INTRODUCING SINGLE-PHASE DISTRIBUTION SYSTEM

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0. ABSTRACT

The author conducted a study to analyze the causes of interruption in the WAPDA Distribution System and tried to find out least cost solution to the problem. According to the analysis 70% of the interruption are visible faults due to poor maintenance and workmanship which mostly constitute loose jumpers and connections, improper conductors clearances, loose binding of conductor to insulator, improper line sag and imbalance load on the transformers etc. In the opinion of the author WAPDA has unnecessarily extended three-phase system to all the domestic consumers which in his opinion should be changed to single-phase system. Single-phase system is not only 30% to 40% cheaper but will also improve power supply by reducing interruptions drastically. The author has strongly advocated his view point supported by calculations and reasons.

1. BASIC CONCEPT

An electric power system can be defined to consist of a generation, a transmission and a distribution system. The distribution system called primary and secondary system is spread throughout the entire load area serving each individual consumer load. The primary and secondary system can be of overhead or underground construction. Throughout residential, rural, commercial and industrial areas, three-phase overhead system predominates. In developed countries underground system is used to feed downtown areas and heavy commercial loads which is quite expensive. Due to its high cost WAPDA has not adopted underground system although it is more reliable than overhead system.

2. WAPDA DISTRIBUTION SYSTEM

2.1 In developed countries distribution system, on national average, is roughly equal in capital investment to generation facilities and constitute 40% to 50% of total investment in power system. Thus distribution system rates high in economic investment that makes careful engineering, planning, design, construction and operation. In WAPDA, Distribution System has the lowest priority, while more importance is given to higher voltages. The distribution cost in WAPDA is about 10% of total investment.

2.2 99% of WAPDA Distribution System is three-phase overhead and radial. The overhead radial system cannot be free from outages, caused by lightning, hanging tree limbs, wire, strings, kites, winds and dust storms, vehicle accidents, pollution etc, but WAPDA has worsen the situation due to poor workmanship, lack of maintenance and non compliance to their own standards. The system is being expanded without taking into account loading and voltage drop, in addition to poor standard of construction resulting in damage to equipment, high level losses and poor standard of supply delivered to the customers. A lot of work has been done under Energy Loss Reduction (ELR) programmes but it has hardly covered 20% of the existing system.

2.3 The interruptions on WAPDA distribution system are numerous. The power supply system is far from satisfactory and cannot be compared with any national or international standard. We as a nation have accepted this enormity as a norm. Although sudden failure of power supply in sultry and sizzling weather puts every one to inconvenience, but the public restricts themselves to cursing WAPDA, while in developed countries suits are filed even if there is an interruption of power supply for a few minutes. Thanks to our accepting people, who believe that disruption of power supply is a matter of routine, and part of their living. The question arises why WAPDA has failed to achieve the required performance standards? We have to analyze and find a solution to improve the existing system within our available resources.

3. FAULT ANALYSIS

3.1 In view of limited financial resources available it is imperative to analyze the causes of interruption in the system and fix priorities. The least cost solutions with maximum impact on improvement in system efficiency should be handled first. For this purpose I carried out analysis of distribution system by collecting data of interruptions from few sub-divisions in Lahore some years back, the results of which are given hereunder. It may be noted that 70% of the system interruptions lie under the category of “Low Tech Faults’ and mostly constitute visible faults on line VIZ loose jumpers/connectors, improper conductor clearances, excessive sage due to large spans, which can be resolved within available financial resources. High and Medium tech faults constitute 20% of the total and are difficult and expensive to work with. These faults should be dealt later, once the low tech faults have been fully attended.

FAULT ANALYSIS

Type	Causes	Percentage
HI TECH Faults (Difficult to Identify)	1) Switching Surges 2) Lightning discharge 3) Power frequency synchronisation problems 4) Harmonies 5) Corona 6) Capacitances & inductance of Transmission Line 7) Air pollution	5%
Medium TECH (Simpler to identify)	1) Equipment failures/maloprations 2) Relay malfunctions 3) Indiscriminate trappings 4) Lack of proper protection 5) Insulation Co-ordination	15%

Low Tech Faults (Common Fault, Most of them Apparent & Visible)	1) Non compliance to standards a) Construction b) Materials - Loose Jumpers & Connections - Improper conductor clearances - Loose binding of conductor with insulators - No or Poor earthing - Improper line sag - Unequal or excessive tension on conductors (poles out of alignment) - Broken or cracked insulators - Improper protection to equipment - Imbalance of three phase loads	70%
Low TECH Faults (Beyond Control)	1) External interferences 2) Lightening, Wind storm, Kites, Traffic Accidents Bridge	10%

4. OPTIONS FOR IMPROVEMENT:

4.1 It may be noticed from the fault analysis that majority of faults mostly constitute loose jumper connections, improper clearances, excessive sag, overhanging branches of trees and nuisance of kite strings. All these problems can be resolved with proper operation and maintenance of the distribution system which WAPDA has failed to achieve over the past four decades. There could be several options to improve the Power Supply System. One of the most economical approach to resolve this issue is to change the existing three phase system to single phase system which is being widely used and practiced in U.S.A. and will be discussed at length here under.

4.2 Single Phase System

4.2.1 The simplest Form of single-phase system is the supply to consumers through radial feeders which depending upon geographical position of the load center with respect to the location of the grid station. Here are few examples to illustrate single-phase distribution system.

a) When load center is located within the grid station, each individual phase goes directly to its area right from the sub-station and each phase feeds a defined area as shown in Fig 1. Such system is not very popular as future expansions of the system could create a problem of load balance.

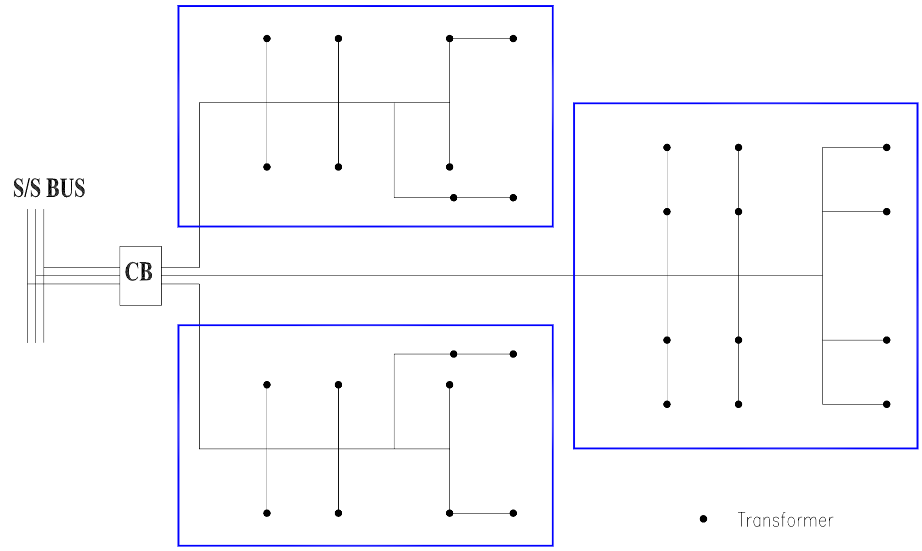

Fig-1: Phase area feeder system

b) When load centers are located at a distance from the sub-station 11 kV, 3 phase express feeder is laid to the load centers and no load is distributes over this portion. The typical example of this is the villages located in small clusters over the area. The express feeder is so designed that it passes close to the load centers. Single phase feeders are taken out near the load centers from the three phase express feeders and then bifurcated into single phase feeder in three different directions which feeds the consumers as shown in Fig 2.

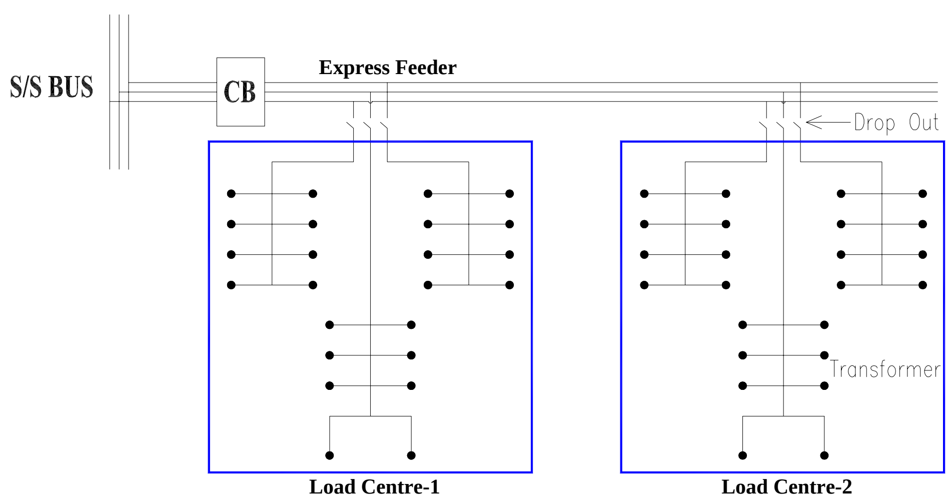

Fig-2: Express feeder distribution system

c) A more extensive radial 11 kV circuit is shown in Fig 3. Three phases 11 kV circuit passes through the load center where it can feed three phase supplies to commercial and industrial areas. Single-phase feeders are taken from three-phase main line to feed residential areas. Such a radial feeder is more commonly used in low-density urban areas.

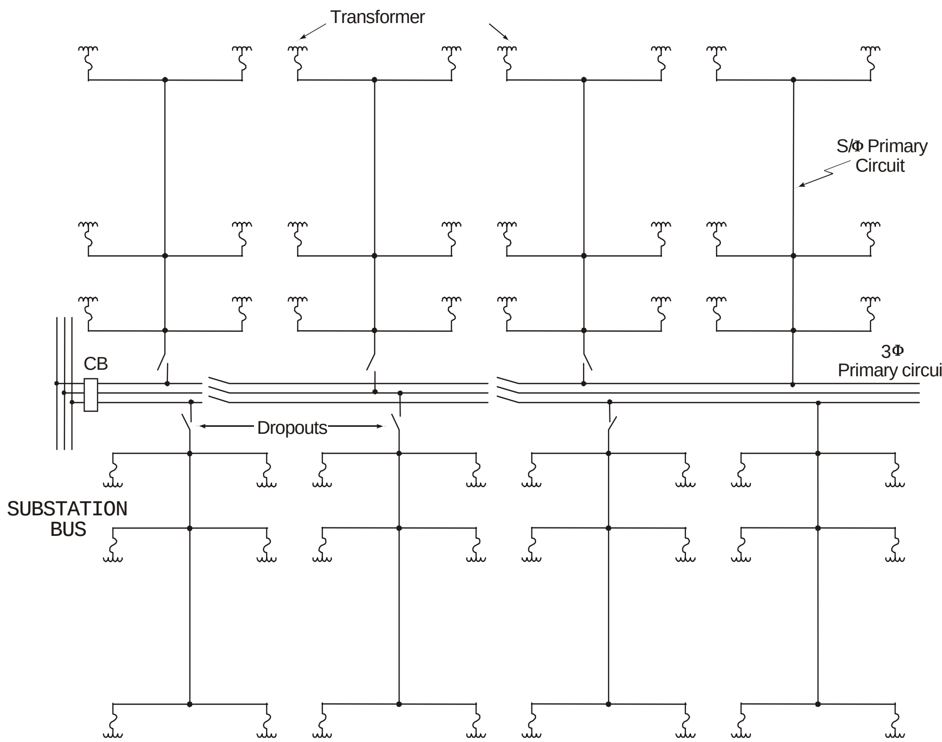

Fig-3:

d) A more reliable and commonly used system for domestic areas is loop system. The loop feeder start from a sub-station and returns to the sub-station. Single-phase lateral feeders are tapped off the main to obtain the load area coverage as shown in Fig. 4.

e) A most reliable single and three phase system used in high density urban areas is the inter connected Network mesh System of distribution feeders which are served by several distribution sub-stations or network units located through out the area.

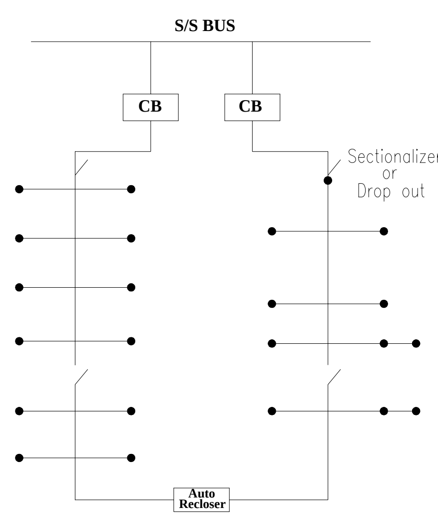

Fig-4: Loop Circuit Arrangement

f) It is very advantageous to use auto reclosers and line sectionlizers as shown in Fig 5. A fuse may be used as line sectionalizer. On long feeders to minimize fuse blowing due to temporary faults, a line recloser must be added along the feeder. It opens instantaneously for a fault and then recloses. On each subsequent tripping, if fault persists, tripping will take place with some specified time delay until temporary fault is cleared. If fault on a section is permanent it will be cleared by blowing of the fuse. In cases where it is difficult to co-ordinate the fuse blowing with re-closer operation autoline sectionalizers can be used instead of fuses. Positive co-ordination between circuit breakers, recloser and fuses or sectionalizers is essential to eliminate faulty sections or clear temporary faults.

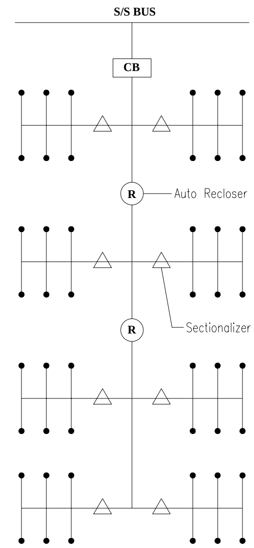

Fig-5

4.2.2 Following is a typical example of WAPDA 11 kV three-phase radial feeder, feeding to domestic consumers. In this system almost all the domestic consumers are fed through three-phase supply.

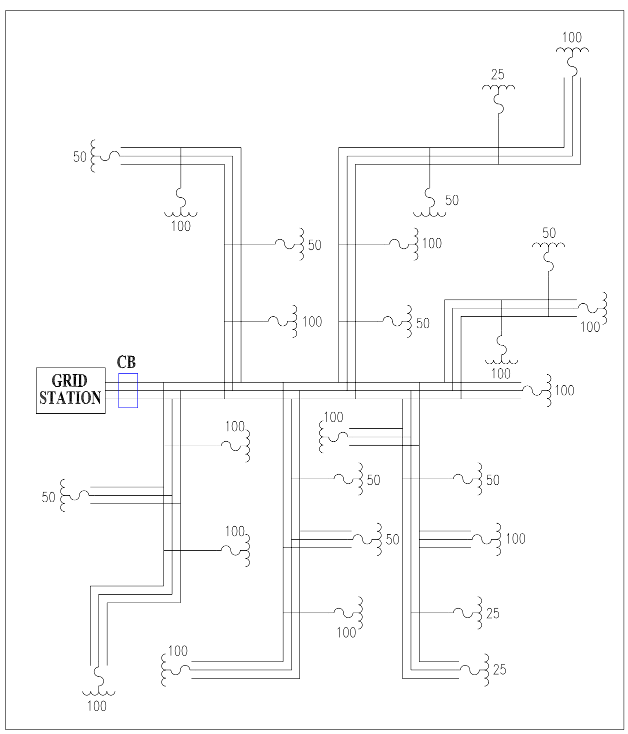

Fig-6: Typical WAPDA 11 kV 3-phase radial feeder

The above three-phase feeder when represented on a single-phase system would be as under:

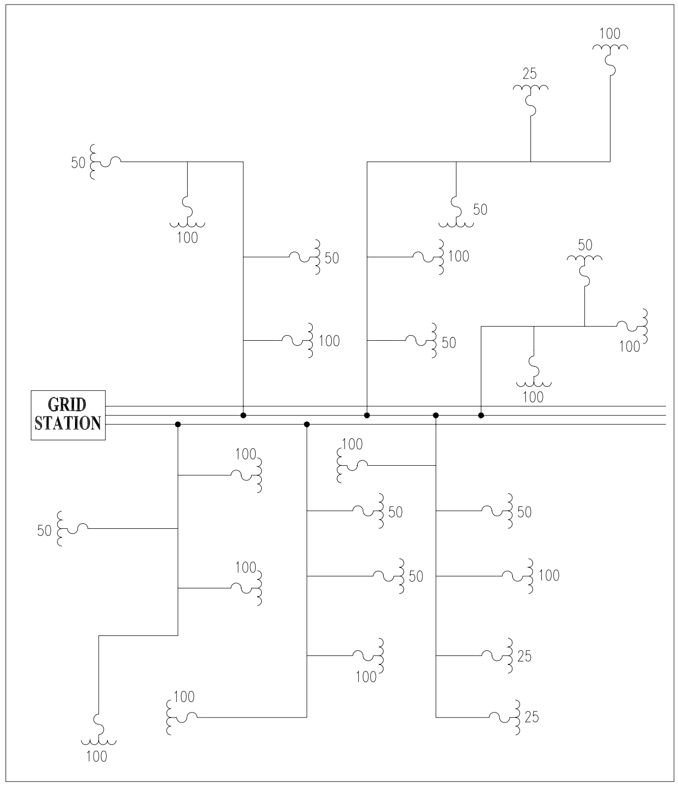

Fig-7: 3-phase feeder shown in Fig-6 converted to Single-phase System

Comparing the two system one can imagine the savings in terms of cost and reliability of service which will be discussed next.

4.2.3 Cost Comparison of Three Phase and Single Phase System

The cost comparison of single and three phase system assuming I KM length of HV feeder with 2 Nos. transformer of 100 KVA each and 1 KM length of LT feeder is as under:

a. Cost of 3 phase system

	Qty	**Unit rate**	**Cost**
– 3 phase 11 kV line with P.C. poles & Dog Conductor	1 KM	408,000	1408,000
– 100 KVA (11/0.4 KV) complete S/S	2 Nos.	175,000	350,000
– 3 Phase Service connection with 7/0.36, 4 core cable	30 Nos.	9400	282,000
– LT line with rabbit conductor	1 KM	225,000	225,000
Total Cost			**1,265,000**

b. Cost of single phase system

– Single phase 6.3 KV line with P.C. poles & dog conductor (No cross arms, No supports only one conductor)	1 Km	272,000	272,000
– Single phase 100 KVA transformer (6.3/0.24 KV) transformer s/s complete	2 Nos.	140,000	280,000
– LT line with two wasp conductors	1 KM	120,000	120,000
– Services 3 phase with 7/064 conductors	30 Nos.	4500	135,000
Total Cost			**807,000**

Cost of single phase system is at least 33% cheaper compared with three single phase system. We can have still more savings up to 40% of total cost by designing lighter poles for single conductor. In addition single phase system will drastically reduce cost of maintenance and improve power supply as there will be no problem of phase to phase short circuits.

4.3 Advantage of Single-Phase System over Three-Phase System

The advantages of single-phase system over three-phase system are elaborated below:

i. Single-phase system is 30% to 40% cheaper compared to three-phase system.

ii. It is simpler and easier to maintain as Single-phase will carry only one conductor for 11 kV and two conductors for LT feeders.

iii. 11 kV single-phase system can be laid down in narrow streets as cross-arms are eliminated.

iv. 30% larger span can be used with the same height of structures.

v. There will be no phase to phase short circuits due to improper sags, unequal or loose tension on conductor, broken or tilted cross-arms.

vi. Over hanging branches of trees will not cause any short circuit as in case of three-phase system.

vii. There will be no short circuits on 11 kV feeders due to kite strings.

viii. There will be no problem due to imbalance of loads on single-phase transformers as in case of three-phase system.

ix. Three-phase transformers are more vulnerable to short circuits compared to single-phase transformer.

x. Damage to grid station equipment will be reduced proportionate to reduction in faults on 11 kV system.

xi. Balancing of load on 11 kV feeders will be easy.

4.4 How to change existing Three-Phase System to Single-Phase System

There may be some apprehensions that how the existing three-phase system can be used with the single-phase system. Following are suggestions to implement this change in a systematic manner and in phases:

i. Three-phase transformers when burnt should be replaced with single-phase transformer of the same rating.

ii. All the three-phase conductors on L.T. feeder should be short circuited by fixing a conductor across the three-phases to change it to a single-phase supply.

iii. Three-phase meters need not to be replaced and will continue to record energy on three conductor single-phase supply without any effect on its performance.

iv. Each DISCO will prepare a programme for conversion of three-phase systems to single-phase system, feeder-wise and in phases as under:

- Programme should be carried out feeder-wise.
- Under this programme all the existing three-phase transformers on a 11 kV feeder should be replaced with single-phase transformers.
- Central conductor on the cross should be shifted first and fixed to the pin insulator installed on top of the structure.
- All cross-arms, spare insulators and pins along with two conductors per phase of 11 kV feeder should be removed. Similarly all the excess conductors and insulators of L.T. lines should be removed thus creating an inventory of billions of rupees which can be used for the future system expansion.
- Spared three-phase transformers should be used for replacement of burnt transformer instead of procuring new ones.

5. RECOMMENDATIONS

i) WAPDA MUST consider to introduce single phase distribution system for supply to domestic and small commercial consumers in all rural and urban areas. It will not only reduce 30% to 40% of investment and maintenance costs but will also drastically reduce interruptions, prolonging life of distribution transformers and equipment installed at grid stations.

ii) All 3 phase small transformers on damage may be replaced with single-phase units thus substituting three-phase with single-phase system, where applicable. We can replace the existing three-phase system to single phase in stages. It may added that existing three-phase LT distribution network can be very effectively used on single-phase system without any change.