary Voltage of distribution transformer shall be 6.35 KV between the phase and neutral on HV side. For this system, there is a need to run the earth wire from 33/11 KV sub-station throughout. In case of (b), 2 phase 2 wire is adoptable where additional earth wire is not being run from the sub-station. Two phases of main 11 KV 3 phase line can be tapped and 1 phase distribution transformer of primary voltage rating of 11 KV be connected.

IV Proposed System

In case (c) the system becomes most viable in Indian context where small three phase transformers of rating 16KVA, 25KVA etc.are fed from primary side by 11KV extended feeder A group of 8 or 10 consumers shall be connected on secondary side of transformer. The consumers are supplied by two core armored cables up to sealed meter box. On the transformer side the cables shall be connected to transformer through sealed bus bars of appropriate rating. The other salient features would be as follows

a) A three phase digital meter fitted with a modem and GSM SIM card shall be installed at the output terminals of the Trans former on the LV side to facilitate computerized remote measurement device installed at substation.
b) Sealed transparent meter cover boxes to be used for meter unit at some exposed location at consumer premises
c) Meter installed at consumer premise shall have adequate digital circuitry for keeping a record of several parameters for a period of 12 months
d) The static meter installed at consumer premises shall measure and record Maximum demand over a stipulared period of time, Average power factor, Cumulative power consumption record
e) An air break switch (isolator) along with Drop out fuse units shall be fitted on HV side to provide protection to the transformer
f) A three phase overload switch before bus bar shall fulfill the need of protection to consumer.

V Advantages of High Voltage Distribution System

The HVDS offers the following direct advantages.

1) Only few numbers of consumers are connected to transformers and as a result chances of unauthorized connections and theft of energy are reduced.
2) Reduction of system faults because of low length of LV lines.
3) Distribution losses are reduced by 75% or more depending on the load factor
4) The HVDS is cost effective to electrify remote villages and hamlets where bringing of long 3 phase lines is costly due to low demand.
5) In the event of failure of transformers, it will affect only a small number of consumers, whereas failure of large sized distribution transformers will affect large number of consumers.
6) In view of less LT system and usage of ABC, which has tough insulating cover, direct tapping by unscrupulous consumers is avoided.
7) Since losses are reduced considerably, power can be supplied to additional loads without any further investment on infrastructure.
8) No additional generation capacity is needed for giving new loads due to reduction in power drawl.
9) Single phase motor up to 5 HP can operate efficiently on single phase lines. The power factor of these motors is nearly unity. And thus the system efficiency also gets improved.

VI Conclusions

1. Line Losses: The losses in HVDS for distribution of same power are less than that of LV line. Thus, the losses in LV network are negligible bringing down the total energy losses considerably.
2. Voltage Drop: The voltage drop for distribution of same power is less than that of LVDS and thus ensures proper voltage profile at consumer points.
3. System Power Factor: The single phase motors have built in capacitors and PF is more than 0.95. This high PF causes low energy losses and better voltage profile.
4. Failure of Distribution Transformers: The failure of distribution transformers due to LV line faults is eliminated as the length of LT lines is minimized
5. Theft of Energy: The LT lines are virtually eliminated and even short LT lines required will be with armored Cables. This makes direct tapping very difficult.
6. End Use Equipment: Due to better voltage profile, the efficiency of end use equipment is high, bringing in considerable benefit by way of energy conservation.
7. Reliability of Supply: The failure of transformer will affect only a small number of consumers served by it, thus the reliability of supply is high.
8. Voltage Fluctuations: The voltage drop on LV lines is negligible and voltage profile is very stable. Any voltage fluctuations occurring can be remedied by

installations of Automatic Voltage Regulators on HV line.

VII Scope for future Research

Static Energy Meters with Remote Digital Access, Application of Evolutionary Techniques for Study of Load Disdtribution Patterns and Transformer Fault Diagnosis are the related areas for research.

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